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USE OF ACCELERATORS IN HIGHWAY CONCRETE

Foreword

This report was prepared by a Special Subcommittee of Highway Research Board Committee MC-B5 on Chemical Additions and Admixtures for Concrete. It was reviewed by the committee as a whole and approved by letter ballot for publication.

Accelerators have useful application in concrete when decreased setting time or increased rate of strength development is desired. Extensive literature on the subject has been published, a selection of which is listed at the end of the report. It is the objective of this publication to summarize that portion of the information particularly relevant to highway construction and likely to be useful to the highway engineer.

Definition

An accelerating admixture is a material that is used for the purpose of accelerating the setting and strength development of concrete.

Applications to Highway Work

General

Accelerating admixtures are useful (1), particularly in cold weather, for modifying the properties of portland cement concrete to (1) expedite the start of finishing operations and, when necessary, the application of insulation; (2) reduce the period of time required for proper curing, especially in late fall paving where early application of de-icing salts may be expected; and (3) permit earlier loading or opening of pavements and structures to traffic.

The setting and hardening of portland cement result from a chemical process and, in common with other chemical reactions, the rate of reaction is dependent upon the temperature. The rate of concrete strength development drops rapidly with reduction in temperature; near and below the freezing point concrete gains strength very slowly. The benefits of an accelerator are the result of a higher rate of hydration of the portland cement which reduces the

(1) Numerals in ( ) refer to references at the end of this article.

initial setting time of the concrete, releases the heat of hydration more rapidly, and increases the initial rate of development of compressive and flexural strengths.

Cold Weather Concreting

When an accelerator is properly used, the rate of strength gain is considerably enhanced at low temperatures so that the concrete reaches the maturity required to resist the deleterious effects of freezing with or without the presence of ice-removal salts much ealier than if no accelerator were used. Likewise the heat given off as the portland cement hydrates will be released earlier and be available to the concrete during the vital early-hardening period. In addition, the concrete can be finished sooner so that the loss of heat to the outside during the period between placing the concrete and the application of insulation will be reduced.

The quantities recommended for use as outlined below lower the freezing point of concrete only a negligible amount, and hence calcium chloride should never be considered as an "anti-freeze." In fact, no materials are known which can appreciably lower the freezing point of the water in concrete without being harmful to the concrete in other respects.

The use of calcium chloride is usually not sufficient in itself to protect the newly placed concrete during cold weather. Other measures are often required, and recommendations on preparation of the base, heating the concrete ingredients, insulation, and application of external heat are available (2, 3).

Early Use of Structures

Accelerating strength gain at cold, or at normal temperatures, will permit the use of the pavement or other structure at an earlier date when an accelerator has been employed than if it has not. On some projects this may be of more advantage from the standpoint of allowing movement of the contractor's equipment over completed work at an earlier date, while in others, opening to normal or to by-pass traffic may be more important. The earlier use permitted by employing an accelerator may be particularly advantageous where traffic must be stopped or detoured during repair work.

In some patching operations, especially against water heads, the required quick-set mortar or concrete can be obtained by using an accelerator.

Reduction in Curing Period

To develop its potential properties to the fullest, concrete must be prevented from drying long enough for adequate hydration of the cement. Attempts to maintain the concrete in a moist condition for a sufficient period are often ineffective and may entail considerable expense and inconvenience. Since the length of moist curing required is dependent upon the rate at which the cement hydrates, the use of an accelerator may make possible a shorter curing time or, at least, minimize the damage from insufficient curing.

(2, 3) Numerals in ( ) refer to references at the end of this article.

Accelerator Types

The best known and most widely-used accelerator is calcium chloride (4). A great number of other materials have been found to accelerate the setting of cement, but in general they are little used in the United States, usually adequate information is not available for judging their probable other effects on concrete, and many are suited only to the preparation of fast-setting patching or plugging compounds. Many of the chlorides, alkaline carbonates, sulfates, nitrates, and silicates, and hydroxides of alkaline metals and earths have an accelerating action. Fluorides and fluosilicates also accelerate as do some organic materials such as triethanolamine (5,6)

ASTM Designation C 494 "Tentative Specification for Chemical Admixtures for Concrete, Type C" furnishes performance requirements and tests for accelerators. Calcium chloride should also meet the requirements of AASHO M 144, ASTM Designation D98, or Federal Specification O-C-105, all of which cover the two types: Type 1, regular flake ($CaCl_2$ min. 77%) and Type 2, concentrated flake, pellet or other granular ($CaCl_2$ min. 94%).

Moderate percentages of high alumina cement added to portland cement produce acceleration (7) as does the "seeding" of portland cement with about 2 percent of finely-ground, fully-hydrated cement pastes (8).

Subsequent discussion here will be limited almost wholly to calcium chloride.

Many proprietary compounds sold as accelerators or as "anti-freezes" are largely, if not wholly, composed of a calcium chloride or solutions thereof, and the advantages and limitations of calcium chloride also apply to such products.

