Discussion

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The early shrinkage characteristics of hand-placed concrete*

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We have recently made a study of the early shrinkage of mortar and set cement paste in order to determine the reliability of the datum on which long-term shrinkage measurements are based. The results, which have been published⁽¹⁾, were made with standard equipment and therefore do not cover the earliest period dealt with by the author, when the material is not sufficiently strong to stand handling. It is encouraging to find, however, that our investigation also showed the dormant period before long-term shrinkage began. In Figure 3 of the author's paper this period appears to be slightly less than thirty hours, whereas in our work it was slightly more, but this difference is negligible in the circumstances.

It may be of interest to note here that our work showed that this dormant period ended and long-term shrinkage began when the volumetric ratio of

$$\frac{\text{water remaining in material}}{\text{total volume of cement paste in material}}$$

is effectively constant for a particular cement.

The behaviour reported by the author for the first few hours after the placing of the concrete has been noted with interest, and it is possible to offer a little further evidence to support the explanation given. We have found that, if a glass tube embedded in the concrete, mortar or cement paste is connected to a mercury manometer, under ordinary drying conditions the mercury starts to rise rapidly to indicate a negative pressure in the specimen at about the time of initial set. This effect has also been noted by others⁽²⁾. We have considered that the negative pressure was the result of suction developed by the surface tension of water evaporating from the capillaries.

The rapid rise of negative pressure usually begins about two hours after the specimen is cast, and would therefore support the explanation given by the author for the very early shrinkage d . We have noted that this negative pres-

sure usually starts about the time of initial set, and that a method is thus available for measuring directly the initial set of cement pastes, mortars or concretes.

Reply by the author

Dr Blakey's recent article⁽¹⁾ and his contribution to the discussion of the present paper form an interesting and useful part of our understanding of the early shrinkage characteristics of concrete and mortar.

His suggestion, that the determination of negative pressures or the time to the peak of the trace (the term t in the paper) could be taken as an indication of the initial set of the mix, would appear to need some clarification, because these tests deliberately introduce drying conditions whereas initial setting time is a standardized measure of chemical setting in which the physical effects of drying are eliminated as far as possible. In the paper the terms 'initial set' or 'setting time' have intentionally been avoided and the undefined term 'stiffening' used. However, it is correct to say that these tests give an indication of when the mix is able to stick together under chemical and/or physical forces.

Some recent data given in Table I may be of interest in comparing the results of some tests on cements with the early shrinkage characteristics of concrete made from the cements. The eight cements were ground from the same clinker for research purposes and were therefore not subject to the specification limits given in B.S. 12:1947. The early shrinkage tests were carried out on mixes similar to those of the first series in the paper but the results, which are given in the same units, indicate only a poor relation between the setting times and t . With regard to the amount of early shrinkage, the results tend to confirm the theoretical explanation put forward in the paper.

REFERENCES

1. BLAKEY, F. A. and LEBER, I. Early shrinkage of mortars. *Constructional Review*. Vol. 31, No. 6. June 1958. pp. 33-35.
2. WURZNER, K. Vakuumbildung im Beton. *Zement*. Vol. 29, No. 7. 15th February 1940. pp. 75-78.

*Pages 3-12.

TABLE I: The early shrinkage characteristics of concrete made with cements of different fineness and sulphate contents.

Cement No.	Specific surface of cement* (cm ² /g)	Sulphate content (%SO ₃)	Standard consistency* (%)	Initial setting time* (hr)	Final setting time* (hr)	<i>t</i> (hr)	<i>d</i> (× 10 ⁻⁴ per unit length)	θ (°C)	<i>h</i> (%)
1	2,670	1.92	24.25	1.38	5.38	3.25	3.0	19	83
2	2,580	2.81	25.75	1.42	5.75	3.11	3.7	18	80
3	3,440	1.98	26.25	2.12	4.10	3.03	5.3	17	83
4	3,460	2.96	27.25	1.83	5.67	3.08	3.9	14	83
5	4,370	1.92	25.25	0.85	2.01	1.92	5.3	13	83
6	4,430	2.88	24.5	0.50	2.42	1.75	5.2	14	82
7	5,630	2.05	29.5	0.20	0.83	1.21	8.1	14	80
8	5,280	2.88	30.25	0.42	1.62	1.23	7.5	17	70

* These tests were carried out in accordance with the appropriate part of B.S. 12:1947.