4084

LIBRARY COPY
Materials & Research Dept.

61-15

ClibPDF - www.fastio.com

LR
BT/3/61
4084
LIBRARY COPY
Materials & Research Dept.

March, 1961

FACTORS INFLUENCING DRYING SHRINKAGE OF CONCRETE

By

Bailey Tremper
Supervising Materials and Research Engineer
California Division of Highways

Presented at meeting of
Structural Engineers Association of Northern California
San Francisco, March 7, 1961

Concrete shrinks upon drying because of its content of hardened portland cement paste which consists largely of a gel having hygroscopic properties. It gives off or takes on water slowly in reaching or approaching equilibrium with the surrounding atmosphere. Loss or gain of water is accompanied by shrinkage or swelling of the cement gel. Shrinkage of the gel in mortar or concrete is resisted by aggregate particles with the result that shrinkage is greatly reduced below that of neat cement paste. Restraint to shrinkage is a function of the absolute volume of aggregate. Restraint to shrinkage is furnished also by the coarser particles of cement which hydrate slowly if at all, and by calcium hydroxide crystals that are a product of cement hydration.

Factors affecting the overall shrinkage of concrete are:

ClibPDF - www.fastio.com

(1) Characteristics of the cement. Commonly used types in order of increasing shrinkage are (a) Type II, low-alkali, (b) Type I, and (c) Type III. Not all cements of a given type perform the same and there may be some overlapping among individuals in one type with those of another. The proportion of gypsum added to the clinker during grinding has a large effect on shrinkage.

(2) Clay-like particles and coatings on aggregates increase drying shrinkage by an amount that is greater than is indicated simply by an increase in water requirements due to the presence of such materials.

(3) Aggregates, even though clean, vary greatly in their contribution to drying shrinkage. Aggregates of high absorption tend to produce greater shrinkage but other commonly determined properties of aggregates are not at present definable with respect to their effect on shrinkage. Among a few California aggregates that have been tested, differences among them approach 75 percent. Aggregates available in the Bay Area are among the highest shrinkage producers.

(4) There is a general relationship between drying shrinkage and unit water content (gals. per cu. yd., etc.). The relationship is modified to some extent by variations in richness of mix, but such modification is minor compared to the overall effect of change in unit water. These

ClibPDF - www.fastio.com

(4) statements are compatible with that in the opening paragraph that restraint to shrinkage is proportional to the absolute volume of aggregate. Aggregates of smaller maximum size require more mixing water and hence produce more shrinkage.

(5) Higher slumps require more water and produce greater shrinkage.

(6) The higher the temperature of concrete at the time of mixing, the greater the quantity of water required to produce a given slump.

(7) Concrete that is held in a transit mixer or agitator with the drum rotating beyond 70 revolutions, the minimum required to produce thorough mixing, requires more mixing water because of the formation of dust of abrasion and the absorption of heat of work.

(8) Admixtures have effects on shrinkage varying from none to a substantial amount. Air-entraining agents have little effect if mix proportions are adjusted properly. Water-reducing retarders that have been compounded to destroy the retarding effect, as a class, appear to produce the greatest increase in drying shrinkage. Drying shrinkage is increased notwithstanding a substantial reduction in water content, a fact that indicates that some basic change in the nature of the gel has

ClibPDF - www.fastio.com

(8) been produced.

Each of the above factors acts independently of the others. Their combined effect is in geometric ratio, not simply additive.

If concrete made with the best materials, proportioned for best results and mixed and placed under optimum conditions is assigned a rating of 100, departures from such conditions can have a cumulative effect as illustrated by the following table:

100 x 1.25 = 125	increase due to choice of cement
125 x 1.25 = 157	increase due to excessive clay in aggregates
157 x 1.50 = 235	increase due to use of aggregates of poor inherent quality with respect to shrinkage
235 x 1.30 = 306	increase due to use of 3/4" max. aggregate where 1-1/2' max. could have been used
306 x 1.10 = 336	increase due to use of 6"-7" slump where 3"-4" slump could have been used
336 x 1.05 = 350	increase due to allowing temperature of concrete to reach 80°F during mixing, whereas with reasonable precautions, a temperature of 60°F could have been maintained
350 x 1.10 = 385	increase due to too long a haul in a transit mixer, or too long a waiting period at the jobsite before discharge, or to too many revolutions at mixing speed
385 x 1.30 = 500	increase due to poor choice of an admixture

ClibPDF - www.fastio.com

The value assigned to each factor in the above table is realistic with respect to probability of occurrence in commercial concrete. It is thus seen that the drying shrinkage of concrete can be increased five fold by the combined effect of many factors which singly are of much less consequence.

In the San Francisco Bay Area, where available aggregates are inherently poor with respect to their effect on drying shrinkage, it is of particular importance to make provisions to minimize other factors. Such provisions include designing members with a conscious effort to permit placing low slump concrete containing large aggregates, specifying good materials and workmanship and providing competent inspection with full authority to act promptly and decisively.

ClibPDF - www.fastio.com

Selected References

Carlson, R. W.,
"Drying Shrinkage of Concrete Affected by Many Factors",
Proc. ASTM Vol. 38, Part II, 1938, pp 419-440

Hveem, F. N. and Tremper, Bailey,
"Some Factors Influencing Shrinkage of Concrete Pavements"
Proc. ACI, Vol. 53, 1957, pp 781-789

Tremper, Bailey
"Control of Gypsum in Portland Cement"
Proc. ASTM, Vol. 59, 1959, pp 1101-1110

Concrete Manual, U.S. Bureau of Reclamation,
Denver, Colorado

Powers, T. C.,
"Causes and Control of Volume Change"
Journal of the Research and Development Laboratories, Portland Cement Association, Vol. 1, No. 1, January, 1959

ClibPDF - www.fastio.com