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VOLUME CHANGES IN CONCRETE

by Inge Lyse*

The knowledge of concrete design and control has been greatly advanced during recent years. Scientific research combined with construction practice has brought the material of concrete on a par with any other structural material; and methods for producing concrete of given strength, permeability, durability, and other qualities have to a certain extent, been applied successfully in the construction. However, information on volume changes in concrete has not been readily available, and the problem of controlling their occurrence is as yet a moot question. From an engineering standpoint the volume change due to variation in moisture content is one of the most important factors in concrete structures and the study of what constitutes its principal causes becomes a major problem. It probably is the one concrete problem which today is mostly in need of more fundamental research. The Portland Cement Association's Research Laboratory has for many years given thorough study to this problem. A brief summary of the results obtained has been presented in the so-called "sunshine diagram". This diagram is valuable insofar as it illustrates the effect of the richness of the mix and of the water content of the cement paste. In order

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to ascertain in which manner these factors contributed to the volume change of concrete, an investigation was recently carried out at the Fritz Engineering Laboratory of Lehigh University. Since a detailed report of this investigation has already been published*, only a brief summary will be presented here. The investigation revealed that neither the richness of the mix itself nor the water content (as such) constituted the important factor for the shrinkage of the concrete. The all-important factor was found to be the paste content of the concrete. Both the cement content and the water content in the paste had little if any effect upon the shrinkage, which was in all cases practically proportional to the amount of cement paste used.

Thus it was found that the shrinkage of concrete could be expressed approximately by the equation:

$$s = k \cdot p$$

where s represents the shrinkage of the concrete, k is a constant which depends upon the materials used and the conditions of exposure, and p is the percent of cement paste in the concrete. It follows that the problem of reducing shrinkage of concrete is principally one of decreasing the paste content. Thus any method by which concrete of low paste content can be properly placed is beneficial in reducing the volume changes. Vibration, tamping, and similar procedures for placing concrete of low paste content are thus very helpful in reducing the shrinkage.

* SHRINKAGE OF CONCRETE by Inge Lyse, Proceedings of the American Society for Testing Materials, 1935, Vol. II, pp. 383-398.

An illustration of the general relationship between shrinkage and paste content is given in Fig. 1. Two types of cement paste were used, the cement-water ratios by weight being equal to 1.0 and 2.0 respectively. It is noted that the shrinkage increased in proportion to the increase in paste content for both these types of paste, and that the shrinkage per each per cent of paste was nearly the same for both. For the results given in Fig. 2 several pastes of various cement-water ratios were used. Nearly the same value was obtained when the shrinkage of the concrete was expressed in terms of shrinkage per each per cent of paste. The broken lines indicate the shrinkage per each per cent of paste. The slightly greater shrinkage per each per cent of paste for rich mixes as compared with lean mixes, is probably due to the fact that segregation of mixing water takes place more readily in a lean than in a rich mix.

It should be pointed out that this paste content theory explains very well practically every factor which has been found to influence volume change, and therefore is in harmony with previous experimental results. As previous investigations have shown, lean concrete mixes will shrink less than rich mixes, wet mixes will shrink more than dry mixes, and mortars will shrink more than concrete. Concrete with well-graded aggregates requires less paste content than with a poorly graded

aggregates and therefore shows less shrinkage. In general, fine sand requires more paste than coarse sand and consequently its mortar and concrete will show more shrinkage. Therefore admixtures and powdered materials would also be expected to add to the shrinkage of concrete.

Since it is not yet possible to obtain cements with special low volume change qualities, the only way of producing concrete of low shrinkage is the use of low paste content. If for example, concrete can be placed with twenty-five per cent less paste than is generally used, the shrinkage would be correspondingly twenty-five per cent less. Thus it seems that the method of placing is at present the most important factor for producing concrete of low volume change.

