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SOMMAIRE

On a remarqué que diverses briques d'argile ont été soumises à des contraintes, car leur longueur a été modifiée par suite du dégagement des contraintes. Ces contraintes sont attribuées à la cuisson des briques et peuvent atteindre jusqu'à 1 750 pi/lb^2 (12.0 MPa). On a aussi remarqué des contraintes résiduelles dans de vieilles briques provenant de bâtiments démolis. Toutefois, le fait que des contraintes aient été exercées sur les briques ne semble pas avoir influé sur le rendement des ouvrages en briques.

RESIDUAL STRESS IN CLAY BRICKS

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ABSTRACT

Clay bricks from several sources were found to be in a stressed condition, as indicated by their length changes that apparently resulted from stress relief. The stress, attributed to the firing of the bricks during manufacture, varied in amount from very low values to a maximum estimated to be about 12.0 N/mm^2. Residual stress was also found in old bricks recovered from demolished buildings; their stressed condition apparently did not affect the performance of the brickwork.

1. STRESSES IN BRICKS

The high heat required in the firing of bricks subjects them to stress and may cause them to crack. Factors involved in the occurrence of such "firing cracks" have been described by K.E. Bell[1] and include temperature gradients in the brick that cause one part of a brick to expand or contract differently from another, thus setting up stresses that may result in cracking. In addition, the brick may be composed of materials that expand or contract at various rates and amounts, even when heated to the same temperature, thus stressing the brick, possibly to fracture. Laminar flow of material formed by extrusion, by bringing fine particles to the slip-planes and by producing particle orientation at these planes, may result in their non-uniformity; different dimensional changes of the main portion of the brick and that part at the slip-planes may stress the brick enough to provide yet another cause of firing cracks.

Even though the conditions that produce firing cracks in some bricks may not cause sufficient stressing in other bricks to crack them, the existence of stress in bricks should be expected. The studies described here indicate that residual stress, probably attributable to the temperature gradients in firing and the resulting differential dimensional changes, exists in many clay bricks as indicated by the length changes that occurred when perforated bricks were cut through the face into the perforations, and when solid bricks were cut longitudinally to remove a portion of the brick, such procedures apparently relieving a stressed condition.

2. METHOD OF TEST

The bricks to be studied were fitted with reference points for length measurements by means of the Whittemore gauge. Holes spaced 152 mm apart were drilled in the face and back of the bricks to receive cylindrical brass plugs which were cemented in the holes with epoxy resin. The plugs had been drilled previously and countersunk to receive the points of the gauge, the dial of which was marked in 0.0001-in. (0.0025 mm) increments. A change in the dial reading of 0.0025 mm in relation to the 152 mm distance between the plugs, thus represented movement of somewhat less than 0.002 %.

Measurements were made along the long axis of the brick. Perforated bricks, formed by extrusion, were checked for stress by cutting through the face into a perforation, leaving the back intact. Length changes of the face and back resulting from the cutting were considered to represent the effect of relief of stress in the brick. Other bricks were tested by cutting them longitudinally to remove a slab about 25 mm thick from both the face and back of the brick; their length changes were considered to indicate the effect of relieving stress.

Because cutting the bricks required the use of a diamond saw operating under water spray which resulted in dry bricks becoming wet, the bricks were soaked in water prior to the first measurement, made before cutting.

3. RESULTS

Ten samples of a large-format brick 140 mm wide and 292 mm long, which had been formed by stiff extrusion with five slots, were fitted on the face and back with reference points for length measurement, as shown in Figure 1. The wet bricks were measured,

