BRICKWORK

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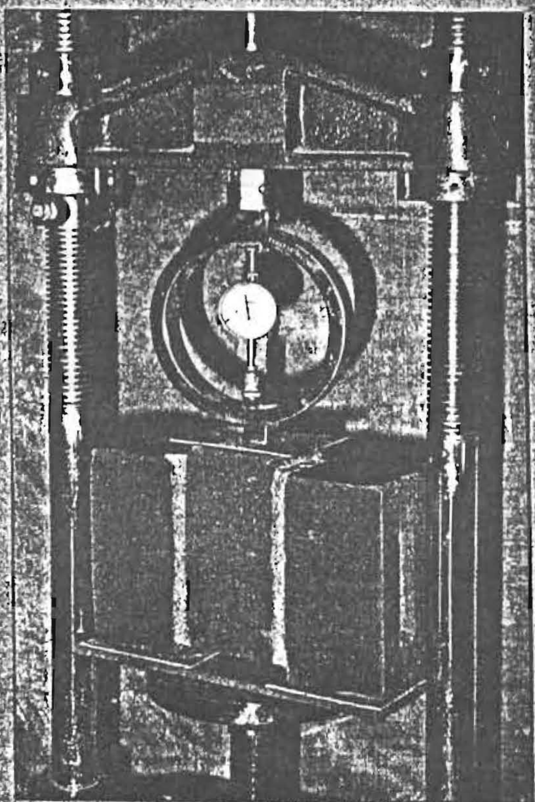
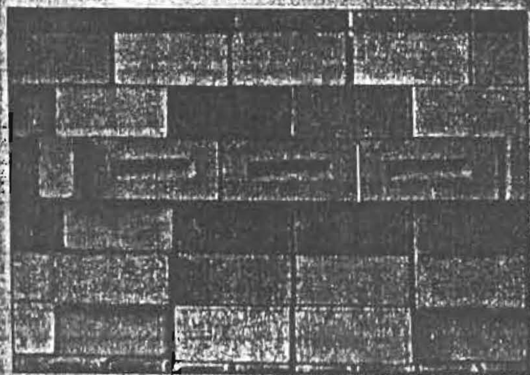
C I V I L E N G I N E E R I N G &

CONSTRUCTION REVIEW

India's Leading Monthly On Methods, Materials & Machinery. September 1995





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Impact Of Surface Texture And Frog Of Bricks On Strength Of Brick Masonry

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The impact of surface texture of brick on the quality of masonry is often discussed but still remains a controversial issue. Similar is the case with advantages of a brick having frog over a plain brick. With the advent of extrusion machines the use of frogless extruded bricks also has increased. In spite of good quality and high consistent strength the extruded bricks have been, sometimes, looked at with a doubt for the bonding characteristics, perhaps due to their smooth surface and froglessness. Unfortunately, hardly any studies are available, throwing light on these two aspects of the brick and their impact on the masonry strength. One of the reasons for this (absence of decisive data) may be that, as such, there is a large variation in the unit strength of hand-made burnt clay bricks and it might be very difficult to produce bricks of identical strength, with and without frog, as well as with different surface textures, which happens to be a prerequsite for a logical comparison. The extruded bricks can not be provided with frog in the production process in vogue.

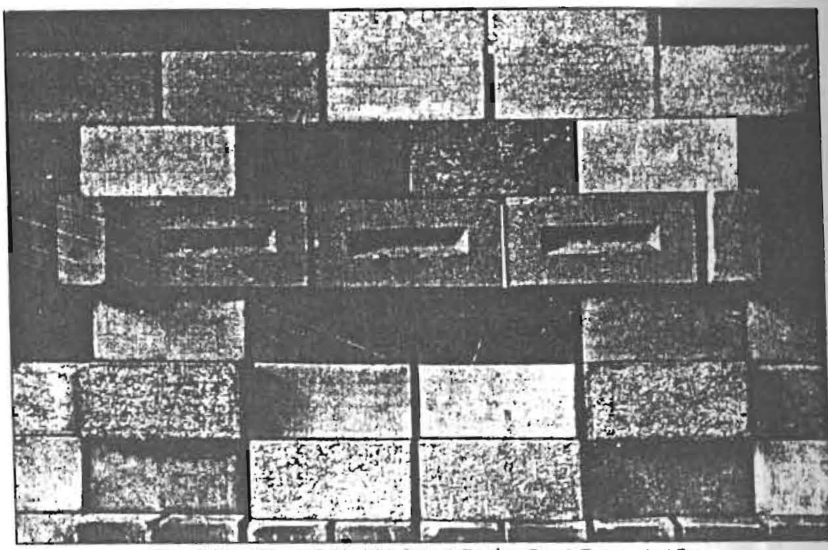

Fig.1. Calcium Silicate Bricks With Smooth Texture, Rough Texture And Frog.

