Measurement of Volume Changes of Concrete in Service

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•THE PRESENCE of cracking on the surface of concrete is generally accepted as an indication of some kind of a volume change in the body of the concrete. A correct interpretation of the nature of the volume change is not a simple matter, and more extensive observations are usually necessary before it can be said with certainty whether the cracking is the result of expansion or contraction or a combination of both. Where a reaction between alkalies in the cement and some component of the aggregates is suspected, there may be a gross expansion within the body of the concrete, but the surface cracks may be due in part to a shrinkage or to a lack of expansion of the surface layers. The cracks will open wherever the stresses exceed the tensile strength of the surface layer, and if there is no restraint in any direction, a typical pattern-cracking appears. However, the same kind of pattern-cracking may be due entirely to a shrinkage of the surface with no expansion or comparable shrinkage of the interior. Shrinkage of concrete is a common phenomenon and cements are now being marketed that are shrinkage-compensated. At the other extreme, there are many examples of so much expansion in concrete pavements that blowups occur, with total failure of areas of the pavement.

In order to eliminate the need for speculation as to the nature of the movement in concrete bridge decks and other bridge elements, a program of precise length-change measurements was undertaken by the Portland Cement Association in 1954 in cooperation with several state highway departments and other organizations. The equipment, assembled in the PCA shops, consisted of a 100-in. Invar steel tape, with means for attaching to brass inserts in the concrete and for applying a tension of 30 lb. Ten accurate subdivisions of 0.10 in. are provided on each side of the 0 and 100-in. marks, and readings are made with a shop microscope that further subdivides each 0.10 in. into 100 parts. Two different tapes are used each time and the calculated measurements are checked within a tolerance of 0.002 in. Finally, the internal temperature of the concrete is obtained and the measurements are corrected to 74 F, the temperature at which the tape is calibrated in the laboratory. This equipment is shown in Figures 1 and 2.

In two southeastern states, 32 installations were made in 12 bridges, the usual

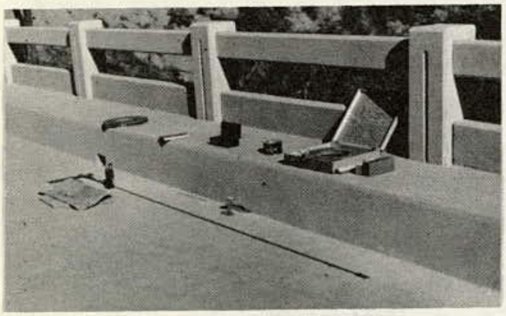

Figure 1. Precise measurement equipment showing typical installation in gutter line.

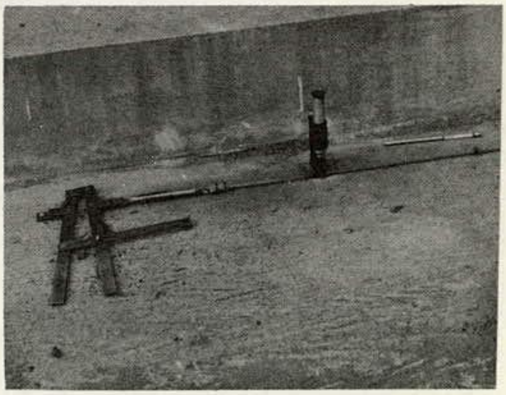

Figure 2. Tensioning device and shop microscope reading to thousandths of an inch.

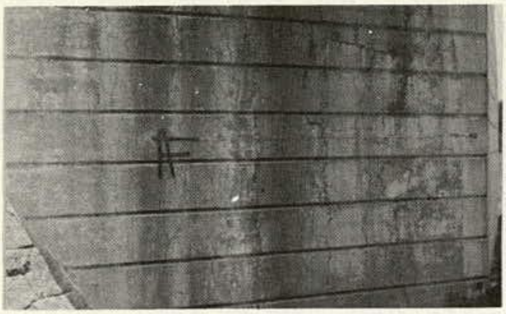

Figure 3. Precise measurement installation in severely cracked abutment.

Figure 4. Setting brass insert with lead wool. This concrete is expanding at 0.03 percent per year.

