

# HIGHWAY RESEARCH CIRCULAR

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COMMITTEE ACTIVITY  
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Highway Research Board

## RESEARCH NEEDS

### Research Problem Statements

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### FOREWORD

The Concrete Division, Department of Materials and Construction, Highway Research Board, occupies a unique position relative to concrete research as compared with other organizations. It is the only organization whose concern with concrete ranges broadly from physical and mechanical to chemical properties; from effects of practices such as curing and ice control to basic research; and including chemical additions and admixtures, but whose concern is focused solely and directly on RESEARCH. It is not responsible for test methods or purchase specifications nor for codes for design or construction. Thus, when it speaks of research that, in its opinion, is needed, it is speaking from the standpoint of its evaluation of the state of that part of concrete technology which is its sole concern.

The Concrete Division appreciates that the research problem statements given in this circular are only a few of the many that could -- and should -- be prepared. It notes, for instance, that the American Concrete Institute Committee 115 on Research found 300 agencies engaged in research on more than 2100 projects in its report dated January 1966. Readers of this circular are invited to submit comments either on these research problems or others that might be included in a later edition of this circular.

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Research Problem Statement No. 1  
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Title:

Investigation of Chemical Reactions in Portland Cement Concrete that Affect Concrete Durability.

The Problem Area:

Chemical reactions of hardened portland cement concrete.

The Problem:

It is well established that certain reactions occur in hardened concrete that may result in the deterioration of such concrete. The reactions of sulfate bearing waters with constituents of the hardened cement paste and the reaction between certain siliceous aggregates and the alkali constituents of portland cement have been recognized and studies have shown that certain carbonate aggregates also react with alkalies with deleterious results. These reactions are perhaps only the most obvious deleterious chemical phenomena and other reactions occur which may also have a profound effect on the durability of concrete. These are not always deleterious but may in some cases be beneficial. Consequently, there is a great need for studies that will catalogue such reactions and also establish their role with respect to concrete durability.

Objectives:

Detailed and fundamental studies of all observed chemical reactions between the various constituents of concrete excluding those involving the normal hydration of portland cement constituents should be made. Such research must include both fundamental laboratory work on the nature of the materials used in concrete, their chemistry, physical chemistry, constitution and microstructure. The second phase of this research should be investigations designed to show the practical effect of such reactions on the durability of highway concrete. Finally, studies should be conducted to show how the deleterious effect of such reactions can be prevented.

This general problem is of such magnitude that it must necessarily be split up into a number of specific studies. These may be investigations of types and sources of aggregate, specific studies of a particular chemical phenomena or studies to determine the relation of various chemical characteristics or reactions to the service behavior of particular materials.

All of the more modern techniques for measuring fundamental chemical properties and reactions of materials should be employed. These would include X-ray diffraction, differential thermal analysis, infrared spectroscopy, petrography, etc.

References:

1. Highway Research Board - Special Report No. 31
2. Highway Research Board - Research Report 18-c
3. Highway Research Board - Bulletins 94, 171, 196, 239, 275
4. Highway Research Board - Research Record 45.

Note:

Items 1, 2, and 4 include extensive bibliographies on chemical reactions in concrete.

Urgency:

The information to be obtained from the studies of this nature is urgently needed. Such information will assist greatly in solving problems of material proportioning, evaluation of aggregates from new sources, and in establishing new techniques and specifications that will improve concrete durability.

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Research Problem Statement No. 2  
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Title:

Alkali Reactive Carbonate Rocks in Portland Cement Concrete.

The Problem Area:

Chemical reactions of hardened portland cement concrete.

The Problem:

Methods are needed for controlling the use of alkali reactive carbonate rocks in Portland cement concrete. Present acceptance tests, designed to determine the suitability of rock for use in Portland cement concrete, fail to detect the reactivity to alkali of carbonate rocks.

Objectives:

The objectives of the research would be to establish the level of reactivity which can be tolerated under various conditions of service, and to develop methods for sampling and testing of carbonate rocks to determine their reactivity to alkali and appropriate limits which would serve as a basis for specification controls.

References:

An annotated bibliography of reports concerning this problem appears in Part IV of Highway Research Record Number 45.

Urgency:

The widely reported incidences of concrete affected by alkali-carbonate reactivity and the indication that the increased use of certain de-icing salts could be causing an increase in the amount of affected concrete, clearly indicate that an early solution to this problem is most urgent.

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Research Problem Statement No. 3  
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Title:

Use of Small Quantities of Calcium Chloride in Prestressed Concrete.

The Problem Area:

Corrosion of metals embedded in portland cement concrete.