Now, with the introduction of pressed, autoclaved, calcium silicate bricks, it is possible to produce bricks with and without frog, having desired strength and with an excellent consistency in strength. The experimental studies, therefore, conducted to assess the impact of these two parameters on the strength of brick masonry, were specifically based on calcium silicate bricks, produced using CBRI process (Fig.1).

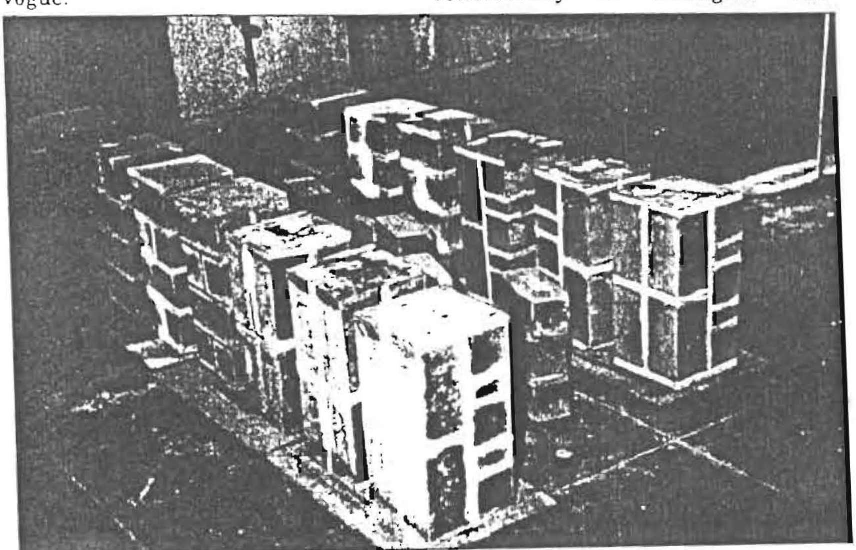

Fig.2. A Batch Of Prisms Ready For Testing (Height : Width Ratio Is 2).

Properties Of The Bricks Used

The properties and other salient features of the bricks used in the experimental work were as follows:

- Modular, having a nominal size of 20 cm x 10 cm x 10cm produced in a rotary press.
- Perfectly shaped, with level faces, square corners and without warping.
- Having a dimensional tolerance of ± 1 mm.
- Having no efflorescence.
- Having 20% water absorption on 24 hours of immersion in water at room temperature.
- Having an initial rate of absorption of 29 gms.
- Having a (wet) average unit compressive strength of 101 kg/cm^2,

with a coefficient of variation of 6.11.
Having smooth sides and rough top.

Salient Features Of Mortar Used

For a brick having a strength upto 100 kg/cm², it is customary to use cement-sand mortar of 1:6 or a composite mortar of 1:2:9 (cement:lime:sand). Using a standard flow table, pre-suction and post-suction flow of these two mortars was measured. The values of the ratio of "post-suction flow to pre-suction flow" were observed to be 0.4 and 0.7 for 1:6 cement-sand mortar and 1:2:9 for composite mortar respectively. Considering the initial rate of absorption of the brick, which tends to be on higher side, it was decided to adopt composite mortar (1:2:9), which has an equivalent compressive strength (36 kg/cm²) as that of conventional straight cement-sand mortar, and at the same time is superior in water retentivity, which imparts a better bonding quality.

The mortar joint thickness (for bed joints as well as for the perpends) was maintained 10 mm with a tolerance of +2 mm. Utmost care was taken to control the uniformity in joint thickness, especially in the bond-test specimens, with a view to maintain parallel faces to match with the loading gadgets, used during the test.

Tests And Test Set-Ups

The following tests were conducted to facilitate the assessment of impact of surface texture of brick and provision of the frog, on the strength of the masonry.

