Zeitschrift: IABSE reports = Rapports AIPC = IVBH Berichte

Band: 57/1/57/2 (1989)

Artikel: Durability aspects in maintenance, repairs and rehabilitation

Autor: Roper, Harold

DOI: https://doi.org/10.5169/seals-44280

Durability Aspects in Maintenance, Repairs and Rehabilitation

Aspects de la durabilité dans la maintenance, la réparation et l'assainissement

Dauerhaftigkeitsaspekte bei der Unterhaltung, Instandstellung und Sanierung

Harold ROPER
Assoc. Professor
University of Sydney
Sydney, NSW, Australia

Harold Roper, is Associate Professor in the School of Civil and Mining Engineering at the University of Sydney. With degrees in mineralogy and civil engineering, his research, consulting and teaching interests centre on durability aspects of materials, and their influence on serviceability of structures.

SUMMARY

Durability of construction materials is defined, and problems of the quantification thereof are outlined. Design life of structures is considered in terms of repair requirements. Investigative procedures are considered and this leads on to the consideration of surveys of structures and application of some repair methods.

RÉSUMÉ

La durabilité des matériaux de construction est définie et leurs valeurs quantitatives sont commentées. La durée de vie des constructions est exprimée en fonction des besoins en réparations. Des méthodes d'analyse et de surveillance sont présentées, ainsi que des méthodes de réparation.

ZUSAMMENFASSUNG

Die Dauerhaftigkeit der Baustoffe wird definiert und die Probleme bei deren Quantifizierung umrissen. Die Lebensdauer von Bauwerken wird von den erforderlichen Instandstellungsarbeiten abhängig gemacht. Anschliessend werden Untersuchungs- und Instandstellungsmethoden besprochen.

1. INTRODUCTION AND DEFINITION

"Durability is an essential attribute of a building material". While this statement would be agreed upon by most persons concerned in the construction, maintenance, repair and rehabilitation of buildings , the exact meaning of the term durability could lead much discussion. The Shorter Oxford English Dictionary defines durability as "the quality of being able to withstand change , decay or wear". In applying such a definition to a property of concrete, steel or any other building material, it must be appreciated that none of these materials will continue to fulfill its role indefinitely, and, the same material may last a long period in one environment while deteriorating rapidly in another. Consider, for example, a high C3A-cement concrete in dry air, and in contact with sulphate charged ground water, or an unpainted steel structure exposed to dry desert enviroment and in a marine climate.

Rather than consider the dictionary definition, one may seek a definition of durability, and its related concept, serviceabilty, in technical literature related, for example to concrete; in this case we find the following :

<u>Durability</u> - the safe performance of a structure or a portion of a structure for the designed life expectancy. (Note - because the forces of nature , coupled with some man created exposure, may cause progressive deteriorations, these recommendations do not preclude the need for normal maintenance), (from ASTM Recommended Practice for Increasing Durability of Building Constructions Against Water-induced Damage, E 241 -77).

<u>Durability</u> - the capability of maintaining the serviceability of a product, component, assembly or construction over a specified time, (from ASTM Recommended Practice E 632).

<u>Serviceabilty</u> - the capabilty of a building product, component, assembly or construction to perform the function(s) for which it is designed and constructed, (from ASTM Recommended Practice E 632).

In recent structures codes throughout the world significant changes to the durabilitity provisions for materials are occurring. A trend has developed wherein durability is defined with respect to a series of relevant serviceability states as well as designated design requirements in order to resist any specific environmental effects which might apply, such as temperature extremes and aggressive atmospheres. Several points arise from the definitions of durability and serviceability. The most important is that <u>time</u> plays an important role in the property of durability; durability is to be considered <u>at the design stage</u> of a project; and, <u>"normal maintenance"</u> may or may not be allowed for in considering durability.

