SUPPLEMENTARY RECOMMENDATIONS FOR CONTROL OF SHRINKAGE OF CONCRETE

STRUCTURAL ENGINEERS ASSOCIATION
OF CALIFORNIA

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INTRODUCTION

In May, 1965, the Structural Engineers Association of California published a report by the Committee on Shrinkage of Concrete which included in the Appendix some sample specifications outlining how an engineer might place some controls on the quality of materials used on his project and thereby help to minimize the adverse effects of drying shrinkage.

During the intervening years since the publication of that report, the outline specifications contained therein have appeared in one form or another in thousands of project specifications throughout the state, particularly in the immediate San Francisco Bay Area. The document has been cited as a reference in many publications throughout the country and internationally, wherever engineers have encountered excessive cracked or deflected structures.

Although the overall effect has been to upgrade the quality of concrete used, there have arisen some problems which the authors could not foresee when the report was written. However, one of the purposes of the report was achieved; that is, to stimulate more research and to collect factual data on which to base limiting values.

Studies were soon available which pointed out wide variations in shrinkage data obtained between different laboratories, between different brands of cement and between laboratory and field-cured specimens of the same concrete.

A special task force subcommittee of the research committee of the SEAONC was established in January, 1971, to review available data and to make recommendations for revisions to the outline specification shown in Appendix I of the original report. The task force was made up of representatives from cement manufacturers, aggregate suppliers, ready-mix companies, testing laboratories and structural engineers.

The task force of SEAONC completed its task in July, 1974, when it submitted its recommendation to the SEAONC board. A minority report also was prepared by the 1975 SEAONC Research Committee. Both reports were referred to the State Research Committed for review in 1976. This final revised report was prepared by a special Ad Hoc Committee of SEAOC.

The recommended guide contained herein is written in outline form and contains certain suggestions and commentary. It is not intended that this be copied directly into project specifications. Rather it is to be used merely as a guide in preparing them. The purpose is to stimulate engineers to consider all the factors that help to control shrinkage and to select the methods best suited for his project within the limitations of the local environment and economics involved.

Prior to preparing specifications the engineer should review again the discussion of the drying shrinkage problem as presented in the 1965 report on Control of Shrinkage Concrete by SEAOC. The practical recommendations contained therein are still valid today. This supplement should be considered as a clarification and extension of that report.

The design engineer must have knowledge of the characteristics of the materials which are available for his project. Serious problems have developed when restrictive shrinkage requirements have been specified which were impossible to meet with locally available aggregates and cement.

It is recognized that by requiring drying shrinkage control, the engineer is merely attempting to establish a standard of quality for the concrete materials. Although absolute numbers are used, it should be clear that they are somewhat arbitrary and are used as guides in qualifying the materials proposed for use on a project.

Because there is considerable variation in results of drying shrinkage tests prepared in the field when compared to those prepared in the laboratory, it is unreasonable to require that field test results exactly duplicate the laboratory test results.

The initial qualifying laboratory tests must meet the specified requirements to comply with the level of quality desired. Once the materials have been accepted, shrinkage tests during construction may be desirable to provide a general evaluation of the quality of materials actually supplied. It may be equally as important to provide inspection of batching operations to check cleanliness of materials and to give reasonable assurance that the materials proposed are actually being used.

In summary, the engineer should remember that all of the following factors influence shrinkage:

Cement - Type and Manufacturer
Aggregates - Source and Gradation
Admixtures - Type and Manufacturer
Water/cement ratios
Batching operations
Placement methods
Weather conditions
Curing methods

In order to effectively control shrinkage, proper quality control procedures also must be followed throughout the entire operation.

As a final admonition, drying shrinkage limitations should not be specified unless: (1) the record of performance of at least some of the available materials have been reasonably established. (2) The entire concrete operation will have adequate quality control.

RECOMMENDED GUIDE FOR CONCRETE

SPECIFICATIONS CONTROLLING DRYING SHRINKAGE

a. Concrete Requiring Control of Drying Shrinkage

Where the different uses for concrete are listed, each specific class of concrete requiring special shrinkage control should be so designated. Seldom is drying shrinkage a factor for concrete placed below grade or where continuously exposed to moisture. However, some engineers prefer to use one class of concrete throughout the project to give less chance for error.

b. Acceptance of Materials

(1) It is advisable to require that concrete mixes be designed, tested and, if necessary, adjusted in ample time before the first concrete is scheduled to be placed. Sometimes it may be advantageous to permit the placing of the shrinkage class of concrete in the first placement of footing concrete so that field testing can be performed well in advance of actual required use.

(2) Laboratory or field trial batches for each shrinkage class should include the preparation of at least three specimens for determining drying shrinkage as outlined under "Test Procedures", in addition to six compression test specimens.

(3) One of the following three classes of drying shrinkage limitations may be stipulated as a condition of acceptance. The maximum values indicated are based upon laboratory prepared specimens as outlined in the "Test Procedures" (Paragraph "e").

