PRODUCTION OF GROG FIRECLAY BRICKS

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An attempt has been made to produce standard grog fireclay bricks, chiefly from abundantly available Pakistani raw materials. Bricks of 18 compositions were formed and their essential characteristics, such as thermal conductivity, permeability thermal expansion, thermal shock resistance, bulk density, shrinkage, porosity, crushing strength and re-heating shrinkage were determined and the results discussed.

In Pakistan, the industrial development has reached a stage, where refractories of exact specifications are badly needed and this demand is being met with through imports, which result in a constant drain on our foreign exchange. It is therefore, very essential that our refractory industry is developed to meet, if not all, at least a part of the demand of the industry. With this objective in view, an attempt has been made to produce standard grog fireclay bricks, a much needed constructional refractory from the abundantly available indegenous raw materials. The clay used in this investigation is from Mianwali district and the same has been utilized for making grog.

RAW MATERIALS

As their name implies, the chief constituents of grog fireclay bricks, are the grog and good quality fireclay, and those used have the following chemical composition:

	Fireclay	Grog
I/L% ..	14.4	—
SiO_2% ..	44.21	48.50
Al_2O_3% ..	40.36	49.95
Fe_2O_3% ..	0.69	0.69
CaC% ..	0.4	0.39

PLAN OF INVESTIGATION

A review of the literature[1] showed that various non-plastic materials, such as silica sand, aluminium hydrates, chromite etc. were suggested as alternatives for grog. It was a common, although unfortunate mistake to suppose that the addition of silica improves the quality of the bricks. It, in fact, reduces the refractoriness of high-grade fireclay, and, in addition to this, also shortens the range of vitrification.

In the present investigation, the base was made according to the following composition of refractory materials[2]:

Grog	..	90%
Fireclay	..	10%

It is evident that the composition consists mainly of grog. But during the preparation of the test pieces, it was observed that this composition could not be shaped into a stable brick, due to insufficient amount of binding material (clay). So here the successive replacement of grog by fireclay upto 45 percent was tried. The test pieces were fired at 1400°C. with a soaking period of 5 hours, the rate of heating being 150°C. per hour.

PREPARATION OF GROG

Grog was prepared by calcining the clay at a temperature of 1150°-1200°C. This was done by keeping the lumps of washed fireclay in saggers and then firing them in an oil-fired furnace to the abovementioned temperature. After cooling, it was crushed and graded into the following size:

Between 10 and 25 mesh	—Coarse grains
Between 25 and 72 mesh	—Medium grains
Below 72 mesh	—Fine grains

PREPARATION OF TEST PIECES

Individual brick compositions were prepared by taking weighed quantity of each ingredient. The grog-clay mixtures were thoroughly mixed to ensure uniform mixing. Water was then sprinkled and each mass was repeatedly turned over until a homogeneous paste was obtained. The material was then aged for a sufficient time to get uniform distribution of water and maximum attainable plasticity in the batches. The bricks of the size 2.7″×1.5″×1″ were made in a mechanical press, air-dried and subsequently fired at 1400°C. as described in the plan of investigation.

The compositions of the bricks are as follows:

Brick	Clay %	Grog %	
A	10	90	
B	20	80	
C	25	75	
D	30	70	—10 mesh (A to G)
E	40	60	
F	50	50	
G	25	75	(25 — 10–25 mesh) (50 — –72 mesh)
H	25	75	(25 — 10–25 mesh) (25 — 25–75 mesh) (25 — –72 mesh)
I	25	75	(50 — 10–25 mesh) (25 — –72 mesh)
J	25	75	(50 — 10–25 mesh) (25 — 25–72 mesh)
K	35	65	(22 — 10–25 mesh) (43 — –72 mesh)
L	35	65	(22 — 10–25 mesh) (22 — 25–72 mesh) (21 — –72 mesh)
M	35	65	(43 — 10–25 mesh) (22 — –72 mesh)
N	35	65	(43 — 10–25 mesh) (22 — 25–72 mesh)
O	45	55	(18 — 10–25 mesh) (37 — –72 mesh)
P	45	55	(18 — 10–25 mesh) (18 — 10–72 mesh) (19 — –72 mesh)
Q	45	55	(37 — 10–25 mesh) (18 — –72 mesh)
R	45	55	(37 — 10–25 mesh) (18 — 25–72 mesh)

PROPERTIES

Bulk Density and Porosity.—Bulk density and porosity of the test pieces were determined by standard methods.[3] Density values are expressed in pounds per cubic feet while porosity in terms of percentage porosity.

Crushing Strength.—Crushing strength test was conducted on "Avery" 5 tons testing machine.

Thermal Conductivity.—The thermal conductivity was measured by a simple modified apparatus,[4] designed and fabricated in these laboratories. The calculations were carried out at an average temperature of 500°C. according to the following formula:—

$$K = \frac{H \times Q}{T_h - T_c} \quad \text{C.H.U}$$

$$= \frac{H \times Q}{T_h - T_e} \times 1.8 \text{ B.T.U./hr./Sq. ft./F/inch.}$$

The quantity of the heat i.e. Q is found out by the following formula:

$$Q = Q_c + Q_r$$
$$= 8.07\,(T_p - T_a)^{1.25} + 1.77\,(T_p/100)^4 - (T_a/100)^4 \text{ C.H.U.}$$

where

T_h=Temp. of hot face; T_c=Temp. of cold face; T_p=Temp. of copper plate; T_a=Temp. of air 12″ above the plate surface; H=Thickness of brick and K=Thermal conductivity.