As yet no-one has satisfactorily quantified the durability of concrete in service, although some attempts at such evaluation have been based on statistical concepts [1]. Durability analyses, statistically considered, have to include both the possibility of a certain event taking place, and the possible consequences thereof [2]. This leads to complicated risk-analysis procedures which are only really worthwhile if the damage mechanisms can be described reasonable well. This stage has not been reached even for thoroughly studied phenomena such as sulphate attack on concrete, where a change in the cation species without changes in the sulphate concentration, may entirely upset any prediction of the rate of attack [3]. It follows that, as yet, the necessary data for undertaking risk-analyses relating to durability of building materials such as concrete is not yet available to engineers under all anticipated exposure conditions.

2. DESIGN LIFE OF A STRUCTURE

A definition of the design life of a structure is "the minimum period for which the structure can be expected to perform its designated function, without significant loss of utility, and not requiring too much maintenance ". Words such as "expected", "designated", and "significant" require definition in turn. Somerville [4] points out that the concept of design life is not new, and quotes codes of practice dating back to 1950 in which figures, for both building components and buildings as a whole, were given. Since then, nominal design lives have often been prescribed. Somerville presents a relationship between the performance in durability terms, and time. This is reproduced as Fig.1. The objective of Somerville's presentation was to set a framework for future research and development work on durability. The diagram shows several important points which according to him reflect the apparent state of the art. These are:

The variation in inherent durability built in at the construction stage (which is not quantified).

The spread in performance, represented by the hatched area, (we need to know more about this in quantitative terms - about the spread itself, and the factors which contribute to it).

The need to define minimum performance requirements - on both axes.

The need for a lifetime performance plan lying somewhere between Curve 1 (normally much too expensive) and curve 3 (both dangerous in safety terms and expensive in remedial terms); some variant of Curve 2 is probably the answer.

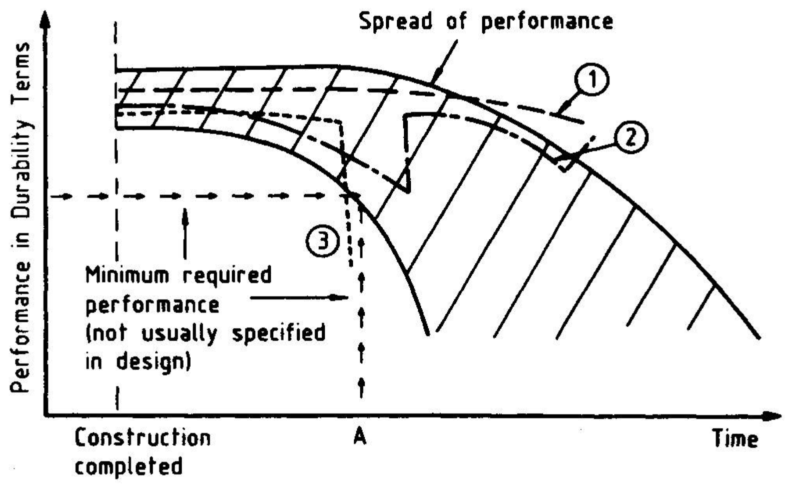

FIG.1 LOSS OF DURABILITY WITH TIME

Somerville notes that filling in the detail on the diagram requires much work in the future, although he suggests that current understanding would permit a start to be made. Great impetus would be given to this work by simply defining A, (the nominal design life). What is important here is the information required and applied to facilitate maintenance, repair and rehabilitation of a structure such that curve 2 can be folllowed. Not only is it important that the repair necessisary to extend the structure's useful life can be executed, but that it can be economically justified.