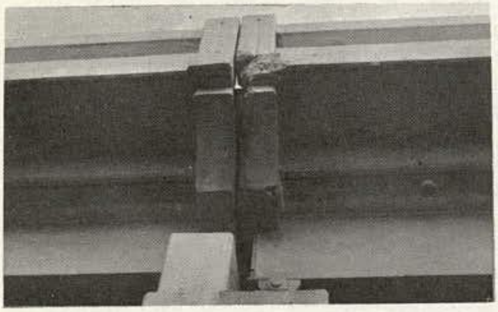

Figure 5. Expansion in bridge deck results in tight joint and broken end web.

location being in the gutter at 6 to 12 in. from the face of the curb. Other locations were on the top of the curb or safety walk, or on a wing wall or abutment. The concretes included a wide range of cements and aggregates, and the structures were new bridges in most cases, although a few were several years old. After 2 years of observation and measurements with no appreciable change in any of the concretes, another bridge, in which the concrete was definitely pattern-cracked, was added to the program (Figs. 3 and 4).

RESULTS OF THE STUDY

A few of the brass inserts have been destroyed or damaged beyond use, but many of the original points have remained undamaged for over 10 years. In the 32 original installations, the maximum contraction

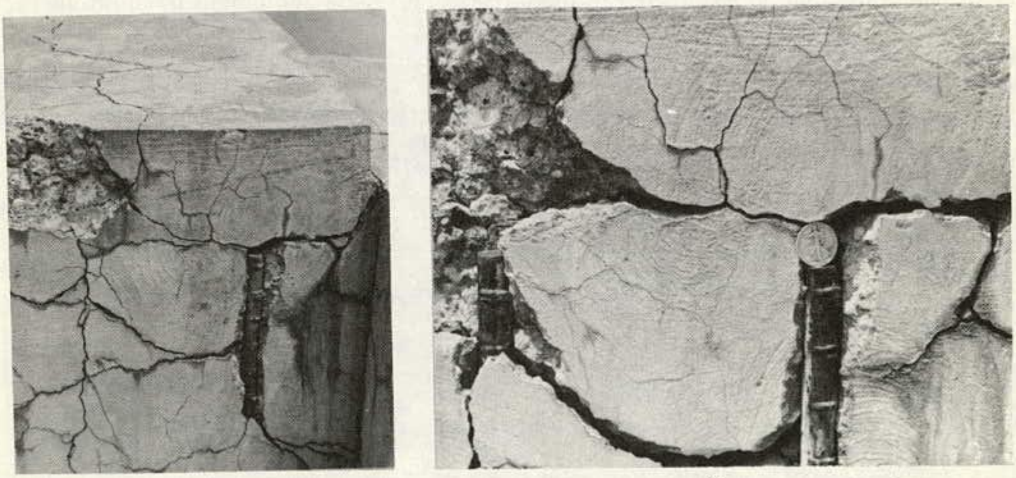

Figure 6. Hand rail post in 1956 (left) and 1964 (right) vertical expansion is 1 $^{3}/_{16}$ in. in spite of reinforcing.

has been 0.021 in. or 0.02 percent. The maximum expansion has been 0.017 in. or 0.017 percent. However, it is recognized that these installations were made in more or less heavily reinforced concrete and there was a possibility that any potential volume change might have been affected by the reinforcement. That this is not necessarily the case is shown by a bridge deck (Fig. 5) that has expanded sufficiently to shear reinforcement for end webs and to spall off the concrete cover for the bars. The steel girders are the reference media in this case.

Another example of expansion of a reinforced concrete is shown in Figure 6. This post was observed to be severely cracked in 1956, with one of the heavy vertical bars being partially exposed. By 1964, the concrete had expanded vertically $1\frac{3}{16}$ in. This is the clear distance between the top of the bar and the concrete that originally was in contact with the top end of the bar. In this case, the reinforcement had no significant effect in preventing expansion.

For the bridge that was added to the program because it was already cracked, two installations in the abutments have revealed expansion at an annual rate of about 0.03 percent for a total of 0.185 and 0.171 in. between the reference points. This example provides the assurance needed to show that the precise measurement program does indeed measure expansion or contraction in concrete if it is present.

CONCLUSION

The techniques and equipment developed by PCA for measuring volume changes in concrete in service are convenient, easy to use, and reliable. The concrete in 12 bridges, measured over periods of as much as 11 years, has shown no appreciable dimensional change in either direction. During the same observational period, concrete that was cracked, and known to be affected by alkali-aggregate reaction, has shown a steady rate of expansion.