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Preliminary Investigations on the Physico-chemical Properties of Some Indian Bricks

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A LARGE variety of bricks are used in India for building purposes. They have distinctive characteristics of their own depending on the properties of the clays from which they have been made and the methods employed in their manufacture. Data on the properties and characteristics of the various brick types in use in the country is not available and the present investigation relates to a study of some brick types in use.

Experimental

Samples of bricks were obtained from 20 different localities (TABLE I) and are representative of the types manufactured from the clays available in the respective localities.

TABLE I

Sample No.	Locality	Burning characteristics	Colour	Sound	Shape	Structure & composition	Resistance to Breaking	Resistance to Abrasion
1	Rupar HCC (Punjab)	Well burnt	Dull red	Metallic	Very good	Even (in some cases there is layer or lump formation)	Hard	Hard
2	Amritsar AS (Punjab)	do	do	do	do	Even (lump formation and iron nodules)	do	do
3	Jullundur KLM (Punjab)	do	Brick red	do	do	Even (air holes)	do	do
4	Delhi M45	do	Dull, brick red	do	do	Uneven (air holes)	do	do
5A	Roorkee PMW (U.P.)	Under burnt	Yellowish red	Dull	Fair	Even	do	Medium
5B	Roorkee SJS (U.P.)	Well burnt	Copper	Metallic	Good	Even (containing mica flakes)	do	Hard
6	Muzaffarpur APD (Bihar)	do	Yellow skin up to 0·5 cm., buff core	do	Very good	Even	do	do
7	Dhanbad SBS (Bihar)	do	Dull red	Dull	Good	Uneven (air holes, mica flakes, quartz crystals, lumps of iron nodules, carboniferous matter)	Easy	Medium
8	Chinsurah ROSE (Bengal)	do	Crimson red	Metallic	Fair	Even (air holes)	Hard	Hard
9	Bhandara BHS ; NH (C.P.)	Under burnt	Dark red	Dull	do	Uneven	Easy	Soft
10	Pachmarhi DK (C.P.)	Well burnt	Pale, brick red	do	Good	Uneven (flint grains)	Very easy	do
11	Piparia (C.P.)	do	Dark orange	do	Fair	Even (air holes)	Not very hard	do
12	Belgaum (Bombay)	Under burnt	Yellowish red	do	Good	Fairly even (air holes, iron nodules)	do	Medium
13	Dowladshwaram VBK (Madras)	do	Copper	Semi-metallic	Fair	Uneven (air pockets due to burnt straw, flint, stones, etc.)	Easy	Soft
14	Chepauk CS (Madras)	Well burnt	Brick red	do	Good	Even (flint and iron nodules)	Very hard	Hard
15	Mettur (Madras)	Under burnt	Light chocolate	Dull	do	Uneven (air holes and stones)	Very easy	Soft
16	Vellore (Madras)	Well burnt	Brownish red	Semi-metallic	do	Even (air holes and stones)	Easy	do
17	Ootacamund JRK (Madras)	do	Chocolate red	Metallic	Fair	Uneven (air holes, stones, burnt straw)	Hard	do
18	Coimbatore (Madras)	do	Dull red	Semi-metallic	do	Even (air holes)	Easy	do
19	Anantpur (Madras)	do	Pale chocolate	do	Good	Even (air holes, stones)	do	do
20	Calicut CTL (Madras)	do	Bright red	Metallic	Very good	Even (a few burnt iron nodules)	Not very hard	Hard

The bricks were tested for the following : (i) bulk density; (ii) percentage porosity; (iii) compressive strength; (iv) pressure deficiency ; (v) permeability ; (vi) rate of water absorption ; and (vii) chemical composition.

The bulk density of the brick was calculated by cutting out a cube from the brick and determining its dimensions and weight.

The porosity and compressive strength were determined according to standards laid down in *B.S.S.* No. 1257 (1945). The porosity was determined by boiling a brick in water for 5 hr. and allowing it to cool overnight ; the difference in weights before and after this treatment gave the porosity. The compressive strength was determined by crushing the brick in a hydraulic press between 2 thin pieces of plywood after the frogs have been filled up, and the bricks planed by 1 : $1\frac{1}{2}$ cement mortar. A study of the rate of absorption of water by bricks immersed in water was also made.

