

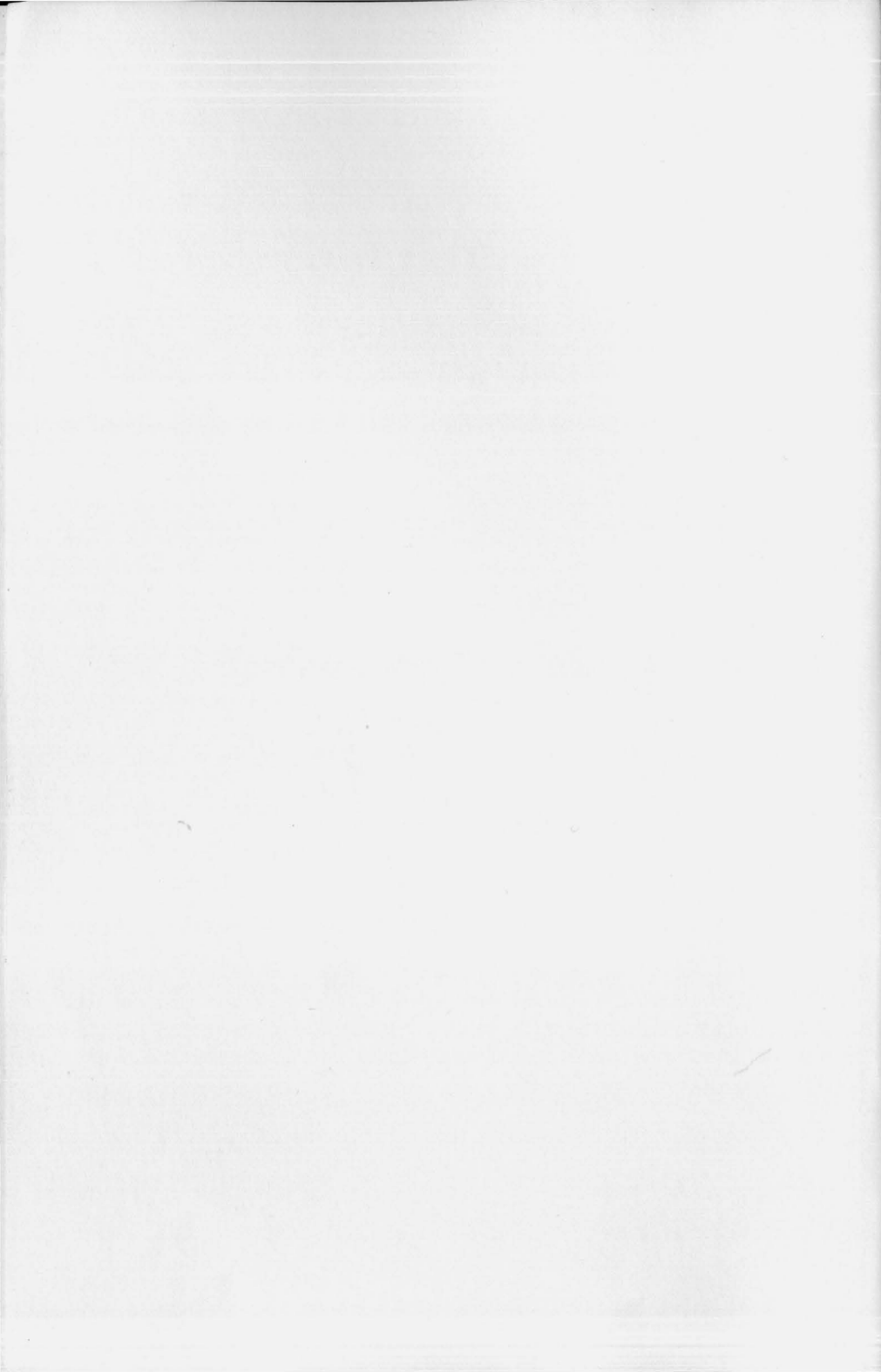
CONCRETE PRACTICE IN IRELAND 1985

SYMPOSIUM

MARCH, 1985



UNIVERSITY COLLEGE,
DUBLIN



CONCRETE PRACTICE IN IRELAND 1985



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FOREWORD

**PROFESSOR THOMAS J. CASEY, B.E., PH.D., D.I.C. D.S.E. (DELFT),
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The Proceedings in this volume relate to the third decennial Symposium at University College, Dublin on the subject of "Concrete Practice in Ireland". This symposium, which was held on the Belfield campus from the 21st - 23rd March, 1985, attracted 179 participants representing a wide spectrum of interests in the subject.

Symposia such as this serve a number of important functions. They provide a forum for the exchange of views among specialists, an opportunity to take stock and learn from past mistakes, and a means of communicating new ideas and developments. The theme of this symposium is a nationally important one as concrete is a key component material in the built environment in Ireland. This volume of Proceedings may be regarded as a state-of-the-art review of Concrete Practice in Ireland in 1985 and I feel sure its publication will be widely welcomed, particularly by those who did not have the opportunity to participate in the Symposium.

Seven papers were presented and discussed. Their subject matter includes concrete as a material, codes of practice and specifications, computer-aided design, durability of concrete construction, the use of concrete in housing and bridges, and the conservation and renewal of concrete structures. The collected views recorded in the Proceedings will help to guide progress in this field over the next decade.

The Department of Civil Engineering at University College Dublin is indebted to all those who contributed to the success of this symposium, in particular to the Organising Committee and the authors of papers, and to all who participated in the Symposium. A special word of thanks is due to Professor J. W. de Courcy, the initiator of this Symposium series and editor of the three volumes of Proceedings.

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OPENING ADDRESS

PROFESSOR E. T. HANRAHAN, M.E., D.SC., PH.D., F.I.E.I.

Head of Department of Civil Engineering, University College, Dublin
(March 1985).

Ar oscailt na díospóireachta, chuir an t-Ollamh O h'Annracháin fáilte roimh na dacinne go léir don comhdhail seo, an triú i ndiaidh a chéile. He remarked how quickly time had passed since the first of the series in 1965, and how much had happened since then. He recalled the names of men who had contributed much to concrete technology who had now died, Liam Stephens, Michael Hogan, Tom Garland, Denis O'Leary, Jock Harbison. He saw the three symposia as milestones.

In 1965 there had been a feeling of optimism. Prestressed concrete was firmly established, concrete was considered to be virtually indestructible, failure as such rarely entered into consideration. The cost of the labour involved in making a cubic yard of concrete was 25 pence and of transporting it on site, 10 pence. Many of today's commonplaces had not yet appeared. The computer had scarcely been heard of, CP110 was still seven years away, SI units were not used. References to tower cranes and to pumped concrete were meagre, and little was known about ready mixed concrete, then in its infancy in Ireland. Eighty per cent of all reinforcement was round mild steel. There was little reference to sulphate resisting cement or to lightweight concrete, and Irish precasters were said to have been deemed unable to make the elements for the American Embassy building in Ballsbridge. The value of very small proportions of sugar in concrete was being mentioned, as was the difficulty of attaining satisfactory E-values for concrete in Cork. Gap grading was discussed.

At the time of the second symposium, in 1975, many things had changed, and indeed there were the first rumblings of the recession ahead. Energy conservation was already a major issue. In the direction of progress however, tower cranes and pumped concrete were now in wide use, while in design, there was a significant increase in emphasis on wind loading. By that time, An Foras Forbartha had made a material input to Irish building, particularly with reference to standardization, dimensional control and modular co-ordination, and the adoption of a common structural system for the Regional Colleges was being cited as a significant advance. On the other hand, the possibility of failure was being admitted, and the indestructibility of concrete questioned. Ronan Point and high alumina cement had had their effect and there had been some panic reactions. At the same time however the use of concrete in architecture was advocated strongly in a paper to the symposium, and again, new materials, such as lightweight concretes and glass reinforced concretes, were being mentioned.

OPENING ADDRESS

The 1985 symposium saw us, Professor Hanrahan felt, in a period of passing pessimism, which he hoped would vanish with better things ahead. Many new guides were appearing. We had had a national building specification prepared by An Foras Forbartha, and a new masonry code prepared with the encouragement of the Concrete Consultative Committee of the Institute for Industrial Research and Standards. We were expecting a new road code, a major restructuring of CP110 and a series of relevant Eurocodes. We were right in the middle of the computer age, but would have to ensure that the increased analytical facility and consequent short term economy that the computer offered us did not lead to a reduction in the durability of our buildings. It was clear that the durability of concrete, with the many complex factors involved, was now a matter of great and growing concern. He noted the difficulties of competition between concrete product manufacturers in the Republic and Northern Ireland and felt this was a matter that needed discussion.

Looking ahead towards the 1995 Symposium, Professor Hanrahan observed that at the moment, civil engineering had gone, as it were, somewhat out of fashion. One should not be unduly worried about this because it was recognised that its wellbeing lay at the core of the national development, as indeed the forthcoming roads programme indicated. He would like to see concrete technology receiving more attention and recognition in the industry. In particular, having an interest in soils and rock materials, he would favour a more sophisticated testing approach to the complicated three-phase material that concrete was. Such matters, as diffusion, permeability, pore water pressure, needed attention. Consideration should be given to triaxial testing. In conclusion he expressed the hope that the symposium in 1995 would see the present recession over, and just as much a bad dream as the hungry thirties were to the older people amongst us.

SESSION A

STANDARDS SPECIFICATIONS CODES AND REGULATIONS FOR STRUCTURAL CONCRETE

J. A. SCANNELL, B.SC., B.E., F.I.C.E., F.I.STRUCT.E., F.I.E.I., M.CON.S.E.I.

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Summary

The purpose of this paper is to review and comment on the current situation with regard to Codes of Practice, Standards, Specifications and Regulations as they apply to structural concrete. The current approach for specifying concrete is discussed, taking account of the views of those engaged on the design and construction side of the industry. At the present time, many of the commonly used B.S. Codes and B.S. Standards are under revision and it has therefore been necessary to review those at present in use and, where possible, indicate the direction of the principal revisions intended for the future codes.

In Ireland, there has been considerable movement in the past ten years. The Irish Building Specification was published, and Irish Codes of Practice and Standards have been issued in draft form while others are at the production stage. These are commented on as appropriate.

The most important recent event has been the issue of the Proposed Building Regulations and possible proposals for building control. Both of these are reviewed.

The Commission of the European Communities has issued to this country its Concrete Code in draft form for comment, and the background to the Eurocodes is briefly discussed. (The time of writing this paper is December 1984.)

1. General

1.01

Very significant events and trends have taken place in the Building and Civil Engineering industries as a whole, including the field of structural concrete. Developments have taken place and difficulties have arisen. The construction boom period of the 1970's has altered to recession in the 1980's. As with all recessions this has meant that the amount of State funded construction has greatly increased relative to private sector work. These changed conditions have been accompanied by requirements for strict cost controls by State, Local Government Authorities and private clients, and a drive for ever

increasing economy in design and construction. While economy is the keynote, it has to be emphasised that it must not be achieved by an erosion of safety principles and a risk of poor performance later. Many ideas are promoted by sources who do not bear the responsibility for later consequences, and these ideas are often justified on the basis of cost savings, which later prove to be short-term.

Greater knowledge of structural performance and the increasing use of computers allow the general use of refined analytical techniques in structural design. These developments have led to a reduction in redundancies in modern structures, together with optimisation for minimum material content. The structures may therefore be less able to withstand abnormal or unexpected loadings or movements than older buildings, and this must be recognised.

The traditional relationship between client/consultant/contractor is under examination together with different forms of approach to construction contracts, and the future may see changes in this area also.

1.02

In recent years, many problems in relation to concrete work, which previously were not fully appreciated, have manifested themselves. In the early 1970's, conversion problems with high alumina cement arose, and the past use of calcium chloride in reinforced concrete, under certain conditions, is now resulting in considerable difficulties. Aggregates containing particular varieties of silica may be susceptible to attack by certain alkalis originating from the cement or other sources, producing an expansive reaction which can cause cracking and disruption of concrete. This aggregate-alkali reaction is currently causing much concern in the U. K. Fortunately no cases have been reported here so far.

1.03

Responsibilities of those engaged in design and construction have increased considerably in recent years. New legislation, proposed legislation, and official reports have been produced, e.g. Safety in Industry Act, Fire Safety Act, Defective Premises Bill, etc. Much of this legislation is motivated by consumerism and has placed additional legal burdens on those who design and build structures and civil engineering works. Similarly, recent court decisions have created further problems and difficulties.

All these changes highlight the need for the assistance of good Specifications Codes and Standards so that the basic requirement relating to public health and safety is maintained.

1.04

The Concrete Consultative Committee has been set up at the IIRS. The Committee advises on International Standards and Codes of Practice and on Irish Standards and Codes of Practice, in relation to concrete. This policy is a welcome development.

A summary of Irish Standards, Irish Codes, and other Irish publications which refer to structural concrete work is given in Appendix A.

2. Loading

2.01

The assessment of loading is one of the initial and fundamental operations necessary for the design of a structure. The weights of building materials used in the structure may be obtained from B.S. 648 (1964) (35), or from actual known weights, and the resulting load assessed. Until recently, dead and imposed loadings used for the design of buildings were normally obtained from data given in B.S.C.P. 3, Chap. V. Loading — Part 1 (1967) and its amendments, No. 141 (Nov. 1968), 587 (Sept. 1970), 1024 (Sept. 1972). Part 2 (1972): Wind Loads, of this Code is used for calculating wind loads for the design of buildings, structures, and the components thereof. Both Part 1 and Part 2 (1 & 2) are the codes contained in the mandatory clauses on loading in the proposed new Building Regulations.

2.02

C.P. 3 : Chap. V : Part 1 : 1967, has now been withdrawn by BSI and is replaced by B.S. 6399 : Part 1 : 1984. The new code is entitled "Design loading for buildings : Part 1 : dead and imposed loads". The format of the code has been altered from the previous one and it is now laid out in occupancy classes with the loads in each class given in order of descending magnitude. There are relatively few changes in the actual loads. Table 1 of the former code is now presented in this new format with some welcome increased loading values mainly related to stairways. Horizontal loading values on balustrades have been adjusted to bring them more in line with B.S. 6180 (4) values.

Loading for vehicle barriers in car parks remains the same, but it should be noted that the design of barriers is often empirical and checked by full-scale tests, using an actual vehicle impact and, where successful, such barriers are acceptable. Movable partitions are now considered under imposed loads rather than dead loads, as in the previous Code, and the definition of Dead Loads now includes services. Minimum loadings have been given for balconies in the various occupancy classes. Reduction of total distributed loads on large areas has now been excluded for roofs.

2.03

C.P.3.: Chap. V : Part 2, is at present being revised and will be issued as B.S. 6499 : Part 2, Code of practice for wind loads." Pending its issue, guidance on the revised Part 2 is given in BRE Digests 119 (1984 Edition), 283 and 284 (5,6,7). In the new code, the use of a direction factor S_d is under consideration. At present gust speeds are used as a basis of wind load calculations. Maximum gust speeds at a height of 10 m above ground likely to be exceeded on average once every 50 years in open level country are shown by the lines of equal

SESSION A

wind speed, Isopleths, on the Map, Fig. 1. These Isopleths are supplied by the Meteorological Office. The risk of exceeding the wind speeds given on this map is assessed irrespective of direction, but the risk is not distributed uniformly by direction. The risk is greatest from the direction of the prevailing winds, i.e. from south west to west in Ireland. To redistribute the risk uniformly by direction, designers may at their own discretion choose to adopt the data from Table 1.

TABLE 1 — Direction Factor S_1 .

Winds from :												
Deg.	.0	30	60	90	120	150	180	210	240	270	300	330
	N			E			S			W		
S_1	0.78	0.73	0.73	0.74	0.73	0.80	0.85	0.93	1.00	0.99	0.91	0.82

Factors S_1 , S_2 , and S_3 still apply with S_4 now perhaps added.

Digest 283 deals with the assessment of mean and gust wind speeds over topographic features such as hills, ridges, escarpments and cliffs for wind loading calculations. Used in conjunction with Digest 119 (1984 Edition) it replaces the "Escarpment Rule" for the calculation of the Topography factor S_1 from Appendix D of CP 3 Chap. V : Part 2 : 1972.

2.04

It is expected that alterations in the approach to assessment of wind loads on free standing canopy roofs without walls, including the effects caused by internal stacked contents, will be incorporated in the new code (7).

2.05

Section 8 of B.S. 6399 draws attention to dynamic effects of loading (excluding wind) due to crowds. As it is fashionable sometimes for people to jump up and down on suspended floors, problems associated with the dynamic response of these floors may occur. BRE Information Paper ID 17/83 gives support information to this item.

2.06

A further part, i.e. Part 3, of B.S. 6399, is currently in course of preparation, and this will be "Code of practice for snow loading". A footnote on page 3 of B.S. 6399 draws attention to the possibility of increased loading due to sliding, drifting and non-uniform build-up of snow on roofs. In recent years, there have been a number of collapses or partial collapses of roofs when snow has been accompanied by strong winds, and checks of structural designs of roofs for adequacy against high local snow loads are necessary where proposed roof shapes are likely to cause accumulations of drifted snow. While awaiting the new Code, guidance for design for snow loads may be obtained from BRE Digest 290 (8).

2.07

Bridge loadings were formerly, and sometimes still are, catered for by B.S. 153 : Part 3A incorporating its amendments, together with information from M.O.T. memoranda and standards. B.S. 153, Parts 1, 2, 3A, 3B, and 4 : Specification for Steel Girder Bridges, although dealing specifically with steel bridges, provided the basis for loadings which were used in the design of concrete bridges.

2.08

The current Code B.S. 5400 : 1978 : "Steel concrete and composite bridges" is a document combining codes of practice for each of these bridge types and covers loading, design and construction, and materials and workmanship. In relation to Concrete Bridges in particular, "Specification for loads" is dealt with in Part 2 and design in Part 4 : 1984. (B.S. 5400 : Part 4 : 1978 : is now withdrawn and is superseded by Part 4 : 1984). Specification for materials and workmanship, concrete, reinforcement and prestressing tendons, is contained in Part 7 with recommendations for same in Part 8. Bridge Bearings are covered in Part 9 : 1983. B.S. 5400 is a limit state code and, as such, differs in principle from its predecessor B.S. 153. As with all limit state codes, the aim of B.S. 5400 is "the achievement of acceptable levels of probability in order that the structure being designed will not become unfit for the use for which it is required." Adjustments are being made to the code from time to time to better achieve this aim.

2.09

Most engineers designing bridges in Ireland at present use B.S. 5400 together with Department of Transport (U.K.) Standard BD/14/82. This standard relates to the use of B.S. 5400 : Part 2 : 1978. Department of Transport memoranda also apply to other aspects of bridge design and details (9).

2.10

It is also acceptable to use the "permissible stress" basis for design of concrete bridges. B.S.C.P.s used are CP 114, Part 2 (refer to Tech. memorandum BE 1/73), CP 115 Part 2 : for prestressed concrete (refer to Tech. memorandum BE 2/73), C.P. 116 precast concrete (refer to Tech. memorandum BE 1/73 and BE 2/73). B.S. 5400 : Part 2 : 1978, applies for loadings and B.S. 5400 : Part 9 : 1983, for bridge bearings. Further Department of Transport memoranda also apply to other bridge design and details (10).

Bridge Loading is further expanded in Session "F" of this symposium.

2.11

Three Codes of Practice which are used with all forms of structure, including concrete are :

1. C.P. 2 Earth retaining structures (11) : which contains information for the calculation of loads, forces, and surcharges for many types of retaining structures including, concrete gravity retaining walls,

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- R.C. retaining walls, R.C. abutments, and R.C. sheet pile walls. Design information is also included.
2. C.P. 2004 : 1972, Foundations : provides data and design information which covers all foundation types, and includes a comprehensive bibliography at the back.
 3. B.S. 5930 : 1981, Code of practice for site investigations : covers the procedures for carrying out site investigations and includes descriptions of soils, geological information, and testing. This code was formerly C.P. 2001 (1957).

2.12

"A guide to the structural design of pavements for new roads : Road Note 29" from the M.O.T. deals with the loading and design procedures for the design of concrete pavements both unreinforced and reinforced. Recommendations for joints and joint spacings are included.

Concrete roads are also dealt with in the D. o. E. "Specification for road works" and "Recommendations for site development works, for housing areas": 1984, by An Foras Forbartha.

2.13

Enquiries indicate other codes referred to by a few engineers for loadings and design are :

DIN 1054 (32), 1055 (32).

A.C.I. 318-77 (17 and 18), A.C.I. 531-79 (17).

3. Codes and Standards for Design

3.01

B.S. C.P. 114 "The structural use of reinforced concrete in buildings" was first published in 1948, and the most recent edition, which included previous amendments, was issued as C.P. 114 : Part 2 : 1969 : Metric Units. This code is a satisfying document in the U.K. Building Regulations, and, for example, in the London area many planning applications (perhaps up to 50%) are still made, using C.P. 114. It appears that the code will remain in force until it is withdrawn from the U.K. Building Regulations and ceases to be a B.S.I. document. This seems unlikely to occur for about two years or thereabouts, and it will be interesting to see if its many backers can succeed in having it updated and republished outside of the B.S.I. In the Republic of Ireland the majority of engineers now use C.P. 110—only about 15% still use C.P. 114 and a few of these use it only in circumstances where they are obliged to check older buildings which were designed to this code.

C.P. 114 permits the use of :

1. the 'modular ratio' method based on elastic theory. The elastic theory is concerned with the equilibrium at working stresses of the forces and moments due to actual loads. The working stresses are the ultimate stresses reduced by a factor of safety OR
2. the 'load factor method' which was introduced in 1957. This

method is concerned with the equilibrium at ultimate stresses of the forces and moments due to the actual loads multiplied by a load factor, the design stresses being the full ultimate stress.

However, to avoid confusion, the load factor method was not introduced in this strict sense, but was modified and produced in terms of working loads and working stresses (which were numerically the same as those for the 'modular ratio' method) except that plastic stress/strain relations were to be assumed for ultimate conditions in place of the elastic relation of Hooke's Law appropriate to working loads and the elastic theory. Both the above methods may now be regarded as permissible stress forms of design. C.P. 114: Part 2: 1969, is a "regarded as satisfying" code in the Proposed Building Regulations.

3.02

C.P. 110: 1972 (12) had already been accepted into Irish concrete practice at the time of the previous symposium in 1975, and together with its amendments, is still the principal code in use by Irish engineers. The code expresses strength and stability requirements in terms of ultimate loads and stresses in strict conformity with ultimate load theory, or, more precisely, the theory of limit states. Details of the code were comprehensively commented on at the 1975 symposium (13).

3.03

C.P. 110 is at present under revision and will be re-issued as "B.S. 0000: The structural use of concrete". Drafts of the parts of this code were issued for public comment early in 1982, and taking account of the comments received, a final draft has recently been circulated to the Drafting Committee only. B.S.I. hope to issue the new code in the middle of 1985.

3.04

The final draft has not been circulated generally but, from enquiries made, the author understands the new code has been rewritten in a more comprehensible form and should be easier to use. Many of the changes introduced in Part 1 of the new code are concerned with clarification and removal of ambiguities which are considered to have emerged from C.P. 110: Part 1. Technically, the changes are not great. The area where the largest changes have been made is in the treatment of slabs in order to produce consistency between the simplified and the more rigorous design approaches and to take account of more recent technical information related to punching shear and the analysis of flat slab structures. A more thorough treatment in relation to durability is also included, and there is a new feature on the treatment of P.F.A., and blast furnace slag.

3.05

Section 6 has been considerably shortened and the material on specifications for concrete will be considered for inclusion in B.S. 5328. There is some relaxation of the concrete cover to reinforcement in fire

by taking account of an increased width of member where such is available.

3.06

Section 4 of C.P. 110 deals with the design and detailing of prestressed concrete. The design is, of course, in accordance with limit state principles and general aspects of prestressed concrete are dealt with, including materials. The original B.S.I. Code C.P. 115 still continues to be used but the intention of B.S.I. is to phase it out in due course. B.S. C.P. 115 : 1969, including its amendments, is a "regarded as satisfying" code in the proposed Building Regulations, as is C.P. 110.

3.07

The design and detailing of post-tensioned flat slabs are specially dealt with in Concrete Society Technical Report No. 17, (1979) (14) and No. 25 (1984) (15). T.R. 17 is a revision of T.R. 8 (1974), the main difference between them is that design procedures are now on limit state methods and based on C.P. 110 : 1972, whereas the 1974 recommendations were based on C.P. 114 and 115. In the U.K. it is now mandatory that flat slabs be designed to C.P. 110. The decision to publish the Handbook (TR 25) (1984) was influenced by the increase internationally in the use of this method of construction which, when used appropriately, is revealing technical and economic advantages for many types of building. The Handbook explains the overall concept of this method and amplifies the design recommendations.

3.08

Section 5 of C.P. 110 deals with design and detailing precast, composite and plain concrete construction. The limit state philosophy applies equally to precast and in-situ construction and, in general, recommended methods of design and detailing in C.P. 110 for R.C. and for prestressed concrete apply also to precast and composite construction. C.P. 116 may still be used for precast work and it contains many of the design clauses of C.P. 114 and C.P. 115. Again it is the intention of B.S.I. to phase it out in due course. B.S. C.P. 116 Part 2 : 1969, with its amendments and addendum, is a "regarded as satisfying" code in the Proposed Building Regulations, as is C.P. 110.

3.09

The design and construction of reinforced and prestressed concrete service reservoirs and tanks used for storage of water and other aqueous liquids are dealt with in B.S. 5337 : (1976) (16). When a structure is subject to external water pressure on floors and walls, it may also be designed in accordance with this code. Dams, and r.c. or prestressed aqueducts, and other structures for the conveyance of liquids are not included. The code provides for two methods of design, the one based on limit state philosophy being generally in accordance with the methods of C.P. 110, while the alternative uses the methods found successful in the earlier code C.P. 2007 : Part 2 (1970). These latter methods were based on C.P. 114 and C.P. 115.

3.10

Codes and standards for design of bridges and roads have already been mentioned in Section 2 on Loading.

3.11

Indications are that only a small number of Irish engineers now refer frequently to American Codes for design. ACI Code 318-77 (17) is the general reference for design. The code allows alternative design methods:

1. Using load factors and strength reduction factors, which is a limit state approach, and
2. alternatively, non-prestressed R.C. members may be designed using service loads and permissible service load stresses. Imperial units are used. The code forms part of the ACI Manual of Concrete Practice (18) which is revised annually.

Specifications for concrete in buildings are dealt with in ACI 301-72 (Revised 1981) (19). This is a very comprehensive book on the various aspects of specifying concrete and its construction.

3.12

The Irish Code of Practice 6: The structural use of concrete was issued in draft form in September, 1984, and is expected to be published in final form during 1985. The code consists of the text of C.P. 110: Part 1, 2, and 3, and is amended principally to include the use of Irish Standards and practices. I.S. references to cement, aggregates, and test sieves are used. Where no I.S. exists, the corresponding B.S.I. one in C.P. 110 applies. Specifications for concrete mixes are referred to B.S. 5328 (21) which is used in the I.B.S. Where materials to a standard called for in the code are not available, it is permissible to use other materials of satisfactory performance, provided adequate checks on the properties of concrete made with them are carried out. A fuller Irish Code will be published based on the current revision to C.P. 110 when this is issued.

One reason the Irish Code is being introduced to solve an anomaly in the Building Regulations. C.P. 110 calls for the use of British Standards, but when I.C.P. 6 is eventually included in the Regulations it will cover the use of Irish Standards.

3.13

The following Eurocodes are proposed:

- | | |
|--|--|
| E.C. 1: Common unified rules for different types of construction material. | E.C. 5: Timber structures. |
| E.C. 2: Concrete structures. | E.C. 6: Masonry structures. |
| E.C. 3: Steel structures. | E.C. 7: Foundations. |
| E.C. 4: Composite steel and concrete structures. | E.C. 8: Construction in seismic zones. |

3.14

Having gone through laborious initial stages of development, E.C. 1., E.C. 2., E.C. 3., and E.C. 8 have now been issued as drafts for

comment. The Commission of the European Communities intends to produce the European Codes—the EUROCODES—for the design and execution of buildings and civil engineering structures. These codes are intended to establish common rules as an alternative to the different rules in force in the various Member States. The final codes will be optional rather than mandatory and will have a fundamental effect on the construction industry. No European Community member country will be able to refuse a design purely on the grounds that it conforms to European rather than national codes of practice, and the Eurocodes will be “regarded as satisfying” the Irish Building Regulations. It is therefore of primary importance for Irish engineers, and the construction industry as a whole, to ensure that the contents of the Eurocodes are fully and critically examined, and their implications understood by the industry.

It is in the national interest that the State and the industry should fund the studies necessary to achieve this end, not only from the technical aspect but also to maximise Irish competitiveness both in the home market and abroad.

3.15

The codes which so far have reached draft form and are of interest to this paper are : E.C. 1 (20) and E.C. 2 (20). Eurocode 1 is the base document for the common unified rules for different types of construction and materials, i.e. for the preparation of the other Eurocodes. It aims to ensure an adequate and appropriate treatment of safety, serviceability and durability, whatever the material or type of construction, but does not aim to cover special structures such as dams, nuclear power stations, or marine platforms. It is not intended for direct use by engineers in the design of particular structures. The criteria to be followed are laid down, but no safety factors are given numerically as each national government will be responsible for the level of safety required of any particular design, and for the magnitudes of the loads used in design.

3.16

Eurocode 2 : Concrete Structures :

The form of the Code, which is in draft only, is structured in a similar manner to the CEN (Comité Européen de Normalisation) document. It is generally a performance code which could be regarded under two main headings : (1) Principles and (2) Rules of application. The “Principles” contain general rules derived from the laws of engineering mechanics and authoritative experience, and the essential content would not seem capable of much modification. The form in which these are set out may be subject to criticism. The “Rules of application” contain the criteria which have to be satisfied in order to comply with the requirements set out under “Principles”, and may be regarded as methods and rules derived from experience. These rules are capable of a variety of interpretations. They depend on the partial

safety factors which have been adopted—workmanship, materials, etc.—so that, presumably, flexibility would be allowed for their application in the different European countries. The Standards referred to in this Code and the other Codes must be acceptable to the Member States.

It may be assumed that agreement on the form and content of the technical document will be reached within a few years but the legal and administrative problems associated with the implementation of the Codes in Member States are difficult, and resolution will probably take a considerable time.

4. Concrete Specifications

4.01

At present, a number of Codes and Standards are used in the specification of concrete : C.P. 114, C.P. 110, C.P. 115, C.P. 116, B.S. 1926, B.S. 5328, I.S. 194, IBS are all in use to some degree. This wide spread may be due to the current transitional stage with many of the British and Irish Standards. By far, the greatest number of engineers use C.P. 110 as a base reference for their concrete specifications, and most engineers use their own "in-house" documents when specifying for contracts. The future trend would appear to be towards using B.S. 5328 : 1981 (21) as the base reference, particularly as the current revision of C.P. 110 will have less material on concrete specification. This trend may also mean increasing use of the Irish Building Specification.

4.02

On very large contracts, where the amount of concrete production would justify setting up a batching plant with accompanying site control, contractors would tend to manufacture their own concrete. For small work, or work in remote areas, again contractors would produce the concrete themselves. In between lies the largest amount of concrete work carried out in this country, and here ready-mixed concrete is now nearly always used.

Engineers are, therefore, specifying most of the time for a main contractor who will pass on the specification to a ready-mixed concrete manufacturer. Concrete manufacturing is now a large industry and there are not many areas of the country that would not be within range of a ready-mixed concrete plant. With this scale of operation, it has been possible for the concrete manufacturers to establish efficient concrete batching plants, with the necessary technical back-up and quality control for the production of good concrete to specification. The Concrete Manufacturers Association of Ireland continue to press for more uniformity in specifications and an agreed form or forms of specification for general use. This same topic was discussed at the Symposia in 1965 and 1975. The C.M.A.I. recently carried out an analysis of specifications received by member companies and this revealed a wide variation in the specifications currently in use.

4.03

The Irish Building Specification, Part 1 : Vol. 1 (22) was published in 1976. Section 'E' covers cast in-situ concrete work in both R.C. and prestressed concrete. Section 'G' covers precast concrete, both reinforced and prestressed, Section 'F' covers blockwork and brickwork. This Building Specification is a library of specification clauses for use in the preparation of specifications for a complete project, including the concrete work. Constructions which are considered unusual or unique are omitted. Each construction is divided into work sections which provide a breakdown following the general sequence of work, groups of similar materials, and associated workmanship clauses, all coded under the SfB system. In many clauses, blanks are left so the individual specifier can fill in the particular code, standard, or description to suit his requirements. Using the I.B.S., the specification for a whole project can be in the same format which contrasts with the usual situation where each member of the design team does a separate specification for his own part of the work, and these are put together into one Specification, often by the quantity surveyor. It is recommended by An Foras Forbartha that Project Specifications be prepared using the I.B.S. as a source document on each occasion, rather than by using a previously prepared specification or a standard office specification. Separate mark-up copies of the various constructions or elements, without the guidance notes, are available from An Foras Forbartha, and these copies need only have the blanks filled in to create a specification for a particular construction or element. Each member of the design team can then send the appropriate mark-up copies to the project co-ordinator and the specification for the whole project can be printed in the same format. With the increasing use of micro-computers and word processing, the future trend would seem to be towards Master Specifications, with individual project requirements taken from the master unit, and the I.B.S. is particularly well-suited to this approach.

4.04

Work on the content of the I.B.S. has now been completed, at least for the foreseeable future. Sections E, F, and G have not had any major revisions since publication but occasional up-dating is done, usually only in connection with B.S. numbering or current Standard Methods of Measurement, etc. In the I.B.S., concrete specification and compliance are set out on the lines of B.S. 5328, and the workmanship/construction aspects accord with C.P. 110.

4.05

Having said all this about the I.B.S., enquiries indicate that, at present, a minority (about 40%) of engineers make extensive use of it. As already stated, most engineers use their standard Office Specification for specifying concrete and it is a major step for a firm to move away from a specification format which has served them well on their projects. Such a step requires a lot of time and careful consideration,

hence there is perhaps a lack of incentive to make a radical change of approach.

4.06

Prescribed mixes are those for which the purchaser specifies the mix proportions and is responsible for ensuring that these will provide him with the performance he requires. With a prescribed mix, strength testing is not used to judge compliance, the requirements being that the constituent materials and their proportions shall comply with those specified. Prescribed mixes are not used now in the majority of cases by Irish engineers, the requirements almost always being for designed mixes.

Designed mixes are those for which the purchaser is responsible for specifying the required performance and the producer selects the mix proportions to produce this performance. A standard method of designating concrete by the use of grades has been adopted in B.S. 5328 (based on ISO 3893) and the I.B.S. and I.S. 194 (23) follow B.S. 5328 also.

Prescribed mixes are dealt with in Section Two of B.S. 5328 and designed mixes and special prescribed mixes are dealt with in Section Three.

4.07

Over the past number of years, the trend with designed mixes is to specify concrete quality by means of strength grade. For designed mixes, this involves specifying (B.S. 5328), as a minimum, permitted types of cement (I.S. 1 : 1963), permitted type(s) of aggregate (I.S. 5 : 1974), nominal max. size aggregate, grade of mix (compressive), minimum cement content, and rate of sampling. The principal optional items are workability, maximum free-water/cement ratio, maximum cement content and admixtures. The concrete manufacturers point out that, when specifying for designed mixes, care should be exercised so that anomalies do not arise between the items above when specified. This occurs sometimes, for example, when both minimum cement content and maximum water/cement ratio are specified together with workability fixed. In more recent times, problems in durability of concrete have come prominently to the attention of engineers and greater care must now be given to its specific inclusion in design and specification so that the structure will be durable. Specification of minimum cement content and cover to reinforcement are important elements in this context. For their guidance the contractor and concrete manufacturer should be informed of the environmental conditions prevailing and the durability requirements of the design. There is a paper devoted to this topic in this Symposium, so it is not necessary to dwell further on it, except to summarise, in respect of specifications, by quoting the draft of the revised C.P. 110 "With strong normal weight aggregates, a suitably low permeability is achieved by having an adequate cement content and a sufficiently low water/cement ratio, by ensuring complete compaction of the concrete, and sufficient

hydration of the cement through proper curing methods". The recommendations of C.P. 110 (particularly in the coming version) if applied carefully, will meet the durability requirements of almost all structures, and for exceptionally severe environments, additional precautions may be necessary and specialist literature should be consulted (34).

4.08

The C.M.A.I. have produced their own code (similar to the corresponding U.K. Code) with recommendations on specification, ordering and production. This is the C.M.A.I. Code for ready-mixed concrete and concrete blocks : 1980. It is noted that the recommendations in the document do not require a minimum cement content to be specified.

4.09

Compliance

Procedures for compliance with specified requirements for both designed and prescribed mixes for ordinary structural concrete are given in Section 6.8 of C.P. 110, together with recommendations for a testing plan and action in the event of non-compliance with the testing plan. A review of this section was given at the 1975 Symposium and the position has not altered substantially since then. B.S. 5328 covers compliance for prescribed mixes in Section 10 and for designed mixes in Section 16 of that document. Contractors consider that, on the whole, they do not have problems with the specified compliance requirements, although cube failures do occur from time to time. They would prefer, however, if engineers were more specific in their specifications as to how concrete which does not comply should be dealt with and particularly at what stage it must be removed. C.P. 110 in paragraph 6.8.2.3 (and 2.3.2) gives guidance on this point and on the testing programme that may be carried out. B.S. 6089 : 1981 (24) on the assessment of concrete strength in existing structures is also useful here. Other references are the various parts of B.S. 1881 (Testing concrete), B.S. 4408 (non-destructive methods of test for concrete) and Concrete Society Technical Report No. 11 (25). This is a complex area and probably the point to be appreciated is that cubes are a sample of the concrete to be poured, and the same concrete in the structure is compacted differently, cured differently and behaves differently. The engineer can preserve in contract specifications his right to make the final decision to accept or reject the concrete.

4.10

Admixtures for concrete

Not many engineers in Irish practice (less than 20%) at present specify admixtures for concrete. The reason is probably that good concrete can be produced easily without admixtures and there is a distrust of the longterm effects, this distrust being fuelled by the problems (reinforcement corrosion) which have arisen from the use of calcium chloride as an admixture. The use of a limited amount of calcium chloride in R.C. work was encouraged in engineering litera-

ture during the early 1960's as a means for example of combating delays in construction in cold weather, thereby producing large benefits in economic terms for the industry and its use was still allowable up to 1.5% by weight of cement in C.P. 110 : 1972. Engineers now, however, would be very cautious with an admixture which contained a significant element of calcium chloride or sulphates in its composition. Unless specifically prohibited, ready-mixed concrete manufacturers will probably use an admixture in their mixes, in which case they should inform the purchaser of the constituents of the admixture. The current edition of C.P. 110 : 1972 strongly recommends that calcium chloride should never be added to reinforced or prestressed concrete.

4.11

The general situation with regard to admixtures will probably change. Some admixtures have been marketed for over twenty years now, and, in the future, it may not be possible to ignore the economies and the improvements in certain properties of concrete which admixtures can provide when properly used. In most industrialised countries, admixtures are controlled by way of compliance with standards. In Irish and U.K. practice, admixtures come within the British Standards framework. B.S. 5075 Parts 1 & 2 are probably the most commonly used (see also Ref. 26). The importance of admixtures is also recognised in the draft C.P. 110 which has clauses on their specification, approval and performance requirements.

4.12

The principal types of admixtures in use may be classed as (1) accelerators, (2) retarders, (3) water reducing/plasticisers, (4) super-plasticisers. Probably the most widely used type is (3) above which is used basically to achieve higher strength with reduced water content at a maintained workability.

4.13

Pulverised fuel ash (P.F.A.), a fine powder, is the residual product of the pulverised coal burnt in the furnaces of many electricity power stations. P.F.A. is used in concrete and as an additive in cement, in the U.K. The author understands it is under consideration for use in Ireland. In concrete its use is controlled by B.S. 3892 : Part 1, and in accordance with the requirements of C.P. 110. Reports indicate that the quality can vary depending on the type of coal used. Hence, definite approval procedures will be required before it is used.

4.14

Waterproof Concrete

As already referred to in 3.09, the structural use of concrete for retaining aqueous liquids is dealt with in B.S. 5337 (16). Indications are that the majority of engineers at present use this code, both for design and specification, although over 20% still use the former code C.P. 2007. In addition to design, B.S. 5337 also covers detailing and

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workmanship, including the very important topic of joints. Recommendations are also given for specifying, producing and assessing concrete for compliance to ensure that the strength, durability, and impermeability will be adequate for aqueous liquid-retaining structures. The requirements of Section 6, C.P. 110, apply for structures designed on limit state principles, and for the alternative method, the requirements of C.P. 114 and C.P. 115 apply. Table 8 of B.S. 5337, which gives minimum cement content to ensure durability relative to exposure classes A and B, is an important item of the code which was not directly stated in its predecessor.

It is notable that there is no reference to B.S. 5337 or to waterproof concrete in the Proposed Building Regulations.

4.15

Contractors experience some difficulties with waterproof concrete. They point out that some specifications do not state clearly how the waterproof concrete is to be achieved by the contractor and there is a lot of divergence in specifications on this point. Some contractors suggest that a performance specification for the concrete and its finish would be appropriate leaving the achievement of impermeability and durability to the contractors and concrete supplier subject to the approval of the engineer. This approach requires close co-operation between contractor and engineer. Contractors suggest that such a procedure is preferable to a specification requiring an admixture which may be difficult to obtain together perhaps with some anomalies in specification clauses. Joints can present more problems than the concrete and require careful detailing. For ease of construction and good performance later, joints and reinforcement detailing should be kept as simple as possible.

5. Concrete Blockwork

5.01

Concrete blocks and bricks are a major product of the concrete industry. In Irish practice, concrete blocks are specified in accordance with I.S. 20. Standard concrete blocks are produced in solid and hollow forms in a "450" and "400" range. High strength solid concrete blocks are also produced with average strengths of 10.5, 21, and 28 N/mm². These strengths are determined by testing "on edge".

5.02

I.S. 20 is currently under revision and has been issued in draft form for comment. It is possible that, in the future, a further part of I.S. 20 will be prepared dealing with lightweight concrete blocks. This latter would be a very useful addition to the range and, apart from use in walling would, provided a strong block can be produced, yield economies in the structure of many buildings (e.g. hospitals, universities, etc.) which at present carry heavy loading from block partitioning which is not placed along the structural lines.

5.03

The design of loadbearing concrete blockwork may be carried out in accordance with B.S. C.P. 111 : Part 1 : 1970 (28), and this code is "regarded as satisfying" in the Proposed Building Regulations. The majority of engineers, however, have been using the newer limit state code B.S. 5628 : Part 1 : 1978 (28), although indications are that up to 40% still use C.P. 111. A new and very significant Irish code of practice for unreinforced masonry has recently been issued in draft form. The document I.C.P. 5 (29) generally conforms with B.S. 5628, but with some important departures, the principal ones being :

- (a) references to Irish Standards for Irish masonry materials
- (b) references to block masonry constructed from solid blocks, having an aspect ratio of between 0.4 and 0.5, have been included
- (c) the reference to wall ties has been developed to reflect more accurately Irish practice.

There is a new Irish Standard on wall ties at present in preparation. I.C.P. 5 will eventually become a "regarded as satisfying" part of the Building Regulations.

For walls in brick or block of a residential building having not more than three stories, Schedule 2 of the Proposed Building Regulations applies, and this is commented on later in para. 8.11.

6. Regulations and Approvals**6.01**

Bye-laws, with respect to the construction of buildings, are in existence only in the major city areas of Ireland and are generally old and inappropriate to modern construction. Most Local Authorities apply the Proposed Building Regulations although these regulations have not yet been officially introduced. In Dublin City and County, it is now necessary, to submit general arrangement drawings and structural calculations for structural concrete in order to obtain bye-law approval, and the situation in Cork is similar. The remaining Local Authorities are usually prepared to grant bye-law approval provided design and construction are in accordance with the Codes of Practice and other Standards generally in use, and a certificate from the consulting engineer in this regard is acceptable. At present, the Fire Authority in each Local Authority requires the submission of relevant drawings and information for approval by the Chief Fire Officer.

6.02

Approvals for projects which benefit from State financial grants usually require the submission of at least drawings and specification to the relevant Government Department or Semi-state body, and in the case of bridges (Department of the Environment) structural calculations are also required. The project is then examined technically and with regard to costs before approval is granted.

6.03

Various building control arrangements in relation to the Proposed Building Regulations are mentioned later in the paper.

7. The Proposed Building Regulations

7.01

Probably the most significant development in the Irish building practice in this century has been the publication of the Proposed Building Regulations, dated October 1983, and generally released to the public in May 1984. This document is the latest draft of the Building Regulations which the Minister for the Environment proposes to introduce after the enactment of the enabling legislation. The Proposed Building Regulations are an extensive revision of the Draft Building Regulations published in 1981, which they replace. The regulations will be the basis on which Specifications, Standards and Codes will be used in Irish Practice in future years. It is therefore necessary to discuss their implications for concrete structural work.

An Foras Forbartha have produced a Guidance Manual to the Building Regulations which provides interpretation for the Regulations.

8. Concrete Codes and Standards in the Proposed Building Regulations

8.01

Direct references to concrete in the Regulations are relatively few :
A3 (1) refers to brick and block : rules for measurement of work size.
C5 (2) refers to concrete ground floors re : ground moisture. E : see 8.03 below.

P3 (2) Concrete floors : in relation to sound insulation.

M (7) and (8) Concrete to drain beds and haunching.

N : see section 9.00 below.

R : (various clauses) : chimneys in blockwork.

Schedule 6 : thermal insulation of concrete walls, roofs and exposed floors.

Schedule 8 : sound insulation related to concrete.

8.02

Basically the regulations say nothing about concrete as a material. In Part B, Materials, there is a performance/functional statement which applies to concrete as well as other materials. Any materials used shall be :

- (I) of a suitable nature and quality for the purpose and use conditions,
- (II) adequately mixed or prepared and
- (III) applied, used or fixed to perform adequately the functions for which they are designed.

The Regulation is satisfied if the material, its preparation and application, conform with an Irish Standard or Irish Code of Practice.

8.03

Part E : Structural Strength and Stability, is the principal part covering structural work as a whole, including concrete. Unlike some other Parts, Part E in general does not state how to perform its requirements, but refers to other sources throughout. Structures other

than buildings are not covered in the regulations nor is there a definition of a building as distinct from, for example, a civil engineering structure. The only guide in this respect might perhaps be the application of Schedule 1, Designation of Buildings by Purpose Group. In the Control Bill, however, a building is defined and it permits the Minister to prescribe any class or classes of structure to be a building. This could have considerable consequences as we do not know the extent to which this power will be used.

As with other parts of the regulations, Part E contains:

- (a) Regulations, contained in the mandatory clauses (these may be relaxed),
- (b) "regarded as satisfying" clauses. Where these relate to codes the provisions of the relevant code cannot be relaxed.
- (c) Schedule 2, a "regarded as satisfying" Schedule which gives sixteen rules covering requirements as to structural stability of certain walls. The application of the Schedule is for residential buildings of not more than three storeys, and it applies to any structural work in bricks or blocks. In Ireland, concrete block walls would probably constitute the major application of this Schedule. For people engaged in smaller building works, where structural calculations are not normally used, the schedule, together with the Manual, gives comprehensive guidance on the arrangement and sizes of walls, openings, and beam or lintel bearings.

8.04

It is relevant to consider the position when the "regarded as satisfying" codes become out-of-date and are replaced by new codes. The designer or contractor would usually regard the newer code edition as an improvement on the old one and, therefore, more relevant for use. It is unlikely that a Local Authority would dispute an up-dated code, but it is for the user to satisfy himself that the new code complies with the relevant mandatory clauses and he adopts the new code on his own responsibility. New codes can be introduced into the Regulations by Ministerial Order.

8.05

As with the remainder of the Regulations, Part E is a performance specification, the individual regulations being for the finished object. Generally it is the work which is covered, not just the design.

Summary of Selected Clauses

8.06

Loading (E3)

This important regulation refers to the only mandatory codes in Part E, B.S.C.P. 3: Chap. V: Part 1: 1957, and Part 2: 1972. These codes cover dead, imposed and wind loads. The regulations also provide in Schedule 3 a map of Ireland showing isopleths of basic wind speed in m/sec. provided by the Meteorological Service, Dublin. The isopleths show gust wind speed in m/sec. with a return period of 50

years at a height of 10 m above open level country. Interpolation between the isopleths to the nearest metre per second is allowed for various locations in the country (Fig. 1).

The British Standards Institution have now withdrawn C.P. 3 Chap. V : Part 1, and replaced it by B.S. 6399 : Part 1 : 1984. This code has been discussed in para. 2.02 above. C.P. 3 : Chap. V : Part 2 is at present being revised and will be issued as B.S. 6399 Part 2. A further part of this British Standard is also under preparation and this will be B.S. 6399 : Part 3 : Code of practice for snow loading.

8.07

Foundations (E4)

Mandatory regulations for foundations are generally similar to those in the U.K. The foundations must be capable of sustaining and transmitting all relevant loads to the ground so that "any settlement or other movement does not impair the safety or durability of or cause significant damage to the building, or any adjoining building or works". A difficulty here is to define "significant damage". Some damage appears to be allowable provided it is not significant. Correctly, the clause also applies "to any adjoining building or works". Temporary works, currently handled as the contractor's responsibility, are sometimes involved here and in view of the implications of this clause, contract procedures may need to be reviewed.

8.08

"Regarded as satisfying" codes for foundations are B.S.C.P. 2004 : 1972 : Foundations, B.S.C.P. 101 : 1972 for buildings of not more than four storeys, and where foundations are constructed of reinforced concrete, either C.P. 110 : 1972, or C.P. 114 : 1969. C.P. 2004 does not deal directly with concrete mixes, except for precast piles, and it states that reference should ALSO be made to C.P. 101 for structures of not more than four storeys. This latter code in para. 3.8 deals with *mass concrete* strip foundation in good ground and stressed in direct compression only. Such foundations must contain at least 180 kg/m³ cement, which appears to be rather low cement content for current practice.

The original draft for the revised C.P. 110 gives C. 25 with 250 kg. cement minimum as the lowest grade permitted for *reinforced concrete*. It appears to suggest that, for R.C. strip foundations used in non-aggressive soil conditions and with mild exposure, this may be reduced to C.20 provided cement content is not less than 220 kg/m³ and the nominal cover is not less than 50 mm.

8.09

In the Building Regulations no minimum width is suggested for strip foundations. The rule of three times the wall thickness required under Dublin bye-laws will no longer be obligatory and some people will regret this.

MAP OF IRELAND
SHOWING BASIC WIND
SPEED IN m/s

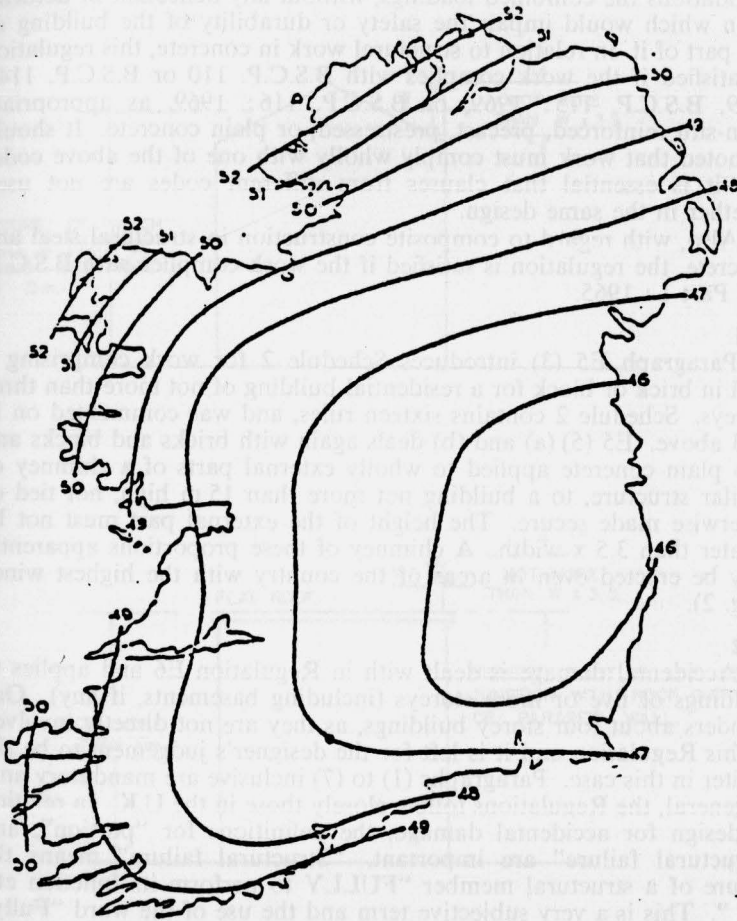


FIG. 1

MAXIMUM WIND SPEED IN A GUST m/s WITH RETURN PERIOD 50 YEARS. VALUES REFER TO A HEIGHT OF 10 m ABOVE OPEN LEVEL COUNTRY,

Based on information provided by the Meteorological Service, Dublin

8.10

The structure above ground (E5) probably contains the kernel of the structural strength and stability regulations. The structure shall be so constructed (performance again) as to sustain and transmit to the foundations the combined loadings, without any deflection or deformation which would impair the safety or durability of the building or any part of it. In relation to structural work in concrete, this regulation is satisfied if the work complies with B.S.C.P. 110 or B.S.C.P. 114: 1969, B.S.C.P. 115: 1969, or B.S.C.P. 116: 1969, as appropriate to in-situ reinforced, precast, prestressed, or plain concrete. It should be noted that work must comply wholly with one of the above codes and it is essential that clauses from different codes are not used together in the same design.

Also, with regard to composite construction in structural steel and concrete, the regulation is satisfied if the work complies with B.S.C.P. 117 Part 1: 1965.

8.11

Paragraph E5 (3) introduces Schedule 2 for work comprising a wall in brick or block for a residential building of not more than three storeys. Schedule 2 contains sixteen rules, and was commented on in 8.03 above. E5 (5) (a) and (b) deals again with bricks and blocks and also plain concrete applied to wholly external parts of a chimney or similar structure, to a building not more than 15 m high, not tied or otherwise made secure. The height of the external part must not be greater than $3.5 \times \text{width}$. A chimney of these proportions apparently may be erected even in areas of the country with the highest winds (Fig. 2).

8.12

Accidental damage is dealt with in Regulation E6 and applies to buildings of five or more storeys (including basements, if any). One wonders about four storey buildings, as they are not directly involved in this Regulation and it is left for the designer's judgement to be the arbiter in this case. Paragraphs (1) to (7) inclusive are mandatory and, in general, the Regulations follow closely those in the U.K. In relation to design for accidental damage, the definitions for "portion", and "structural failure" are important. "Structural failure" means the failure of a structural member "FULLY to perform its function etc. . . .". This is a very subjective term and the use of the word "Fully" has implications that perfection is required. C.P. 110 interprets failure as "unfitness of the structure for use" which seems a more practical definition.

8.13

A new feature not in the U.K. regulations is given in paragraph E6 (4). This is the treatment at the corner junction of two external load-bearing walls in the event of the simultaneous removal of the "portions" of both walls forming the corner. Any structural failure occurring will be limited to the extent specified in E6 (3) i.e. no progressive collapse

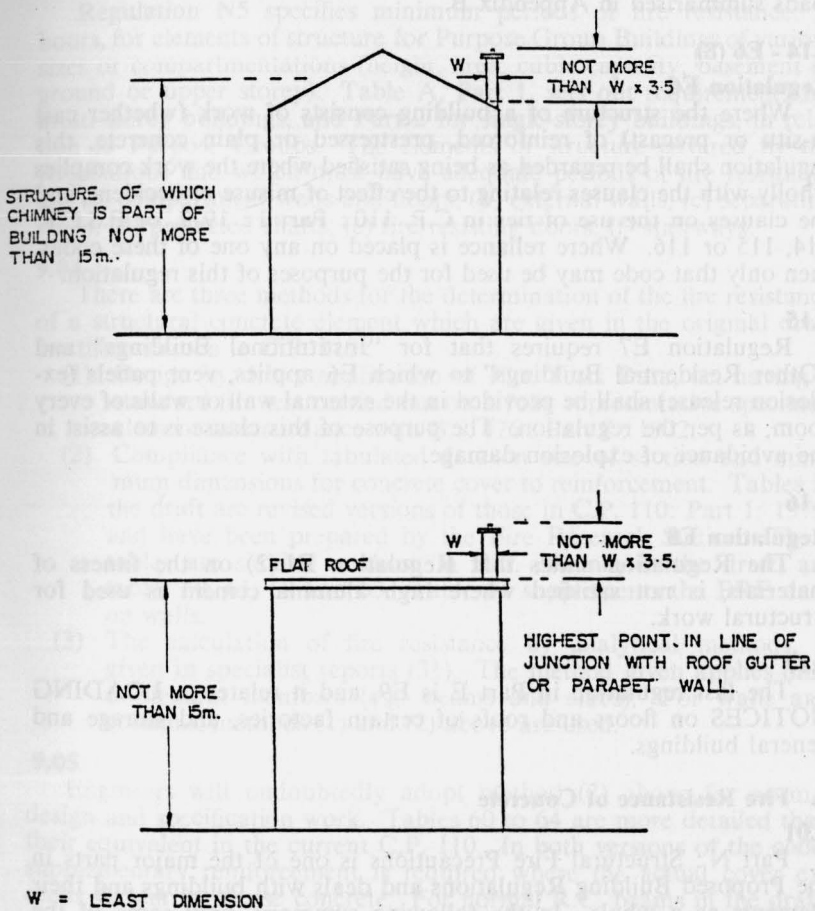


FIG. 2

to occur, failure contained within the storey itself and the one above and the one below, and failure localised within each such storey. Satisfying this requirement gives designers a problem unless, perhaps, a corner column is used (33). Paragraph E6 (5) requires that the "portion" should be capable of sustaining without structural failure the loads summarised in Appendix B.

8.14 - E6 (8)

Regulation E6

Where the structure of a building consists of work (whether cast in-situ or precast) of reinforced, prestressed or plain concrete, this regulation shall be regarded as being satisfied where the work complies wholly with the clauses relating to the effect of misuse or accident, and the clauses on the use of ties in C.P. 110 : Part 1 : 1972, or B.S.C.P. 114, 115 or 116. Where reliance is placed on any one of these codes, then only that code may be used for the purposes of this regulation.

8.15

Regulation E7 requires that for "Institutional Buildings" and "Other Residential Buildings" to which E6 applies, vent panels (explosion release) shall be provided in the external wall or walls of every room, as per the regulation. The purpose of this clause is to assist in the avoidance of explosion damage.

8.16

Regulation E8

The Regulation states that Regulation B1 (2) on the fitness of materials, is not satisfied where high alumina cement is used for structural work.

8.17

The last regulation in Part E is E9, and it relates to **LOADING NOTICES** on floors and roofs of certain factories, and storage and general buildings.

9. Fire Resistance of Concrete

9.01

Part N : Structural Fire Precautions is one of the major parts in the Proposed Building Regulations and deals with buildings and their elements as a whole. In the following summary, only some of the principal aspects related directly to structural concrete can be reviewed in the confines of this paper.

9.02

Regulation N3 sets out the fire performance criteria for elements of structure with regard to stability, integrity, and insulation, together with "regarded as satisfying" clauses in N3 (2) (a) and (b). In the proposed Regulations, C.P. 110 : 1972 is not regarded as satisfying for fire.

Table A in N3 sets out the requirements for fire resistance relative to the above conditions. Specifications and the notional periods of fire resistance are set out in BRE Report "Guidelines for the construction of fire resisting structural elements : 1980" (30).

9.03

Regulation N5 specifies minimum periods of fire resistance, in hours, for elements of structure for Purpose Group Buildings of various sizes or compartmentations (height, area, cubic capacity, basement or ground or upper storey). Table A, Part 1, sets out requirements for multi-storey buildings, and Part 2 for single-storey buildings, in relation to Purpose Groups. The elements of structure covered by the Regulations and which must have adequate periods of fire resistance are (a) compartment walls and floors, (b) external walls, (c) separating walls, (d) protected shafts, (e) fire-resisting doors, (f) stairways.

9.04

There are three methods for the determination of the fire resistance of a structural concrete element which are given in the original draft for the revisions to C.P. 110 :

- (1) Design by direct application of Fire Tests Data, i.e. having a standard fire test carried out on a fully representative specimen element in accordance with B.S. 476 : Part 8 : 1972.
- (2) Compliance with tabulated data on size of section and minimum dimensions for concrete cover to reinforcement. Tables in the draft are revised versions of those in C.P. 110: Part 1: 1972, and have been prepared by the Fire Research Station. These tables are similar to those in Ref. 30 and, in the draft, are tables 60, 61, 62 and 63. Table 64 supplements the BRE data on walls.
- (3) The calculation of fire resistance by analytical methods, is given in specialist reports (31). The method given applies only to flexural members (e.g. beams and slabs). For walls and columns, methods (1) and (2) above are used.

9.05

Engineers will undoubtedly adopt method (2) above for normal design and specification work. Tables 60 to 64 are more detailed than their equivalent in the current C.P. 110. In both versions of the code, supplementary reinforcement is required where the actual cover exceeds 40 mm for dense concrete. For normal R.C. beams in the draft, covers have generally been increased and supplementary reinforcement will be required at 2 hours or more fire resistance, and for slabs covers have in general also been increased with supplementary reinforcement required above 2 hours fire resistance.

10. The Building Control Bill 1984

10.01

The Building Control Bill 1984, for enabling legislation, was circulated to interested parties by the D. o. E. early in 1984. The Bill

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provides the Minister for the Environment with powers enabling him to make regulations related to the technical requirements of the Building Regulations and to the administrative controls for the Regulations. At the time of writing (Dec. 1984), the Bill has passed its second stage in the Dail and the next stage (Committee Stage) is expected early in 1985. When the Bill eventually has passed all stages and becomes law, two sets of regulations, as indicated above, will be introduced : (1) Building Regulations and (2) Building Control Regulations. Eventually each of these regulations will also become law and an order will then be made as to the date on which each comes into operation. At present it is intended that the Proposed Building Regulations will be adopted as they stand, with the word "Proposed" omitted and with the operative date and the Minister's seal added.

10.02

The Construction Industry Federation has made submissions to the Minister concerning the liability sections, and the administrative procedures in the Bill. Joint submissions were also made to the Minister by the engineering (I.E.I. and A.C.E.I.), architectural, and surveying professional Institutions, stating their views and suggestions on various clauses of the Bill. Among many important aspects discussed, the main item of concern to the Institutions was the possibility of statutory negligence being introduced in the area of civil liability as a consequence of certification to Building Regulations which legally require strict compliance. The author understands that active attention is being given to this and the other matters by the Minister.

10.03

It is the intention of the Minister to set up the Building Regulations Advisory Body which will include representatives from the building professions and the industry. One of the functions of the BRAB will be to advise the Minister on detailed proposals for the control system along the lines envisaged in the Bill. The Building Control Regulations will contain the administrative procedures for the control system whether it be an approved system, a certification system, or some other option.

10.04

One of the options in the Bill envisages building controls being achieved through a system of certificates issued by private individuals and bodies rather than by Local Authorities. This would represent a major change in current control systems and responsibilities. Designers of building works would certify compliance of the particular design aspects for which they are responsible and, presumably, contractors would certify compliance of the construction. Should this system be the one adopted, it will be unique to this country.

Acknowledgements

The author wishes to express thanks to the many engineers in private practice, State bodies, Local Authorities, contracting firms, and suppliers, who completed questionnaires and provided information for the preparation of this paper. Their contributions have been both helpful and most valuable.