The Problem:

Specifications generally warn against the incorporation in prestressed concrete of admixtures containing calcium chloride. A number of commercially available admixtures contain about 20 per cent  $\text{CaCl}_2$ . If the admixture is used at the rate of  $1/4$  pound per sack of cement, the amount of  $\text{CaCl}_2$  is about 0.05 pound per sack. Is this small amount likely to promote corrosion of prestressed wires or rods? Is the amount of  $\text{CaCl}_2$  equal in corrosive effect to an equivalent amount of  $\text{NaCl}$ ?

Objectives:

The objective should be to establish, if possible, the maximum concentration of  $\text{CaCl}_2$ , or of chloride-ion below which corrosion of prestressed steel is not likely to occur.

References:

Calcium chloride in amounts up to 2 per cent by weight of the cement is generally not believed to cause detrimental corrosion of normal reinforcing steel. On the other hand, such a concentration has been found to cause corrosion of prestressed wires. California Division of Highways constructed a number of 6" x 6" x 36" concrete prisms of 8-sack concrete which contained one  $3/8$  inch pretensioned strand. The prisms were steam cured and then exposed out of doors over a trough of water with towels draped over the center portion and dipping into the water. The water used in mixing the concrete contained chloride equivalent to 0.04 pounds  $\text{CaCl}_2$  per sack of cement. The cement itself contained 0.01 per cent by weight of chloride, calculated as  $\text{CaCl}_2$ . Additions of  $\text{CaCl}_2$  were made during mixing in amounts of 0.00, 0.05, 0.09, 0.19, 0.38, and 0.73 per sack of cement. The total amounts of chloride, calculated as  $\text{CaCl}_2$ , per sack were therefore 0.05, 0.10, 0.14, 0.24, 0.43, and 0.78 pounds. After 3 years the strands were removed and examined for evidence of corrosion. In general, no corrosion was evident on the outer surfaces of the wires in the strand where intimate contact with cement paste was obtained. Corrosion was found on interior surfaces of the strand where the cement paste had not penetrated. Corrosion was found to increase with increasing amounts of chloride but in the lower ranges did not correlate well with chloride content. Evidence of corrosion was quite definite in concentrations equivalent to 0.19 per cent and greater calculated as  $\text{CaCl}_2$ , 0.05 of which was due to  $\text{NaCl}$  in the mixing water and chloride in the cement. At the lowest concentration, 0.05 pounds per sack, there was some evidence of corrosion, but there was less evidence in the next

higher concentration. In general, the results show that relatively small amounts of chloride can induce corrosion of prestressed wires in strand form, but the tolerable limit is not well defined.

Urgency:

There is no great urgency for solution inasmuch as present specifications warn against introducing any calcium chloride and are therefore conservative. However, there is an economical problem in prohibiting admixtures containing small amounts of chloride which conceivably could be used safely if the mixing water were substantially free from chlorides.

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Research Problem Statement No. 4  
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Title:

Comparison of Membrane Curing to Water Curing of Concrete.

The Problem Area:

Curing of concrete.

The Problem:

Membrane applications are at times used to cure structural members that are not in direct contact with the ground. The efficiency of such curing method may be less than that obtained in curing slabs that are supported directly on the ground for the reason that membranes are not required under existing specifications to be completely impervious to the passage of water vapor. When slabs are in contact with the ground, moisture can enter the concrete at a rate equal to the loss of water through the membrane. In elevated members there is no means of replenishing moisture lost through the membrane. How serious is the loss of moisture in elevated members with respect to strength, permeability and abrasion resistance? Are the practical difficulties in maintaining a continuously moist surface by the application of water sufficiently great to offset the presumed loss in quality resulting from membrane applications?

Objectives:

The objective should be to determine the relative effect on strength, permeability and abrasion resistance of concrete subjected to membrane curing as opposed to water curing.

References:

Unpublished work by the Washington Department of Highways in 1937 gives results of flexural strength of concrete prisms that were wrapped and glued with water proof paper, on all surfaces but one, and were then buried in the ground with the top (uncovered) surface flush with the surface of the ground. Twelve beams each were cured with water, were cured with membrane, or received no curing. After 12 days the paper wrapping was removed, the curing compound was removed with solvent and the prisms were buried in wet earth for 2 days. The prisms were then broken in flexure with the top surface as cured in tension. Relative strengths relative to continuous water cure were:

Membrane Cure	-	86 per cent
No Cure	-	69 per cent.



In other tests, Washington inserted 3-inch diameter by 1-inch deep tins filled with mortar in the surface of a pavement at the time of construction. Six tins each were cured in place with water, with one coat of membrane, with two coats of membrane, and with no curing. After 10 days in place the specimens were removed, the tins stripped and were allowed to air dry. The top surface was then subjected to abrasion by agitation on a bed of Ottawa sand. Losses in weight after 90 minutes of abrasion in grams per specimen were as follows:

Wet Cure	-	10.6
2 Coats Membrane	-	11.3
1 Coat Membrane	-	11.9
No Cure	-	12.1

Urgency:

The question should be answered with reasonable dispatch because of conflicting opinions on the subject.