3. INVESTIGATIVE PROCEDURES

No maintenance, repair or rehablitation scheme can be successful in cost and long-term efficacy unless, prior to the implementation thereof, the effects of age and exposure conditions to which the structure has already been subject are properly assessed. The problems of such assessment are unique to each material or combination of materials used in the structure, and depend on the characteristics and performance requirements of the structure. Unless several essentially similar structures in comparable environmental exposure conditions are to be assessed, no common outline of investigative procedures can be decided upon. For this reason the investigation team must adopt certain of a host of techniques as a means to best assess any problems of durability, which may influence the structural engineer's particular proposed repair scheme. Many of these techniques are not necessarly familiar to the practising structural engineer who is ultimately responsible for decisions, as most are borrowed from disciplines such as applied physics, analytical chemistry, electro-chemistry, mineralogy, metallography and even geophysics. Often the results tend to be descriptive of the conditions rather than in the form of a set of all embracing specific numbers, and even then, many of the units are not those common to the the structural engineer. A comprehensive paper by Clifton [5] describes eighteen non-destructive evaluation methods, that can be used in assessing the condition of concrete and masonary materials and components in structures being rehabilitated or preserved. At least eight of these are covered by ASTM Standards.

When repairs are proposed for a specific type of problem on a particular section of a structure, then, provided that sufficient experience has been accumulated, a well defined assessment scheme can be outlined and followed. The best example of such a problem is the reinforcement corrosion, due to the use of de-icing salts, of concrete bridge decks in North America and elsewhere. In this case a scheme of required procedures has been defined by Manning and Bye [6]. Such a scheme must relate the aquired information back to the repair or maintenance procedure, and in the example chosen, the mapping of defects, information on levels of salt ingress, and other condition data allow cost and management planning to be made, provided the repair and maintenance procedures are themselves well defined, which in this example they are [7,8]. Under certain circumstances these procedures may, with caution, be directly applied to other similar structures such as decks of wharfs influenced by saline water.

The greatest problems arise when aspects of durability are divorced from serviceability during maintenance or repair considerations. The only time that this should be done is when durability is influencing nothing other than the visual apperance of a structure. Under all other circumstances durability of the materials needs to be linked directly to serviceabilty and structural performance criteria. For this reason investigations of structures are best performed as durability and serviceability surveys rater than simply assessments of the durability condition of the materials per se. Two other important objectives of such surveys are to define the actual cause of the durability problem, and to make available to the repair team a mapping of problem areas. From conclusions reached on causes, some assessments can generally be made as to the likely progress of deterioration under continued use of the structure, and its consequences. Also steps can be considered to decrease the attack rates or if possible eliminate the conditions under which the deterioration is progressing.

The use of maps of non-durable sections of structures is obvious. Such mappings can be achieved by many different techniques, but it has been found, in the experience of the writer, that provided the problem presents even subtle visual evidence of its occurrence, the simplest and most informative method is to combine in situ visual inspection with photo-interpretation, using either colour prints or video-tape. Such photo-interpretation methods are based on the same techniques as those used for study of aerial photographs and satellite imagery. Information from either photo-mosaics or video-tape can be rapidly accumulated in computer files, which can in turn be used to present the data in almost any required form. Under particular circumstances sterioscopic techniques may be of special help, but readily available image-analysis programmes for monocular images may be employed for most purposes.

When using such photo-interpretation techniques in particular, but also for general purposes of durability description, it has been found necessary to consider indivdual structural elements, or groups of similar element types, which make up the structure rather than the structure as a whole. This has not often been appreciated or emphasised during surveying of structures. Inspections of concrete structures in situ on large scale have been primarily stimulated by the requirements of maintenance programmes. Guidelines produced by the Transportation Research Board [9], on the assessment of bridge deterioration used a purely qualitative approach. Various defect conditions were assigned an "urgency index" relating to the necessity for repairs according to the observer. In other work [10,11,12] assessment of defiencies is made on the basis of qualitative engineering judgements. Condition surveys of Continuously Reinforced Concrete Pavements (CRCP's) proved impetus to place assessment on a more quantitative basis. Several published works [13,14] indicate the importance of a quantitive approach to the assessment of durability. Carrier and Cady [15], assessed the defiencies of CRCP's on a quantitative basis and then analysed the data using computer methods. Although quantitative in nature, their methods have the deficiency that they were only applicable to slab elements of similar design, and only a limited number of durability defects were considered. A method of universal application to full scale structures relating to a large number