APPENDIX A

1. Summary of Irish Standards and Codes of Practice relating to Structural Concrete : I.I.R.S.

Irish Standards :

I.S. 1 : 1963	Portland Cement. Revised 1972 and 1982 (under revision)
I.S. 5 : 1974	Aggregates for Concrete (under revision)
I.S. 20 : 1974	Concrete Building Blocks (under revision)
I.S. 189 : 1974	Concrete Building Bricks
I.S. 194 : 1980	Method of Production and Supply of Ready-Mixed Concrete
I.S. 214P : 1980	Precast Prestressed Concrete Units for use in Composite Lintels—Dimensions
I.S. 215P : 1980	Precast Reinforced Concrete Lintels—Dimensions
I.S. 240 : 1980	Precast Prestressed Concrete Units for use in Composite Lintels
I.S. 249 : 1982	Cattle Slats
I.S. 255 : 1983	Precast Reinforced Concrete Lintels.

Irish Standards and Codes of Practice being prepared :

I.S. - - - :	Wall ties for Masonry Walls
I.S. - - - :	Masonry Mortars
I.C.P. 5 : Part 1	The Structural Use of Unreinforced Masonry (in course of publication)
I.C.P. 6 :	The Structural Use of Concrete (in course of publication)

2. Some other relevant Irish Documents :

Specification for Road Works: Department of the Environment, Dublin.

Recommendations for Site Development Works, for Housing Areas : by Minogue and Connell : An Foras Forbartha 1984.

Irish Building Specification. An Foras Forbartha.

APPENDIX B

E6 Accidental Damage

Applies to : 5 storeys or more.

Mandatory.

If any portion of any one structural member removed, structural failure is confined to that storey and the one directly above and directly below.

AND

Localised within each storey.

(Satisfies : If localised to an area of 70 m^2 or 15% of the area of the storey whichever is less).

The relevant portions must be designed to support 105% of :

Dead Load

Plus

One-third imposed load (but full plant and/or storage loads included.
For factories imposed load not to be reduced below 5 kN/m^2).

Plus

One-third wind load

Plus

34 kN/m^2 in any direction

Plus

Load transmitted directly from adjacent part if that
part loaded with 34 kN/m^2 .

For Reinforced Concrete Work :

SATISFIES : where the work complies with C.P. 110 Part 1, Stability clauses.

Or

C.P. 114, C.P. 115, or C.P. 116 (and addenda), Stability clauses.

An exception is the corner condition in Clause E6 (4) of the Regulations.

References

- (1) BSCP. 3. Chap. V : Loading : Part 1 : 1967. Dead and imposed loads.
- (2) BSCP 3. Chap. V : Loading : Part 2 : 1972. Basic data for the design of buildings : Wind load.
- (3) BS 6399 : Part 1 : 1984 : Design loading for buildings. Code of practice for dead and imposed loads.
- (4) BSCP 6180 : 1982 : Protective barriers in and about buildings.
- (5) BRE Digest 119. New edition 1984.
- (6) BRE Digest 283. The assessment of wind speed over topography.
- (7) BRE Digest 284. Wind loads on canopy roofs.
- (8) BRE Digest 280. Loads on roofs from snow drifting against vertical obstruction and in valleys.
- (9) Department of Transport Technical Memoranda. BE5, BE27, BE29, BE3/72.
- (10) Department of Transport Technical Memoranda. BE5, BE27, BE29, BE3/72, BE1/73, BE2/73, BE7/74.

- (11) Civil Engineering Code of Practice No. 2 : 1951 : 1. Struct. E.
- (12) C.P. 110 : Part 1 : 1972 : Design materials and workmanship.
 Part 2 : Design charts for beams and rectangular
 columns.
 Part 3 : 1972 : Design charts for circular columns.
 and
 AMD 2289, May 1977 (incorporating AMD 1553, AMD 1881),
 AMD 3451, November 1980.
- (13) Concrete Practice in Ireland : 1975 : Symposium, University
 College Dublin.
- (14) Flat slabs in post-tensioned concrete with particular regard to
 the use of unbonded tendons — design recommendations. The
 Concrete Society.
- (15) Post-tensioned flat-slab design handbook. The Concrete Society.
- (16) BS 5337 : 1976 : Code of practice for the structural use of con-
 crete for retaining aqueous liquids.
- (17) (a) ACI Standard : Building code requirements for reinforced
 concrete (ACI 318-77).
 (b) Building code requirements for concrete masonry structures
 (ACI 531-79) (Revised 1981).
- (18) ACI manual of concrete practice 1984 : Part 3. Use of concrete
 in buildings — design, specifications and related topics.
- (19) Specifications for structural concrete for buildings : ACI 301-72
 (Revised 1981).
- (20) Commission of the European Communities : Eurocode No. 1.
 Common unified rules for different types of construction and
 material.
 Eurocode No. 2 : Common unified rules for concrete structures.
- (21) B.S. 5328 : 1981 : Methods for specifying concrete, including
 ready-mixed concrete. (Replaces B.S. 1926).
- (22) Irish Building Specifications : Part 1 — Volume 1. An Foras
 Forbartha.
- (23) I.S. 194 : 1980 : Method of production and supply of ready-mixed
 concrete. (I.I.R.S.).
- (24) B.S. 6089 : 1981 : Guide to assessment of concrete strength in
 existing structures.
- (25) Concrete core testing for strength : Concrete Society Technical
 Report No. 11.
- (26) I. Struct. E/Foras Forbartha Seminar : Durability of concrete :
 May 1983.
- (27) I.S. 20 : 1974 : Concrete Building Blocks : (I.I.R.S.).
- (28) BSCP 111 : Part 2 : 1970. Structural recommendations for load-
 bearing walls.
 B.S. 5628 : Part 1 : 1978 : Code of practice for the structural use
 of masonry : unreinforced masonry.
- (29) Draft Irish Code of Practice 5 : Part 1 : The structural use of
 unreinforced masonry.
- (30) BRE Report : Guidelines for the construction of fire resisting
 structural elements : 1980 : Read, Adams and Cooke.

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- (31) Design and detailing of concrete structures for fire resistance : Institution of Structural Engineers (1978).
- (32) Deutsche Normen : DIN 1054 : Permissible loading of subsoil. DIN 1055 Design loads for buildings—various Parts.
- (33) I.E.I. : The Engineers Journal : Volume 37, Oct./Nov. 1984, P. 20, "The corner stability problem" by N. M. Ryan.
- (34) Journal of the A.C.I. : December 1966 : Guide for the protection of concrete against chemical attack by means of coatings or other corrosion-resistant material.
- (35) B.S. 648 : 1964 : Schedule of weights of building materials.

Discussion

MR. SCANNELL introduced his paper.

He referred to an aspect of the construction industry that had become more pertinent in the last ten years. As codes, regulations and other such documents proliferated and became more complex, engineers were now having to spend a great deal of their time checking their work against these various documents. It left them less time to think generally about overall aspects of their projects, and this limitation combined with clients' demands for rapid completion to meet short term economic advantage, and the over-optimistic programmes which such demands sometimes extracted from designers, could lead to the missing out of some important general engineering considerations. Added to that, the liability of those engaged in design and construction was increasing, in the absence of appropriate legislation, and the result was a system at the moment approaching the stage of being almost unworkable, and certainly not in the best public interest. Codes of practice tended to be given an increasing status, that they should not have, and designers were being forced to seek defensive shelter behind them. The problems were intensified in his opinion by the inability of the various codes and other documents governing a project to co-ordinate all the elements, materials, and methods, engineering and architectural, in such a manner that when combined they were compatible and performed well in the total project. This aspect of industry needed attention. Mr. Scannell commended the Concrete Consultative Committee at the Institute of Industrial Research and Standards for its efforts in monitoring ISO documents which would in due course be influencing our work through the Eurocodes.

In the area of loading, Mr. Scannell said that while in general we were well served by the British codes, it would be useful for Ireland to develop its own wind loading figures for areas west of the river Shannon, and it would also be appropriate to seek from the Meteorological Office a snow map similar to that which the UK authorities will provide. On design in reinforced and prestressed concrete generally, CP110 was likely to be replaced in the near future by BS8110 which, while it would not represent a change in design philosophy, would show extensive alterations. Most recent information suggested that the

CP114 controversy would continue, in that a new edition of the British building regulations now in preparation would, after their enactment, continue to give approved document status to CP114 for a further two years, possibly in a revised version. On the matter of prestressed concrete, the speaker found CP110 deficient in not giving advice on simplified methods of analysis or on the selection of ducts and sheaths, and on leaving such information as deflexion and creep, and the design of prestressed flat slabs to specialist literature.

Mr. Scannell referred briefly to the forthcoming Irish Standard Code of Practice No. 6 on the structural use of concrete and noted that while it lay close to CP110 in its approach, its main function was to enable the better introduction of relevant Irish Standards to the Irish building regulations.

The advent of the Eurocodes and in particular Eurocode 2 should be kept under review. It would be the responsibility of each country in the Community to establish its own safety margins for work in its own territory, and there should be comparative design and assessment studies carried out in that context. In the United Kingdom, the Department of the Environment had funded this work. There was no equivalent scheme here, and it should be recognised that such studies were costly and should not be expected to be done by private practitioners at their own expense. The Association of Consulting Engineers of Ireland and the Irish branch of the Institution of Structural Engineers were examining the matter, but some more positive basis for funding study should be made available. The enhanced opportunity given through the Eurocodes to designers from outside Ireland to work on projects for this country could not be overlooked.

On the specification of concrete, Mr. Scannell urged the adoption of a single standard document to cover both specification and compliance, and he noted with favour that BS 5328 might become generally accepted. He had circularised the Irish concrete manufacturers and had found them, as expected, urging a simple coherent approach to specification. Points which they had made included (i) the clear stipulation of a minimum cement content where one was intended, (ii) the danger of specifying for the one material both a minimum cement content and a maximum w/c ratio, (iii) the clear stipulation of a maximum w/c ratio where one was intended, (iv) the problems of specifying the limit of maximum slump at placing, without prior consultation with the general contractor, (v) the value of using BS 5328 and BS 1881 for compliance and testing.

Referring to Professor Hanrahan's comment on durability, Mr. Scannell mentioned alkali-silica reaction, which we had not identified over here, as well as carbonation and chloride attack, as topics now influencing our thought more than in the past. He was interested to note that the age factor table had been removed from the new code for structural concrete. Dealing with the compliance testing of completed buildings, the use of cores as discussed in BS 6089 was valuable, but it was essential to underline the ultimate importance of the

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engineers' judgement, which might possibly be conditioned now rather more than before by the legal implications of difficult borderline decisions.

The speaker saw the proposed national building regulations as the most significant development in Irish building for many years, and forecast that the implications of the regulations and the complementary control system, whatever that might be, would be immense. The two sections of the regulations of main interest in the present context were Parts E and N. In Part E, Mr. Scannell expressed some reserve about the relatively lean concrete (180 kg of cement in 1 cubic metre of concrete) permitted, through the acceptability of CP101, in house foundations. There did not appear to be sufficient attention given to the possible variability of ground under a long block of houses. Other matters that had interested him were (i) Schedule 2 for domestic buildings of not more than three storeys, (ii) the definition of failure in rule E6, (iii) the banning of high alumina cement for structural concrete. Part N was an important and complex section. In dealing with the fire resistance of concrete, it was important to note that CP110 did not necessarily comply with the regulations.

Mr. Scannell offered very general figures in certain matters on the practice of Irish concrete users. These had come from a questionnaire he had circulated, but he emphasised that they indicated trends rather than, in any sense, precise figures. He had found that 60% of engineers specify grade 30 concrete for superstructures, 50% and 25% respectively specify grade 25 and grade 30 for general foundations. In house foundations about 50% specify grade 20, 40% grade 25, the remainder using either grade 30, or grade 15 which was a quality used in earlier Dublin Corporation specifications. For precast concrete, about 50% used grade 30, and 30% grade 40. Grades 40 and 50 were popular for prestressed concrete; while for water retaining structures, 80% used grade 30 and 10% grade 40, with no designer specifying less than grade 25. For bridges, grades 30 and 40 were used, but grade 50 was also used.

Cubes were used for virtually all compliance testing, and workability was based generally on the slump test, although there was some use of the compacting factor test. For testing of hardened concrete, most reliance was placed on core testing, the use of non-destructive tests being confined to comparisons rather than absolute determinations of strength. The stripping times for formwork given in CP110 were followed, although some preferred to extend these times, and some others, generally precast concrete manufacturers, tended to reduce them. Regarding the size of casts, slabs on grade had been cast up to 1000 square metres with suitable precautions, and suspended slabs at 100 square metres were often specified. Free-standing retaining walls were found to be jointed at from 10 to 30 metres, and 5 to 10 metres was a usual range for walls in water retaining structures. Kickers were almost universal for columns and walls. Power floating had become very usual, although some Local Authorities still used screeds in housing; and screeds were used also where services were to be con-

tained within them. The mix was generally 1 : 3, the thickness varied, the screed joints coincided with the base slab joints, generally 20 to 30 metres, and about 30% of users used a light mesh reinforcement in the screed and cast after completion of the base slab. Other users deliberately placed a membrane between the base slab and the screed and then cast the screed 50 to 100 mm thick, but that was not usual.

In conclusion, Mr. Scannell referred briefly to the genesis of the Building Regulations and control procedures. The Public Health (Ireland) Acts of 1878 and 1890 gave power to local authorities to make bye-laws for, amongst other things, securing the stability of buildings and prevention of fire. Only a few authorities took advantage of this, and what was produced varied considerably from one authority to another. In 1963, the Local Government Planning and Development Act enabled national building regulations to be introduced. This led in due course to the existence now of a set of regulations more or less fully accepted by the construction industry and by engineers and architects, and accompanied by an explanatory manual prepared by An Foras Forbartha in conjunction with the Department of the Environment. Whilst these Regulations were now being observed generally by designers, they had not become law. A control system was required for their enforcement and legislation had been prepared to establish it also. The nature of the control had been under discussion for some time, whether it should be self-regulatory by way of self-certification, or should be by an approval system, or by some combination of the two. This matter had been under active discussion in the United Kingdom also, and there was no doubt that any self-regulatory system would become heavily involved with professional indemnities. In that context, Mr. Scannell urged that whatever control system be decided on, it should not further aggravate the present difficult legal situation in the building industry by imposing further legal liabilities on those concerned.

MR. P. PIGOTT opened the discussion.

Looking back at the papers of Mr. Gwynn in 1965 and Mr. Harrington in 1975, he observed two trends emerging in 1985. Firstly there was a better understanding now of specification in concrete practice, and secondly there was evidence of an increase in Government interest in, and control of, construction practice generally. Mr. Scannell had referred to the State as the corporate client insisting essentially on better value for money, and Mr. Pigott would submit that the State assumed thereby a responsibility to ensure that adequate procedures, codes, and standards were made available to the construction industry towards that end. The Eurocodes and Building Regulations were two major areas for consideration. The Department of the Environment had taken responsibility for the Eurocodes, which itself was a break with tradition. It was setting up an Advisory Committee to help its deliberations, and, as Mr. Scannell had said, it was important that the Industry and the professional bodies should make a serious input into that work. In the United Kingdom, formal

studies had been made of Eurocode 2 by the Building Research Establishment to establish the adequacy of coverage given by the Code, to relate its provisions to those of CP110, and to provide appropriate numerical values for its partial safety factors as applied to work in the UK. Some startling conclusions had been reached in this study, in that it considered that beams designed to Eurocode 2 could be unsafe in shear where the quantity of main tensile steel was low and that CP110 called for 50% more cover than the Eurocode. It also found that current British thinking would not suggest that any reduction in the covers specified in CP110 would be justified, and that Eurocode 2 did not give any specific requirements for fire protection. Such findings as these should put us on our guard, and should urge our careful consideration of the draft Code.

Referring to the proposed Building Regulations and the associated control procedures, Mr. Pigott first drew attention to a current proposal to omit housing from the control regulations. While he believed all would agree that the level of professional structural input in housing was relatively low, this omission was a subject that might be debated in the symposium. On the matter of self-certification, he felt that that was not a completely new concept, and recalled that Mr. McCullough had favoured it in 1975, deprecating, at that time, the waste of scarce resources in duplicating the calculations of the designer and also questioning the efficiency of a process in which it was possible that checkers would not have at their disposal all the information available to the designer.

Mr. Pigott asked Mr. Scannell whether he had any particular problems of collapse in mind when he spoke of the need for guidance on snow loading, and whether there were particular situations in which he would require special checks to be made for local build-up of snow load. He wondered how, in the light of a proposed Irish Code of Practice for structural concrete, Irish designers would react to the pending major revision of CP110; and what indeed their attitude was to CP110 after thirteen years experience of its use. He questioned the wisdom of giving specific guidance to contractors and concrete manufacturers on the environmental and durability requirements of a design, maintaining that it was the designer's responsibility to design, and the contractor's to comply with that design. Responsibility could not be transferred.

Referring to the making of concrete, he noted that minimum cement content had received little attention at the earlier symposia. The CMAI code published in 1980 did not require that any minimum cement content be specified, and he believed that the Symposium should address that issue. Regarding admixtures, he would like specifications to say that they should not be used unless explicitly called for, and indeed the Irish Building Specification did contain such a clause.

Finally, in a reference to the proposed Building Regulations, Mr. Pigott mentioned the difficulties being experienced in deciding on the accidental damage requirements to be stipulated for the corners of

load-bearing wall structures and advised that a committee of the Institution of Engineers of Ireland was currently considering that matter. As it was, designs to existing UK codes for structural concrete did not necessarily satisfy the proposed Regulations in that aspect. He pointed out also that the terms of Schedule 2 of the proposed Regulations mentioned in paragraph 8.03 of the paper, did in fact relate also to any external wall or internal wall of any small building or annexe as described in Rule 14 of the Regulations.

PROFESSOR J. de COURCY noted that both Mr. Scannell and Mr. Pigott had referred to possible reductions in the thickness of cover. At present ISO documents under consideration were proposing reductions in cover. Those documents would influence Eurocode 2, and we could in due course be required to adopt that Eurocode. Durability was becoming an increasingly critical criterion in structural performance. It was intimately linked with cover, and consequently no decision to reduce cover should be accepted by us without full debate by all concerned. This was merely one item of the input that Irish designers should make on the content of Eurocode 2.

MR. J. GWYNN recalled that, in preparing a parallel paper twenty years ago, he had met exactly the same reaction from contractors, namely why it was that design engineers could not get together and decide on a specification for concrete that contractors could understand. An Foras Forbartha had produced such a specification in the Irish Building Specification and yet it transpired that, in 1985, only 40% of consultants were using it. In his own firm, he had not yet managed to persuade his partners to use the IBS specification. It had been an important contribution to Irish practice, although perhaps he was biased through having been on its drafting committee; and it was of increasing value now, in that litigation and professional indemnity, topics rarely mentioned twenty years ago, were now commonplace in discussion. He would like to ask Mr. Pigott whether the adoption of the IBS clauses on concrete were in fact continuing or had it come to a halt, and if so, was this because revision was required to it.

MRS. P. PIGOTT assured Mr. Gwynn that the promotion of the IBS was proceeding actively. At present it was being developed for use with word processors. He felt that the answer to Mr. Gwynn's question lay partly in his own frank admission, that despite his personal involvement in the preparation of the IBS, he had not been able to convince his partners of the value of the document. An Foras Forbartha sometimes found it hard to reach consultants with its proposals, although the concrete section of the IBS had been prepared by a fairly representative group including designers, manufacturers, and contractors.

MR. J. McCARTIE spoke, as a supplier of concrete, of the difficulty facing suppliers in the great variety of specifications given to them for

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the provision of what were after all very similar end products. An amendment to the CMAI document had made additional reference to the parameter of durability. There certainly were occasions on which minimum cement contents needed to be specified. It would, he believed, help if designers and suppliers could agree on what such minima should be, for various circumstances, and he urged a greater use of the relevant tables in CP110 and BS5328. He suggested that we should consider what was being done in Britain to establish national durability grades, where basically if you did require a higher cement content from a durability point of view, you specified a higher grade of concrete. He mentioned that the manufacturers were collaborating at present with the Irish Concrete Society in studying that matter. We would not necessarily reach quite the same conclusions as in Britain, because of minor differences between the cements in the two countries.

Referring to compliance testing, Mr. McCartie observed that variations in strength arose basically from three causes, the ingredients of the mix, the operation of the mixing plant, and the sampling and testing programme. Everyone recognised that variations were inevitable in test results on concrete, and he urged designers to consider fully the general quality of the concrete revealed by an overall testing plan, when faced with a low result that might not indeed reflect the quality of the concrete as placed.

MR. SCANNELL replied to the discussion. Regarding the omission of housing from the proposed control regulations, he had served on a committee which had discussed those regulations with the Minister for the Environment and his officials, and that had been a major topic of discussion. The reason for its omission had been the difficulty of its inclusion and the problems it would cause Local Authorities. The Committee had argued for its inclusion because it was an area where frequently no professionals were involved, and that could lead to increased risk. He could only see self-certification of design calculations as bringing increased responsibility, and he concluded that the possibility of a clause in the control regulations making it mandatory for the certifier to carry professional indemnity underlined his view.

He could not give Mr. Pigott precise references to snow-induced collapses, but the circumstances he envisaged included the filling up of deep valleys in roofs, and the deep drifting of snow against over-roof projections. He agreed that the giving of guidance to builders on environmental matters could not transfer the responsibility for durability away from designers, but he felt co-operation with the builder in such a matter had to be valuable. In reply to Mr. Gwynn, he could report that a number of consultants had said they were changing over to the use of the Irish Building Specification, although most Local Authorities when asked about this, had said they were not using it. It would appear, in the instance of the consultants, that an increasing use of word processors was contributory in their move to the IBS.

THE CHAIRMAN in closing the session endorsed Professor Hanrahan's wish for an end to the present recession. He saw the expansion that had occurred in the roads programme as hopeful, and looked forward to increased activity in bridge engineering, both in new alignments and replacements and in grade separation on motorway routes.

MR. N. V. TORPEY in a written contribution commented that whereas in 1965 and 1975, the symposium discussions carried the implication that, with so many British Standards available, further Irish Standards were not necessary, developments since 1975 suggested however the need for us in Ireland now to put some questions to ourselves.

- (1) What is Ireland's formal position with relation to (some international topic in question) and how can it be stated internationally?
- (2) How do we reach a national finding in such a matter?
- (3) How, to reach such a finding, do we examine UK and international developments?
- (4) With a view to the proposed Building Regulations, how do we show approval for Irish building materials used in a design based on a British code which presumes that materials comply with British Standards.

He believed that questions 1, 2 and 3 remained unanswered. Developments in technology had taken place in an unstructured way and without any formal Irish approval. While we were generally familiar with UK developments, we could not afford to ignore the work of the International Standards Organization (ISO) and the British Committee for Standards (CEN). We did make some assessment of the work of these bodies, as for instance in the technical committees (TC) :—

ISO	TC 71	Concrete, reinforced concrete and prestressed concrete
	TC 179	Masonry
CEN	TC 51	Cement
	TC 94	Ready mixed concrete
	TC 104	Concrete production compliance criteria.

The matter of "simple codes" had been raised, and, whilst he felt that all modern precedent tended against simple codes, he would like to record the existence of two ISO studies, namely TC 71 : Subcommittee 2 : RC design by simple rules; TC 179 : Subcommittee 1 : masonry design by simple rules.

He mentioned the establishment of the Concrete Consultative Committee set up in 1981 to work with the Standards Division of the Institute for Industrial Research and Standards. It had eighteen members and had up to now been enabled to draw on the experience of, in all, some forty engineers. He would like to record the thanks of the Institute to the Committee and the panels it convened for all the advice they had given.

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MR. TADGH WALSH in a written contribution, regretted the low participation of architects in the Symposium and felt also that the quantity surveyors, as construction economists, might have had a useful contribution to make. He noted as a teacher the tension that existed between architects, engineers and quantity surveyors. He thought that perhaps the typical engineer was now so preoccupied with codes of practice, regulations, and computers that he could no longer see the wood from the trees. There were too few engineers in practice with an awareness of the visual impact of their work. There were perhaps too many specialists in civil engineering, and for that reason the well balanced individual giving overall leadership within the profession in Ireland was becoming rare.

MR. J. A. SCANNELL in a written contribution gave some additional information on comments offered to him by contractors. On concrete pumping, it appeared that at present less than half of specifiers included a special clause for ready mixed pumped concrete. Pumped concrete was best suited to inner city work, but the costs involved in maintaining a pump and perhaps using a plasticiser could not be ignored. One major contractor estimated that up to 10% of his concrete was pumped.

Regarding self-finished concrete, not so popular now as it had been some years ago because of its expense, interpretation of specifications led to difficulties. The quality of surface and the incorporation of features on panels were best described by the use of ad-hoc samples or by reference to existing buildings, and the contractor then preferred to quote against performance specifications, leaving him to decide on his method of work.

Composite steel-concrete construction was used occasionally, sometimes to insert mezzanine floors, sometimes in conjunction with the beams in steel framed buildings. Permanent shuttering was often used for the slabs in such buildings, and fire proofing was based on spray-on materials or on the use of patent boards.

Precast concrete floors were widely used, but the problems of screeding sometimes led to the substitution of in-situ floors with power floating. Architectural load-bearing external wall precast panels were not now so popular as before perhaps because of durability problems, and some contractors now felt that, timewise and cost-wise, in-situ concrete could compete favourably with precast concrete in multi-storey framed buildings. Precast concrete was of course seen as well suited to single storey industrial buildings. Precast concrete cladding was still in wide use, but there was some anxiety about its quality, and supervision of the materials used by precasters was necessary to ensure conformity with specification.

Referring to site personnel, Mr. Scannell recorded that there had been an increasing use of technicians on site since 1975; and that sub-contractors were becoming increasingly involved with such matters as formwork, and were being made themselves responsible for dimensions and levels.

SECTION B

CONCRETE AND ITS CONSTITUENTS — PRODUCTION PERFORMANCE AND USE

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Abstract

Trends in the production, supply and use of concrete and its constituent materials over the last decade are examined. Aspects of performance are discussed and some areas of potential development are outlined.

1. INTRODUCTION

Over the last decade, two aspects of the construction industry in Ireland are noteworthy. Firstly, in line with the general state of the country's economic fortunes, the late 1970's were characterised by unparalleled growth in the industry and this expansion has itself been followed by years of decline into recession, the depths of which were generally unforeseen. Secondly, there has been an increasing awareness, among specifiers and users, of the technology associated with the materials employed by the industry.

These two factors have given rise to changes and developments in the production, supply and use of concrete and its constituent materials and to a greater interest within the industry in performance aspects of our primary building material.

The author, through discussions with suppliers, specifiers and contractors, has endeavoured to identify significant developments of the last decade and current trends in the industry.

2. CEMENT

2.1 Production

Significant developments have occurred over the last decade in the production of cement in Ireland. In 1975, cement was produced by Irish Cement Limited in plants at Drogheda, Platin and Limerick. Drogheda and Limerick, where production had originally commenced in 1938, then had annual capacities of 570,000 tonnes, and 750,000 tonnes respectively. Platin, where a single kiln had come on stream in 1973, had an annual capacity of 420,000 tonnes and was producing

cement by the new energy efficient dry process. In 1977, Drogheda was closed when a new 1 million tonne per annum dry process kiln came into production at Platin. The increasing demand for cement in the late seventies led to a decision being made in 1980 to increase the capacity at the Limerick Plant by the addition of a new 650,000 tonne per annum dry process kiln. This kiln came on stream in 1983 and, unfortunately, due to the reduction that subsequently occurred in the demand for cement, the wet process plant at Limerick has not been required since.

The situation now is that the country has a dry process capacity for cement production of 1,420,000 tonnes per annum at Platin and 650,000 tonnes per annum at Limerick.

All kilns are now fired by coal rather than oil, which was the fuel of the seventies. Platin was recently converted to coal while the new Limerick Plant was constructed to run on coal.

The following cements are currently manufactured in Ireland :

1. Normal Portland Cement
2. Rapid Hardening Portland Cement
3. Sulphate Resisting Portland Cement
4. Oil-Well Cement
5. Slag Binder

Normal Portland cement accounts for approximately 93% of sales. Rapid Hardening cement accounts for approximately 5%, and is used by some precast concrete manufacturers and block producers, particularly in the winter months. Sulphate resisting cement, used in specific jobs where resistance to sulphate is called for—sewage works, concrete pipes for the transport of effluent—shares the remainder of the market with two specialist products produced for the oil and mining industries.

2.2 Distribution

Significant improvements have occurred in the cement distribution system over the last ten years.

2.2.1 Bulk cement

Bulk cement is distributed :

- (a) Ex Works — collected by customers' own vehicles or hauliers' vehicles
- (b) By road — by Irish Cement Limited and C.I.E.
- (c) By rail — to depots around the country.

Bulk cement depots have been operational in Dublin and in Cork since the mid-sixties and an expansion of this system was undertaken in the late seventies, leading to the opening of 1,000 tonne capacity rail-head silos at Athenry, Sligo, Waterford and Tullamore in 1979 and 1980.

Table B1 shows the percentage breakdown of bulk cement distribution over the decade. The main trend to be noted is the increase in ex-Works collections and the reduction in cement delivered by Irish Cement Limited and C.I.E. Much of the ex-Works cement is now collected by hauliers (owner drivers).

Restrictions on collections which used to apply at Works due to Work Practices, etc., were removed in the late seventies and customers now have much greater flexibility in relation to the manner in which they receive cement.

Table B1
CEMENT DISTRIBUTION

	Bulk		Packed	
	1975	1984	1975	1984
Ex Works	37%	55%	25%	27%
By Road	34%	19%	10%	12%
By Rail	29%	26%	65%	61%

2.2.2 Packed cement

Palletisation of packed cement which has considerably improved handling and distribution of the product was introduced at Platin Works in 1976 and at Limerick Works in 1978. Packed cement is distributed:

- (a) Ex-Works — collected by customers directly
- (b) By road — by Irish Cement Limited and C.I.E.
- (c) By rail — to 37 depots at rail-heads around the country where it is in turn collected locally by customers.

A depot has also recently been opened at Letterkenny to cater for the Donegal area.

There has been no major change in the pattern of packed cement distribution shown in Table B1, but it is worth noting that, as in the case of bulk cement, greater flexibility relating to supply is now available to users.

2.3 Demand

Sales of bulk and packed cement for the decade are given in Table B2.

Table B2
IRISH CEMENT LIMITED HOME SALES (TONNES)

Year	Total	Bulk %	Packed %
1975	1,452,298	57.5	42.5
1976	1,506,280	57.9	42.1
1977	1,516,419	59.2	40.8
1978	1,751,775	62.4	37.6
1979	2,064,090	66.0	34.0
1980	1,815,186	66.8	33.2
1981	1,815,593	66.2	33.8
1982	1,486,196	65.4	34.6
1983	1,382,424	64.1	35.9
1984	1,297,856	64.7	35.3

Trends in cement sales are often taken as a good indicator of the health of both the construction industry and the country's economy. It is interesting to note that expansionist government policies of the late seventies and the present deep recession are mirrored in both the cement sales statistics and the construction output figures given in Table B3. The peak years for cement sales of 1979, 1980 and 1981 parallel very clearly the peak construction industry outputs achieved between 1979 and 1981.

Table B3
CONSTRUCTION OUTPUT 1975 - 1984*
(at 1975 Price Levels) £m.

	1975	1977	1979	1981	1982	1983	1984
Housing	253	267	359	288	254	275	275
Market Sector**	132	164	261	280	212	137	118
Infrastructure	140	144	178	195	212	202	190
TOTAL	525	575	798	763	678	614	583

*Source: Report of the Sectoral Consultative Committee for the Construction Industry. December 1984. (1).

**Market Sector — Industrial, Semi-State, Commercial, Agriculture.

In relation to bulk/packed demand the main trend has been for an increase in bulk sales and a consequent reduction in packed sales, giving rise to a situation now of approx. 65% bulk, 35% packed. It is noteworthy that the minor peaks in bulk cement usage achieved in the years 1979 to 1981, correspond to the years of greatest activity in the construction industry in the decade.

2.4 Performance

The performance of Normal and Rapid Hardening cements is assessed in accordance with Irish Standard No. 1, 1963 (2). Supplementary testing, notably extra chemical testing and fineness determinations, are carried out regularly by the manufacturer. IS 1, first issued in 1963, is now in need of revision as it does not take account of some current user requirements, notably 28 day strength.

It would seem that strength testing to IS 1 gives a reliable indication of the performance of cement in concrete. Recent research work (3) carried out by Irish Cement Limited in association with the IIRS showed that over a wide range of cement strengths, the performance of cements, evaluated using standard cement tests, mirrors very closely the performance of the cements in concretes.

An interesting development in relation to cement quality has been the introduction by the IIRS of a Certification Scheme for Portland cement to IS 1 similar to those operated for other products and standards whereby licences to use the Standard Mark are available to approved manufacturers who comply with the Irish Standard and further particular regulations drawn up by the Institute. Irish Cement Limited has been granted a licence under this Scheme.

On the broad question of cement quality, it would seem that it is the experience of the majority of concrete producers that the quality of cement manufactured in the country is such that concrete of consistent performance can be produced. A brief review of the strength performance of cement over the last decade is set out below.

2.4.1 Platin cement

Average Blaine fineness and average 3, 7, and 28 day IS 1 test results are reported for the last decade in Table B4 for normal Portland cement.

Table B4
PLATIN WORKS

Average Yearly Blaine Fineness and IS 1 Compressive Strength Results (N/mm²)

Year	Blaine	3 Day	7 Day	28 Day	7/28 %
1975	3106	26.2	33.3	44.5	75
1976	3067	25.9	32.8	42.5	77
1977	3178	25.9	32.9	41.9	79
1978	3279	25.0	32.2	41.7	71
1979	3269	25.7	33.0	42.8	77
1980	3127	25.5	32.5	41.8	78
1981	3069	25.3	32.5	42.8	76
1982	3199	25.9	33.5	44.0	76
1983	3266	27.6	35.7	46.3	77
1984*	3289	30.0	37.4	47.4	79

*Results for 46 weeks.

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The fineness of cement has remained constant at approximately 3000 Blaine. Minor fluctuations will occur from time to time as variations in clinker quality at the grinding mills are smoothed by the manufacturer through differential grinding.

There has been an increase in the strength performance of cement in recent years and discussions with concrete manufacturers have indicated that this increase has also been reflected in site concrete results.

The 7/28 day relationship has remained constant at between 75% and 79%.

IIRS monitoring of concrete cube results confirms the above in practice.

2.4.2 Limerick cement

Average Blaine fineness and average 3, 7, and 28 days IS 1 test results are reported for the last decade in Table B5 for normal Portland cement.

Table B5

LIMERICK WORKS

Average Yearly Blaine Fineness and IS 1 Compressive Strength Results (N/mm²)

Year	Blaine	3 Day	7 Day	28 Day	7/28 %
1975	2920	25.4	33.4	44.2	76
1976	2947	25.0	32.9	42.6	77
1977	3117	24.7	33.1	43.9	75
1978	3128	24.7	33.7	44.8	75
1979	3248	25.2	34.0	44.2	77
1980	3156	24.2	32.7	43.1	76
1981	3108	25.0	33.5	44.1	76
1982	3062	25.2	34.5	45.1	76
1983	2968	28.0	35.4	43.7	81
1984*	2969	29.1	35.1	43.4	81

*Results for 46 weeks.

Fineness has remained constant at approximately 3000 Blaine.

Strengths have not changed significantly, except for a shift in 1983 and 1984 when the new plant came into operation, in the proportion of the 28 day strength achieved at early ages. This change reflects the process and raw material changes made as the new plant came on stream. Again IIRS monitoring of site cube results confirms the above in practice.

2.4.3 Historical data

There has been much discussion in the U.K. of late on changes over the years in cement properties and their effects on concrete and a draft report "Changes in Cement Properties and their Effects on Concrete" was produced in September 1984 by a Concrete Society Working Party (4). The main conclusions of the Working Party's investigations to date have been as follows:

- (a) There has been a marked increase in the strength of concrete made with a given quantity of cement and this strength increase has been most notable at early ages.
- (b) The changes which have taken place have implications for the durability of concrete. The report shows that for concretes, designed only to a strength specification, specified strengths can now be met in the U.K. with lower cement contents and increased water/cement ratios.

This report is still in draft form and there are some errors in the text. Caution is needed in interpreting its findings as it deals with general trends which may not apply totally to a particular cement plant. Also, the findings of the report have given rise to considerable debate in the U.K. and some of its conclusions have been challenged. Further work will be required before the Working Party's final report is issued.

Nevertheless, the question obviously arises as to whether or not the Report's findings apply to Irish cements.

The performance characteristics of cement produced at Platin and Limerick over the last decade have been outlined above. A thorough investigation would be required to establish in detail the historical situation as it has developed in this country over the last twenty or thirty years. However, a preliminary examination of historical data on Limerick cement, where the product has been manufactured continuously since 1938 has been made.

This examination has indicated that the draft conclusions of the U.K. Working Party do not apply to the Limerick product. For example, a marked increase in cement strength over the last twenty years has not occurred. An interesting change in the 7/28 day relationship has been identified and this is shown in Table B6.

Table B6
HISTORICAL DATA LIMERICK WORKS
(Yearly Average)

Years	Average 7/28 % Strength	Range %	Test
1939 - 1953	67	62 - 69	Concrete
1954 - 1966	75	69 - 78	Concrete
1967 - 1982	75	73 - 77	Mortar
1983 - 1984	81	81	Mortar

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In the early 1950's, the proportion of 28 day strength reached at 7 days increased significantly from 67% on average to 75% and this remained constant until the change referred to above in 2.4.2 occurred in 1983.

2.5 End uses of cement

Information about end uses of cement is helpful in understanding the main markets for concrete products and Irish Cement Limited estimates are given in Table B7.

Table B7
END USE OF CEMENT BY SECTOR

Residential	53%
Agriculture	17%
Industrial	11%
Public	14%
Private/Commercial	5%

The primary importance of the residential market is noteworthy as is the significance of the agricultural sector. The private housing market and the D.I.Y. market which account for a substantial proportion of the residential sector usage are areas where concrete specification and workmanship are likely to be least controlled. Concrete work in agriculture, where the material may be used in an extremely aggressive environment, is not supervised and checked during construction, even when grant-aided.

As an industry, we need to pay more attention to education and training in these important sectors.

A break-down of current cement sales by product is given in Table B8.

Table B8
END USE OF CEMENT BY PRODUCT

Ready-mixed Concrete	33%
Concrete Products	29%
Site-mixed Concrete	38%

The ready-mixed concrete sector has grown since 1975 from a figure of 25% to 33%. Sales to this sector peaked in 1981 at about 35%.

2.6 Imported cement

The unprecedented growth in demand for cement in the late seventies led to a situation where Irish Cement Limited imported

cements from selected locations to satisfy demand. Despite the fact that, for some years now, the country has had sufficient plant capacity to meet the industry's requirements, some importation of cement has continued and it is estimated that currently approximately 70,000 tonnes of cement, mostly packed, is imported.

The performance of imported cements is difficult to quantify due to the variety of sources involved. The author, from his experience of the situation over the last number of years, can make the following comments:

1. Some imported cements perform in a satisfactory manner in structural and other concretes in Irish conditions.
2. Some imported cements have strength gain characteristics dissimilar to the domestic product. Blended cements, with unfamiliar properties, have caused difficulties on site.
3. Some cements have been sold as conforming to IS 1 and BS 12 when in fact containing fillers not permitted by the Standards.
4. The use of unfamiliar cements by tradesmen in blocklaying and plastering has given rise to difficulties, due to unknown water demand and consistency properties.

A recent development of some concern to both the cement and concrete industries has been that cement imported in bulk into Belfast is finding its way into the country in ready-mixed concrete and concrete products manufactured in Northern Ireland. Many ready-mixed concrete companies along the border have been experiencing great difficulty in the last year; difficulties with which our precast concrete industry has had to contend for many years now. Northern Ireland manufacturers have been able to undercut prices due to the great differences in Government aid to industry in the two regions. A secondary factor — the cost of raw materials — has arisen recently due to the market situation in Northern Ireland.

3. AGGREGATES

3.1 Production

Ireland continues to be fortunate in relation to the availability of good quality aggregate sources. Natural dense gravels and sands and crushed rock are won from the traditional sources of gravel pits and quarries dotted around the country. Sands and gravels are generally of glacial origin. Crushed rocks vary throughout the country, but the mother rock is generally limestone, granite or sandstone. Most producers have installed modern processing equipment — crushing, screening, and washing machinery. In the last ten years, the use of unwashed pit-run sands and gravels has almost been eliminated. Problems of workability and strength have led the ready-mixed concrete industry to reject such materials for the production of strength concrete. Some "dry screened" gravels are, however, still used in the manufacture of "nominal mix" concrete.

Aggregates are generally produced in single sizes, with the following sizes being most common: 20 mm, 14 mm, 10 mm and sand. 40 mm aggregates are rarely used.

When some natural sizes are deficient in the output of a plant, it is common to install extra processing equipment. For example, in the Cork area, one manufacturer has been using a rodmill for some years to produce fine aggregate gradings. Extra crushers are sometimes installed to crush gravel to produce particular gradings. This has led to a situation where many gravels have a shape more irregular than heretofore.

However, with the growth of a quality conscious ready-mixed concrete industry, well versed in concrete technology, no problems have arisen in this regard as mix designs are easily adjusted to produce concretes with required workability and strength characteristics.

An interesting review of aggregate production in Ireland is to be found in "The Extraction of Aggregates" (5) published in 1981.

3.2 Performance

The performance of concrete aggregates has generally been excellent. Problems that have been noted relate particularly to small jobs using site-mixed concrete where unwashed locally available as-dug materials are used. Where grading or shape might be a problem, ready-mixed concrete producers are, as noted earlier, in a position to adjust proportions to ensure that the material used will produce concrete capable of providing the required performance in relation to workability, strength and durability.

Concrete durability problems associated specifically with inadequate aggregate performance are, to the author's knowledge, extremely rare in Ireland. One particular instance has been noted where a siliceous limestone disintegrated in an extremely aggressive environment brought about through the presence of chemicals and cyclical high temperatures.

Doubts have been expressed about the durability performance of concretes made with badly shaped and graded aggregates from two sources, one now extinct, where high concrete porosity could result from the aggregate characteristics.

In summary, however, it can be stated that, over the last decade, the quality of aggregates used in concrete has improved and quality monitoring has increased, as reflected in the growth in requests from producers and users to the I.I.R.S. for grading, cleanliness, and organic impurity tests.

3.3 Alkali-silica reaction

Prior to 1940, it was generally assumed that aggregates were inert constituents of concrete. Stanton (6) in the United States was probably the first to recognise the fact that certain forms of silica, if present in aggregates, can under certain circumstances, react with alkalis present in concrete. Since then, there has been a growing interest in the subject

and the Sixth International Conference on Alkali-Aggregate Reaction was held in Copenhagen in June 1983.

Damage to concrete in the U.K. due to alkali-silica reaction was first identified on the island of Jersey in 1971 and on the mainland in 1976 and since then, about fifty cases have been catalogued. Of these fifty cases, only a few give serious cause for concern. It should be remembered that reactions may take place in many concretes, but that it is only those where damage to the concrete occurs that are of concern in practice.

In the U.K., most cases have occurred in the South-West area and River Trent Valley. In the South-West, cracking has been associated with the use of sea-dredged aggregates: which have not been used since 1974. Cherts and flints in these materials have been identified in damaged concrete while in Trent Valley sands and gravels, cherts and quartzites have been associated with the reaction.

As a result of the identification of cases of damage to concrete, a Working Group was established and in September 1983 produced its report "Minimising the Risk of Alkali-Silica Reaction — Guidance Notes", commonly known as the "Hawkins Report" (7).

Alkali-silica reaction will occur only if *all* of the following three conditions are present — sufficient moisture, sufficient alkalis, and a critical proportion of reactive silica, and the "Hawkins Report" recommends in summary that damage due to the reaction is unlikely to occur if *any one* of the following conditions prevails:

- (a) Concrete is not exposed to moisture;
- (b) The aggregates come from rock groups considered to be non-reactive;
- (c) The alkali content of the cement is less than 0.6%;
- (d) Blended cements are used with specified minimum proportions of slag or pulverised fuel ash (p.f.a.).

So what of the situation in Ireland? To date, to the author's knowledge, no case of damage to concrete due to alkali-silica reaction has been identified. Cements produced in Ireland have an alkali content of approximately 1% and we have had some twelve years experience of the use of Platin cement with this alkali content in structural concretes with no problems reported. This is indeed extremely encouraging and would lend weight to geological opinion that we are unlikely to have difficulties as reactive materials are unlikely to be present in our aggregates. Indeed, the "Hawkins Report" suggests that no specification requirements may be necessary where the "combination of cement and aggregates has a long history locally of satisfactory use in concrete".

A difficulty arises in relation to establishing definitively the potential reactivity of aggregates which do not fall easily into rock groups which can be considered inert. There is no British Standard Test Method for aggregates and the American Mortar Bar Test according to ASTM C227 (8) does not predict reactivity of U.K. aggregates known to have reacted in the field.

The current thinking of the U.K. Working Group examining this problem outlined by Nixon (9) is that a two tier system of screening should be introduced where doubt exists—a rapid “indirect” screening test followed by a “standard” long-term test based on the degree of expansion of concrete specimens. This appears to be a very sensible approach and is worth adopting in the Irish context.

4. ADMIXTURES

Admixtures were mentioned briefly at the 1965 and 1975 Symposia. Since 1975, however, there have been many fundamental developments in relation to the Industry's use of admixtures. Now, in 1985, they have come to take their place as constituents in their own right in concrete and are used extensively throughout the country. There are four major suppliers of admixtures to the industry, three of which now manufacture some of their products in Ireland.

Admixtures are rarely used in site-mixed concrete. They are, however, extensively used in the production of ready-mixed concrete. It may come as a surprise to some that discussion with ready-mixed concrete producers indicate that the proportion of ready-mixed concrete produced in the country containing admixtures is probably in excess of 50%.

The most commonly added materials are normal water-reducing admixtures which account for about 90% of admixture usage. Most of the water-reducers are based on salts of lignosulphonic acids which function by being adsorbed onto the surfaces of cement and through the mutual repulsion effect of like charges, bring about a more uniform dispersion of cement grains in a concrete mix. They are generally used to reduce the water content and cement content of mixes while maintaining workability and strength and thus achieve economies in mix design.

Provided minimum cement contents required to ensure durability are met, the technical benefits that accrue from the use of lignosulphonates are:

1. Reduced bleeding, due to slight air-entrainment;
2. Slight retardation, which is useful in the placement of concrete during the summer months.
3. The concrete mix is more sensitive to unauthorised water additions on site. Ready-mixed concrete companies regard this as a major benefit, as extra water added on site is one of their constant headaches.

On the basis that the use of any quality controlled product in concrete to reduce the water content of the mix is good, the use of water-reducing admixtures which are compatible with the cement used and which conform to BS 5075 “Concrete Admixtures”, Part 1 (10) can be regarded as reducing the risk of “wet” concrete being poured, with all the consequent problems in relation to strength, shrinkage and durability. With respect to long term durability, the concrete

industry world-wide now has over fifty years experience with ligno-sulphonate based materials with no adverse effects reported.

Some water-reducers based on hydroxycarboxylic acid and hydroxylated polymers are also used.

Accelerators are rarely used and materials based on CaCl_2 are banned by most specifiers with most producers aware of the increased risk of steel corrosion if CaCl_2 is a constituent of a concrete mix.

Retarders are sometimes used to maintain workability for extended periods — ready-mixed concrete deliveries subject to delays or long distance haulage, pumped concrete and concrete being poured by the slipform method. Retardation is sometimes achieved by double dosing of normal water-reducing admixtures available at a plant.

Air-entraining agents are generally specified for concrete used in cold stores. Some manufacturers use them in nominal mixes to improve workability and thus minimise the risk of excess water additions on site giving rise to segregation and low strength.

There is a view that air-entrained concrete should be specified for all concrete used outdoors and exposed to freeze-thaw cycles. Due to our relatively mild winters, we have come to believe that no major problems exist in relation to freeze-thaw in Ireland. Many of our pavements, particularly in the private housing sector, are generally poured using nominal mixes, sometimes with extra sand specified to achieve workability. The results in terms of poor performance are very evident. The use of air-entrainers would overcome many of the workability problems on site and give rise to less permeable, more durable pavements.

The use of both a retarder and an air-entrainer has allowed for the introduction to Ireland of "Trowel-Ready Mortar"— a ready-mixed retarded mortar which includes cement. This material appears to have found wide acceptance in Dublin with contractors and bricklayers. Delays at the batching and mixing stage are eliminated on site and the consistency of the material appeals to the bricklayers. It was introduced to the Cork area in early 1985.

The use of superplasticised concrete has come to Ireland over the last ten years. Superplasticizers were used initially to produce flowing concrete mainly to overcome placing problems in areas of congested reinforcement such as in-situ bridge decks. Lately, they have found acceptance in the "large-pour" method of factory floor construction which will be referred to later. They are also used by some ready-mixed concrete manufacturers to produce normal workability concrete with large water reductions and consequent high strength.

The general use of superplasticised concrete has not come about, due basically to the extra cost involved. The extra cost of a superplasticised mix as against a similar strength mix is approximately £4/m³. New developments in admixtures are constantly taking place and a new material has recently been introduced to the Irish market which the manufacturers hope will reduce the extra cost to the order of £1.50/m³. A secondary factor mitigating against their general adop-

tion has been the need for extra care and attention to trial mixes, batching, initial workability and admixture addition at site.

Most specifications ban the use of admixtures without the express authorisation of the specifier. In many situations, ready-mixed concrete producers will make a case for the use of a particular admixture and submit mix designs based on its use. As this usually relates to the use of standard water-reducing admixtures, the materials are permitted by the specifier. An attitude among specifiers that all admixtures are to be avoided because of past problems with CaCl_2 appears to be losing ground. Also, some ready-mixed concrete companies have developed the practice of declaring admixtures used on delivery dockets. This is to be commended. The publication generally of BS 5075, "Concrete Admixtures", Parts 1 and 2 (11) with uniformity and performance requirements is a considerable help to the specifier. A Part 3 to this Standard dealing with superplasticising admixtures is in the course of preparation.

In relation to the more recent advances in admixture technology, we need to keep abreast of information about long term durability as it becomes available. There is only limited data available on the long term performance of concrete produced as a result of these advances. Recent research work (12) in the U.K. concludes that superplasticised flowing concrete is more susceptible to deterioration by freeze-thaw and wetting and drying than normal concrete having the same mix composition and strength. It is suggested by the authors of this work that increasing the cement content or introducing air-entrainment would improve the performance — a further argument for the air-entrainment of exposed concretes.

In summary, water-reducing admixtures are used in a significant proportion of ready-mixed concretes. The standard materials used, provided they conform to BS 5075, should give no cause for concern. Provided users check for the absence of CaCl_2 , compatibility with Irish cement, and effects of overdosing, they will continue to play a significant and useful part in the production of quality concrete in Ireland.

5. OTHER MATERIALS

5.1 Pulverised fuel ash

Traditionally, the potential for the use of waste materials in concrete has not been the subject of much debate in Ireland due to the fact that such materials, e.g. blastfurnace slag and pulverised fuel ash have not been available as by-products of native industry.

With the expected commissioning of Moneypoint Coal Fired Power Station during 1985, there has lately been some discussion in the industry in relation to the possible use in concrete of ash which the station will produce.

It is appropriate to review the situation, as decisions affecting the potential for ash from Moneypoint will have to be taken by the E.S.B., Specifiers, Standards Committee, and the Concrete Industry within the next few years.

When pulverised coal is burned in the boilers of coal-fired power stations, about 25% of the resultant ash falls to the bottom of the furnace and is known as furnace bottom ash (f.b.a.). The remaining ash is carried out with the flue gases and is removed from the gases by mechanical and electrical precipitators.

This ash is finer than the bottom ash and is known as fly ash (p.f.a.). Chemically it is a glassy material, its main constituents being silica, alumina and iron. It is an artificial pozzolana and as such will react with calcium hydroxide produced during Portland cement hydration to form a gel product.

Fly ash particles are almost spherical in shape and consequently allow water reductions to be made when incorporated in concrete mixes. The main benefits of the addition of p.f.a. to concrete are — lower heats of hydration, increased durability in relation to sulphates, lower permeability, less bleeding, reduced water contents, higher long term strengths, less susceptibility to alkali-silica reaction.

A material with such benefits, if available at an economic price, should, one would think, be used to its full potential. The reason that this has not been the case elsewhere is that run-of-station p.f.a. can vary widely due to variations in the day-to-day running of a power station, the individual furnaces and precipitators, and most of all the coal used to fire the boilers. The U.K. experience, given that the concrete industry here is similar in outlook, is worth noting.

During the year 1982/83, the CEBG produced 12.8 M tonnes of ash. Sales of fly-ash for use in concrete amounted to only a small fraction of the ash produced (see Table B9). The CEBG recognises

Table B9
U.K. SALES OF ASH (1982/83)*

Market Sector	Pulverised Fuel Ash	Furnace Bottom Ash
Structural Fill	0.98 Mt	—
Lightweight Aggregate	0.50 Mt	—
Lightweight and Concrete		
Building Blocks	0.65 Mt	1.65 Mt
Grouting	0.13 Mt	—
Fillers and other usage	0.12 Mt	—
Cement Manufacture and		
Cement Replacement in Concrete	0.36 Mt	—
SUB TOTAL	2.74 Mt	1.65 Mt
TOTAL SALES	4.39 Mt	

*Source: D. P. M. Keeling, (13).

that in dealing with an increasingly quality conscious specifier and concrete producer, an increased market will only be opened for p.f.a. if a quality assured product certified as complying with appropriate parameters is made available.

BS 3892 : Part 1, (14), was published by BSI in 1982. This Standard lays down chemical and physical requirements for p.f.a. deemed suitable for use in structural concrete, the main parameters being a particle size limitation of 12.5% maximum retained on a 45 micron sieve and a loss on ignition (LOI) maximum of 7%.

Despite suggestion (15) that more variable ashes should be allowed in structural concrete, it is CEBG policy that only ash to Part 1 of this standard should be released for use in such concrete. The U.K. concrete industry to date has had good experience with Part 1 ash and it would appear that quality ash has performed satisfactorily from an economic and technical viewpoint. A second part to this Standard, BS 3892 : Part 2, (16) was published in 1984.

What of the situation in Ireland? It is difficult at this stage to establish the potential for any material that may become available at Moneypoint. In the first few years, systems may not be optimised, fuel will be bought from a variety of sources, the station may not operate as a base load station and, consequently, the resultant product may be extremely variable. In relation to Standards, therefore, it seems prudent in the light of the U.K. experience to adopt the main parameters of BS 3892 : Part 1, until the definitive nature of the Moneypoint product is established.

5.2 Blended cements

Experience in Irish concrete practice with cement has been almost totally confined to 100% clinker cements manufactured by burning a mixture of limestone and clay or shale with the subsequent addition of gypsum to control setting characteristics.

In continental Europe most standards for normal/ordinary Portland cements allow the addition of up to 5% filler — either inert, such as kiln raw meal and ground limestone, or active such as blast-furnace slag and fly-ash.

It can be argued that this option should be available in Ireland. It is interesting that in the U.K., following research, a Working Group has reported that "the addition of up to 5% p.f.a. or slag may modify some properties of ordinary Portland cements. However, the programme has produced no firm evidence to indicate that satisfactory ordinary Portland cements cannot be produced with such additions" (17).

In relation to blended cements where 10% or more of slag or fly-ash is interground or blended with Portland cement clinker to produce Portland p.f.a. cements, Portland pozzolanic cements or Portland blastfurnace cements, it would seem that the prospect of p.f.a. availability from Moneypoint Power Station will give rise to debate relating

to the need or otherwise to develop standards and codes in relation to their manufacture, specification and use.

Advantages

1. Increased long term strength.
2. Increased long term durability.
3. Reduced risk of alkali-silica reaction.
4. Reduced risk of early age thermal contraction cracking.
5. Better workability characteristics.

Disadvantages

1. Reduced early age strength.
2. Higher formwork cost.
3. Increased susceptibility to poor curing.
4. Increased risk of colour variation.
5. No experience in Ireland.

6. SITE-MIXED CONCRETE

Site Mixing of concrete has changed significantly over the last decade in two respects.

Firstly, the volume of concrete which is site-mixed has decreased due to the increased market which has been attracted to ready-mixed concrete.

Secondly, due to this growth in the ready-mixed concrete sector, on all medium to large jobs site mixing is used only for low volume work like screeds, mortar and infill and consequently large output mixers are no longer required on site. Another factor associated with this reduction in mixing capacity on site has been the recession, during which smaller jobs with a lower volume requirement for concrete are the norm.

The capacity of site-mixers still covers the range $5/3\frac{1}{2}$ (100 litre output) to $21/14$ (400 litre output). There has been a very marked tendency towards the lower end of the range in recent years for the reasons outlined above and the $14/10$ (300 litre output) would satisfy most needs on even large jobs. Machinery distributors report that the smaller drum mixers with outputs of 100, 85 and 65 litres have been most popular in recent years.

In a recent market study of packed cement sales carried out by Irish Cement Limited, just over 50% of sales were in lots of two tonnes or less and 25% in lots of ten bags or less. This represents a surprising demand for the product in small lots and fits in well with the current situation outlined above in relation to mixing practices. The likely continued growth of the proportion of concrete which is ready-mixed and the increasing interest in ready-mixed mortars will probably mean that the trends as outlined above in relation to site-mixing will continue.

7. READY-MIXED CONCRETE

7.1 Industry structure

The ready-mixed concrete industry, currently accounting for approximately 33% of cement sales, has further established itself over the last decade. The 1983 Annual Report of ERMCO, The European Ready-Mixed Concrete Association (18), shows that in that year about 70 firms with a turnover of £63 million produced almost two million cubic metres of concrete at 129 plants. It is interesting that our consumption of ready-mixed concrete in 1983 @ 0.57 m³/capita compares with a figure of 0.39 for the U.K., 0.42 for France and 0.77 for West Germany.

There are three main reasons for the growth of the industry. Firstly, during the building boom years 1979-81, there was not enough room for contractors to establish plant on many commercial re-development sites. Secondly, experience with ready-mixed concrete during these years led to a wider realisation that the industry is capable of producing a quality product suitable to current needs. Thirdly, the price of ready-mixed concrete has become extremely competitive.

7.2 Production and delivery

Ready-mixed concrete producers utilise two methods of production:

- Central batching and truck-mixing (60 - 70%)
- Central batching and mixing (30 - 40%)

Central plant production is associated mainly with large centres of population where output rates justify the installation of a full mixing plant. Mixing is generally carried out in pan mixers which are extremely efficient and have the added ability to produce lean-mix concrete. There has been an increasing trend to computerise these plants, thus increasing the level of production control and resultant concrete quality. Another advantage of computerisation is that detailed mix information is recorded and can be recalled for scrutiny at a later date, if required. Central mixed concrete is transported in agitator trucks. The capacity of trucks has increased over the decade to a situation now where most trucks carry 7 - 8 cubic metres.

Central batching and truck-mixing accounts for the largest proportion of ready-mixed concrete produced in Ireland today. Materials are batched at a central plant and mixed in the agitator truck, either at the plant or in transit. Some producers use automatic chart recorders to keep batch weights of materials for record purposes.

Batching of materials in both cases is by weight, with water addition methods varying. In the case of central mixers, the water requirement is sometimes fixed, based on the sand moisture cement. In other plants, the batcherman will judge the requirement by eye. The electric power required to turn the mixer is sometimes used as a reliable guide. In the case of truck-mixed concrete, a predetermined water quantity is usually batched and final adjustments are made by the truck driver. Admixture dispensers are fully automated and have visual displays.

They are calibrated by volume against specific cement contents.

The subject of water additions on site is still topical in relation to the delivery of the product. Some producers insist that no extra water be added, others allow additions to bring the concrete back to the specified slump. Some require signatures for extra water, others regard this practice as inoperable and therefore have abandoned it.

7.3 Specification — testing and compliance

Increasing attention is being paid by specifiers to designed rather than prescribed and nominal mixes and now approximately 70% of ready-mixed concrete is ordered to a strength specification. There is little doubt amongst the majority of purchasers that the quality of ready-mixed concrete has increased and that strength specifications are generally met in a very consistent manner.

Producers have two approaches to strength testing of the product. Some take samples on a regular basis for testing in-house or by the IIRS or other testing houses. A computerised cusum regime run on the basis of accelerated testing is used by one major manufacturer. Others take samples infrequently and rely on feed-back from client testing, arguing that if raw materials are carefully monitored, then client testing of the product provides sufficient information.

The mobile technical service of the IIRS has played a major role in concrete quality monitoring over the last decade. In 1977, the Institute tested 8,000 cubes in Dublin. This number has grown to 45,000 cubes tested in Dublin and Cork in 1984. With the benefits offered by computerisation, a cube analysis contract has been offered to ready-mixed concrete producers since 1981, when 500 cubes were first tested for a total of four producers. In 1984, 12,000 cubes were tested for eighteen producers in the scheme. The Institute's monitoring of concrete variability indicates that standard deviations for most concrete plants are in the range 4 - 6 N/mm² with approximately 80% in the 4.5 - 5.5 N/mm² range.

Site made cubes tested by the IIRS are usually stored on site for a number of days before being collected by the Institute and subjected to curing in accordance with BS 1881 (19). The fact that on some sites, concrete is not sampled and cubes made and stored in accordance with BS 1881 before collection has given rise to non-standard cubes being tested on occasions and queries being raised about otherwise satisfactory concrete. Difficulties in this regard are not uncommon during the summer months. It would appear that there is a gap in our general cube testing procedures. BS 1881 : Part 116 (20) requires that a test report on the compressive strength of concrete cubes should state "whether or not certificates of sampling, specimen preparation and curing are available".

Specification is being dealt with in detail in another paper at this Symposium. However, there are two particular points relevant to ready-mixed concrete and relating to specification and compliance that are currently the subject of some debate in the industry.

(i) Redundant and Ambiguous Specifications

It is regrettable that many specifiers include redundant and ambiguous clauses in specifications causing different producers to base quotations on different parameters — strength, cement content, aggregate/cement ratio, water/cement ratio. Despite the publication of clear recommendations in British and Irish Codes and Standards, notably CP 110 (21), BS 5328 (22) and the Irish Building Specification (23), many specifiers have not revised specifications in line with these documents. There is an urgent need for a national approach to this problem and The Concrete Manufacturers' Association of Ireland and The Irish Concrete Society are working on developing solutions.

(ii) Durability — Compliance

Where durability may be a problem, minimum cement contents are specified. In many cases, appropriate cement contents may be in excess of those required to produce the specified strength. Generally, only strength is measured and compliance with cement content requirements is assumed. The rationality of an approach where testing to establish compliance is omitted for some requirements is questionable.

The "National Durability Grades" approach to these difficulties as outlined by Dewar and Deacon (24) for the U.K. is seen as one solution. Obviously, research with the co-operation of producers would need to be carried out relevant to Irish materials. It can be argued that this approach would lead to higher strengths and more expensive concrete. However, if designers take advantage of higher strength concrete economies may ensue in relation to section size and reinforcement requirements.

A second approach is to reduce the level of attention given to the "cube test" and concentrate on the in-situ concrete, carrying out appropriate "durability" compliance tests as specified. The availability of an accurate and speedy cement content test for hardened concrete at the IIRS may encourage some to adopt this approach.

8. PRECAST CONCRETE

8.1 Production

The precast concrete industry in Ireland has gone through difficult times over the last decade. Statistics on the industry are still difficult to extract from official tables and figures. The Census of Industrial Production figures for the Production of Precast Buildings and Sections provided by the C.S.O. for the decade which are available are given in Table B10.

The main trend is the increasing value of production in the late 1970's. It must be assumed that when the figures become available for the 1980's, the first half of the decade will show a continuing fall in the production in line with the cement sales and general construction activity for the period.

Table B10
PRECAST BUILDINGS & SECTIONS

Year	£ (1975 Prices)
1975	1,398,541
1976	166,537
1977	1,857,583
1978	2,756,798
1979	3,849,398
1980	2,873,688
1981/84	Not Available

The industry has had to deal with an increasing import threat almost exclusively from Northern Ireland. Again reliable specific information is difficult to obtain but the figures shown in Table B11 provided by the C.S.O. for "Other Articles of Cement" which includes concrete blocks but excludes lightweight concrete, asbestos cement products, tiles and paving, shows the alarming trend.