I. The Unit Compressive Strength of Brick
  - in pressing direction
  - normal to pressing direction

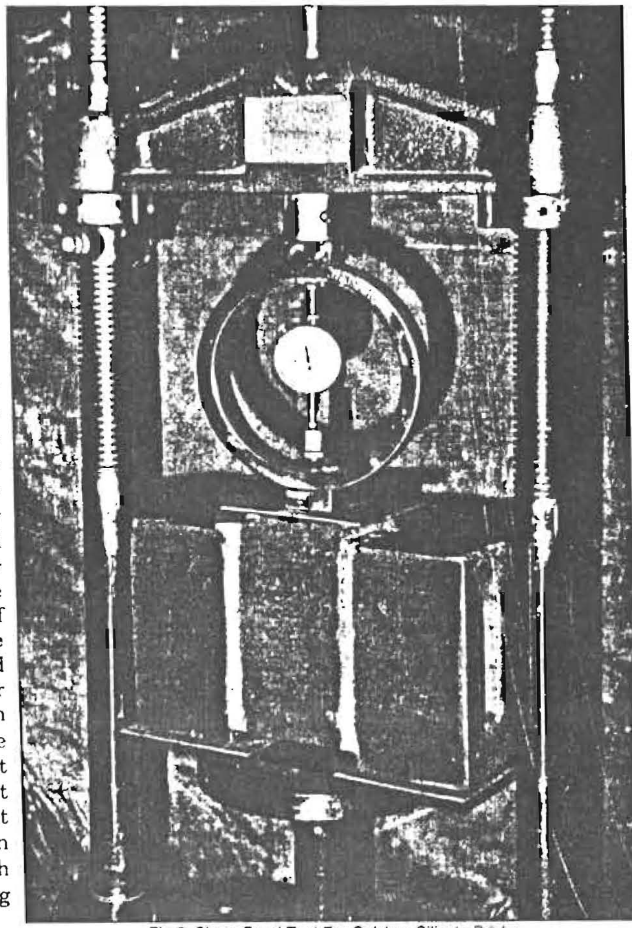

Fig.3. Shear Bond Test For Calcium Silicate Bricks.

II. Prism Strength (Normal to Bed Joints)
  - Smooth bedding face (Plain bricks)
  - rough bedding face (Plain bricks)
  - frogged bricks

III. Prism Strength (Parallel to Bed Joints)
  - Plain bricks
  - Frogged bricks

IV. Shear Bond Strength at Zero Compression
  - bed joint against smooth face
  - bed joint against rough face
  - frogged brick (frog size 10cm x 4cm)

V. Tensile Bond Strength
  - joint against smooth face
  - joint against rough face
  - joint against frog

The unit compressive strength as well as masonry prism strength was determined in a hydraulically operated universal testing machine.

The prism size having H/B ratio of 2 was adopted for convenience of fabrication and handling (Fig.2).

The shear bond strength and the tensile bond strength was determined in a smaller, manually operated equipment attached with a proving ring, for precision in observations. This was essential considering the low range of loading involved (Fig.3).

Discussions

Unit Strength Of Bricks And Other Relevant Properties

All bricks, with and without frog, were produced with identical materials in identical proportions and maintaining identitical production conditions. Plain bricks were produced with a rough top, intentionally. A perfect quality control at all stages imparted a high degree of consistency in the strength of bricks having an average value of 101 kg/cm². The coefficient of variation being 6.11.

There is no significant difference in compressive strength of the brick in pressing direction and that normal to the pressing direction (Table 1).

Compressive strength and other physical properties of the frogged bricks were identical to those of plain bricks, used for experimental work. It is worth mentioning that the initial rate of absorption was identical, irrespective of texture of the surface. It is an important observation, as the initial rate of absorption determines the bonding property, which, in turn, has an impact on behaviour of the masonry.

Prism Strength - Smooth Bedding Face Vs Rough Bedding Face (Compression Normal To Bed Joints)

The average values of stress at first crack (31.6, 32.6), as well as those at failure (38.2, 39.0) of the prisms constructed with rough bedding face and smooth bedding face, indicate that the difference in surface texture of the brick has no impact on the prism strength (Table 2). The values at first crack as well as those at failure are almost identical in both the cases. The failure invariably occurred by tensile splitting of bricks, in line of perpends. This is a typical phenomenon manifested due to differential lateral deformation between masonry unit and the bed mortar, causing tensile stresses in the masonry units, resulting into their splitting. Average "Prism strength to unit strength" ratio observed was about 0.40.