Properties of Calcium Chloride

Rate of Use

Usual recommendations limit the dosage of calcium chloride to a maximum of 2 pounds Type 1 per bag of portland cement. When substantially larger quantities are used, or where the material is not uniformly distributed, there is danger of flash set or formation of disruptive chemical compounds. The actual quantity added should depend on job conditions and on the purpose for which acceleration is sought. At low temperatures the full 2 pounds per bag might advantageously be used while at higher temperatures smaller dosages may be indicated. ACI "Standard Recommended Practice for Winter Concreting", ACI 604-56, recommends 1 percent calcium chloride by weight of cement (2).

The rate of application of proprietary materials should be such that the quantities of calcium chloride actually added are equivalent to not more than 2 percent of the Type 1 form by weight of cement. Calcium chloride should not be added to the concrete in addition to such proprietary materials unless it is determined that the total calcium chloride content will not exceed the 2 percent recommended limit.

Calcium chloride can be used with all types of portland cement, but the magnitude of its effect may vary considerably depending both on the type of cement and the particular source of a particular cement type.

Unless otherwise indicated, the statements following refer to the use of 1 to 2 percent $CaCl_2$ by weight of cement, whether added as the salt or as a proprietary compound.

Effects on Concrete

Setting Time. Tests and experience with concrete indicate that both the initial and final setting times are reduced significantly. Four percent calcium chloride may cause very rapid set. In some applications the calcium chloride addition should be adjusted to give optimum setting time for placing and finishing the concrete.

Strength. Many data are available on the effects of calcium chloride on compressive and flexural strengths of concrete (4, 9, 10), and some on tensile strength. Compressive strength is increased substantially at early ages, 3 and 7 days, as compared to similar concrete without calcium chloride. The percentage increase in strength is substantially less at 28 days than at earlier ages, but an increase has usually been found to persist over extended periods of moist curing. The percentage strength gain resulting from the addition of calcium chloride is more pronounced at low temperatures than at higher ones (10). Benefits are greater with rich than with lean concretes. Usually the improvement in flexural strength is less than in compressive strength and at later ages unaccelerated concrete may even be slightly stronger in flexure than that in which calcium chloride has been added. Excessive additions of calcium chloride are detrimental to strength, particularly at later ages.

Heat Release. Calcium chloride accelerates the early heat development, but has no appreciable effect on the total heat of hydration.

Volume Change. The effect of calcium chloride on volume change is not thoroughly established but the consensus is that it increases the volume change of concrete both during continuous moist curing and during drying (9, 11). The magnitude of the effect as measured in the laboratory depends on many factors, including the conditions of test.

Water Requirement. Calcium chloride usually slightly reduces the water required to produce a given slump.

Air-Entrainment. Usually less air-entraining admixture is required to produce a given air content when calcium chloride is used than when it is not. The addition of 1 percent calcium chloride has been found to result in somewhat larger air bubbles and a higher spacing factor (12).

Calcium chloride is not compatible with some air-entraining agents and in such cases the two admixtures must be added to the concrete mixture separately.

Resistance to Freezing and Thawing. Calcium chloride has been found to increase the resistance of concrete to the deleterious action of freezing and thawing at early ages and decrease it at later ages (9). The increased resistance at early ages is of particular importance in winter concreting, and in concrete which will be subjected to ice-removal salts (13).

Sulfate Resistance. Calcium chloride has been found to contribute to low sulfate resistance. Its use is not recommended, therefore, where sulfate attack is probable.

Alkali-Aggregate Reaction. Data have shown that the magnitude of expansions produced by alkali-aggregate reaction is greater when calcium chloride is added than when not. However, when the expansion is controlled through the use of low-alkali cement or addition of a suitable pozzolan, the effect of calcium chloride appears to be unimportant.

Corrosion of Metals. The use of calcium chloride in reinforced concrete has not been found to cause corrosion of the reinforcement provided that the adequate concrete cover and thorough consolidation required for concrete without calcium chloride are provided. However, calcium chloride should not be used in reinforced concrete where stray currents are present. It should not be used when steam curing is employed unless tests of the specific application demonstrate the absence of objectionable corrosion. Calcium chloride has been found to contribute to the corrosion of prestressing reinforcing wire and it therefore should not be used in prestressed concrete.

By contrast it has been reported (14) that stannous chloride, when properly used, acts as an accelerator and does not cause corrosion of steel even under steam-curing conditions.

Severe corrosion of galvanized steel sheets used as permanent forms has been attributed to the use of calcium chloride (15).

Combinations of metals such as steel reinforcing and aluminum conduit should not be employed in concrete containing calcium chloride (16).

Method of Use

Storage

Calcium chloride should be stored in a manner which will prevent the pick-up of moisture. Storage conditions suitable for cement are satisfactory. Lumps which may inadvertently develop must be discarded, since they are not readily soluble in solution preparation, and if added to the mixture in solid form, may produce popouts.