Table B11
OTHER ARTICLES OF CEMENT — IMPORTS

Year	£,000	Tonnes
1975	3,162	69,635
1976	3,399	62,757
1977	2,349	101,004
1978	3,104	163,457
1979	4,423	158,438
1980	4,757	143,110
1981	5,387	133,582
1982	5,415	157,572
1983	6,524	173,888

Production of precast concrete falls into two main categories. Small items — garden and street furniture, ornaments, sills and lintels, and paving slabs are produced in many locations throughout the country in small to medium sized plants.

Quite a variety of excellent quality materials is produced and indeed being exported. Many feel that greater use of precast products in hard landscaping in our towns and cities would contribute significantly to our streetscapes.

SESSION B

Precast production on a large scale now takes place in a smaller number of firms than heretofore due to the recession. Current production facilities are highly automated and controlled, with pan mixers, specialised compaction machinery and curing regimes and increasing attention being paid to quality.

The major precast structural sections and components produced in the country together with the names of the manufacturers are listed in Tables B12, B13, B14 and B15. Other precast units are listed subsequently.

Precast concrete structural units, many of which are prestressed are produced using very low water/cement ratio concretes in the strength grade range of 40 - 50 N/mm². Hollow-core floor units are generally produced by sophisticated extruding or slide-form machines where correct mixing and concrete consistency are essential. Most other units are produced in static steel moulds.

Table B12
STRUCTURAL SINGLE STOREY SYSTEMS

Manufacturer	System	Roof Pitch	Max. Span
Concast Ltd.	C 6 Beam	6°	22 m.
Grangeford	Atcost A Frame	11¼°, 22½°	18.28 m.
Structures Ltd.	Atcost A Frame	14°	21 m.
	Atcost Concrete	6°	36 m.
	& Steel K Frame	Flat Roof	35 m.
Shay Murtagh Precast Ltd.	A Beam	4°	24.4 m.
Oran Precast Ltd.	4° Beam	4°	24 m.
Rocrete Ltd.	12° Beam	12°	19.4 m.
	23° Beam	23°	18.0 m.
	4° Beam	4°	30.0 m.

Some of the above systems can be modified to allow for the inclusion of a first floor.

Table B13
STRUCTURAL MULTI-STOREY FRAME SYSTEMS

Manufacturer	System
Concast Ltd.	C3
Grangeford Structures Ltd.	Atcost Post & Beam
Rocrete Ltd.	T6

Table B14
STANDARD PRESTRESSED BRIDGE BEAMS

Manufactured	System	
Banagher Concrete Ltd.	T Beam	16 m.
	M Beam	29 m.
Shay Murtagh Precast Ltd	T Beam	16 m.
Roecrete Ltd.	T Beam	16 m.
	M Beam	29 m.

Bridge sections based on solid slab sections, T - Beam sections and box units are produced by some manufacturers.

Table B15
FLOORING UNITS

Manufacturer	System	Depth	Width
Breton Ltd.	Hollowcore Slabs	110, 150, 200, 220, 300, 320	1200
Concast Ltd.	Hollowcore Slabs	150, 200, 250, 300	600 1200
	T Beam System with solid or hollow blocks		
Noel C. Duggan Concrete Ltd.	"Ducon" Hollowcore Slabs	125, 200	600 1200
Flood Flooring Ltd.	"Katzenberger" Wide Slab and Block and Plank		2350
Shay Murtagh Precast Ltd.	"Rivcon" Solid Slab Double T Units	150, 200	1200
O'Regan Precast Ltd.	"Lyncrete" I Beam with hollow blocks		
Roecrete Ltd.	"Wideslab" Hollow core with Insulation	100, 125, 150, 175, 200, 250, 300	1200
	Double T. Units		

Concrete Pipes

Spigot and socket concrete pipes to IS 6 (25) and "ogee" pipes to IS 166 (26) are manufactured by Spollen Concrete Ltd., Condron Concrete Ltd. and John A. Wood Ltd. Asbestos cement pipes to IS 243 (27) and IS 188 (28) are manufactured by Tegral Pipes Ltd.

Other Units

Retaining wall units, prestressed reservoir units, cladding units, concrete tiles, asbestos cement slates and sheeting, culverts, cattle slats and other specialised products are also produced.

8.2 Performance and use

The versatility of precast concrete and the options it offers to the designer have been fully utilised in Ireland over the last decade.

Structural single storey and framed systems were used extensively in the commercial sector boom of the late seventies and the expanded IDA building programme of that time. Flooring systems with advantages over timber floors in terms of fire and sound proofing and in many cases over in-situ construction in terms of economy have found a ready market in the domestic flat and apartment building expansion of the last number of years. Most manufacturers believe that the housing market offers considerable potential for the precast flooring industry in the coming years. Many flooring units and systems have been adapted for use as cladding and roofing units.

In the agricultural sector, a circumferentially prestressed precast plank reservoir system and a tank based on the upright use of precast pipes have proved popular. Precast cattle slats found a ready market with farmers during the years of agricultural expansion in the seventies.

Some concrete cattle slats produced during the last decade have been reported as showing signs of deterioration due to reinforcement corrosion. Concrete in the agricultural sector is subject to very severe environmental conditions and detailed investigation will be required to establish if the Irish Standard for slats (29), which is based on best European practice, is adequate or whether the problems reported are the result of production deficiencies.

Precast concrete cladding produced to a variety of designs and details has been manufactured successfully in Ireland for many years. Due to durability problems on a few specific buildings, and adverse and in many cases ill-informed media comment, precast cladding is currently at something of a cross-roads in many peoples' minds. This is unfortunate as the amount of concrete, both precast and in-situ, suffering from serious lack of durability is not significant and the reasons for inadequate performance are now generally well known.

The main problems is reinforcement corrosion leading to the spalling of concrete which can result from a number of factors acting either alone or in combination:

- (a) Inadequate design and detailing — inappropriate reinforcement bar size and spacing, particularly at returns and arrises leading to difficulties in compaction; also, reduced cover leading to inadequate protection for steel.
- (b) Inadequate materials and mixes — low cement contents, high water/cement ratios, badly shaped aggregates leading to permeable easily carbonated concrete.
- (c) Bad workmanship — incomplete cover, inadequate compaction.

- (d) Environment — air pollution increasing the likelihood of chemical attack.
- (e) Presence of CaCl_2 —promoting the rate of corrosion by electrolytic means. The practice of adding CaCl_2 to concrete to accelerated the rate of strength gain which was permitted 15 - 20 years ago is now prohibited by specifications.

An interesting development in relation to the use of precast concrete has been the advent here of the American tilt-up system of site precasting. Two factories were constructed by this method in the last few years. It is felt by some that the speed of wall erection together with the reduction in the blockwork requirement on sites is a major benefit and that the system has potential in Ireland. Others are of the opinion that our weather conditions mitigate against any major growth in its use.

8.3 Glass reinforced cement

The last decade has seen the development in Ireland of production facilities for GRC and a number of manufacturers now produce a variety of units and products under licence to Pilkington Brothers Ltd., the U.K. firm who commercially developed the discovery of methods to produce alkali resistant glass fibres.

Rocrete Ltd. were the first company in Ireland to establish a major production facility for GRC units. Single skin and sandwich units using lightweight cores have been produced successfully by the spray process. A variety of other units can be produced in GRC and a manufacturer in Donegal is currently producing septic tanks. A firm in Meath has produced GRC window frames which, following testing by the IIRS, have been accepted by the Department of the Environment as eligible for use in grant-aided houses.

From a design and construction viewpoint, GRC is a very different material to conventional precast concrete. For successful exploitation, its properties, particularly its thermal and moisture movement potential must be catered for. Also, great care must be taken on site in handling due to the lightness and thin section of the GRC skin.

As regards movement, Irish designers using GRC have learned that the number of fixings on panels, particularly large panels must be kept to a minimum. Localised restraints where stress concentrations could lead to cracking are to be avoided and consequently fixings in the centres of large panels are not recommended. Also, bowing on large insulated panels due to thermal or moisture differentials must be taken into account and flexible joints between units and between units and cross-walls should be provided.

9. CONCRETE BLOCKWORK

9.1 Production

Concrete blocks have been the building industry's basic walling material for decades. There have been some developments in both production and use over the last ten years.

Concrete blocks are currently produced in Ireland using one of two methods. There are seven static plants in the country which account for approximately 20 - 30% of block production. At all other locations which account for the vast majority of blocks produced, mobile or "egg-laying" machines are used. Here, there has been an increasing tendency for blocks manufactured by this method to be produced "on-end" which approximately doubles the production rate. Automatic batching plants are now widely used and computer controlled batching and mixing has been introduced by some manufacturers. Admixtures are being used more widely than heretofore.

Improved methods of handling and packaging have been developed over the last decade which has led to the virtual disappearance of the practice of tipping blocks on site, which was prevalent ten years ago.

Three different block finishes are available — Common, Fine-Textured and Masonry. Fine-Textured blocks are usually produced using a greater proportion of sand and cement than common blocks, and masonry blocks aside from the extra fines generally incorporate pigments and waterproofer (used as efflorescence inhibitors).

The introduction of "Forticrete" masonry, now manufactured at two locations has been a very significant development and has offered increased architectural possibilities to designers. It is of interest that ribbed masonry, with a face size of 440 x 215, which is now a standard item was in fact designed in the first instance by a firm of Irish architects for a project in Wexford.

Concrete blocks manufactured in the country are most commonly produced in two size ranges — Metric 450 x 225 and Modular 400 x 200. The strength of I 20 (30), 5, 10.5, 21, and 28 N/mm² for solids and 3 and 5 N/mm² for hollows are available, but only some manufacturers produce blocks in the higher strength categories. A survey of concrete blocks manufactured in Ireland was carried out by the Irish Concrete Society in 1980 (31).

9.2 Performance and use

The performance of concrete blocks is generally regarded as satisfactory. There is, however, a perception that the quality of finish of blocks manufactured on mobile machines is lower than that achieved on static plants.

Walling construction methods vary across the country and in the Dublin area, there has been a tradition of using the 225 mm hollow block particularly in speculative housing. Outside Dublin, cavity wall construction using 100 mm solid blocks is the norm in the housing sector while in the agricultural sector, farmers have traditionally used the 150 mm solid block around the farm.

Modular blocks have proved quite popular with designers using dense concrete masonry. However, for common and fair-faced blocks, most manufacturers have found that the demand for the metric sizes far exceeds that for the modular units.

Increasing attention has been paid over the last decade to the thermal insulation properties of concrete. Generally speaking, the insulation properties of concrete block walls have been improved by the use of materials used in association with the blocks, e.g. expanded polystyrene systems for use in cavities, dry lining, external insulation and cavity fill systems. Block manufacturers are constantly exploring new methods of improving the insulation properties of the block itself and over the last decade, foam filled blocks and blocks with polystyrene bonded have been manufactured or imported. None of the products has been used on a large scale.

Indeed, lightweight blocks have never found a ready-market in Ireland for a variety of reasons:

- High-rise construction is uncommon.
- Lightweight blocks used as the inner leaf of cavity walling generally require extra insulation to meet the $0.6 \text{ W/m}^2 \text{ K}$ U value. It has been pointed out in the U.K. that the use of autoclaved aerated blocks without insulation does not meet the 0.6 requirement due to heat loss through the mortar joint (32).
- Lightweight natural and artificial aggregates have not been available locally. The potential availability of fly-ash from Moneypoint may lead to an increasing interest in this area.

A new product has recently been launched by Dan Morrissey Ltd., of Carlow. This product is a sandwich unit of concrete block and polystyrene which are interlocked by dovetailing. The product meets the Proposed Building Regulations (33) U - Value requirement of $0.6 \text{ W/m}^2 \text{ K}$ when used as the inner leaf of a conventional cavity wall.

In recent years, there has been an increasing demand for high strength blocks in apartment construction due in part to Government tax incentives.

More attention is now being paid by designers to the causes and elimination of cracking in blockwork. Concrete blocks shrink after manufacture and the use of fresh blocks continues to cause some difficulties. CP 121, Part 1, 1973 (34), recommends that concrete blocks should be stored for at least four weeks and protected from rain before use. The use of strong mortars has also given rise to cracking. Designers are, however, now paying more attention to the provision of movement joints, and the detailing of appropriate panel lengths and heights to reduce to acceptable levels the restraints inherent in block wall construction. Also, the use of bed-joint reinforcement at doors and windows is increasing and has proved in practice to be an effective method of reducing cracking at such openings.

The use of unsuitable materials as mortar plasticisers and the incorrect use of quality materials continues to give rise to some difficulties.

10. HANDLING OF CONCRETE

Paralleling the growth in the proportion of concrete which is ready-mixed, one of the most significant recent developments in concrete

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handling on site has taken place in association with this industry. Mechanical belt conveyors have rarely been used in Ireland by contractors placing concrete, despite their popularity in other countries. Concrete conveying has been popular in some continental countries for many years, but it is only in recent years that interest has arisen in Ireland and the United Kingdom and two French conveyors were imported into Ireland in 1981 by a ready-mixed concrete manufacturer.

Moffett Engineering Ltd. of Clontibret, Co. Monaghan, identified the market potential for such units. The imported conveyors had very limited capability and Moffett developed its own articulated mounting system to improve performance. The first unit developed by Moffett was designed to park at the side of the ready-mixed concrete truck. It had a total length of 8 metres, a working angle of 220° , could discharge concrete at a height of 4 metres and could also discharge concrete to a depth below ground of 1.5 metres. After two units had been fitted, the original design was improved upon and a conveyor with a total length of 10.5 metres, a working angle of 300° , a discharge height of 6 metres and a discharge depth of 2 metres, was developed. This unit is mounted at the back of the truck and folds over the drum in its parked position.

It has an independent hydraulic circuit and a separate power take-off is fitted to the truck gear box.

The conveyor is used typically for first floor pours, foundations, low level pours, underground tanks, and walls. It has found applications in the agricultural sector, typically in the pouring of concrete for silage pit walls, and in the commercial sector on confined sites as an alternative to pumping. The growth in the use of the truck conveyor, as indicated in Table B16, would seem to indicate that both ready-mixed concrete manufacturers and contractors regard the conveyor as efficient and cost effective. Contractors appear willing to pay the extra £20.00 approximately per 7 m^3 load for the convenience afforded by the conveyor. It has tremendous potential, particularly in the pouring of columns, to do away with many of the supply problems associated with using JCB buckets or similar machinery.

The export market penetrated by Moffett testifies to the fact that this particular Irish product can take its place anywhere in the world alongside competing equipment and systems.

Concrete conveying is sensitive to the belt speed and segregation may occur if care is not exercised. However, the conveyor has an advantage over the concrete pump in that special mix designs are not required. Also, the fact that extremely wet mixes cannot be handled is an added bonus.

The volume of concrete pumped in Ireland has not increased over the last number of years. The disadvantages of requiring a more expensive mix and occasional pump break-downs have tended to limit any growth. Also, on medium to large jobs, the availability of tower cranes leads contractors to use crane and skip.

Table B16
GROWTH OF MOFFETT "MIXVEYOR" SALES

Year	No. of Mixveyors	Customer Location
1982	2	Ireland
	2	Northern Ireland
	—	
	TOTAL	4
1983	6	Ireland
	4	Northern Ireland
	4	England
	2	Australia
	1	The Netherlands
	TOTAL	17
1984	14	Ireland
	4	Northern Ireland
	1	England
	3	The Netherlands
	8	Finland
	1	Sweden
	12	Canada
	2	U.S.A.
	TOTAL	45

In the last decade, approximately twenty jobs have been slip-formed, typically silos, chimneys and building cores. Hoists, and crane and skip have been used to handle concrete with final placement generally by wheelbarrow.

On small jobs where direct access is not available for ready-mixed concrete trucks or where site-mixed concrete is used, concrete is still handled in dumpers, JCB buckets and wheelbarrows.

Concrete is generally placed underwater by tremie or underwater bucket. Preplaced grouted aggregate systems have also been used with reports varying as to the effectiveness of such methods. Off-shore work is occasionally carried out using helicopters and skips.

Precast concrete units are generally handled at factories by gantry cranes, tower cranes and vacuum lifting equipment. On sites, mobile cranes and sometimes tower cranes place the units.

11. PLACING AND FINISHING OF CONCRETE

11.1 Flooring techniques

A minor revolution in floor laying techniques has taken place over the last decade.

By the early 1970s, the "long strip" method of floor construction as outlined by Deacon (35) had almost totally superseded the inefficient "chequerboard" method of construction throughout the country.

Three new methods have since been introduced to the Irish construction scene:

(a) Large Pour

Following on the construction of the floor in the Fieldcrest factory at Kilkenny in the late seventies by a large pour system using labour from abroad, this method of floor construction has been developed in Ireland by Lacon Limited. Commencing in 1979 with key operatives being trained in the United States, Lacon has laid many of the larger factory floors constructed in Ireland in the last five years. This system relies on skilled crews to lay floors without side screeds using laser levelling techniques and mechanised finishing methods to complete rapidly large areas of floor with suitable wearing surfaces.

Joints are subsequently cut to accommodate shrinkage. When the system was first introduced, concrete with a 100 mm slump was used. Superplasticised concrete is now used. Shake-on hardeners can be used with the system. An indication of the extent to which the technique has been improved is shown by the increased speed of construction over the past few years. Using this method, in 1984, 10,000 sq. metres was laid in five days at a factory in Galway compared with 15,000 sq. metres in twenty days in Dublin four years previously.

(b) Wide Screed

This method is similar to the long strip method except that wide span vibrating screed rollers or triangulated trusses are used to level and compact concrete. Specialised machines have been imported.

(c) Superflat

This method is similar to the long strip method with particular attention paid to initial levelling of the screeds and with a close examination of concrete levels made at an early stage to allow grinding to correct any irregularities.

A very interesting survey of the surface regularity of concrete floors carried out by An Foras Forbartha (36) ranks the floor laying techniques in order of descending accuracy as follows:

- Superflat
- Large pour
- Wide Screed
- Long Strip

11.2 Other developments

Other major developments associated with concrete placing and finishing techniques have been the increased use of systemised shuttering system and the increasing tendency for reinforcement prefabrication. Pour sizes have also got bigger and there is more mechanised handling of formwork. At Moneypoint construction site recently, contractors using ready-mixed concrete completed the largest single pour ever completed here of 1600 m³ in one day.

While vacuum dewatering is not used extensively, the E.S.B. now specifies this technique in many of its medium industrial applications to achieve the required wearing surface as an alternative to shake-on floor hardeners.

Sprayed concrete has remained a specialist area. P. J. Edwards & Co. have carried out reinstatements of many masonry arch bridges over the last decade with the dry mix process and generally using 50 - 150 mm of concrete built up on soffits on mesh reinforcement. Some repair of fire-damaged concrete has also been carried out by spraying.

In pavement construction, in-situ kerbs have been laid by a specialist machine which forms the concrete kerb by extrusion.

11.3 The concrete operative

At the last Seminar ten years ago, a call was made that attention be paid to training concrete workers on site. In many countries in Europe and in the United States, the concrete worker has craft status. Following research into the situation in Europe by the Irish Concrete Society and AnCO's Construction Industry Committee, AnCO has run two formal courses for concrete operatives recently. Unfortunately, due to the recession, the demand for these courses has not been as great as had been anticipated. It is hoped that some way can be found to increase interest in the formal training procedures set up by AnCO as, otherwise, a vital opportunity to consolidate formal training may be lost. The concrete worker has such an influence on final quality that as an industry, we ignore his training at our peril.

12. SUMMARY

12.1 Materials

The country now has a dry process capacity in cement manufacture to meet the needs of the industry for the foreseeable future. The performance of cement has been satisfactory over the last decade and minor changes in strength characteristics have been noted over the last two years.

Aggregate production methods have become more sophisticated and the use of unwashed materials has almost disappeared.

Admixtures are playing an increasing role in the production of ready-mixed concrete. Used mainly for economic reasons, they afford useful technical benefits.

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The potential for use of secondary materials such as p.f.a. in concrete will be of interest in the coming years.

12.2 Mixing and supply

Ready-mixed concrete now accounts for approximately 33% of cement used. Increasing attention is being paid to quality control. Site-mixing is carried out mainly for low volume work. There is need for the industry's approach to concrete specification and testing to be rationalised.

12.3 Precast concrete and concrete blockwork

A wide variety of precast concrete units is manufactured. Performance difficulties have been noted in some cladding units, but the quality of work is generally very satisfactory. GRC units have been manufactured and the architectural potential of this material is likely to be explored further in the next decade.

Concrete blockwork continues to be the basic walling material in Ireland and greater attention is being paid to the elimination of cracking. The architectural possibilities of dense concrete masonry have been exploited.

12.4 Handling, placing and finishing concrete

The advent of the truck-mounted conveyor has eliminated double handling on many sites. The large pour and wide screed methods of factory floor laying have taken their place alongside the more traditional long strip method of floor construction. A training scheme for the concrete operative has been launched by AnCO and deserves support from industry.

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Discussion

MR. BANNON introduced his paper.

Speaking first of cement, he noted that with Platin now having, since 1977, a capacity of 1.4 million tonnes, and Limerick since 1983, a capacity of 0.65 million tonnes, the country now had a dry-process capacity of just over 2 million tonnes annually. Sales had reached just over 2 million tonnes in 1979, but recession had reduced that level to 1.3 million tonnes in 1984. An increasing proportion of bulk sales was now collected directly ex-works, while palletization introduced at Limerick and Platin in the late 1970s had improved the handling of bagged cement considerably. Well over 90% of all cement used in this country was normal Portland cement. The strength of the Platin cement had increased, at all ages, marginally in the last few years. The strength of the Limerick cement at 28 days has not changed but the 7-day strength was now approximately 81% of the 28-day strength, as against about 75% formerly.

A working party in Britain had been studying the properties of modern cements in the UK and its draft report published in 1984 was causing some controversy. The report suggested that cements had got stronger and the consequence that concrete could be made with less cement than before was leading to concern about durability. The working party also found that the proportionate increase in strength of concrete after 28 days had probably decreased. The report could not be taken on face value as applying to Irish cements. For example, concrete tested recently by coring at six weeks and at six months showed an increase in strength of between 28% to 40% in that time. Also strength increases such as these reported had not occurred in Ireland. The end uses of cement in Ireland were of interest. One noted the increase from 25% in 1975 to 33% in 1984 in the proportion

of cement going to the ready-mixed concrete industry, and one noted also the importance of housing and agriculture as end users.

Speaking of aggregates, Mr. Bannon observed that aggregates were now generally produced in modern washing and processing plants. On small jobs, the use of unwashed locally available pit run gravels was continuing to cause problems. The phenomenon of alkali-silica reaction currently giving concern in some areas in Britain, and being examined there at present by a working group, had not been reported to date in Ireland. The approach being studied in Britain of initial screening of aggregates followed by long term tests on concrete specimens were, in the view of the author, the course of action that should be adopted if concern arose regarding aggregate sources.

Mr. Bannon considered that admixtures had very much become the fourth ingredient of concrete during the last ten years. Admixtures in his opinion, could play an important part in producing better concrete and the total banning of admixtures where adequate technical back-up information was available was unreasonable. He felt that water reducing plasticisers, retarders, and air entraining agents could make significant contributions to the quality of finished concrete. Retarders were particularly valuable where ready-mixed concrete was subjected to long hauls in hot weather. He had observed no real growth in the use of superplasticizers over the last ten years. The extra cost involved of £4 per cubic metre could be significant, but a reduction to £1.50 per cubic metre which now seemed possible with new materials could alter the picture. It was his opinion that we should specify air entrainment for all exposed flat work. In the matter of admixtures generally, he thought the industry would be better served by a closer liaison between specifiers and producers, and in that context commended the practice of detailing admixtures on all delivery dockets, as one supplier was now doing.

Turning to the use of waste materials in concrete, Mr. Bannon noted that the forthcoming commissioning of the Moneypoint electricity generating station was now leading us in Ireland to consider the use of pulverised fuel ash, or fly ash, a material that would be a waste product at Moneypoint. Fly ash was a very interesting material that could be used in structural fill, lightweight aggregate concrete blocks, and grout, and in cement manufacture and replacement. Its use in or as a replacement for cement always had to depend on its quality, as it was an extremely variable material. It was of interest to note that of a quantity of 12.8 million tonnes of fly ash produced by the Central Electricity Generating Board in the UK over a period, only 0.36 million tonnes were used in cement or as a replacement for it. It was the policy of the CECB, as outlined by Mr. Keeling when opening the Ashtech '84 conference in London to make available for this purpose only such fly ash as met the requirements of BS 3892: Part 1 which prescribed limits for the fineness and loss on ignition of suitable ash. It was recognised that fine high density ash led to a considerable reduction in water demand for given workability, but

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coarse low density ash had the opposite effect. It appeared to the speaker that ash of good quality could benefit concrete and would have an impact on Irish concrete technology in the next decade, if it was available at an economic price.

Mr. Bannon recalled that there had been considerable debate at the symposia ten and twenty years ago on the relative merits of site-mixed and ready-mixed concrete. The growth of off-site mixing since 1975 could be seen as one answer to the debate. Large output mixers were no longer required on most projects. Machinery suppliers reported that the increased demand in recent years was for small drum mixers and this tied in with a recent survey by Irish Cement Limited which showed that 50% of all sales of bagged cement were in lots of two tonnes or less and 25% in lots of ten bags or less. There had been a growing tendency to computerise ready-mixed concrete plants, and the high level of quality control at these plants had been demonstrated by the IIRS records which indicated standard deviations of the order of 4-6 newtons per square millimetre as normal for ready-mixed concrete. The extent of concrete testing in the country could be gauged by the fact that IIRS tested about 45,000 cubes in 1984. In that context, Mr. Bannon suggested that more attention should be given to the proper making and site-curing of concrete test cubes, as he considered that low results could sometimes be attributed to deficiencies in these particular stages. He could not believe that the paper cup filled with grout which he showed his audience on a slide should be a normal constituent in cube preparation. He, as had earlier speakers, would commend the use of the Irish Building Specification and BS 5328 to specifiers, and he hoped that the current study by the Irish Concrete Society of the UK approach to national durability grades would receive the co-operation of the Irish concrete producers and would be of value to the industry.

Referring to precast concrete, Mr. Bannon observed that both the import of components and the ill-informed media comments on defects in cladding panels had caused difficulties in the industry in recent years. Very few buildings had suffered defects, and the causes were well known. The high quality that precast concrete panels could attain was well demonstrated in buildings on the Belfield campus. He noted an increasing interest in GRC panels, mentioning the AnCO training centre at Loughlinstown as an example. Problems that arose sometimes with the durability of GRC could, the designers had told him, be eradicated if the designs catered for the increased thermal and shrinkage movement effects associated with the material. As a new technique in precasting, he mentioned the construction in recent years of two factories using an American system of tilt-up construction.

The most significant developments of recent years in concrete block production in Ireland had been the computerisation of batching plants, an increased proportion of blocks cast on end, and the introduction, on a large scale, of dense concrete masonry. The Forticrete range of blocks had offered Irish architects a new medium of expression, and

indeed the opportunity for designing not only the block work, but also the actual block elements. More attention was now being paid to the use of control jointing and bed-joint reinforcement in the elimination of cracking.

Probably the only major development in the handling of concrete since 1975 had been the introduction, through the ready-mixed concrete industry, of mechanical belt conveyors, such as those manufactured by Moffett Engineering Co. of Clontibret, who had supplied two installations in 1982 and fourteen in 1984. These benefits were evident, in load capacity and speed of delivery, and their use was likely to continue of interest.

There had, over the years, been a minor revolution in the techniques of casting floors on grade, with the earlier checkerboard pattern of casting now largely superseded by long strip methods. In recent years three new methods of floor construction had been introduced. These were (i) the "wide screed" method which by using specialised wide span vibrating rollers on screeds supported on triangulated trusses allowed for 10-metre floor widths to be constructed, (ii) "the large-pour" method, developed by Messrs. Lacon, relying on skilled crews and laser surface levelling techniques to enable large area to be cast without screeding, using superplasticised concrete, raising the reinforcement into place during casting, and cutting control joints in the hardened concrete and (iii) "super flat" method, similar to long strip construction, but paying particular attention to the initial level of the side screeds, and grinding down irregularities after hardening.

Referring to site practices, Mr. Bannon noted in general the increasing use of mechanical handling plant for formwork and prefabricated reinforcement cages and in particular the introduction by the SIAC organization of a machine for the extrusion of concrete kerbs in situ. He believed other uses might be found in the next ten years for plant following that principle. He had noted the increase in size of single casts on large sites and commented particularly on a one-day cast of 1600 cubic metres at Moneypoint, which he understood was the largest single day's cast on record in the country. It was of interest that the trend now, instead of cooling down large casts, was to insulate them to reduce temperature differentials and so reduce thermal stress and cracking.

Mr. Bannon concluded by looking forward to a continuing significant place for concrete in the better times ahead, emphasising that the guarantee of that lay in the proper retention and development of operative skills within the industry.

MR. RAYMOND MESCAL opened the discussion.

He first paid a tribute to Maurice Sweeney who had made major contributions to the 1965 and 1975 Symposia but who sadly had not lived to join the 1985 event, which in 1975 he said he was already looking forward to.

Speaking to Mr. Bannon's paper, he also recognised that the earlier debate on ready-mixed concrete was now over. As a contractor for a structural project, he would now automatically propose ready-mixed concrete, and he believed specifiers would concur. In 1965, the reverse would have applied and it was a sobering thought that the 21/14 was now almost a thing of the past. For a contractor, the last ten years had been hectic, with recession of a sort in 1975, boom in 1979, and deep recession in 1985. Added to that there had been the great increases in size of one-day casts, and the enormous increases in areas of slab on grade cast as one-day operations. To have spoken ten years ago of acres of floor to be cast in a single day would have been unthinkable. He saw these developments resulting from more thorough planning and co-operation both with specifiers and with suppliers, and from the greater reliability of contractors' plant. He noted from Mr. Bannon the increasing tendency of users to collect their own cement ex-works. This reflected, he thought, problems of industrial relations that had existed some five or six years ago, but which, possibly in part as a result of recession, had now largely disappeared. One recalled how skilful contractors had become at that time in taking the possibility of industrial disputes into account as a factor in planning large casting operations!

He would make two observations on Mr. Bannon's references to cement. Firstly, as a question, if the demand in Ireland for cement were to rise again to the 1979 level of over two million tonnes, would the wet process kilns at Limerick be brought back into service, or would the decision be to increase cement imports? Secondly, and this was a comment, if we had had problems with imported cement, was this possibly because we were not familiar with the material rather than that the material was in some way substandard. About admixtures, he had recorded considerable experience with them in 1975, and his view now was that he would be satisfied with their use by ready-mixed concrete suppliers and precast component manufacturers because they had the facility to control dosage and production. To do that with site-mixed concrete was more difficult and certainly was costly in time, and supervision. Mr. Mescal wondered whether we would ever see "synthesized" cement, bagged with an admixture included, to offer for instance a measure of retardation or an enhanced workability. Regarding fly ash, it was his belief that only a need for cheaper cement would lead to its use in Ireland.

Referring again to ready-mixed concrete, Mr. Mescal considered that the consistency of the product, the improved communication system with for instance radio-controlled trucks, which had been advocated in 1975 and were now very widely used, and the provisions made for placing by pump or conveyor, were probably the three main factors in its adoption. The question of specification had been raised by both Mr. Scannell and Mr. Bannon, and, in particular, the significance of minimum cement content. He had sympathy for a concrete supplier, who, faced with a requirement solely for minimum strength, met that

requirement with the most competitively priced mix that he could devise. Where a minimum cement content was specified in the interest of durability rather than strength, then the specifier should make that clear and quite obviously, the supplier should honour that specification.

In the matter of transporting concrete, Mr. Mescal recalled that both Mr. Sweeney in 1965 and he himself in 1975 had forecast an increased use of conveyors. It was clear that they had now arrived. It was gratifying now to see that Messrs Moffett had had the foresight to develop a conveyor system and had been able to export their product to Canada and the United States. The conveyor had been found particularly useful on smaller contracts, where formerly placing had often been somewhat haphazard. With its use, rates for instance of one cubic metre every four minutes could be achieved in casting 225 mm thick walls.

Speaking as a contractor, he was very satisfied with the new large-pour methods for casting slabs on grade. It was no cheaper than the earlier strip methods, but it had made the task of ensuring the accuracy of finished surfaces much easier. He was interested in the report of An Foras Forbartha about the extreme accuracy of the super-flat method. It was however highly expensive and the standards it could achieve, ± 3 mm, were generally higher than needed. Large-pour methods could readily work to ± 6 mm or ± 8 mm, and these tolerances were perfectly acceptable to modern fork lift trucks.

In summary, Mr. Mescal believed the industry now understood very well the making and handling of concrete and the control of its quality. There was still much to be learnt about placing and finishing concrete. Mr. Bannon had suggested that the concrete operative should possibly serve an apprenticeship and be given trade or craft status. In his opinion the latter would not happen, but there would be an increase in the number of specialist groups concentrating, as for instance in the large-pour area, or particular aspects of concrete work. He wondered indeed whether we were far from the day when architects and engineers would be nominating sub-contractors to place and finish concrete.

MR. J. A. HILL was interested in seeing the value of cement production and consumption used as an indicator of the economic health or otherwise of a community. Also it was quite salutary to realise that the quantities of cement used by engineers in their designed works were not necessarily dominant in overall cement consumption. While engineers would be reassured by Mr. Bannon's being able to report that cement strengths had not reduced during the ten years of his survey, it would be a further reassurance if we could be told that cement was now as consistent as it had been ten years ago. He was concerned that cement was ceasing to be a relatively standard product. This was already the position in Northern Ireland, for economic reasons, and one now had to fear for the durability of new reinforced

SESSION B

concrete. Our codes today allowed us to produce an acceptable standard of reinforced concrete with cements that we knew. What assurance could now be given that, with blended cements or with cements containing cement replacements, the properties that affected cement alkalinity and carbonation would be thoroughly investigated in the light of current perceptions of cement content and cover to reinforcement, and was it possible that those perceptions would have to be changed?

MR. W. MURPHY found great interest in comparing Irish practice with practice in Britain with which he was more familiar. A similar paper to Mr. Bannon's, on British practice would have the same emphasis on durability and on the characteristics of cement. The concept of durability grades was more advanced in Britain and indeed BS 8110 which would be issued in September to replace CP 110 would incorporate national durability grades although not under that precise name. One then had to face the possibility of being able to reach specified concrete strengths with less and less cement, if cements became stronger, and the effect of that on minimum cement content and so on durability could not be ignored. In Britain also there was nowadays much talk about alkali-silica reaction, something which in 1975 they would have dismissed as non-existent on the British mainland. Irish designers might have to be considering this problem in the next ten years, but it did seem to him that they should be rational about it in not fashionably identifying faults as due to ASR when in fact they could be due to other factors. Nor should they rush into decisions to demolish suspect structures as was being mooted in Britain. There was no case in the ten or more countries where ASR had occurred since the early 1900's where a structure in service had been demolished for that reason.

Mr. Murphy suggested that air entrainment would be receiving more attention now in Britain, than the present paper implied for Irish practice. Undoubtedly, air entrainment enhanced the durability of pavements, exposed to frost and to de-icing salts. It was a further effect of such salt spraying that it reached not only bridge decks, but also the bearings and the piers. Chloride attack in bridges had become with them a major concern, and air entrainment had a large part to play in overall bridge durability. About pulverised fuel ash, again he believed that a cautious approach to existing evidence was appropriate. He felt its use was to a degree related to the curing of concrete containing it, with water-cured concrete behaving differently to that resulting from the indifferent curing experienced today on many sites. He had heard no reference to "quality assurance" for concrete, a process gaining in popularity in Britain, with Government encouragement. It was a step in the right direction, he believed, that a scheme should develop through which a customer could purchase a material and assume with confidence that what was being supplied was what had been specified. One further difference he had noted was the absence of mention to

concrete paving blocks. Their use was fast expanding in Britain but at a present annual usage of about 2.5×10^6 square metres, they were still far behind Denmark and Germany where the usage was roughly 1 square metre per head of population per annum. That they did not seem to be making any impact in Ireland suggested that there was there perhaps a use of precast concrete that might be worth further exploration.

MR. M. DONNELLAN noted that Mr. Bannon in his reference to alkali aggregate reaction had referred to the safety of cements having an alkali content of less than 0.6%. Bearing in mind that very little large-scale testing of aggregates was being carried out in Ireland, he wondered whether it would be possible for Irish Cement Ltd. to limit the alkali content of its products to 0.6%, to head the problem of AAR off, once and for all. Regarding PFA, perhaps its pozzolanic qualities should not be overlooked as an advantage in its use, and he wondered also whether it could play any part in controlling AAR. He had been interested in the references to the rapid placing of concrete by conveyors. Users accustomed to the slow filling of, say, wall formwork might be taken by surprise by the increase in pressure on the formwork arising from the accelerated rate of casting. Had there been any reports of formwork failure?

DR. D. ORR criticized sloppy practices in the making of concrete test specimens. It was unpardonable to inscribe a number into the surface of a cube, and all testing laboratories should refuse to handle specimens so damaged. He had heard no mention of the VB consistometer apparatus. He was sure it was used in precast concrete works, and he wondered whether the lack of reference pointed in some way to some ambivalence in the attitude of engineers towards the supervision of concrete being produced in precast concrete works. There was a problem of course in supervising both site work and work in a yard possibly quite far away, but he just wondered whether this difficulty was part of the cause of situations where precast concrete had not in fact been satisfactory in the past.

MR. D. LENNON wondered whether the use of epoxy-coated steel or stainless steel in stirrups would not permit the reduction of covers quite significantly. Had that been considered for Irish practice so far? He questioned also whether there had in fact been a change in the chemical composition of Irish cement in the last twenty years. In reply to Mr. Mescal there were some building chemical companies producing what one might call synthesized bagged cements. He had in mind free flowing grouts for mounting machinery and cements for free flowing self-levelling floor screeds, although he did recognise the very high cost of using that second material.

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MR. S. SHARPE made three points. Firstly, there was little point in specifying a minimum cement content unless there was a speedy and reliable method of checking the content. Was there such a method? Secondly, endorsing Mr. Mescal's comment, it was not easy now to keep general operatives with skill in placing concrete employed in the periods between large pours. This was leading towards the engagement of specialist sub-contractors. The need to organize the learning of concreting skills was essential, as was the need to teach these skills properly. He believed that at present rates of production in the building industry, about 2000 skilled men would be required. For his third point, Mr. Sharpe asked when the industry could expect to have available, some standard colour other than grey for exposed concrete.

THE CHAIRMAN was concerned that engineers did not appear to know as much about concrete as once they had, that young engineers were not being trained to design concrete mixes, to work in laboratories, or to recognise good concrete from bad. The industry did need skilled personnel to place concrete but also needed skilled engineers who could judge the quality of the work being done. In the ESB, they had experienced staff on site and generally very good quality control. However they still had problems. The first chimney at Moneypoint was being built using the slip-form technique and advancing at 3 to 4 metres per day. A grade 40N concrete had been specified. In the early stages the cube test results were averaging about 58N per mm^2 , but then over a period of about three weeks that figure fell to 50N per mm^2 , and in the August week-end they had a series of results down to 33N per mm^2 . They had been making the unusually high number of 28 test cubes per day. When the low 28-day test results were received the chimney had already advanced approximately 60m, and the potential problem was considerable. Construction was stopped, and cores taken — sixteen in all from the affected area. These showed a concrete strength in-situ of 38N per mm^2 and this, coupled with a check on the design of the stack, satisfied the ESB that construction could continue as the work as built satisfied design criteria. Theories had been advanced as to what had caused the change in concrete quality. Possibly heavy rain had washed dirt to the bottom of a pile of aggregate, so dirty aggregate was suspected. The cement was blamed. The admixtures were questioned. However, they never really solved the problem. Specially washed aggregate gave, in fact, worse strength results than the alleged dirty aggregate. They then completed the first chimney and a second chimney with concrete that returned throughout an average strength of 61N per mm^2 . Whatever had occurred during construction of the first chimney underlined to them the need for extreme vigilance right through the concreting programme. On another chimney in the Dublin area they had had a similar problem, but there the solution was apparent. Ready-mixed concrete was supplied for a chimney base which after about a month showed some circumferential cracking. It emerged on checking that the sup-

plier of the concrete had increased the specified cement content off his own bat by about 100 kg per cubic metre, producing a concrete far too rich in cement and consequently prone to the form of cracking that occurred.

MR. BANNON replied to the discussion.

He assured Mr. Mescal that if the demand for cement were again to exceed the dry-process capacity of the Irish Cement industry, Irish Cement Limited would use all available means to meet the greater demand. He believed synthesised cements were quite far in the future, if for no other reason than on the grounds of cost. He also saw a growth in the conveyor-placing of concrete and believed it could occur hand-in-hand with developments in the ready-mixed concrete industry. Regarding the training of concrete operatives, he believed that Mr. Mescal and he would agree that irrespective of whether the training was for general contractors or for specialist sub-contractors, such training as for instance being pursued by AnCO now in this time of recession, was very desirable if we were to make the best use of concrete in the coming decade. In response to Mr. Hill, he felt that a detailed presentation of cement characteristics over the last ten years might have been out of balance in his paper. He hoped that the elaboration he had given of the IIRS work on standard deviation in the concretes produced with the Irish cement during that time would be found helpful in that regard. Without doubt, we had to be careful about the possible implication of cement change, and the use of blended cements on the properties of concrete including carbonation. We must study the history of blended cements in other countries before launching the Irish industry into their manufacture and use.

Addressing the points raised by Mr. Murphy, Mr. Bannon underlined the value of hearing comparative views from a different arena. The topic of durability grades for concrete in Irish practice was still very much open. Curing, as Mr. Murphy had emphasized was of paramount importance and especially in the context of any proposal to use blended cements. An increased use of concrete paving blocks was certainly a matter that should get interested attention from Irish producers. With reference to Mr. Donnellan's comments on ASR, Mr. Bannon mentioned that the Hawkins Report, in issuing recommendations for the U.K., recommended that where reactive aggregates were used, it was prudent to keep the alkali content (expressed as equivalent sodium) of cement below 0.6% or alternatively, the total alkali content of concrete below 3 kg/m^3 . He had noted the development in the U.K. of a technique of petrographic analysis of aggregates and it might be that the British would soon standardise an overall approach to ASR. If reactive aggregates came to be used in Irish concretes, appropriate checks would have to be made on aggregates and aggregate/cement combinations. On the matter of conveyors and possible increased rates of casting, while he would prefer to see an amateur using a conveyor than attempting by other means to fill 4-metre high formwork, he did agree that there was a lot of work to be

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done in educating farmers and other home users on the problems of concrete work.

About the problems of sampling adverted to by Dr. Orr, the industry recognised this deficiency in Irish practice. The certification of sites, or of individuals on sites, as reliable samplers, a proposal he had made in the symposium, was one possible approach. The matter certainly needed to be resolved. About supervision in the precast concrete industry, he had no experience of any major problem. He believed that the slimmed down precast concrete manufacturing sector was very conscious of quality, but perhaps there was a need for the manufacturers to convey their concern for their responsibility to users. He could tell Mr. Lennon that coated steels were being used in Ireland today. Perhaps some of the consulting engineers present would say where. He did not have the time, he felt, to discuss changes in Irish cement over the last ten years, but he would say that the change from the wet to dry process in Limerick had represented only a minor change in the chemistry of the cements produced. To Mr. Sharpe, he would say that the IIRS did have a reasonably accurate cement content test that could provide an answer within twenty-four hours. It was not however being regarded as a standard compliance test. Regarding coloured concretes, he believed that Irish Cement Limited would always be glad to look at the possibility of adding pigments at the manufacturing stage. There were good pigments and they were being used in the block industry. Without pigments, the colours achieved could really only depend on the raw materials available in Limerick and Platin, and on the aggregates used. Mr. Bannon thanked the Chairman for his case study on the need for vigilance, and again underlined the thesis of his paper that for the good concrete we required, all we needed were good materials and good workmanship under good supervision.

DR. B. L. BOND in a written contribution discussed the discrepancy between durability and strength grades. Durability criteria could often result in a concrete of significantly higher strength than that specified. In his experience most concrete specifications were unsatisfactory contractually and many were also technically inadequate. The reason for this might be the strict observance of the provisions of CP 110 without adequate thought about compatibility between the strength and durability criteria. It might on the other hand be because it took time and care to change and improve a specification that had been deemed "to serve a practice well" over perhaps very many years. He cited two examples of designed mixes where this discrepancy had been apparent. In the first, minimum cement content, maximum w/c ratio, and limits on aggregate/cement ratios were nominated and a 28-day works test strength of 25 N per mm² was given. The resulting designed mix met all the requirements but had a 28-day strength of 45.5 N per mm². In the second, compliance with a similar series of criteria led inevitably to a designed mix having a 28-day strength of 49 N per mm² for what was nominated as a Grade 30 concrete.

Such inconsistencies had considerable commercial and contractual implications. Tender prices in the construction industry were so competitive at present that there was an unprecedented duty put on the specifier to state unambiguously what was required. There was equally a real need for supervisors to ensure that required standards were met. It was virtually certain that at least one tenderer for a job involving concrete construction would be using a price based on the concrete grade without reference to other aspects of the specification. Faced with that likelihood, what was a conscientious and technically competent contractor to do if he wanted his tender to be competitive? In Mr. Bond's view to specify a strength that was significantly below that which derived from the rest of the concrete specification encouraged unfair tendering that favoured the unscrupulous or ignorant. Subsequent to the award of a contract, such practice could lead to a confrontation with the contractor or perhaps to the use of lower quality concrete than specified. The industry had, for the present to rely on the well established cube test for compliance, but there was little point in that procedure if the contractual compliance acceptance criteria were well below those which should be achieved because of durability criteria.

Mr. Bond had concluded that the current practice of divorcing strength from durability in concrete specifications was most undesirable, that the proposal in Britain for national durability grades, and the recent SEMSELB model specification (see "Concrete", April 1985) offered a realistic and sensible approach, that there was no reason why designers should not start now to choose durability criteria and state characteristic strengths approximately compatible, and that if they did so start, they should consider taking those larger characteristic strengths into their designs, with, of course due regard for deflexion and safety factors.

MR. BANNON noted in a written comment that the Second Edition of the Hawkins Report issued for public comment in the U.K. in 1985 did not include guidelines on aggregate evaluation based on well established international tests or modifications of such tests.

He regarded the Hawkins Committee approach of listing rock groups which could be taken as non-reactive as suspect and he noted that in other countries, particularly Canada and Germany, aggregate test routines had been successfully developed to classify aggregates.

His own Company based on a study of the situation abroad had commenced a detailed programme of aggregate and aggregate/cement testing and initial results from the programme were very encouraging and indicated that the British Guidelines were not appropriate in Ireland in this respect. This was not surprising due to the different geological history of Irish and British rock types.

He believed that a classification system based on screening tests and medium to long term expansion tests could be developed for Irish materials and could serve as a basis for specification.

SESSION C

CURRENT METHODS TECHNIQUES AND AIDS IN REINFORCED CONCRETE DESIGN AND DETAIL

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1. INTRODUCTION

In the decade 1975 to 1985, the most significant factors which contributed to change in reinforced concrete design and detailing in Ireland were BS CP110 (1) and computing. As Codes of Practice and Standards are covered by another paper to this symposium, only limited reference is made to these here. This paper therefore concentrates on the impact of computing on the design process.

2. DESIGN OBJECTIVES AND THEIR ACHIEVEMENT

Perhaps we might state that the aim of structural design is essentially to produce a structure which can transmit dead, wind, imposed loads safely to the ground. The design must therefore yield a robust and stable structure which will not collapse catastrophically under the possible effects of misuse or of accidental damage to any element. Of course, the structural engineer should be conscious of much more than just the mechanics of the structure. He must also aim for solutions which are both economic in construction and maintenance and he should strive to contribute what he can towards achieving a design of aesthetic merit.

Regarding the health and safety aspects of structural design Building Bye-Laws (2) and Regulations (3) have for a long time been the instruments of control used by state and local authorities to protect the public. These documents are usually written as performance specifications but to allow convenient implementation they invariably have deemed-to-satisfy clauses which can include the specification of various physical minima/maxima or reference to national Codes of Practice and Standards. The Standards and Codes of Practice themselves are designed to represent the best experience and research thought avail-

able and the coupling of these with Building Bye-Laws and Regulations gives them an enormous influence on the way in which we design and detail reinforced concrete.

3. CODES OF PRACTICE

3.1 The decade to 1985

In 1975 Harrington (4) in his paper presented to the symposium 'Concrete Practice in Ireland 1975' wrote: "It is a considerable time since the introduction of any standard relating to concrete construction or structural design has caused such a volume of comment and controversy as has the introduction of two British Standard Codes issued in 1972 namely CP3: Chapter V—Part 2 and CP110—Part 1. Each of these documents has received extensive study by designers because of the considerable changes which their implementation requires in design work." Having discussed the existing codes CP114, CP115 and CP116, Harrington went on to say: "The introduction of British Standard Code of Practice CP110 in November 1972 initiated a new era in the design of structural concrete At present it is possible to base design either on the New Code, or on the other three documents. In Britain the code was received with considerable resistance by many engineers . . . In this country the introduction of the unified code into design office practice has been a gradual process and while more than seventy per cent of designers now use CP110, some proportion of them also use CP114 and CP116. There was reluctance initially to use the new code because of the fundamental departure from existing practice and the increase in design office costs which result from implementing the changes." So in 1975 we may conclude that 70% of concrete designers were using CP110 for some of their design work and 30% were not using it at all.

Subsequent changes to CP114 excluding provisions for flat slab construction were accompanied by revisions to the British Building Regulations requiring that buildings should be designed either wholly to CP110 or wholly to CP114. This meant that CP110 now had to be used for any building with flat slabs; there was no longer any choice. These changes and increasing experience in the application of CP110 mean that we can say that in Ireland in 1985, CP110 is used for all major concrete building projects and for many minor projects but that CP114 continues to be used in many of the design offices not involved with major projects.

3.2 Complete design needed

But how many of those now designing to CP110 do so completely? The CP110 clauses regarding load factors and load case patterns are relatively easy to apply for span analysis and the inclusion of column restraint in beam and slab analysis is easily done by those using computer programs to aid them. But how many rigorously apply the more difficult clauses? On questions of redistribution, of curtailment, of bond, of anchorage and of detailing, CP110 is mostly quite specific

about what is required and leaves little room for individual interpretation. But on these points, many experienced engineers rely on good practice rules which they have acquired for themselves over the years. However, considerable care is needed here since without CP110 compliant details it may not be possible for the structure to behave in the way it has been assumed to behave for the CP110 analysis !

3.3 Brave designers

While designers working to CP110 should be urged to produce designs fully compliant with its clauses, it still needs to be recognised that CP110 offers designers a choice of assumptions in the derivation of analytical models which will produce some rather different design solutions depending on the particular assumptions made. In this respect, Beeby & Taylor (5) have presented some calculations for a single storey building with concrete slab roof supported on single bay concrete beam and column portal frames, the roof slab being monolithic with the beam. Perhaps it can be argued that the loading for this example is unusual and that extreme options regarding section behaviour have been considered but what the two authors have shown is that depending on how the second moments of area of the column and beam/slab are calculated, it is possible for the support moment at the beam ends to vary from 34 kNm to 66 kNm, each calculation complying with CP110. Another study by Chakrabarti, Nayak and Agarwala (6) has looked at the effect of construction sequence on internal loads and has shown a variation of beam moments in multi-storey frames of up to 60% from those normally assumed. We must conclude from these examples that it would be a brave designer who is convinced that he can predict internal loads in statistically redundant structures to within $\pm 20\%$ when working to a Code of Practice. None of this is said to detract from the value of code of practice design, rather to put it in perspective.

3.4 Code review

Since its publication in 1972, CP110 has been the subject of much debate. In 1978 a code review committee was established to bring together comment from all sources and to propose revisions where appropriate. A new edition of the code will be published in 1985 (7). There will be some clarification, a little simplification, some minor technical revision, some changes to remove anomalies present in the existing edition and the introduction of an index to supplement the contents list for quick reference.

3.5 Primary reference

In time, we can expect the Eurocode (8) to supersede CP110 for concrete design but the complexity of achieving a workable technical agreement between the experts of so many nations and of bringing that into effect through local legislation in each country seems rather remote at this stage. The publication of the Eurocode in draft form

is only a step towards a unified approach and does not imply immediate actual use by the practitioners of any nation. National pride means that no one will be allowed to dominate the process, the final workable document will have to be a compromise for all. So for the foreseeable future, CP110 looks like being our primary reference for guidance on design and detailing.

3.6 Secondary references

Secondary references for CP110 designers include the two supplementary volumes to the code which provide design charts to speed the application of the Part 1 requirements for beams and columns. Part 2 is concerned with singly reinforced beams, doubly reinforced beams and rectangular columns and seems to be widely used by designers who design by hand. Part 3, concerned with circular columns and prestressed beams, is rarely used.

Many designers find that the handbook by Reynolds and Steadman (9) is a more valuable design aid than Part 2 and Part 3 of the code. Reynolds' handbook for designs to CP114 was always popular and on its adaption and expansion to suit CP110 requirements it had an immediate loyal following such that many designers use it to guide their design with only very occasional reference to CP110 itself. For a deeper understanding of the reasoning behind various CP110 clauses and for guidance on their application the C&CA commentary (10) is highly valued. A handbook by Allen (11) is also popular. For guidance on detailing the volume by Whittle (12) is valuable.

4. COMPUTING

4.1 An overview

By 1975 quite a number of Irish engineers had experience of using some form of computing in their work. If the analytical aspect of what they were doing was sufficiently complex they might process this through a computer bureau, either preparing the data in the required form themselves and posting it on to the bureau for processing or perhaps employing experts in structural modelling to do this for them. From about 1970, Trinity College had been providing a service on their IBM 360 computer in Dublin using the STRUDL software from MIT. Later on, University Computing Company were able to offer the Engineering Systems Incorporated software on their UNIVAC 1108 in London, through a fast terminal in Dublin. In turn, through a link to the same machine, the Institute for Industrial Research and Standards were for a time providing a computer modelling and consultancy service. At about the same time both the Electricity Supply Board (13) and Dublin County Council established computing facilities for their design engineers on their own in-house computers. And, at UCC, UCD and UCG the civil engineering departments were showing increasing interest in computing for research and had occasional contact with structural designers outside the universities who were tackling particularly tricky design problems and were in need of some assistance.

4.2 Developments at Ove Arup and Partners

In 1970 Ove Arup and Partners had developed a modest suite of structural analysis programs (14) of their own and were using these with overnight processing on the TCD IBM 360 and later on, for faster turn-round and much reduced cost, using daytime processing on the UCC UNIVAC 1108. Before moving to the UNIVAC 1108, Ove Arup and Partners had experimented with an in-house time sharing terminal linked to a remote computer in England through the telephone system. The objective of these experiments had been to see whether a faster turn-round could be achieved and therefore a better service for the design engineers. The experiments were quickly concluded as soon as the frustration of data transmission through the public switched network were fully realised, the cost of telephone calls calculated and when the inordinate amount of time it took to transmit data and receive results for even modest analytical problems was determined. The overall time sharing costs were many times those of processing the same problems through the TCD computer.

So Ove Arup and Partners were still searching for modest in-house computing facilities to aid small routine analytical and design calculations. During the late 60's and early 70's there had been a series of electronic desk-top calculators available from Hewlett-Packard and from Olivetti but these all lacked capacity and speed and presented output on a narrow strip of paper, all rather difficult to handle in a busy design office environment. By 1974, more powerful machines were available and an HP9830 from Hewlett-Packard, with page width printer was identified as having the potential to satisfy the firm's immediate needs. A machine was purchased together with A3 size four pen colour plotter and by the time of the CPI 75 symposium, a modest suite of programmes (15) was operational for frame and truss analysis and for concrete beam analysis, at that stage to CP 114 requirements.

4.3 Desktop computing

The years 1973-75 were the dawning of desktop computing in the design office and little could it be imagined then how fast hardware developments would follow and how wholeheartedly business in general would have accepted desktop (micro) computing by 1985. Indeed many of the larger firms who installed main frame systems and remote terminals in the past are now moving towards decentralisation of computing resources through the installation of desktop computers, possibly with some form of communications link to allow the sharing of data between machines. This trend will accelerate now that desktop computers are faster, more powerful and cheaper than many of the mini-computers of five years ago.

In 1985, business desktop computing is dominated by the IBM PC and compatible machines. Other PC manufacturers, unheard of in desktop computing in 1975 are ACT (Apricot), Victor (Sirius), DEC (Professional, Rainbow), Apple (Apple, Lisa, Macintosh) and ICL (PC).

WESLEY COLLEGE EXTENSION
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API02 : CONTINUOUS BEAM ANALYSIS - Issue 3.0
GRAPHICAL OUTPUT

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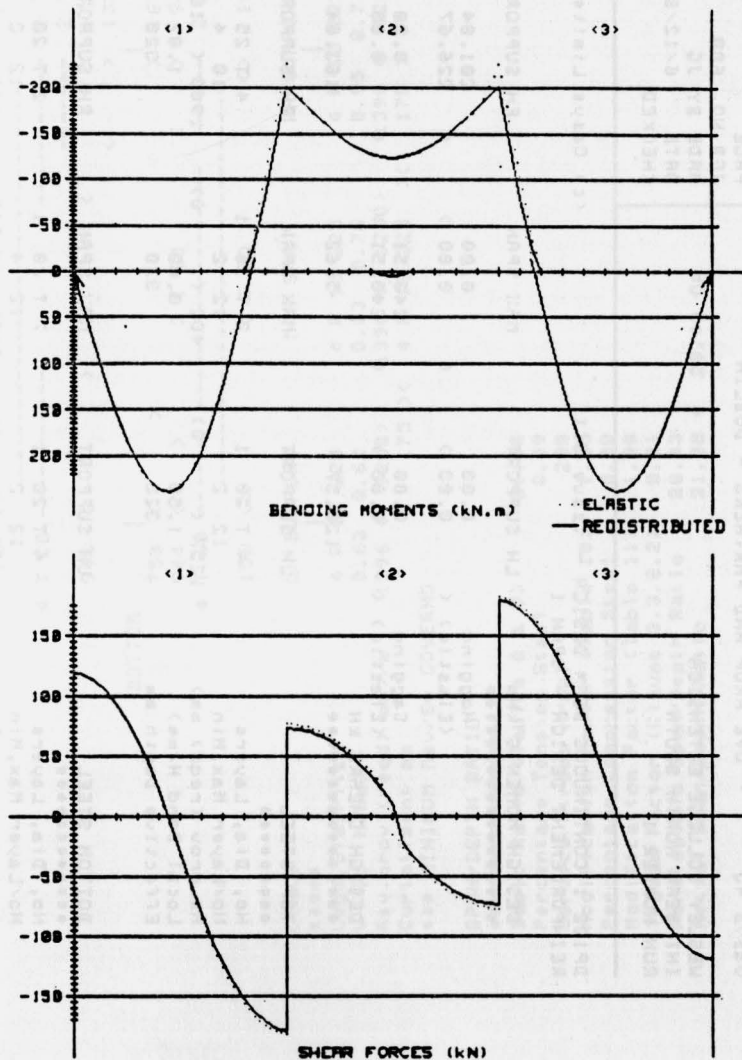


FIG. 1

OASYS BEAM ANALYSIS TO CP110 — WESLEY COLLEGE.

Oasys 45

OVE ARUP AND PARTNERS - DUBLIN

WESLEY COLLEGE EXTENSION
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DP102 : CONTINUOUS BEAM DESIGN - Issue 3.1
REINFORCEMENT DESIGN - SPAN 1

(c) Oasys Limited 1984

DESIGN MOMENTS kNm *****	LH SUPPORT	MAX SPAN	RH SUPPORT
Hogging	0.00	0.00	201.04
(Elastic) (	0.00)	(0.00)	(226.67)
Sagging	0.00	240.51	0.00
(Elastic) (	0.00)	(240.51)	(0.00)
DESIGN SHEARS kN *****	120.57	5.62	163.04
TOP STEEL *****	LH SUPPORT	MAX SPAN	RH SUPPORT
No, Dia, Layers	4 T 20 1	2 T 16 1	4 T 25 1
No/Layer Max,Min	12 2	12 2	10 4
As.prov (reqd) mm ²	1257 (0)	402 (0)	1963 (1823)
Local Bond N/mm ²	1.50	0.00	1.02
Effective Depth mm	320	320	320
BOTTOM STEEL *****	LH SUPPORT	MAX SPAN	RH SUPPORT
No, Dia, Layers	4 T 20 1	7 T 20 1	2 T 20 1
No/Layer Max,Min	12 2	12 4	12 2
As.prov (reqd) mm ²	1257 (0)	2199 (1965)	620 (0)
Local Bond N/mm ²	1.49	0.04	0.00
Effective Depth mm	322	322	322

CURTAILMENT mm

TCP

LH SUPPORT		RH SUPPORT	
150	<>	2 T 16	<> 150

4 T 20	-----	-----	2 T 25

944	< >	< >	1730

		< >	1320

BOTTOM			
759	< >	< >	1679
944	< >	3 T 20	< > 944
4 T 20	-----	-----	2 T 20

150	<>	4 T 20	<> 150

LINKS

Legs, Dia, Pitch

V Vc H/mm>

Asv.prov (reqd) mm>/m

Curtailment mm

*** MINIMUM Asv/Sv GOVERNS

LH SUPPRT

MAX SPAN

RH SUPPORT

4 R 10 225

4 R 10 225

4 R 10 225

0.63 0.62

0.03 0.76

0.95 0.73

1396 < 1200

1396 < 1200

1396 < 1200

< 175 ><

4 R 10 225 ><

175 >

SPAN/DEPTH RATIO

Basic Ratio (Tables 8 & 9)

26.00

Percentage Tension Steel

0.39

Service Stress H/mm>

238

Modification Factor (Table 10)

1.35

Percentage Compression Steel

0.00

Modification Factor (Table 11)

1.00

T-Beam Factor (Clause 3.3.8.2)

0.81

Permissible Span/Depth Ratio

28.43

Actual Span/Depth Ratio

21.30 < 28.43 OK

FIG. 2

OASYS BEAM DESIGN TO CP110 — WESLEY COLLEGE.

SESSION C

In Ireland IBM PC compatible machines are manufactured by Sord and North Star. Hewlett-Packard offers the HP150 PC and in technical computing they offer some very useful machines in their Series 80 and Series 200 ranges, the 32-bit HP Series 200 machines certainly being ideal for engineering computation.

In the private sector, there are now some thirty-five engineering design offices in Ireland using in-house computer aided design. Most of these have desktop computers for engineering calculations, there are a small number of mini-computers used for the same and an equally small number of computer draughting systems.

In the universities and colleges, there has been widespread recognition of the importance of introducing desktop computing into engineering curricula. The value of using desktop machines for the computing aspects of project and research work has also been recognised. The success of desktop computing is explained first by the convenience of having a machine fully under the control of the local user. The frustrations of telecommunications problems, of processing priorities decided by others, of degradation of performance as more users join the system, of feeling helpless when the central machine suffers mechanical failure, are all removed. The second explanation for success comes from the cost effectiveness of desktop computing which has arisen from the increase in power and reduction in cost due to volume production and sales. The rapid hardware evolution has been accompanied by an equally rapid evolution in the software available for engineering design.

Notable applications software improvements include the introduction of interactive graphics routines to aid interpretation of input data and of computed results and far more sophisticated input and editing facilities, all designed to improve user productivity and make the system more pleasant to work with.