Table 1: Compressive Strength Of Bricks In Pressing Direction Vs That Normal To Pressing Direction

	FAILURE STRESS (kg/cm^2)		
Sp. No.	Pressing Direction	Sp. No.	Normal to Pressing Direction
PD1	102	ND1	103
PD2	106	ND2	101
PD3	108	ND3	98
PD4	96	ND4	103
PD5	100	ND5	88
PD6	94	ND6	108
PD7	111	ND7	98
PD8	104	ND8	99
PD9	92	ND9	106
PD10	108	ND10	93
Average	102		99.7

Average Compressive Strength of all above samples : 101 kg/cm^2

Coefficient of Variation : 6.11

Prism Strength - Plain Bricks Vs Frogged Bricks (Compression Normal To Bed Joints)

The average value at the first crack for the prism with plain bricks was observed to be about 32 kg/cm^2 and that for frogged brick masonry was 42.4 kg/cm^2, indicating a clear superiority in the strength of prisms with frogged bricks. This trend was seen in the values of failure stresses as well. The average failure stresses for the plain-brick prism and the frogged brick prism were about 39 kg/cm and 54.6 kg/cm^2 respectively (Table 2). Thus the presence of frog gave an additional 40% strength over the plain brick masonry. This rise in strength could be attributed to othe resistance, offered by the frog, to differential lateral deformation between brick and the bed mortar, thus delaying the tensile splitting of the brick. The splitting of the brick in this case occurs near the face of the prism and not in the centre in line of perpends, unlike plain-brick masonry prism.

Prism Strength - Plain Bricks Vs Frogged Bricks (Compression Parallel To Bed Joints)

There is a distinct difference in the behaviour of the prism subjected to compression, normal to the bed joints and that parallel to the bed joints.

When the compression is parallel to the bed joints both in the plain-brick prisms and frogged-brick prisms, the first crack occurred vertically by opening out the bed joint. No splitting or crushing of masonry unit was observed in this case. The average stress value at the first crack in plain-brick prism was 21.8 kg/cm^2 and that in frogged-brick prism was 24.9 kg/cm^2 (Table3), thus the latter bearing 15% extra stress. However, the failure stresses in both the cases (i.e. the plain brick specimens and frogged-brick specimens) were observed to be practically the same, the average values being 41.5 kg/cm^2 and 39.3 kg/cm^2 respectively (Table 3). Average "Prism Strength to Unit Strength" ratio observed was 0.40.

In other words, when the compression is acting parallel to the bed joints (in plain of the wall) the frogged brick does not show significant

Table 2: Prism Strength (Compression Normal To Bed Joints)

Smooth Surface			Rough Surface			Frogged Bricks		
Sp. No.	Stress at first crack kg/cm^2	Stress at failure kg/cm^2	Sp. No.	Stress at first crack kg/cm^2	Stress at failure kg/cm^2	Sp. No.	Stress at first crack kg/cm^2	Stress at failure kg/cm^2
S1	33.2	41.5	R1	32.7	37.7	F1	44.3	52.6
S2	22.2	31.5	R2	27.7	31.6	F2	44.3	57.6
S3	33.2	40.4	R3	30.5	39.3	F3	41.5	52.6
S4	36.0	41.5	R4	33.8	38.2	F4	44.3	60.4
S5	31.0	36.0	R5	38.8	50.4	F5	40.4	52.6
S6	33.7	38.8	R6	32.1	37.1	F6	39.9	52.0
Average	31.6	38.2	Average	32.6	39.0	Average	42.4	54.6
Prism Strength / Unit Strength		0.38			0.39			0.54

Table 3: Prism Strength (Compression Parallel To Bed Joints)

Plain Bricks			Frogged Bricks		
Sp. No.	Stress at First Crack kg/cm²	Stress at Failure kg/cm²	Sp. No.	Stress at First Crack kg/cm²	Stress at Failure kg/cm²
P1	16.6	40.4	F1	27.7	45.7
P2	19.3	43.2	F2	24.9	34.6
P3	24.9	44.3	F3	22.1	38.2
P4	27.7	36.0	F4	25.5	37.3
P5	25.5	43.7	F5	24.9	40.8
P6	-	-	F6	-	-
Average	21.8	41.5	Average	24.9	39.3
Prism Strength / Unit Strength		0.41			0.39

advantage over the plain bricks.