Permeability was determined by allowing water to pass through the brick under a known pressure head and measuring the amount of water passing through it per unit time.

To determine the pressure deficiency, 2 methods were employed. In one method[1], a piece of brick was waxed round the sides and sealed in a funnel-shaped apparatus. The apparatus was filled with air-free water and as evaporation took place on the free and unwaxed surface of the brick, water in the tapering end of the apparatus was drawn towards the surface. This caused a rise in the mercury column of the manometer attached to the apparatus. The pressure registered by the manometer is a measure of the capillary force. This method is slow, and the testing takes a long time. In the second method[2], suction, just sufficient to overcome the capillary force of the brick, is applied as in the method originally used.

for the determination of pressure deficiency of sand and silt. The method is rapid and has been adopted for determining the pressure deficiency of bricks also. The values obtained by this method are invariably higher than those obtained by the first method.

The results of these tests are given in Table II. The rate of absorption of water is represented graphically in Fig. 1.

Discussion

Some of the accepted characteristics of a good brick are that it should be of a good shape, hard to scratch, have a metallic ring when struck, and be free from foreign matter. It was, however, noticed that most of the bricks studied contained stones and carboniferous matter. These inclusions weaken the bond between the different brick particles. This can be avoided by sieving the clay before moulding. The lumps in the brick are responsible for low compression strength values even though the bricks were good in other respects.

A study of compressive strengths of bricks (Table II) shows that 5 samples have a value of 1,000-2,000 lb./sq. in. while 7 others have a strength of 500-750 lb./sq. in., and the rest below 500 lb./sq. in., the lowest being 157 lb./sq. in. for a sample from Pachmarhi (C.P.). Most of the bricks tested are weak, except those made from the alluvial soils of the Indo-Gangetic tract. Considering the importance of bricks as building material, it is important to study the mechanism by which a brick derives its strength and to devise methods by means of which bricks of high compressive strength can be obtained from different types of Indian soils.

The mechanical strength of a brick depends upon: (i) the internal resistance of the particles constituting the brick; and (ii) the bond provided by the vitrification of the clay. The higher the firing temperature, the better is the vitrification and, hence, the stronger is the bond. Soils are made up of particles of different sizes. Particles greater than 0·02 mm. diam. are classified as sand, those between 0·02 mm. and 0·002 mm. as silt, and those less than 0·002 mm. as clay. It is the sand fraction that provides the greatest internal resistance. Consequently, a certain percentage of sand is essential for getting strong bricks. The chemical composition of the bricks (Table III) shows that bricks whose strength is between 1,000-2,000 lb./sq. in. contain 70-80 per cent of silica. However, there are samples containing silica within the above range but are still weak. Thus, samples from Piparia, Mettur and Bhandara