Type or Class*	Laboratory Cast Specimens Maximum permissable drying shrinkage after 21 days of drying**
M	.036% of length
N	.048% of length
O	.060% of length

**These types are comparable with the Classes A, B and C established in the 1965 Report of SEAOC Committee on Shrinkage of Concrete. They were arbitrarily chosen to divide the whole spectrum of shrinkage control into 3 divisions. Any value above 0.08% may be considered as uncontrolled.*

***The laboratory shrinkage of small concrete specimens may be related to actual shrinkage in the building in the following manner:*

> *Experiments show that shrinkage of 4"x4"x11" specimens approaches the ultimate in about 64 weeks of laboratory drying at 50% relative humidity. The shrinkage at 21 days of drying may be taken at about 35% of this ultimate. In real buildings exposed to variable environmental conditions, the concrete will usually not shrink as rapidly nor as much as the laboratory specimens because of larger member sizes with lower surface area to volume ratios and higher humidity. Consequently, the ultimate shrinkage of concrete in the building may be taken as about 40% of the ultimate shrinkage of the laboratory specimen after 21 days. The ultimate shrinkage in the building may be considered, therefore, to be $\frac{(.40)}{(.35)}$ times lab shrinkage, or 10 to 20% greater than the values at 21 days given in the above table.*

(4) As an alternative, trial batching to determine drying shrinkage may be waived by the structural engineer if a satisfactory prior record of compliance has been established on comparable concrete mixes. Previous mixes may be considered comparable if they contain the same materials, i.e., identical geologic sources of coarse and fine aggregates, same brand and type of cement and admixture. A satisfactory prior record of compliance could consist of three or more laboratory trial batches for concrete used, on 3 or more separate projects. The average shrinkage should be equal to or less than the specified maximum. Data is acceptable only from laboratories furnishing evidence that they have been surveyed by the Cement and Concrete Reference Laboratory of the National Bureau of Standards and meet requirements of ASTM E-329.

(c) Evaluation During Construction

(1) During construction, drying shrinkage specimens should be prepared at the jobsite in a manner that closely follows the conditions required for laboratory prepared specimens. Utmost care should be used in curing and transporting these

specimens to minimize any adverse effects of weather. It is recommended that at least one set of three specimens be taken from each 1000 cubic yards placed, but at least 3 sets of three specimens be taken for the project. It is desirable that compression test specimens be taken from the same concrete as used for preparing drying shrinkage specimens. These compression test specimens may be considered as part of the normal requirements for tests on the project.

(2) Considering the statistical variations in properties of field placed concrete, the following values are recommended for the maximum allowable average drying shrinkage after 21 days of drying of field sampled concrete.

Type or Class	Field Cast Specimens Maximum permissable drying shrinkage after 21 days of drying
M	.048%
N	.064%
O	.080%

d. Other Field Control Measures

(1) Cleanliness of Concrete Aggregates

Since cleanliness of aggregate as used at the batch plant is a significant contributing factor affecting shrinkage, it is mandatory that some sampling and testing program be specified.

All concrete coarse aggregate should have a minimum C.V. (Cleanliness Value of 75) and all fine aggregates should have a minimum S.E. (Sand Equivalent of 75). The sampling should take place as discharged from the weigh hopper or as close to the point of discharge into the mixer as possible.

Sampling should take place no more than 2 days prior to mixing concrete for the project so that corrections can be made to the equipment, bins or material in the event the material does not pass. A fair sampling rate during production might be once per 200 cubic yards of concrete placed, but not less than three times during construction. Tests shall conform to Test Method No. Calif. 217 for fine aggregates and 227 for coarse aggregates. (Materials Manual, Testing and Control Procedures - Materials and Research Department, State of California-Sacramento.)

(2) Temperature of Concrete

Since one of the primary causes of concrete cracking in flatwork is sudden temperature drop during the first 24 hours, it is essential that some control be placed on the maximum temperature of concrete at the time of placement. It is recommended that this not exceed 75 or 80^{o} F. Aggregates can be cooled by sprinkling. Concrete trucks can be cooled by wrapping with saturated blankets and, if necessary, chopped ice may be introduced in place of mixing water to keep the temperature low. It is also important to protect the concrete after placing, particuarly so for thin flatwork subject to severe changes in temperature.

(3) Since excess mixing water adversely affects drying shrinkage, it is essential that concrete be placed with as low slump as feasible and slump be carefully controlled and measured at the site. Concrete exceeding the maximum upper limit allowed by ACI should not be accepted for use.

e. Test Procedures, Laboratory or Field Cast Specimens

(1) The "Drying Shrinkage" specimens shall be 4 by 4 by 11 in. prisms with an effective gage length of 10 in. fabricated, cured, dried and measured in the manner outlined in A.S.T.M. Designation C 157-69T and modified as follows: Specimens shall be removed from molds at an age of 23 $\pm$ 1 hours after trial batching, shall be placed immediately in water at 73^{o} $\pm$ 3^{o} F. for at least 30 minutes, and shall be measured within 30 minutes thereafter to determine original length and then submerged in saturated lime water at 73^{o} F. $\pm$ 3. Measurement to determine expansion expressed as a percentage of original length shall be made at age 7 days. This length at age 7 days shall be the base length for drying shrinkage calculations. Specimens then shall be stored immediately in a humidity control room maintained at 73^{o} $\pm$ 3^{o} F. and 50% $\pm$ 4% relative humidity for the remainder of the test. Measurements to determine shrinkage expressed as percentage of base length shall be made and reported separately for 7, 14, and 21 days of drying after 7 days of moist curing.

(2) *Although the Test Procedures (in paragraph e(1)) are completely detailed and written in specific language they are not intended to depart significantly from those spelled out in ASTM C-157-69T. Rather, they provide the necessary clarification for specimen size, time for removal of specimens and specific curing information that is needed in order to use C-157 properly. Only 2 major departures were taken, one is to shorten the initial storage period in water from 28 days to 7 days, the second is to use a 4x4x11" prism size rather than 3x3x11. Sufficient test data have been collected to demonstrate the adequacy of the 7 day initial curing period and practically all of the tests performed since 1965 (upon which these recommendations are based) were on 4x4x11" specimens water cured initially for 7 days before air drying. It would be futile for an engineer merely to specify that all tests be performed in exact conformance with ASTM-C-157 without clarification. The procedures given here should be followed exactly as written, otherwise different results would be obtained which could not be directly compared with the main body of information used to set the standards.*

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