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Effect of Restraint on the Shrinkage of Masonry Mortars*

By T. RITCHIE

An unrestrained bar of mortar normally shrinks as it dries. If you apply a tensile load during drying, the shrinkage is less.

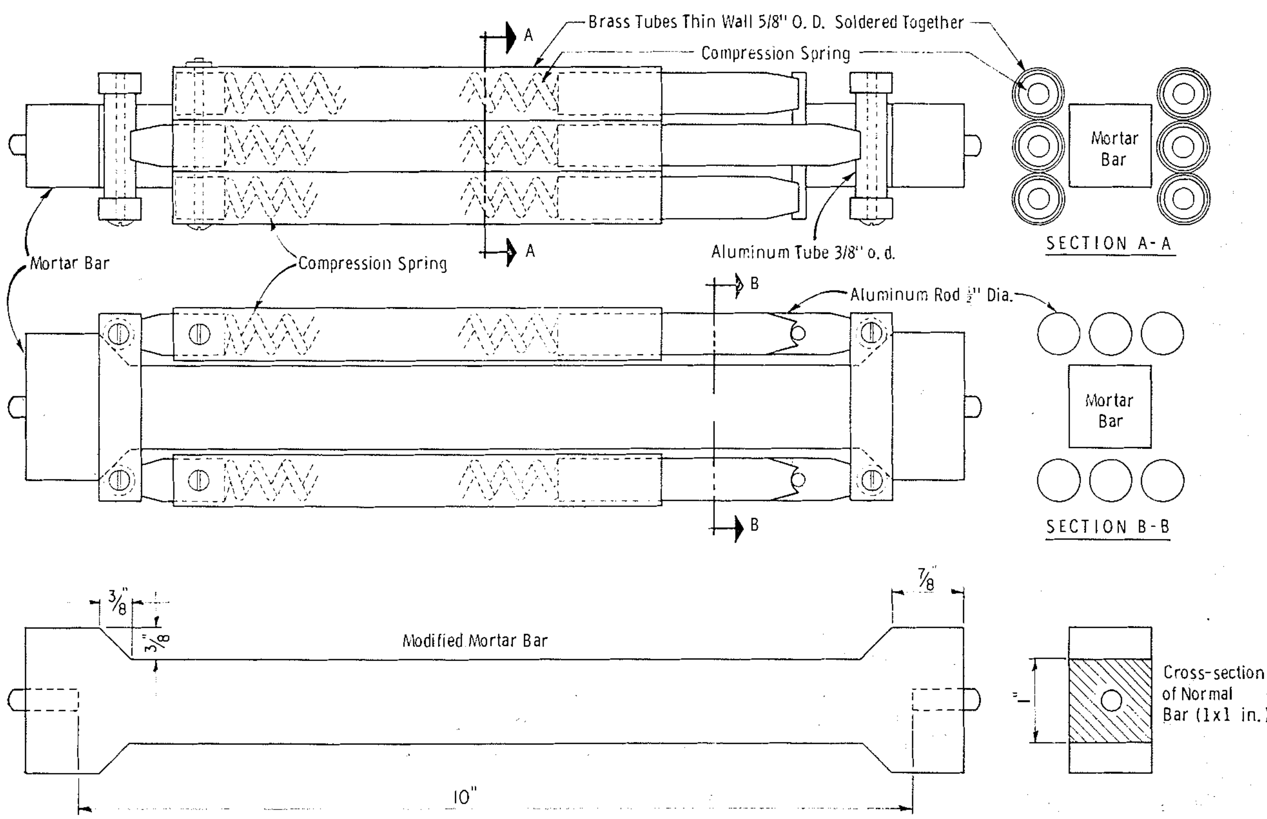

Fig. 1—Apparatus for applying restraint to mortar bar during shrinkage.

Previous tests[1] showed that the expansion of bars of masonry mortars was reduced when restraining forces were applied to the bars during the process of expansion, indicating that the restraint normally operating on mortar in masonry (due to its bond with the masonry unit and to structural loads on the masonry) would affect its expansion. The following tests were made to determine what effect restraining forces have on mortar shrinkage.

