II-3. Brick Durability Tests and the Method of Freezing

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ABSTRACT

The testing of bricks for durability has come under critical review in recent years because of differences in the performance of bricks in the standard freeze-thaw test and in service in the walls of buildings. The difference in performance is believed by the author to be due in part to differences in the process of freezing; bricks in service are frozen by the passage of a freezing plane through the exposed face of the brick, whereas in the standard test the freezing of the brick takes place through several of its surfaces.

The two processes of freezing, "unidirectional" and "omnidirectional", were applied to bars of clay bricks and other masonry materials, which had been fitted with reference points for measurements of length changes. The bars were subjected to freezing and thawing, with length measurements made periodically. Certain bars showed little difference in behaviour regardless of the method of freezing, but for several materials the bars frozen omnidirectionally expanded quickly and excessively, while companion bars frozen unidirectionally were either unaffected or underwent much less expansion. The dependence of the durability of a brick on the particular freezing process employed, and its implications in the testing of bricks, is discussed.

Requirements for the durability of clay bricks set out in Canadian and U.S. Standards1,2 are based on a procedure for freezing and thawing bricks used by McBurney and Lovewell.3 This procedure was to immerse half-bricks in water, then set them on edge in a shallow tray containing a half-inch of water; the tray was placed in a cold chamber to freeze the bricks, which were then thawed by immersion in water. The bricks were subjected to 50 freezings and thaws. From such tests of several thousand bricks, they concluded that certain combinations of values of the compressive strength, water absorption and saturation coefficient could be used to predict the performance of bricks in their freeze-thaw test.

Recent failures in service of bricks that apparently met specification requirements have brought the durability testing of bricks under scrutiny. Blachère and Young4 drew attention to the influence of such factors as sample saturation, size of sample, the rate of cooling and the scheduling of the freeze-thaw cycle on the results obtained. Inadequacies of the present durability test for bricks have been described by Robinson, Holman and Edwards,5 who tested a large number of bricks by the standard method with the aim of improving the accuracy of predicting brick durability from the properties of water absorption, compressive strength and saturation coefficient. Even with the improvements suggested by their study, however, they believed that the test method and specification would remain imperfect.

Discrepancies between the performance of bricks in the standard test and in service in a wall are believed by the author to be due, at least in part, to differences in the way bricks are frozen, in particular, the manner in which the freezing plane passes into the brick. In the standard method of test, bricks are frozen by heat loss from all surfaces exposed to cold air, i.e., omnidirectionally, while in service in a wall bricks are frozen through the face only, i.e., unidirectionally. In a study6 comparing the behaviour of bricks frozen by the standard method with the behaviour of similar bricks frozen unidirectionally, significantly different results were obtained by the two freezing methods, as assessed by visual examination of the bricks for cracking and spalling.

The present study is similar to the former investigation except that bars of masonry materials instead of half-bricks were used, and the effects of freezing were assessed by measurements of the length changes of the samples, some of which were frozen unidirectionally and others omnidirectionally.

MATERIALS

The materials studied included three clay bricks, two masonry mortars, one concrete block, and one natural stone, which were made into bars one square inch (25 mm) in cross-section and five inches (127 mm) in effective length.

Bricks, concrete block and sandstone were cut into bars with a diamond saw. Holes were drilled in their ends into which were cemented, with epoxy, round-ended stainless-steel studs. The ends of the studs provided the surfaces against which the length measurements were made, using the standard comparator for cement testing. Three different bricks were used, one formed by dry-pressing, the other two by stiff-mud extrusion. Bars of the former brick, however, had to be withdrawn early from test because cracks developed at their ends, apparently associated with the epoxy cement and studs, but this problem did not arise with any other of the materials studied.

One of the mortars was prepared from portland cement, hydrated lime and sand in volume proportions of 1:1:6; the second mortar consisted of masonry cement and sand, proportioned 1:3 by volume. The materials were mixed with sufficient water to produce mortar of stiff consistency; the flows were 116 and 114 per cent, respectively, for the two mortars. The fresh mortar was cast in standard cement-testing moulds, which provide bars one square inch (25 mm) in cross-section and five inches (127 mm) effective length. Round-ended stainless-steel studs, embedded in the mortar when cast, projected from the ends of the bar for length measurement.
The concrete block used in the study had been made from lightweight aggregate; the stone was Wallace sandstone from Nova Scotia.

**METHOD OF TEST**

Six bars of each material were stored for two weeks in a laboratory maintained at about 50 per cent relative humidity and 73°F (23°C). Prior to the freezing tests, the bars were immersed in water at 73°F for four hours, removed, and the length was measured. Three bars of each material were then placed in the freezing chamber with all surfaces exposed to the cold air; this provided the test condition for what is termed here, omnidirectional freezing.