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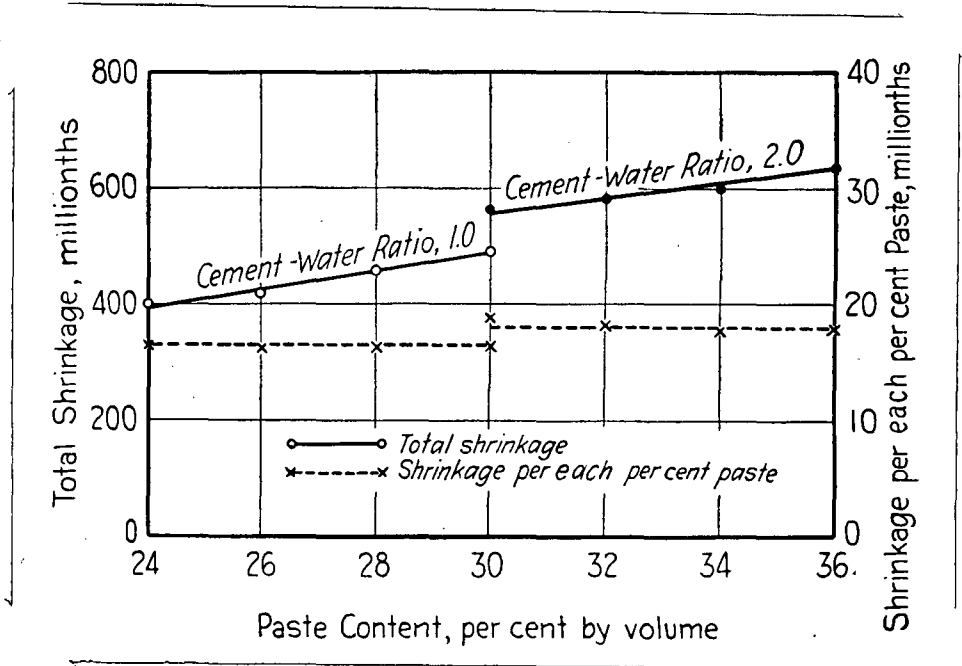


Fig. 1 - Effect of Paste Content on Shrinkage of Concrete at 80°F and 40 to 60 per cent Relative Humidity

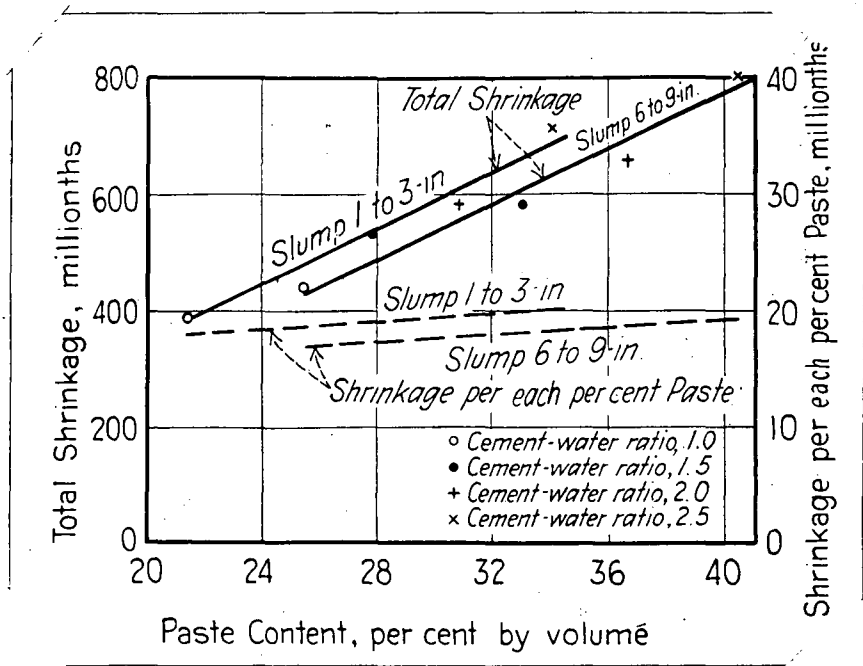


Fig. 2 - Shrinkage of Concretes of Different Cement-Water Ratios