Method of Applying Restraint

Modified standard mortar bars were used. The molds which produce 1 by 1 in. mortar bars (10 in. effective length) were modified to form small shoulders at each end of the bar. The enlarged part of the bar was tapered at an angle of 45 deg to the remainder, which was the normal 1-in. cross section. Small rods bearing against the shoulders were used to provide restraining pressure longitudinally in the

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* This is a contribution from the Division of Building Research, National Research Council of Canada, and is published with the approval of the director of the Division.

[1] T. Ritchie, "Effect of Restraining Forces on the Expansion of Masonry Mortars," *Materials Research & Standards*, Vol. 4, No. 1, January 1964, pp. 15–19.

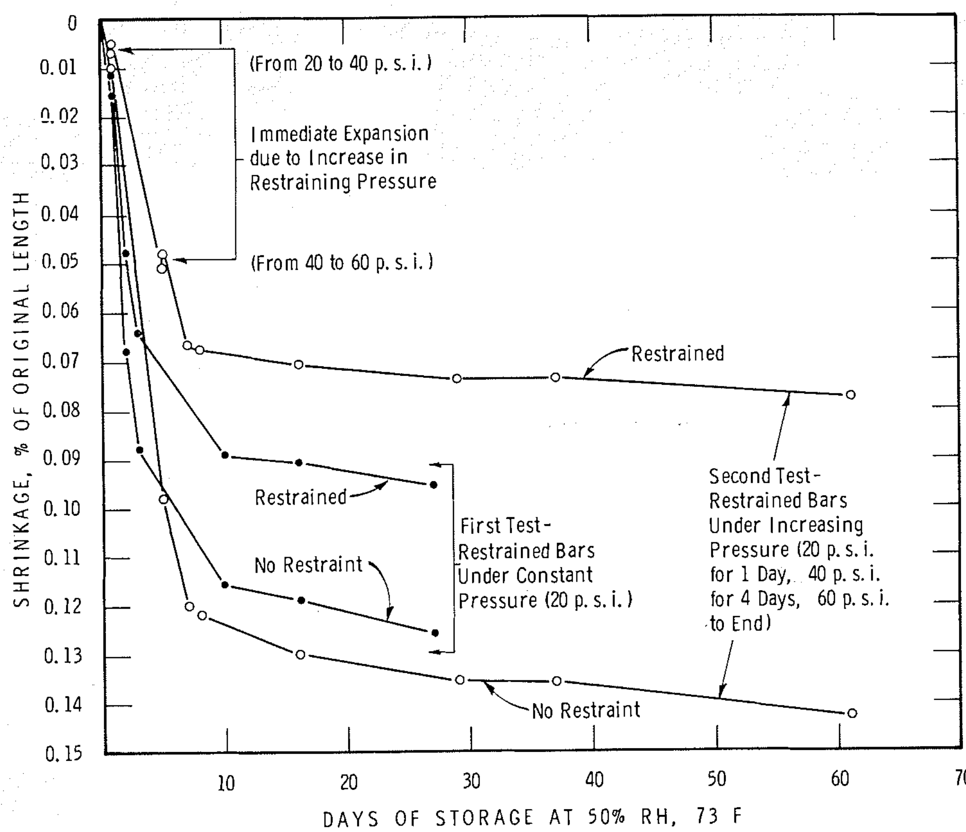

Fig. 2—Effect of restraint on shrinkage of 1:2:9 cement: limes: and mortar.

bar as it shrank, the restraint being provided by compression springs pushing against the rods. The force provided by the springs was known and adjustable.

The mortar bar and the spring arrangement are shown in Fig. 1. With this arrangement it was possible to fit the mortar bar and springs in the standard comparator for measurement of length. In early tests two springs were used, one on each side of the bar, but in later tests a group of springs was used (Fig. 1), which permitted two springs to be used early in the test and additional springs later.