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Research Problem Statement No. 5  
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Title:

Temperature Effects in Curing of Concrete Pavements.

The Problem Area:

Curing of concrete.

The Problem:

Present specification requirements for the maximum temperature of the plastic concrete vary considerably. This item can have a significant effect on the maintenance of favorable moisture and temperature conditions in the concrete immediately following placement. There is a need for a reliable basis for establishing the maximum safe temperature of plastic concrete for various conditions.

Objectives:

1. To determine the effects of high temperatures of freshly mixed concrete on the properties of the hardened concrete and on pavement performance.
2. To determine the effect on the maximum safe temperature of plastic concrete of such variables as humidity, air temperature, concrete mix design, concrete materials, and curing methods.
3. To determine relative costs of various methods of maintaining satisfactory concrete temperatures during hot weather paving.

References:

1. A Charted Summary of Concrete Road Pavement Standards Used by the State Highway Departments (PCA), p. 13, column 120.
2. Current Road Problems No. 1-2R, Curing of Concrete (HRB), p. 1-3.
3. "Proposed Practice for Hot Weather Concreting," Journal of the ACI, November 1958, V. 55, p. 525.
4. Hot Weather Concreting (PCA Concrete Information Sheet).

Urgency:

Random cracking and other difficulties in pavement performance associated with hot weather concreting are a major problem in several areas. Present specifications and recommendations for the maximum temperature of plastic concrete vary widely and are often vague. There is an immediate need for a better understanding of the effects of high concrete placement temperatures.

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Research Problem Statement No. 6  
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Title:

Use of Retarding Admixtures to Improve Finishing of Concrete Structures.

The Problem Area:

Concrete strength

The Problem:

Laboratory research has indicated the effects of retarders on setting and strength development of concrete in terms of standardized tests. Exploitation of these effects is handicapped by lack of research correlating laboratory tests with field experience, particularly with respect to placing, finishing, protection, and curing of the concrete.

Objectives:

Information is needed most urgently on the following aspects of this problem:

1. The procedures, sequence, and timing of finishing operations in different types of structures using concretes with different materials and proportions, and under different ambient conditions;
2. The ability of retarders of various types and at differing rates of use to provide benefits or to increase allowable tolerances in finishing under various conditions, with particular emphasis being given to the resulting durability, wear resistance, and riding qualities of surfaces;
3. The evaluation or development of operational procedures to permit predicting, specifying, and controlling the use of retarders, especially with respect to their effect upon finishing of concrete;
4. Effects of disturbances of the retarded concrete during placement, such as from revibration or slab deflection, on bond with reinforcing steel;
5. Ability of freshly-placed concrete to be integrated with concrete placed earlier;
6. The extent to which cracks or separations in the concrete can be "healed" by screeding or revibration;
7. Effects of construction variables -- timing, frequency of vibration, concrete proportions and ingredients, etc. -- on the above;
8. Permissible time lag in actual field operations in relation to laboratory tests of retarders.

Simulated field conditions should be employed in overall comparisons of variables. Desirably, the studies should be made by an organization which would also have opportunity to make evaluations and spot checks on actual jobs.

References:

No research of this specific nature and scope is known to have been made or to be underway at present.

Urgency:

Since difficulties with finishing have contributed to serious problems in highway structures, particularly bridge decks, the study could be considered urgent.

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Research Problem Statement No. 7  
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Title:

Achievement of Frost Resistance Through Air Entrainment with Minimum Effect on Structural Strength of Concrete.

The Problem Area:

Concrete strength

The Problem:

Especially in the manufacture of precast prestressed units such as bridge members for highway work, very high structural strength requirements exist. Many such members are made without air entrainment. Air entrainment has been shown necessary to provide frost resistance to concrete exposed to freezing while wet. Air entrainment reduces strength in greater proportion as the cement content of concrete is raised. Means are needed to provide the protection of an entrained air void system in high cement content concrete with minimal strength loss.

Objectives:

It has been shown that strength reduction is proportional to air void volume but frost resistance may be achieved by adequately small void spacing even at low air volume. A means of producing adequate spacing at reduced volume of air would appear to be a possible solution to the problem. This might be achieved by extended vibration of mixtures so proportioned as to avoid undesirable segregation if vibrated for an extended period.

References:

1. ACI Committee 212 "Admixtures for Concrete", Journal ACI Proc. 60, No. 11, Nov. 1963, pp. 1481 - 1523 (esp. pp. 1496-98).