The other three bars of each material were placed to fill an opening in one side of a box whose other five sides were closed and heavily insulated. These bars, arranged side-by-side and close together, were frozen unidirectionally when the box was placed in the freezing chamber; the freezing plane passed from that surface of the bars exposed to the air of the freezer, to the opposite surface, across the one-inch thickness of the bars.

The bars remained in the freezer, where the air temperature was usually in the range of 0° to −10°F (−18° to −23°C) for 20 hours, then were removed for thawing in water. Those bars forming part of the insulated box were removed for thawing. After four hours in the thawing tank, the bars were measured for length and again placed in the freezer. This arbitrarily selected process of freezing and thawing, with length measurements made after each thawing, was continued until the tenth thawing, after which the bars were stored in the laboratory for one week before another series of 10 freezings began. This period of time was intended to allow the bars to dry, so that the gradual increase in their saturation with repeated thawing in water did not result in their reaching a high degree of saturation. The bars were subjected to a total of 100 freezings if they had not deteriorated before this number was reached.

**RESULTS**

The length changes of the bars, expressed as a percentage of the original length (after the first 4-hour immersion), are plotted against the number of freezings in Figures 1, 2 and 3.

Bars of three materials, the mortar prepared from masonry cement and sand, one of the bricks, and the sandstone, showed no significant difference in behaviour when frozen 100 times unidirectionally and omnidirectionally, but the other materials tested behaved quite differently, as shown in the graphs.

The mortar bars of cement, lime and sand (Figure 1) were frozen unidirectionally about 80 times before appreciable expansion occurred. The three companion bars frozen omnidirectionally, however, expanded almost continuously from the start of test and at such a rate that the expansion exceeded 0.05 per cent before 50 freezings and 0.10 per cent before 70 freezings. After 90 freezings the bars had expanded 0.30 per cent and were broken before 100 freezings.

The bars of brick A (Figure 2) that were frozen unidirectionally showed little length change in the 80 freezings to which they were subjected. Their companion bars, however, frozen omnidirectionally, expanded very rapidly after 10 freezings, were cracked between 19 and 25 freezings, and were in such a deteriorated condition after 30 freezings that they had to be removed from test.

The bars prepared from concrete block (Figure 3) and frozen unidirectionally expanded slightly over the course of their 100 freezings, whereas the companion bars, frozen omnidirectionally, expanded at a very rapid rate such that their length change exceeded 0.10 per cent before 20 freezings had been carried out. The expansion exceeded 0.50 per cent after 35 freezings and the bars, marked with a very fine pattern of cracks, were so fragile that they had to be removed from test.

**DISCUSSION**

The results confirm those of a previous study that bricks frozen by heat loss from several surfaces simultaneously behave quite differently from bricks frozen unidirectionally.

Another study of unidirectional freezing indicated that the water in a brick is forced away from the advancing freezing plane and may be forced from the brick, a process that may provide relief from stress. But no such possibility of stress relief can operate when freezing planes pass simultaneously into several of the brick surfaces, which probably accounts for the differences in the effects of freezing by the two processes, although this remains to be proven.

The apparent relief of freezing stresses has been noted by the author in the freezing of cylindrical specimens (1-1/8 in., 29 mm, diameter and of length equal to brick height) cored from various bricks. Three such samples from a brick were compared with three other samples from the same brick in which a 1/4 in. (6.3 mm) hole was drilled down the centre. The samples were saturated, frozen by exposure in a cold chamber and thawed in water. Many of the solid samples cracked in the first freezing and others after the second or third freezing. The samples with central holes, however, were unaffected by many freezings, presumably because under essentially similar rates of freezing and moisture content there was no confinement of the freezing water.

**CONCLUSIONS**

The behaviour of certain bricks and other masonry materials frozen unidirectionally, such as occurs in service in a wall, differed significantly from their behaviour when frozen through several surfaces. This difference is believed to account in part for the reported difficulties in relating the results of freeze-thaw tests of bricks by the standard (A.S.T.M.) method to their performance in service. The standard method of freeze-thaw testing of bricks accordingly should be changed to correspond more closely to the actual conditions of the freezing of bricks in service in a wall, which is unidirectional.
This paper 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.

REFERENCES
1. American Society for Testing Materials, Specification C62.75a, "Building Brick (Solid masonry units made from clay or shale)."

Figure 1. Length changes of mortar bars frozen unidirectionally and omnidirectionally

Figure 2. Length changes of brick samples frozen unidirectionally and omnidirectionally

Figure 3. Length changes of bars of concrete and sandstone frozen unidirectionally and omnidirectionally