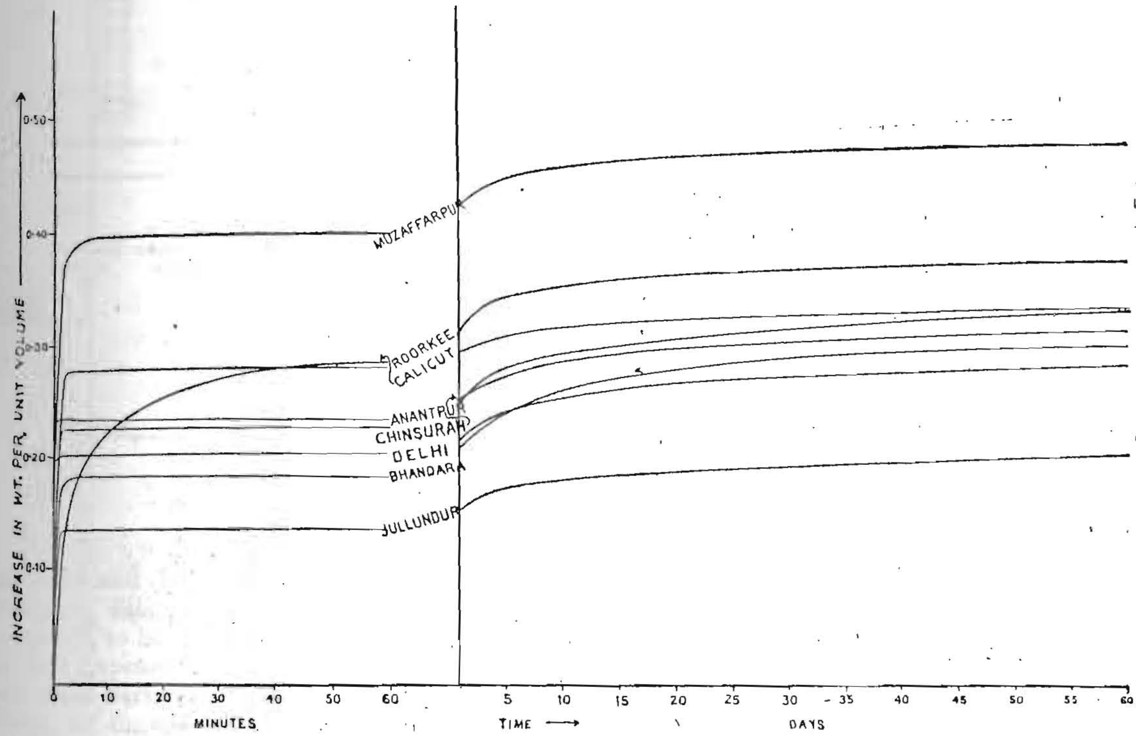

Fig. 1

TABLE II

Sample No.	Actual density of brick powder gm./c.c.	Bulk density of brick gm./c.c.	Porosity, % of wt. of sample	Compressive strength lb./sq. in.	Increase in wt. on soaking in water for 24 hr. %	Absorption of water in 1 hr.; % of water absorbed in 24 hr.	Pressure deficiency		Permeability ×10[10]
							Evaporation method, cm. of water	Suction method, cm. of water	
1	2·85	1·65	35·8	1792	16·8	92·2	...	637	...
2	2·57	1·74	32·1	1165	14·0	90·3	...	406	...
3	2·43	1·87	23·0	1142	8·2	91·4	...	460	...
4	2·66	1·77	33·7	1993	12·8	94·9	206	349	1·90
5A	2·56	1·65	37·6	1254	19·4	90·7	182	...	0·12
5B	2·58	1·74	33·1	1725	15·4	89·9	240	...	1·80
6	2·54	1·33	47·4	492	31·8	94·8	371	...	0·16
7	2·46	1·58	36·0	425	17·0	92·3	55	123	8·80
8	2·52	1·71	32·0	694	15·6	91·2	483	871	0·55
9	2·56	1·72	32·8	470	12·9	87·2	176	579	0·98
10	2·37	1·68	30·0	157	15·3	93·5	36	173	3·30
11	2·44	1·72	29·6	649	12·2	90·3	115	358	1·50
12	2·68	1·62	39·7	739	19·2	92·5	...	513	...
13	2·44	1·47	41·0	582	23·6	85·8	64	...	3·20
14	2·56	1·80	29·0	358	13·4	84·6	97	443	2·35
15	2·59	1·70	33·9	179	13·4	89·2	59	167	4·00
16	2·60	1·72	33·8	582	11·3	95·4	75	348	2·40
17	2·81	1·67	40·6	515	18·1	91·7	36	86	15·00
18	2·54	1·57	38·0	515	18·5	95·7	...	175	...
19	2·43	1·58	35·0	358	16·5	96·7	...	143	...
20	2·58	1·64	36·5	627	18·8	97·0	106	795	...

TABLE III

Ser. No.	Silica SiO_2	Sesquioxides R_2O_3	Lime CaO	Magnesia MgO	Alkali salts as NaCl & KCl	Sulphate as SO_3	Loss on ignition
1	77·37	15·50	2·80	1·90	3·38	0·03	0·28
2	74·86	19·62	1·75	0·74	3·42	0·10	0·25
3	75·46	19·86	3·02	0·63	1·91	0·05	0·25
4	79·61	15·07	2·14	1·70	1·50	0·01	0·21
5	71·75	23·43	2·01	1·15	1·05	0·03	0·26
6	51·43	19·99	24·71	0·46	2·60	0·01	2·13
7	80·54	15·50	1·16	0·41	3·80	0·05	0·29
8	69·42	23·66	3·52	1·51	2·29	0·04	0·43
9	71·09	22·31	1·95	1·28	0·72	0·01	1·55
10	63·76	27·33	1·48	1·23	1·90	0·01	3·83
11	79·09	15·68	1·94	2·57	1·51	0·01	0·80
12	71·75	21·64	3·11	0·74	0·50	0·02	0·90
13	69·99	24·01	3·94	1·70	1·21	0·03	0·40
14	70·52	22·79	2·60	0·04	3·31	0·05	0·31
15	72·31	19·95	3·41	1·34	1·40	0·02	0·40
16	59·69	29·01	6·01	0·56	3·76	0·02	0·66
17	52·91	36·42	5·80	2·36	4·25	0·07	0·23
18	63·22	29·21	5·97	0·71	2·07	0·03	0·44
19	73·80	18·65	3·79	0·41	3·00	0·00	0·38
20	55·32	36·86	2·88	0·99	0·81	0·01	2·15