of individual concrete members for a larger number of observed deficiencies has been proposed in two publications by Roper et al [15,16]. In these the guidelines for evaluation of the durability of concrete structures apply to all types of concrete structures, be they in bridges, buildings or any other category. A complete durability assessment includes:
(i) Reviewing the structure considering design details, construction reports and maintenance data, all of which provide background information on the structure,

(ii) Classifying the structure in terms of first its use, and then its structural elements,

(iii) Classifying the deterioration phenomena that may occur on these structural elements,

(iv) Carrying out in situ durability assessments or measurements on individual structural elements, and

(v) Combining information and data collected on similar elements, thereby gaining an indication of the durability condition of the structure.

4. RESULTS OF SURVEYS OF CONCRETE STRUCTURES IN AUSTRALIA

In a recent Australia-wide survey by questionnaire on repair problems and procedures, 621 reported cases related to structural problems, whereas 484 were related to diminution of functional efficiency and surface aesthetics of the structures. Also reported were 590 structures which showed effect of concern to the owner and public, but not to the engineer. These figures do not support the conclusion that the necessity for repair of structures in Australia principally results from any non-durability of the concrete. Structural problems are still of great importance in the cost of repair.

The use of Fly-ash in concrete has recently been the subject of considerable criticism [17,18]. In an extensive durability survey of NSW structures and Sydney buildings its role in the durability problems of actual in-service structures has been considered.Two dams, two pavements, a water channel, a retaining wall and a series of slabs on grade were studied, using apart from conventional Civil Engineering Techniques, those of electron microscopy and chemical analysis. A general conclusion was that PFA concrete fulfilled the requirements of the design engineer, and that durability problems were not accentuated by its use. Although carbonation rates were shown to be greater for PFA concretes than for comparable OPC concretes, overall durability was similar for structures build with the two types of concrete.

A total of 136 buildings were examined to assess their long-term durability. Neither PFA nor OPC concrete can boast a proud record of long-term durability, as between 80 and 90 percent of the building examined showed some type of durability defect. No evidence could be found to suggest that a sub-group of buildings, all of which were constructed using PFA concretes, are in any better or worse condition than buildings chosen at random which may have been constructed using OPC or PFA concretes. There is some evidence to suggest that, if problems occur in PFA concrete structures, their appearance is observable at somewhat earlier ages than is the case for all non-durable buildings.

The conclusions that in the "old days", buildings were better built and hence more durable, and that the introduction of modern mix designs or techniques has caused the non-durability, cannot be substantiated or refuted using the available data. The demolition of less durable members of older age-strata sets may influence such data significantly. As a general rule, lower percentages of non-durable buildings are found in older age groups, if stained buildings are not considered non-durable. For the total set of buildings it ws found that all age groups are similarly affected by corrosion of reinforcement (Roper, 1985).

5. REPAIR EXAMPLES INVOLVING STRENGTHENING

Janney [20] discusses repair techniques for columns or piers, which he states may need strengthening for one or more of the following reasons:-

(i) Concrete deterioration or low strength original concrete.
(ii) Corrosion of reinforcement or inadequate amount included in design or placed during construction.
(iii) Load increases over those originally provided for in original design due to unanticipated change in use.