Use as Solution

Calcium chloride may be added either in solution or dry form, but the former is preferable. A standard solution containing 1 pound of Type 1 or 0.8 pound of Type 2 calcium chloride per quart of solution is recommended. When specifications call for 1 percent calcium chloride, one quart of standard solution per bag of cement may be added to the mixture. For 2 percent calcium chloride, two quarts of standard solution per bag of cement are added.

Solutions of greater concentration are not recommended because they are more difficult to prepare and because they may not be stable at all temperatures.

The solution is considered as part of the mixing water, and often is added to it. Automatic dispensers are available for the purpose. The concentrated solution should not be allowed to come in contact with the cement for this may cause flash set. In ready-mixed operations it may be desirable to batch the concentrated solution with the first charge of aggregate to prevent contact of the solution with cement until after water has been added and mixing begun.

Calcium chloride, unless caked, dissolves readily in either hot or cold water. Heat is released during the dissolving period and the solution should be allowed to cool before use. The calcium chloride should be added to the water, rather than water added to the salt, for a hard, difficultly-soluble coating may otherwise result. A small mechanical mixer or air lance is recommended for use in solution preparation.

Use Dry

Completely-dry calcium chloride, free from lumps, can be batched and may be measured by volume or weight, but as such should not come in contact with the cement. When measured by weight it should be added in amounts not to exceed 2.0 pounds of Type 1 calcium chloride, or 1.6 pound of Type 2 calcium chloride per bag of cement. When volume measure is used, it is necessary to calibrate a container for type and form used, noting differences in bulk density between types and forms. In the case of ready-mixed concrete when long hauls are involved it may be desirable to add the calcium chloride at the destination. To insure adequate dispersion in the concrete, the dry calcium chloride should be added during the first half of the mixing period.

Addition With Other Admixtures

As mentioned above, concentrated calcium chloride solutions are not compatible with some air-entraining admixtures. This may also be true with other admixtures. It is preferable, therefore, that calcium chloride and other admixtures be added to the concrete separately.

Extent of Current Highway Usage

A recent poll of state highway departments revealed that about 1/10 of them use accelerators frequently, about 1/2 use them on occasion, and about 1/3 never use them. Extent of use on structures and pavements is about the same.

Selected References

1. "Admixtures for Concrete," Reported by ACI Committee 212, J. ACI, Proc. Vol. 60, p. 1481, Nov. 1963.

2. "ACI Standard Recommended Practice for Winter Concreting", J. ACI, Proc. Vol. 52, p. 1025, June 1956.

3. "Construction of Concrete Pavement in Cold Weather", Portland Cement Association (1955).

4. "Calcium Chloride in Concrete", Bibliography No. 13, Highway Research Board, 1952 (annotated).

5. "The Chemistry of Cement and Concrete", F. M. Lea and C. H. Desch, St. Martins Press (1956), p. 252.

6. "The Setting of Portland Cement", Harold H. Steinour, Portland Cement Association Bulletin 98, November 1958.

7. "The Characteristics and Applications of Mixtures of Portland Cement and High-Alumina Cements", Chemistry and Industry (London), Jan. 5, 1952.

8. "New Possibilities for Ensuring the Rapid Hardening of Cements, Mortars, and Concretes", M. Duriez and R. Lezy, Ann. Inst. Batim. 1956(9).

9. "Calcium Chloride in Concrete", J. J. Shidler, J. ACI, Proc. Vol. 48, p. 537, March 1952.

10. "Effect of Mixing and Curing Temperature on Concrete Strength", Paul Klieger, J. ACI, Proc. Vol. 54, p. 1063, June 1958.

11. "Shrinkage of Concrete - Comparison of Laboratory and Field Performance", Bailey Tremper and D. L. Spellman, Highway Research Record No. 3, HRB Publication 1067, p. 30, 1963.

12. "Origin, Evolution, and Effects of the Air-Void System in Concrete", Part 3, James E. Backstrom, Richard W. Burrows, Richard C. Mielenz, and Vladimir E. Wolkodoff, J. ACI, Proc. Vol. 55, p. 374, September 1958.

13. "Curing Requirement for Scale Resistance of Concrete", Paul Klieger, Highway Research Board Bulletin No. 150, January 1958.

14. "Some Chemical Additions and Admixtures in Cement Paste and Concrete", H. E. Vivian, Proc. Fourth International Symposium on the Chemistry of Cement, (1960), NBS Monograph 43, Vol. II, p. 909.

Selected References
(cont'd)

15. "Corrosion of Galvanized Steel in Contact with Concrete Containing Calcium Chloride", Clarence E. Mange, Preprint, 13th Annual Conference, National Asso. of Corrosion Engineers, St. Louis, 1957. ACI Abst. p. 431, Proc. Vol. 54, Nov. 1957.

16. "An Unusual Case of Corrosion of Aluminum Conduit in Concrete", T. E. Wright, The Engineering Journal V. 38, p. 1357 (1955).