5. COMPUTER AIDED DESIGN

5.1 CP110 analysis design and detailing

Two established software systems for CP110 concrete design are the DECIDE (16) suite from Taylor and Beeby and the OASYS CP110 suite (17) from Ove Arup and Partners. Both systems offer similar suites of programs for beam, slab, column and foundation pad design but the OASYS system pursues the design into greater detail than the DECIDE system. An example of this would be beam design where DECIDE stops at section design but OASYS follows detail design right through to the stage where the computer output pages have all the information (main bars, continuity steel, links and curtailment) necessary for the detailer to complete his drawing. In the OASYS design, working solutions are produced with a proper tie-up of the reinforcement in each span with that in the adjacent spans. In such a program the designer can influence the bar selection process to achieve an appropriate degree of consistency with the design of other elements in

Oasys 45

OVE ARUP AND PARTNERS

9

PROGRAM MANUAL EXAMPLE 3
ANALYSIS WITHOUT LOAD CHECKS
RUN NUMBER 123

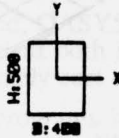
PAGE
JOB NO. 9999/99
MADE BY HMC
DATE 14/12/82
CHECKED

DP103 : RECTANGULAR COLUMN DESIGN - Issue 2.2
GRAPHICAL OUTPUT

(c) Oasys Limited 1993

Mx/N INTERACTION PLOT - Major axis

Fcu 30.00 N/mm²
Gamma C. 1.50
Fy..... 425.00 N/mm²
Gamma S. 1.15



No	COVER	BAR GROUPS		STEEL (X)	Muz (kN)
		H-SIZE	B-SIZE		
1	40	4 T 32	4 T 32	4.025	5561
2	40	4 T 32	3 T 32	4.021	5201
3	40	3 T 32	3 T 32	3.217	4601
4	40	2 T 32	2 T 32	1.689	2048

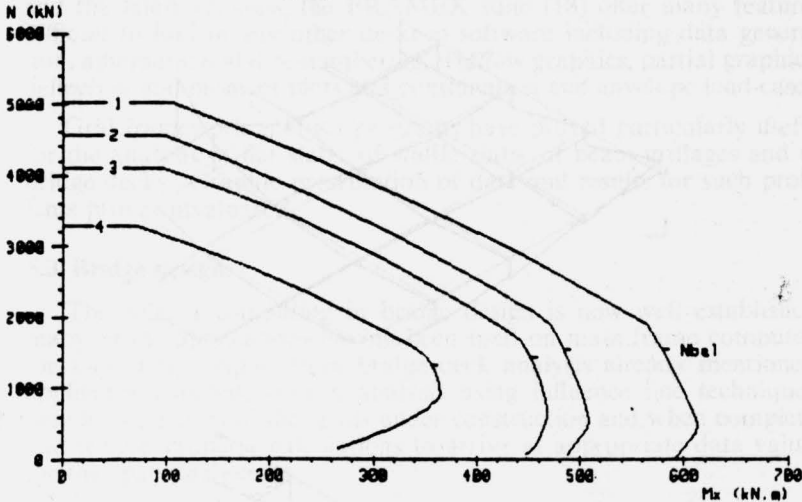


FIG. 3

OASYS RECTANGULAR COLUMN DESIGN TO CP110.

the project. Good beam analysis and design programs can be enormously cost effective. Slab analysis and design programs and rectangular column design programs can also be good time savers.

5.2 Framework analyses

Plane and grid frame analyses have also made their contribution to concrete design and in this the STRESS and OASYS programs (17) should be noted.

STRESS was the forerunner of STRUDL available as part of the ICES system on main frame computers. Both are batch processing

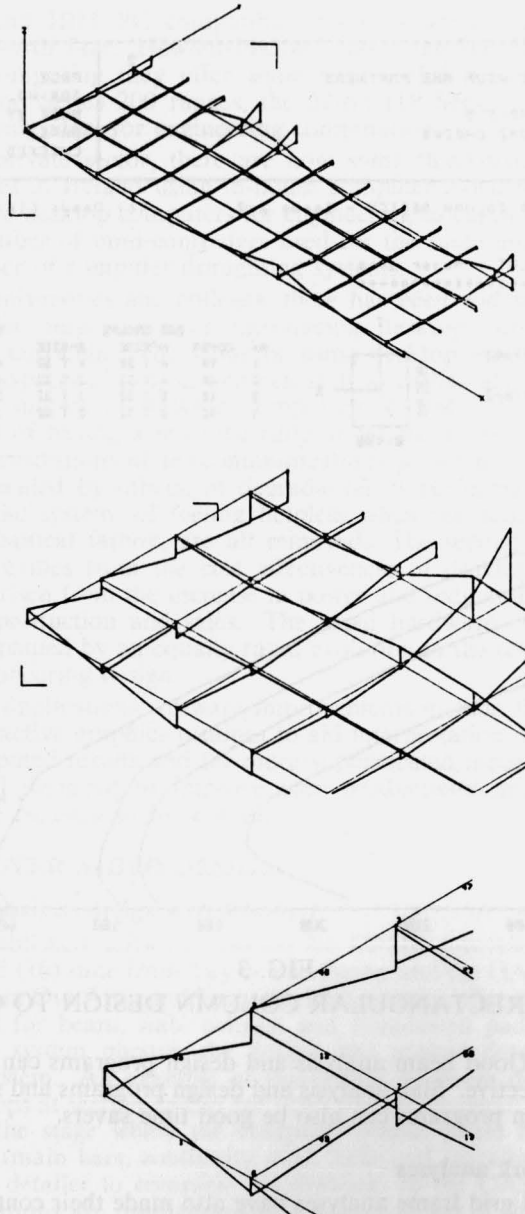


FIG 4

OASYS FRAMEX WINDOW GRAPHICS — WAFFLE SLAB ANALYSIS, UCD ENGINEERING SCHOOL.

programs and when STRESS was converted to run on desktop computers it was surprising that no attempt was made to take advantage of interactive data input and editing or of the graphics potential of desktop computers. As a consequence, STRESS users could not have anywhere near as efficient data preparation procedures as interactive program users and the absence of graphics prevented efficient interpretation of results. But in the hands of experienced STRUDL and STRESS users the desktop version of STRESS proved quite useful but painfully slow. However some more adventurous versions of STRESS for desktop computers are now beginning to appear and these go some way towards curing the problems.

On the other hand, OASYS analysis programs were designed from the outset to be efficient both in the use of user time and of computer time and were extremely cost effective from the start.

These OASYS programs have been wholly developed in Ireland and the latest versions, the FRAMEx suite (18) offer many features difficult to find in any other desktop software including data generation, automatic nodal re-numbering, window graphics, partial graphics, deflection and moment plots and combination and envelope load cases.

Grid framework analysis programs have proved particularly useful for the analysis of flat slabs, of waffle slabs, of beam grillages and of bridge decks. Graphic presentation of data and results for such problems proves invaluable.

5.3 Bridge design

The role of computing in bridge design is now well established, many of the applications having been used on main frame computers for some time. Apart from bridge deck analysis already mentioned, applications include overall analysis using influence line techniques, pre-stress analysis of the spans under construction and when complete, and section property calculations to arrive at appropriate data values for the span analyses.

Considering the less functional aspects of bridge design, it is important that a bridge should not only be attractive to look at, but that it should also express a sense of achievement, however modest, which is a mark of all well designed structures (19). It should have in addition a natural permanent association with its setting, which calls for special attention to the scale and form of the structure. This can be achieved through the use of models. Models should be made as realistic as possible and should show all the physical features close to the structure, including topography, roads, trees, rivers, canals and buildings. With a good model of the setting it is easy to try out various design alternatives. Currently physical modelling dominates this activity but computer graphics modelling is another technique and although this new technology is still very much in its infancy, it is fast becoming a very important design aid.

 Dasys 200 OVE ARUP & PARTNERS - DUBLIN

ATHLONE BRIDGE
 BENDING MOMENT INFLUENCE LINES
 RUN NUMBER 1

2 :
 : PAGE
 : JOB NO. D541
 : MADE BY KD
 : DATE 17/6/83
 : CHECKED

 AP107 : CONTINUOUS BEAM INFLUENCE LINES - Issue 2.6 (c) Dasys Limited 1983
 OUTPUT RESULTS

RESULT FOR STATIC LOADCASE

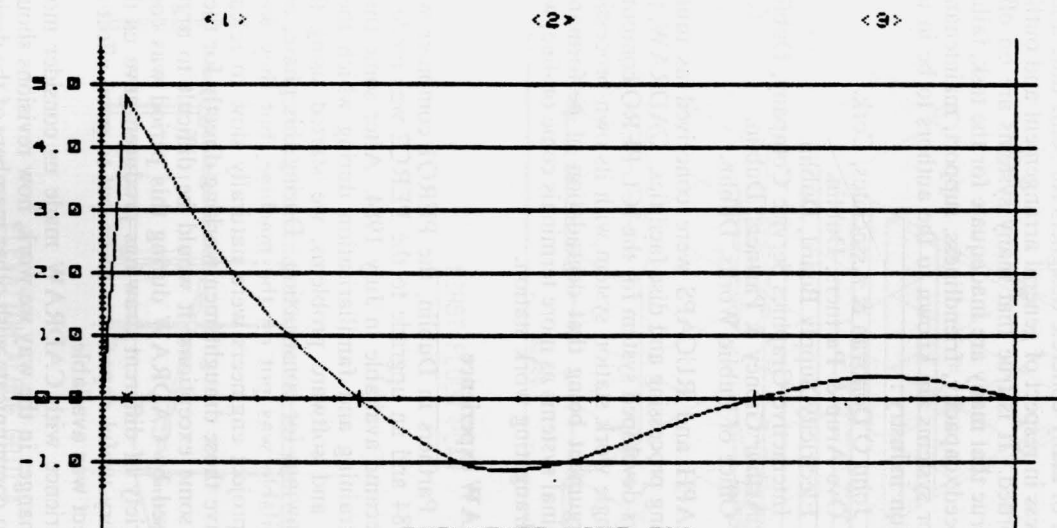
SPAN 1 DISTANCE 5.600(m) FROM L.H. SUPPORT

UNDER THIS LOADCASE= 0.000KNm

INFLUENCE LINE FOR

SPAN 1 DISTANCE 5.600(m) FROM L.H. SUPPORT

	SPAN: 1	2	3
L.H. SUPPORT	0.000	0.000	0.000
.1	4.827	-.451	.103
.2	4.070	-.840	.200
.3	3.346	-1.093	.280
.4	2.671	-1.145	.336
.5	2.060	-1.045	.350
.6	1.531	-.848	.326
.7	1.088	-.608	.272
.8	.697	-.378	.194
.9	.337	-.177	.101
R.H. SUPPORT	-0.000	0.000	-0.000



INFLUENCE LINE FOR
SPAN 1 DISTANCE 5.600(m) FROM LH SUPPORT

FIG. 5
OASYS BENDING MOMENT INFLUENCE LINE
CALCULATION — ATHLONE BRIDGE.

6. COMPUTER AIDED DRAWING

6.1 Draughting systems

The economic preparation of production drawings on computers has been the ambition of many concrete designers for some time and a certain degree of success in respect of general arrangement and outline drawings can be recorded. It is true that many systems are on offer now but it is equally true that many are inadequate for the task, falling down on facilities, speed, capacity, friendliness, support, maintenance or cost. Some 6 major systems are known to the authors to be in use in the Irish construction industry :

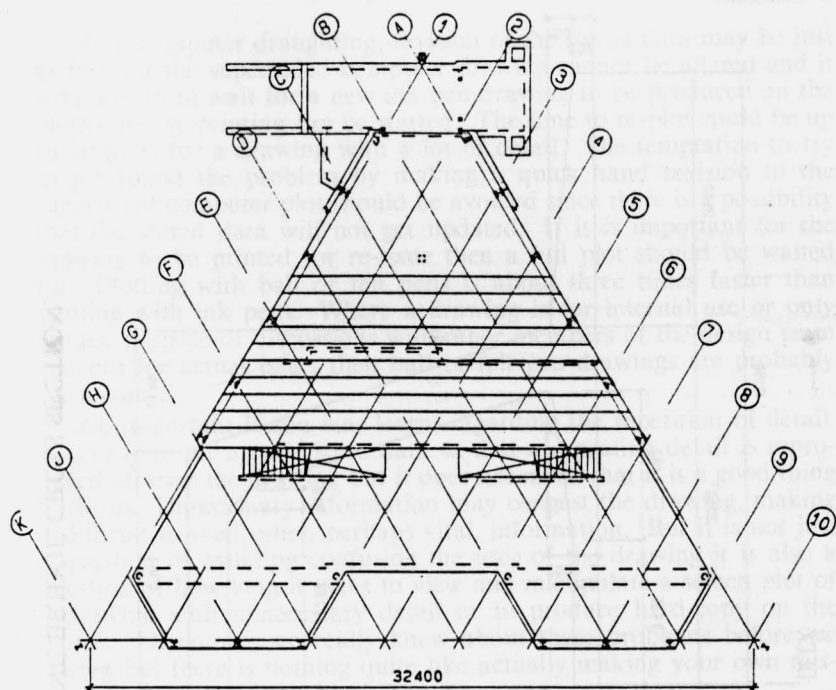
ARC	—	John O'Donovan & Associates, Cork.
CADRAW	—	Ove Arup & Partners, Dublin.
INTERGRAPH	—	Electricity Supply Board, Dublin.
	—	Interactive Graphics Service Company, Dublin.
RUCAPS	—	Arthur Gibney & Partners, Dublin.
	—	Office of Public Works, Dublin.

ARC, INTERGRAPH and RUCAPS were conceived as multi-terminal systems sharing processing and disc facilities. CADRAW, the Ove Arup and Partners developed system for the ICL PERQ computer was conceived as a single work station system with its own processing and hard disc, the argument being that degradation of performance common to most terminal systems as more terminals come on-line, was unacceptable with a draughting work station.

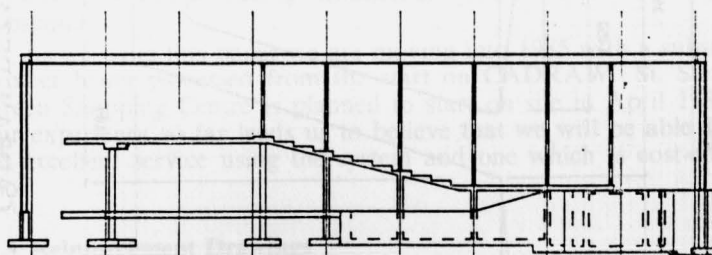
6.2 Ove Arup CADRAW experience

At Ove Arup and Partners in Dublin, the PERQ1 computer was installed in March 1984 and an upgrade to the PERQ2 was made as soon as this model became available in July 1984. After some three months of operator training and familiarisation during which there were some hardware and software problems, we started using the system to produce drawings for construction. During this phase, any work which was available was put on the machine, but they were lean weeks and our project engineers were naturally slow to release work which would leave those draughtsmen working directly for them under-utilised. With some exceptions, it would be difficult to argue that the work processed by CADRAW during this period was cost-effective. But the variety of different drawings produced gave us the opportunity to gain very useful experience to be put to good effect as soon as a major project was available.

Our start-up experience with CADRAW made us consider more closely the need for changes in the way we work, how revisions should be handled and how to communicate with other members of the design team. The need for change at all is largely due to the speed of plotting which seems restrictive at times. Minor revisions illustrate the problem. With manual draughting a detail can be quickly altered and the drawing ready for re-printing perhaps in minutes.



FIRST FLOOR PLAN



ELEVATION ALONG GRID A

FIG. 6
CADRAW PLAN AND ELEVATION — UNIVERSITY
INDUSTRY CENTRE, BELFIELD.

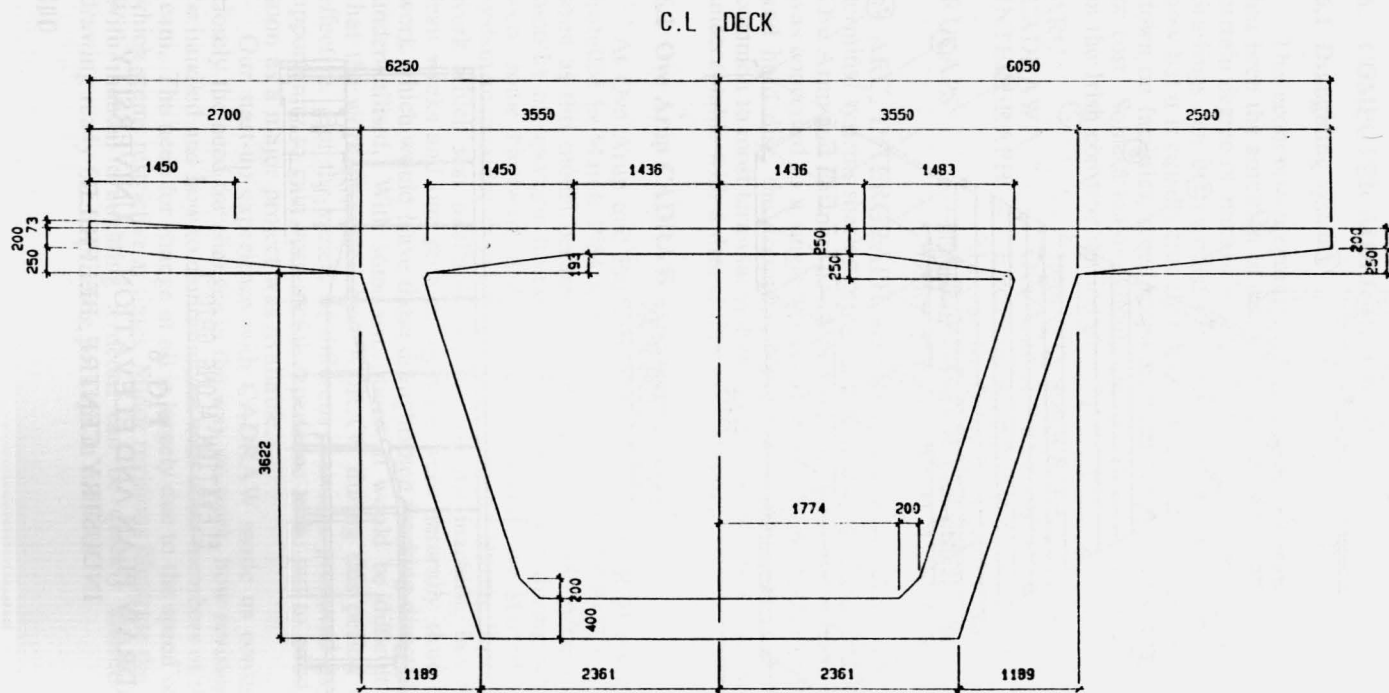


FIG. 7

CADRAW DETAIL — ATHLONE BRIDGE CROSS SECTION.

With computer draughting, revision of the stored data may be just as fast but the superseded computer drawing cannot be altered and it is necessary to wait for a new ink pen drawing to be produced on the plotter before printing can be started. The time to re-plot could be up to 30 mins for a drawing with a lot of detail. The temptation to try to get round the problem by making a quick hand revision to the superseded computer plot should be avoided since there is a possibility that the stored data will not get updated. If it is important for the drawing to be printed for re-issue then a full plot should be waited for. Plotting with ball or felt pens is about three times faster than plotting with ink pens. Where a drawing is for internal use or only for the purpose of discussions with other members of the design team and not for actual issue, then ball or felt pen drawings are probably the answer.

An important lesson was learnt regarding the repetition of detail. It is easy to set up and store data so that a repeating detail is reproduced all over the drawing but it does not mean that it is a good thing to do so. Unnecessary information may congest the drawing, making it difficult to read other, perhaps vital, information. But it is not just a question of avoiding confusing the user of the drawing it is also a question of how long it takes to view and manipulate a screen plot of a drawing with unnecessary detail or to produce hard-copy on the plotter. Of course, we really knew about these problems before we started but there is nothing quite like actually making your own mistakes to drive the point home !

One thing we did agree before we started and which we have adhered to is to use CADRAW for general arrangements and outline drawings only. We can see that there is the potential for developing special routines within CADRAW to handle standard reinforcement patterns, but at this stage we are not at all convinced of the cost-effectiveness of producing traditional reinforcement drawings by computer.

As we write this paper we are moving into 1985 with a substantial project being processed from the start on CADRAW. St. Stephen's Green Shopping Centre is planned to start on site in April 1985 and our experience so far leads us to believe that we will be able to give an excellent service using the system and one which is cost-effective too.

6.3 Reinforcement Drawings

In the report on our CADRAW experience we have stated that we see little immediate prospect of producing traditional reinforcement drawings cost-effectively by computer. We should qualify this statement a bit since if the computer draughting system is to be used to produce the drawings for a building system product, for example the user is concerned with multi-storey car parks or with concrete portals for factory estates, then the pattern of reinforcement will be so well

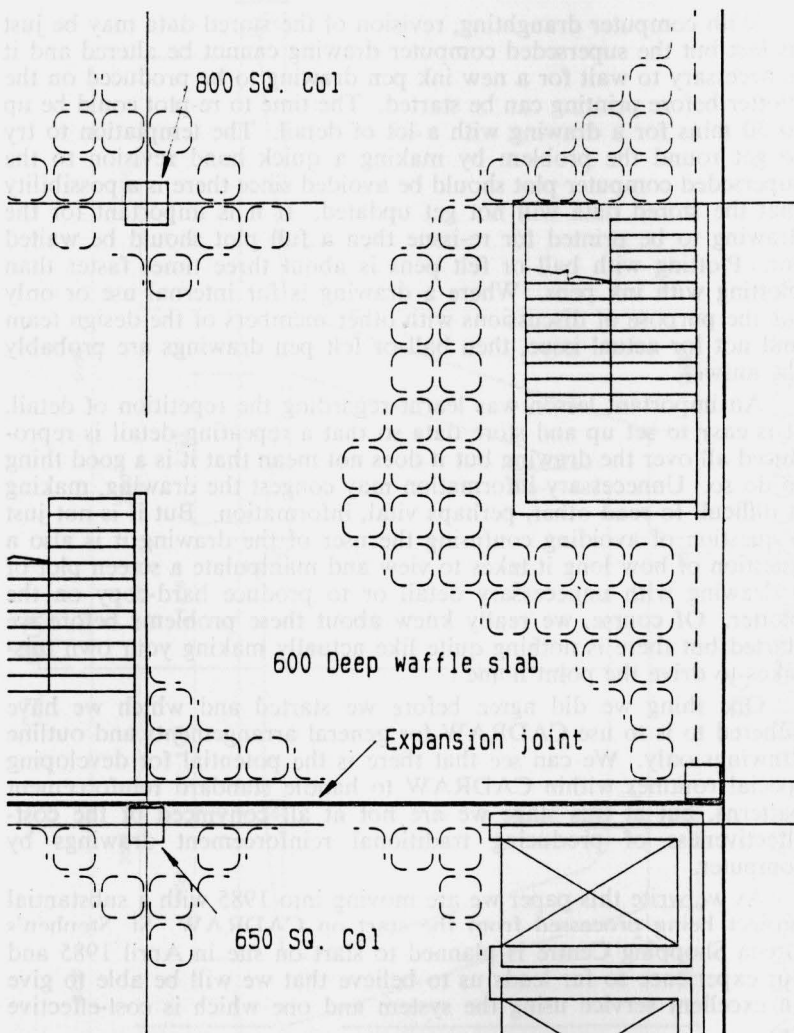


FIG. 8

CADRAW FLOOR DETAIL — ST. STEPHEN'S GREEN SHOPPING CENTRE.

established that it is well worthwhile setting up the routines to handle these on a computer. In such cases, the opportunity is there to recover initial special software development costs over a long run of the product. This is not the case with the vast majority of work handled in consulting engineers' offices in Ireland.

A number of reinforcement detailing systems producing normal size drawings have been reported in the professional literature over the years. In the main, these have been systems produced by large consultancies for their own use. There is little evidence that they have been adopted by others and we may assume that in some cases, due to lack of flexibility or cost-effectiveness, they have now fallen into disuse.

With the BARD system (20), the Cement and Concrete Association have attempted to break away from the traditional presentation of reinforcement drawings. With this system, drawings are produced on A3 size plotters which cost only a fraction of the cost of A1 plotters and show single element reinforcement drawings only.

In general this means one bay of a slab or one span of a beam per drawing, each including a bending and fixing schedule produced by the plotter. The BARD system works on desktop computers and cannot handle non-standard situations. It is a cheap solution but perhaps one which will not be taken up extensively because of its lack of completeness and the non-standard presentation of the drawings.

7. PROGRAM VALIDATION

The need to validate all computer programs is clear and is particularly important in the case of calculation programs, the more so with those that produce tabulated output only. At least with graphical output, peculiarities in patterns are rapidly recognizable and errors easier to detect.

A year ago problems with cracking in the decks of a multi-storey carpark in Birmingham attracted a lot of publicity (21) when it was discovered that the computer output either showed the short and long span steel in carpark deck the wrong way round or that it was misinterpreted this way when the construction drawing was produced. While the report of the investigating consulting engineers soundly condemned the local authority design engineers for completely inadequate checking procedures in this instance, the incident has caused concern amongst computer users and has certainly been held up by some as an example of how dangerous computer aided design is.

For bad cracking to have become evident under the self weight of the carpark decks, there must have been quite a big difference in the steel requirements in the two directions and it is both amazing that the drawings could have passed out of the design office without the error being noticed and surprising that it did not elicit comment from the contractor. Could the same mistake have been made with a hand design by a graduate fresh out of college? We should hope not, even with inadequate supervision from a project engineer.

What the incidents should have done, is to bring home to all designers the importance of independent design checks no matter how the design is produced. Those experienced in computer aided design have always emphasised this but some new practitioners may be tempted to cut corners.

So what about software validation itself? Clearly the first responsibility is that of the software developers to establish as comprehensive a range of tests and checks as they can conceive and to make sure that their product satisfies these before offering it for use in real design. The problem is indeed complicated by the enormous complexity of good interactive software compared with the relative simplicity of batch programs in times gone by. The point is that with batch programs there is a limited number of paths through the program code but with interactive programs there is effectively an infinity of paths. Nevertheless it is possible to reduce the validation task to manageable proportions.

Apart from the tests established by the software developer himself, there are a limited number of worthwhile published tests which should be considered. For framework analysis programs some of the best tests are those produced by the University of Loughborough (22) and the Australian user group (23).

A few clients have established their own tests, notably the UK Ministry of Transport. Any design work done on MOT projects may only use MOT approved software. While helpful, there is no guarantee that programs with the stamp of approval will not cause problems sometime when enhanced or converted to other hardware. In the UK, the Construction Industry Computing Association showed some interest in the needs of the concrete designer when they published a report in 1978 giving a comparative study of seven continuous reinforced concrete beam design programs (24). This was a useful first step but has not been built on since then. Bearing in mind that the CICA report was prepared at a stage when such programs were in their infancy and that the data was about two years out-of-date by the time it was published, might it not be considered that further comparative reports are overdue? CICA is still selling their 1978 report. That CICA has devoted more attention to architecture than to engineering is understandable. Apparently engineers want such studies to be done but do not seem prepared to pay for them by being members of CICA or by paying realistic fees for the reports.

The software developer should not allow his programs to be used in real design until software validation has been completed. Once in use for real design it is probable that problems will be reported by users from time to time. As long as the validation work was done responsibly, it is most unlikely that serious errors will be discovered by users. In interactive programs, most problems will be ones of control. The larger the user base, the more exhaustive will be the user testing and the sooner any quirks will be eliminated. A large user base is a considerable asset in the production of quality software.

8. SYSTEM SELECTION

8.1 General

Having discussed some of the advantages and some of the pitfalls of computer aided design, we give here some views on the question of

computer system selection which we hope will be of value. Unfortunately there are no independent sources of advice here in Ireland at the moment.

It is recommended that to aid system selection, the prospective purchaser should prepare a checklist of features required. This will help the objective evaluation of the various systems available. Management consultants would be more than willing to prepare such checklists but it is unlikely that these could act as more than just pointers for technical computing selection though they should be good for non-technical applications. It is necessary to understand the design process intimately to be able to specify requirements and to evaluate proposals properly. Few management consultants have this expertise.

8.2 Calculation system selection

The careful preparation of a check list is important. Noting down an item such as "RC design" is not enough since that could really be a statement of the whole activity of a design office and it may be over ambitious to expect to get all that in a £10,000 hardware/software package !

An example of a checklist item might be :

- either 1. Up to 8 span RC beam analysis to CP110.
- or 2. Up to 8 span RC beam analysis to CP110 with calculation of required steel areas at supports and mid-span.
- or 3. Up to 8 span RC beam analysis to CP110 with calculation of possible bar arrangements at any specified sections.
- or 4. Up to 8 span RC beam analysis and design to CP110 with full calculation of top, bottom and bar spacing checks, bond checks and span-depth ratio checks.

Having itemised the design office activities which could be computerised, the estimated cost (salaries + overheads) of those activities should be determined. The next task is to seek out possible application programs and the hardware they are available on and to estimate for each the cost (salaries + overheads) of using them. Particular care is needed here as some programs are far easier to use than others doing nominally the same thing. From these figures, the savings can be established which should indicate the upper cost of hardware and software (annual cost for expenditure on both with maintenance for both). A good computing system will improve the speed with which the designer can respond to new situations, which is useful to the designer as he markets his consultancy service, but there is no way of quantifying this benefit and it cannot therefore be part of the cost-effectiveness calculation.

Having established the existence of suitable applications software, we suggest that further pertinent questions would be :

- 1. Is software support available locally, abroad, or not at all?
- 2. Is there a software maintenance scheme ? What is the cost ?
- 3. How are software improvements handled ? What is the cost ?

SESSION C

4. How long has the software house been producing engineering software? Is it going to be in business in 5 years time? Is it actively involved with product enhancement or new product development?
5. Is the software Irish or imported?

Finally, it is always worthwhile getting in contact with other design offices to get their views of the systems they are using. If they are still using the system they purchased 5 years ago, it must be pretty good but because of rapid developments in the interim, the software they are using may be a bit out-of-date at this stage, certainly not state-of-the-art material.

8.3 Draughting system selection

Draughting system selection is a bit more difficult than calculation system selection, though the principles are similar.

Some of the CAD appreciation courses may be useful in helping focus attention on important features to specify in the checklist. IIRS and others have been presenting such courses and these may be a good starting point. An in-depth study of the operation of each serious candidate system should then be undertaken so that the impact on office procedures is fully understood.

For the financial justification of a draughting system, it is worth thinking of writing-off the system over three years because of the rapid evolution of both hardware and software. With borrowing rates as they are at the moment, funding on this basis will cost 40% per annum of the capital cost. To this, 10% per annum of capital cost should be added for system maintenance giving a total cost of 50% per annum of capital cost. Few if any system vendors are now claiming average improvements in draughtsmen productivity greater than 200%. An upper limit on what should be spent on a system can be estimated from these figures, depending on whether the design office is slack and able to take on 2 extra draughtsmen without incurring extra overheads, or is stretched and bound to incur substantial extra overheads by taking on extra staff.

3. CONCLUSION

Structural designers in Ireland have come a long way in the last decade. By and large they have learnt to work well with a new concrete code of practice and in doing so have improved their understanding of structural behaviour. They have further taken quite well to computing as a design aid and have welcomed desktop computing with confidence. The speed and flexibility of computers has allowed designers to study more options during the design process than before and this again has improved their appreciation of factors influencing structural behaviour.

Computing developments in the next decade will be at least as exciting as those in the last and CPI 95 might be receiving reports of widespread successful introduction of expert systems into Irish design offices. These systems could encapsulate some of the expertise of the most experienced staff in the office for the benefit of the less exper-

enced, as it were making the ear of the expert available always at the flick of a switch. Perhaps then we might be able to let the experts go skiing or fishing or whatever a bit more than now.

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Discussion

MR. SHEEHY introduced the paper.

It had been apparent to his co-author, John Gaughan, and to him that it would be quite difficult to steer a course for their paper through the topics being covered in other sessions, and also that the collection of data, particularly on developments in computation, from the profession generally did present problems. They had consequently drawn largely on in-house experience for their report. They had had some discussions with their colleagues in other organizations, but he suggested that a fuller record might be possible, if firms would themselves communicate their own systems and methods of work to the Symposium. One interesting point he had noted in his discussions was the continuing use by some designers in his own organization and elsewhere of CP114.

Mr. Sheehy saw the work of the design office as comprising three phases. Phase 1 evolved a structural system. This was the time of maximum consultation and interdependence with the client and with his advisors including possibly the proposed contractor. Much of the arrangement and sizing of elements in this phase came from the judgement and experience of the engineer with a minimum of calculations. Phase 2, the analysis phase, produced the detailed information on loadings, materials, and control documents, codes and standards, and the calculations required to justify the system selected during Phase 1. Phase 3 was in reality a production phase in which working drawings, reinforcement schedules and shop details were prepared against the information on detailed calculations, and then checked independently. The paper presented today would be set against that background.

Referring to a journey through the United States with Dr. Gaughan, it had appeared to them that desk top computers were used less extensively there than here, and that the software available for them

in the US was inferior to that available in this country, or in Britain. Most engineers in the US thought in terms of main frames or personal computers, and great publicity was being generated at the time for the IBM PC particularly. Some graphics systems which they saw as suitable for desk top computers appeared to them possibly more directed to marketing an image than to cost-effectiveness. There was a feeling however that computerised graphics and drafting were inevitably coming, and that any graphics system learned now must be a useful introduction. The Massachusetts Institute of Technology had been given a grant of equipment to the value of fifty million dollars by IBM, together with a grant of funds to sustain fifteen full time academic staff for five years, to further the study of computer techniques, and a personal IBM PC had become a required item in the equipment of each new undergraduate in that Institute. It appeared to be the intention of US programme developers to produce design programmes which would be interactive with codes of practice in an expert systems approach, and to use the IBM PC in this process. The work involved seemed incredible, but the vastness of the research funding perhaps made it possible.

DR. GAUGHAN continued the introduction to the paper.

Design and detail of reinforced concrete had been dominated in the last decade by CP110 and the computer. It was possible that CP110 coupled with the concept of national Building Regulations was in fact thought to have an excessive influence on our design and detail procedures. Designers found it relatively straightforward to analyse structural requirements along the lines laid down in the code, but one felt that in the many details that went to make up complete designs, experienced engineers tended to rely on their own good practice rules rather than on strict compliance with Code clauses. This was understandable, but the danger existed that non-compliance with code detail might produce a structure which could not comply with the code based analysis used in its design. Also individual interpretations of Code requirements could lead to anomalous solutions. Taylor and Beeby had, for instance, shown in a recent study of a single storey structure based on portal frames with a roof slab cast monolithically with them that by choosing one's interpretation of the Code, the knee moments in the frames could be made to vary from 34 kNm to 66 kNm, while remaining in compliance with Code requirements. Again the significance of construction sequence and construction period loading was often ignored by designers who, and most did, assumed for design that their buildings arrived with a "big bang" rather than through a relatively long period of gradual assembly. One study in that area had shown that some forces in partially built multi-storey frameworks could vary as much as 60% from those appropriate to the completed structure. In all, he considered that it would be imprudent for a designer to assert that the magnitude of the internal forces in a structure as predicted by his calculations lay within 20% of actual real values. While

however, CP110 could not pretend to rigorous accuracy, it did embody good practice and research findings and had to be seen as the designers' primary reference. Other useful sources for designers were the handbook produced by Reynolds and Steadman, Allens' design text and Whittle's volume on detailing.

Turning to the part played by computers, Dr. Gaughan mentioned that the first general service was in 1970 when Trinity College using an IMB 360 offered the STRUDL programmes from the ICES package, together with other modules from that package. Later the University Computing Company using a UNIVAC 1108, set up an office at the Agricultural Institute, offering structural programmes, linked by fast terminals to systems based in the U.K. The Institute of Industrial Research and Standards also availed of access to those systems. At about the same time, the Electricity Supply Board and Dublin County Council were acquiring their own hardware and software, and the other universities were developing their own interests in their civil engineering departments, a development that was leading to an increasing use of university expertise in a consultancy role.

In their own firm, they used the TCD and University Computing Company facilities at first but early in the 1970's the delays and costs involved in using shared facilities brought them to recognise the need for in-house processes. So in 1974 they introduced a Hewlett Packard 230, the first of the desk top calculators, with a page-width printer for permanent records. By 1975, when so far as Dr. Gaughan could ascertain, the Symposium made no reference to computers, they had a modest suite of structural programmes dealing with frame analysis and reinforced concrete design. At about that time, the profession was beginning actively to consider desk top computers and microcomputers, the suppliers available being Hewlett Packard, Wang, and Olivetti. That pattern was to change in the early '80's with the arrival on the market of ACT Apricot, Apple Lisa and Macintosh, and IBM. One should accept now the dominance of IBM and software compatible with it, although he personally remained convinced that the HP series 200 was a system ideally suited to engineering computation.

A survey of the Association of Consulting Engineers of Ireland had brought thirty-seven responses, that being about a 50% return of the questionnaires issued. Of that response, thirty-one were from firms engaged in civil engineering work solely, or in work including civil engineering. Twenty-four of these firms reported that they had in-house computing facilities, and their returns suggested a total of twenty-four desk top computers and five minicomputers. At least seventeen of these units were being used for reinforced concrete design. Dr. Gaughan had not been able to assemble complementary statistics from the education or semi-state sectors, but he could say from his own records that the numbers he had gathered for the private sector could possibly be increased to include a further twelve design offices in the Republic. One could possibly make some subjective assessment of the overall use of computers in the Republic from consideration of the

figures he offered. The beginning of the expansion that they suggested would have been in about 1976.

Dr Gaughan then showed slides to illustrate the use of desk top computers in reinforced concrete design. These included the full analysis and print-out sheets for a three-span beam at Wesley College, the analysis, design, and detail of columns with uniaxial bending, an influence line diagram for bending moments in a beam at the Athlone by-pass bridge, and the depiction of loading patterns on complex structures, and of their consequent deformations, (a church at Ballybrack, Queen's Old Castle in Cork, a framed structure at Pembroke Road in Dublin, and the new Engineering Building in Belfield being shown as examples). The ability to enlarge the details in any part of a print-out was important, and this also was demonstrated on slides. The value of such illustrations to help young graduates and engineers generally to gain a fuller appreciation of structural behaviour seemed clear, and it had been his experience that there was indeed a willing and productive response to their use.

Regarding the use of the computer for graphics, their firm had installed and developed the CADRAW system which used a PERQ computer. The arrangement embodied screen, keyboard, processor and desk unit, a large plotter (in the example illustrated on the slide, an AO sized plotter), and a printer if required. It would also be observed that the use of light pens with cursor control through knobs or joy sticks had been superseded by the digitising tablet. In micro-computer use, one would nowadays employ a "mouse" for this purpose. Dr. Gaughan illustrated the CADRAW system with slides showing its application on small sheets in the proposed St. Stephen's Green shopping centre, Athlone by-pass bridge, and the University-Industry Centre at Belfield, and on large sheets, in the Trinity College dining hall restoration and again at the St. Stephen's Green shopping centre and the University-Industry Centre. He had to say however that his firm was not enthusiastic about computer drafting for reinforced concrete details. He did not believe that the use of computing for such work had yet been shown to be cost effective.

On other matters, he could not emphasize enough the importance of programme validation, and in relation to the Birmingham car park, said that whether one were working manually or by computer, a failure to control the quality of information produced would always lead to trouble. He commented on the work of the Construction Industry Computer Association in Britain. It seemed to him that their work of maintaining software was not keeping pace with modern developments but he did sympathise with the Association in that users expected more and more material from them but did not seem inclined to contribute to the cost of preparing it. Dr. Gaughan, in conclusion, then showed examples of the hidden line removal technique (The National Exhibition Centre at Birmingham) which tended to develop three-dimensional effects in 2-D views, and the area fill technique (the Pex Exhibition Centre at Milan, a tower proposal for Stanstead Air-

port, the Garden Festival building at Liverpool, Lloyds Bank in London) in which, through the introduction to the programme of selected "sun" positions and graded filling in of outlines, full dimensional effects were attainable, with views being possible from many angles.

MR. G. McCONNELL opened the discussion.

He agreed that the two most significant developments in reinforced concrete design and detailing in Ireland since 1975 had been the implementation of CP110 and the advances in computing. He would like to add something to setting these two factors in context, one with the other. Design in reinforced concrete demanded the identification of the problem to be solved, a knowledge of the technical, social, and economic restraints involved, an awareness of the state of the art, and personal experience in the art. Whilst not overlooking the personal ingenuity of the designer, an essential element in any design, these aspects of a particular design could be extracted from some computer data base, and computer techniques could then be used, either highly automated to lead to a single end product, or interactively with the designer to steer the exercise to a particular solution of his choice out of several offered to him. CP110 gave regular slab layouts, and most CP110 computer programmes operated at that tidy end of structural problems. When layouts become irregular, with awkward boundary conditions and cut-out sections, and when loading became complex, and even more with shell-type problems, it became a far more personal matter for the designer to establish his model for analysis.

In common with other areas of structural mechanics, Mr. McConnell saw reinforced concrete design as being developed now under five headings, namely physical research, theory, numerical methods, computer software, and computer hardware. Physical research underpinned all codes of practice. CP110 reflected the vast research experience built up in the UK since the second World War, and that experience, of the physical behaviour of reinforced concrete, would certainly be expanded in the coming decade through the increasing use of computer-controlled testing machines and load rigs. Regarding theory, reinforced concrete structures prior to 1939 had been regarded in the code of practice then current as being like cast iron, liable to collapse abruptly when a critical stress level was exceeded at some point in the structure. However, the theorems of plastic collapse enunciated in Britain and the USA in 1950 and used by Baker, Heyman, and Horne in Cambridge for the plastic design of steel frameworks had been applied also to reinforced concrete, with CP110 guiding designers to the selection of sections so reinforced as to be ductile rather than brittle. Of the various theorems of plastic collapse, that most used in reinforced concrete design was the lower bound theorem which represented safe design; and most computer programmes tended to operate with that theorem when considering design for the limit state of collapse. That design approach had developed since about 1960 from elastic moments through redistribution of moments with gradually increasing percent-

ages being allowed, and in slabs through the use of the Wood/Armer orthotropic yield criterion to the Hilleborg strip methods. Those techniques all stemmed from consideration of the lower bound theorem of collapse and suggested the kind of evolution in progress in structural design. It should be accepted that further progress would not be to more exact solutions but rather towards more fully understood safe solutions. It should also be noted in that context that yield line theory was an upper bound, and therefore strictly speaking, an unsafe method of design, although made safe to use by building in, and recognising, appropriate compensations. It was of interest that in USA the allowable redistribution of moment was, still, more limited than in UK, the Hilleborg strip method had not yet been adopted, and yield line design was only beginning to be accepted during the late '70's.

Mr. McConnell went on to describe computer programmes being used for undergraduate exercises in University College Dublin. They included continuous beam analysis on an OASYS programme, and finite element analysis of plates using STRUDL. He agreed with Dr. Gaughan about the importance of programme validation. In that connection, he noted the establishment of a national agency for finite element standards and implementation in Britain, and suggested the advantage of being associated with that agency to keep abreast of developments. The complexity of the area could be emphasized by reference, for instance to an existing finite element package that offered thirty-eight possible models for use, with the appropriate model for a particular purpose being selected by the guidance through question and answer, of an expert system.

The advent of the micro-computer had made the use of interactive programmes very attractive and the OASYS suite of programmes exploited that admirably. But the main frame computer network had to be seen as a reality, and with increased use leading through economy of scale to reduced costs with the rapid rate of improvement in communication throughout a global network, it was important that its value should not be underestimated. He did of course consider that the stand-alone micro-computer was the most cost effective system for standard reinforced concrete design. One should also recognise the international implications of being able to transmit, electronically, drawings from one country to another and we in this country should be ready to take advantage of that development. One should recognise that a single system of computer aided design (CAD) could be made to serve both the engineering and architectural aspects of a project; and it should be accepted that much of our technology for CAD was likely to come to us from outside sources, including mechanical engineering in which discipline the techniques of CAD and computer aided manufacture (CAM) were already well advanced.

MR. B. O'REGAN accepted the importance of desk top computers and mini-computers for design work, but said that for very large or complicated structures where the work was handled by design teams,

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a mini-computer with many terminals or with intelligent work stations attached to it was an essential tool. He instanced such problems as jetties on piles in variable soil conditions, large steel structures with some thousands of nodes and transmission towers with perhaps 1200 members and up to twenty loading conditions, with the loading conditions themselves running into pages of computer programme; and suggested that in such examples, the desk top machine must let one down. In the ESB, they used many terminals and INTERGRAPH workstations on a VAX machine for engineering design and computer drafting. It had the valuable characteristic that several work stations, each with its own function and capacity, could work on different aspects of a scheme using the VAX as a data base machine. Thus, for instance, the mechanical engineers could at all times call up and use the latest developments of the structural engineers design. It was also possible to pass data from drawings on the CAD system to programmes such as STRUDL for analysis and to check member capacities.

This whole process was very powerful for large complex structures, and he had noted with interest that the architectural firm of Sir Percy Thomas had introduced it into the practice of several of their regional offices.

MR. N. RYAN asked two questions. Firstly, there appeared to be no reference in the paper or in the presentation to the "site phase" of construction. If, using normal methods, one discovered during a site inspection something that needed attention, then one arranged for this to be dealt with. Was there any routine for dealing for such a matter when using computer methods? Secondly, was there any safety device in the computing process that ensured that drawings did not leave an office without being checked?

DR. GAUGHAN replied to the discussion.

Mr. McConnell had been right to draw attention to the need for main frames and networking, with special reference to international consultancy, and to such topics as large finite element problems. There were many changes ahead, and in that, he would of course include developments in mini- and micro-computers. The value of a facility to transmit drawings electronically from an office to a site was clear, and that practice would develop. He felt however that it would have to be preceded by an improvement in communication systems. He admired the scope of the ESB computer installations, which he felt were unique in this country. They handled highly specialist structures in very exciting projects and did need tools and machines not at the disposal of most consulting engineers. The VAX was very important in that sphere and indeed his own organization used these in their London-based specialist research groups. He would say in reply to Mr. O'Regan that it was in fact possible to handle 1200 member

frames on a micro-computer although it would be taxing its capacity to treat space frames of that complexity and to deal with twenty load cases. He agreed about the power of the INTERGRAPH system and perhaps had not made his own point sufficiently clearly, that the CADRAW system, unlike others, was a stand-alone system incorporating its own local data base. He was very interested to learn of the ESB use of colour with the STRUDL system in the high-lighting of stress levels.

Mr. Ryan had raised the very important topic of site control. The electronic communication of, say, amendments from office to site would come although it was some way in the future. All drawings and calculations, however made, still had to be and were subject to independent check. The Birmingham car park situation could not really be attributed to the computer. It was a glaring example of bad management that had permitted the reinforcement to be laid in the wrong direction, and the development of structural cracks in the deck under dead load only suggested quite clearly that one was dealing with a human error rather than a misbehaviour of the computer; and it was an error that should have been apparent both to the project engineer and to the contractor.

SESSION D

THE DURABILITY OF CONCRETE IN INTEGRITY AND APPEARANCE

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Introduction

"Concrete composed of stone fragments or gravel set in some type of cement has been used as a building material for a very long time; it was the Romans' principal constructional material, and the condition of the structures built by them shows how well it has weathered the storms of twenty centuries. Modern concrete made with good Portland cement has the prospect of even greater durability".

The above is a short extract from an article "The Concrete Industry" which appeared in the 1921 edition of "The Irish Year Book". It was written by a Michael A. Hogan, B.E., M.Sc., M.Inst. C.E.I., a research graduate who, over thirty years later, was to become Professor of Civil Engineering in University College, Dublin. The extract contains what is possibly one of the earliest references to durability of concrete. Now, some sixty years later, durability is on everybody's lips. Some recent buildings are showing signs of early deterioration. The phenomenon of young buildings growing old prematurely is not confined to Dublin nor even to Ireland. It appears to be worldwide. One wonders if the prospect of modern concrete having even greater durability than the 2000 year old concrete of Roman times is too optimistic.

The word "durable" is defined in the Shorter Oxford English Dictionary as follows:

- (1) capable of continuing in existence, persistent, permanent,
- (2) able to withstand change, decay or wear.

The notion of permanence is inherent in these two definitions. However, in building dictionaries and encyclopaedias, there is less emphasis on the permanence aspect of durability and the possibility of a limit to the ability of a material to resist decay is at least implied. For example, in one of them, namely, "A Concise Building Encyclopaedia" (compiled by T. Corkhill), durability is defined as the resistance of a material against the action of the atmosphere, decay and wear. The

same idea of ability, rather than certainty, is contained in J. W. de Courcy's definition of the durability of a structure, contained in his paper to the 1965 Symposium on Concrete Practice in Ireland: (3) "The durability of a structure is that quality which measures its ability to achieve the satisfactory life required". This definition, although concise, nevertheless manages to encapsulate several important aspects of durability — the measurement of it, the period of time which is regarded as a satisfactory life for a structure, the decision as to what satisfactory life is required and the achievement of that satisfactory life span.

It is clear from the foregoing that neither buildings nor the materials of which they are made will last forever. The life of a material may be very short or very long. A serious spillage of strong acid could so erode a poor quality concrete slab as to cause rapid disintegration. On the other hand, gold window frames in a dry climate might last many million years. The useful life span of each differs widely but both share the same property of non-everlastingness.

To place concrete in a general picture of service life of materials, S. E. Pihlajavaara (1) has suggested a table showing the service life for different materials under various environmental conditions. See Table 1. This table would attribute a life for concrete varying from as low as one year for very severe exposure to over 10,000 years for high-strength concrete under very mild exposure.

The object of this paper is to investigate the durability of concrete in Ireland over the last hundred years or so and in particular over the last twenty years. To carry out this investigation as comprehensively as possible, a questionnaire (see Appendix) was circulated to 192 engineering and allied organisations who were likely to be involved, directly or indirectly, in concrete design or manufacture or research. Twenty-one of these were in Northern Ireland. The total number of engineers who returned information was 65, that is, a response rate of 34%. The remainder of this paper is based on the information supplied by these 65 respondents. The aim of the questionnaire was to collect information on concrete durability—its successes as well as its failures. The findings of the survey are summarised under four main headings: durability failures in concrete, some observations on durability failures, durable buildings, general comments.

1. DURABILITY FAILURES IN CONCRETE

The concrete structures which suffered in some way due to deterioration are listed in Tables A1 to A7 and Tables B to H. The headings under which information is given are as follows:

1.1 Building

With a few exceptions, all the buildings are without identification of exact location. Some engineers may recognise some of the buildings

TABLE 1 — Order of magnitude classification of the age or service life of materials under various conditions *

Materials	Class of Degradation Factors and Expected Age			
	1	2	3	4
	Very Severe Exposure ^a	Severe Exposure ^b	Mild Exposure ^c	Very Mild Exposure ^d
	Age in Years			
Precious metals	1,000 to 10,000	100,000	1 million	> 10 million
Strong natural rocks	100 to 1,000	1,000 to 10,000	100,000	> 1 million
Natural rocks	10 to 100	100 to 1,000	10,000	> 100,000
Strong ceramic materials	100 to 1,000	1,000 to 10,000	1 million	> 10 million
Ceramic materials	1 to 100	100 to 1,000	10,000	> 100,000
High-strength concrete	10 to 100	100 to 1,000	10,000	> 100,000
Concrete	1 to 100	50 to 500	2,000	> 10,000
Mortars	1 to 10	10 to 100	2,000	> 10,000
Gypsum		1 to 10	500	> 2,000
Metals (for example, iron)	1 to 10	10 to 100	5,000	> 10,000
Wood	1 to 10	10 to 100	1,000	> 10,000
Plastics	1 to 10	10 to 50	100	> 1,000
Paints		2 to 20	500	> 2,000
Leather	1	10 to 50	500	> 2,000
Textiles of natural fibres		1 to 10	500	> 2,000
Bone, hair	10 to 100	100 to 1,000	10,000	> 100,000

^a Frost, snow, ice thawing, great changes in temperature and humidity, erosion, dissolution, strong sunlight, pollution, conditions with strong corroding effects, for example, seawater, polluted water, corroding chemicals, etc.

^b Average variable outdoor conditions, moderate changes in freezing and thawing.

^c Moderate temperature, dry, slight changes in environment.

^d Dry, very slight ventilation, low temperature, no sunlight, constant conditions.

*S. E. Pihlajavaara, Head of Materials Section, Concrete Laboratory, Technical Research Centre of Finland. See Ref. 1.

from the various notes about them. Total anonymity would have been almost impossible and would have detracted from the usefulness and interest of the tables. The term "building" is taken to include roads, bridges, pavements, as well as precast units, blocks, etc.

1.2 Age

The stated age refers to the age of the building at the time the failure was recorded.

1.3 Exposure

This was included to give some indication of the environmental conditions affecting the concrete, e.g. on the one hand, whether the concrete was internal (exposed or covered), external (exposed or sheltered or covered) or on the other hand, whether the location of the building was rural, suburban, urban, industrial, aqueous, coastal or marine (i.e. exposed to sea water or sea spray).

1.4 Failure

A variety of failures was recorded. These have been tabulated under eight main headings as follows :

Tables A1 to A7 : Cracking, spalling and reinforcement corrosion (65 cases). See below.

Table B : Honeycombing, porosity (4 cases)

Table C : Erosion, abrasion (5 cases)

Table D : Disintegration (9 cases)

Table E : Visual disfigurement (6 cases)

Table F : Potential failures (2 cases)

Table G : Use of high alumina cement (5 cases)

Table H : Roads and pavements (10 cases)

Owing to the relatively large number of failures under the first heading, the A-tables have been subdivided according to the principal or first reason for the failure listed in the questionnaires as follows :

Table A1 : Inadequate cover to reinforcement (23 cases)

Table A2 : Poor workmanship (6 cases)

Table A3 : Calcium chloride (8 cases)

Table A4 : Poor design (8 cases)

Table A5 : Defective materials (either in quality or in quantity (10 cases)

Table A6 : Acid attack (4 cases)

Table A7 : Miscellaneous reasons (6 cases)

1.5 Reason

The reasons given or suggested by correspondents for the various failures are given in summary form.

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1.6 Repair

The methods of repair, where used or known, are given. Occasionally an indication of the success or otherwise of the repair is noted. In the tables, the following abbreviations are used :

Exposure :	exp :	exposed
	ext :	external
	int :	internal
	ind :	industrial
	sub :	suburban
Failure :	CR :	cracking
	SP :	spalling
	CS :	corrosion of steel
	ES :	exposure of steel
	CL :	collapse
Reasons :	LC :	low or inadequate cover
	PW :	poor workmanship
	CC :	calcium chloride
	BD :	bad design
	M :	materials
	AA :	acid attack

TABLE A1 CRACKING SPALLING, REINFORCEMENT CORROSION
PRINCIPAL REASON GIVEN AS INADEQUATE COVER TO REINFORCEMENT.

	BUILDING	AGE	EXPOSURE	FAILURE							REASONS										REPAIR
				CR	SP	CS	ES	CL	OTHER - NOTES	LC	PW	CC	ED	M	AA	OTHER - NOTES					
1	Office Building Dublin	20	exp, suburban		x				vertical ribs	x								cementitious			
2	Bridge, Wexford	72	estuary, tidal		x	x				x					x	poor concrete, settlement cracks, overstressing.	guniting.				
3	Water Tower				x					x											
4	Engine Sheds	50	ext, rural		x		x		extensive internally, minor externally	x						(probably)	guniting proposed.				
5	Several concrete encased steel buildings								serious defects	x											
6	Offices, Dublin	14	ext, exp, urban		x	x			white concrete	x							epoxy proposed.				
7	Offices, Dublin	22	ext, exp, urban		x					x							mortar to match.				
8	Office blocks (two)	20 17			x	x			narrow in-situ columns	x						cover as low as 6mm. carbonation has presumably reached the reinforcement	none				
9	School - precast concrete package	12	ext, exp		x	x			external columns and beams	x						cover as low as 5mm	none proposed				
10	Stadium - P.C. steps units	13	ext, exp, urban ind. coastal	x	?				at edges along line of reinforcement	x						inadequate use of spacers	modified mortar.				
11	Quays, Co. Louth	57			x				severe and extensive in beams	x						also porous concrete					
12	Pavilion and toilets	20	ext, exp, marine	x	x	x			suffering the ravages of sea and storms	x							to be considered soon.				

TABLE AI (Contd.)

	BUILDING	AGE	EXPOSURE	FAILURE						REASONS						REPAIR		
				CR	SP	CS	ES	CL	OTHER - NOTES	LC	PW	CC	ED	M	AA		OTHER - NOTES	
13	Bridge decks	35+			x						x							guniting in early life, successful
14	Water tower	49	ext, exp, rural		x				external walls, floor and columns		x							guniting proposed
15	Bridge, Co. Roscommon	50	rural aqueous		x	x					x							guniting proposed
16	Bridge, Co. Clare	57	ext, exp, rural	x	x	x			primarily visual but potentially structural - cracking, crazing, lime leaching, spalling	?						ingress of moisture, rusting of reinforcement (limited), frost action to small degree		guniting twice, with extra mesh over larger cracks; still performing remarkably well.
17	Cooling tower	34			x	x					x					cracking being investigated		
18	PC slats in cattle sheds, Co. Tipperary	12	ext almost, damp conditions	x	x	x		x	brittle fracture		x					also due to an additive		none, replaced 1984
19	PC slats in cattle units Co. Meath	9-14	damp conditions			x		x	brittle fracture		x							replaced 1983
20	Precast cattle slats	4-	severe		x	x					x					also possibly low cement content and possibly plastic spacers		replacement

TABLE AI (Contd.)

	BUILDING	AGE	EXPOSURE	FAILURE							REASONS							REPAIR
				CR	SP	CS	ES	CL	OTHER - NOTES	LC	PW	CC	BD	M	AA	OTHER - NOTES		
21	RC Bridge, Mizen Head, Co. Cork.	75	ext, exp, marine		x	x			rc beams and ribs, reinforcement corrosion and surface spalling	x					x	cover 10-15mm, also lack of fines leading to somewhat porous concrete	1972: entire bridge coated with bitumen, glassfibre membrane and masonry paint; 1980: repairs to rust stained areas (SBR cement slurry), further repair work will be required in adjacent areas.	
22	Offices, Dublin	22	ext, sheltered, urban			x			spalling of concrete cover on sides and soffits of rc beams	x						5-10 cover in places with plastered repair work at time of construction	polymer cement mortar (RONAFIX); appears satisfactory after 6 months	
23	Warehouse, Dublin	27	ext, exp, urban	x	x	x	x			?								

TABLE A2 CRACKING, SPALLING, REINFORCEMENT CORROSION
PRINCIPAL REASONS GIVEN AS POOR WORKMANSHIP

	BUILDING	AGE	EXPOSURE	FAILURE						REASONS							REPAIR
				CR	SP	CS	ES	CL	OTHER - NOTES	LC	FW	CC	BD	M	AA	OTHER - NOTES	
24	Silo, Dublin	48			x		x		extensive. Also vertical split 3-4m	x	x						gunac, twice, life about 20 years.
25	Shopping stores, Dublin	30	int, exp, mild		x		x		slab soffit, also extensive honey-combing.		x			x		poor compaction, bad mix.	guniting proposed
26	Bridge, Co. Dunlin	26	ext, exp, marine			x			soffit beams		x					poor vibration	gunited 1978
27	Farm silos - retaining walls	5-	normal					x			x					inadequate reinf. and low concrete strength	rebuilt
28	Precast rc sewage pipe, large diameter	5-	marine				x		an unusual case; pipe conformed with B.S.		?					plastic settlement circumferential cracks during casting.	relining of pipes
29	Precast prestressed pressure pipes 600mm dia.	10-	normal, rural			x		x	failure of tendons causing explosive failure of pipe		?					air trapped under tendons behind gunite?	replacement

TABLE A3 CRACKING, SPALLING, REINFORCEMENT CORROSION
PRINCIPAL REASON GIVEN AS CALCIUM CHLORIDE

	BUILDING	AGE	EXPOSURE	FAILURE							REASONS							REPAIR
				CR	SP	CS	ES	CL	OTHER - NOTES	LC	PW	CC	BD	M	AA	OTHER - NOTES		
30	Office Building, Dublin	15	ext, exp, urban		x				ribs of precast units			x				also variable cover. Carbonation average 10mm	modified mortar (Inertol system)	
31	Not identified	9	industrial or mild sulphate attack	x	x							x					epoxy mortar	
32	Not identified	14	industrial or mild sulphate attack	x					precast units			x					replaced (commercial decision)	
33	Not identified	14	industrial or sulphate attack	x	x							x				also carbonation	permanent repair not yet carried out	
34	Office structure	?	ext, exp.		x	x	x		a dramatic and very severe case			?				calcium chloride and sulphur dioxide suggested as reasons	none	
35	Library building	14	ext, exp, coastal	x	x				on line of reinf. in cladding panels			x				CaCl measured at +4% by weight of cement.	modified mortar	
36	Precast cladding panels.	10-15	urban		x	x				x		x		x		large quantities of CaCl ₂ . Poor quality concrete		
37	Recent buildings in Northern Ireland								deterioration							often due to carbonation, sometimes due to calcium chloride		

TABLE A4 CRACKING, SPALLING, REINFORCEMENT CORROSION
PRINCIPAL REASON GIVEN AS POOR DESIGN

	BUILDING	AGE	EXPOSURE	FAILURE							REASONS							REPAIR
				CR	SP	CS	ES	CL	OTHER - NOTES	LC	PW	CC	BD	M	AA	OTHER - NOTES		
38	College, Dublin	14	ext, exp, urban	x		x	x		local cracking of some structural members		x		x			inadequately detailed, ineffective supervision	epoxy resin injection and epoxy mortar; considered successful	
39	Precast portal frame system	5	int, exp	x					splitting/cracking at junction of rafter with column				x			poor fit, high bearing stresses, poor detailing of reinforcement cage causing cracking.	pressure grouting (epoxy) - very successful	
40	Bridges, Donegal	35	sub, coastal	x	x	x			beams are seriously weakened by loss of reinforcement	x			x	x		congested reinf. possibly wrong mix.	guniting proposed.	
41	Factory, Co. Limerick	2	int, rural			x			at tops of columns				x			inadequate provision for expansion and contraction of the large building.	epoxy patching	
42	Industrial floor	5+	int, covered	x	x				breaking of corners and joint arris	x			x			poor design and construction	replacement	
43	Concrete block walls of houses	1-	ext, exp, rural/urban	x									x			shrinkage cracks, no joints provided, fresh blocks	cracks filled with compressible material	
44	Warehouse, Dublin	30	int, coastal			x			spalling of bearing nibs at beam expansion joints				x			incorrect joint detailing resulted in no reinforcement in a part of the nib which was load bearing	steel straps bolted across roof beams no repairs elsewhere, propped in region of expansion joints.	
45	RC deck of ro/rc ramp	16	marine, heavy vehicle traffic	x	x				at ship's end					?		Impact from ship's ramp. A constant problem	part new slab cast with heavier duty metal wearing strip, use of non-shrink grouts.	

TABLE A5 CRACKING, SPALLING, REINFORCEMENT CORROSION
PRINCIPAL REASON GIVEN AS DEFECTIVE MATERIALS (EITHER IN QUALITY OR QUANTITY)

	BUILDING	AGE	EXPOSURE	FAILURE							REASONS							REPAIR
				CR	SP	CS	ES	CL	OTHER - NOTES	LC	PW	CC	BD	M	AA	OTHER - NOTES		
46	Football stand	56	ext, exp, sub, coastal		x	x			alkali protection removed by carbonation	x	x			x		probably low cement content lack of cover and poor compaction	early repairs in gunite, recently demolished to make way for a larger stand.	
47	Sports ground stand Dublin	50	ext, sub,		x					x	x			x		mix, compaction cover.	sika repair, successful	
48	Factory, Co. Limerick	10	sub, floor subject to high temperature and humidity from process		x				floor top surface spalled extensively under machine					x		dolomite aggregate had expansion reaction under exposure condition	floor removed and replaced.	
49	Basilica,	65	aqueous		x		x		extensive spalling of beams, ground slab and terrace.	x	x			x		had aggregates, variable mixing, inadequate cover for exposure	guniting in progress	
50	Factory, Dublin	New	int		x				shrinkage cracking in large area pour of thin slab on permanent metal deck formwork.					x		high cement content causing greater shrinkage forces than designed for	none, cracking occurred parallel to span direction.	
51	Bridge parapets Co. Carlow	35+				x			deterioration of concrete and reinforcement	x	x			x		mainly defective materials - use of unwashed fender gravel, inadequate cover, poor compaction.	replacement	

TABLE A5 (Contd.)