He notes that columns and piers derive their load carrying capacity from the interaction of concrete and reinforcing. Repair or strengthening methods must, therefore, asure that added concrete and/or reinforcement act with the existing materials. He considers a column which has suffered corrosion of the vertical and tie reinforcement. "Assume this corrosion came about becuse the original concrete strength was low and the concrete cover was inadequate to protect the steel from a very humid atmospheric exposure. First, the strength of the core concrete must be determined by coring or by a combination of coring and pulse velocity measurements. Next, determine the loss of steel area that has resulted from the corrosion. In order to make this determintion, it is necessary to remove the corrosion products from the reinforcement. This cleaning is required before new concrete is placed around the steel anyway. After the strength of the concrete, the amount of steel and the yield point have been established, it is possible to determine the amount of added reinforcement and concrete needed to bring the column up to required strength. The fact that the original concrete and the reinforcement is stresed under dead load and the new concrete and steel will not be, must be taken into consideration in the design of repair. Steel required to replace that lost from corrosion of reinforcement in addition to the original amount, if required, is tied in place. All added vertical reinforcement should be surrounded by ties spaced and sized to meet applicable code requirements,ignoring ties that remain in the original column after removal of deteriorated concrete. If the elimination of the cause of corrosion, moisture or oxidizing agent cannot be assured, epoxy coated reinforcement may be used to minimize corrosion and extend the life of the structure being repaired.

If the column is long or the amount of replacement concrete represents a considerable percentage of that in the original column or pier, shear ties are recommended. The spacing and size of these drilled-in dowels to assist in holding the original and repair concrete together should be an engineering determintion. Replacement concrete may either be cast and vibrated in place or pneumatically placed. As stated previously, the use of pneumtic concrete should be carefully considered and applied by persons skilled and experienced in the use of this material."

Probably the most striking features of his recommended repair procedures are the extent to which original concrete is removed, the extensive replacement of reinforcement and the care taking in including ties, stirrups and extended lap lengths in the repair designs. From personal observation it would appear that in Australia there is a degree of reluctance to remove concrete to the extent recommended. It is probable that this reluctance is related to extra costs of propping and reforming, but unless such cost problems associated with sound repair methods are faced, repeated repairs will be necessary.

6. REPAIRS ASSOCIATED WITH STEEL CORROSION OF BUILDING FACADES

If the reader hopes to be informed that there is a single, proven, acceptably priced method for the repair and rehabilitaion of building structures suffering from problems of reinforcement corrosion then he should prepare himself for a disappointment, as this paper offers no universal panacea to troubled owners, engineers and architects. The question which must be answered is, "Why is there no set procedure?" There are two answers. The first is that the rusting of reinforcement is cused by many different factors despite the fact that carbonation or the presence of chlorides are often held to be the only reasons. Secondly, the substrate concrete to which the repair must adhere varies significantly in innate characteristics and to different ambient conditions.

6.1 The Influence of Factors Causing Distress

Experience suggests that a host of causes of corrosion are responsible for the observed damage to building facades. There is a significant danger that if the cause of the problem is not fully understood then a repair method will be used which will not improve durability. Consider the case of non-load bearing, pre-cast concrete mullions. These have, in at least one case, been fixed by dowels which have been pressure grouted with expansive mortar formed of a mixture of portland cement, sand, iron fillings and calcium chloride. The expansion of this type of grout never tends to cease, and cracking of the concrete along reinforcing bars results. If now the repair only concerns itself with the reinforcing bars there is no chance that a lasting repair will result. Similarly, if a panel set has been cast such that the reinforcement lies at the interface of veneer and backing concrete, each of which have different properties, local repairs have little chance of ensuring longevity of the panel set. If panels have been acid-dipped, to provide special surface finishes, then this too, may influence decisions with respect to repair or restoration procedures.

6.2 The Influence of Concrete Properties

The hygrothermal properties of concrete are such that they form an ill-matched set when compared with those of most patch materials. The shrinkage of even a shrinkage-compensated mortar patch is different to the dimensional change properties of a substrate concrete. Concrete may shrink on heating due to drying while an epoxy patch expands. Because of these types of problems, detachment of patches is always a possibility. A greater risk however is if depassivating ions such as chlorides remain at bar level and continue the expansive reactions.