To fit the restraining apparatus on the bar, the end pieces containing the rods which are later to bear against the mortar bar are assembled around it near each end. The end pieces consist of two metal bars joined together by two bolts which pass through the rods. Before the spring housing is fitted in place, the springs are compressed and held in the compressed position by a pin which passes through holes in the tube housing the spring, and through the aluminum rod bearing against the spring. The spring housings are placed between the end pieces, which are drawn tight against them by means of two long thin threaded rods that join the side bars of the end pieces. These threaded rods are not shown in Fig. 1. The pins holding the center springs are removed, and the threaded rods are slowly unscrewed until the end pieces bear against the shoulders of the mortar bar. To bring additional springs into play, which is done later, the pins that have held the springs in the compressed position in the other tubes are removed. This allows the springs to extend, and their pressure is transferred to the center spring system by the method shown in Fig. 1.

Mortars

The mortars were composed of the conventional materials—portland cement, hydrated lime, masonry cement, and sand. Various proportions of cement and lime were used, including the mixes 1:2:9, 1:1:6, and $1:\frac{1}{2}:4\frac{1}{2}$ cement:lime:sand (by volume); the proportion 1:3 by volume of masonry cement to sand was used in the other mortar. The procedure followed was to mix the mortar to a relatively low flow (105 to 115 per cent) and place it in the molds, which were stored in the humid room (100 per cent RH, 73 F) for 24 hr. The bars were then removed from the molds, except for the 1:2:9 cement:lime:sand bars, which required 48 hr in the humid room to develop sufficient strength for de-molding without breaking. The bars were returned to the humid room until the start of the test. Four bars of each mortar were used, two for unrestrained shrinkage and the other two to be restrained during shrinkage. The unrestrained bars were of normal shape (1 by 1 in. cross section, 10 in. effective length),

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but the effective length of the restrained bars was considered to be 9.25 in., the distance between the points of application of restraining pressure.

Shrinkage was induced in the bars by drying them in a room at 50 per cent RH, 73 F. The bars were measured immediately on removal from the humid room and periodically during their storage at 50 per cent RH. In some earlier tests a constant restraining force was used which had to be small because of the low tensile strength of certain bars at their early age. In later tests a small restraining pressure (20 psi) was applied to the bar initially, and as the strength of the bar subsequently increased the restraining pressure was also increased (to 40 psi, then to 60 psi).

Test Results

Unrestrained bars shrank more than restrained bars. A comparison of the shrinkage of unrestrained and restrained mortar bars of composition 1:2:9 cement:lime:sand is shown in Fig. 2. In the first test made with this mortar the restrained bars were subjected to a constant pressure of 20 psi; these bars shrank considerably less than the corresponding unrestrained bars. In a second test of the same mortar, the initial restraining pressure of 20 psi was increased after one day to 40 psi and after four days to 60 psi. Comparison of the results of the first and second tests (Fig. 2) indicates that the shrinkage decreased as the restraining pressure was increased. When the restraint applied to the mortar bar was increased, there was an immediate slight expansion of the bar, as shown in Fig. 2.

A comparison of the shrinkage of unrestrained and restrained bars of the masonry cement mortar and of the 1:1:6 and 1:$\frac{1}{2}$:4$\frac{1}{2}$ cement:lime:sand mortar is given in Fig. 3. For the cement:lime:sand mortars the shrinkage of the unrestrained bars increased as the proportion of lime in the mortar increased; the shrinkage of these bars after 30 days of storage at 50 per cent RH was approximately 0.135, 0.120, and 0.095 per cent, respectively, for the mortars 1:2:9, 1:1:6, and 1:$\frac{1}{2}$:4$\frac{1}{2}$ cement:lime:sand (Figs. 2 and 3). The effect of the restraining pressure was to reduce the shrinkage of all the mortars, but not to the same extent. Although the 1:2:9 mortar bars, for example, had the greatest unrestrained shrinkage, they had the least restrained shrinkage. For these bars the effect of the restraint was to reduce the shrinkage by about half. The bars of 1:1:6 cement:lime:sand mortar were less affected by restraint than those of the 1:2:9 mortar, but were more affected than the bars of 1:$\frac{1}{2}$:4$\frac{1}{2}$ mortar. It is probable that the strength of the mortar had some influence on its response to restraint.

The unrestrained and restrained shrinkage of the masonry-cement:sand mortar bars was the least of all the mortars tested. The effect of restraint on the shrinkage of this mortar was unusual in that the restrained bar shrank for several days after the restraining pressure of 60 psi was applied, then started to expand slightly.