	BUILDING	AGE	EXPOSURE	FAILURE						REASONS								REPAIR
				CR	SP	CS	ES	CL	OTHER - NOTES	LC	PW	CC	ED	M	AA	OTHER - NOTES		
52	Reservoir, Co. Meath	94	ext, covered (open on top), rural	x	x				in walls and floor				?	x		no reinforcement, defective materials	cracks sealed with mortar and then asphalted	
53	Piers, Co. Cork	50	severe, marine		x	x				?			x	?		Sea erosion, possibly defective materials and inadequate cover, definitely poor detailing	strip affected area, primarily in wetting zone, add additional reinforcement and cast in- situ work.	
54	Tarbert Dock Co. Kerry (mass concrete pier head)	70	ext, exp, marine						bad separation of structure at day joints with horizontal movement of layers up to 40mm						x	local beach aggregate and sand used, probably unsatisfactory cleaning of laitance and exposed aggregate after tidal washings and before next lift	complete replacement or construction of new external concrete skin encompassing old structure (proposals)	
55	Warehouse, Dublin	30	ext, coastal		x				on some parts of columns		x				x	insufficient cement content and compaction giving rise to a less durable concrete, inadequate attention to shuttering and finish.		

TABLE A6 **CRACKING, SPALLING, REINFORCEMENT CORROSION**
PRINCIPAL REASON GIVEN AS ACID ATTACK

	BUILDING	AGE	EXPOSURE	FAILURE							REASONS										REPAIR		
				CR	SP	CS	ES	CL	OTHER - NOTES		LC	PW	CC	BD	M	AA	OTHER - NOTES						
56	Factory Carrickmacross	17	rural, int		x				internal spalling due to chemical disintegration of concrete .								x	aggressive chemicals in dyeing process spilling on floor and thence to soffit through opes.					membrane on top, epoxy mortar to soffit proposed
57	Rail overbridges (2), Dublin		ext, exp, urban		x				beam soffits								x	loco fumes					none yet
58	Locomotive shed, Limerick	74	int, exp, urban		x				beam soffits								x	loco fumes					certite
59	PC sewerage pipes	5-	slow flowing sewage		x				severe corrosion of concrete at crown of pipe, i.e. above water line								x	hydrogen sulphide gas					relining of pipes

TABLE A7 CRACKING, SPALLING, REINFORCEMENT CORROSION
MISCELLANEOUS REASONS.

	BUILDING	AGE	EXPOSURE	FAILURE							REASONS							REPAIR
				CR	SP	CS	ES	CL	OTHER - NOTES	LC	PW	CC	ED	M	AA	OTHER - NOTES		
60	Turf hopper	4	moderate		x											fire damage	gunite - very satisfactory	
61	School, Dublin	40 to 50	mild	x		x			moderate to severe, excessive water/damp penetration							slight settlement, corrosion of embedded steel beams, lack of reinforcement, lack of bond between plaster and concrete	(i) mechanical stitching of some cracks, stainless steel dowels, (ii) application of external reinforced gunite render.	
62	Pier, Co. Wicklow	104	ext, marine, wave attack					x	cavitation at internal tidal area leading to collapse of deck							horizontal day joints had inadequate resistance to wave attack	shutter face with sacks filled with concrete, fill core with concrete from deck; approximately 5 year life.	
63	Old Hospital Dublin - precast concrete cill and mullions	20	50' above ground level		x	x										porous concrete lead to total carbonation (special 3:1 sand cement dry mix to simulate stone finish)	replacement with ordinary dense aggregate concrete	
64	Shopping centre, Dublin	New	atmospheric		x				at tops of precast columns							freezing of water trapped in steel tube enclosing anchor bolt heads	adhesive mortar	
65	Rail underbridge Co. Kildare	64	ext, exp, rural		x				soffit of main beams							none given	none to date	

TABLE B HONEYCOMBING, POROSITY

	BUILDING	AGE	EXPOSURE	FAILURE	REASONS	REPAIR
1	Ribbed floors (various buildings)		int, covered	serious honeycombing, reinforcement often completely exposed	use of open-textured permanent formwork - concrete did not penetrate far enough to give cover to the main tensile reinforcement in the ribs.	various (The system was discontinued).
2	Offices/Warehouse Dublin	3	atmospheric	high porosity of precast concrete beams and columns, water penetrating through concrete.	not known, presumably lack of proper vibration	water proofing with silicone-based product.
3	Manufacturing facility, Dublin	New	int	honeycombing and large cavities in thick walls containing dense security reinforcement in vault.	pump breakdown resulting in slow pouring and loss of workability in concrete.	cutting out and repouring
4	School, Monaghan	50	int, covered	honeycombed concrete in ribs, exposed reinforcement	inadequate compaction	modified mortar and load test

TABLE C

EROSION, ABRASION

	BUILDING	AGE	EXPOSURE	FAILURE	REASONS	REPAIR
1	Ferry Terminal			Concrete erosion has been very swift.	?	
2	Factories, Co. Limerick	4-10	acidic effluent	concrete drainage damaged by corrosion of concrete	attack of concrete by aggressive effluent resulting from failure to pretreat effluent	polyester linings drawn in.
3	Factory floors, Dublin, Athlone	2	mild	dusting	incorrect w/c ratio. poor preparation.	etching and epoxy resin mortar, (satisfactory); scabbling and epoxy resin mortar (satisfactory but far costlier).
4	Rock storage pens	16	severe, ext, exposed to water spray	undercutting of wall by JCB.	inadequate surface resistance to abrasion and impact.	demolish and rebuild
5	Industrial floor slabs	5-	int, covered	severe abrasion	low strength concrete and poor finishing	replacement of bays

TABLE D DISINTEGRATION

	BUILDING	AGE	EXPOSURE	FAILURE	REASONS	REPAIR
1	House, N. Ireland	6-		crumbling of yellow sand cement bricks	it appeared that once the manufacturer went beyond his very restricted colour range, he found difficulty in matching different batches in colour, strength, etc.	numerous loads of bricks were returned or replaced
2	Concrete drainage pipes, 2'dia.		Peaty ground	Inverts eaten away quickly.	acid attack from peaty water being carried in pipe.	
3	Commercial building, Co. Dublin	1-		roof concrete showed considerable segregation and lack of compaction, pieces of coarse aggregate could easily be removed in places from soffit, also reinforcement was exposed in places on soffit; considerable moisture penetration occurred through roof after rain.		roof slab was rejected as it was doubtful if satisfactory repairs could be carried out in order to make it durable and its demolition and replacement was recommended.
4	Cold stores, silage apron floors, pavements, kerbs, driveways, house sub-floors		exposed to freezing temperatures	frost damage, sometimes concrete reverted completely to gravel	frost, freeze-thaw cycle (in cold stores).	screeding compounds, after cleaning
5	Bunker silo - floor slab, Co. Tipperary	20	ext, silage effluent	surface deterioration followed by internal deterioration and potholes	acidity of silage effluent (pH = 4 to 4.2) and the fact that the surface gradients were too small (required 1 in 40)	patching - short term, slab replaced in 1982.

TABLE D (Contd.)

	BUILDING	AGE	EXPOSURE	FAILURE	REASONS	REPAIR
6	Concrete storage tank for whey	11	ext, rural	surface deterioration followed by internal deterioration.	acidic nature of whey	not practical, lining of such tank is recommended
7	Industrial floor slab	3	chamber on slab with high temperature and humidity in it.	failure of coarse aggregate - the concrete i.e. the matrix remained intact but coarse aggregate disintegrated to a depth of approx. 40mm.	unsuitable aggregate for this particular use (although complying with Irish and British requirements); aggregate contained minute lenses which swelled with the high temperature and humidity.	replacement.
8.	Blockwork rising walls to house foundations	5-10	wet ground	disintegration of blockwork resulting in major cracks in house walls, (blocks complied with IS 20)	(i) unsuitable aggregate (mudstone) used in blocks. (ii) aggregate o.k. but a flow of slightly acidic water existed at some times of the year.	not known
9.	P.C. kerbs (meeting I.S. and B.S. requirements)	5-	urban, coastal	severe spalling leading to disintegration of concrete	lack of freeze-thaw resistance - wet casting system.	replacement

TABLE E

VISUAL DISFIGUREMENT

	BUILDING	AGE	EXPOSURE	FAILURE	REASONS	REPAIR
1	Stores, Dublin	17	urban	bush hammered exposed concrete has suffered from atmospheric pollution This has caused disfiguring streams over the dark brickwork under	severe pollution and unsuitable finish	none
2	College building	14	ext, exp, coastal.	primarily visual, - weatherstaining, algae growth, (white cement, granite aggregate, bush-hammered finish)	poor detailing of roof trims, fine grade of surface finish - silicone coating provided short term protection.	sand blasting and application of clear surface coating.
3	Water tower,	44	ext, exp, rural	leakage through horizontal construction joints	defective workmanship and waterbar	cut back joints internally and seal with chemical compound and mortar.
4	Underpasses, Midlands			weatherstaining		
5	P.C. frames			rust marks	lack of cover	rust marks were not of a serious nature.
6	R.C. structure Rathlin West, Co. Antrim	70	ext, exp, marine	green discoloration of external surfaces	presumably an algal growth	none, will probably be considered in the near future.

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TABLE F POTENTIAL FAULTURE

	BUILDING	AGE	EXPOSURE	FAILURE	REASONS	REPAIR
1	House foundations, (several throughout the country)	new	normal, rural/urban	concern expressed by designer as to longterm durability of concrete particularly if footing was reinforced	poor quality concrete, obvious by visual examinations and confirmed by core testing	replacement or over-slabbing of strip footing with new foundation
2	Educational building (r.c. columns)	new	int, covered, rural	inadequate cover to reinforcement determined by test, concern expressed as to fire resistance and durability	poor workmanship	demolished and rebuilt

TABLE G USE OF HIGH ALUMINA CEMENT (HAC)

	BUILDING	AGE	EXPOSURE	FAILURE	REASONS	REPAIR
1	Floors in buildings		int	?	problems due to bad workmanship, (not to HAC).	load test - o.k.
2	Plantroom		int, condensation	no problems, despite serious condensation		
3	Floors in buildings, Dublin			no information regarding any		
4	College building (HAC + broken brick)			no information regarding any.		
5	PC floor slabs, varied form swimming pools to public utility building	10-22		no structural failure. (fully converted strength well in excess of 20N/mm ²)		stiffening and in one case replacement of an entire floor in an office block with in-situ R.C.

TABLE H ROADS AND PAVEMENTS

	BUILDING	AGE	EXPOSURE	FAILURE	REASONS	REPAIR
1	Distributor roads, Dublin	10	ext, urban, mix not known	(a) lateral cracking of panel at at 1/3 points (b) corner cracking	(a) panels inadequately reinforced (b) no dowels across joints and inadequate seal at joints.	removed and replace.
2	Bray, Co. Wicklow	40-50	unreinforced and sandwich type 175-120mm mix 6:1	failure	as a result of heavy axle loads for which they were not intended.	some have been overlaid recently with 40-50 bituminous macadam
3	Sligo	40		slab broken up progressively with time	traffic	
4	Co. Clare	20		failure	poor foundations and inadequate sealing of concrete joints	
5	Co. Kildare	20 (?)	main road	worrying signs of failure	being investigated, weakness appears to be in foundation or sub-base.	will need attention shortly.
6	Co. Kildare		regional road, on a bog rampart	indications of serious failure	peat foundation and sub conditions are extremely poor.	overlaid by bituminous materials over the years. Investigations re-initiated.
7	Airport runway	30	mix not known, rural exposure	(i) surface spalling (ii) joint edge failure	(i) aggregate (ii) poor detail at joints	epoxy - unsuccessful, slurry sealing - overlay of 3mm bituminous mix still being evaluated.

TABLE H (Contd.)

	BUILDING	AGE	EXPOSURE	FAILURE	REASONS	REPAIR
8	Airport pavements	37 and less	mass concrete 525 lb cement/ yd ³ of concrete, no additives; aircraft parking; in winter de-icing or anti-icing agents; also jet blast and fuel spillage	primarily structural resulting in cracked slabs; at times, some spalling of joints also occurred as well as fractures of corners of slab	basically overloading with modern aircraft; main structural weakness of the older pavements is the absence of a sub-base course.	break out and reconstruct in stronger concrete including a lean concrete sub-base (quite successful); temporary repairs using "off the shelf" materials occasionally
9	Roads, farm lanes in Northern Ireland	6-7	1:2:4 + air entraining agent, rural	spalling - surface deterioration; potholes, cracking, discoloration	frost	replacement, using air entraining agent.
10	Roads in housing and industrial estate, Dublin city and county	1 mth to 5 yrs	generally 30N/20 or 40N/20	(i) plastic cracking (ii) shrinkage cracking (iii) breaking off of corners	(i) inadequate curing (ii) poor design in relation to joints (iii) poor workmanship in relation to compaction of sub-base and construction of joints	replacement of bays and filling of cracks.

2. SOME OBSERVATIONS ON THE DURABILITY FAILURES

The average of all concrete listed in the tables and for which an age was given is approximately 26 years, the ages ranging from one month to 104 years. The total number of cases listed is a little over 100, a quite small number out of all the concrete buildings, bridges, roads, precast units, concrete blocks, etc. that exist in the country. It is useful to bear these points in mind when considering the seriousness of failures. It is very difficult to generalise from the results given because of the variety of building types, ages, exposures and types of failures. However, a pattern is observable and is worthy of note.

2.1 A-Tables (Cracking, spalling, and reinforcement corrosion)

Cracking in concrete structures does not always worry engineers—the nature of reinforced concrete is such that cracking in tensile zones must occur. However, if spalling of concrete occurs, one begins to worry, especially, if the spalling coincides with reinforcement positions. All of the tables in the A-group reflect this concern—the entries under spalling (SP) as a mode of failure are much more frequent than those under cracking (CR). Many of these entries are followed also by evidence of corrosion of steel (CS) and some also, by exposure of steel (ES). There is the odd case of collapse (CL). Over a third of all the failures listed in the A-tables (23 out of 65) gave the primary cause of failure as inadequate cover to reinforcement (Table A1) and the same reason was noted as a contributory cause in several of the other A-tables. Failure in this category occurred in concrete of average age 30 years—four more than the overall average of all concrete listed but with the same range of ages. This difference is probably insignificant. However, in those failures attributed primarily to calcium chloride (Table A3), the average age of the structures was only 13 years. On the other hand, where defective materials were suggested as the principal cause of failure (Table A5), the average age was 46 years.

In the last decade or so, engineers have become more aware of the potential damage that calcium chloride, from whatever source, can cause to reinforcement and have therefore been more alert to this as a cause for spalling, especially on recent buildings. Calcium chloride has been used for a long time as an admixture to concrete in order to promote more rapid setting, especially in cold weather, although its use in Ireland for normal in-situ work was probably not widespread. The dangers of excessive amounts of chloride have also been known for a long time. Research to-day, however, is showing us that smaller percentages of calcium chloride than believed heretofore may cause corrosion of reinforcement.

There is probably a lesson to be learnt from each individual case of failure, but the overall picture would appear to be that low or inadequate cover (LC) is either a primary or a secondary reason for failure in over half the cases recorded. Poor workmanship (PW), a primary cause of cracking in six cases (Table A2), could also include inadequate cover as a form of careless workmanship.

It should be noted that nearly all the concrete affected by cracking, spalling and reinforcement corrosion, is external, often in urban, suburban, coastal or marine conditions. Thus, the environment in these cases is, in varying degrees, aggressive.

2.2 Table B (Honeycombing, porosity)

This table lists four sets of structures where failure was in the form of honeycombing or porosity. In these structures, there was no reference to cracking or spalling in association with the honeycombing, although porosity of concrete was a contributory factor in some cases of cracking listed in the A-tables. Of particular interest in this table is No. 1, listed simply as "ribbed floors in various buildings". Serious honeycombing was reported with the reinforcement often exposed completely. An open-textured type of permanent framework was apparently used to shutter the ribs and, being permanent, the ribs were not seen until, for whatever reason, sections of the formwork were removed, revealing the honeycombed concrete. This particular system of formwork has not been used in recent times.

2.3 Table C (Erosion, abrasion)

This table gives some examples of erosion of concrete and associated problems. The examples are significant by virtue of the ages of the concrete — an average of $7\frac{1}{2}$ years. In regard to the failures in Limerick factories, aggressive effluent was suggested as the cause, in other cases, the concrete was inadequate for its purpose in some way.

2.4 Table D (Disintegration)

Some examples of disintegration are presented. Frost action and acid attack feature largely in these, although acid attack is also given as a cause in some cases of cracking in Table A6. The average age of the concrete is about $7\frac{1}{2}$ years—a significant factor in itself. Although No. 1 (House in Northern Ireland) is strictly speaking not concrete in the normal sense, it was included because of its unusualness, namely, crumbling of yellow sand cement bricks. Of interest also, and probably of rare occurrence, was No. 8, where disintegration of blockwork occurred due to an unsuitable aggregate (mudstone) being used in the blocks in one case and presence of acidic water around the blockwork in another case. Frost damage in some cases led to complete reversal of concrete to gravel (No. 4). No. 7 was a case of aggregate disintegration but leaving the concrete matrix quite intact.

2.5 Table E (Visual disfigurement)

This table gives some cases of visual disfigurement to concrete surfaces. The number of buildings and amount of information supplied is inadequate to enable conclusions to be drawn. Nevertheless one should note the combination of disfigurement and adverse environment in numbers 1, 2 and 6 (severe pollution, coastal and marine environment respectively). The first two of these featured bush-hammered concrete on buildings less than 20 years old, the third building, 70 years old, had turned green in its marine environment. In this last

example, the reason had not been diagnosed but an algal growth was suggested as a possible cause.

2.6 Table F (Potential failures)

Although recorded as failures, these cases were not strictly speaking so. In the two listed, the concrete was deemed to have been sufficiently unsatisfactory to be discarded before any defects could arise.

2.7 Table G (Use of high alumina cement)

Not many cases of buildings in which high alumina cement had been used were reported, and none of them had any failures attributable to the use of HAC. In building No. 1 the floors were load tested and found to be satisfactory. In No. 5, which encompassed several buildings, although there were no failures, one floor was replaced and others stiffened, presumably in anticipation of possible future weakening of the concrete—a characteristic of HAC concrete. The comments of one engineer are interesting in this respect. According to him, the misuse of HAC had given the material a bad name, but, if used in accordance with the manufacturer's instructions, it should be satisfactory. He added, however, that it was right to ban the material since it could lead to sudden collapse without warning when improperly used.

2.8 Table H (Roads and pavements)

The failures of roads and pavements appear to be related mainly to overloading by modern heavy traffic for which the slabs were not intended originally and to unsatisfactory joint practice, e.g. inadequate dowelling and sealing. However, the foundation and sub-base were also mentioned as problem areas.

3. DURABLE BUILDINGS

In the previous section we have seen how concrete, in some cases, has failed to live up to its reputation as a material that will last a long time. In this section, to redress the balance, we will look at some examples of concrete that has endured well. In the questionnaire, there was a section entitled "Durable Buildings" and the following list, with notes, is based on information supplied under this heading. To broaden the picture a little more, I have added to this list those buildings over about fifty years old which were listed in the tables of failures as having suffered some form of deterioration but which are still in use. These are given in brackets and reference may be made to the tables of failures for further information regarding them. The buildings are listed in order of age, from the newest to the oldest. There are, of course, many other concrete structures besides those listed below and readers are referred to the paper given in the 1965 Symposium by J. W. de Courcy on "The Durability of Structural Concrete including Roads" (3) for further examples of durable concrete structures.

1. 1981 Ballagh Rocks Landing, Co. Donegal. Although only three years old, this island structure is an interesting one in several ways, including durability. Owing to the

- distance from the nearest accessible mainland being approximately 5 km, the landing, consisting of 49 cubic metres of concrete, was constructed using an inner fast core of 26 cubic metres consisting of blockwork, 40 gallon drums filled with seawater and site mixed concrete using seawater. The outer face of the structure used ready mixed concrete 25N to minimum thickness of 230 mm, airlifted by helicopter.
2. 1972 Memorial to our Lady, Bull Wall, Dublin. Precast prestressed concrete units. There is no cracking due to prestress therefore there is no water penetration and no rusting in this very exposed location.
 3. 1967-72 Caissons at South Bank Quay, Dublin. Medium and deep berth. To-date in good condition.
 4. 1986 Caissons constructed for Ro/Ro terminal, Dublin. Also including bridge slabs. Are in good condition.
 5. 1954 Grain silo, Enniscorthy. As far as the consultants know, this is in good condition. (See next item).
 6. 1952 Grain silo, Dublin. Designed by Mr. T. J. S. Mallagh for the North City Milling Company. When inspected in 1982 the external faces of the bins were in perfect condition. The durable material in these instances (i.e. Dublin and Enniscorthy 1954) is gunite which is rather different to ordinary in-situ concrete.
 7. 1952 Bridges at Convoy and Gweebarra Bay, Co. Donegal. Both bridges are generally in good condition, only signs of age are weathering and discoloring. Gweebarra Bridge is coastal and does show a few signs of reinforcement corrosion by rust spots on concrete but not to any great extent.
 8. 1949-54 No. 2 graving dock, Dublin. In good condition.
 9. 1950 National Board and Paper Mills, Waterford—jetty on R. Suir. The reinforced concrete deck is in very good condition.
 10. 1945 Pavement at Dublin Airport. One of the original concrete pavements that was not overlaid with asphalt is still in good condition. It is little used now.
 11. 1941 Old Terminal Building, Dublin Airport. Although altered many times it has endured well with virtually no repair necessary.
 12. 1940 Batchelor's Building, Sligo. In quite good repair, no signs of any major repairs.
 13. 1936 Silo, Dublin. (See A24).
 14. 1936 Water tower, Elphin, Co. Roscommon. In use and in perfect condition (as in 1965).
 15. 1935 Water tower, Strokestown, Co. Roscommon. In use and in perfect condition (as in 1965).
 16. 1935 Water tower. (See A14).

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17. 1935 King's Hall, Belfast. Has shown excellent durability.
18. 1935 Sports ground Stand, Dublin. (See A47).
19. c1935 Carlton Cinema, Dublin.
20. ?1934 (probably earlier), Dept. of Agriculture Building, off Baggot St., Dublin. A small 3 storey block constructed at least 50 years ago, a gem of early design. Some of the columns have spalled but were easily repaired, but, in general, the building "seemed sound to me and I was impressed at the economy of size of the members, even by present day standards".
21. mid 30's Bridge, Co. Roscommon. (See A15).
22. c1934 Piers, Co. Cork. (See A48).
23. 1933 Kenmare Bridge, Co. Kerry. No repairs observed. Some cracks but condition generally excellent.
24. 1932 Concrete streets and road, Kilkenny. Still in use and performing well. Some mud pumping but not a concern.
25. 1930's School, Monaghan. (See B4).
26. 1930's Roads, Bray, Co. Wicklow. (See H2).
27. 1930 s Engine sheds. (See A4).
28. ?1930's Mass concrete houses, Beech Road, Bray, Co. Wicklow.
29. c1930 Galley Bridge, Co. Roscommon. In use and in perfect condition (as in 1965).
30. 1923-32 Basilica. (See A49).
31. 1929 Extension to Surgical Hospital, Cavan. External walls plastered. No failures apparent.
32. 1928 Silo No. 1, Alexandra Road, Dublin. Some deterioration of decorative parapet. Guniting of exterior carried out in the past, but now removed. Structure very sound. Slight spalling externally. Marine environment at docks.
33. 1928 Football Stand. Now demolished. (See A46).
34. 1927-28 Ardnacrusha Bridges, Co. Clare. No observable deterioration.
35. 1927 Bridge, Co. Clare. Two fixed, one suspended span. (See A16).
36. ?1927 Quays, Co. Louth. Consist of a fairly extensive area of reinforced concrete columns. (See A11).
37. 1925-27 Shannon Hydroelectric Scheme—dams, weirs, bridges, power station. All concrete structures associated with the scheme are, by and large, in excellent condition and have endured the test of time extremely well. We (i.e. E.S.B.) had occasion in 1979 to demolish some of the mass concrete under the fish pass at Parteen Weir and found that it was in extremely good condition with incredible tensile strength and resistance to bursting—we used hydraulic "plug and feather" rock bursters. The mix was anything but homogeneous, containing "plums" up to two foot diameter equivalent.
38. 1920 Rail underbridge, in Co. Kildare. Some minor deter-

- ioration to parapet. Condition excellent. No repairs. (But see also A65).
39. 1916 College Bridge, Cork. The first reinforced concrete bridge in the south of Ireland was constructed in 1910 to the design of James H. Waller. It was rebuilt in 1916 after a collapse due to a river flood. Designed by Waller, H. C. Johnson and Prof. Alexander of U.C.C. and built by BRC. Still in use.
40. 1912 Ferrycarrig Bridge, Wexford. Designed by Mouchel and Partners, London. Reinforced concrete deck supported on precast hollow piles made up of 10" cast iron pipe. Outside diameter of piles 20". Piles varied in length from 30 feet to 80 feet. Bridge now replaced by new bridge but part of old structure is still standing and is used as a fishing and viewing platform.
41. 1910 Arnott & Co. Ltd., Henry St., Dublin. Floor slab using clinker aggregate and diamond mesh reinforcement. No deterioration except where water penetrated external wall and corroded reinforcement causing slab to crack.
42. 1910 John's Bridge, Kilkenny. Still in use. It is a reinforced concrete single arch bridge over the Nore. It was the largest in Great Britain at the time. Designed by Mouchel and constructed by the Yorkshire Hennebique Co. Some trouble with spalling—cover less than 1"—gunited in 1942 or '43. Little trouble since but some spalling in parapet. No works were required since 1965.
43. 1910 King's Bridge, Belfast. Has shown excellent durability.
44. 1910 Locomotive shed, Limerick. (See A58).
45. pre 1910 Lighthouse structures. Most of the concrete water tanks, landings and steps at the lighthouses around the coast are over 75 years old and have endured very well with few repairs necessary except where physically broken away by heavy seas. In the majority of cases the concrete landings were constructed using sea water or slop water collected locally.
46. c1904 Sewer lining, Ringsend, Dublin. Some concrete was broken out recently from the lining of the main cast iron sewer pipe at Ringsend. Appeared to be in good condition.
47. c1900 Sewage settling tanks, Ringsend, Dublin. Mass concrete construction. Still in use and in fairly good condition.
48. c1890 Reservoir, Co. Meath. (See A52).
49. c1880 Pier, Co. Wicklow. (See A62).
50. 1875 St. Vincent's Bridge, Cork. Concrete filled steel caissons.
51. 1874 Footings to old masonry quay walls, Cork.
52. 1861 St. Patrick's Bridge, Cork. Concrete in iron caissons using Ardenne's cement.

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53. ? Old British Forts at Spike Island, Fort Davis, Fort Camden and Bere Island, Co. Cork. Concrete for gun positions. (The forts were primarily coastal defence forts).
54. ? R.C. Wharfs at Fords, Marina, Cork.

4. GENERAL COMMENTS

In the final section of the questionnaire, respondents were asked as follows :

"From your experience, have you any words of wisdom or advice in relation to durability of concrete, to pass on to other engineers involved in designing, manufacturing or erecting concrete structures; are there areas where you think research should be undertaken. What should engineering and architectural graduates know about concrete as a material, etc."

A variety of replies was received. The comments, which came from experienced and practicing engineers in all walks of civil engineering life demonstrated that there is substantial agreement among them on what they regarded as important basic matters.

Table 2 gives in a concise form the contents of the replies. Those matters to which particular attention should be given, according to the respondents, have been grouped under four principal headings—design, materials, workmanship and specification and codes, with various associated subheadings. A fifth column gives extra notes and view points. The respondents, who remain unidentified, are listed simply as A, B, C . . . and the number under the various headings indicate the order in which the comments were listed in the questionnaire. The numbering may not necessarily reflect the order of importance, but the fact that they were mentioned at all is sufficient indication of their relevance in the eyes of the respondents.

If it were possible to extract a concrete practice equivalent of a "best buy" from the list of comments received, then the following three groups would probably emerge, as the most important factors to which attention should be paid :

- (i) cover to reinforcement, attention to design and detailing,
- (ii) adequate compaction, non-use or correct use of additives,
- (iii) mix design, care with aggregates, workmanship.

From the general words of wisdom in relation to durability, I have extracted four comments that may well give food for thought and they are given verbatim :

- (a) essentially, if you want durable concrete, you have to work hard at it,
- (b) lack lustre supervision is worst of all (i.e. of all causes of failure),
- (c) the indications are that present day cement will not gain appreciably in strength with age (as it did formerly). This alteration in such a basic property of cement may have significant effects on durability.
- (d) it is wrong to give clients the impression that concrete is a maintenance free material.

TABLE 2

GENERAL COMMENTS

DESIGN			MATERIALS						WORKMANSHIP		SPECIFICATION, CONTROL						NOTES	
	Design, detailing	Cover	Mix design	w/c ratio	Cement content	Aggregates	Clean reinforcement	Batching, mixing	Workability	Workmanship	Compaction	Curing, Finish	Specification	Codes	Additives	Supervision, Q.C.		Site management
A	5	2			1			4			3							
B		2	3												1			(1) No calcium chloride
C	2				5	4				6					3	1		(3) No additives (4) Proper testing of aggregates
D	1									2								Where concrete fails, the cause is not in the material itself but in the way it has been used or placed. The misuse of High Alumina Cement has given it a bad name. If used in accordance with manufacturers' instructions, it should be alright. However, it was right to ban it. It could lead to sudden collapse without warning when improperly used.
E		1																CP 110 cover is essential for durability. Concrete spacers should be specified at pre-tender stage. Additional cover is vital when exposed aggregate finishes are used.
F	3	1									2							Avoid trapping water in recesses, etc.
G										2	1							It is wrong to give clients the impression that concrete is a maintenance-free material. Cracks were shown (in a particular case) not to have any influence on the ultimate strength of the structure - however, they were a source of concern for the lay person.

TABLE 2

GENERAL COMMENTS

DESIGN			MATERIALS						WORKMANSHIP		SPECIFICATION, CONTROL						NOTES	
Design, detailing	Cover	Mix design	w/c ratio	Cement content	Aggregates	Clean reinforcement	Batching, mixing	Workability	Workmanship	Compaction	Curing, Finish	Specification	Codes	Additives	Supervision, Q.C.	Site management		
H		1															Inadequate cover to the reinforcement is the single factor most likely to cause future problems which will initially be primarily visual but will eventually become a structural problem.	
I			1		2				4	3							Where emphasis is laid on these factors, then a dense strong and durable concrete can be produced. These factors should form an important input into the training of engineering and architectural graduates. I would wish to see construction site visits play a greater part in developing the technical expertise of engineering and architectural students alike.	
J	3										4	2			1		(4) especially in hot weather	
K			1	4	3		2	5		6	7						Where ready mixed concrete is used, special care should be taken to prevent the addition of water to mixer trucks while idling on site. Engineers and site agents need to be constantly on the alert for this practice.	
L			7	3		2 4	11	8	10		6	1			5		9	(2) good quality, hard, clean, graded aggregate (4) sand content reduced to minimum (5) no additives (7) no pumped mix (8) preferably wet batching (9) e.g. no undue delays

TABLE 2

GENERAL COMMENTS (Contd.)

DESIGN		MATERIALS				WORKMANSHIP		SPECIFICATION, CONTROL				NOTES							
		Design, detailing	Cover	Mix design	w/c ratio	Cement content	Aggregates	Clean reinforcement	Batching, mixing	Workability	Workmanship		Compaction	Curing, Finish	Specification	Codes	Additives	Supervision, Q.C.	Site management
M															1				(1) Compliance with relevant Codes is essential
N				1							3					2			(2) Use an additive against frost damage in roads
O	1						3									2			(1) Designer, specifier and precast company should get together (i.e. for precast work) (2) I would ban chloride-based accelerators. (3) In precast concrete, I would recommend Zone 3 sand or if possible Zone 2 as anything finer means that one does not get the proper value from the cement. Works (i.e. precasting works) should be clean, tidy, with proper testing and records. I recommend hydraulically pressed concrete for durability. I would be wary of the modern dry mix mass produced system in our damp climate. An advantage of GRC cladding is that there is no steel reinforcement content and therefore no corrosion and spalling, but strict quality control is nevertheless required. Repairs to concrete can be successfully carried out but only by trained personnel.

TABLE 2 GENERAL COMMENTS (Contd).

	NOTES
P	Essentially, if you want durable concrete, you have to work at it. Ninety nine times out of a hundred, a well designed mix without additives, will perform satisfactorily - provided the contractor follows the recipe. Regarding additives generally, there are perhaps a few nowadays which could be worth using, espically for water-retaining structures. However, even with this type of structure, it would perhaps be more economical to provide an asphalt or similar lining and normal reinforced concrete as opposed to designing (hopefully) on the basis of the water retaining code.
Q	Repair work is an area where there seems to be considerable controversy and several of the specialist firms in the U.K. offering repair systems differ substantially in their techniques.
R	A sub-base (under pavements) protects the subgrade, assists in the load transfer at joints and controls mud pumping. It does not significantly add to the total strength of the pavement.
S	Frost damage is a major problem on farm work and do-it-yourself work and is thus not often noticed by engineers. Use of air entrainers would prevent the problem. Further advice and supervision by grant authorities is suggested.
T	Suitable gradients are essential (for floors and aprons of silage tanks). A revised standard on cattle slats is suggested.
U	Is there a place for epoxy resin coating of bars?
V	It is my experience that the majority of problems in relation to concrete construction relate to lack of durability and cracking due to restrained shrinkage rather than failure in conventional structural design. Poor quality concrete and lack of adequate cover have been found to be responsible for most cases of deterioration. My concept of durability is based on a belief that the strength of the material would continue to increase for a number of years after pouring. Some work by the Institution for Industrial Research and Standards in 1975 showed that a nominal 30 N/mm² mix increased in strength by over 50% after two years. The indications are that present day cement will not gain appreciably in strength with age. This alteration in such a basic property of cement may have significant effects on durability.
W	Most of the problems concerning deterioration of concrete buildings in Northern Ireland have been on concrete which is less than 30 years old - the older concrete appears to have been more durable or alternatively so little was used then that the number of problems which have arisen are limited.

5. CONCLUSION

This survey represents the results of 34% of all questionnaires sent out. It would be unwise, and unrealistic, to extrapolate from these results. The picture it gives of the state of concrete in Ireland would probably not alter greatly if all questionnaires were returned—some of those who responded even said there was, happily, nothing in their experience to report. However, there are some areas where very little or no information came to light on concrete deterioration. For example, concrete is used fairly extensively in farm buildings, dairies, sewage works, swimming pools and constructions in peaty ground all over the country. The environment surrounding these structures is not exactly ideal for concrete. Yet not many instances of deterioration were reported as occurring in these situations. No cases of alkali-aggregate reaction were diagnosed in any of the failures recorded. Biological attack (e.g. attack by organisms such as lichens, algae, fungi, bacteria, etc.) is not mentioned although two cases of algal growth were noted. Since 1965 when J. W. de Courcy wrote his paper on durability (3), some developments have taken place in the concrete scene. The saga of high alumina cement has been in the headlines abroad but the material was not widely used in Ireland. Alkali-aggregate reaction, although not new and not widespread, has been in the news for some time in a few countries. The quality of the environment has changed in the last twenty years. The reported increase in carbon dioxide levels, the pollution of the atmosphere from increasing fuel consumption, traffic, and industrial process, will continue to effect concrete and other building materials. Carbonation—the chemical effect of atmospheric carbon dioxide gas on concrete—has always been here, but it is only now beginning to receive the attention it deserves. It is being seen more and more as an important factor in the durability of reinforced concrete. Research into carbonation and into the corrosion of reinforcement is at present being undertaken in University College, Dublin. Related to both carbonation and reinforcement corrosion is another property of concrete that is receiving close attention, namely permeability. In Queen's University, Belfast, research is under way into methods of measurement of concrete permeability. Admixtures are receiving more attention and study. Their quantities in a concrete mix may be quite small but the effects of their use, for better or for worse, are far from insignificant. The consequences of poor or careless workmanship are evident in this paper. In this regard it is of interest to note that An Chomhairle Oiliúna (AnCO) has twice run a course for workers in concrete over the last two years in Dublin. The aim of the course is to help improve the knowledge and skills of those who handle concrete in the construction industry. In 1984, the course lasted four weeks and covered such topics as proportioning, mixing and placing of concrete, use of pumps, tampers and vibrators, finishing, curing and floating, reinforcement cutting, bending and fixing. Such a course is welcome and one wishes it success in the future. Engineers, by and large, understand the importance of good design and good

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detailing. Yet a moment's carelessness by any one of a whole team of designers, detailers, concrete manufacturers and construction workers could put the safety or service life of a building element at risk maybe long before the potential life of the material has been reached.

In conclusion, an examination of the recorded failures received and reasons given and comments made reveals that nowhere is there any condemnation of either concrete or reinforced concrete as a suitable structural material for buildings. With due care and proper attention, at all stages from design to execution, there is every reason to believe that the composite material that is called reinforced concrete will endure for a long time.

6. ACKNOWLEDGEMENTS

I would like to acknowledge, very gratefully, all those who took the time and trouble to fill in the questionnaires and return them to me. This paper would have been impossible to write without such help. If the courageous baring of the collective engineering breast at this symposium results in a raising of the quality of design and construction of concrete structures, then the respondents to the questionnaire may take full credit for it. I would also like to thank Professor de Courcy, organiser of the Symposium, for the privilege of being asked to present this paper.

APPENDIX

Copy of letter, explanatory note and questionnaire

27 July, 1984

Dear

I am preparing a paper on "The Durability of Concrete—Integrity and Appearance" at the invitation of the organisers, to be presented at the Symposium in Dublin next March on "Concrete Practice in Ireland 1985".

At a similar symposium in 1965 Mr. John de Courcy presented a paper on "The Durability of Structural Concrete including Roads" and my intention would be to try and fill in the intervening 20 years or so and bring the state of the art on concrete durability in Ireland up to date.

To help me with this, I would be obliged if you filled in the attached questionnaire in so far as you think fit and in as much detail as you deem to be appropriate. I recognise of course that it is frequently not possible to be precise about the reasons for a lack of durability. Clearly a general comment would be appropriate and this would be of very much more value than no comment at all.

Please feel free to photocopy the questionnaire if you need further space or if you wish, you may add supplementary notes on ordinary paper. I would like to emphasise that the purpose of the paper is to collect information on concrete durability—its successes as well as its failures. All cases discussed in the published paper or in the subsequent introduction to the paper at the symposium will of course be without identification of location. In this regard, the returned questionnaires will be treated confidentially throughout.

If you have any photographs or slides that might be of interest at the presentation, perhaps you might be good enough to let me have a loan of them. With your permission, I would like to have them copied here in the College before returning them to you, as was done at the 1975 Symposium.

I would appreciate receiving a reply before Monday 10th September at the above address. I shall be away on holidays for the month of August but if you want to get in touch with me before or after then, I shall be glad to give you any assistance that I can.

I thank you in anticipation for your assistance.

Yours sincerely,

Seoirse Mac Craith.

CONCRETE PRACTICE IN IRELAND 1985 — SEMINAR QUESTIONNAIRE ON DURABILITY OF CONCRETE

If you are aware of any concrete in buildings or in roads which has been repaired or replaced in the last twenty years or so, please give information for each case separately under the following main headings insofar as information is available or relevant.

- | | | | | | | | | | | | | | | | |
|--------------------|---|------------------|-------|------------------|----------|------------------|-------|--------------------|------------|------------------|---------|--|---------|--|--|
| Building | (or structure, road, bridge, etc.) with address, brief general description and year built. | | | | | | | | | | | | | | |
| Age | i.e. age of concrete approximately at time of repair. | | | | | | | | | | | | | | |
| Mix | i.e. details of mix ingredients, including additives, if known. | | | | | | | | | | | | | | |
| Exposure | <table border="0"> <tr> <td>internal exposed</td> <td>rural</td> </tr> <tr> <td>internal covered</td> <td>suburban</td> </tr> <tr> <td>external exposed</td> <td>urban</td> </tr> <tr> <td>external sheltered</td> <td>industrial</td> </tr> <tr> <td>external covered</td> <td>aqueous</td> </tr> <tr> <td></td> <td>coastal</td> </tr> <tr> <td></td> <td>marine (i.e. exposed to sea water or sea spray).</td> </tr> </table> | internal exposed | rural | internal covered | suburban | external exposed | urban | external sheltered | industrial | external covered | aqueous | | coastal | | marine (i.e. exposed to sea water or sea spray). |
| internal exposed | rural | | | | | | | | | | | | | | |
| internal covered | suburban | | | | | | | | | | | | | | |
| external exposed | urban | | | | | | | | | | | | | | |
| external sheltered | industrial | | | | | | | | | | | | | | |
| external covered | aqueous | | | | | | | | | | | | | | |
| | coastal | | | | | | | | | | | | | | |
| | marine (i.e. exposed to sea water or sea spray). | | | | | | | | | | | | | | |
| Failure | <p>What was the nature of the failure that necessitated repair work, e.g.</p> <p>primarily structural : type of element, cracking, spalling, surface deterioration, internal deterioration, reinforcement corrosion, excessive deflection collapse, curling of slabs, potholes, accidental impact, etc.</p> <p>primarily visual : cracking, crazing, weatherstaining, discoloration, mould growth, water leakage, etc.</p> | | | | | | | | | | | | | | |
| Reason | <p>Can you suggest any particular reason for the failure, e.g.</p> <p>mix proportions, wrong or excessive additive, defective materials, defective workmanship, inadequate reinforcement, congested reinforcement, inadequate cover, overloading, foundation settlement, unsatisfactory joint design, frost, groundwater attack, corrosive atmosphere, poor detailing (e.g. in relation to climatic factors), building movement, etc.</p> | | | | | | | | | | | | | | |
| Repair | Give details of the type of repair carried out and an idea as to how successful it was. | | | | | | | | | | | | | | |
| Durable Buildings | Give examples, from your own area or sphere of activity, of old concrete buildings (say over 50 years old) which have endured well with little or no repair. | | | | | | | | | | | | | | |

General
Comments

From your experience, have you any words of wisdom or advice in relation to durability of concrete, to pass on to other engineers involved in designing, manufacturing or erecting concrete structures; are there areas where you think research should be undertaken? What should engineering and architectural graduates know about concrete as a material, etc.?

CONCRETE PRACTICE IN IRELAND 1985 — SYMPOSIUM QUESTIONNAIRE ON THE DURABILITY OF CONCRETE

Questionnaire filled in by :

Date :

Address :

Page :

Heading	COMMENTS
1. BUILDING	
2. AGE	
3. MIX	
4. EXPOSURE	
5. FAILURE	
6. REASON	
7. REPAIR	
8. DURABLE BUILDINGS	
9. GENERAL COMMENTS	

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Discussion

MR. Mac CRAITH introduced his paper.

The popular saying that "nobody is perfect" could be applied not only to ourselves but to the buildings that we had made. The best and most carefully built structures, from concrete blocks to dams would sooner or later succumb to the physical and chemical laws of nature and revert to some more stable, though useless, form such as a heap of rubble. As Professor Hanrahan had pointed out, concrete was a most complex material with an extremely complicated mechanism for deterioration. The paper in this Session was the first on durability in this series of symposia since that given by Sean de Courcy in 1965. It had set out to show the state of concrete in Ireland in 1985 in the context of durability. A questionnaire had been issued to two hundred engineers all over Ireland and the paper was based on the sixty-five comprehensive replies received. He was grateful to all who had replied for their patience and for their co-operation in providing slides and photographs and in allowing him to visit and photograph their buildings. His paper would be found to include, from the questionnaires, firstly the opinions of those concerned as to why certain failures in durability occurred, and secondly a list of "durable" buildings from four to over a hundred years old.

Mr. MacCraith suggested that deterioration could occur in three modes, physical, chemical and visual. Under the heading of physical deterioration he would list erosion by abrasion or otherwise, cracking and frost action. Under the heading of chemical deterioration, one would note the electro-chemical corrosion of reinforcement, acid attack of concrete, whether by leakage, spillage, air-borne water/gas solutions, sulphate-bearing groundwater, alkali attack by highly concentrated alkaline solution, the influence of carbonation on reinforcement, chloride contamination and its effect on reinforcement, and stress corrosion of reinforcement. Under the heading of visual deterioration, where indeed the problem was one of disfiguration rather than actual

material deterioration, the main factor was the effect of weather on the concrete in its environment, and there was little doubt about the complex inter-relationship of the shape and texture of a building with both its macro-climate and its micro-climate.

Mr. Mac Craith then showed 66 slides of concrete buildings, which illustrated various types of deterioration, examples of weathering, and also some "durable" buildings that had endured the test of time. The views included

- a water tower 40 to 50 years old, showing spalling and exposed reinforcement;
- a school, less than twenty years old, with the pattern of the binders, or the binders themselves, visible on beam surfaces;
- a seaside building showing the influence of a marine environment on corrosion;
- the Mizen Head footbridge, now seventy-five years old, prepared for repair work (now repaired and repainted but with a few rust spots remaining). The cover specified for the reinforcement in this bridge in an exposed marine environment was approximately 16 mm;
- main bars almost completely exposed in the ribs of a floor slab cast in situ in the 1960's using a highly water-absorbent permanent formwork;
- a precast floor in a farm structure, which had cracked;
- the influence of silage on the walls of a concrete silage tank;
- a cooling tower about forty years old in which concrete was spalling from the exterior surfaces;
- a building in which one could observe the laminations in the rusting reinforcement in window sills and the "necking" of reinforcement as a stage in corrosion;
- very narrow concrete ribs where clearly the maintenance of adequate cover for contained reinforcement was impracticable;
- the surface of a stairway near the sea which had been eroded by sand and gravel moving over it with rising and falling tides;
- two examples of discoloration by algal growth, including a quite old structure on Rathlin Island that illustrated also a variation in staining which was attributable to the orientation of the surfaces concerned;
- a durable memorial structure on the Bull Wall, in dense pre-stressed concrete in a very difficult environment;
- the Ctesiphon grain store in Kilbeggan, another durable structure built in the early 1950's, showing some slight cracking but clearly adequate as a grain store;
- another similar structure, built with gunite in the early 1950's in Cork, and in good condition;
- the cross on Bray Head, now about thirty-five years old, and in good condition despite its exposed environment;
- the old East Stand at Lansdowne Road before its demolition, showing some spalling but it was then over fifty years old;
- one of the Ardnacrusha head race bridges about fifty years old

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- which had suffered from some spalling but was being maintained by resurfacing;
- a major building in Waterford, about sixty-five years old, in very good condition;
- an ice house in Cork having a mass concrete arched roof of 6 m span that had already been very many years out of service in 1940;
- mass concrete settling tanks at Ringsend, some eighty years old and in reasonably good condition;
- a reinforced concrete bridge at University College, Cork, dating from 1920;
- concrete at the edge of the river Lee in Cork dating from the 1870's, the earliest concrete known to the author.

Mr. MacCraith concluded by reminding his audience that what they had seen were, as in a visit to a hospital, some examples of a small minority of ailing structures in a world full of fairly healthy concrete buildings; and that just as it behoved us mortals to keep healthy and get good value from a good life span, so was it sensible to get good value from our concrete buildings by understanding our materials and by designing and constructing our buildings in accordance with well established principles of good engineering practice.

MR. J. GWYNN opened the discussion.

Engineering had developed from two streams, an understanding of materials and an ability to analyse structural behaviour. We tended nowadays to emphasize analysis at the expense of materials, but nevertheless admired engineers of the past for being able to achieve so much with limited analysis. He had been impressed by a tower in Ulm, brought to 104 metres high in 1460, and extended to 162 metres in 1880. The project gave evidence of a fine understanding of material, and he wondered who today would have the courage to repeat it. Again, who was there today who would build the Roman aqueduct in Segovia, 818 metres long and 56 metres high, consisting of two storeys of masonry arches? The durability of these structures showed the knowledge of masonry possessed by their builders. One did of course recognise that masonry was not always durable, that there had for instance been failures of masonry in Dublin due either to decay or to the use of ferrous metal cramps and dowels. Our knowledge of materials now was mostly second-hand or third-hand. Since the inception of Standards and Codes of Practice a revolution had taken place whereby our knowledge of materials was gained from reading the work of others. At worst we substituted obedience to code of practice rules for knowledge of materials. This was not meant as criticism of the development of standards and codes. The way in which design and materials were standardised now was a great blessing, and it was impossible to think of the construction industry of today without these developments. However, the advantages that these had brought were to some extent offset by the distancing of designers from materials which the convenience of standards had caused. As well as this, compliance with

standards was built into the regulations which controlled building development, and this strongly influenced the designer to know the standards and codes rather than the materials themselves.

Another factor which should not be ignored was the development of standards. It was always difficult to accept a new standard which revised substantially the requirements of the old. Many of his audience would remember the development of the shear stresses permitted by the old concrete code of practice BSCP 114, and the almost dramatic revision of the new provisions as a result of some failures and subsequent research. He remembered the introduction of the present code with some embarrassment; it had happened at a time when his firm had just completed the details of an elaborate steel bell tower for a church in Northern Ireland. When they studied the new code, it became obvious that the design which satisfied the previous code was quite inadequate for the new code, and he had to tell the architect that overnight the design had become too weak to be acceptable and that drastic changes had to be made to suit the new wind code. Those two examples served to show that codes and standards at no time represented comprehensive knowledge of any topic; they only presented the best opinion current at the time the standard or code was drafted.

Some of the most important revisions of codes of practice in recent years related to durability. When ready-mixed concrete came into general use, it was claimed to be most advantageous because the precise control of a central mixing plant would allow the mix design to be left in the hands of the specialists, with resulting economy. It was not an exaggeration to say that the recommendations on minimum cement content for durability in BSCP 110 had largely removed any such advantage. We were now almost back to prescribed mixes, since the minimum cement content almost eliminated any opportunity of economising on cement by skilful mix design.

His reason for dwelling on that aspect of engineering was that this paper had shown all too plainly the limitations of the design method which we now practiced and the method of construction which followed from it. There were several references in the paper to materials which had failed although they complied with the relevant standards. Apart from that, however, most engineers must have met some puzzling troubles when the construction seemed perfectly satisfactory. There were also the equally puzzling cases in which the construction appeared very unsatisfactory, with many design rules broken, in which no trouble had resulted. He imagined most engineers had been in the position of trying to persuade an architect that expansion joints were necessary in a building where they were most unwelcome, with the certain knowledge that many buildings like it had been built in previous years without expansion joints and yet were free of cracks.

He had recently been involved in a long dispute about durability based on Table 19 in BSCP 110. He had, frankly, very little confidence in that table. Without knowing the background research on which it was based, it was difficult to know if it represented reality or whether it expressed recommendations so cautious that the authors could not

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be faulted for rashness—that is, recommendations based on all the worst factors of construction, materials and environment occurring together in every locality. It suggested for exposure classified as mild, that is, completely protected from the weather, the nominal cover should be 25 mm for grade 20 concrete. He was sure that many of his audience had opened up existing buildings during alterations and had seen unpainted steel placed there for some purpose; it was usually slightly rusted. He found it difficult to accept that steel which could survive without any protection at all needed 25 mm of grade 20 concrete, which was quite good concrete, to be considered durable. In the older designs of rib floors, the stirrups always rested on the metal formwork of the ribs, so there was theoretically no cover at all to the ends of the stirrups. He had never seen any defects which suggested that this construction was not durable. And then the table had indicated that, for moderate exposure, no amount of grade 20 concrete was apparently adequate. He could not help wondering about the many reinforced foundations using concrete no better than that which must exist at present. He wondered on what basis strength of concrete was related to durability.

This brought to mind a lecture which had been given in Dublin many years ago by Alan Harris, now Professor Harris, a distinguished British engineer who had sat on several BSI committees. He had told them that he had reminded one committee of the practice of map-makers of previous years, who, when they had an area of their map about which nothing was known, decorated the area with symbols of dragons to indicate their lack of knowledge. He had suggested that BSI could well have an appropriate symbol for the same purpose.

In the earlier sessions the training in concrete practice had been referred to, and in his paper Mr. Mac Craith remarked on the AnCO training courses on concrete. There had been other courses like those in the past, and they deserved our support. It was a reflection on present contract procedures that concreting was not yet a skilled trade, and that the carpenter who made the formwork was required to have greater skill than the concreter on whom, as many of the examples given in the paper showed, many of the factors affecting the durability of work depended. He would much prefer to see concreting as a skilled trade than, as had been suggested elsewhere, making concreting a sub-contract.

Information such as that which the author had collected for this paper was invaluable, because it represented real field experience, and that is why he had been disappointed that only 34% of his information sheets had been returned. Could it be that only 34% of the firms to which he had sent the questionnaire had experienced or observed problems of concrete durability? He rather doubted it. Mr. Mac Craith very charitably observed that the picture would not greatly alter if more questionnaires had been returned. He could not help wondering if the lack of replies might be partly due to the difficulty of deciding if a durability problem had occurred. He could think of several instances in which creep had been excessive, causing large

cracks in blockwork adjoining or supported by the structure. Such defects were hardly classified as failures, but they represented unusual performance of the materials involved, and for that reason perhaps had relevance here. At the start of his paper, Mr. Mac Craith had given some definitions of durability, but none of those indicated the levels of importance involved. For instance, if slight spalling or cracking occurred in places where it was of no structural or architectural significance, was the durability of the building unsatisfactory? Should designers go to any length so as to obviate any possible defect? Surely the notion of factors of safety which designers applied to strength needed also to be applied to durability?

Durability was a sensitive subject, because no-one liked to publicise failures, but studies like the present one brought designers much closer to the knowledge of materials which current practice tended to dispense with. They needed to know much more about the concrete which was made in Ireland, one of our few native products, instead of relying on the work of others elsewhere, which might not even be relevant. They needed more research into matters like this, and because durability defects took some time to appear, it had to be long-term research. He would suggest that this could be taken in hand by the universities or by IIRS with yearly reports. It would be of great interest to hear a proposal of this kind from the organisers of this symposium.

Lastly, Mr. Gwynn referred to the four comments which the author of this paper had extracted from those questionnaires returned to him. They were all very much to the point, but he believed that workmanship was the most important element of durability, so would add a fifth: (e) get a good contractor with an experienced concreting gang.

DR. D. ORR suggested that more attention should be given to problems associated with the detailing, bending, and fixing of reinforcement. Did Mr. Mac Craith feel that some of the deterioration he had described might have arisen from defective workmanship in those areas? It appeared to him important that skilled and trained fixers should always be employed and a high standard of supervision be maintained. The use of the "lump" approach needed to be viewed carefully.

MR. W. MURPHY questioned whether sufficient attention was being given to cover. We had complicated statistical processes for determining probable strengths, but how often did one hear about the rejection of a structure due to lack of cover. He suggested that, generally speaking, inadequate cover was a more serious defect in a structure than a slight deficiency in the strength of the concrete. To arm a clerk of works with a covermeter and authority to make and report on checks on the cover in random parts of completed elements of structure could offer a strong incentive to builders to be more careful. The quality of the concrete concerned, the cover-crete as it was sometimes termed, was of enormous importance to the durability of the structure. Then better attention to curing became very significant, and needed careful specification and enforcement. Why was it

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that in establishing covers, so vital to durability, designers did not consider there, as in loading, the concept of a safety factor ?

MR. E. CANNON asked whether Mr. Mac Craith had done any work in assessing the durability of repairs, or for instance the durability of work done with epoxy resin, or polyester resin, or with special repair mortars or gunite. It was fundamental in the assessment of damaged structures to decide whether to repair or to replace. Guidelines in that area would be of interest.

DR. B. MURPHY said, arising out of Mr. Cannon's question, that a senior researcher from the US Environmental Protection Agency had told him recently that research on repair techniques in USA had largely been abandoned, because it had been found that many repair methods were very expensive and even at that the repairs did not always work too well. Consequently, it was now generally accepted that it was cheaper to tear down the building and replace it.

MR. R. T. HOLLOWAY asked Mr. Mac Craith whether he had come across any example in Ireland of a structure containing high alumina cement that had been found defective, or whether it might be that the restrictions imposed on its use in Ireland had been introduced as a result of failures that had occurred elsewhere.

MR. J. McCULLOUGH referred to two wharves he had been asked to examine. They were side by side, of identical design, one built in 1910, the other about 1930. The earlier wharf had few defects, some rust patches and some cracking, but for its age was in remarkably good condition. The later one was in an advanced state of decay and close to collapse. It emerged that the earlier wharf had been designed by a consulting engineer, the covers were generous and the construction had been supervised. The later had been built to the same drawings, but without supervision, with appreciably less cover and indeed without informing the original designer of the reuse of his drawings. The significance of cover could scarcely be better demonstrated.

MR. G. DOUGLAS noted that Mr. Mac Craith had received only five replies relating to buildings containing high alumina cement, a small number in the light of the problems just surfacing at the time of the last Symposium. The Institute for Industrial Research and Standards had identified some 70-80 schools, offices and industrial buildings, mostly in public ownership, but so far their investigations had revealed no structural failure due to HAC. Two firms, one in Dublin and one Cork, had used this cement in the manufacture of prestressed concrete floor beams over a period of 10-15 years and IIRS tests on fully converted beams had shown shear and flexural strengths comfortably in excess of the strengths quoted for the same beams manufactured in Britain.

PROFESSOR de COURCY said that bearing in mind the extra responsibility that the Building Regulations, and particularly a control

system, were going to place on designers, and recognising that litigation was playing an unhappily increasing part in client-designer relationships, the need seemed clear for prior agreements between the various parties concerned as to how long a particular building was required to last. Chapter 9 of BSCP 3, entitled "Durability" had discussed the concept of designed life and satisfactory life some thirty years ago, and it was a topic that should now again be formalized. He wondered whether the Association of Consulting Engineers of Ireland were not the proper body to pursue this.

MR. N. J. O'GORMAN asked Mr. Mac Craith to comment on the impact of air pollution on the carbonation of concrete in buildings in Dublin to-day and on possible measures that could now be taken to protect buildings constructed twenty to thirty years ago with 25 mm cover specified to reinforcement.

MR. T. McCORMACK commenting that the durability of concrete depended in great measure on the placing of the concrete and on the tightness of the shutters, said that this short significant phase of concreting was often sub-let to shuttering contractors. While it was logical that a specialist sub-contractor should develop a high level of expertise in his work, he felt that that had not happened yet. He believed the profession should encourage the development of such expertise, and wondered whether demanding training and trade status for the operatives, and possibly requiring statements of experience before accepting a gang on site, would help.

MR. J. P. COYLE speaking as representative of local authority engineering where there lay a function of maintaining the structures designed and built by others, argued that one of the great lacks in the building industry was the expert supervising engineer. Why, if we recognised consultants for design and contractors for profit, did we not equally recognise the engineer who could extract, from these two aspects of the industry, work of high and durable quality? The symposium should, he felt, project to the industry the urgent requirement in Ireland of the authoritative career supervising engineer to replace the inadequate resident engineers too often encountered nowadays on building sites.

MR. M. TREACY was pleased to see the emphasis being placed on good concreting practice in ensuring durability. Training was essential for good practice. They in AnCO had studied this need and had run a number of pilot courses for operatives, covering topics right across the field from raw materials to concrete finishes, and including the bending and fixing of reinforcement. He believed it essential that this training be continued and urged the industry to take advantage of the availability of the courses.

MR. Mac CRAITH replied to the discussion.

While he agreed on the need for research into durability, it was

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clear that to mount a major programme of research on this particular topic would require a large expansion of personnel at all levels and a considerable financial input. He agreed fully with Dr. Orr and Mr. Murphy about the total importance of accurate steel fixing in the context of the maintenance of cover. He believed Mr. Murphy was right in suggesting that cover did not get all the attention it deserved, but, while he would favour the use of covermeters on site, he felt they could only be an adjunct to more direct supervision. Research into repair methods was to be commended. Nevertheless, recognising the new problems that arose when old concrete and new repair concrete were brought together, and when perhaps it was suggested to renew a facade while not disturbing the structure behind, there was substance in Dr. Murphy's comment that replacement might, in the long run, be preferable to repair.

M. Mac Craith had nothing to add to Mr. Douglas' remarks on HAC. About Professor de Courcy's observations on the concept of the designed life of a building, he had heard him mention that at other times. He questioned who, whether the architect, the consulting engineer, the client, a politician, would take the responsibility of nominating a design life, and even if some one did, how could one design for one period of years rather than another? In reply to Mr. O'Gorman, there was no doubt that current air pollution levels in Dublin were a damaging factor in concrete durability. Some research was in progress on damage from this cause to masonry buildings in Dublin and he would like to see it extended to reinforced concrete and structural steelwork. He could not immediately recommend protective measures for concrete in buildings twenty to thirty years old, but he would refer to guidelines on repair produced recently by the Concrete Society in Britain. Finally he would like to congratulate AnCO and wished them continuing success.

THE CHAIRMAN in his remarks said that in recent years we had all been surprised to realise that it was being found necessary to call the durability of concrete into question. Perhaps this was a factor on which the profession had not enhanced its reputation of factual and logical approach. We enjoyed a high level of skill in mix design and concrete manufacture but it did appear that the essential complementary aspects of concrete placing, cover, and general supervision perhaps did not always get due attention. He agreed strongly with Mr. Gwynn that periodic reports on trends in building failure be given to the industry, and felt that these could usefully draw in part on the information available to the IIRS.

MR. C. KEARNS in a written contribution recalled that Dr. Glynn had given a paper on some of the Irish research in concrete to the 1975 symposium. It would be a valuable contribution to a possible 1995 event to have available for it a review of Irish concrete research in the period 1975-1995, not only in the university and college context but for the whole of Irish industry.

SESSION E

CONCRETE AND THE NATIONAL HOUSING PROGRAMME

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1. INTRODUCTION

Irish housing accounts for 50% of the output of the construction industry and uses over 2×10^6 cubic metres of concrete in components and materials. This includes blocks, bricks, in-situ concrete, precast concrete, mortar and rendering. This state of the art paper looks at concrete practice in Irish housing, at the performance of concrete and at the prospects for the near future.

2. CONCRETE IN HOUSING

Concrete has been a major structural material in Irish housing for only about 50 years. Previously brick and rubble walling of various types was used. In the early days solid concrete walls were formed in handmade timber shutters rising nine inches at a time. Bigger and better shutters were developed but these were largely abandoned when the concrete block making machine came along. Initially big blocks were made by hand on the site and hefty men tossed them around. Early blocks were 18" x 9" x 6" and weighed about 38 kg (85 lbs), later they were reduced to 18" x 9" x 4½" and became much more manageable. Small block yards appeared in widespread locations and the quality of the blocks produced was very variable. The use of reinforced concrete beams over windows and doors came very early and was a largely empirical matter. Precast lintels and sills were first produced as a copy of the earlier stone items which they replaced. Rationalisation of the production of precast blocks, sills and lintels came with the introduction of the Irish standards IS 20 : 1959, IS 81 : 1958 and IS 240 : 1980 respectively but concrete for in-situ work has been subject to the judgement of individual specifiers and has only recently been afforded the possibility of consensus with the introduction of the Irish Building Specification in 1976 (1).

Precast concrete items such as slabs and panels are governed by CP 116 (2) or by CP 110 (3). Housing produced by arranging precast concrete panels produced in a factory has been used for a number of years. It has not gained a large share of the housing market for a number of reasons. Firstly there is the problem of the need for continuity to ensure adequate return on the fixed investment, secondly

there is the problem of the poor public image of prefabricated buildings which is difficult to circumvent even if the particular component or system being offered is completely without fault. There is a problem which requires the attention of the concrete industry. Who will speak for concrete, who will tell the building industry and its clients of the widespread success of precast concrete throughout the world?

