stantial contraction. From August to October the slab shows expansion, which again can be explained by an increase in moisture content as there is no rise in temperature.

There are no data available to indicate the expansion which might be expected in green concrete due to a rise in temperature brought about by chemical action during setting. Several of the curves of results obtained would indicate that this setting heat might be effective in causing expansion. Temperature measurements have been taken in a number of cases, and the temperature increases were noted to range from 17° F. to 108° F. in less than 18 hours after mixing. Such a great increase in temperature as these, it is believed, would have some effect, but its magnitude can only be determined by further investigation.

A variation in the quality of the concrete may also cause a variation in the thermal co-efficient of expansion, and it will, of course, affect the movement which takes place, as the modulus of elasticity of the concrete does change with a change in the quality.

Effect of Variation in Moisture Content of Concrete.—It has been definitely established that with an increase in moisture content there is an expansion of the concrete and with a decrease in the moisture content a contraction. This phenomena is apparently true for all concretes at all ages. The magnitude of this change is not definitely known, but experiments show:—

(1) Neat cement hardening under water expands + 0.15 per cent. by volume, and the increased volume is approximately 0.08 per cent. for a period of from 30 days to five years. The maximum expansion obtained at one year is nearly as great as at five years.

(2) Neat cement hardening in air contracts 0.25 per cent. by volume in from 16 weeks to five years.

(3) Cement-sand mortars change in like manner but to a lesser degree.

Experiments by the University of Michigan show the following results:—

(1) Neat cement hardening in air has an average unit linear contraction of —0.00109 at 7 days; —0.00190 at 28 days; —0.00236 at 6 months; —0.00270 at 1 year; —0.00289 at 2 years; —0.00322 at 4 years.

(2) That neat cement that has been hardened under water for three years will expand 0.0011 per unit of length, and if then exposed to air for 60 days will contract 0.0005 per unit of length less than the initial length, and will, therefore, show a total linear contraction of 0.0016 per unit of length.

(3) That neat cements under water show a linear expansion of from 0.0007 to 0.0015 per unit of length at the end of one year, and after that a very slight additional expansion.

(4) That neat cement alternately exposed to air and water will show results if platted that will form a regular saw-tooth curve.

(5) That 1.3 mortars show linear changes in the same direction as those of neat cement, but to a lesser degree. Submerged bars show a linear expansion in the first few weeks of as much as 0.0005 per unit of length, but decrease slightly after that, and then expand later to a length greater than the maximum expansion of 0.0005. Bars of 1.3 mortar in air shrink in length to an average of 0.0008 per unit of length within three months.

(6) Experiments with sections of a top coat of a cement walk which had been laid 20 years showed that it expanded when immersed 0.0005 per unit of length and contracted the same amount when again dried.

(7) Experiments with a section of stucco two years old, from a brick house showed a linear expansion when immersed of 0.0008 per unit of length in four days, and a return to its original volume when dried.

(8) Experiments with a section of cement walk in which a sample of both the top course and base were bound together showed that upon immersion the base reached its maximum expansion in 15 minutes, while it took the top coat three days to reach the same expansion.

This is interesting, partly because of the evidence of alternate bending stress in the concrete due to the more rapid expansion of the lower layer and partly because of the ultimate agreement in expansion of the top and bottom portion. This cement sidewalk was in good condition after 20 years' service.

The results of experiments made by the Bureau of Standards are shown in Table I.

Table I.—Linear Expansion of Neat Cement Stored in Various Manners.

Test piece (1 in. by 1 in. by 13 ins.) neat cement prisms.

No. of cements.	Manner of storing.	Age of test piece.	Change in length per unit of original length.
6	In water	30 days	+0.00095
8	In water	30 to 60 days	+0.00105
4	In water	120 days	+0.00113
20	In water	6 to 9 months	+0.00152
6	In air	30 days	—0.00150
15	In air	30 to 60 days	—0.00167
4	In air	120 days	—0.00211
40	In air	6 to 9 months	—0.00285

It was noted that prisms which had been stored in air, when placed in water at practically any age, began expanding, the expansion proceeding in manner similar to prisms placed directly in water after moulding. Similarly, prisms stored in water contracted when removed and kept in air.

Note.—The original reading was taken on removal from damp closet 24 hours after moulding.

Investigations have not been extensive enough to form final conclusions on the effect of moisture on expansion and contraction, but the following statements may be made, which are in part applicable to concrete roads:—

All of the tests quoted above show expansion of neat cement and of mortar and concrete when the samples are hardened under water. The results show the extent of this expansion to be greater with neat cement and to decrease when the addition of sand or coarse aggregate is made.

These tests also show that neat cement mortar and concrete will contract when hardened in air and that the contraction of neat cement is the greater, while that of mortar or concrete varies with the amount of sand and coarse aggregate used in the mixture.

They show that to an age of 20 years, and possibly for all time, these changes may be looked for in concrete.

They show that the condition which would provide for a decrease in moisture content when the temperature increases and an increase in the moisture content when the temperature decreases would be an ideal one.

All these tests indicate that the effect of moisture content is very much greater than the effect of temperature change, and may be sufficient to cause a stress in the concrete opposite to that which would be caused by a normal temperature change.

A variation in the quality of the concrete will cause a variation in the tendency to expand and contract with change in moisture content, as dense mixtures absorb water less rapidly than porous mixtures.