Urgency:

This problem was suggested by its having been stated to exist in negotiations between the Oregon Highway Department and a fabricator of bridge members.

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Research Problem Statement No. 8  
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Title:

Supplying Pure Hydration Product Compounds to Researchers.

The Problem Area:

Basic research, cement and concrete.

The Problem:

Preparation and operation of a "Standard Sample Bank" for dissemination of pure cement hydration product compounds to research workers.

Objectives:

To prepare, characterize, and distribute to active research workers a collection of pure, standardized, samples of cement hydration compounds of controlled composition and crystal structure so as to assist the progress of basic research in the problem areas mentioned.

References:

This suggested project forms a logical extension of the work being carried out on a small scale by Subcommittee MC-B6(3). References to the current status of research in the field may be found in various articles in the current literature and in "The Chemistry of Cement," H.F.W. Taylor, editor, 2 volumes, Academic Press, 1964.

Urgency:

Considerable. Progress of research in this technologically important field is slow and sporadic, due to the inherent complexity of the chemical systems involved, and to the small number of investigators that are active in the field. Inherent difficulties (multiplicity of varieties, solid solutions, carbonated forms, and lack of a consistently-accepted nomenclature) make it very difficult for one laboratory to reproduce work carried out in another. Distribution of a set of samples, such as proposed here, together with characterization data (chemical, analysis, X-ray, D.T.A., infrared, etc.) would have a major influence in dispelling current confusion in the field, and may be helpful in attracting the interest of new research groups which now hesitate to undertake the study of these materials. Progress in the study of these hydration compounds is a prerequisite for effective research on the influence of useful additives and modifiers on cement hydration and on soil-stabilizer reaction, thus may have important practical consequences.

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Research Problem Statement No. 9  
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Title:

Mechanism of Hydration Reactions of Cement Constituents.

The Problem Area:

Basic research, cement and concrete.

The Problem:

Basic research is needed to study the mechanisms of the hydration reactions of the various constituents of portland cement.

Objectives:

It is hoped that this understanding will serve to explain the mechanisms of early structure formation. This may also lead to the explanation of the influence of various additives and may enable a significant improvement in the mechanical properties of hardened cement paste, or reduce the undesirable physical characteristics such as shrinkage or creep.

References:

Rehbinder, Segalova and Mikhailov, U.S.S.R. (see Bibliography).

Urgency:

None given.

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Research Problem Statement No. 10  
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Title:

Utilization of Expanding Cement in Highway Construction.

The Problem Area:

Expansive cements and expanding concrete.

The Problem:

Observed behavior of the experimental concrete pavements demonstrated the need for more comprehensive information relative to the properties of expansive cements and expanding concrete. Some of the problems encountered included difficulties in the placement of rich mixes and insufficient information in the prediction of expansion and stress development.

Objectives:

To establish by laboratory investigations the factors influencing the placeability of fresh concrete and the control of rates and magnitudes of expansions of the expanding concrete. Included in this evaluation should be the effects of compositions and physical properties of portland cement, the fineness of expansive cement, and the fineness of the components of expansive cement. Also to be determined are the relative effects on properties of expanding concrete of blending the components of the expansive cement as compared to various methods of intergrinding.

The effects of age and exposure of expansive cement, upon expansion and mechanical properties of expanding concrete, requires investigation.

The influences of chemical admixtures, such as water reducing and set retarding, on the properties of fresh and hardened concrete should be evaluated.

Tests for properties of hardened concrete should include, in addition to mechanical properties, the durability of expanding concrete.

All tests for these investigations should be carried out on laboratory size specimens.

References:

None given.

Urgency:

None given.



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Research Problem Statement No. 11  
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Title:

Coordination of Basic Research in Cement and Concrete.

The Problem Area:

Basic research on cement and concrete.

The Problem:

A considerable amount of competent work is being carried out in the area of basic research on cement and concrete. It seems that anything additional that can be done in the direction of coordinating research efforts would be in order. For example, a thorough study of a given specimen of hardened concrete would involve a study of the microstructure by optical and electron-microscope methods, quantitative X-ray diffraction analysis, chemical analysis including small-scale electron microprobe analysis, chemical and kinetic studies of the hardening process, thermochemical measurements, surface area and porosity determinations, study of the role of the H<sub>2</sub>O by infrared spectra and possibly microwave or NMR techniques, differential thermal analysis, and additional techniques.

Objectives:

A careful correlation of sophisticated physical and chemical data from such measurements with structure-related mechanical and physical properties, all from the same set of samples is really essential to give the unified knowledge needed. This would necessitate cooperation between various laboratories.

References:

None given.

Urgency:

None given.

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\* Department, Division, and Committee Status  
as of December 1965