Another matter of serious concern is the dominant notion that prefabricated systems must be boring and repetitive and indeed it must be admitted that many of them have been so. Internationally there has been a great investment in the concept of an open system of interchangeable components. An Foras Forbartha has been actively involved in this work and a wide range of publications covering the dimensional characteristics of such systems have been published. Many people throughout the world see this as the means whereby components can be manufactured and offered on the open market, thus it is not necessary to have all parts of a house made specially for each contract and a wide variety of geometric configurations and materials mixes are possible.

House shells formed of no-fines concrete have been successfully completed in Ireland. However, the thermal performance of these shells is such that it is necessary to apply further insulation and this militates against their continued use. Market conditions which might give rise to the further use of no-fines concrete could be expected if the supply of blocklayers becomes scarce or blocklaying costs rise sufficiently.

Foundation work in housing is carried out using concrete in the form of strip footings in general. In appropriate circumstances, various forms of piled solutions or trench fill is used as is vibrocompaction. These have been well developed and will continue to help in difficult ground. Raft foundations are sometimes used and a very helpful guide to their empirical design is included in the Cement and Concrete Association's publication on house foundations (4).

3. QUALITY OF THE HOUSING STOCK

In 1971, 8% of our housing stock was less than 10 years old. By 1980 this had risen to 21% and in 1984 to 26%. With our ongoing programme of housebuilding the average age of our stock is reducing and the overall quality of the conditions of housing is improving.

A survey of the condition of the housing stock (5) was carried out in 1980 by the Local Authorities with the assistance of An Foras Forbartha. The sample size was 22,000 houses and these were carefully selected to represent the mix of the housing stock. The results were grossed-up to give a picture of the whole housing stock which at that time was of the order of 881,000.

Table 1 gives information on the number of houses deemed unfit for habitation (but not necessarily beyond economical repair).

Table 1
FITNESS FOR HABITATION

Urban Housing			
Year of Construction	Number	Fit %	Unfit %
Pre 1860	19,000	82	18
1860 - 1899	45,000	90	10
1900 - 1918	28,000	93	7
1919 - 1940	75,000	96	4
1941 - 1960	111,000	99	1
1961 - 1970	81,000	98	2
1971 +	109,000	99	1
All	468,000	96	4
1919 - 1980	376,000	98	2
Rural Housing			
Year of Construction	Number	Fit %	Unfit %
Pre 1860	55,000	73	27
1860 - 1899	67,000	77	23
1900' - 1918	49,000	82	18
1919 - 1940	66,000	87	13
1941 - 1960	59,000	93	7
1961 - 1970	38,000	96	4
1971 +	79,000	96	4
All	413,000	87	13
1919 - 1980	242,000	93	7

It would appear that 18,720 urban and 53,690 rural houses are unfit for habitation, of these 6,820 and 17,390 respectively are from the post 1918 period and are properly associated with the concrete era. A house is deemed unfit for habitation when it constitutes a danger or health hazard to its occupants. It is clear that the younger houses in the post 1918 period are more satisfactory than those built before concrete became popular. It is probable that this is because of better building practice but some defects may take a long time to become manifest. Stability of structure and resistance to moisture are the major parameters of fitness. 4,680 urban and 16,520 rural houses have poor structural stability, 3,670 and 2,420 respectively of these being from the post 1918 period. Dampness which is serious enough to con-

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stitute a threat to health occurs in 23,400 urban and 53,690 rural houses, 11,280 and 19,360 respectively being from the post 1981 period (since only 18,720 urban houses are deemed unfit for habitation it is clear that some of those which were deemed to constitute a health hazard from the point of view of dampness, were not deemed unfit).

These figures indicate a reason for concern with regard to the quality of the existing Irish housing stock and a need for remedial measures to be undertaken both to improve the existing stock and to avoid recurrence of further problems.

A survey of new house purchasers was carried out by AFF in 1984 (6). The sample size was 500 and the houses purchased were located in private housing estates in Dublin, Cork, Limerick and Galway. Satisfaction with the overall standard of work was recorded by 53% of those interviewed, 9% were not satisfied and 38% gave a non-committal answer. When asked about areas in which they would like to see improvement, 54% included construction and workmanship. The number of respondents who noted defects in various items is given in Table 2 together with their expectation of maintenance costs.

Table 2
DEFECTS AND MAINTENANCE COSTS

Defects in	Defects Noted		Expected Maintenance Costs	
	Yes	No	Heavy Costs	Reasonable Costs
Outer Doors	30	70	20	80
Inner Doors	23	77	10	90
Windows	25	75	22	78
Insulation	7	93	13	87
Condensation	21	79	18	82
Dampness	10	90	16	84

Taking the general comments into account and on this basis making an adjustment of the non-committal answers, the levels of concern given in Table 3 are produced.

Table 3
QUALITY CONCERNS

Item	Level of Concern
Level of wall insulation	1 in 14
Windows and Doors	1 in 4
Wall Finishes	1 in 6

While having no direct relevance to concrete these results indicate a need for attention to quality matters in private housing work where it is generally agreed to be lower than that pertaining in local authority work. Improvement in ope detailing and formation procedures might be expected to reduce the incidence of cold bridges and of air leakage and provide greater user satisfaction in the future.

4. USE OF CONCRETE MATERIALS

The shapes and sizes of houses built have a critical influence on the amounts of concrete materials used. Table 4 shows that the average private semi-detached house theoretically requires only 40% of the concrete required for the average private bungalow.

Table 4

VOLUME OF CONCRETE PER HOUSE (Calculated Minimum)

House Type	Floor Area (m ²)	Volume of Concrete Needed (m ³)
1. Local Authority Semi-detached	83	52.9
2. Private Semi-detached	101	45.16
3. Private Bungalow	125	113.06

In 1976, 66% of the private houses built were in estates while 34% were one-off, by 1983 the trend had shifted so that private one-off's accounted for 59%. Local Authority completions are not as variable as the private market, 85% of these are mainly two storey, 3 bedroom houses of 83 m³ area with about 9% old persons dwellings, 3% 4 bedroom 2 storey and about 2% 3 storey infill work. Table 5 shows the changes in average sizes, accommodation and house type which have occurred in the private housing sector since 1976 (7). Estate houses increased in average size up to 1980 and have reduced in response to market conditions since then. One-off houses, however, have continued to increase in average size, a feature which is difficult to explain but which bodes well for the concrete industry.

Various choices of materials can be made for ground floor construction and Table 6 shows a decline in timber usage with a corresponding increase in concrete usage.

First floors in houses are almost entirely timber as shown in Table 7. A small quantity of both precast and in-situ concrete is used but there is no real sign of growth as yet.

Table 5
FLOOR AREA AND PRINCIPAL FEATURES OF PRIVATE HOUSES

	Year	Average floor area m ²	Number of Bedrooms			House Type		
			3	4	Other (mainly 2 & 5)	Det. 2 Storey	Semi-det. 2 Storey	Others
Estate Houses	1975	95	71%	26%	3%	6%	82%	12%
	1980	111	46%	48%	6%	23%	71%	6%
	1983	92	53%	31%	16%	10%	57%	33%
	Year	Average floor area m ²				1 Storey	2 Storey	Dormer
Single Houses	1976	106	49%	44%	7%	88%	8%	4%
	1980	121	41%	51%	8%	86%	7%	3%
	1983	125	40%	52%	8%	78%	13%	6%

Table 6
GROUND FLOOR CONSTRUCTION

	Year	Concrete	Concrete with T & G	Timber with T & G	Timber with Chipboard
Estate Houses	1976	69%	—	24%	7%
	1980	76%	—	24%	—
	1983	90%	—	8%	2%
Single Houses	1976	76%	12%	11%	1%
	1980	76%	20%	3%	—
	1983	96%	3%	1%	—

Table 7
FIRST FLOOR CONSTRUCTION

	Year	Concrete in-situ	Concrete Precast	Timber with T & G	Timber with Chipboard	Timber with Plywood
Estate Houses	1976	—	—	50%	41%	5%
	1980	—	—	66%	30%	—
	1983	—	1%	46%	36%	3%
Single Houses	1976	—	1%	11%	—	—
	1980	—	2%	11%	1%	—
	1983	2%	1%	17%	2%	—

Roof covering in private estate houses is usually of concrete tiles with asbestos slates now taking 1% of the market. In 1976 asbestos slates had 11% of the market for private single houses and they had increased their share to about 40% in 1983.

Hollow blocks have held on to 55% of the outer walls in estate houses but have virtually no hold on private one off's. Table 8 shows this in detail while it also shows that timber frame has captured 2% of the market.

Table 8
EXTERNAL WALLS

	Year	Hollow Block	Cavity Wall	Timber frame
Estate Houses	1976	86%	14%	—
	1980	58%	42%	—
	1983	55%	43%	2%
Single Houses	1976	2%	95%	—
	1980	1%	97%	1%
	1983	1%	97%	2%

There has been some growth in the use of brickwork facing in the 1970's and some growth in this area still persists in the estate houses in the early 1980's. This is shown in Table 9. Single houses with some stone facing work were also a feature of the past decade.

Table 9
FACING BRICKWORK

	Year	All Walls	Front Walls	Lower Walls	None
Estate Houses	1976	2%	3%	26%	67%
	1980	4%	19%	35%	39%
	1983	4%	23%	31%	34%
Single Houses	1976	—	6%	14%	57%
	1980	7%	3%	8%	58%
	1983	6%	2%	8%	60%

The finish to external walls is generally sand/cement, rough cast or dry dash with a small proportion of Tyrolean.

The concrete share of the market for roads, paths and driveways is high in estate houses and this is indicated in Table 10. The share in one off houses is not recorded at this stage.

Table 10
CONCRETE IN ROADS, PATHS, DRIVEWAYS
(ESTATE HOUSES)

Year	Roads	Paths	Driveways
1976	60%	97%	80%
1980	27%	99%	86%
1983	27%	99%	85%

The AFF publication (7) on which the data in Table 5 to 10 are based contains data which highlight regional variations in materials and these may be significant. For example, the use of concrete in roads for the country as a whole is 27% but this varies from 49% in Dublin to 2% in the West. Such data could be most useful in seeking out areas for potential increases in concrete usage.

5. QUANTITY OF CONCRETE

In order to make an estimate of the quantity of concrete materials used in housebuilding in 1983 the quantities required to build a typical Local Authority semi-detached house, a private bungalow and a semi-detached house were calculated. The results are given in Table A. Figure 1 shows the location of the concrete material referred to in the following Tables and text.

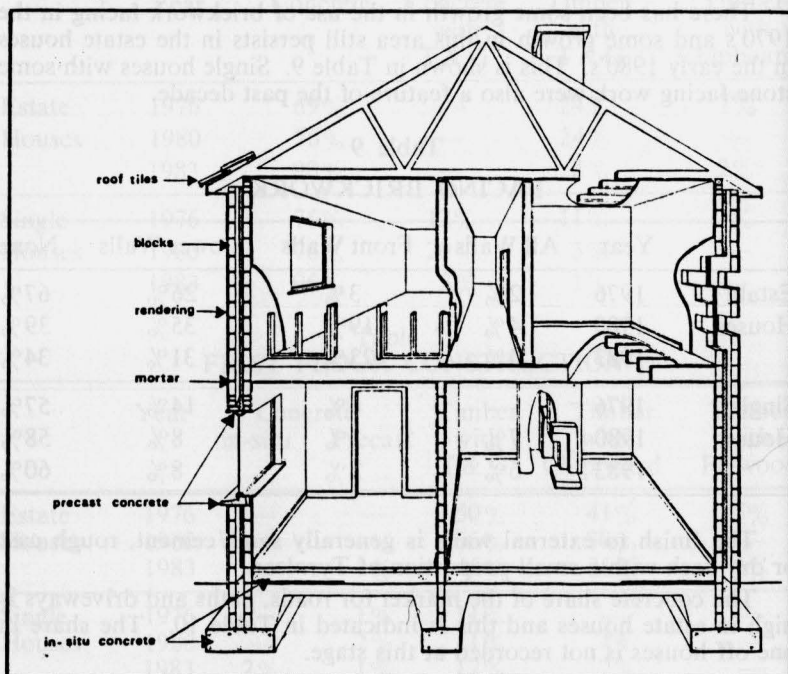


FIG. 1 CONCRETE MATERIALS

The actual amount of concrete used is influenced by particular matters like over excavation and spillage. Studies of wastage on building sites in Britain (8) have been supplemented by enquiry among major house builders in Ireland and the wastage figures used in assessing materials usage (Tables 12 to 16) are shown in Table 11.

Table 11
MATERIALS WASTAGE

Material	Percentage Wastage
Blocks	7
In-Situ Concrete	8
Precast Concrete	5
Roof Tiles	10
Mortar	10
Rendering	10

Table 12
HOUSE TYPE 1 ((LA 83 m³))

Material	Vol. (m ³)	Waste (m ³)	Total Vol. (m ³)
Blocks	33.32	2.33	35.65
In-Situ Concrete	13.22	1.06	14.28
Precast Concrete	0.53	0.03	0.56
Roof Tiles	1.31	0.13	1.44
Mortar	2.68	0.27	2.95
Rendering	1.84	0.18	2.02
All	52.90	4.00	56.90

Table 13
HOUSE TYPE 2 (Private 101 m²)

Material	Vol. (m ³)	Waste (m ³)	Total Vol. (m ³)
Blocks	28.73	2.01	30.74
In-situ Concrete	9.94	0.80	10.74
Precast Concrete	0.72	0.07	0.79
Roof Tiles	1.99	0.20	2.19
Mortar	1.51	0.15	1.66
Rendering	2.27	0.23	2.50
All	45.16	3.46	48.62

Table 14
HOUSE TYPE 3 (Private 125 m²)

Material	Vol. (m ³)	Waste (m ³)	Total Vol. (m ³)
Blocks	49.99	3.50	53.49
In-situ Concrete	49.09	3.93	53.02
Precast Concrete	0.83	0.04	0.87
Roof Tiles	3.93	0.39	4.32
Mortar	6.25	0.63	6.88
Rendering	2.97	0.30	3.27
All	113.06	8.79	121.85

Table 15
ESTIMATE OF MATERIALS USAGE IN 1983

Material	Local Authority (m ³ x 10 ³)	Private Estates (m ³ x 10 ³)	Private Singles (m ³ x 10 ³)	Total (m ³ x 10 ³)
Blocks	221	229	540	990
In-situ Concrete	88	76	575	739
Precast Concrete	3	6	12	21
Roof Tiles	9	16	28	53
Mortar	18	12	74	104
Rendering	13	16	31	60
All	352	355	1,260	1,967

These figures allow for a portion of the housing completions having brick facings, asbestos slates and concrete first floors. They do not allow for siteworks or for materials used in apartments or conversions.

Coal sheds and gossip walls are included with the vast majority of Local Authority houses and Table 16 shows an estimate of materials used.

Table 16
COAL SHEDS AND GOSSIP WALLS

Material	Vol. (m ³)	Waste (m ³)	Total Vol. per house (m ³)	Total for 1983 (m ³ x 10 ³)
Blocks	2.67	0.19	2.86	18
In-situ Concrete	1.33	0.11	1.44	9
Mortar	0.20	0.02	0.22	3
Rendering	0.46	0.05	0.51	1
All	4.66	0.37	5.03	31

The regional variations and the wide variety of geometric configuration make it difficult to estimate the countrywide usage of concrete materials in site works in general. However, it can be said that a substantial quantity is currently used and that there remains potential for further use in this area. It is also true that there is serious competition with alternative materials trying to gain a greater share of this market. A typical Local Authority scheme involving 22 houses with associated roads, paths, kerbs, driveways and boundary walls was analysed and it was found that an additional 34 m³ of concrete was used per house when the roads were of concrete and 15 m³ was used if the roads were not of concrete. Extrapolating this information to cover private housing developments a rough estimate indicates something of the order of 270,000 m³ in site works exclusive of piped services.

6. HOUSING DEMAND

The dwelling stock is currently about 975,000 and one year's building will provide us with a million dwellings having an average household size below 3.66 persons.

Table 17 is a record of the dwelling completions in the last decade (9).

Table 17
NEW DWELLING COMPLETIONS

Year	Local Authorities	Others	Totals	Previous 5 years; (000)
1975	8,794	18,098	26,892	115
1976	7,263	16,737	24,000	123
1977	6,333	18,215	24,548	126
1978	6,073	19,371	25,444	127
1979	6,214	20,330	26,544	127
1980	5,984	21,801	27,785	128
1981	5,961	23,236	28,917	133
1982	5,686	21,112	26,798	135
1983	6,190	19,948	26,138	136
1984*	6,000	EF,200	25,200	135
1975-1984			263,166	

*Estimated

Detailed studies of housing requirements and population changes for 1981 to 1991 have been carried out by the NESC (10) and direct enquiries to the authors who are currently updating their figures indicate that the demand for houses in the period 1986 to 1991 is likely

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to lie between 133,000 and 136,000 dwellings. It seems likely that a little less than 27,000 dwellings per annum will be required.

The main means of providing these dwellings are:

- Provision of new Local Authority houses
- Provision of new Local Authority flats
- Provision of new private estate houses
- Provision of new private one-off houses
- Provision of new private flats and apartments
- Provision of accommodation in refurbished buildings which were formerly unoccupied or underoccupied.

The mix of new houses built in the past decade is shown in Table 18. The continued growth of the share taken by single houses ensures high concrete usage.

Table 18
MIX OF HOUSE COMPLETIONS

Year	Local Authority Houses	Private Estate Houses	Private Single Houses
1976	7,263 (31%)	10,749 (46%)	5,538 (23%)
1980	5,984 (22%)	10,579 (40%)	10,066 (38%)
1983	6,190 (25%)	7,435 (30%)	10,757 (44%)

The number of Local Authority flats built is rather low but there has been some growth in private flats and apartments in recent years.

Table 19 shows the number of apartments completed (11) together with the percentage in the Dublin area.

Table 19
APARTMENT COMPLETIONS

Year	No. of Units	% in Dublin
1981	437	98
1982	819	81
1983	1,306	86

Section 23 of the Finance Act 1981 provided incentives for the provision of rented accommodation. These incentives have been reduced since March 1984 and this is expected to cause a slowing down in this type of development.

Provision of accommodation in refurbished buildings satisfies a small part of the dwelling demand. However, it is probably worth noting that some Local Authorities are looking at the possibility of meeting some of their needs through upgrading underutilized space in their cities and towns. In Cork (12) a survey of 750 buildings in the

city centre revealed that over 45% had in excess of 30 m² of floor space either vacant or underused. This space generally occurred in the upper stories over business premises and it was thought to be suitable for refurbishing for use by single persons.

7. CONCRETE PRACTICE AND PERFORMANCE

7.1 Foundations

The vast majority of house foundations are unreinforced strip footings. These are generally empirically designed on the basis of their width being three times the width of the wall supported. When a technologist is commissioned to design the foundations the width is determined taking into account the loads carried and the bearing qualities of the particular soils. In schemes controlled by consultants or Local Authority personnel, the grade of concrete used is likely to be 10/40 or 20/40 with a slump of 40 to 50 mm. Regular testing of concrete is carried out. On those sites without independent control the concrete is likely to be a nominal 8 to 1 mix giving a strength of 7 to 10 N, testing is not normal.

Concrete as a material has been found to perform very well in house foundations. In general foundation failure has to do with the bearing capacity of the substrata rather than deterioration of concrete. Deterioration due to alkali-silica reaction has not yet been reported from housing sites in Ireland and attack from aggressive soils and ground waters is quite rare. Some examples of sulphate attack and attack by acid ground waters have occurred. Generally good dense foundations are not seriously disturbed but rising walls in less dense material may suffer. It is important to ensure that adequate knowledge of the nature of the service environment of the foundation is obtained before construction commences. In particular, good dense concrete of structural quality is desirable in all cases in which running water is likely to be encountered. Other precautions are given in the C & CA pamphlet on House Foundations (4). Taking this comment into account it has to be said that there is no evidence of concrete failure in house foundations due to the slackness of the quality control on single house sites and although this should not be taken to be an argument in favour of bad workmanship, it might reasonably be seen as indicating some over cautious specification and control requirements where engineers are in charge.

7.2 Walls

Walls in housing are generally of solid blockwork up to DPC level, over this level they are composed of either hollow blocks or two leaf cavity construction with some brick or stone facing work as shown in Table 8. The thermal requirements for external walls have increased with the growing awareness of energy costs. In 1979 minimum standards were introduced in advance of the Building Regulations. A maximum U value of 1.1 W/m²°C was required. However, in 1982 an improved maximum of 0.6 W/m²°C was introduced. Figure 2 shows

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the typical results of these developments. Plastered hollow block walls which were acceptable in 1975 are no longer acceptable. Although this development is generally good there are also detrimental aspects. In the event of failure of the external render the internal plaster formed a second line of defence against air and water infiltration. This is now gone and leakage may be occurring behind the inner insulation boards. In some cases the insulation takes the form of matting fixed between softwood grounds and the durability of these grounds is in doubt. The insulated inner face also removes the possibility of storing heat in the concrete and this may influence the efficiency of heating systems. The hollow block still demands a significant share of the private estate houses but is rarely used in private one-off houses. Its share of private estate houses in the Dublin area is 50% while in the West it is near 10%. It is true that driving rain is a greater problem in the West than it is in Dublin, however, the East is not immune to driving rain.

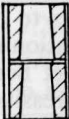
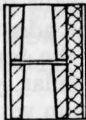
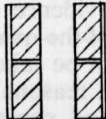
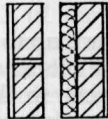
	Plastered Hollow Block U Value > 2.0
	Hollow Block Wall 50mm insulation U Value < 0.60
	Plastered Cavity Wall U Value > 1.5
	Cavity Wall with 50mm insulation U Value < 0.60

FIG. 2
EXTERNAL WALL INSULATION

Many people have voiced concern about the suitability of hollow block walls for housing and it is surely time to confirm or refute the fears by undertaking a detailed study of their performance in use.

Imperforate concrete block walls are very good at performing their structural function and there is little evidence of difficulty when properly used. Under the Proposed Building Regulations, separating walls are required to provide adequate resistance to the transmission of airborne sound and a table giving the sound reduction in decibels at various frequencies is given. The deemed to satisfy alternative is a solid wall with an average mass of 415 kg/m^2 . Both of these requirements are based on an empirical British decision that a 9" wall with $\frac{3}{4}$ " plaster on both faces is adequate. Because block making techniques, block sizes and plastering practices have changed since this was first introduced we now have the anomaly of British firms offering special heavy weight aggregate blocks for separating walls. We should not allow this to happen here. If what we really want to say is that we want a solid wall plastered on both sides, then we should adjust the 415 kg/m^2 figure to 350 kg/m^2 to allow the use of 190 mm thick walls composed of concrete blocks of the normal minimum density of $1,750 \text{ kg/m}^3$. This would avoid the annoyance of density identification on site. Alternatively the real needs should be ascertained.

The performance of block walls with substantial perforation for windows and doors has not been as good as solid panel work. Cracking due to shrinkage and other movements is widespread and in hollow block walls built without internal lining, ingress of moisture through such cracks is not uncommon. Reliance on lining to hide such failures is likely to be successful only in the short term and deterioration of plasterboard and softwood grounds is likely to occur. During the late 1970's many block producers were working at full capacity and the turnover of finished items was very fast. The building-in of masonry units before the early shrinkage has taken place is thought by many to have contributed to local cracking to a degree which does not arise when material has time to mature. There is an awareness now of the significance of concrete masonry shrinkage and efforts are being made to eliminate or minimise its effects. The use of localised joint reinforcement is sometimes specified at points of stress concentration above and below openings in walls. However, we are still too ready to accept cracks in houses as inevitable. The knowledge and the skill to control these by reinforcement or release of stress using control joints is well established at this stage and should be used more extensively.

The use of lining materials instead of directly applied plasters has also accentuated the need for proper formation of flue liners and packing around flues. Smoke leakage into adjacent rooms and adjacent houses is a cause of great concern to house owners and occurs often enough to be described as a significant problem (13).

The insertion of insulating materials in cavities is now a commonplace activity for blocklayers. The coordination of sizes of insulation

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bats to suit block/brick courses has progressed but many bats are broken to allow wall ties to pass and many open joints between bats are evident. The efficiency of the insulation system is influenced by the snugness with which the bats cling to the inner leaf and also by gaps and breakages. During the 1970's an awareness of the importance of cold bridges has led to the use of split lintels and the insulation of cavity closers at window and door opes. These details are not yet universal and condensation and mould growth around opes still occurs in some new houses although the worst effects may be alleviated by the widespread practice of drylining. An Foras Forbartha is currently looking at the efficiency of various insulating techniques and more positive guidance on these matters may be available in the near future.

In measuring the widths of window opes, a recent AFF survey found that there were sites where a standard deviation of 15 mm occurred, implying a variability of ± 45 mm. The norm was ± 25 mm and even this leaves a lot to be desired. Heavy reliance is placed on plaster to fill gaps and provide weather tight junctions. Inaccuracy in the erection of external walls to receive roof trusses is also a matter for concern. The Irish Standard for Roof Trusses (14) requires that special calculations be undertaken when the distance from the wall plate edge to the junction of the rafter and the tie exceeds 50 mm (Figure 3).

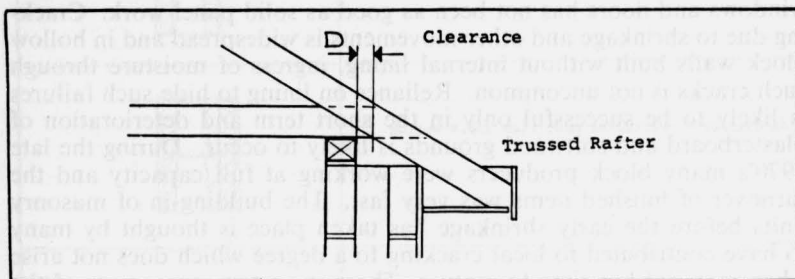


FIG. 3

SECTION THROUGH WALL PLATE

In the same recent survey it was found that the distance between wall plates had a standard deviation of 15 mm implying a variability of ± 45 mm, the maximum difference between the largest and smallest dimension on any site was 84 mm.

At the beginning of the 1970's the majority of blocklaying work was carried out by subcontract and much concern was expressed about quality. During the last 10 years there have been many stories of blocklayers walking off projects when their work was criticised. At the height of the building boom at the end of the 1970's some builders could not criticise bad work for fear of being left without the means to complete their contracts. At that time there was also concern about the training of apprentices (15) since high output was the primary

concern of the subcontractors. The main union responsible for block-layers has carried out quite a successful operation whereby they have ensured that the major sites negotiate with them and men now get the benefits of productivity based (lump) bargaining together with the security of tax, insurance, pension rights etc. previously denied them when working in, often fragile, subcontracting organisations. Men now submit to quality control set up by reputable building firms and apprentices have a more secure basis for their training.

The growth of brick veneer detailing in houses and apartment building has led to the widespread use of steel lintels, while a history of failure of galvanised mild steel wall ties in many types of building has been established. This history has shown that the environment in a cavity may be more aggressive than previously expected and much doubt has been cast on the use of mild steel fittings. A new Irish Standard for wall ties has been prepared and work has commenced on guidance for the use of wall ties which may form part of an Irish Code of Practice for masonry.

The use of unplastered blockwork surfaces both inside and outside has developed during the 1970's. Blocks are available in three visual qualities: a) common or standard blocks, b) fine textured blocks and c) masonry quality. All three have been used self finished in what is loosely called fairfaced work. A very significant development occurred in 1978 when the Forticrete range of dense concrete masonry blocks were introduced. This presented designers with a range of colours and textures not previously available. Some high quality blocks had previously been available from other sources but variety was greatly increased with this development. Ready-mixed mortars have also developed and are widely used in house building. These vary from simple mixes of lime and sand requiring the addition of cement on site to a special trowel-ready mix which has all ingredients included and which may be used up to 2 days after mixing. Quality controlled addition of pigment at the ready-mix plant has also improved the reliability of mortar colour. Schedule 2 of the Proposed Building Regulations requires walls to be anchored to floor and roof diaphragms and metal straps must be built in as the blocklaying proceeds. This calls for a greater attention to course levels than was previously necessary and great care is needed, as shown in Figure 4 to ensure that the bent end in the cavity is in contact with the outer face of the inner leaf.

This Schedule gives rules for determining the thickness of certain walls without calculation. It applies in general to housing and other small residential buildings. However, in being general it fails to handle all possible situations and one notable omission is the means whereby a single storey internal wall carrying only the first floor can be sized. The general rule for internal walls is qualified by a requirement that the thickness be at least one sixteenth of the storey height and there are cases where this is too rigorous.

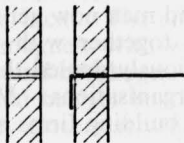
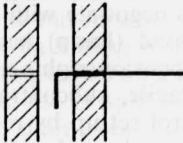
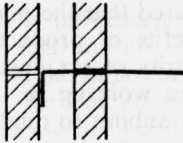
		
Strap in correct position	Strap not effective	Bridging cavity

FIG. 4
LOCATION OF WALL STRAPS

7.3 Floors

Simple ground floors composed of timber on tassel walls had a substantial share of the market in 1975. However, the changes in thermal requirements have virtually removed this type of ground floor from Irish housing. The Regulations introduced in 1982 require a maximum U value of $0.6 \text{ W/m}^2\text{C}$ and Figure 5 shows the result.

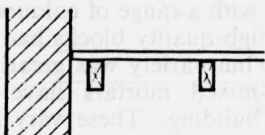
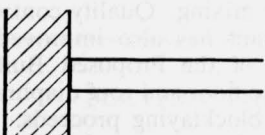
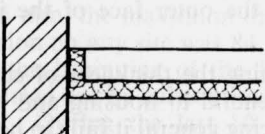
	T & G on Joists	U Value will be above 0.60 if any of the edge dimensions are less than 7.5m
	Concrete slab on hardcore	U Value may be below 0.6 dimensions depending on plan dimensions
	Concrete slab with insulated edge	Slab edge insulation up to 1m vertically or horizontally may be needed to satisfy Regulations

FIG. 5
GROUND FLOOR INSULATION

On sites controlled by independent inspection the concrete grade used in ground floors is likely to be 20/20 with a slump of about 50 mm and testing and proper curing are likely to be carried out. On private sites without external control the concrete is likely to be a nominal 6 to 1 mix giving a strength of 15 to 17 N at 28 days but testing is unusual. Ready-mix suppliers are likely to add a water reducing admixture as a safeguard against over watering on site and as an aid to curing. Up to about 5 years ago the majority of Local Authority houses were formed with a 50 mm screed applied after the rough work was completed. Screeds are still included in many specifications but builders are now allowed to place the whole thickness (normally 150 mm) in one operation. Manual tamping is followed by power floating and both curing and protection from damage is achieved by spreading a 50 mm layer of "silt sand" over the surface. On private estate the total thickness is seldom in excess of 100 mm and the Proposed Building Regulations may cause this to be increased to 150 mm to satisfy clause C5 which requires adequate protection from ground moisture.

Where floating ground floor slabs were used on infill material in the past this has given rise to many settlement problems. The National House Building Guarantee Scheme (NHBGS) has banned the use of floating floors or infill in excess of 600 mm in depth (13). Settlement of floating concrete ground floors causing damage to partitions mounted on these floors is caused by the characteristics of the formation rather than by the concrete or its use. However, many may consider this disclaimer to be a little lame when it is conceded that a floating slab is intended to replace the old suspended timber floor which did not display such a problem. On properly controlled sites the compaction of infill less than 600 mm in depth is now carefully executed. Selected granular fill is laid in layers and mechanically compacted before blinding off and placing the slab. The necessity to ensure a stable support for internal loadbearing partitions has now been enshrined in NHBGS rules which require all such to be taken to foundation level. The decision to use a suspended concrete floor instead of deep fill must not be expected to solve all problems as it has been noted that filling outside the building may give rise to the formation of a sump under the ground floor causing high humidity and concern about biological activity producing gases and/or harmful bacteria within houses. Precast concrete suspended ground floors have found a small share of the market. There have been difficulties associated with the need to prop beam and pot types until the slab has matured enough to act on a loadcarrying platform. Some systems which do not need propping are now on stream and these may gain a wider market in the near future. Hollow core slabs and slab plate formers which require craneage for handling are most popular in apartment construction and techniques for providing continuity ties and a positive mechanical connection to the peripheral walls have been developed. A practice of forming foundation and floor slab as a raft

has been developed particularly in the West. Problems which have arisen in their use include incorrect detailing of slab edges causing ingress of water and uneven bearing capacities causing tilt or cracking of the slab. Skill in the design and construction of raft foundations is necessary to ensure satisfactory functioning and the C + CA have issued Guidance (4) on this subject.

Suspended upper floors in concrete are still relatively rare and there is no record of serious problems where they have been used in Irish houses. They have, of course, been used extensively in apartments and again, performance seems to be good. When lightweight beam and pot type precast slabs grow in popularity as a means of solving the deep fill problem at ground floor level it is likely that they may find use in upper floors in houses also.

7.4 Miscellaneous concrete items

Many items such as lintels, sills, chimney caps, copings and flue gatherers are made of concrete and the performance record of these items is good. Precast sills are sensitive to handling and may, relatively easily, become cracked or chipped. There are many examples of such sills in houses which are badly stained with rust. Cracked sills should be rejected during pre-handover inspection. The most common precast lintel is a shallow prestressed component which is intended to act compositively with masonry overhead. There have been many incidences of insufficient composite action due to such things as too little masonry over the lintel, failure to fill the vertical joints in the masonry and insertion of joists within the composite lintel. There is no record of any failure occurring when the lintels have been properly used. Concrete is used in siteworks for roads, paths, kerbs, boundary walls, manholes and drains. In all of these areas performance has been good when properly used. It is unreasonable to expect a deep manhole formed of concrete blocks to withstand serious external water pressure without leaking and failures such as this have occurred. Similarly footpaths formed by using up scrap bits of left-over concrete and mortar could hardly be expected to prove durable. Even when properly formed, roads and paths may perform badly if subjected to extremes of temperature, wind and moisture during curing and there are many examples of poorly cured roads and paths in Irish housing estates.

8. PROSPECTS

A growing population together with other social and economic conditions currently combine to give a slightly increasing demand for dwellings. Residential building currently accounts for 53% of the cement used in this country. It is thus the single most important section of the construction industry and must be expected to attract much attention from all levels of Irish life from the purchasers to the policy makers.

The rights of consumers are now being highlighted throughout the world. The Law Reform Commission has most strongly represented this trend with regard to building work in their papers. "The law relating to the liability of builders, vendors, and lessors for the quality and fitness of premises" (16) and "The report on defective premises" (17). The industry is conscious of the number of court cases here and in Britain where builders and designers have been challenged and their professional performance found inadequate. This is leading to greater caution which has some good effects. The NHBGS is one expression of this caution and structural engineering consultants who were seldom involved in housing in 1975 are now regularly involved, particularly in foundation design.

This could be described as a period of consolidation of established practices. Many processes which were "known to work" are now being subject to examination on a performance basis and refinements in design and quality control are taking place.

The very stable demand for houses makes this section a most interesting area for further development of precast concrete elements and the use of coordinated components throughout the industry can eventually lead to a substantial advance in component building. This has been inhibited by poor public perception of "prefab" work but performance testing leading to quantifiable improvements can be expected to produce a slow careful advance in the future. Concrete block and brick masonry can be expected to improve and because of its versatility it is likely to retain a position of importance for the foreseeable future. The challenge from timber framed systems is likely to grow in intensity and eventually to capture a larger share of the market. However, certain quality improvements are required on Irish house building sites before the durability of homegrown softwoods in timber frame work can be assured.

Development in concrete technology will continue. Mix characteristics, handling and placing methods and product variety will advance. Areas in which research and development efforts could usually be deployed include:—

- Application of crack prevention techniques.
- Studies in catalogue component building.
- Assessment of sound insulation needs.
- Development of practical means of improving dimensional control.
- Detailing practice in concrete masonry work with particular regard to heads, jambs and sills of opes where air and moisture infiltration remains a problem and current thermal insulation practice is inadequate.
- Studies in the production of a lighter weight concrete block to achieve productivity advances.

With residential development being responsible for 50% of the construction industry output it is reasonable to call for research and development aimed at ensuring the best return on investment both in terms of quantity and quality. The call should now be made to the

research institutes, universities, professional and commercial associations, developers, manufacturers, builders and all those who owe their professional and commercial wellbeing to the people who support this industry through taxes, mortgages and investment.

Perhaps the CII and CIF could consider setting up an independent research fund and initiate development for the purpose of marketing high quality construction product and service both at home and overseas.

Acknowledgements

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Discussion

MR. RYAN introduced his paper.

Housing accounted for 50% of the national investment in construction and used about 50% of our output of cement. The use of concrete in Irish housing began about fifty years ago. First we had in-situ mass concrete, then solid blockwork, then cavity walls with solid blocks, and then cavity blocks. We also had some precast systems, mainly closed systems. We had not made any serious effort as yet to develop an open system. There had been some use of no-fines concrete. The expansion of our population had led to the development of a young housing stock. In 1971 only 8% of the housing stock was less than ten years old; the figure now was over 26%. Today, 8.2% of our total housing stock was unfit for habitation (as compared with 6% in Britain), and that figure included about 4% of post-1918 houses. Others in that post-1918 group were a health hazard on account of dampness. Such figures raised the question as to how long a house should last. Built of durable materials properly disposed with regard to compatibility and protection from degrading processes, a house could last for several hundred years. Concrete in Irish housing had a high potential for good durability, but its use had to be viewed in the context of its use with other materials. Bad design leading to the premature decay of timber or metal led on to high maintenance costs and early obsolescence. His paper would suggest that local authorities were more concerned with quality in that regard than many private builders. A perception of the level of on-going responsibility might well influence such attitudes.

In a comment on the sizes of houses, Mr. Ryan noted that the floor area of local authority houses remained constant at about 83 sq metres, that private estate houses having reached about 111 sq metres in 1980 were now, at 92 sq metres, lower than they had been in 1975, but that private one-off houses were steadily continuing to increase in average floor area. Whilst concrete was little used in the upper floors of housing units, except in flats and apartments, it was now widely used in ground floor construction, and thicknesses of 100 mm and 150 mm might be taken as applying in private and local authority housing respectively. Local authority walling was virtually all in concrete block cavity construction, and about 55% of private estate external walling was 225 mm hollow block. About 2% of private estate external walling was timber framed. Concrete in open area slabs, e.g. roads, paths and driveways ranged in private estates from 49% in Dublin to 2% in the west of the country. Concrete in foundations had behaved very

well, with such failures as occurred relating to the quality of the ground rather than to the concrete. Local authority housing would be found to have about 71% more concrete in its foundations than private estate housing. Also, it was customary to use Grade 20 concrete in local authority foundation work as against Grade 7 concrete in private estate work. There was no evidence of inadequacy in the use of the weaker material and smaller foundation sizes, and possibly the local authorities were too conservative in those regards.

The controversy on whether or not to use hollow blocks in housing was of long standing. Its resolution would be beneficial to the industry. Clearly it was possible to build durable houses with hollow block work, but ordinary site practices today left a lot to be desired and surely would not offer a satisfactory life of 200 to 300 years. Bearings were often skimpy and badly made, preservatives were casually applied, and dry linings based on white deal battens could not be expected to last very long inside hollow block external walls.

Cracking had always been a problem in concrete walling. Informed opinion, supported by many official publications including a BRE digest, would hold that a moderate degree of cracking was acceptable. Whilst Mr. Ryan agreed that unless care was taken, concrete walls must crack, he was not prepared to accept that visible cracking should be tolerated, and he recommended a review of this matter in Irish practice. The industry could deliver buildings free of visible cracking if clients were prepared to pay for them. It would be necessary to season blocks for about three months, to reinforce bed joints above and below windows, and to make increased use of control joints. It would be necessary also to get, and control, improved workmanship on site. The increased use of "lumpers" in laying blockwork presented problems, as did the tendency, now receding, for block layers to walk off sites because of criticism of their work, leaving jobs uncompleted. That was not a new phenomenon, as the masons' craft guild had been forced to take action against its members in Dublin in the seventeenth century for exactly the same form of default. It was good to know however that the Brick and Stone Layers' Union had, in recent years, considerable success in replacing "the lump" on the major public and private sites in the country by arranging useful productivity packages and other benefits for its members, with the result that "lumpers" were operating now only on smaller developments.

We should recognise that good quality building in Irish housing was not a rarity and that many advances had been made in our techniques in recent years. The Government, through An Foras Forbartha, had made a considerable investment in an approach to dimensional co-ordination suitable for Ireland, and we were developing a substantially rationalized building industry that incorporated many pre-manufactured components and improved site procedures. Clearly an open system of component building had much to offer. A new market was being opened up in which the customer, or client, played a larger part through his selection of open-system components and his increasing

reliance on "do it yourself" processes. This market and its medium and long-term stability should be explored and entrepreneurs venturing into it should be supported as appropriate.

Mr. Ryan, pointing out that the long-term interests of the house purchasers were so often in conflict with the short-term interests of the speculative house builder, urged the need for, as it were, a Users' Charter that would identify minimum basic needs in such matters as space and durability. Purchasers were also entitled to a guarantee of good workmanship. This needed skilled supervision without which many dubious practices would continue to be hidden under the finishes. Only one-third of Irish houses were built under the supervision of a clerk of works or resident engineer, with two-thirds continuing to be built under the control of developers whose interests were short-term. That fact presented the greatest challenge for those who would like concrete practice in Irish housing to keep in line with growth and knowledge. Perhaps this Symposium was the correct assembly in which to explore the need for better supervisory procedures to eliminate the constructional abuses that were to be seen on many speculative building sites.

MR. J. McCULLOUGH opened the discussion.

One saw how important the housing area was in Ireland when one recognized that 50% of the construction market represented the annual expenditure of a thousand million pounds, a very impressive investment. Two facts had struck him at once, firstly that 41% of Irish houses now being built were individual one-off projects, and, secondly, that there was evidence of a move back towards terraced houses. He believed the advantage in insulation of being in a terrace was not necessarily outweighed by the difficulties of back access and remarked on the acceptability of terraced living to wealthy Georgians in their day. He endorsed Mr. Ryan's view that local authority housing was on the whole of higher quality than private housing and felt that a greater input of professional design and independent supervision contributed to that state of affairs. Certainly inadequate preparation of the ground was a major factor in house failure, with whole houses being founded on slabs on inadequate fill as a case in point. The ground under foundations could also be suspect. In one investigation he had made of a house where severe cracking had occurred, it emerged that part of the foundation was resting on a tree! One should not accept that single storey buildings needed any less degree of attention than those of twenty storeys. Both could fail if their foundations were inappropriate.

Mr. McCullough had a particular concern about concrete footpaths and other pavements. Local authorities leaned towards in-situ concrete, because, as he understood it, of the greater ease in organizing its construction. One could lay in-situ footpaths with semi-skilled labour. Such paths could be ugly from the beginning, they were unpleasantly glaring in sunlight, and when patched after opening for cables or after

repair showed the new work only too obviously. He believed we should emulate our neighbours, and he quoted Frankfurt, Stuttgart and Paris, where thousands of square metres of precast concrete paving, often in the form of concrete cobbles, were laid right through the centres of the cities. Mr. Ryan had raised a valid question in denying the acceptability of cracking. All understood the argument that housing was in fact very cheap considering the area of construction one purchased and the time one expected it to last for, but the control of cracking was a valid study that should be pursued for Irish practice.

About supervision, it was always necessary, but there were difficulties. Clients were not keen on paying for whole time supervision, and where it was agreed, one could find the resident engineer, if competent, acting more and more as the contractors' quality control officer, with the contractor reducing his own quality control input accordingly. He favoured the development of skilled supervisory engineers and endorsed Mr. Coyle's plea made at an earlier session in that regard. In the Middle East, the practice was for the appointment of a completely independent team, at a fee equal to that paid to the designers, to check the calculations of the design team and to supervise the construction on the site. That was taking site supervision seriously and he believed we should do likewise.

The matter of building regulations and controls was clearly of high interest at present, and he had been surprised to hear in an earlier session that the proposed control bill would not be applied to housing. He personally did not welcome the advent of building regulations. They were inhibitory and unnecessary. A surgeon proceeding to take out one's appendix, an operation that might in building terms be low technology, was not compelled as he opened the abdomen to look over his shoulder to a long list of rules with numerous clauses couched in legalistic language. Instead he did what he did because he had been well trained and because he was registered to practice; and he followed in the various stages of the operation the equivalent of a code of practice. As building designers, it would surely be better for us, rather than hide in regulations, to take the much more independent line of improving our educational standards, certifying only those who were qualified to practise in a particular field of engineering, and then relying much more on codes of practice than on building regulations. If however building regulations were to come, and he had little doubt that they would, then he would say that the best way to implement a control system was by self-certification. The duplication of effort involved in checking the work of a designer, and indeed the danger of that being done by a checker not familiar with all details of the project, made any process other than self-certification hard to justify, except possibly where very complex structures were involved. It seemed to him that the practising engineer, purporting to be a person able to act with due care and diligence in the pursuit of his profession, should be prepared to stand over his work; and that a client engaging him should assume that he was insured if the engineer should turn out

to be negligent. Basically, he believed, that was the way in which the matter of control should be approached.

MR. E. McDONAGH said that the normal practice in the Dublin area would be that all ground floor slabs should be 150 mm thick, and that any control system would expect that that practice was being followed.

MR. T. CONROY made the point that whereas in the late 1970's concrete blocks were being delivered to sites at very tender ages, even less than a week old, because of the dramatic increase in activity at that time, that was not the case now. It was unrealistic to require blocks to be seasoned for three months. There were other factors that contributed to the difficulty of shrinkage control. They included bad storage of blocks in damp conditions on site, and the exposure to rain of partly completed walls. Regarding the use of concrete in footpaths, he suggested to Mr. McCullough that the remedy lay in improving the workmanship rather than in ceasing to use the material. He felt that glare was a subjective matter and that he personally felt that one should put up with glare in sunny weather because of the valuable quality of reflectivity that the concrete surface could give in dull and dark weather.

MR. McCULLOUGH agreed wholly with the improvement of competence urged by Mr. Conroy but wondered how that improvement could be achieved. His comment suggested another form of concrete rather than the exclusion of concrete. He agreed that glare was subjective, and that views would differ.

DR. D. ORR mentioned Dutch lightweight foam concrete blocks used in solid wall construction in Connemara some years ago. They were sawable and were used in walls which were then rendered on the outside. They appeared very effective, and he wondered whether they represented a product that could be developed here.

MR. J. NEWELL said that he had experience of importing at one time the kind of units mentioned by Dr. Orr. There were difficulties in attaining adequate U-values, and they, added to the level of capital investment required to establish the necessary factory, made the proposition not worth while. He believed that two plants involved in that kind of work had closed down in Britain. The problem was marketing rather than technical.

MR. T. McCORMACK found that the level of specification for house construction was often very poor. He had had to deal recently with a specification that included a paragraph purporting to absolve a builder from blame for cracks that might develop in walling or plasterwork in a house, should the future purchaser decide to instal central heating. One wondered what level of understanding speculative builders and

SESSION E

their designers had of the materials they were specifying and using in their work. In a recent court hearing relating to privately built houses, he had been accused by a defence counsel of maintaining too high a standard in his inspections. His reply that he would expect the standards in such houses to be not less than those applying in local authority housing was not further challenged. In that action, he believed the judge inclined to the opinions that cracking was not inevitable and not necessarily acceptable.

MR. M. DONNELLAN gave it as his experience that reinforced foundations generally preserved houses against cracking arising from differential settlement. About other aspects of Mr. Ryan's paper, (i) he recalled that in the early 1960's the then Department of Local Government had specifically forbidden the use of hollow blocks; (ii) he could endorse from his own experience the damage caused by dampness to dry linings; and (iii) he had found at least one builder who would not appreciate that lintels were designed occasionally to act compositely with the blockwork above them. He believed that there was a great need for education, especially for the smaller builders.

PROFESSOR J. de COURCY said that it appeared probable that we would spend a thousand million pounds on housing in the Republic every year for the foreseeable future and that it seemed to him likely that our techniques and methods would be very much the same in twenty years time as they were now. Little imagination was being displayed as to how improvements might be made and how they might be coupled with even small percentage savings in the enormous expenditure involved. He had seen some years ago local authority housing in Luxembourg excellently designed and behaving very well in service. The stairs and first floors in the houses had been invariably reinforced concrete, the stairs being superbly made, from a factory, precast and helical in form. The reason given for this choice of material was economy, steel (in Luxembourg!) and timber would have been too costly, concrete was the cheapest medium available to them. The enhanced fire resistance was not a primary requirement. Whilst it would not be proper in Ireland to hinder the development of our valuable native timber potential, we should be making the slow careful advance back into industrialised building that Mr. Ryan had mentioned, and in particular into the area of component building which he had advocated. Whatever our reliance on blocks and mortar, we, in common with Western Europe, were inevitably facing back to a new era of industrialised building, if only because of the growing demand for "dry work" factory-based employment; and surely an assessed expenditure of a billion pounds merited some directed research. One aspect of our future house building would be the need to build on sites of poor bearing quality, sites which our predecessors shunned. The raft, sometimes in concept, and more often, as built, could be doubtful. It did seem to him that a fruitful area of research could be

into the development of light duty piling, capable of providing economically the strength and stability needed for single houses and for pairs of houses.

DR. B. MURPHY believed that architecture and engineering in many parts of Europe had suffered some serious setbacks in the last thirty years through rushing too quickly into practice with innovative and insufficiently tested new ideas. The thorough testing of new ideas was a function of research and the building industry compared for instance with the pharmaceutical industry put an appallingly low effort into research. If we were to take the cost of just ten of the thirty thousand houses we built each year, that would be £300,000, we could employ indefinitely a team of thirty junior professionals or fifteen seniors, or a mixture, on whole-time research into the development and testing of improved housing techniques. He could not understand how the logic of that approach escaped the industry or indeed the national economists.

MR. N. J. O'GORMAN reminded the symposium that housing was a politically sensitive industry. The hollow block, which was surely going to cause us trouble of perhaps crisis proportions when the houses of the sixties and seventies reached an age of about thirty years, should have been banned early in the seventies. However because an alternative would have cost more, and because the principal financiers of housing in the private sector, the building societies, were interested only in the survival of houses for 25 to 30 years, by which time mortgages would have been cleared, it was decided that the hollow block should continue to be used. He believed that the professions in the building industry should make the policy makers aware of the extreme likelihood of a durability problem arising and should in general make the community aware of the requirements of long-term durability.

MR. P. PIGOTT taking up earlier comments said that whilst he of course would welcome an increased investment in building research, there was, he believed, a step which should be taken even earlier. The defects that Mr. Ryan had found resulted from faulty workmanship, not from the basic techniques which were very well known. The first need was to educate builders in using the well-known techniques properly. There appeared more need for education and training in building to ensure that such techniques were being used in an adequate manner.

MR. T. CONROY agreed with Mr. Pigott. The symposium was not aware of the misunderstanding of the basics of concrete technology and practice that existed in the national work force. He lectured about fifty times each year on basic technology to small builders and farmers and found them very uncertain, amongst other things, about the significance of water in concrete, and the merits of curing. As Mr. Pigott had said the problem today was far more a matter of conveying existing information to users than of doing more research.

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MR. RYAN replied to the discussion.

He agreed with Mr. McDonagh that the requirement in the Dublin area was for 150 mm thick concrete ground floor slabs but it seemed to him that it was far from being the practice on sites he had visited in the speculative end of development in Dublin. In reply to Mr. Conroy, he was quite satisfied that unseasoned concrete blocks were being used at present, and that the length of seasoning too often depended merely on what was available when a consignment was to be delivered, and that was not good enough. He would not venture to dictate how old blocks should be before use, but evidence from the United States had suggested an age of perhaps three months. He noted that Mr. Newell had replied to Dr. Orr about the manufacture of light-weight blocks.

There were clearly occasions when foundations needed reinforcement, but he could not go so far as to say that it need always be used. Sometimes in fact the foundation itself was scarcely required. He fully accepted the point made by Mr. Donnellan about composite action. The difficulty lay in the difference between a craft industry, as building was, and the newer component industry in which builders did not understand the action of components. He believed that the understanding would develop over the years. In the matter of research, he would have hoped that the relatively stable market for house building would have encouraged some investment in development and he knew that An Foras Forbartha and the educational establishments would offer to assist. Many inferior practices on site, or rather in some instances, malpractices perpetrated by those who did know better, were not however a problem for research but rather a case for more honesty on the part of the builder and for better control on behalf of the prospective occupier. Many of the problems of the sixties and seventies related to greed, carelessness, and poor control, more than to the introduction of new techniques. It seemed clear to him that these particular problems would continue until the nettle of control had been grasped, and there seemed little evidence of a national interest in doing just that.

THE CHAIRMAN in closing the session referred to the 72,000 houses in the country that were reported as unfit for human habitation. One would assume that most might be rehabilitated rather than knocked down and the question then had to be asked as to what use could be made of concrete in the reconstruction. Concrete for floors seemed obvious and concrete could replace natural slates in the roofs; and probably other uses could be developed. He agreed that prefabricated building must come. Undoubtedly it had fallen into disfavour, due partly to its ugliness, and whether the future was to lie in whole prefabricated houses or in components, it was vital that a far higher design element, in engineering as well as in architecture, be introduced to

housing development. The present design input into housing nationally was pitiable.

He had been interested in the comments made on concrete pavements. There had been a decline in the use of concrete in road construction in recent years, and he wondered to what extent that had to do with the appearance of the concrete surfaces. In the more general use of concrete in building, he understood that the level of wastage of concrete products could be as high as 10%. Such a proportion would appal him. If it could be, surely the industry should be examining way to reduce it.

On the topic of research, the symposium might recall that the Construction Industry Federation had, in 1984, endowed with £10,000 a National House Design competition under the National Housebuilding Guarantee scheme. It had been monitored by the Department of the Environment and the Royal Institute of the Architects of Ireland and he believed that that represented research and funds well spent.

MR. P. FAGAN in a written contribution noted that Grade 10/40 concrete was not now being generally specified for foundation concrete, and concrete with 40 mm aggregate was not now supplied by ready-mixed concrete firms except on special order. In his opinion, minor cracking could occur in housing even with good building control. Tenants or owners of houses should not be led to believe that minor cracks had major significance, as many did believe, and should recognise that most minor cracks could be successfully repaired.

On the question of infill under house floors mentioned by Mr. Ryan, it was of interest to note that the National Housebuilding Guarantee Scheme allowed that infill to be up to 900 mm deep. Also Mr. Ryan had referred to the Defective Premises Bill. That Bill which applied only to housing in the U.K. proposed to refer to all buildings in Ireland. He did not fault the ideals of the Bill but deprecated the limits to which it had been taken. It was attempting to create legislation for building design and construction similar to that which applied to completed manufactured goods, and there was little parallel between the two. To hold otherwise would be to misunderstand the philosophy and principles of the engineer in relation to his work and the contractual relationships involved in building. He believed that Bill could considerably damage the building industry and hoped it would not become law in its present form.

SESSION F

CONTEMPORARY IRISH BRIDGE PRACTICE

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1. INTRODUCTION

The earliest concrete bridges in Ireland were built at the beginning of the century.

A typical example is Redmond Bridge in Waterford, first opened to traffic in 1913. It contains twelve fixed spans of 46 feet each and a central opening span of 80 ft.

The deck has deteriorated badly in recent years and the bridge is currently being replaced. Distress was displayed in the form of spalling of soffits of beams and slabs and corrosion of the steel.

It is of some interest to note here that if :

- (a) better quality concrete had been provided;
 - (b) better technique of providing shear steel were known at the time;
 - (c) more attention to concrete cover had been given;
- then, it is possible, the useful life of this bridge would have been extended for many more years.

Another bridge of this period was Hartley Bridge in Roscommon. This bridge crosses the Shannon about 2 miles north of Carrick-on-Shannon and consists of 6 spans totalling 62 metres. Construction is beam and slab deck spanning transversely between longitudinal parapet beams about 5 m apart. The deck is supported on braced columns.

Extensive spalling of the concrete has occurred and a 5 tonne weight restriction has been recommended. By to-day's standards, the structure would be considered excessively light and grossly under reinforced in almost all elements.

2. CONCRETE BRIDGES

From this period, more and more bridges were built in concrete with the exception perhaps of railway bridges. Certainly over the past 40 to 50 years, practically all highway bridges have been in concrete. This is understandable when we consider the abundance of natural aggregate available, the production of Irish cement, and the relatively maintenance free properties of concrete.

3. BRIDGE DECK TYPES

The types of concrete bridge decks commonly in use are outlined in diagram form on the following pages. The most common types are as follows :

- (a) reinforced concrete deck slabs for spans up to 12-14 m;
- (b) infilled precast prestressed inverted T beams for spans up to 15 m;
- (c) precast prestressed M beams for spans up to about 28 m depending on haulage.

Since over 90% of all bridges in the Republic are short span, a large part of the practice up to recent years has centred on the above three types. The development by the MOT/CACA of a range of precast prestressed beams up to 28 m span has influenced to a considerable degree the type of bridge deck in use. It is unusual now to see a RC T-beam structure although this type was common in the 1940's and even 1950's. The popularity of the precast beam deck is due to the following :

- (1) costly falsework over railways and rivers — and even over dry ground — is eliminated.
- (2) speed and simplicity in erection;
- (3) design basis is readily available from tables or data furnished by MOT/CACA or by manufacturers of prestressing cables. This reason is by no means the least of the reasons for their popularity. Furthermore, in most cases, designs may be carried out manually, although a wide range of computer programmes is available.

(a) Reinforced concrete deck slabs

Fewer of these are seen nowadays. They are being ousted except in the very short spans by inverted T beams. In some cases at least, particularly over dry firm ground, they are likely to prove more economical than precast work.

One of the factors militating against their use has been the almost paranoid occupation with shear in reinforced concrete since the publication of BE 1/73 in 1973. In this document, allowable shear stresses were reduced considerably below C.P. 114 figures. This generally resulted in thicker slabs than normal or in increased quantities of tensile steel, or both.

It was hoped that the latest edition of BS 5400 would offer some improvement, e.g. by permitting enhancement of shear resistance near supports, but this has not materialised.

A variation of the solid reinforced slab is the voided RC slab, in an effort to reduce the large self weight effects. In most cases however the benefits are largely reduced by the cost of the void formers and the need to tie them down during concreting.

(b) Infilled inverted T-beams

These have proven to be the most popular of all bridge decks and are particularly suitable over rivers and railways, up to about 14-15 m span. These have also been the subject of some concern regarding shear using design methods of BE 2/73, but again modifications in the recent issue of BS 5400 : Part IV may have largely removed the problem, depending on interpretation.

The range of these beams has been increased somewhat in the past few years by the inclusion of T-8, T-9, and T-10. These are formed by the addition of increments of 40 mm to the top flange up to a maximum depth of 815 mm.

The writer has no experience of these larger beams. One must presume that the dead load effect of the infill concrete would be severe and some form of voiding would be essential to obtain benefit from the increased depth of beam. Most designers would probably prefer the use of M-2 and M-3 beams, in lieu of the T-8, T-9 and T-10.

A variation of the inverted T Beam is the inclusion of voids between beams although this form is not commonly used. Since a large part of the strength of beams is absorbed by the dead weight of the infill concrete, the inclusion of voids offers additional scope in increasing spans.

(c) M-Beam decks

These are widely used for the longer single span bridges up to 28 m, and also for the common four spans over motorways. There are two types :

- (i) Pseudo-box decks with transverse steel through slots in the bottom of the webs of the beams. This steel is encased in concrete about 50 mm thick to form a bottom slab which improves the distribution properties of the deck.
- (ii) Beam and slab decks (1). This form omits the bottom slab but as in (I) above, end diaphragms are required. The distribution properties of BM, and shear are not as good as in the pseudo-box and consequently a deeper beam is required. Contractors seem to see the provision of bottom steel and concrete as troublesome and time consuming and prefer the simple beam and slab deck.

It is of some advantage to make multispan M beam decks continuous for live load at the supports. In addition to a reduction of live load moments, the number of undesirable deck joints e.g. in a four span deck is reduced from five to two. Some secondary effects from this continuity occur. Where a continuous diaphragm is placed over a support, sagging moments are developed due to restraint of shrinkage and creep and appropriate reinforcement must be provided in the bottom of the diaphragms between the beams.

Continuity also will often increase the longitudinal load applied to the supports. The longitudinal load appropriate for HA loading to a 20 m loaded length is 360 kN but for a 63 m loaded length is 700 kN.

However, many bridge engineers prefer to rely on simply supported determinate structures and hence continuity using precast beams has not been used frequently, here.

Other forms of bridge include :

(d) Beam and slab decks

In this form discrete precast I beams are used, normally, at approximately 1.5 m centres with a top slab of about 300 mm thickness. This

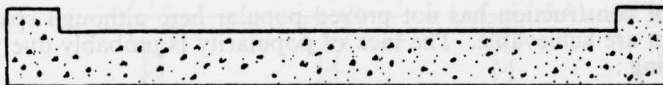
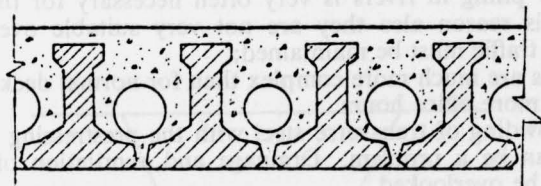
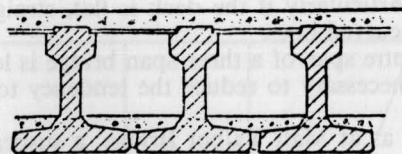
FLAT SLABINVERTED T BEAMVOIDED INVERTED T BEAMM BEAM PSEUDO-BOX

FIG. 1

SESSION F

form of construction has not proved popular here although spans up to 36 m are achievable. The lack of popularity is probably due to the following :

- (i) beams are usually extremely heavy and long; they are cast close to the site and post tensioned;
- (ii) formwork for deck slab and diaphragms is difficult;
- (iii) intermediate diaphragms, normally 5 total, are necessary;
- (iv) very deep sections are used, at least 1500 mm depth of precast section, for the spans not catered for by the M beam sections. Examples are Dillon Bridge, Carrick-on-Suir, and Kilcarne Bridge near Navan.

(e) Box girder decks for spans over 25 m

Box girders take many shapes and forms depending on width required, the width of cantilevers and the slope of the external ribs.

They have not been popular in the Republic and the writer knows of only three examples, Scarawalsh Bridge in Wexford, Boyne Bridge in Drogheda and Maudlins Bridge, Naas. Their lack of popularity may be due to the following :

- (i) expensive and difficult formwork including the internal sides of boxes and deck soffit;
- (ii) demanding nature of falsework; dead loads are usually very heavy requiring unyielding supports during construction; temporary piling in rivers is very often necessary for this purpose; for this reason also they are not very suitable over highways where traffic must be maintained;
- (iii) designs are much more complex than for normal decks, requiring many more office hours.

The crowding of transverse steel with the prestressing cables over supports can be a problem. Drainage and ventilation of the boxes should not be overlooked.

(f) Decks of varying section

Examples of these are Matt Talbot Bridge and Frank Sherwin Bridge in prestressed concrete and reinforced concrete respectively.

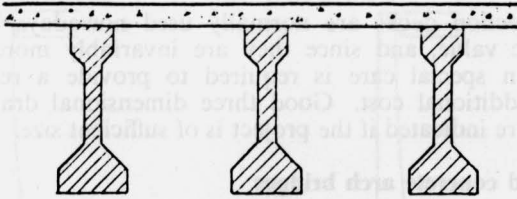
A curved soffit with thickened haunches at the supports is regarded as the classical shape for three span bridges. If correctly proportioned they usually look better than straight beam decks.

Sometimes, particularly if the deck is flat, straight haunches may look better than curved ones.

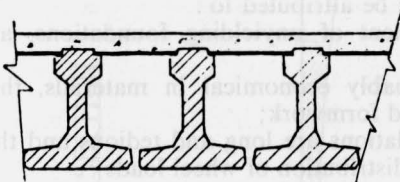
Where the centre span of a three span bridge is long, some form of voiding may be necessary to reduce the tendency to uplift at the end supports.

Occasionally, as at Matt Talbot Bridge, a suspended span is used to suit precasting and avoid costly falsework, and also to facilitate articulation of the deck.