contain 79 per cent, 72 per cent and 71 per cent silica respectively, yet they are weak. This may be due to the fact that the firing temperature for these bricks was low or the soil cannot give good bricks at the temperatures attainable in the ordinary brick kiln. Results of the mechanical analysis of the soil from which bricks are made are given in Table IV.[3] Though the analysis does not represent the results on actual soil samples from which the bricks under test were made, yet it gives a fairly good idea of the sand content of the soils from which these bricks were obtained. It is seen that the sand content of Piparia and Bhandara soils are as high as 61 per cent and 50 per cent while those of Delhi and Jullundur are only 26 per cent and 33 per cent respectively. This clearly indicates that the bulk of silica in Piparia and Bhandara bricks is derived from the coarser fraction, while in the case

TABLE IV

Sample No.	Mechanical composition		Total silica content %	Active silica %	Inactiv silica %
	Coarse fraction (sand) %	Fine fraction (silt & clay) %			
1	...	...	77	...	...
2	...	...	75	...	...
3	33	67	76	43	33
4	26	74	80	54	26
5	45	55	72	27	45
6	3	97	51	48	3
7	45	55	80	35	45
8	48	52	69	21	48
9	50	50	71	21	50
10	37	63	64	27	37
11	61	39	79	18	61
12	...	...	72	...	...
13	...	...	70	...	...
14	34	66	70	36	34
15	...	...	72	...	...
16	14	86	60	46	14
17	24	76	53	29	24
18	45	55	63	18	45
19	...	...	74	...	...
20	17	83	55	38	17

