that the mortar between the bricks is bonding the frogged surface of the lower brick to the flat surface of the upper course. Failure from such shearing stresses will take place across the weakest horizontal section, which would be in this case the sections at the flat surface. Therefore, the resistance to shear between the bricks depends upon the bond between the mortar and the flat surface, hence it is obvious that equal resistance to shear would be obtained if the surfaces were flat below and flat above. In practice the Canadian bricklayer spreads his mortar on the preceding course, which is laid frog downwards, as in Fig. 2a, then he takes the point of his trowel and runs a gutter in the mortar along about the centre of the course of bricks. The bricks are then laid frog downward, making the frog fit over the gutter in the mortar, as shown in Fig. 2b. That this is the case has been proven by a test, in which fifty bricks were selected on different jobs; so that the fault could not be claimed as local to any one contractor, and of the fifty selected but three frogs contained any mortar, and in those cases it seemed to have been more by accident than intention. The present practice clearly destroys the bonding and shearing theory supporting the use of a frog in bricks, and it also furnishes a very strong argument against its use at all.

The above is by no means the most serious defect of a wall so constructed. Consider the effect the loss in bearing area, caused by this practice, has on the compression value of a wall. The average brick laid flat gives a bearing area of 4″ × 8½″ = 34 sq. ins., the area of the frog is 2″ × 6″ = 12 sq. ins., so that the actual bearing area of a frogged brick is 22 sq. ins. Thus the frog decreases the effective strength of the wall by 35%. Actually the strength is decreased by much more than 35%, as experiments will show. Brick masonry, under an increasing load, begins to fail by the lime failing and breaking the bond between the small particles of sand; the mortar then acts in the same manner as sand, flattening out and flowing to the points where the pressure is least, which would be in this case the outside edge or the frog of the brick. Also, the sand in flowing at the edges and at the frog, assumes the same angle of repose as ordinary sand (about 45°), and thus decreases the bearing area of the upper brick, as shown in Fig. 3. It might be pointed out, further, that the process of failure of a wall is, first, the failure of the mortar as described above, and later the failure of the bricks. Between these two failures there is a difference of anywhere from 15 to 35% of the ultimate strength of the wall. To illustrate: if a wall has an ultimate compressive strength of 1,000 lbs. per sq. in., the mortar will fail anywhere between 650 and 850 lbs. per sq. in.

That the different positions of the frog has a real effect upon the strength of the wall is recognized by our building by-laws where pier wall construction is defined as requiring that the bricks should be laid frog upwards and the wall grouted, thus making certain that the frog is well filled. Additional bearing values must therefore be allowed for a wall so constructed. If a wall of a certain compressive strength per sq. in. is desired and the bricks may be laid either of these ways, it follows that to build the wall pier construction throughout, ought to mean a saving in bricks, and thus an economy in material would be effected.

Another argument which is sometimes advanced in favor of the frog is that bricks are easier and quicker laid when placed frog downward. As has been already stated, this is the Canadian practice. English and continental practice is to lay every brick frog upward, and fill the frog. The question of which way is easier and quicker seems to be only a matter of which way a bricklayer is taught and rapidity then is but a matter of practice.

Variation in Size of Bricks.—Bricks vary in height from 2 ins. to 3 ins., due to at least two causes: (1) a difference in the size of the forming mould; (2) the process by which they are solidified. It seems necessary to establish a minimum and a maximum dimension in height, allowing a variation of not more than one-eighth of an inch in the finished product. The difficulties of estimating air-shrinking and fire-shrinking in clay brick is well known, but they are not such that they cannot be overcome. That some precaution is necessary can be very well illustrated by considering the difference in the amount of mortar in the face and back of a wall, where the bricks differ by one-eighth inch in height. (The writer knows of cases where the face and filling bricks have differed by as much as one-half inch.) The difference of one-eighth of an inch in the height of the bricks would mean a difference of one-half to the vertical foot of wall, assuming four bricks to the vertical foot. In a fifty-foot wall there is a difference of twenty-five inches in

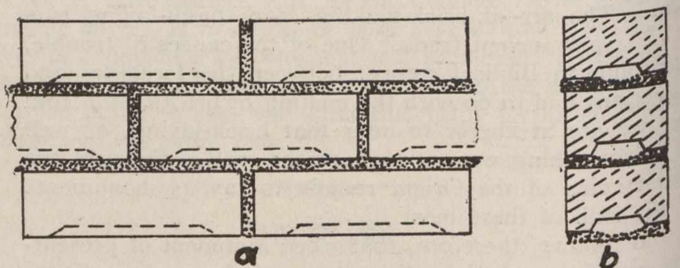

Fig. 2.

the amount of mortar. The mortar is the weaker material in the wall, and therefore the inside of the wall, which has to carry the floor loads and should be stronger, is weaker than the outside.

Classification According to Strength.—There should also be a minimum requirement of strength in a definite period after a brick is made. Bricks, as they are used now, vary in crushing strength from 400 lbs. per sq. in. to 7,000 lbs. per sq. in., and are classified according to appearance and not according to strength. The above-mentioned brick showing a strength of 400 lbs. per sq. in. would probably be used as a filler, and placed in the back of the wall where it would have to carry the greater portion of the load. It is because these poor bricks are used that building regulations are justified in allowing a compressive strength of from 50 to 75 lbs. per sq. in. This laxity in allowing the use of the poor bricks is the reason for discounting the strength shown in 85% of the bricks produced, for any of the modern kilns will show 85% of the bricks to be hard burnt. Therefore, if some rigid standard was enforced for factory and office building construction, such as a requirement of 2,000 lbs. per sq. in. in compression, one month after being made, it would only exclude about 15% of the bricks produced and many uses could be found for the rejected 15%. Building regulations would then be justified in raising the allowable unit stresses in brick wall construction.

Lime versus Cement Mortar.—In Table I. is given the results of compression tests on blocks of cement and lime mortar.