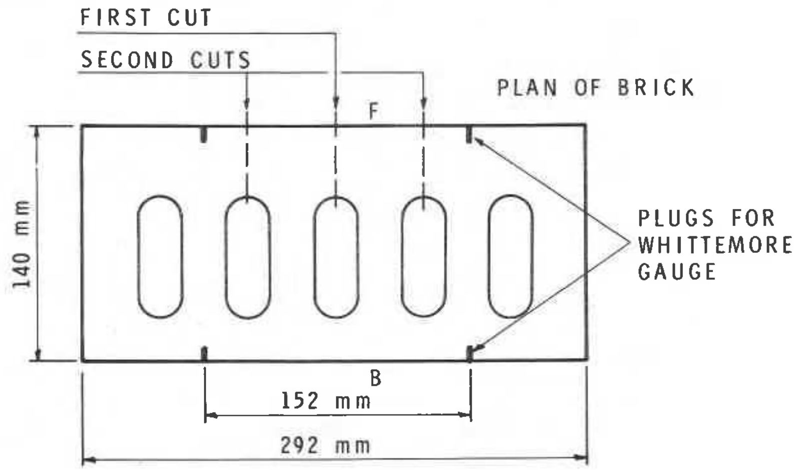

FIGURE 1—Position of reference points and saw cuts on the brick.

then the saw blade was run through the face (F) into the centre slot and the bricks were measured again. Two additional saw cuts were then made through the face into the slots adjoining the central one, after which the measurements were repeated. The back of the brick (B) was not cut.

The results of the measurements in Table 1 indicate that substantial length changes resulted from the cutting of the bricks. The first cut produced length changes in the faces varying from 0.002 to 0.018 % of the length before cutting. The second cutting produced additional changes, such that the total movement ranged from 0.005 to 0.045 % The two bricks (Nos. 5 and 8) of greatest length change after the first cutting, broke when the second cuts were made.

Table 1

Length changes (+ or -) of bricks

Brick No.	Length change % of original - second cut cumulative			
	Face of brick		Back of brick	
	First cut	Second cut	First cut	Second cut
1	-0.015	-0.045	+0.002	+0.005
2	+0.003	+0.005	0	-0.002
3	+0.007	+0.012	-0.002	-0.002
4	-0.003	-0.015	+0.002	+0.005
5	+0.018	*	-0.007	*
6	-0.005	-0.013	+0.002	+0.002
7	-0.012	-0.028	+0.002	+0.003
8	+0.018	*	-0.022	*
9	-0.002	-0.013	0	0
10	+0.010	+0.022	-0.002	-0.003

* bricks broke in cutting

Half the bricks of the ten tested exhibited expansion of the face when cut, the remainder shrinkage. The amount of movement of the face was generally greater than that of the back, and the movement of the face was opposite in direction to that of the back.

Ten samples each of two additional large-format bricks were also tested. These bricks were the same size as the first, but instead of having the five slots of the first brick they had circular perforations arranged in two rows of five each. The bricks were cut initially through the face into the centre hole of the first row, then cuts were made into the holes on each side of the central one.

Length change occurred in these bricks when they were cut, but the amount of movement was less than that of the first brick. The maximum length change of the ten bricks of one lot was 0.008 % and of the ten other bricks, 0.010 %. The bricks of both lots produced movement of the face opposite in direction to that of the back.

4. AMOUNT OF STRESS

An estimate of the stress level in certain bricks was obtained by determining the amount of stress that had to be applied to a brick to produce a length change equivalent to that resulting from its stress-relief on being cut. This procedure is considered to be somewhat analogous to that used[2] to determine the stress in restrained structural members that attempt to change length as a result of temperature change; the amount of stress is that required to produce strain equal to the unrestrained movement calculated from the coefficient of thermal expansion and the modulus of elasticity of the material.

A brick from the same lot as those cut, and fitted like them with reference pins for length-change determination, was capped on the ends to provide plane surfaces for compressive loading. The brick was placed in the testing machine, loaded, and the change in dimension corresponding to various loadings was noted. The stress producing a particular amount of length change in the brick was calculated on the basis of the brick's minimum cross-sectional area.

The stress-strain relationships for samples of the three large-format bricks described previously are shown in Figure 2, along with the maximum length change that occurred in those samples of each of the three bricks cut for stress-relief. It is seen that in the case of the brick that showed length-change of 0.069 mm on being cut, the corresponding stress was about 12 N/mm^2 while for the other bricks the stress level was between 3.4 and 4.8 N/mm^2.

5. TESTS OF OLD BRICKS

Bricks obtained from several demolished buildings were also studied. They varied in age from about 20 to 100 years, and included bricks formed by the soft-mud, dry-press and extrusion methods. Their residual stress was determined by fitting the bricks as before with reference plugs on the face and back, then cutting off a 28 mm slice from the face and back. The length change resulting from the removal of these parts of the brick was considered to represent the effects of the release of stress.