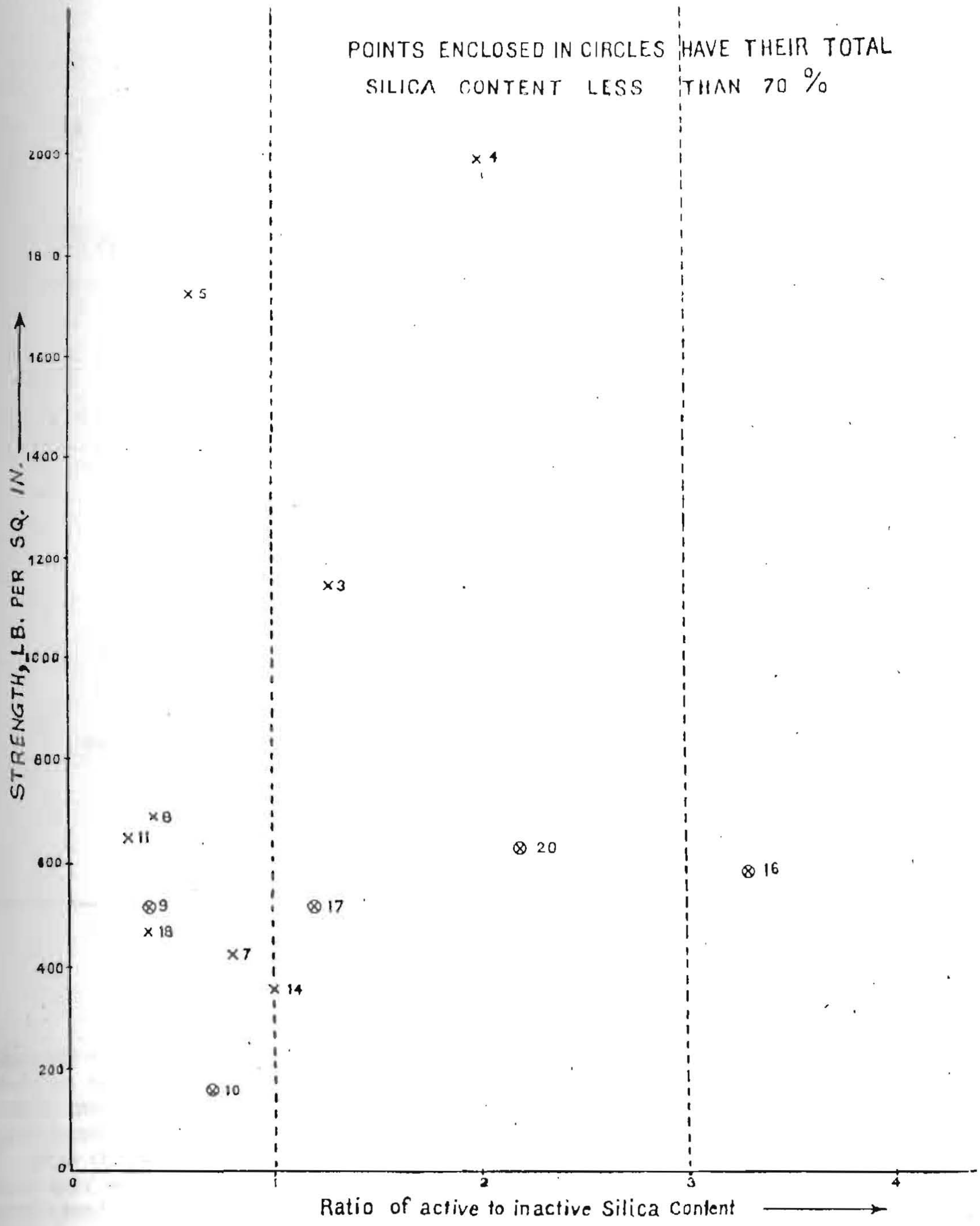

FIG. 2

of Delhi and Jullundur, it is from the finer fraction. Silica from the finer fraction is supposed to be more active due to a greater surface exposed for chemical reaction than the silica derived from the coarser fraction. Thus, for the present discussion, silica from the finer fraction is termed *active silica*, while that from the coarser fraction is termed *inactive silica*. Active silica helps in the vitrification of the brick, while inactive silica provides greater internal frictional resistance than the active silica. It seems that (FIG. 2) there is a definite ratio of active to inactive silica (between 1 and 3)