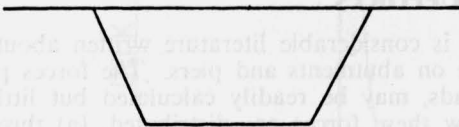
Continuous spans in reinforced concrete are limited to about 18 m if very heavy sections are to be avoided.



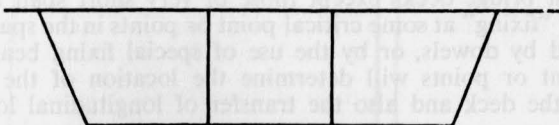
BEAM & SLAB



BEAM & SLAB - M BEAM



BOX GIRDER



MULTI-CELL BOX GIRDER

FIG. 2

Varying section decks are normally used nowadays because of their aesthetic value, and since they are invariably more costly to construct, then special care is required to provide a result which justifies the additional cost. Good three dimensional drawings, and even models are indicated if the project is of sufficient size.

(g) Reinforced concrete arch bridges

These are suitable for spans up to 20 m depending on the rise available. Sometimes they are faced in masonry and appear as masonry arches.

There are not many examples in the country but Tullamore Canal Bridge, Spiddal Bridge in Galway and Ballinacargy Bridge in Westmeath come to mind.

This scarcity may be attributed to :

- (i) the requirement of unyielding foundations, at least for fixed arches;
- (ii) while reasonably economical in materials, they are costly in falsework and formwork;
- (iii) design calculations are long and tedious and there is little guidance on the distribution of wheel loads;

In general, however, where good foundations are available, because of the economy of materials, the cost is not that much greater than for other bridge types, and where the site demands an arch bridge, then they are well worth the endeavour.

An excellent example is the bridge at Spiddal in Galway, faced in masonry and with masonry parapet walls.

4. BRIDGE SUPPORTS

While there is considerable literature written about decks, much less is available on abutments and piers. The forces produced from longitudinal loads, may be readily calculated but little guidance is given as to how these forces are distributed, (a) through the deck itself to the supports and (b) through the supports to the footings. The problem is aggravated somewhat in B.S. 5400 by the necessity to examine nominal loads, service loads and ultimate loads in the various combinations.

4.1 Abutments

In most bridge decks except those of very short span the deck is located by "fixing" at some critical point or points in the span. "Fixity" is achieved by dowels, or by the use of special fixing bearings. The fixing point or points will determine the location of the expansion centre of the deck and also the transfer of longitudinal loads to the supports.

For the normal bridge site, abutments here are generally of three types.

- (a) strutted, or vertical beam type;

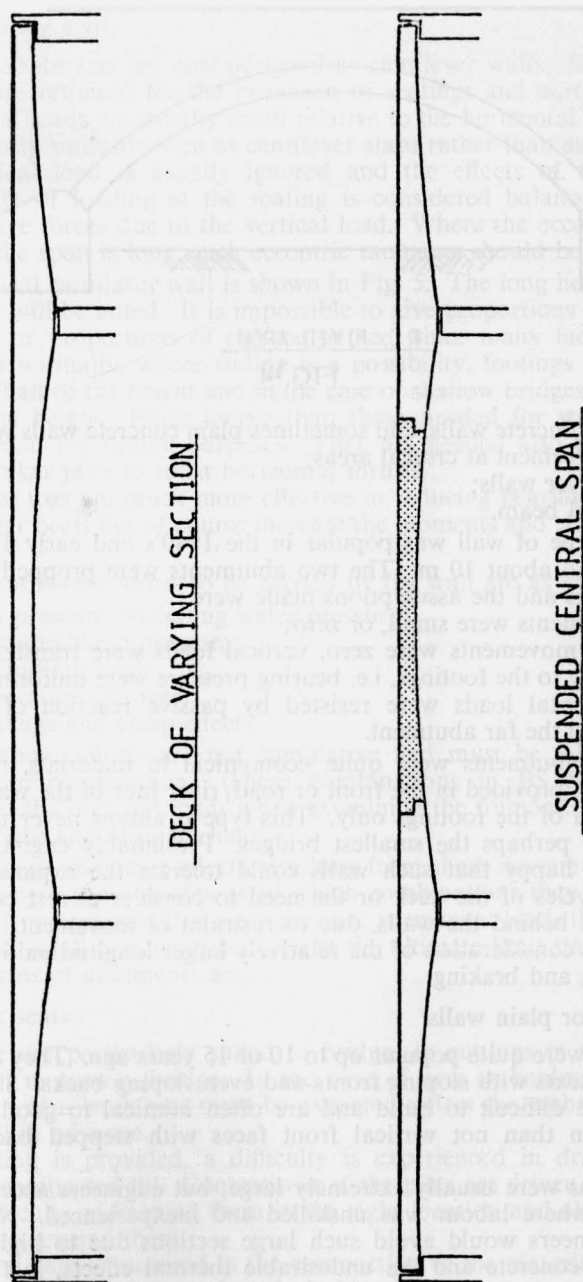


FIG. 3

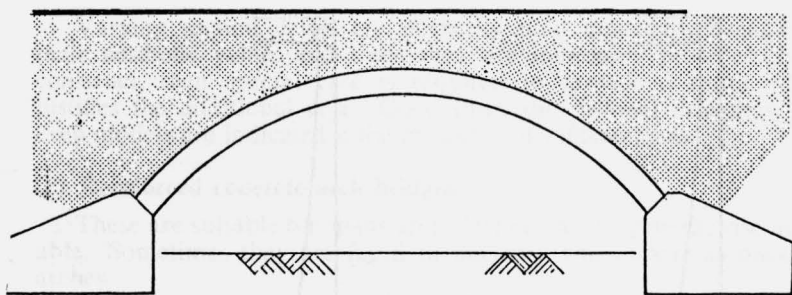
R.C. FIXED ARCH

FIG. 4

- (b) mass concrete walls, and sometimes plain concrete walls with some reinforcement at critical areas;
- (c) cantilever walls;
- (d) vertical beam.

This type of wall was popular in the 1940's and early 1950's for spans up to about 10 m. The two abutments were propped apart at the seatings and the assumptions made were :

- (i) movements were small, or zero;
- (ii) since movements were zero, vertical loads were transferred uniformly to the footings, i.e. bearing pressure were uniform;
- (iii) horizontal loads were resisted by passive reaction of the soil behind the far abutment.

These abutments were quite economical in materials, reinforcement being provided in the front or road/river face of the wall and in the bottom of the footings only. This type is almost never used now except for perhaps the smallest bridges. Presumably engineers were no longer happy that such walls could tolerate the expansion/contraction cycles of the deck or the need to consider at rest conditions of the soil behind the walls, due to restraint of movement. Another factor was consideration of the relatively larger longitudinal loads due to traction and braking.

- (b) Mass or plain walls

These were quite popular up to 10 or 15 years ago. They are often shown in texts with sloping fronts and even sloping backs. Since such batters are difficult to build and are often inimical to good finishes, more often than not vertical front faces with stepped backs were favoured.

Sections were usually extremely large, but engineers accepted this situation where labour was unskilled and inexperienced. Nowadays most engineers would avoid such large sections due to high cost of providing concrete and the undesirable thermal effects, in favour of reinforced concrete walls.

(c) Cantilever walls

Most abutments are now designed as cantilever walls. Since thick sections are required for the provision of seatings and curtain walls, the vertical loads are usually small relative to the horizontal loads and consequently walls are seen as cantilever slabs rather than as columns. The vertical load is usually ignored and the effects of any small eccentricity of loading at the seating is considered balanced by the compressive forces due to the vertical load. Where the eccentricity is large or the span is long, such eccentric moments should be included.

A typical cantilever wall is shown in Fig. 5. The long heel relative to the toe will be noted. It is impossible to give proportions of footing to height or proportions of the toe to heel since many factors alter these, but normally, where sliding is a possibility, footings will be at least one half of the height and in the case of shallow bridges may well exceed the height. Heels longer than those needed for stability are often needed for sliding purposes. They are needed also to develop load on raker piles to resist horizontal thrusts.

Longer toes are much more effective in reducing bearing pressures than longer heels but of course increase the moments and shears in the toe.

The horizontal forces to be carried by the wall are as follows :

- (1) earth pressure (including water pressure);
- (2) traffic surcharge pressure;
- (3) longitudinal load;
- (4) temperature changes;
- (5) shrinkage and creep effects.

The above effects are not cumulative and must be taken in the appropriate combination. These combinations in BS 5400 apply equally to the nominal loads when examining the foundations as they do to service and ultimate loads.

Shrinkage and creep effects, resulting from shear movements of the bearings, pose some doubts as to which combinations they should be used in. It is suggested that since they are permanent loads they should be applied in all combinations even at the ultimate limit state.

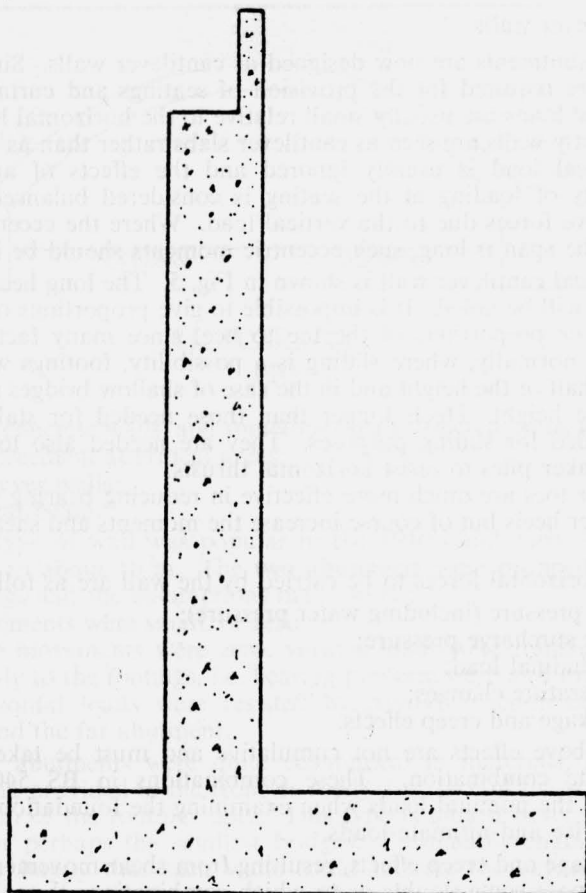
Other forms of abutments are :

(d) Bank seats

These are particularly suited to bridges in cuttings in the typical four span motorway bridge. In the case of new embankments some settlement of a bank seat must be expected unless the embankment is built well in advance.

If piling is provided, a difficulty is experienced in driving piles through compacted fill. Contrariwise if the piles are driven first, there is the difficulty of keeping them in the right location and also of compacting fill around them.

Special care is required in the compaction of the material near the slope under the bank seat. It is desirable also in these cases that bank



Cantilever Abutment

FIG. 5

seats are not so shallow that future access to the bearings becomes almost impossible.

(e) Skeleton or open type abutments

The fill is permitted to flow through the piers or columns. Ideally the capping beam should be delayed until most of the fill has been placed and compacted. Sometimes columns are carried up to a capping beam as extensions to piles. Compaction of fill is a problem and if the subgrade is soft the results can be unhappy, the fill visibly settling away from the columns.

(f) Box culvert and U-type structures

In soft ground where the span is short, box or U structures are sometimes used. Where piles are indicated, they are placed under the walls and propped apart by the bottom slab. Unfortunately in river bridges, drainage requirements may depress the bottom slab unduly, or rule it out altogether.

4.2 Piers

As distinct from abutments, designers often attempt to introduce some variations in shape of piers other than a rectangular wall support. Piers may be tapered upward or downward, V shaped, and even twinned. In general most piers in this country have been simple rectangular walls, sometimes tapered and occasionally with openings or "windows".

In many cases of bridges over highways particularly over motorways, head on views of the bridge only are presented and the proportions of thickness of pier to depth of deck are more important than internal shapes of the pier.

Piers of unduly thick section are sometimes forced on the designer because of the nature of the deck. A multi-span M beam deck will require a very wide seating particularly if skewed. Such a pier may be improved by downward taper, or corbels, or bearer beam.

Pier design is largely influenced by articulation of the deck. In a two span or four span continuous deck the central pier is ideally "fixed" when it will carry the longitudinal load only in addition to vertical loads. The other piers will carry temperature, shrinkage and creep effects only, unless the central pier is quite flexible. Alternatively if there is an expansion joint across the central pier, it will carry no horizontal load, the two abutments carrying the full longitudinal load separately.

Where it is required to remove "fixing" from end abutments in a continuous deck—e.g. with bank seats—fixing may occur at one or more piers. In these cases, the longitudinal load attributable to each fixed pier for HA and for HB loading is proportional to the relative stiffness of the piers. The vertical load on each pier is derived from the influence line for the pier reaction, as is the loaded length for the assessment of HA load. In this matter it should be noted that the longitudinal load in B.S. 5400 may be as high as 700 kN depending on the loaded length.

Since the vertical load and the horizontal load will change for HA and HB loading, and also will change with loaded length, a number of calculations may be necessary to assess the most critical condition in any support.

If spans are long it may be worthwhile considering the relief of shrinkage and creep effects — and perhaps some of the temperature effects — by jacking the deck off its supports before finishing. At least half of these effects may be relieved in this way depending on the time lapse. It may be desirable to mention here the desirability of

making provision for future jacking to replace defective bearings. This is a matter that we seem to have neglected in the past.

In regard to foundations it is inadvisable to use different forms of construction under the supports, particularly in continuous construction. The differential settlement of abutments and piers may result in structural problems and sometimes in visual problems. A severe example of this is Wexford Bridge where some of the supports were piled and others not. Although the deck is not continuous, severe down drag deflections have occurred through the keyed joints in the deck.

Finally attention is drawn to the need in the new code BS 5400 to protect all bridge supports where speeds over 80 Km/hour are permitted. The supports must be able to sustain the specified collision loads, and in addition must be protected by safety fences.

5. PILING FOR ABUTMENTS AND PIERS

5.1 General

Bridge engineers' approach to piling varies widely. Some, because perhaps of a poor experience in the past, prefer to avoid them if at all possible. Others will use them where there is any doubt about the foundations.

A second difference of approach is in methods of design of pile groups. Some use vertical piles only relying on subgrade reaction to resist the horizontal thrusts. Others use simple statical methods with only two rows of piles, with one row raked. Others again, and these seem to be in the majority, use the Elastic Centre method using at least three rows of piles but with two directions only. Where there are more than two directions some form of computer programme is used.

A third difference in approach is in the selection of pile type. Many engineers seem to have a favourite pile type. This is understandable when we consider the possible number of bridges dealt with in any one office and the numbers of these involving piles. In most cases now, the driven precast concrete or steel pile is much more popular than formerly when the bored pile was common. Noise and vibrations are rarely problems in bridges except perhaps the occasional city or town bridge.

The precast pile is favoured for a number of reasons:

- (i) piles may be visually examined before driving;
- (ii) preliminary piles may be driven and test loaded rapidly;
- (iii) the set achieved gives some assurance that the pile is reasonably satisfactory;
- (iv) working piles are usually more quickly placed and driven, than say, bored piles;
- (v) larger batters can be provided than with bored piles.

For these reasons again and also for cost reasons, the precast concrete segmental pile is now widely used.

Hambly in "Bridge Foundations and Substructures" deals admirably with the pros and cons of design methods and usage and this reading is recommended.

In particular he highlights the problem of horizontal movement of soft subgrades below new embankments. Furthermore in addition to negative skin friction on the piles, there is the vertical loading on back rakers due to the settling subgrade.

Engineers resort to a variety of solutions in these cases and these include :

- (1) propping from opposite abutments or pier;
- (2) provision of piles strong in flexure and shear;
- (3) "dead men" or ground anchors coupled with vertical piles of slender section; piles are sometimes coated with special bitumen to reduce friction;
- (4) solution (3) with sheet piling acting compositely with vertical H piles;
- (5) soil stabilisation.

In acute cases of this problem, i.e. where there are deep soft compressible subgrades, it is advisable to consult with a specialist with soil/piling experience. Such consultations can save considerable cost and embarrassment later.

5.2 Elastic centre method of design

Because of its simplicity and because of the conservative results obtained, this method is widely used. Care must be taken that *all* loading cases are examined. A layout of piles may well prove ideal for say maximum vertical and maximum horizontal loading and be totally unsuitable for other loadings. It should be remembered that the horizontal thrusts may not exist or have much reduced values.

5.3 Test loading raker piles

Hambly places emphasis on the need to test raker piles rather than the alternative of test loading similar vertical piles. Obviously this is sound advice when using bored piles or any form of cast-in-situ pile.

The most common form of pile currently being used in bridges is the segmental precast pile. Where all rakers are being used it is common practice to test load a preliminary non-working vertical pile. The cost of test loading a raker pile is two or three times the cost of test loading a vertical pile and is much more time consuming. Since in these cases the capacity of the pile itself is not in question and since the pile is loaded to 2.5 times the working load, a good result must indicate the likelihood of a good result with a raker pile. Some precautions are however necessary.

- (a) The preliminary piles should be in the same ground as the working piles.
- (b) The driving of both test piles and working piles should be carried out preferably by the same machine or at least by similar machines. This may appear to be obvious, but contractors will on occasions move a machine to another site in the necessary event of there being an interval between driving of test piles and driving of working piles.

- (c) The depth of penetration should be approximately the same for test and working piles, allowing for the rake of the piles.

6. LOADING

- 6.1 All concrete bridges have been designed to U.K. standards from the beginning. The only exception to this might be in the number of units of HB loading applied.
- 6.2 Up to about 1953 the loading was M.O.T. standard equivalent loading of 220 lb per sq. foot with a knife edge load of 2700 lb per ft. width. There was a concentration of uniform load below spans of 10 feet and a gradual reduction over 75 feet.
- 6.3 B.S. 153 : 1954 introduced the concept of HB loading. The HB load consisted of 4 axles up to 450 kN/axle or 112.5 kN/wheel.
- 6.4 The loading in the U.K. was as follows.
 - (i) Motorways and Special Roads—45 units HB.
 - (ii) Class I and Class II Roads—37.5 units HB.
 - (iii) Class III and other Roads—HA only.
 HB occupied one lane while all other lanes were deemed to be occupied by $\frac{1}{3}$ HA.
- 6.5 The general principle was accepted here but maximum loading was 35 units HB.
- 6.6 BE 5/73 made minor changes in this loading but much more drastic changes were to follow with BE 1/77.
- 6.7 In BE 1/77, the increased loading in the shorter spans was removed but all public road bridges were now subject to check for at least 30 units HB loading.
- 6.8 B.S. 5400 : 1978 introduced some minor changes but these were altered again by BD 14/82, a document from the U.K. Department of Transport. The main changes were as follows :
 - (i) on undivided bridges, any two lanes could be loaded with full HA in addition to HB in one lane; all other lanes would be loaded with 0.6 HA;
 - (ii) even accommodation road bridges needed checking for 25 units HB.
- 6.9 It will be noted that all bridges now needed checking for HB loading.
- 6.10 The present loading in Ireland is as follows :
 - (i) National Roads — 45 units HB.
 - (ii) Regional Roads — 37.5 units HB.
 - (iii) Other Roads — 30 units HB.
- 6.11 It will be concluded from above that :
 - (i) The loading has steadily increased over the years.
 - (ii) HB has entered into all road bridges and HA has become almost a secondary loading. However it must not be concluded from this statement that HB effects always exceed HA.

7. ENGINEERS AND BRIDGES IN IRELAND

The involvement of Irish engineers in bridges over the past thirty years or so has been rather low key. This has been due to a number of factors.

- (i) The numbers of large bridges to be built were quite few. One can count on one's hands the number of these — such bridges as Wexford Bridge, Valentia Bridge, Lifford Bridge, Boyne Bridge (Drogheda) were rare and well spaced apart !
- (ii) There were no motorways and consequently no grade separation so that over bridges were rare.
- (iii) Railway, overline bridges were generally of short span and since roads were commonly two lane only, bridges were also narrow.

This situation was obviously not conducive to great activity amongst consulting engineers since the amount of work coming their way was small and very often spaced. Consequently expertise in bridge design was at a premium.

This position has changed rather dramatically over the past five years or so. With the promotion of such projects as the Naas Bypass, An Droichead Nua Bypass, Santry Bypass, Airport Road, Corrib Bypass, Galway, Athlone Bypass and Western Parkway, Dublin, there is almost a new "glut" of bridges to be built.

Hand in hand with this change in the scene is the arrival of the new code BS 5400, a limit state code with which many of the older bridge engineers will not be familiar. It is understood that the D.O.E. in Ireland encourage, if not require, the application of the new code to new bridges.

These two developments—a surge in bridge building and the advent of a new code—present somewhat of a challenge. The numbers of skilled bridge engineers in the country are relatively few, so that in the writer's opinion there is somewhat of a vacuum to be filled. Undoubtedly sufficient engineers will be drafted into this area to meet the demand.

Mention may be made here also of the situation regarding bridge engineers in the Local Authorities. Only in a few Local Authorities is there a recognised engineer in charge of bridges. This situation has pertained since the beginning of the Local Authorities and is obviously an unhealthy one. Our heritage of sturdy masonry arch bridges which seems to go on and on even where neglected, has not helped to bring bridge engineers forward in the Local Authorities. The major difficulty here is the creation of some establishment within which engineers can make a career. Promotion to the top ranks is more easily achieved and more certain from the other departments of roads, sanitary services, etc. Whatever can be done should be done — the matter is one of importance.

8. SHEAR IN REINFORCED CONCRETE

Shear resistance, whether in reinforced or prestressed concrete, has been the focus of much attention over the past twenty years or so.

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This concern arose from research by the University of Illinois about 1959 and by the Shear Study Group of the Institution of Structural Engineers.

The changes arising from these studies have caused some confusion and even dismay to bridge engineers. The first direct indication of major changes came in BE 1/73, although these changes had to some extent been heralded by C.P. 110 : 1972.

The main clauses were as follows :

8.1 BE 1/73

8.1.1 Reinforced concrete beams

The allowable shear stresses in the concrete were more or less as before, but shear links were governed by the following :

- (a) where $v > v_c$ all the shear was carried by shear links, as before;
- (b) where $v < v_c$, 2/3 of the shear was carried by shear links, where formerly nominal links only were required.

Enhanced shear resistance due to concentrated loads near supports did not apply.

8.1.2 Reinforced concrete slabs

Three principal changes were made.

- (a) The allowable shear stresses without shear reinforcement, were considerably reduced and depended on the amount of longitudinal tensile steel. The permissible stresses are shown in Fig. 6.
- (b) Enhancement of shear resistance near supports for concentrated loads was permitted, provided the concentrated load formed 70% of the total shear.
- (c) Increase in the basic shear stresses was permitted for slabs below 250 mm thick.

The rather low basic stresses often lead to more tensile steel for shear, than for flexure, particularly when using high yield steel which is far more common now than mild steel. The graph in Fig. 6 illustrates the large increase in steel required for a relatively small increase in shear stress.

The enhancement in (b), while useful in bases and footings, was rarely or never usable in deck slabs since concentrated loads would not normally reach 70% of the total shear.

8.2 B.S. 5400 : 1978

The arrival of BS 5400 did nothing to alter the exacting requirements for shear, but a different approach was outlined for beams and slabs.

8.2.1 Reinforced concrete beams

- (a) The ultimate shear stress v_c in beams, as in slabs, was now as in C.P. 110, dependent on the percentage of tensile longitudinal reinforcement.
- (b) Enhancement was now permitted in beams due to concentrated loads, but with the 70% proviso.

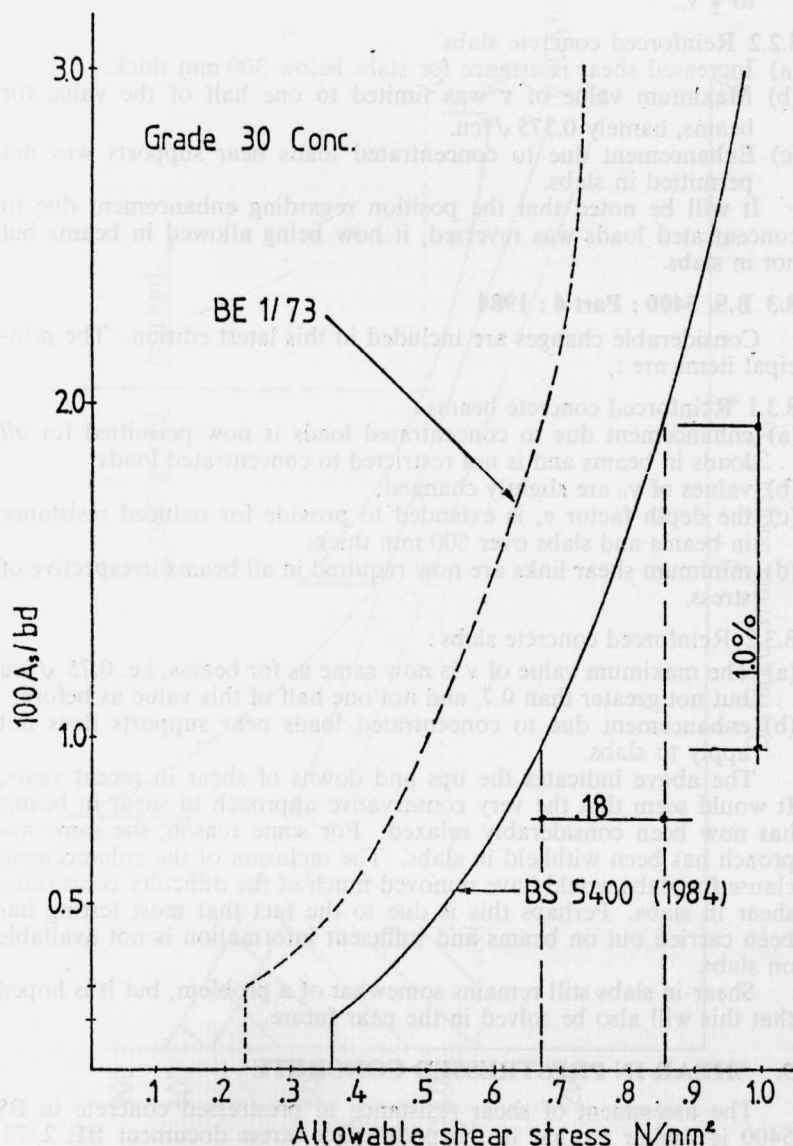


FIG. 6

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- (c) Shear links were to be provided when v was greater than or equal to $\frac{1}{2} v_c$.

8.2.2 Reinforced concrete slabs

- (a) Increased shear resistance for slabs below 300 mm thick.
(b) Maximum value of v was limited to one half of the value for beams, namely $0.375 \sqrt{f_{cu}}$.
(c) Enhancement due to concentrated loads near supports was not permitted in slabs.

It will be noted that the position regarding enhancement due to concentrated loads was reversed, it now being allowed in beams but not in slabs.

8.3 B.S. 5400 : Part 4 : 1984

Considerable changes are included in this latest edition. The principal items are :

8.3.1 Reinforced concrete beams :

- (a) enhancement due to concentrated loads is now permitted for *all* loads in beams and is not restricted to concentrated loads;
(b) values of v_c are slightly changed;
(c) the depth factor e_s is extended to provide for reduced resistance in beams and slabs over 500 mm thick;
(d) minimum shear links are now required in all beams irrespective of stress.

8.3.2 Reinforced concrete slabs :

- (a) The maximum value of v is now same as for beams, i.e. $0.75 \sqrt{f_{cu}}$ but not greater than 0.7, and not one half of this value as before;
(b) enhancement due to concentrated loads near supports does not apply to slabs.

The above indicates the ups and downs of shear in recent years. It would seem that the very conservative approach to shear in beams has now been considerably relaxed. For some reason, the same approach has been withheld in slabs. The inclusion of the enhancement clause for slabs would have removed much of the difficulty concerning shear in slabs. Perhaps this is due to the fact that most testing has been carried out on beams and sufficient information is not available on slabs.

Shear in slabs still remains somewhat of a problem, but it is hoped that this will also be solved in the near future.

9. SHEAR IN PRESTRESSED CONCRETE

The assessment of shear resistance in prestressed concrete in BS 5400 is similar to that in the permissible stress document BE 2/73, both requiring examination under ultimate loads in the uncracked and cracked conditions.

In both, unfortunately, the calculations are fairly tedious. Results for a 23 m span using M-7 beams in a pseudo-box, are shown in Fig. 7.

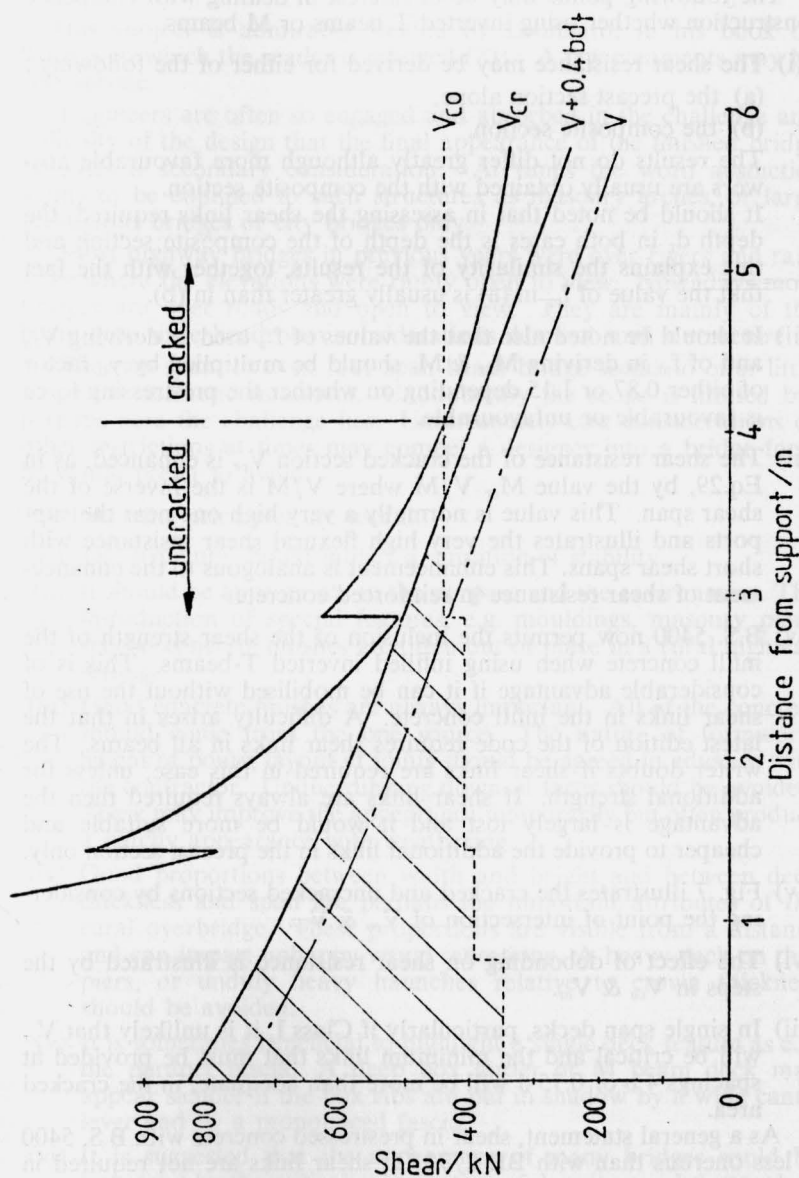


FIG 7

The following points may be of interest in dealing with composite construction whether using inverted T beams or M beams.

- (i) The shear resistance may be derived for either of the following :
 - (a) the precast section alone,
 - (b) the composite section.

The results do not differ greatly although more favourable answers are usually obtained with the composite section.

It should be noted that in assessing the shear links required, the depth d_t in both cases is the depth of the composite section and this explains the similarity of the results, together with the fact that the value of f_{cp} in (a) is usually greater than in (b).

- (ii) It should be noted also that the values of f_{cp} used in deriving V_{co} and of f_{pt} in deriving M_{cr} & M_o should be multiplied by γ_n factor of either 0.87 or 1.15 depending on whether the prestressing force is favourable or unfavourable.
- (iii) The shear resistance of the cracked section V_{cr} is enhanced, as in Eq.29, by the value $M_{cr} V/M$ where V/M is the inverse of the shear span. This value is normally a very high one near the supports and illustrates the very high flexural shear resistance with short shear spans. This enhancement is analogous to the enhancement of shear resistance in reinforced concrete.
- (iv) B.S. 5400 now permits the inclusion of the shear strength of the infill concrete when using infilled inverted T-beams. This is of considerable advantage if it can be mobilised without the use of shear links in the infill concrete. A difficulty arises in that the latest edition of the code requires shear links in all beams. The writer doubts if shear links are required in this case, unless for additional strength. If shear links are always required then the advantage is largely lost and it would be more suitable and cheaper to provide the additional links in the precast section only.
- (v) Fig. 7 illustrates the cracked and uncracked sections by considering the point of intersection of V_{co} & V_{cr} .
- (vi) The effect of debonding on shear resistance is illustrated by the steps in V_{co} & V_{cr} .
- (vii) In single span decks, particularly if Class I, it is unlikely that V_{cr} will be critical and the minimum links that must be provided at spacings $4b$ or $0.75d$ will be more than adequate, in the cracked area.

As a general statement, shear in prestressed concrete with B.S. 5400 is less onerous than with BE 2/73. If shear links are not required in the infill concrete in Inverted T's, the requirements would be much less onerous, although this is largely due to a different approach rather than the requirement of the codes themselves.

10. AESTHETICS

This subject is admirably treated by Leonhardt in his book on Bridges to which the reader is referred (23). A few comments may be appropriate.

Engineers are often so engaged and absorbed in the challenge and difficulty of the design that the final appearance of the finished bridge becomes a secondary consideration. At times the word aesthetics seems to be confined to such structures as masonry arches, or large prestigious bridges or city bridges only.

Most highway bridges in previous years were over rivers and railways where the elevations were rarely open to view. Nowadays most bridges are over roads and open to view. They are mainly of the beam type since headroom considerations demand such a structure.

The two span, or even four span beam bridge seems to offer little scope for aesthetic treatment. Undoubtedly the scope is limited but perhaps here the challenge lies. Unfortunately cost considerations or other restrictions at times may compel a designer into a bridge form he would prefer to avoid.

The following principles are useful.

- (i) The structure should impart a sensation of stability.
- (ii) It should be appropriate to the purpose and the environment. The introduction of special features, e.g. mouldings, masonry piers, special concrete finishes are often out of place in a rural highway setting.
- (iii) Good concrete finishes are always important. All of the concrete should come from the one source. The nature of formwork, height of pours, layout of joints should be agreed in advance with the contractor. Undue rubbing down of faces should be avoided. These may improve the appearance temporarily but often produce a patchy appearance with weathering.
- (iv) Good proportions between width and height and between deck thickness and span are perhaps the important attributes of the rural overbridge. These proportions are visible from a distance and can impart unhappy visual sensations. A heavy deck on thin piers, or unduly heavy haunches relative to crown thickness should be avoided.
- (v) It is sometimes beneficial to highlight a single deck feature as e.g. the parapet fascia. A deep box girder or M beam deck may appear slender if the box ribs are put in shadow by a wide cantilever and by a pronounced fascia.
- (vi) It is suggested that the appearance of many bridges could be improved by the critical examination of drawings and the production of three dimensional sketches. For large or prestigious bridges, models and the imposition of the bridge on large photographs can be most useful.

- (vii) The employment of bridge architects is not common here. It is almost certain that this will change in the future and surely can do nothing but good.

11. DOCUMENTATION FOR BRIDGE WORKS

11.1 Contract documents for bridgeworks are usually based on the following :

- (a) "Specification for Road & Bridge Works" (S.R.B.W.)
- (b) "The General Conditions of Contract, Form of Tender, Bond etc." Second Edition 1967 supplemented and amended by Circulars from D.O.E. on recruitment of labour and the Prices Variation Clause.
- (c) The "Method of Measurement for Road & Bridge Works" (M.M.R.B.)

Some engineers prefer to write their own specification and use C.E.S.M.M. instead of M.M.R.B. cover. Even where the standard specification of S.R.B.W. is used, the document is often heavily supplemented by additional explanatory clauses.

11.2 Opinions about the merits of M.M.R.B. or C.E.S.M.M. differ but irrespective of these, it is important that the specification and more particularly the method of measurement should be standardised for all bridges. It is confusing and to some degree unfair, for contractors, particularly those without quantity surveyors, to be faced with both methods of measurement depending on which consulting engineer is involved. It is understood that the D.O.E. is now insisting on S.R.B.W. & M.M.R.B.

11.3 Dayworks plant

It is now practice to include a schedule of dayworks plant, which is priced and forms part of the Bill. It is suggested that such schedules should be kept to a minimum consistent with the size and nature of the contract. If such a schedule amounts to a sizeable sum it may have these effects :

- (a) confuse the award of the contract;
- (b) artificially increase the size of the contract. If the bill has been thoroughly prepared the amount of the dayworks should be small or zero. Contractors are disappointed to find that the final bill is much less than the initial tender and may search out ways to make up the deficiency;
- (c) amounts for Insurances and Bond are increased.

11.4 Extras

- (a) While some contractors seem to be more difficult than others in this area, contractors are often blamed wrongly for large increases in costs. The blame in many cases can be traced to faulty drawings, incomplete or ambiguous bills, or poor site investigations.
- (b) The use of proprietary materials should be clearly stated in the bill and the inclusion of such terms as "suitable bridge joints", or "waterproof membrane to be agreed with the engineer", can only lead to difficulty later, since many of these items can differ widely in price, or in laying costs.
- (c) Competition for contracts in recent years is extremely keen, and at times tenders are well below the engineer's estimates. Hand in hand with this is a more extensive demand for extra costs. Many engineers see this as a growing "headache" in contracts. While the engineer may consider a tender price as low, he may not have sufficient reasons for rejection, or he may be put under pressure by the client or bridge authority. One can do little about this situation except again to ensure a complete and unambiguous bill and a thorough site investigation and to see that the bond is completed before work commences.

11.5 Preliminary reports

Engineers vary in their approach. Some provide little more than a very short report and prepare perhaps a single drawing outlining the type of bridge proposed. The type of bridge is judged to be a suitable one based on the engineer's experience.

Others develop a number of options, present outline drawings of each with supporting estimates and make a final recommendation.

Occasionally a preliminary report may require considerable work in examination of options, e.g. in the case of a defective bridge. Work may include assessment of the old bridge, methods of strengthening, whether supports can be retained, and how traffic can be maintained during reconstruction.

The contents then of a preliminary report may vary widely. It is suggested that it should contain sufficient examination of the proposal—site investigations, nature of piling, if any, development and costing of various options, appearance—to enable himself and the client to be satisfied that the recommended solution is the most economic and most suitable one. To achieve this a large part of the design work will have been done at the preliminary stage.

12. GENERAL COMMENT

In this paper I have dealt at some length with the design aspects of bridges rather than their construction. Shear and the design rules of the new code B.S. 5400 have been emphasised. These have been dealt with in a particular way since these are posing particular problems for bridge engineers at the present time.

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In this final chapter attention is drawn to the amount of calculation now required even for the simple single span bridge. To illustrate this the calculation steps for the design of the footing of an abutment are set down in Appendix 1. The steps for a reinforced concrete slab deck are shown in Appendix 2.

The footing is examined under nominal loads, service loads and ultimate loads. When the different load cases are considered together with the various load combinations and the variations of load factors within the combinations then the reader has some notion of the scale of the calculations that may be necessary.

It is highly desirable that the amount of calculations be reduced, at least for the routine simple bridge — a simplified code for simple short span right bridges below 20 metre span.

One hesitates to make recommendations in this regard since examination of a wide variety of structures would be necessary to ensure that overstresses in concrete and steel did not occur, or that inefficient use of materials did not result. However, the calculation of crack widths is one area where simplification could be achieved. In the original code, provided the spacing of longitudinal bars did not exceed 150 mm, the requirements in regard to crack widths were deemed to be satisfied.

The amount of calculation required to check crack widths seems to be disproportional to the risk of excessive crack widths or to any possible wastage of steel. In addition there is considerable evidence that crack widths have little influence on the durability of structures.

Furthermore, since overstress under service loads is highly unlikely in this type of bridge, it is suggested that examination of stresses at serviceability limit state in the reinforced concrete elements could be waived, or at least covered by simple rules. It should be remembered here that the examination of stresses is carried out using the old modular ratio method which is an added difficulty for those trained in the limit state codes.

If these two requirements could be altered then all examination under service loads could be omitted. It should be emphasised that only simple single span right bridges are included in this recommendation. It is assumed that walls, abutments, and wingwalls, are designed as cantilevers.

13. WHAT OF THE FUTURE ?

Undoubtedly most bridge decks now are of the precast type and it is difficult to see this position challenged in a serious way. However bridge engineers are now more concerned with :

- (a) aesthetics requiring longer and more slender spans;
- (b) frequency of dock joints;
- (c) costs;
- (d) speed of construction, where often bridges are needed to link up other parts of the road scheme.

Generally it may be expected that :

- (1) precast beams will hold their own;
- (2) there will be more continuity in decks to reduce frequency of bridge joints;
- (3) in situ prestressing can now be speedily executed and one would expect more voided prestressed slabs;
- (4) central median piers are posing some difficulty particularly if the median is narrow; one would expect more use of the box girder type with the removal of the central pier;
- (5) increased use of computers, main frame and desktop will occur. A surge in the use of latter has already begun. The increased amount of calculations now required should make the desktop computer a must for the bridge engineer.

14. SUMMARY

A paper at this time on bridges in Ireland is appropriate, because of :

- (1) a recent surge in bridge building particularly of the motorway type due to such projects as An Droichead Nua Bypass, Airport Road, Athlone Bypass, Western Parkway, Dunleer Bypass. etc.;
- (2) the advent of the new code B.S. 5400 posing problems of increased office hours, more complex design rules, and difficult interpretation of many clauses;
- (3) a possible shortage of engineers skilled in bridgeworks to cope with (1) and (2) above.

The writer recommends :

- (a) the consideration of a simplified code for single span simply supported bridges perhaps below 20 m;
- (b) that Local Authorities should consider establishment of posts of Bridge Engineer, within which a career in that post can be encouraged.

APPENDIX 1

CALCULATION STEPS FOR FOOTING (BS 5400) OF ABUTMENT SINGLE SPAN SIMPLY SUPPORTED

1	LOADS	γ_{TL} and γ_{ts}
1	<i>Characteristic or Nominal Loading</i>	1.0
1	D.L. Deck, Wall, Footing	
2	D.L. Surfacing	
3	D.L. other superimposed deck loads	
4	Vertical traffic surcharge HA	
5	Vertical traffic surcharge HB	
6	D.L. fill	
7	Earth (& water) pressure	
8	Shrinkage and creep effects on bearings	
9	Horizontal pressure surcharge HA	
10	Horizontal pressure surcharge HB	
1	(a) <i>Comb. 1 Loads</i>	
11	No L.L. on deck	
12	Min. L.L. HA on deck	
13	Max. L.L. HA on deck	
14	Min. L.L. HB on deck	
15	Max. L.L. HB on deck	
16	Min. L.L. on deck 25 units HB (required later for crack control)	
17	Max. L.L. on deck 25 units HB	
18	Hydraulic uplift	
	Calculate bearing pressures; check sliding.	
1	(b) <i>Comb. 3 Loads</i>	
	Loads 1-15 & 18	1.0
19	Temperature fall, effect on bearings	
	Calculate bearing pressures; check sliding.	
1	(c) <i>Comb. 4 Loads</i>	
	Loads 1-15 & 18	1.0
20	Long. Load HA with 12 or 13	
21	Long. Load HB with 14 or 15	
	Calculate bearing pressures; check sliding.	

NOTE. In most cases of above with single span bridges the most critical conditions will be :

For bearing pressures. Comb. 4 with max. HB loading.

For sliding — Comb. 4 with min. HB loading.

It is assumed that full back fill would not be placed before the deck is in position, otherwise the condition with no deck on should also be examined.

2 ULTIMATE LIMIT STATE

	γ_{fL}	γ_{f3}	γ_{fL}	γ_{f3}
It may be necessary to examine Combs. 1 & 4 to assess critical condition. Some loads may have a relieving effect, in which case the factor for all effects of that loading is taken as unity. If max. HB is obviously critical, examine as follows :				
2 a) <i>Comb. 1</i>				
1. D.L. Deck, wall, footing	1.0	1.1	1.15	1.1
2. Surfacing	1.0	1.1	1.75	1.1
3. Other superimposed D.L. on deck	1.0	1.1	1.20	1.1
4. Vertical surcharge HA			1.5	1.1
5. Vertical surcharge HB			1.5	1.1
6. D.L. Fill	1.0	1.1	1.5	1.1
7. Earth pressure	1.0	1.1	1.5	1.1
8. Shrinkage and creep from bearings	1.0	1.1	1.2	1.1
9. Horizontal pressure surcharge HA			1.5	1.1
10. Horizontal pressure surcharge HB			1.5	1.1
15. Max. L.L. HB			1.30	1.1

Calculate ultimate bearing pressure

2 (b) <i>Comb. 4</i>	γ_{fL}	γ_{f3}
Loads 1-10, as before for Comb. 1		
15. Max. L.L. HB	1.10	1.10
19. Long. load HB	1.10	1.10

Calculate ultimate bearing pressures

Provide steel for ultimate loads. Check that ultimate moment of resistance is at least 1.15 times the ultimate design moment. If not check that strain at the centroid of tensile reinforcement is not less than

$$.002 + f_y$$

$$\frac{E_s Y_m}{E_s Y_m}$$

3 SERVICEABILITY LIMIT STATE

	γ_{fL}	γ_{f3}
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The most critical condition will be observed from nominal loading. Check under service loads that stresses in steel and concrete do not exceed 0.75 fy and 0.5 f_{cn} . Also check crack widths under Comb. loads, HA or 25 units HB. Comb. 4 loads will usually be critical for stress limitation with Max HB loading. If so

3 (a) *Comb. 4*

Loadings 1-15 except 2 surfacing	1.0	1.0
2 Surfacing	1.2	1.0
19 max. L.L. HB 25 units	1.0	1.0

Check steel and concrete stresses using modular ratio of 14 or 15

It is unlikely that stresses will be critical

3 (b) *Comb. 1*

Loadings 1-15, except 2	1.0	1.0
2 surfacing	1.2	1.0
17 max. L.L. HB 25 units	1.1	1.0

Check crack widths. It is unlikely that crack widths will be excessive under this loading.

APPENDIX 2

CALCULATION STEPS FOR R.C. DECK SLAB (BS 5400)

	γ_{FL}	γ_{f3}
(a) ULTIMATE LIMIT STATE		
Normally Comb. 1 Loads only		
1. S.W. Deck	1.15	1.10
2. Surfacing	1.75	1.10
3. Other superimposed dead loads	1.20	1.10
4. HA L.L. alone	1.5	1.1
5. HA & HB	1.3	1.1
Calculate reinforcement		
Calculate shear resistance adding shear steel if necessary		
(b) 1. SERVICEABILITY LIMIT STATE		
1. S.W. Deck	1.0	1.0
2. Surfacing	1.20	1.0
3. Other superimposed dead loads	1.0	1.0
4. L.L. HA alone	1.2	1.0
5. L.L. HB	1.1	1.0
Check stress limitations in steel and concrete 0.75 fy and 0.5 fcu		
(b) 2. SERVICEABILITY LIMIT STATE		
1. S.W. Deck	1.0	1.0
2. Surfacing	1.20	1.0
3. Other superimposed dead loads	1.0	1.0
4. L.L. HA alone	1.2	1.0
5. L.L. HB 25 units only	1.2	1.0
Check crack widths		
(c) Check that ultimate moment of resistance at least 1.15 times the ultimate design moment as in (a). If not, check that strain in tensile reinforcement at its centroid is not less than $0.002 + f_y$		

$$E_s Y_m$$

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Discussion

MR. MOLLOY introduced his paper.

He proposed to review bridge practice in Ireland by reference to a series of slides.

Hartley Bridge across the Shannon north of Carrick-on-Shannon was an example of one of the earliest reinforced concrete bridges. Built about 1910, the form of structure was light. The bridge had deteriorated over the years as was evidenced by the extent of cracking and spalling of the concrete. Some of the deterioration may have been due to overstressing of the light structure but was more likely to have been caused by poor quality concrete, inadequate cover to steel and the possible presence of calcium chloride in the aggregates.

Redmond Bridge in Waterford, recently replaced, and built about the same time as Hartley Bridge suffered from similar defects.

Examples of bridges built in recent years were Palmerstown Foot-bridge, Frank Sherwin Bridge and Matt Talbot Memorial Bridge in

the Dublin area. Attention was drawn to the staining of deck fascias below the vertical posts of railings.

Another example of recent bridges was Flesk Bridge in Kerry. In his opinion it was one of the most handsome bridges in the country. Because of the long centre span, he understood that the designers had experienced some difficulty with uplift at the end supports.

Using as examples the series of bridges recently constructed on the Naas Bypass and also the bridge over the Dublin-Bray Road at Belfield, Mr. Molloy discussed the visual balance to be sought between the shapes and dimensions of decks and piers. It was possible for piers to be too heavy in appearance and contrariwise, although structurally adequate, to be visually too slender.

He drew attention to the extensive formwork and falsework required in the building of such in situ concrete decks as for example the box girder bridge at Maudlings on the Naas Bypass. He drew attention in the same bridge to the fixing of the deck to the two centre supports. Movements due to shrinkage and creep were allowed to develop before the final fixing of the bearings over the piers. This was achieved by jacking the deck off the supports. Residual movements and temperature movements were accommodated by flexure of the piers.

Referring to bridges over railways, he spoke of the challenge of providing pleasing solid parapets of a height required by the Railway Authority and illustrated a pleasing example where red brick had been used effectively.

It was current practice, in the interest of good finishes, to cast piers and abutments to full height in a single pour. Since it was desirable that access to the bottom of the wall should be possible for vibration of the concrete, walls should be about 750 mm thick. Such thicknesses, and greater, were normally required in any case, structurally and for bearing purposes.

He had found most of the curing compounds very useful if properly used, the initial staining disappearing in a short time.

He stressed the need for good finishes to deck concrete and illustrated a deck where the texture of the concrete finish was so poor that grinding of the surface was necessary prior to the application of the waterproof membrane.

Mr. Molloy made some observations about cellular construction. In the matter of pseudo box decks, provision for drainage of the individual cells was required. Similarly provision was required for box beams, and this was particularly so where water mains were carried within the boxes. In pseudo-box construction consideration of the permanent deck formwork was required. The use of asbestos sheeting had become unpopular and perhaps some form of precast concrete slabs might be used. Where timber was used, it should be high quality and treated. The ventilation of box beams to prevent undue increase of temperature within the cells was sometimes overlooked.

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Referring to the use of concrete in the maintenance of masonry arches, Mr. Molloy illustrated the use of pressure grouting and guniting of a number of bridges. In the matter of guniting of soffits of arches, it was preferable to carry the thickness, 100 mm - 150 mm, to the full width of the ring rather than tapering near the vulnerable edges, which was commonly done.

Turning to the use of piling for bridges, he discussed the problem of test-loading of precast raker piles. It was a strongly held view that testing of raker piles should be carried out on raker piles only, and not, as often done, on a preliminary non-working vertical pile. The cost of test-loading a raker pile could be up to two or three times the cost of testing a vertical pile. In the case of precast piles he preferred to test load a vertical non-working pile to two or two and one half times the working load. In this matter it was the bearing capacity of the pile that was being tested rather than the strength of the pile itself.

He illustrated in his slides the conflict of prestressing tendons with heavy transverse reinforcement, e.g. over supports in continuous decks, and similarly the congestion of reinforcement at end blocks with reinforcement in curtain walls. These items should be resolved on the drawing board and not on site.

Finally, he drew attention to the drastic changes in shear requirements for both prestressed and reinforced concrete in recent years. The requirements for shear in pile caps and particularly in regard to punching shear in corner piles were very demanding when enhancement was not permitted. Similarly the calculations of shear in prestressed beams were tedious and difficult, especially if a complicated system of debonding was employed.

Mr. Molloy concluded with slides showing how concrete could be satisfactorily mixed with existing masonry arch structures. Examples were Leighlinbridge, Athlone Bridge and the very pleasing span arch bridge in Spiddal, Co. Galway.

MR. REDMOND HOLLOWAY opened the discussion.

He observed that this was the first of the Concrete Practice symposia to have a special session devoted to bridges. Mr. Molloy had presented an admirable summary of bridge designs and construction in Ireland, which would always be a valuable source document. There was in fact no such thing as a bridge practice peculiar to Ireland, and the author's bibliography would show this in that all of his references were to publications and work done outside Ireland. He believed that Irish designers could be more forthcoming in presenting their work to engineers outside the country and in joining in the research which was steadily advancing bridge design. He agreed with speakers in earlier sessions that this Symposium should record the urgent need in Ireland for more funds and effort in engineering research.

One might criticise the appearance of many of our bridges. We seemed unlikely to reproduce the elegance of the Mizen Head footbridge, the Lee Bridge at University College, Cork, or the Ha'penny Bridge in Dublin. Many of the new footbridges around Dublin were

by comparison rather bleak and prosaic. Also we might be accused of approaching a stereotype in our design of city bridges with little difference in character between say, Liffey, Lee, and Shannon crossings. This could be related to enforced cost restrictions. It would not be just to attribute it to any lack of imagination on the part of the designers, as he was quite certain that the encouragement of distinctiveness, at small extra expense, would meet a ready and able response from engineers.

Mr. Holloway agreed with Mr. Molloy about the cluttered confusion of specifications being offered today. In his opinion, what was needed was not still more specifications, but a clear understanding between designers and the ready mixed concrete suppliers as to what each expected from each. With that resolved, the designer could concentrate in his specification more on matters relating to the finished appearance of his bridge. While surprisingly the symposium had not so far mentioned finished appearance of concrete, this was an essential element in bridge design. The specification should then in his opinion develop such matters as formwork, dimensional tolerances, and general appearance making use not only of written text but also of photographs and even test panels.

Perhaps he might be allowed to mention one bright point in the current recession. This was the increasing attention being given to the preservation and rehabilitation of our existing bridges throughout the country. Local authorities were taking that matter, which was one of sound economic sense, very seriously. He would support the author in his plea that more engineers be formally trained in bridge inspection and maintenance. He could not really agree with Mr. Molloy that concrete bridges as a class could be deemed maintenance-free. Conversations he had had with bridge engineers in California and Canada suggested that maintenance of concrete bridges in those areas was now a major work with high budgetary demands; and we knew that some bridges in Britain, barely thirty years old, were already posing serious problems of durability. In that context, any increasing recourse to de-icing salts would surely have significance in this country also.

In the particular context of bridges, he would like to speak about the computer techniques suggested earlier in the symposium by Gaughan and Sheehy. While the availability of comprehensive bureau services was of interest, a designer could retain more feeling for design work by using short programmes with inexpensive hardware for the tedious analytical calculations. He had recently analysed a highly redundant cable-stayed bridge by formulating a 24×24 flexibility matrix to represent the behaviour of the structure. A Commodore 64 home computer had accepted a programme for inverting this and had produced the required solution in six minutes. It was his belief that it was along such lines that the use of computers in design offices would develop.

MR. J. O'DONOVAN believed that the deterioration of bridge decks in the USA resulted largely from the absence of water proof mem-

branes in many of their bridges up to about ten years old. It was good to record that the use of membranes was common practice now in Ireland, and we should develop our knowledge of these to protect the bearings and joint assemblies of our bridges against damage from water, possibly bearing de-icing salts.

He understood and agreed with Mr. Molloy's concern about the growing complexity of analysis. He did of course accept that the shear resistance of abutments needed to be determined, but he believed that an over-emphasis of the analysis for, say, that structural quality, which rarely gave trouble in service, might too easily be accompanied by insufficient attention to more important matters. He mentioned, for instance, the fundamental behaviour of bridge decks, interaction between piers, abutments, and decks, and the consequent design of bearings and movement joints, and the recognition of maintenance. These could be overlooked by a designer, numbed in his mind by the complexity of analysis. He had to question also in his own work how to compromise between compliance with the spirit of crack control formulae that had urged placing reinforcement as close as possible to surfaces, and the common sense that linked depth and quality of cover to durability. This was essentially a matter of design, and he was glad that BS5400 had addressed it. Referring to that standard, he would remind Professor de Courcy that it did indeed stipulate a design life of 120 years for bridges.

MR. EAMON CANNON supported Mr. Holloway's call for more concentration on the appearance of bridges. We could learn from other countries. He would refer in particular to Leonhardt's admirable survey published in 1983 and noted how Leonhardt emphasized the primacy of appearance even at some additional expense. He could also quote the Chief Bridges Engineer of the West Riding of Yorkshire, an area where there had been extensive bridge building, as saying that his office now placed great emphasis on fitting each bridge into its environment. Comparing Leonhardt's examples with the range of Irish practice shown by Mr. Molloy, one might be justified in asking whether we in Ireland relied on too limited a range of models for our design, and whether we should not be studying the breadth of European practice more closely.

There was no doubt that BS5400 fully applied was an extremely complex and demanding document. One might single out the treatment of shear in prestressed beams and the numerous loading conditions that were required to be considered, as just two aspects of design that suggested the absolute necessity of computerised analysis. He wondered whether the approach mentioned earlier by Mr. Sheehy, and very desirable, that the experienced engineer could size his sections on the basis of experience and simple calculations, did nowadays apply to BS5400 bridges. Perhaps we should be looking for simpler codes for the smaller bridges which were more often met with in practice.

Mr. Cannon agreed with Mr. Molloy that the profession in Ireland was short of checking engineers, designers already familiar with BS

5400. Checking could range from short examinations of small straight-forward bridges, to full independent studies for larger and more complex structures. Where would the manpower come from, for such a team of checkers?

There was one further point, to him an anomaly, on which he would welcome Mr. Molloy's comments. In a design incorporating prestressed longitudinal beams and transverse reinforced concrete elements, how could a demand that the prestressed elements be designed to be wholly free from cracking be reconciled with the cracking that was tacitly acceptable in the reinforced concrete? Was cracking acceptable on one axis but not on the other?

MS. Y. FARRELL supported the plea made by Mr. Holloway for a more sympathetic approach to the aesthetics of bridges. There was a major road development programme for 550 kilometres of roads planned for the next ten years, and unless there was close cooperation between engineers and architects in urging fine visual appearance and appropriateness to locale for the many bridges that would be built in the programme, a great opportunity would have been wasted.

MR. N. RYAN acknowledged the truth of the previous comment. He would challenge designers on two points. In the matter of visual appearance, bridge engineers should stop draping miscellaneous ironware on their structures. Rusting iron work was never an adornment. In the matter of simpler codes for simpler structures, if Irish engineers needed them, then they should produce them themselves.

MR. J. P. COYLE suggested that the exposure of concrete on the west coast of Ireland was probably more severe than UK conditions would demand. He was engaged in the repair of reinforced concrete bridges, some less than twenty years old, and their main weakness was inadequacy of cover, either in thickness or in quality. The concrete was probably about grade 30 and the cover was very often less than 16 millimetres. Would Mr. Molloy discuss such a cover and would he possibly suggest that cover was something that should vary from one part of the country to another?

THE CHAIRMAN in his contributions recalled that Mr. Molloy had been involved with highway and bridge design from early in the 1950's right through the 1960's, when there had been radical changes in road design in the country and right up to the present time, and he mentioned with pleasure a bridge project at Craughwell with which Mr. Molloy had been associated which had permitted the preservation of an existing bridge structure up to 500 years old. He had enjoyed the slides very much, although it had been a pity that the fine view from upstream of the widened Leighlin bridge could not have been accompanied by one of the original bridge dating from AD 1219 which was on the downstream side and hidden in the view shown by the new work. Mr. Holloway's clear question as to whether there was any such thing as contemporary Irish bridge practice was most opportune. Up to six years ago, very few road bridges were being built, but undoubt-

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edly there was an exciting period ahead as Government had agreed to make finance available for the ten-year programme. Engineers did then have an opportunity and a responsibility to respond.

There were in Ireland at least seven thousand concrete bridges, and it was probable that because they were relatively young, no major study had been made for their maintenance. In the USA, a crash programme of research had been started, under the title Strategic Highway Research Programme, because of what authorities there had identified as "an epidemic of bridge deterioration". A sum of one hundred and fifty million dollars would be allocated to the programme and repair work associated with it over the next five years and a significant part of that sum would be allocated to concrete components. He recognized that much of the American problem lay in the use of sanding and salting, but we in turn should recognize that the use of de-icing salts on our roads in Ireland was at present increasing rapidly.

If one might summarise points that had been made in the discussion, five that had been noted by him and that he would generally agree with, were (i) the need for a simpler design code for smaller structures, (ii) the need for more engineers with special skill in bridge design, (iii) a more generous recognition of the importance of improved visual appearance even at some extra cost, (iv) a need for applied research into bridge design for Irish roads, (v) an increased appreciation of the techniques involved in the inspection and maintenance of concrete bridges. He hoped that An Foras Forbartha might be seen as having a particular interest in bridges as part of its general Highways Programme, and he believed the organization could be a useful catalyst in the development of bridge practice in Ireland. The Symposium had been of special interest to him in that there appeared to have been no occasion in the country in which Irish bridges had been considered in this manner since the Irish Roads Congresses of 1910 and 1911, and the topic had certainly been ripe for discussion.

MR. MOLLOY replied to the discussion.

In reply to comments regarding the depression in the construction industry, it was a fact that bridge building was in a boom period. There were now more and bigger bridges being built than at any time he could remember. The problem indeed could well be that we had not sufficient numbers of top class bridge engineers to deal with the work.

He agreed with Mr. O'Donovan about the complexity of design to the modern Code B.S. 5400. He thought an explanatory hand book similar to Allen's text on C.P. 110 would be helpful.

Regarding the use of de-icing salts, B.S. 5400 formally required the use of 40N concrete with air-entrainment in parts of a bridge liable to attack by salts. To his knowledge air-entrainment was not used as yet here. However he believed that the problem of ice and de-icing was much less here than in the U.K. and the Continent.

He thought the main problem with shear was in slabs, decks and pile caps, rather than in beams. An enhancement of shear near sup-

ports was permitted now in beams under all loading but not in slabs. This seems somewhat illogical and was perhaps due to lack of investigation into slabs.

The calculations for crack control were tedious and frequent. He thought the simple bar spacing rules in the original edition of the code should be adequate. In that matter, nominal cover to reinforcement which influenced the width of cracks was often far exceeded on site where covers of 75 mm or 80 mm were frequently seen. He queried the effectiveness of the precise crack control calculations in such event.

In reply to Mr. Cannon, he drew distinctions between shear in single span and continuous prestressed decks. Shear in single span decks was a problem near the supports only, but it was a much larger problem in continuous decks.

The independent checking of the designs of large bridges posed somewhat of a problem. While such checking was desirable he found difficulty in the possible division of responsibility between designer and checker.

Mr. Cannon's comment about longitudinal cracking due to transverse moments in bridge decks was interesting. He believed that transverse moments were normally low but he did agree that they could be significant in thin deck slabs of box girder construction. Each situation would need to be examined on its own merits.

He agreed with Ms. Farrell about the importance of good appearance of bridges but he would suggest there had to be some restraint of cost. He recalled asking an architect some years ago how he would price good appearance and aesthetic value, and he had answered that he could not value them as they were priceless. Nevertheless excessive additional costs for aesthetics alone would not generally be warranted and he thought a figure of 10% of the cost and no more could be justified for additional aesthetic treatment.

He thought Mr. Ryan's challenge to Irish bridge engineers to develop their own simplified code for span bridges was a fair one. He would suggest as matters to be debated for inclusion :

- a) Simple bar spacing rules to cover crack control.
- b) All prestressed beam decks to be Class 1 for full live loading.
- c) Abutments designed by including, with the longitudinal load, such items as temperature, shrinkage, and creep, so avoiding examination for the various load cases.

Such simplifications would greatly reduce the volume of calculations without adding greatly to cost or increasing risk of failure.