In all, 57 bricks obtained from several demolished buildings were studied, of which 37 bricks changed length on being cut. The 20 bricks that did not change dimension included all five bricks taken from one of the buildings, and eight of the ten bricks taken from another building.

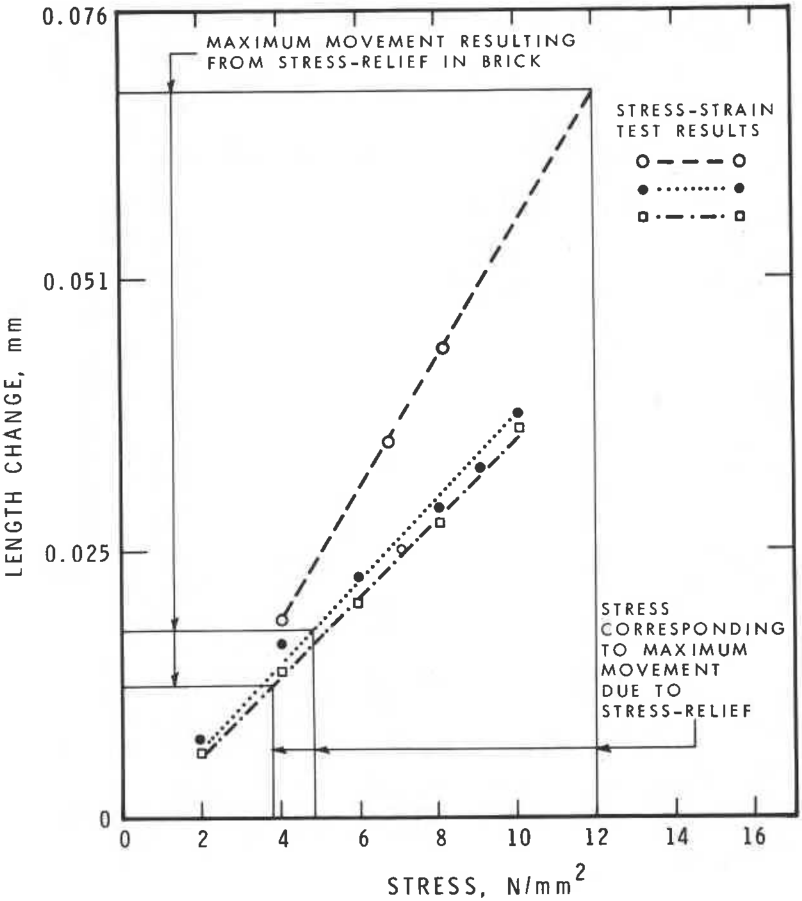

FIGURE 2—Stress/strain relationships for brick specimens.

One of the structures from which extruded bricks were obtained was the Ottawa Journal Building, erected in 1914 and demolished 60 years later. All samples of the bricks that were tested changed length when cut, the maximum length change being 0.010 %. This amount of movement, according to stress-strain measurements of the bricks, reflected a stress level in the brick of about 2.7 N/mm^2. The bricks of this building, and those obtained from other demolition, appeared to have performed well, with no indication of distress in the bricks or the brickwork.

6. CONCLUSIONS

The firing of clay bricks stresses them and may produce "fire cracks" or internal stress. The stressed condition of certain bricks was indicated by their length change when stress was relieved, as, for example, when a saw cut was made through the face into a perforation, or when the outer part of the brick was removed by cutting the brick longitudinally.

Internal stress was detected in 92 of 100 newly-made bricks, representing the production of eight different plants. Some lots of bricks contained unstressed and stressed units, while the level of stress varied considerably. The maximum internal stress of the bricks studied was estimated to be 12 N/mm^2.

Bricks may retain internal stress for a long period of time, as shown by tests of bricks taken from demolished buildings. There was no indication, however, that the performance of these particular bricks or the walls they formed had been adversely affected by the stressed condition of the bricks.

ACKNOWLEDGEMENTS

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