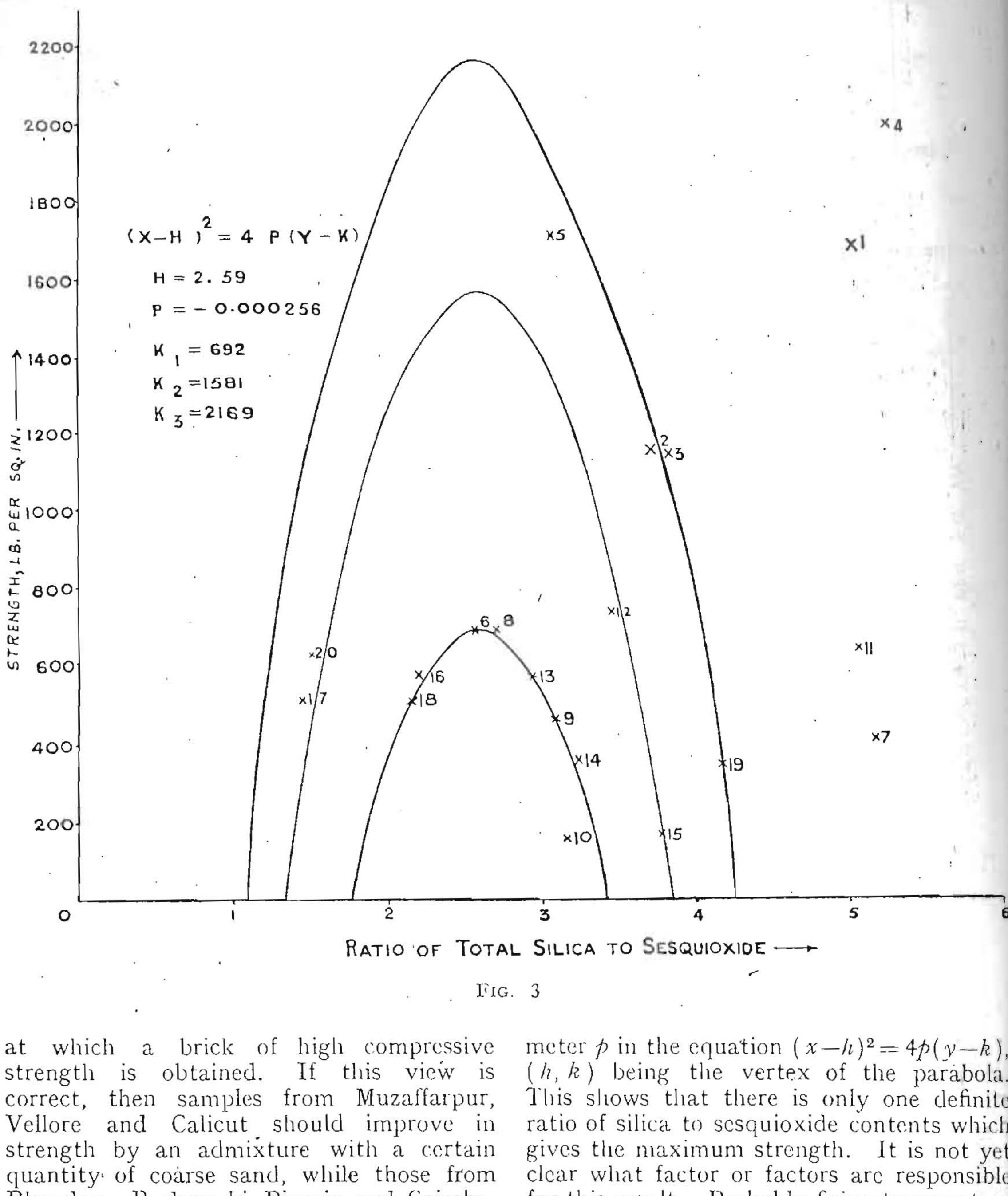

FIG. 3

at which a brick of high compressive strength is obtained. If this view is correct, then samples from Muzaffarpur, Vellore and Calicut should improve in strength by an admixture with a certain quantity of coarse sand, while those from Bhandara, Pachmarhi, Piparia and Coimbatore should improve by an addition of fine sand. It may be pointed out here that these results are not conclusive, but provide guidance for further work on the subject.

If the compressive strength of the bricks are plotted against the ratio of silica to sesquioxide contents of the bricks (FIG. 3), the graphs obtained are a series of parabolas having their foci lying on the same vertical axis and having the same value of the parameter p in the equation $(x-h)^2 = 4p(y-k)$, (h, k) being the vertex of the parabola. This shows that there is only one definite ratio of silica to sesquioxide contents which gives the maximum strength. It is not yet clear what factor or factors are responsible for this result. Probably firing temperature is one of the factors.

Water absorption and saturation coefficients of a brick sample are useful guides in gauging the durability of a brick. The water absorption values of the brick samples are given in Table II. The rates of absorption of water are about the same in all bricks. It is found that they absorb the major part in the first 2 minutes and thereafter it is slow. In this respect, the 24-hr. absorption test, as described in *B.S.S.* No. 1257 (1945), can be usefully shortened to 1 hr. period as the bricks absorb, in the first hour, 92 per cent of the water absorbed in 24 hr. period. A great deal of time can be saved if this test is modified for the 1 hr. period. The 5-hr. boiling test can also be similarly shortened as it is found that boiling for 1 hr. suffices to bring about the same absorption as boiling for 5 hr. does within 1 per cent error.

The subject of pressure deficiency has been discussed in detail in a previous paper[4]. Results of pressure deficiency (TABLE II) show that weaker bricks have smaller pressure deficiencies.

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REFERENCES

1. *Report of the Building Research Board*, England, for the year 1928, p. 12.
2. RAM, GURDAS & VAIDHIANATHAN : *Proc. Ind. Acad. Sci.*, 1941, **13A,** 77.
3. PATWARDHAN, N. K. : *J. Sci. & Ind. Res.*, 1949, **8B,** 144.
4. RAM, GURDAS : ibid., 1947, **6,** 492.