Apart from these factors it has been shown by work at The University of Sydney, that patches of almost any type are much more successful on high strength concrete than on concretes of lower grade. This finding is considered to be extremely important as it explains why some inorganic and organic chemical patch materials may work very well when used on, say, a high strength prestressed concrete tank or oil production platform in the North Sea, but may not show satisfactory endurance performance on Sydney building facades. The reason for this difference is that, for lower grade concretes, diffusion continues to occur through the pore or crack system of the concrete at a relatively high rate when compared with movements through high grade concrete. Furthermore, there is often already a build-up of depassivating ions in the concrete of high permeability. These continue to cause corrosion adjacent to the repair, and they are supplemented by continued diffusion.

6.3 Repair Procedures

The Concrete Society Report on Repair of Concrete Damaged by Reinforcement Corrosion [21] was prepared by a working party established by the Concrete Society Materials Steering Group with the assistance of FERFA (Federation of Resin Formulators and Applicators) and the Association of Gunite Contractors. In their foreword they state that "As the repair of concrete can be a difficult task involving many operaions and using specialized materials, frequently in unfavourable circumstances, the working party has concluded that the most useful report it could produce would be one aimed primarily at specifiers who are dealing with repairs for the first time. It is, however, hoped that others, more experienced in the field, will find it of use as providing an overview of the subject."

The report deals with methods that are currently in common use for the repair of concrete damaged by reinforcement corrosion, and is particularly helpful in providing guidance on contract conditions, specification and measurement. It is less helpful when dealing with local patching, as it is stated: "When local patching rather than overall repair of concrete suffering from chloride-induced corrosion is carried out, further damage may occur in areas close to the repair. The extent and rate of such damage cannot at present be predicted. However, it has been found, in many circumstances, that is is more economical to carry out local patching and accept the need for further work later rather than to do much more extensive work when damage first appears. On theoretical grounds, it seems likely that in these cases the use of resin systems either to create a barrier bonding layer between the old concrete and the repair, or to provide a barrier on the steel surface, will result in less electrochemical interaction between the repair and adjacent original concrete.It could be helpful to record carefully the materials and methods used, so that, when more repairs are carried out later, performance can be judged and compatibility with new materials ensured."

7. APPLICATION OF CATHODIC PROTECTION TO CONCRETE MARINE STRUCTURES AND BRIDGE DECKS.

While there are still substantial technical questions to be answered before cathodic protection of reinforced concrete can be accomplished on a routine basis, it is the only protection method presently available which can be guaranteed to stop reinforcing steel corrosion after it has commenced. It is considered probable that within ten years many of the concrete structures in agressive environments will be cathodiclly protected either at the time of construction or as a restoration procedure.

8. CONCLUSION

Some aspects of the influence of durability on maintenance, repair and restoration of concrete structures have been considered. Lest it be believed from this paper that only concrete is a problem material with respect to durability, the reader is referred to a paper by Manning [22], discussing accelerated corrosion in weathering steel bridges in Canada, a problem also noted in Britian and Germany. Durability problems associated with roofing membranes, timber, plastics and bituminous materials are all noted by Wright and Frohnsdorf [23].

REFERENCES

1. Lever K.R. and Gray C.W., A Durability Study of Concrete Using Monte Carlo Simulation, Proceedings of the Fifth International Symposium on the Chemistry of Cement, Vol. III, Tokyo, 1968.

2. Sentler L., Statistical Evaluation of the Durability of Concrete, 9th FIP Congress, Stockholm, Colloquium C: Predictions of Service Life of Concrete Society Technical Report No. 26, 1982.

3. Chatterji S.K., Mechanisms of Sulphate Expansion of Hardened Cement Pastes, Proceedings of the Fifth International Symposium on the Chemistry of Cement, Vol. III, Tokyo, 1968.