In reply to Mr. Coyle, he could make little further comment on cover to reinforcement in concrete exposed to saline effects. He was surprised that grade 30 concrete should give trouble after 10-15 years. One might suspect the actual cover provided, or possibly the aggregates were at fault.

The use of higher grade concrete, 50N or even 60N, was now coming into use and would be helpful; and some amount of increased cover would always be an additional help.

SESSION G

CONSERVATION RENEWAL AND RECYCLING OF CONCRETE BUILDINGS

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1. Summary

In the light of increased emphasis on the conservation and re-use of existing buildings, this paper examines some of the implications of these trends for concrete practice in Ireland. The paper is more concerned with attitudes and policies than with detailed issues; because of this, and because of its interest in the future, the paper is necessarily speculative. Definitions are given, and some of the basic issues in conservation and re-use are explored. The place of concrete in twentieth century building, and its position in conservation activities are examined. Some of the possible implications for design and for the nature of professional activities are discussed. The use of concrete as a conservation material in buildings made of other materials is examined briefly, as is the process of listing concrete buildings for conservation purposes.

2. Introduction

There is a notable trend in building construction, in structural engineering, in architecture and in planning, which has been present for a number of years and seems to be increasing in strength. There is less emphasis on building new buildings (especially buildings on virgin sites), and more on rehabilitating and extending existing buildings, when new or improved accommodation is needed. The purpose of this paper is to examine that trend and its implications for the design and construction of concrete buildings and structures in Ireland.

The trend cannot be explained solely in terms of a technological development or solely in terms of economic conditions. It is something much deeper and more complex, with economic, social, and cultural dimensions. Here in Ireland our view of this phenomenon may be clouded by the deep recession in the building industry, but it is a phenomenon which is occurring in many parts of the western world. It is impossible to predict how long the trend will continue, and, because we are considering the future, our thoughts must necessarily be speculative. Despite this uncertainty, and the fact that it is not yet a developed area of practice, it is useful to explore the issues involved.

The intention of this paper is to view the continuing developments in this area within a broad framework of policy and cultural attitudes, rather than to probe more detailed, and often highly technical, matters. It is hoped that the paper will stimulate debate, and promote a keener awareness of current developments and their possible implications for the future.

3. Conservation and re-use : Definitions and scope

Conservation has been a growing, if not always very active, concern in many countries for a long time. But it is in the recent past that substantial changes have taken place in the field. The theoretical and technological bases for conservation practice have been enhanced. The scope of conservation has been widened, from being a rather narrow concern for a relatively small number of monuments of great cultural importance, to something much broader which embraces wide categories of buildings and other structures. The practice of conservation has moved to a less peripheral place in the design and planning professions, and encompasses a wider range of professional actions and skills. It is to emphasize this wider view of the field that we use the phrase 'conservation and re-use'.

Many definitions of conservation have been put forward, some contradictory. The following definition is one which reflects more recent concepts, and is thus more useful to us.

Conservation may be simply and broadly defined as a professional responsibility for existing buildings, which can be achieved in many ways : Maintenance, preservation, restoration and repair, consolidation, renewal, rehabilitation and reconstruction. No longer limited to the treatment of ancient monuments and clearly identifiable historic buildings, it is now generally recognised as an element in every aspect of architectural and urban design, and in many cases has become an obligation defined by legislation. . . As an activity, it is becoming an integral part of the everyday work of architects, planners, builders and developers; but it is also one which draws on the knowledge and skills of historians, archaeologists, sociologists and economists. (1)

Other definitions which may be useful in this discussion, and which show the diversity in interpretation of some of the terms used in this field, are given here.

Conservation consists of the cherishing of existing structures so that they may not merely continue, but may also receive a more abundant life from the changes and fresh associations which occur. (2)

Conservation : a term used interchangeably with preservation but having the rather more positive connotation of adaption of parts of a building (or countryside) whilst retaining the essential spirit of the original. (3)

Rehabilitation : The restoration or improvement of deteriorated structures, public facilities, or neighbourhoods. It is more than

repair or remodelling, less than conversion or reconstruction, and close to reconditioning. Nevertheless it has come to be used to describe any substantial improvement in a building. (4)

Rehabilitation : As it implies, the term used to describing the idea of repairing, redecorating and in some cases converting existing structurally sound property to a standard comparable with modern requirements for amenity and health, for use for a period of 20-30 years. (3)

Restoration : 1. The process of returning an object, material or building as nearly as possible to its original form and condition. 2. A replica of a building, or portion thereof, designed to indicate the original appearance. (5)

Durability : The satisfactory life of a structure . . . is the period during which the structure fulfils the function for which it was designed without excessive expenditure on maintenance or repair or on unanticipated decoration. . . The durability of the structure is that quality which measures its ability to achieve the satisfactory life required. (6)

4. Past, present and future trends in conservation and re-use

For much of this century the designers and constructors of buildings in the western world worked with little reference to existing buildings or to the past. The ideal for most designers, whether architects or engineers, was a new building on a virgin site. The ideal for most contractors was a green field, or at least, a site from which all existing structures and vegetation could be removed before construction began. The maintenance and extension of existing buildings was not of great interest.

This position was supported in many ways. The existing urban fabric had been condemned as obsolete and inadequate for twentieth century man, by authorities from Le Corbusier to Frank Lloyd Wright to Walter Gropius. Quickly growing populations and the migration to cities caused large increases in the extent of cities, and expansion into the surrounding countryside. The destruction of cities in the Second World War demanded huge building programmes, often using the most innovative techniques. New industries and new technologies seemed to demand new kinds of structures in new settings. The schools of design as a matter of philosophy forewent the teaching of history, especially the history of styles. Organisations caught for space in the city centre moved to the edge of the city, to sites which allowed generously for expansion. In the 1960s it was generally accepted that more new buildings would be built in the world in the coming thirty-five years than had been built in the whole of human history. In this climate the older, often functionally obsolete, buildings were not given much importance.

In the recent past, these attitudes and practices have been changing, admittedly to a greater extent in other parts of western Europe than in Ireland. Throughout Europe there has been a growing concern for,

and interest in, existing buildings and the existing urban fabric. There is an increasing trend to re-use, adapt and extend existing buildings rather than build new buildings. Over 40% of the projects in architectural practices in southern Germany involve conservation issues. In Britain less than 25% of current architectural projects are for wholly new buildings on sites where no existing building is being retained. These trends in building are usually explained in terms of

- a. changing attitudes which place increasing value on traditional buildings and traditional urban settings,
- b. the realisation that, in a quickly changing world, buildings which have outgrown their usefulness are not necessarily structurally obsolete and can be renovated and rehabilitated to a new use at much less cost than building a new building,
- c. a growing awareness of the problems associated with new buildings in new settings away from the old urban core, and with the abandonment of the urban core, and
- d. the decreasing demand for expansion and new space because of a falling birthrate and more stable population size.

At this moment, largely because of the revolution in information technology, we are in the midst of one of the greatest periods of social, economic, and, ultimately, cultural change in human history. For each one of us, this can be seen as a great privilege, or as distressing and unsettling because of the great uncertainty and potential threats which accompany such change. Furthermore, in Ireland we are at present in a serious recession, and unemployment is greater in the construction industry than in other sectors. In these circumstances it is not surprising that we might be despondent about the future. But I would argue that in the western world we are about to enter a period of great opportunity, following this present unsettled period.

The future, even the short term future, is notoriously difficult to forecast, even when using the most advanced methods available to us today. Yet, as the world changes more quickly, it becomes more important for us to examine future possibilities, and there are a number of observations about present and future trends which can be made about matters which are pertinent.

In the western world throughout this century the rate of change in many aspects of life has been increasing quickly. Despite short term interruptions, family income and national wealth have grown greatly, and continue to grow. (7). The amount of leisure time available to most people has been, and is, increasing. It seems more likely that these trends will continue, and increase in intensity in the foreseeable future, than that they will diminish or be reversed.

With increasing change in science, medicine, technology, manufacturing processes, education, recreation, and the supply of all kinds of goods and services, we can expect increasing demands for change in the built environments in which all these activities take place. With increasing wealth and increasing leisure time, there would be increased opportunities for people to mould their residential environments to

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their own changing needs and desires, and it is reasonable to expect that some will do so. To what extent these changes will be put into effect by the recycling and adaptation of existing buildings or by the construction of new buildings is more difficult to predict.

I would also argue that as incomes, leisure and educational levels rise, and people's more basic needs are met, communities will become much more aware of, and concerned about, their cultural and environmental heritage, and will devote more resources to its conservation. I see little to suggest that the present trends in the conservation and re-use of buildings will be of only short term duration.

I recognise that the view I am advancing is an optimistic one, and that there are contrary arguments which would insist that present conditions are not transitional to a new direction, but are the new direction for the foreseeable future.

5. The significance of concrete

Concrete, in all its forms, is probably the most widely used building material of this century. But its significance goes far beyond that. It is a major part of the most radical change in the nature of building materials in five thousand years. Until less than two hundred years ago there were no building materials widely and economically available which had high tensile strengths, or had tensile strengths approaching their compressive strengths. There were severe limitations to the size and shape of any monolithic structural member. The variety of structural form and architectural form throughout the centuries reflected these realities. In the nineteenth century, with the development of reinforced concrete, there came into use an economic and widely available material with high tensile and compressive strengths, substantial durability, and a high resistance to fire. It could be cast into monolithic members of sizes previously unknown, and, because of its unprecedented plasticity, could be moulded into shapes hitherto not possible. Doubtless, in the longer historical perspective, these developments will be seen as being a major achievement.

The Modern Movement in architecture was likewise an episode of radical change; in this case, of architectural expression. Despite the numerous current criticisms of this movement, it will also be seen in history as a major occurrence. Concrete, steel and glass were the materials with which the Modern Movement was given expression, and concrete was the most widely used and versatile of these. But the crucial point is not that concrete was the material used, but that some of the most important and most characteristic manifestations of architectural form in the Modern Movement would not have been feasible without a material such as concrete. The buildings of Walter Gropius and of Le Corbusier are classic.

The possibilities presented by concrete as a structural material changed significant parts of architectural theory. Concrete is a building material in which some of the most important cultural manifestations of our era have been expressed.

6. Functional and structural obsolescence

By functional obsolescence we mean that a building or structure no longer serves adequately its intended purpose (even though its fabric and fittings may be in sound condition). By structural obsolescence we mean that the fabric of a building or structure is unsound and/or has reached the end of its useful life. An unattained ideal of some theorists in this century was that we could design and construct, at an economic cost, buildings which would reach functional and structural obsolescence simultaneously and could then be removed without detriment to the rest of the environment.

When the rates of change of societies were slow, the tendency was for buildings to become structurally obsolete long before they became functionally so, and in many instances the useful life of the fabric was extended considerably by careful maintenance and repair. There are many examples in history where a church survived for many centuries, and, when it had become structurally obsolete, was replaced immediately by another church on the same site to serve the same purpose.

When the functional life of the intended use of a building is much shorter than the building's reasonable structural life, different problems arise, and we can identify a number of approaches which have been considered. An ideal of the Modern Movement was to respond to increasing change by creating either a disposable architecture or highly adaptable architecture. Explorations of adaptability considered such elements as movable walls, detachable rooms, or "plug-in" dwelling units, and invariably specified lightweight modern materials. In practice these approaches had little success.

There is a well-established tradition of temporary and mobile buildings which have been found satisfactory for a limited range of uses. But the construction of "temporary" buildings of satisfactory quality has never been fully achieved. In other words, we do not have buildings whose fabric has a satisfactory life of only, say, ten or twenty years, which can be built economically for such a time span, provide as good a living and working environment as "permanent" buildings, and which are visually acceptable in their surroundings. So it seems unlikely that the increasing rate of functional obsolescence can be accommodated by buildings of less durable fabrics.

The current approach, and the one which would seem closest to the range of ideas we are discussing in this paper, is to use the existing built environment where feasible, and to adapt and extend it in ways that fulfil functional requirements, are economical, and bear a good design relationship to its surroundings. New buildings are also built, of course, but not in response to every new demand for accommodation.

As the rate of change of many aspects of life increases, we can expect the functional lifespan of any building, for a given use, to decrease. One recent view of the functional lifespan of office buildings in Britain suggests that they might need to be refurbished every eight to ten years to continue in the same kind of use, and to be rehabilitated

every twenty years, possibly to accommodate new uses. (8) Assuming that the structural lifespan of buildings will remain the same, or even improve because of technological advances, we can expect increasing disparity between the occurrence of functional and structural obsolescence in any building.

7. Reasons for conserving and re-using concrete buildings

Buildings are conserved and re-used for a wide variety of reasons, and the nature of the intervention made and works carried out in any given case will be determined by those reasons. (9) The reasons may be summarised as follows: that a building is a significant part of the cultural heritage, or is of high aesthetic value, or has historical associations, or is itself a historic object. For example, Clonmacnoise and Newgrange are significant parts of our cultural heritage, the Casino at Marino is of high aesthetic value, the General Post Office in Dublin has strong historic associations, and Castletown House, the first great Palladian building in Ireland, is itself a historic object. Or the reasons may be based on ecological, economic or social arguments. Ecological arguments for conservation centre around the management of the environment as a part of the earth's resources, and our duty to hand it on to future generations in as good a state as possible. Economic arguments stress the costs and benefits of extending the useful lives of buildings, or the tourist value of fine buildings, or the economic use of existing built infrastructure. Social arguments are based on the maintenance of the quality of life and social cohesion of communities.

Since concrete is one of the newer of building materials, buildings in concrete have had less time in which to build up historic associations and may not yet be seen as strongly a part of our cultural heritage as older buildings are. (For example, we could compare the Central Bank in Dame Street with the Bank of Ireland in College Green). There is as yet no widely recognised group of concrete buildings of cultural and historic importance, as there are of brick buildings or stone buildings, but this can be expected to change with time.

In the immediate future the concrete buildings which are the subject of conservation and re-use can be expected to be so for ecological, economic and social reasons, with a smaller number of cases where a building is of importance in the history of concrete technology. The implication is that the most likely reason for intervention in concrete buildings would be to rehabilitate and adapt them to new uses, which could entail substantial changes to parts of the building fabric. In some cases, of course, where the building fabric itself is of historic importance, the object may be to ensure its continued existence with as little change as possible.

8. Concrete conservation and re-use today

It is not easy to form a coherent or complete image of the present state of the art in concrete conservation and re-use. But there seems to be little doubt that it is an area of professional, technological, and

economic activity in its early stages of development, and one that is growing with some rapidity. For this reason, if for no other, it is useful and appropriate to consider the subject at this Symposium, even if the discussion is necessarily speculative.

There are pockets of activity in concrete conservation in various parts of the world, and in some cases considerable professional and technological skills have been used. Some of the greatest examples of Modern Movement architecture in concrete have been the subjects of major conversion: Frank Lloyd Wright's Unity Temple in Illinois, Le Corbusier's Villa Savoye outside Paris, Walter Gropius's Bauhaus at Dessau. But there is, as yet, no evidence of an easily accessible, widely shared body of sound technical knowledge and experience in the design professions or in the professional schools.

There is a small number of highly specialised companies offering products and processes. These are mostly concerned with repairs, and there is a substantial literature and trade material associated with these. But apart from that there is no easily identifiable, established, commercial activity in concrete conservation and re-use.

The literature in the field is sparse and scattered. The information services of the American Concrete Institute, the Cement and Concrete Association in Britain, the Association of Preservation Technology in Canada, ICOMOS (the International Council on Monuments and Sites) in Paris and ICCROM (the International Centre for the Study and the Restoration of Cultural Property) in Rome were consulted during the preparation of this paper. The bibliographies, reprints and other information kindly supplied by these bodies show the undeveloped nature of the subject area, but also suggest that the field is growing through isolated initiatives around the world.

In November 1984 there was a seminar in San Francisco on the Deterioration and Repair of Concrete in Historic Buildings, and a conference is to be held in October 1985 in Belgium on the Conservation of Early Concrete Structures, under the auspices of the Flemish Association for Industrial Archaeology. Since 1982, *Recuperare*, a journal wholly devoted to rehabilitation, has been published in Milan (10). This is the only journal encountered which deals with the restoration and re-use of concrete as one of its continuing concerns, and as an integral part of building conservation activities of all kinds. The American Concrete Institute has recently formed a National Committee on Rehabilitation.

9. Flexibility of concrete buildings for re-use

In this discussion, a building whose fabric can be easily and economically adapted to accommodate other uses satisfactorily is considered flexible, and the question being addressed is whether concrete buildings have characteristics which render them more or less flexible than buildings of other materials. We need to distinguish here between concrete construction using small elements like blocks or bricks, and construction based on large monolithic elements, whether precast or

cast in-situ, such as beam and slab frames or precast floor beams. There would appear to be few major differences in flexibility between concrete block or brick construction and natural stone or clay brick construction, especially where floors supported by timber joists are used and most of the walls are load-bearing.

Most large monolithic concrete structures are reinforced or pre-stressed. Removing any part of a structure is more costly, requires heavy and noisy power equipment, and is severely limited if the strength and stability of the structure are not to be compromised. In that sense concrete buildings are less flexible.

But most concrete buildings are structurally composed of continuous horizontal planes supported by a grid of columns or by crosswalls, and the space defining elements and the ambient control elements of the fabric are not structural. Buildings of this kind are much more flexible than those of other kinds of construction, with the possible exception of steel frames. For example, some, or all, of the interior walls and doors could be removed and replaced with another pattern of walls designed for a totally different purpose; or the exterior walls, windows and doors could be replaced, again in a substantially different pattern.

The essential characteristic contributing to flexibility is the separation of vertical structural support from the division of space.

10. Implications for practice of a conservation and re-use approach

Like much in this paper, what follows does not claim to be either exhaustive or definitive, and in the absence of a well-documented body of experience, must be seen to be speculative.

A conservation orientation would suggest that, when a concrete building is being designed, the possibility of its outliving its first intended use should be considered. In such considerations we would need to have useful information both about the expected rates of change of building uses and about the durability of concrete buildings. The useful lives of the various parts of the building can vary widely. We can distinguish between parts of the building which are likely to be changed if the use changes, and those which are likely to remain unchanged. We can also distinguish between those materials, components and finishes which are more durable and those which are less so. Performance criteria for durability could be set for those parts of a building which have functionally useful lives of an identifiable length.

At a very elementary level, let us consider the main structural frame of a concrete building, consisting of precast or cast in-situ floors and vertical supports of crosswalls or columns. Such a frame, well constructed, well maintained and in a favourable ambient environment, could endure in good condition for some centuries. Assuming that the main structural frame is durable in the long term and that it offers the potential for accommodating a variety of uses, at different times, without needing to be substantially changed itself, a general design

strategy could be to enhance the durability of the main frame (where economically feasible) and to design its connections to less durable parts of the building so that they can be renewed without damage to the integrity of the frame.

Following from that strategy, the following could be possible design guidelines.

- a. Design the main frame and the external walls and roof so that none of the main frame is exposed to the external environment.
- b. Give extra attention to the durability of footings and parts of the main frame which are underground.
- c. Consider the costs and benefits of using materials in the main frame which are more durable and more impervious to atmospheric attack.
- d. Consider the costs and benefits of using greater cover on steel in critical areas.
- e. Provide connecting systems to other components of the building which do not damage the main frame when changes are made.
- f. Make the main frame less monolithic, if easy to do so, to allow parts of it to be changed without disturbing others.

Apart from its durability, another aspect of the potential of the main frame to accommodate a variety of uses is its capacity to support the imposed loads of the different uses, and to accommodate the services associated with them. Referring to BS CP3, for example, we can see that a building designed for general office (2.5 kN/m^2 distributed load) could support the imposed loads of a change of use to light workrooms, carpark, hotel, hospital or flats (11). When designing a new building in a climate of rapid change, it may be considered a good investment to design the main frame to accommodate a higher imposed load than is required for the first intended use, so as to increase its future flexibility. Proposals of this kind may not be realistic with the present structure of property finance. But these issues involve an element of social responsibility, and could be the subject of public policy in the future, which in turn would influence practice.

A conservation approach has many implications for the management of practices and of contracts. Where the renovation of existing buildings is being carried out there can be substantial differences, when compared with a new building on a virgin site, in forms of contract, in estimating and costing practices, in fee structure, in drawings needed, in site supervision, and in liabilities. An excellent insight into some of these issues was given in a paper "Conservation Contracts—Before and After" at last year's IEI/RIAI Seminar on Conservation and Re-Use of Buildings (12). Temporary works, both in their engineering and organisational aspects, can be a major element of renovation projects, as was also shown at that Seminar (13). When dealing with old buildings, other professional skills need to be drawn on to understand the existing fabric; architectural historians, archaeologists, and analytical scientists are often consulted. There is a level of uncertainty in many aspects of conservation and re-use work, not present in new

building projects, which many people may find unsettling, but which needs to be accepted and handled in a fully professional way.

One of the biggest changes that might be brought about in the design professions by a conservation approach is the redefinition of the scope of professional activities and interests. Instead of seeing our work as a series of discrete projects, each one ending, ideally, with the completion of a new building, we would view it as a continuing series of interventions of various kinds (including the construction of new buildings); the existing fabric, from the oldest archaeological vestiges to the most recent buildings, would be seen as a continuum, no part of which would be altered or destroyed without consideration, and the welfare of all of which lies within our professional responsibility.

All of these considerations raise immediate questions for professional education and training, and for research programmes. The speed with which changes in the nature of professional practice can take place nowadays is unprecedented, and presents a challenge to professional education to respond to new needs and directions not only with excellence but quickly enough to be effective.

11. Maintenance

The maintenance of the fabric of a building in sound condition during its useful life is an essential part of any conservation policy. While the maintenance of buildings of large organisations is usually in the care of a maintenance department, building maintenance generally, in this and other countries, is largely an unstructured and haphazard activity. Faults in the fabrics must be patently evident or causing disturbing consequences before they are attended to. Among engineers and architects, maintenance is often regarded as a less than challenging professional activity. Recent studies, whose concern was the stimulation of activity in the building industry, have suggested that there is at present gross underinvestment in the maintenance of our national building stock. One estimate indicates that,

“over the three years, 1980-83, private sector output in building repairs and maintenance dropped by 57% at constant prices”. (14)

If we take a conservation and re-use viewpoint in the design, construction, and use of concrete buildings, then maintenance becomes a far more important issue. Professional activity would embrace all buildings, those existing, whether old or new, those being built, and those planned for the future. This seems to me to point to the programmed inspection and maintenance of all buildings, beginning when construction has been completed. Such programmes of inspection and maintenance should be under the general supervision of skilled professionals, so that when serious problems begin to arise they can be recognised. Day-to-day work of inspection and minor repairs would, of course, not require high inputs of professional skills.

12. Concrete as a conservation material

Within the wide subject area being discussed in this paper, one sphere in which there is a well-established body of experience and a

substantial literature is in the repair of concrete structures and the use of concrete as a repair material. The durability and repair of concrete have been discussed earlier in this Symposium. Here we examine the use of concrete in substantial interventions in older buildings, usually constructed in stone or brick, and with timber floor and roof structures. This kind of work occurs largely in two contexts; the stabilisation and strengthening of areas of structural weakness in the fabric, where there is no desire to change the appearance or the use of the building, and secondly, as part of the renovation of an existing building, which may or may not be reasonably sound, for new uses. Examples of both these kinds of work were discussed at last year's IEI/RIAI Seminar on the Conservation and Re-Use of Buildings (15). An international conference was held in Cologne in 1975, as part of European Architectural Heritage Year, on "The Role of Concrete in Conservation of Historic Buildings". (16)

The principal difficulties which arise in work of this kind stem from differences and incompatibilities in the nature and behaviour of the original materials and structural systems and those of the introduced concrete. For instance, there can be differential settlements, differential rigidity, differential co-efficients of thermal expansion, and unintended chemical reactions between old and new materials. For these reasons, a principle used in many cases is to keep the introduced concrete structure as independent from the host structure as possible. Many conservationists have reservations at the idea of introducing into an old natural stone or brick building a material as strong, unyielding, and as difficult to remove as poured concrete is. And yet the concrete work underpinning the tower of York Minster forms the basis of a brilliantly conceived museum of the architectural past (16).

13. Listing concrete buildings for conservation

The Local Government (Planning and Development) Acts, 1963 and 1976 provide for the "Preservation of buildings of artistic, architectural or historic interest" (17), and for the "Preservation of plaster-work, staircases, woodwork or other fixtures or features of artistic, historic or architectural interest and forming part of the interior of structures" (18). These are "Purposes for which objectives may be indicated in the Development Plan". The National Monuments Acts, 1930 and 1954 (19, 20), the only other substantial legislation dealing with the conservation of buildings of cultural significance in Ireland, have rarely if ever been applied to buildings later than 1700 AD, or to buildings in everyday use, so they are not of interest here.

Any concrete building or structure in the country of sufficient merit or interest could be afforded the protection of the Planning Acts. Buildings considered by the Planning Authorities to be worthy of preservation are listed in the Development Plan of the area. The protection given by the legislation is limited (some would say inadequate), and it does not guarantee that a listed building will be preserved or rehabilitated or that it will be maintained in good condition by its

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owner (21). Listed buildings cannot be altered or demolished without the permission of the Planning Authority.

Any person or group can make representation to the Planning Authority to have a building or structure listed in the local Development Plan. A check of a number of County Development Plans has shown only one building in concrete which is listed, although each one of us could think of concrete buildings which are landmarks in the history of technology in this country, or which are very fine examples of architecture in concrete, or which, because of their use, are an important part of our culture.

May I suggest that the professional societies and institutions most concerned with concrete technology and building in this country could compile a list of buildings and structures of merit and interest, and make it available to planning authorities, conservation groups, and national agencies. While representations can be made to planning authorities, the decision to list a building rests with the Authority concerned. Lists of this kind could be of great use in heightening awareness of the richness of professional, technological, craft and building industry achievements in concrete in Ireland.

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Discussion

DR. MURPHY introduced his paper.

His purpose was to examine some recent and continuing trends in conservation and re-use and to look to their possible implications for the design and construction of concrete buildings in Ireland. His subject had to be, to quite a degree, speculative in that, firstly, one had to deal with some very recent and not yet well established tendencies, and secondly, the forces creating such tendencies were aspects of large-scale social systems, notoriously difficult to predict. Also, of course, one was dealing with the present and future, rather than the past and present. He believed there were three basic points to make. Firstly, how did we as a society regard our particular built environment and respond to it? Secondly, what values were being expressed by society as a whole in relation to both new and existing buildings? Lastly, what attitudes could be detected in professional activity in relation to new and existing buildings?

Speaking about the first point, it was his experience, gained from personal observations and through extensive co-operation with architects in other countries, that in other parts of the European Community there was a much greater tendency to care for buildings than we had here, and to husband not only the buildings but also their environment.

He quoted the instance of the visiting Belgian tourist agent who, when asked about Dublin, replied "you have a beautiful city here, but it is a shame it was so badly damaged during the war".

In 1982, we in Ireland had spent £35,000,000 on the repair and maintenance of old buildings in the private sector, excluding houses. In the Netherlands, where 40,000 buildings had been classified as their primary building heritage stock, the country had in the same year spent £105,000,000 on the restoration and repair of that stock. The difference was enormous; and similar differences could be quoted for other places. The value of our built environment in Ireland was extremely large. Taking the cost, first, of replacing all of our housing stock, the amount involved would be about forty four billion pounds, or three times the Gross National Product. If one added to this the replacement value of our factories, offices, shops, hospitals, schools, universities, roads, bridges, water and sewerage systems, docks, harbours and airports, one was talking of hundreds of billions of pounds. One then had to appreciate that buildings and structures, by their nature, were bound to deteriorate with time unless used and maintained. If this wastage was at the rate of 1% per annum, one was faced with an annual national wastage of over one billion pounds per year. If we could intervene in that wasting process with a significant maintenance programme, it could be very beneficial to society as a whole, through having a better environment, protecting an important resource, making more efficient buildings available, and creating substantial economic and employment activity. The self-evident possibilities seemed enormous.

Addressing the second point, Dr. Murphy had noted the increasing concern throughout the Community and throughout Europe generally for the preservation and re-use in new functions of existing buildings. In 1983, over 40% of all the projects in the architectural practices of southern Germany contained elements of conservation and re-use. In Britain, less than 25% of current architectural projects, according to a recent estimate, were for wholly new buildings on sites where no existing building was being retained. Many explanations were being offered. Some said there was an increasing liking for traditional buildings in traditional settings. Others pointed to the structural quality of buildings which had out-lived their first intended use, and to the feasibility of rehabilitating such buildings for new houses at costs much lower than involved in new work. There was also a realization that the abandonment of old urban cores presented several problems and that frequently new buildings could be better accommodated there than in new settings. This was a particular feature in American planning. And of course there could be the influence of a falling birth rate in the countries of the Community, although to offset that, one would have to recognize that, for instance, 1984 had been a particularly active year in the French housing programme.

Turning to the third point, it did seem to him that the Irish architect saw the making of new buildings on virgin or emptied sites as his or her primary activity, and all other activity (which would include

conservation) as subsidiary, and the context of dealing with existing buildings as professionally fraught with pitfalls, and boring. He recalled an important lecture in Dublin some years ago given by James Stirling, who had, in describing his recent American practice, observed that the five projects he mentioned all recognised a need for connecting to, or modifying, existing buildings. When leaving the lecture room he had heard a prominent Irish architect humorously and vigorously dismiss the lecture material as of minor importance, since after all it dealt only with "a bunch of extensions". Despite the humour, Dr. Murphy believed the comment might be expressing a basic attitude to practice. It was his opinion that the whole of the built environment, from archaeological ruins to the most recent, lay inside the professional activity of the architect. Each generation of architects took up the built heritage, cared for it, and handed it on. Any inability by architects to take up that burden might, he believed, be attributable in part to their education. In medicine one trained specially as an obstetrician, or surgeon, or physician, as a paediatrician or as a gerontologist. One studied preventive medicine or dental conservation. Universities supported such specialisations. In Irish architecture, one wondered, while recognizing the danger inherent in all analogies, whether there was not an almost exclusory emphasis in the development of architectural obstetricians, whose only concern was with bringing new buildings into the world.

He would divide significant existing buildings into two principal categories; listed buildings or heritage buildings on the one hand, and, on the other, simply sound buildings that could be adapted either by the public or the private sector to new uses. It was important in speaking of the heritage buildings to realise that, regardless of ownership or tenancies, one was treating a public social issue, in which any constraint or adaptation or use might come from legislation rather than private decision. This had to be an important consideration in the planning of works.

As regards maintenance, he believed that any disorganization and neglect associated with it in Ireland should be halted. It should become a fully-developed professional activity.

Against this general background, one could consider the question of concrete buildings in Ireland. Recognizing the new thrust towards conservation in building practice today and seeing durability as a *sine qua non* in conservation, Dr. Murphy saw his paper as echoing much of what had been said earlier in the symposium. The major architectural movement of the twentieth century had seen reinforced concrete as a most significant medium. Concrete in all its forms was probably the most widely used building material of the century; and reinforced concrete had played a major part in the most radical change in the nature of building materials for five thousand years, in that it opened the way to structural members of nominally unlimited size, possessing both tensile and compressive capacity. Designers such as Lloyd Wright and Nervi with their plastic use of form, and Le Corbusier with his demonstration of the total flexibility that a basic reinforced concrete

SESSION G

structure could provide, had shown the potential of the medium. Earlier, the French work of Perret had explored the novel structural potential of reinforced concrete, and Rudolf Steiner in the 1920's built in concrete in a manner that could be used today to demonstrate the truth of concrete durability. It was perhaps partially the excitement of this new medium that made architects, great and not-so-great, appear to forget their history, and work with little reference to the existing buildings of the past. When one considered the Unité des Habitations of Le Corbusier at Marseilles, and such projects as the Roehampton tower blocks built under its influence, and read that Pevsner had placed the Roehampton project four-square in the great tradition of British landscape gardening, and then learned that that project could have provided in the same space exactly the same amount of family accommodation in traditional two and three-storey private houses, with gardens, for exactly half the cost of the tower block scheme, one realised how the new medium had in some ways blinded designers. That failure to recall the past had had, as one knew, quite tragic results. In both Europe and America great housing blocks were now liable to be torn down because they were creating such problems for the socio-economic groups who occupied them.

Despite what he might call these perturbations in architectural history, Dr. Murphy believed that in the increasing demands for a better environment being made by modern man (even if at the moment there was little money to back them), the wealth of architectural expression implicit in the right use of concrete, as developed through the twentieth century, would always be seen as having been highly significant. And he would stress that he had spoken only of buildings. What was one to say of, for instance, the lovely bridges of Robert Maillart, and the extraordinary power of some of the viaducts on the German, Austrian, and Italian motorways, all works made possible by the use of concrete.

Turning to the two facets of obsolescence, the functional and the structural, one might begin by saying that in times of slow change structural obsolescence was likely to arrive first. The first basilica of St. Peter in Rome, built in 330 AD, had been taken down in 1506 AD to allow the building of another basilica, for exactly the same function. Today it was function that became obsolescent first. One had only to look at the great range of functions to which Georgian buildings, intended as residences, had been and were being put to, to recognize that.

There had been little evidence, in his experience of any great attention being paid to the conservation of concrete buildings. He could point to the earliest Corbusier exercise in housing which had now become one of the national monuments of France. On the other hand, the present condition of the Bauhaus, by Walter Gropius, at Dessau, said to be the greatest single building of its time, left a lot to be desired, although he could not say whether neglect or some inherent lack of durability was the cause. He would say to the members of the

symposium, however, that there was in Ireland a process for listing buildings for conservation, and any group concerned with the protection and conservation of a particular concrete building in the country could make representations to the appropriate Planning Authority about it. He only knew of one listed concrete building, the church at Turner's Cross in Cork, but there were clearly many that should now or in the future come into that category, whether as items in the architectural heritage or as significant examples of industrial archaeology.

There were two more points he would like to make about building in concrete. The first related to the education of young designers, and to design in concrete in general. Recognising that functional obsolescence would usually precede structural decay if due attention had been paid to durability, and that the use of a building might well change during its life, the main structural frame should be designed with special regard to durability. Perhaps no part of the frame should be exposed to the external environment, and generous covers should be used in foundations and other underground work. The level of durability in other parts of the building, as for instance cladding and light internal elements could then be less, these being elements liable to be influenced by change of function. Considerations along such lines were appropriate, he believed, to education and to research. The second point related to the use of concrete elements in the rehabilitation of buildings which had not previously contained any concrete. As just one example, he would mention sixteenth century housing in Leuven that had been converted to student accommodation for the University, with all of the old timber work in interior floors, and lintels over door and window openings being restored in concrete.

MR. D. WALL opened the discussion.

He was particularly grateful to Dr. Murphy for having taken such a wide view of his subject, as it was all too easy to concentrate on the details of conservation, recycling, and re-use, and to ignore fundamental principles. The recession was contributing to an increase in the number of buildings being re-cycled, and this might be a blessing in disguise in that most would agree that neo-Georgian and reproduction architecture which was a form of substitute had not always been very successful. He dreaded the day when there might be a neo-Georgian Society for the preservation of neo-Georgian buildings.

However the immediate subject was the association of conservation and concrete. There were two main aspects of the subject, firstly the conservation of buildings made primarily of concrete, and secondly the use of concrete in the rehabilitation of buildings to replace earlier materials. There were so far relatively few examples in the first category, presumably because concrete was a relatively new material, but he did not doubt that there would be many more in the years to come. He could think of three, a forthcoming extension at the College of Technology at Bolton Street that would incorporate an existing rein-

forced concrete structure, an industrial building that had been converted into a Pool club, and the Jacobs warehouse building in which the structure and the floors were being re-used as offices with completely new cladding and windows at, he believed, minimum cost. Generally speaking, there was little structural difficulty in converting former industrial buildings to new uses in recreation, as offices, or as schools, as the new floor loadings were less than the old. In some cinema conversions, however, the transformation of balconies into full first floors for heavier loading did make structural strengthening necessary. In others, where the conversion was from a single large cinema to perhaps two or even four small auditoria inside the original shell, the work could generally be done with very little structural difficulty.

The first step in the appraisal of a concrete building was to examine the architects' and structural engineers' drawings. The difficulty in locating drawings for buildings fifty to sixty years old prompted him to mention the need for a central archive for drawings of new buildings and of extensions and reconstructions of buildings. Local authorities in Ireland and in the U.K. did have some material, but any question of breach of confidentiality in their use would have to be resolved. Of course when the new Building Regulations were brought into force and the principle of self-certification was applying, the number of drawings lodged with the local authorities would be reduced. In the absence of drawings, a structural survey would be the next step. A useful publication had been published on the topic recently by the Institution of Structural Engineers. One had to recognise that the expertise for structural survey was scarce, and that the costs of a full survey were high. One might also consider a series of tests on the reinforced concrete elements of the structure. The use of a covermeter, coupled with some deliberate exposure of some bars, should provide information about the nature and spacing of the reinforcement. For him the most positive test on the strength of the concrete was the extraction and crushing of cores. One might also consider the Schmidt hammer and bolt penetration tests, but should accept that the Schmidt hammer gave more a measure of surface hardness than of strength; and the ultrasonic pulse velocity test was also available. A valid overall approach might be to use cores for absolute strength and then to correlate strengths so found with non-destructive tests carried out at the same places and then throughout the structure. He had seen the approach, used with a framed structure, leading to a convincing assessment of safe load capacity.

Mr. Wall said that Dr. Murphy had dealt with a most important issue in speaking of the deliberate design of buildings for conservation and re-use. While the initial costs might be quite high, there was clearly one factor that could be built in with no cause for extra cost, and that was the durability of the concrete. Badly-constructed reinforced concrete was likely to begin deteriorating in as little as five years, whereas the same ingredients properly used could, with normal maintenance, last for 150 years. He would not like to see Dr. Murphy's

proposal to protect all reinforced concrete from the open air adopted as a universal design maxim. It might well be a useful idea for run-of-the-mill buildings, but it would for instance have denied Le Corbusier, Steiner, and Nervi the ability to make their famous statements in exposed concrete. He did agree that the approach mentioned by Dr. Murphy made the concept of replacable facades feasible. A particular point he would make regarding flexibility and change of function was that ground floors on solid might usefully be designed slightly heavier, to make possible, without new foundations, the erection, for some new function, of internal walls in new positions not explicitly envisaged in the building as built.

Also on the matter of flexibility, it would, he believed, be valuable to design the floors of apartment blocks for a somewhat heavier imposed loading than strictly required, as that would allow partition and internal wall positions to be changed if required to accommodate some new function. Apartment blocks as now designed were among the least flexible of buildings, but he did appreciate the difficulty of persuading their promoters to think beyond first use. One should, he thought, recognize that design for higher imposed loading did not carry a significant cost penalty. On the matter of demolishing quite young buildings, a practice Dr. Murphy had mentioned as acceptable in U.S.A., he recalled that in the 1960's the demolition of the then Inter-continental Hotel in Ballsbridge was seriously considered as, being of cellular construction, it was not easy to turn it to a new function. Demolitions of such buildings were in fact sometimes associated with tax advantages, but surely with another approach to tax concession by Government, it should be possible to encourage design for conservation.

Mr. Wall continued his introduction with slides illustrating rehabilitation works in which concrete had been used. Topics he mentioned included: the vital importance of shoring, the merit of ribbed and other hollow-formed reinforced concrete floors for their combination of lightness and rigidity, the use of internal piling, the lowering of basement floors, the location of new columns behind existing facades, with the new floors cantilevering two metres past them, the insertion of full frames to ring large new openings cut in existing walls, and the insertion of sill beams under other such openings. Amongst the buildings he described were:

- the British Embassy building in Merrion Square
- the Dolphin Hotel building
- the Grafton Cinema building
- the Powerscourt Centre
- the Queens Old Castle building in Cork
- the Methodist Church building in Charleston Road, Ranelagh
- the Methodist Church building in Saint Stephen's Green.

MR. SCANNELL suggested that it was engineers rather than architects who had made possible the enormous new freedom of modern archi-

ture. The architect's use of that freedom had led at one stage to the craze for vertical housing. His experience of living in a tall block in the Netherlands had not won him to the idea, and it was clear, from the social and psychological problems that had arisen from the concept in the United Kingdom and here at home, that that type of housing accommodation had in many cases been a disaster. Whilst he might applaud Mr. Wall's design for enhanced durability and flexibility at a little more cost, it was a regrettable fact that the controllers of national finance were concerned only with getting everything at the cheapest possible price, regardless of what else might suffer.

PROFESSOR HANRAHAN invited Dr. Murphy to comment on three possible approaches to the restoration of the Dublin quays from, for example, O'Connell Bridge up to Grattan Bridge, a project which he believed could make that stretch of river a show piece among the cities of the world. Would Dr. Murphy

- (i) have new buildings designed at the discretion of the particular architect appointed to each?
- (ii) have new buildings, all designed by one architect or, as in the Belfield Campus, by various architects subject to the over-riding control of a single architect's master-plan?
- (iii) have each building as it now stood restored and rehabilitated?

MR. N. J. O'GORMAN pointed out that conservation work had the benefits of being highly labour-intensive and less wasteful to the national economy than total reconstruction. Formal State encouragement would surely be appropriate for those engaged in centre-city redevelopment and conservation. He believed that considerable redevelopment would take place along the Dublin quays if the problems attached to these being main traffic arteries could be removed; and a substantial move would be made in that direction by providing a good traffic link between the Port of Dublin and the Western ring motorway now being developed.

THE CHAIRMAN welcomed the opportunity of hearing the most recent thinking on a subject in which he retained a substantial interest. Dr. Murphy was eminently qualified to speak on building conservation, as an engineer, a deeply-read architectural historian and the first chairman of the Irish National Committee of ICOMOS, the International Council of Monuments and Sites. Mr. Quinn had been struck by three features in listening to both Dr. Murphy's introduction and Mr. Wall's contribution. Firstly, as a student he had been taught how to make buildings, but never how to take buildings apart; and this after all was an essential prerequisite in conservation. An understanding of old building techniques was necessary if one were safely to dismantle them. Secondly, in the costing of a building option, it was clear that direct comparison of green-field and restoration options was dangerous. One was not comparing like with like. The fact that in a restoration project, one had the infrastructure ready-made at virtu-

ally no cost, was clearly an economic bonus; but it was equally a fact that in public works, the system of public accountancy prevented either the Department of the Environment or the Department of Education or the Department of Health taking into account potential savings that would reflect themselves on the budget of another Department. If the economics of conservation were to be made to stand up in terms of the way, for instance, in which quantity surveyors presented costs, or as various formal costs assessing bodies assessed costs, then some multi-lateral assessment process would have to be devised to quantify the benefit of the available infrastructure.

The third feature to strike him was that whereas designers in the earlier years of the century might have felt it professionally necessary to show their skill in making new buildings, the time had now probably come when architects and engineers could display a self-confidence in themselves and in the country by being prepared to express their professional and design expertise by way of extension, or modernisation, or development, or indeed of pure conservation, without having to feel that somehow or other they were denying themselves the right to express their creativity.

DR. MURPHY replied to the discussion.

He agreed with Mr. Scannell that had he made a different selection of slides, he could have shown quite clearly the innovative work of engineers at the heart of twentieth century building. He would offer that comment to engineers as a challenge to them to study the history of their profession, something he believed they did not do properly. He believed Mr. Scannell was right about the shortcomings of early twentieth century urban design theory. Almost every departure away from traditional city forms had been disastrous, and designers were now dismissing those ideas and reverting to the earlier urban forms. Replying to Professor Hanrahan, Dr. Murphy said one could not overlook that urban planning was basically a public and political activity. One could argue for and against each of Professor Hanrahan's scenarios, but one would have to begin by asking whether or not the quays were to continue as the main connecting links between the Port of Dublin and the enormous hinterland west of the city. While this question remained unresolved it was probably better to move quietly, keeping as much existing work as possible, rather than make the wrong long-term decisions that might be inherent in large-scale demolitions.

When one spoke of the labour implications of conservation, and the role of the State, he wondered, in the present company, whether he was indeed the one who should answer! Clearly the financial policies of the State played an enormous part not only in conservation but in the whole development and re-development of urban areas. The transformations that had occurred in the centres of some American cities were indicative of that influence. It was important to foster in a community a sense of social responsibility, and social concern for a proper conservation policy, and we in Ireland could look for inspiration in this matter to our partners in the European Community.

SESSION H

GENERAL REPORTS

Sessional Chairman

PROFESSOR J. W. de COURCY, M.E., F.I.E.I., F.I.STRUCT.E.
University College, Dublin.

The following members of the Symposium gave personal viewpoint reports on the sessions:

Session A: **J. A. Kavanagh**, B.E., M.ENG.SC., F.I.E.I., F.I.STRUCT.E.,
M.I.C.E.

Session B: B. Roche, B.E., M.I.E.I.

Session C: B. O'Regan, B.E., M.I.STRUCT.E.

Session D: P. Clarke, M.I. STRUCT.E.

Session E: **D. Maynard, B.A., B.A.I., M.I.E.I.**

Session F: **S. Sharpe, B.A., B.A.I., M.I.E.I.**

Session G: D. Orr, M.A., M.A.I., PH.D., M.I.E.I.

MR. KAVANAGH saw Mr. Scannell's paper as consisting of three parts, Standards and Codes of Practice, Regulations and Building Control, and Specifications. One saw the first and third groups as normal on-going documents, continually evolving. The Regulations he saw in another light. They resembled the smile of Mona Lisa because one could not be certain whether indeed they existed or not.

Standards and Codes were the backbone of current design office practice, but one had to be concerned at the pseudo-legal status they might be seen as possessing in the light of the proposed Regulations. A Code of Practice was an aid to designers. Engineering design was not a matter of satisfying Codes of Practice, and merely satisfying Codes was certainly not the whole of engineering design. Engineers checking one another's work in the possible context of Building Control should not lose sight of that. The idea of an Irish Code of Practice for structural concrete was good. It was needed, for instance, to introduce Irish Standard references for materials. However, as it was to be essentially CP110 in technical content, the temptation to make small technical changes almost for their own sake should be resisted; and on-going arrangements should be made to keep the Irish Code updated in line with amendments to CP110.

So far as engineering design was concerned, the primary purpose of Building Regulations and Building Control should be to ensure that buildings were designed by properly qualified and competent designers. If it were considered necessary by society that designs be vetted independently, one must ask who should pay for the extra work involved, both for the checker and for the designer? A critical problem of Building Control was the quality of, and responsibility for, site supervision. The current tendency to see this as a consultant's function only was regrettable. The contractor had the primary responsibility, and could not shed it. Furthermore, it would be common experience

that clients did not understand the nature of consultants' supervision and were seldom willing to pay for the level of supervision that they said they wanted from the consultant. He would make two other points on Regulations and Control. Firstly, why was house building being excluded from the Control Bill? Some of the most hair-raising construction he had ever experienced was in one-off house building. Secondly, unless the large list of deemed-to-satisfy documents in the Regulations were kept up to date, there would be chaos in the Control area. He did not need to spell that out.

On the matter of specification, Mr. Kavanagh agreed with the call for greater unanimity between designers, and closer consistency between their specifications. However, human nature being what it was, consistency, for a consultant, meant everyone else using his system. In seriousness, he believed the Irish Building Specification should be a help in achieving consistency. He regretted that only 40% of designers were reported to be using the IBS, but it would perhaps have reached a wider usage by 1995. However, he believed the IBS erred in suggesting that a new specification be assembled, clause by clause, for each new project. For normal every-day practice, reliance on a relatively fixed core to the specification would be a sounder approach, with extra clauses being added as the particular project required. There was a point he should make about specifications, which he believed all consultants had met. This was the unauthorised alteration of specifications by third parties. Such alterations were intolerable and those guilty of making them should be aware of the legal responsibilities they were taking on by introducing such changes.

In a final comment, Mr. Kavanagh drew the attention of the Symposium to the report on accidental damage to buildings prepared by a working party of IEI in 1971-1974. That report was, at present, being reviewed, and the working party would welcome comments from anyone interested in making them.

MR. ROCHE was glad to have heard the review of cement manufacture given by Mr. Bannon. He noted with interest that while cement had in recent years shown no significant change in 28-day strength, the 7-day strength today was about 81% of the 28-day strength, compared to about 75% ten years ago. Mr. Bannon's reference to the relationship between the properties of cements and durability were timely, as were his comments on imported cements. He was glad to hear the author's endorsement of the quality of Irish aggregates; and he would very much agree with Mr. Bannon's attitude towards both the use of admixtures and cement blending; that both practices would be followed, perhaps to an increasing extent in Ireland, and had merit, provided the advice in the relevant British standards was always kept in mind. Mr. Roche noted that the revised BS 1881 had introduced some altered requirements for the preparation of test specimens, and hoped that these would be quickly introduced on Irish sites. He mentioned that IIRS working in conjunction with Irish Cement Limited was even now developing a new test for determining the cement content

of hardened concrete. He believed that that test, in a necessary area, would be an advance on any test now available. He noted Mr. Bannon's reference to the necessity of craft status for workers in concrete and his welcome for the AnCO course in that field.

Mr. Roche had found many comments of interest in the discussion. It was a regrettable fact that the country was using 10% less concrete now than in 1979. He agreed that problems relating to imported cements might arise more from an unfamiliarity with the cements, rather than from any defect in their composition. He believed that, despite comments to the contrary, pulverized fuel ash would be eagerly sought by some sectors of the concrete industry, just as soon as it became available. Mr. Roche was concerned at the dilemma that was developing between concrete for strength and concrete for durability. It was in his opinion not desirable to say in a specification whether the primary need was for durability or for strength. It was the function of the specifier to specify properly. It was the function of the suppliers to quote for a material to that specification, and not to seek economical advantage of minimum cement content.

MR. O'REGAN was glad to make his report against his background both as a designer in reinforced concrete and as a manager of the Computing Service in the Electricity Supply Board. We should acknowledge the significant contribution made by the OASYS programmes to Irish engineering over the last decade. We had been warned in the paper that, despite the quality of the advice of CP 110 and the tools and techniques at our service, we were always dealing with an inexact model of any real structure. Mr. McConnell had underlined that comment in his presentation. One, for instance could get into a dangerous position by playing around with numbers in a finite element analysis without being quite clear of the significance of the numbers or of the appropriateness of the closer grids. The behaviour of a real structure as-built could always be of enormous assistance in design. As an example he might mention the use the ESB designers had made of accelerometer readings from the first Moneypoint chimney in completing the design of the second. The availability of those real results and their almost exact reflexion of the earlier computer-calculated predictions had enabled them to design later chimneys with greater confidence and to underwrite the value of existing international codes.

Decentralized computing was, today, a topic of much debate, not least in the ESB where a strategic report on computing for the future was being prepared. At present, the Board had its own main frame computer with decentralized VAX mini-computers, and many micro-computers, and the whole range was networked into one system. This offered for instance the facility for the site engineers at Moneypoint to report progress to head office by computer, and to enable them to use the head office computer facilities for programmes they might need on site. The Board system had its own permanent high frequency links, and these would soon be greatly enhanced by the introduction of

AIRPAK. The significance of all that interaction became very clear when one considered a large international company such as Bechtel using satellite links in computerised communication between, say, their design office in San Francisco and a construction site in Italy.

Mr. O'Regan congratulated Ove Arup and Partners on their development of CADRAW. His experience was with a large INTERGRAPH system, which, after considerable study, the ESB had introduced on a trial basis some three months ago. To him, its achievements in that time were just extraordinary; and he had little doubt that when the time came for another very large power station to be designed by the Board whether in Ireland or elsewhere, the structural steelwork analysis, design, and detail, would flow through a single integrated computerised process. The output would then be harmonised with the work of the mechanical engineers, the computer system being used in such matters as pipe interference checking. The INTERGRAPH system also had a package for detailing reinforced concrete; and it had been a matter of amazement to him to see an engineer producing 3-D drawings of r.c. details, and in being able to use them to significant advantage in, for instance, the fit of extra bars into complex three-dimensional beam column junctions. How far such 3-D work might be brought into general practice he could not predict, but its use by, for instance, architects and boat designers, to plan interiors and to develop constructional details, and to display them to clients, was already well known.

It was abundantly clear that the various members of any design team were nowadays working more closely to one another than ever before, and the existence of a coherent comprehensive computer-based system accessible to all of them was a superb facility. One should realise that such a system could deal not only with the material elements of a building but could process information on such matters as the relation of energy consumption to space planning, fenestration, and wall insulation. How long such design technology might take to filter down to the normal small practice was not easy to say, but he believed that Mr. Sheehy and Dr. Gaughan had made a most useful contribution to the development of computer usage in their paper.

MR. CLARKE suggested that the paper given by Mr. MacCraith on durability might come in future to be seen as the most important paper of the 1985 symposium. One's perception of the significance of a failure could be coloured by the degree of one's responsibility for that failure. The remark of Plato could be relevant "the boys of the village throw stones at the frogs in jest, but the frogs die in earnest". The frequency with which durability had been mentioned, not only in Session D but throughout the symposium indicated the current concern of engineers for the subject; and one felt that the difficulties of mix specification and quality control on site would keep the problem with us for some time. The importance of cover had been stressed many times, but one might possibly question how significant that really was for concrete in elements within buildings if there was no moisture

SESSION H

present to lead to corrosion of the reinforcement. The importance of high quality workmanship was seen very clearly by speakers and their appreciation for the work being done by AnCO was apparent. Professor de Courcy had mentioned the concept of designed life. Clearly there would be difficulties inherent in that concept, but it was to be recognised that the BS specification for bridges was already suggesting the idea. Regarding high alumina cement, it would appear as of now that Irish works had suffered little from its abuse. Only time could tell whether the problem was now over. He believed however that the possibility existed for failure, due to chemical attack, of poorly maintained screeded roofs, and that problem might be with us for many years to come.

Mr. Clarke endorsed strongly Mr. MacCraith's call for sponsored research into failures and for a process that would enable the circumstances of failures and the techniques of repair to be made known widely, if anonymously, throughout the profession. A particular area of the industry where failure was rather common was the agricultural sector, and here again co-ordinated research and a dissemination of knowledge and information would have great value. The fall-off over recent years in the development of strength of concrete from seven to twenty-eight days, and the fact that the increase in strength after twenty-eight days was now significantly less than formerly had many implications. Not the least of these was the temptation to rely on reduced cement contents for high early strength in concrete, while ignoring the damage possibly being done thereby to durability. The dropping of the age factor in a recent revision of CP 110 reflected the trend towards the reduction in strength gain. In the matter of alkali aggregate reaction, while he accepted that the U.K. experience did not directly apply in Ireland, he believed it might be useful for Irish Cement Limited to note on all in-house cement test reports the relevant total alkali contents. A useful body of information might thus be provided for industry, that would establish the degree of consistency being achieved in alkali content, and help in any forthcoming consideration of blended cements.

MR. MAYNARD saw as the first highlight in Mr. Ryan's paper the fact that housing in Ireland used 53% of our cement, and, linked with that, Mr. McCullough's observation that the country spent a thousand million pounds each year on housing. Further demand was likely to remain at 27,000 homes per annum, and it seemed that an increasing proportion of these would be in the sector of one-off houses. The policy expressed by Government in *Building on Reality* indicated that it was hoped to maintain the local authority housing output and to stimulate the private building sector. It had been interesting to hear Mr. Ryan's account of the development of prefabricated construction and Mr. Beaumont's call for a higher design input into prefabrication. A significant point had been made about the relative quality of local authority work and the work of speculative builders. Clearly the local authority attitude to quality of work was seen to be the superior, and

Mr. McCullough had suggested that this arose from the combination of a higher input of professional design, more skilled contractors, and better supervision. The growth in the use of concrete ground floor slabs, from 70% in 1976 to 90% in 1984, had interested him and again he noted the anxiety about site practice which with bad supervision allowed a specified thickness of 150 mm to become 100 mm when laid.

The topic of hollow block construction had been treated very fully. Its use had declined from 86% in 1976 to 55% in 1984, and the view had been expressed that the hollow block should long ago have been wholly abandoned. It was probably fair to say however, and Mr. Ryan's slides had demonstrated this, that the fault lay in workmanship rather than in the block itself, because if used correctly, it led to a perfectly satisfactory construction. As we knew, hollow block still provided some 50% of the walling in home building, and was used also in the agricultural and industrial sectors. He believed it would still be widely used when the next Symposium was held in 1995.

Mr. Beaumont had identified appearance as a factor militating against the use of concrete in roads and paths. Perhaps the short term cost factor and the use of unnecessarily wide roadways were factors contributing to the declining use of concrete in the area. If people thought a little less of first cost and concentrated on improvement of surface texture, the situation might change. The reference to concrete cobbles had been important.

Mr. Ryan had identified several elements of house building which high-lighted poor performance, and it was interesting to hear how the discussion attributed these inadequacies to a shortage of supervision and to a lack of knowledge of proper building construction practice throughout the country. Whilst house building of good quality was not of course a rarity, we had not yet accepted the transformation of the industry from a base in crafts to a base in component assembly.

There had been an illuminating difference of opinion in the session between those who had advocated the need for formal research and development and those who considered that the way forward was through better education in existing practices and the elimination of existing malpractices. He had however sensed general support in the Symposium for better and more research. In that context he would refer to the recent Report of the Sectoral Consultative Committee on the Construction Industry, which had noted how low the expenditure was in research and development in the industry in comparison both to other sectors in Ireland and to other countries. That Report had recommended the inauguration in the construction industry of research funding programme, and had recommended that the state funding of R & D in the construction industry be increased to a level similar to that obtaining in other developed countries. He looked forward to the achievement of that objective within the next five to seven years.

MR. SHARPE said that it was only proper that a Symposium on Irish concrete practice since 1975 should pay tribute to the degree of excellence and the high levels of craft and operative skills displayed in the

bridges built in the country during that period. One could see it for instance in the three new bridges over the river Liffey and in the group of bridges associated with the Naas bypass. The range of design and of the technology used was impressive. There were several factors that contributed. One might note, for instance the availability of ready-mixed concrete of high quality, and the use of superplasticizers to place concrete in nearly impossible sections where the steel was complex and in the vicinity of prestressing anchorages. One might note also the modern development of falsework systems and large prefabricated crane-handled formwork, the efficiency of high-load prestressing equipment with reliable measuring facilities, and indeed the use of a wide range of precast concrete beams whose quality, he observed, consultants appeared to take almost for granted.

It was clear that there was great need for vigilance in matters of durability. The need for an improved bridge inspection inspection scheme seemed clear, and many speakers had mentioned the importance of structured training programmes to develop the skills of workers on site. There were clearly needs also on the design side. A simplified design code leading to simple constructional details for bridges of up to perhaps twenty metre spans would obviously be very valuable; and more attention would seem to be needed to such important matters as local cracking and the behaviour of bearings. The concern of speakers for a greater attention to the appearance of bridges and to their suitability for their particular environments should be noted. He looked forward to seeing what assistance computer graphics might offer in that respect. For his own part, he considered that all the major bridges constructed in Ireland during the last ten years had been, aesthetically, very successful.

He had been very interested in the comment that with the boom in bridge building mentioned by Mr. Molloy, there was emerging in the country a shortage of skilled designers. He would assure the Symposium that that was not so with bridge contractors. They were available, they had the capacity to build, and they would welcome the boom. To him, the secret of bridge building lay in teamwork. The teams existed as of now, and it would be criminal if sufficient continuity of work could not be provided to keep them intact. It had been a pleasure to him to hear an author so much on top of his work, but then he expected that was the proper place for a bridge engineer to be!

DR. ORR spoke of the infectious enthusiasm of Dr. Murphy for his subject and recalled working in the same design office as Mr. Wall some twenty-five years earlier. Dr. Orr remembered a project from that period, which echoed the topic being discussed, at the Shelbourne Hotel, in which two adjacent buildings having different storey heights were to be linked by a common stairway. It had to him been an introduction to architects and their treatment of problems in reconstruction. He noted Dr. Murphy's three points regarding the built environment, namely the way in which the Irish reacted to their built environment,

current trends in Irish society on that matter, and the attitude and scope of professional activity in the field.

Dr. Murphy had made an important point in showing that the planning tendency today was to move back into the cores of the cities and rehabilitate them, whereas not so long ago the move was predominantly out away from the cores to the peripheries. History suggested, and he would cite Sligo as an example, that town life in earlier times recognized the need to bring vehicles into the heart of a town and to keep personal vehicles, carriages and traps, at private houses. Perhaps one secret of revitalizing city centres lay rather in facilitating entry and parking for vehicles than in excluding them.

The subject of maintenance was vital in Ireland. So many buildings in the cities were mouldering away and no one seemed to know what to do about them. One had to recognize difficulties of access and fire hazards as influencing proposals to redevelop the upper floors of old buildings, but nevertheless there were surely many exciting possibilities in that direction, and close study should be encouraged. Dr Orr believed that Mr. Wall had also given the members of the Symposium valuable pointers to consider in designing for flexibility of usage, and he had noted in particular the advice given on the use of liberal loading rates. One might draw an interesting parallel between building and education. In the earlier times, one made a building for a single purpose and one educated and trained for a single career. Nowadays, the single life of a building might be called on to meet several purposes, and the single life of an individual might be required to encompass work in two or more areas of employment. While it was not appropriate to carry the analogy further, it did appear to him that a highly significant factor in any successful change of function for a building had to be the ability to adapt the services as first installed to the new function. Perhaps that was an area worth considering in design for first use.

Amongst the many interesting points raised in the discussion, he had noted the brief restatement of the old and new timeless argument as to whether it was the engineer or the architect who was to be credited with the introduction of concrete to building. He had noted and agreed that rehabilitation was labour-intensive, and could be costly, although costing was always unbalanced to the degree that all the circumstances of a project might not be taken into account. And he thoroughly agreed with the need to teach engineers and architects not only how to make buildings but also how to take them apart. The most obvious example of that need was possibly the problem of demolishing post-tensioned prestressed concrete. Dr. Orr looked forward to the 1995 Symposium.

THE CHAIRMAN thanked the reporters for their contributions, and on behalf of the Symposium thanked the authors of the papers and the chairmen and lead speakers for their collaboration in what had he believed been a successful meeting. Very many important points had

been made and he hoped they could be brought to influence Irish practice in the decade ahead. It was clear that international design norms, as for instance the Eurocodes, would play a large part in our work and we should correspond positively with these. At the same time, the development of simplified design rules for small structures could be encouraged, and indeed a challenge had been given during the Symposium to engineers in Irish practice that they should prepare short rules for small bridges. Some formalisation of design life for buildings should now perhaps follow the adoption of a figure for bridges, and consideration might be given, in informal discussion, to the use of a gamma factor for durability in our approach to design. Durability, with maintenance and recycling in mind, should be a factor in the first cost of building, and very clearly, the closest attention had to be paid to site workmanship and control. In that context both the AnCO approach to the training of the worker in concrete and the Quality Assurance Programme being promoted by the Cement and Concrete Association in the U.K. deserved both praise and active cooperation. It had been proper to draw to our attention the essential fact that building was not a "big bang" operation, and that, consequently, adequate attention always had to be given to the particular problems of the construction period, and to the influence of the building process on behaviour in service.

One could scarcely speak forcefully enough about the need for research and for appropriate education. It was to be hoped that the Development Council proposed in the recent Sectoral Report would give research a high priority, and that the collaboration of Government and the professions would provide the finance needed to implement it. Regarding appropriate education, it had emerged clearly from the Symposium that the country needed both more dedicated bridge designers and that there was an urgent need for more and better-trained career engineers both in site control for new building and in the maintenance of buildings in service.

Recalling the observation made by the late Denis O'Leary that he understood a symposium to be a discussion between kindred spirits set against a background of feasting, the chairman thanked Irish Cement Limited for the splendid and warm-hearted reception they had offered to the members. It had added a new and welcomed dimension to this, the third Symposium in the series. He concluded by thanking the staff members, academic and technical, and the post-graduate students, in the Department of Civil Engineering, in particular the organising committee, also the staff at Belfield for housing and feeding the gathering, and last, in a special way, the members themselves for their attendance and participation.

PROFESSOR HANRAHAN then closed the Symposium. Wishing the organizers an on-going durability and an increase in strength with age, he looked forward to the next occasion in 1995, expressing as his wish "go mbeirimíd beo ag an am seo arís".

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