Shear Bond Strength - Smooth Face Vs Rough Face Against Bed Joint (Zero Compression)

The average failure stress in case of smooth face and that in case of rough face against the bed joint is practically identical (1.4 kg/cm²) indicating the surface texture of masonry unit has no impact on the shear bond strength of the bed joint (Table 4). It confirms the fact that, it is mainly the absorption characteristic of a masonry unit that governs the bonding quality at brick mortar interface.

Table 4: Shear Bond Strength At Zero Compression

Filure Stress (kg/cm²)					
Sp. No.	Bed Joint Against Smooth Face	Sp. No.	Bed Joint Against Rough Face	Sp. No.	Bed Joint Against Frog
SS1	1.21	SR1	1.44	SF1	2.0
SS2	1.66	SR2	1.53	SF2	1.72
SS3	1.42	SR3	1.33	SF3	1.87
SS4	1.56	SR4	1.62	SF4	1.62
SS5	1.36	SR5	1.20	SF5	1.98
SS6	1.25	SR6	1.48	SF6	-
Average	1.41		1.45		1.84

Shear Bond Strength - Plain Brick Vs Frogged Brick (Zero Compression)

It was observed that the presence of frog in a brick enhances the shear strength of the bed joints. An average value of 1.84 kg/cm² was obtained for the specimens with a frog of 10cm x 4 cm having a depth of 2 cm (Table 4) that means about 131 kg force was resisted by the frog area of 40 cm². In other words contribution of the frog in shear resistance was about 3.3 kg/cm². Overall, it could be concluded that the masonry with frogged bricks offers an extra 30% shear strength as compared to that with plain bricks. This value may vary with the size of the frog.

It is a known fact that the shear strength of masonry bed-joint varies with the dead load above it. More the dead load above the joint, more is its shear strength. Thus the increased normal stress influences the behaviour of brick-mortar interface. The Australian code provides values from 1kg/cm² to 5 kg/cm² for masonry having direct compressive stresses from 0 kg/cm² to 24 kg/cm²; however, these values are for masonry in 1:1:6 mortar.

Tensile Bond Strength - Smooth Face Vs Rough Face Against Bed Joint

The results indicated that the values of tensile bond strength with smooth surface texture (1.25 kg/cm²) and those with rough surface texture (1.16 kg/cm²) were practically identical (table 5). Thus the surface texture of the masonry unit had no impact on the tensile bond strength.

Table 5: Tensile Bond Strength

Failure Stress (kg/cm²)					
Sp. No.	Joint Against Smooth Face	Sp. No.	Joint Against Rough Face	Sp. No.	Joint Against Frog
TS1	1.10	TR1	1.59	TF1	1.74
TS2	1.10	TR2	1.25	TF2	1.01
TS3	1.77	TR3	1.01	TF3	1.51
TS4	1.30	TR4	1.01	TF4	1.16
TS5	0.98	TR5	1.18	TF5	1.39
TS6	-	TR6	0.92	TF6	-
Average	1.25		1.16		1.36

Tensile Bond Strength - Plain Bricks Vs Frogged Bricks

The values observed for

plain bricks (average of 1.2) and frogged bricks (1.36) indicate that presence of frog has a nominal impact on the tensile bond giving an additional 13% strength. The numerical value of this additional strength may seem to be insignificant but it does indicate the superiority of frogged brick over a plain brick in this aspect as well.

It may be mentioned here that the Masonry Code (IS:1905-1987) recommends a permissible tensile stress value of 0.7 kg/cm² across the bed joints for a brick-strength of 100 kg/cm² and M1 grade mortar, whereas the value becomes 0.5 kg/cm² for a masonry constructed with 75 kg/cm² brick in M2 grade mortar.

Conclusions

With the production of calcium silicate bricks using CBRI Technology it was possible to conduct studies to assess the impact of surface texture and provision of frog, on the strength of masonry. It was observed that the variation of surface texture of the unit does not change the compressive strength of the masonry. It is so because the efficiency of the bond is governed by the absorption characteristics of the masonry unit and not the surface texture.

It is observed that provision of a frog has definite advantage over the plain brick as the compressive strength of the prism with frogged brick is distinctly higher than that of plain bricks. It is also found that the shear bond strength of masonry with frogged bricks is higher than that of plain bricks.

Acknowledgement

The work reported in this paper forms a part of the R&D output of Central Building Research Institute, Roorkee and is presented here with kind consent of the Director of the Institute.

References

1. *Calcium Silicate Bricks Specifications IS:4139-1989*
2. *Code of Practice for Structural Use of Unreinforced Masonry, IS:1905-1987.*
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