4. Sommerville G., The Design Life of Concrete Structures, Structural Engineer, Vol 64A, No.2, Feb 1986.

5. Clifton J. R., Nondestructive Evaluation in Rehabilitation and Preservation of Concrete and Masonary Materials, ACI Infrastructure Seminar - Rehabilitation of Concrete Structures, 1985.

6. Manning D. G. and Bye D. H., Bridge Deck Rehabilitation Manual - Part 1. : Condition Surveys, Ontario Ministry of Transportation and Communications, Canada, 1983.

7. ACI Committee 345, Routine Maintenance of Bridges, Report No. ACI 345.1R-83, 1983.

8. ACI Committee 546, Guide for Repair of Concrete Bridge Superstructures, Report No. ACI 546.1R-80, 1980.

9. Transportation Research Board, Assessment of Deficiencies and Preservation of Bridge Sub-Structures Below the Waterline, National Cooperative Highway Research Programme Report 251, National Research Council, Washington, D.C., Oct.1984.11.

10. Rasheeduzzafar D.F.H. and Al-Gahtani A.S., Deterioration of Concrete Structures in the Middle East, American Concrete Institute Journal, Vol. 81, No. 1, Jan..-Feb.1984.

11. Fookes P.G., Pollock D.J. and Kay E. A. Middle East Concrete (2), Rates of Deterioration, Concrete, Vol.15, No.9, Sept.1981.

12. Fookes P.G., Comberbach C.D. and Cann J., Field Investigation of Concrete Structures in South-West England, Parts I and II, Concrete, Vol. 17, No. 3, March 1983, and Vol. 17, No. 4, April 1983.

13. McCullough, B.F. and Treybig, H.J., Condition Survey of Continuously Reinforced Concrete Pavements in North Central United States, 54th Annual Meeting, Transportation Research Board National Research Council, Transportation Research Record 572, Pavement Design, Performance and Rehabilitation, Washington, D.C., 1976.

14. Carrier R.E. and Cady P.D. Factors Affecting the Durability of Concrete Bridge Decks, ACI SP-47, Detroit, 1975.

15. Roper, H., Baweja, D. and Kirkby, G.A., Towards a Quantitative Measure of the Durability of Concrete Structural Members, Proceedings, International Conference on In Situ/Non Destructive Testing of Concrete, American Concrete Institute and Canada Centre for Mineral and Energy Technology, SP 82-32, 1984.

16. Roper, H., Baweja, D. and Kirkby, G.A., Durability - a Quantitative Approach, Concrete 85 - The Performance of Concrete and Masonry Structures, Institution of Engineers, Australia, Brisbane, 1985.

17. Ho, D.W.S. and Lewis, R.K., The Effects of Fly Ash and Water Reducing Agents on the Durability of Concrete, Commonwealth Scientific and Industrial Research Organisation, Division of Building Research, Melbourne, Australia, Research Report, 1981.

18. Ho, D.W.S. and Lewis, R.K., Carbonation of Concrente Incorporating Fly Ash or a Chemical Admixture, First International Conference on the Use of Fly Ash, Silica Fume, Slag and Other Mineral By-Products in Concrete, Montebello, Canada, 1983.

19. Roper, H., The Future of Concrete - Based on Jumping to Conclusions or Learning from Experience?, 12th Biennial Conference, Concrete Institute of Australia, Melbourne, 1985.

20. Janney, J.R., Maintenance, Repair and Demolition of Structures, Chapter 25, Handbook of Structural Concrete, Kong, Evans, Cohen and Roll Eds., Pitman Publishers, 1983.

21. The Concrete Society, Repair of Concrete Damaged by Reinforcement Corrosion, Concrete Society Technical Report No. 26, 1984.

22. Manning D.G. Accelerated Corrosion in Weathering Steel Bridges, Canadian Structural Engineering Conference, 1984.

23. Wright J.R. and Frohnsdorff G., Durability of Building Materials. Materiaux et Constructions Vol. 18 No. 105, 1985.