Conclusions

When restraining pressure was applied to mortar bars that shrank because their condition of storage was changed from 100 to 50 per cent RH, the shrinkage was less than that of unrestrained bars of the same composition. This inhibition of the shrinkage of mortar (and also of its expansion, as demonstrated in a previous study) is probably an important factor in the performance of masonry, since mortar in service in a wall is restrained by its bond to the masonry units and by structural loads on the wall. The

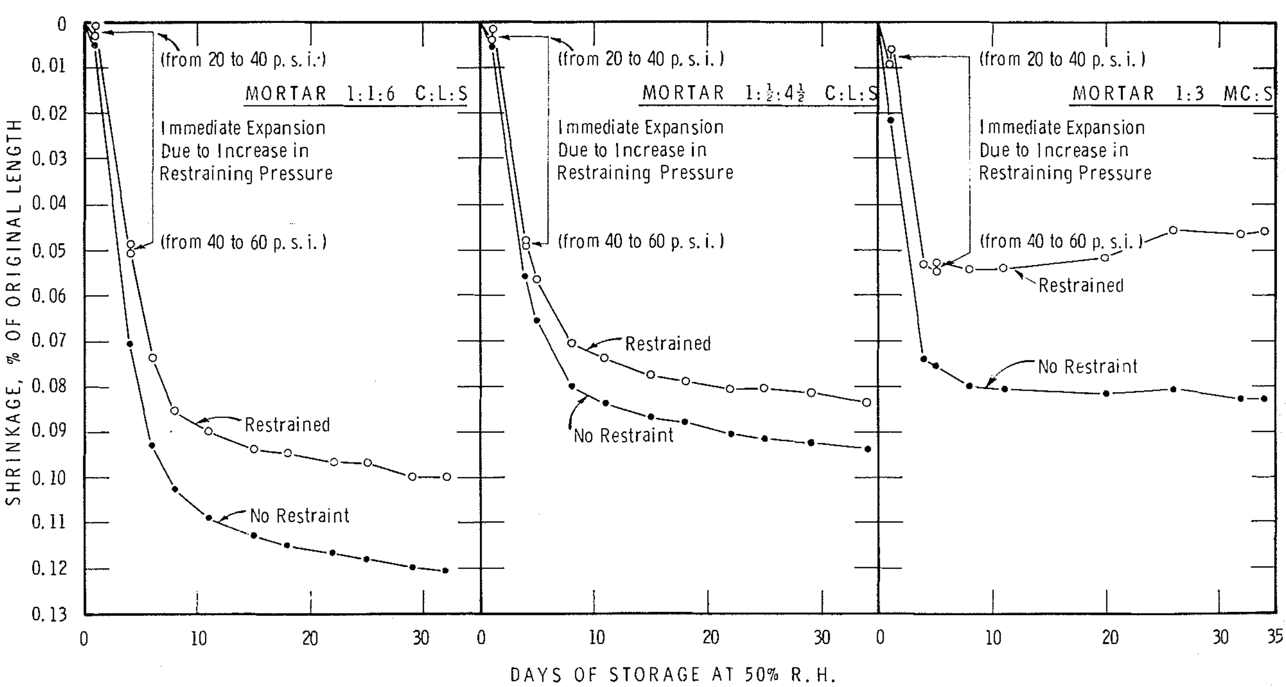

Fig. 3—Effect of restraint on shrinkage of various mortars

dimensional changes of mortar in masonry will therefore be less than those of unrestrained mortar.

The effect of restraint on shrinkage varied, depending on the composition. For three cement:lime:sand mortars, the effect was most pronounced with the lowest-strength mortar, and for these mortars it appeared that the influence of restraint on shrinkage may depend on the strength of the mortar.

The shrinkage of bars of a masonry cement mortar was much reduced when restraint was applied. The behavior of the restrained bars of this mortar was unusual in that the restrained bars shrank and then expanded slightly.

Tests with bars of 1:2:9 cement:lime:sand mortar indicated that as the restraining force was increased the shrinkage decreased.