Thermal Expansion.—The thermal expansion was determined upto a temperature of 1000°C. with a standard horizontal type thermal expansion apparatus designed by British Ceramic Research Association. The test pieces required were made by grinding the bricks on a grinder. The dimensions of the pieces were 1″ length and approximately 2 cm. in diameter. The expansion is reported in terms of percentage.

Fired and Re-fired Linear Shrinkage.—Fired and re-fired shrinkages were calculated by measuring the difference of shrinkage occurred after firing at 1400°C. with a soaking period of 5 hours. The experiment was repeated twice and the shrinkages were based upon the dry length in the former case, and fired length in the latter case.

Spalling Test.—The spalling test was carried out on the test pieces of the specific standard dimensions i.e. 2.7″×1.5″×1″. The procedure adopted was in accordance with the standard test.[5]

Results and Discussion

1. Data relating to the thermal conductivity presented in Table 1 show that the thermal con-

ductivity of the bricks ranges between 10.1 to 18.61. Bricks H,K,L,N,O,P, and Q have thermal conductivity less than 11, while the rest give upto 18.61. The two extreme values are represented by H and F. However, low thermal conductivity is always required to reduce the loss of heat energy.

2. From the thermal expansion of the samples after previous firing to 1400°C. (with 4 hours soaking period), (Table 1) it may be observed that: (i) Sample D has the lowest expansion 0.38 percent, (ii) Samples (R,Q,O,K,I,S) have expansions above 0.5 percent.

These figures correspond with the foreign bricks (Table 2).

3. Table 1 shows that the brands (P and L) have got exceptionally high crushing strengths, 6781 lbs. per sq. in., and 5777 lbs. per sq.in, respectively. These values are greater than the foreign superduty bricks. Samples (Q,O,K,H,G,F) register above 3644 lbs. per sq. in. while the remaining samples show value below this. The crushing strength of J is very poor, and is equal to 333 lbs. per sq. in. It is considered that the crushing strength of refractories, when cold, depends upon the amount of fused materials, which cement the particles together.

4. Linear-fired shrinkage of the samples, per-

TABLE 1.

	Thermal conductivity B. T. U.	Shrinkage at 1400°C. %	Bulk density g./ml.	Crushing strength lbs/sq. inch	Permea-bility C.G.S. units	Porosity %	Thermal expansion %	Thermal shock resistance at 100°C.	Linear change on reheating at 1400°C. %
B.	18.45	7.6	2.17	2683	2.68	10.85	0.437	16 +	+ 1.35
C.	17.80	5.1	1.95	2528	0.32	16.38	0.487	16 +	+ 0.67
D.	14.30	5.7	2.07	2894	0.34	15.94	0.380	16 +	Nil
E.	15.78	5.1	1.89	2125	0.35	14.74	0.440	16 +	,,
F.	18.61	6.4	2.15	3991	0.204	8.82	0.400	16 +	,,
G.	15.86	6.4	2.06	3947	0.038	15.04	0.540	16 +	,,
H.	1.10	7.0	2.13	3929	0.110	11.08	0.415	16 +	,,
I.	11.32	5.1	2.10	2940	0.068	17.85	0.517	16 +	,,
J.	11.19	4.3	1.80	333	3.820	30.78	0.410	16 +	,,
K.	10.80	7.6	2.20	3818	0.032	13.64	0.500	16 +	,,
L.	10.80	6.4	2.14	5777	0.038	16.69	0.470	16 +	,,
M.	11.70	6.4	2.10	2983	0.260	14.70	0.410	16 +	,,
N.	10.72	5.1	1.97	2383	0.778	14.97	0.440	16 +	,,
O.	10.62	7.6	1.94	4053	0.067	18.81	0.500	16 +	,,
P.	10.46	7.6	2.29	6781	0.034	9.38	0.480	16 +	,,
Q.	10.48	7.6	2.16	3664	0.051	9.06	0.517	16 +	,,
R.	14.10	6.4	2.03	2279	0.060	11.37	0.503	16 +	,,

TABLE 2.—PROPERTIES OF SELECTED ALUMINA-SILICATE BRICKS.

	* British		+ American		
	42% alumina	62% alumina	42% alumina	50% alumina	60% alumina
Porosity %	16.4	23.8	18.0	16	25
Bulk density g./ml.	2.48	2.33	2.114	2.339	2.178
Permeability C.G.S. Units	.071	.005	—	—	—
Cold crushing strength lbs./sq. inch on end ..	6050	3380	—	—	—
Thermal shock resistance	30 +	30 +	—	—	—
Permanent linear change on reheating % 2 hrs. at 1400°C. ..	+ .3 expansion	—	±.5	+.5	+.1

* After F.A. Harvey, Steel Plant Refractories, J.H. Chesters, 1957, p. 263. + p. 264.

centages lies between 4.30 and 7.60, this being very low, good and acceptable according to the standard specifications for the fireclay refractories.

5. Data concerning bulk density reveals that with the exception of bricks (C,E,J,N,C,O), the bulk density of all bricks is above 2.

6. It is seen from Table 1 that the permeabilities of bricks (R,Q,P,O,L,I,G) range between 0.037 to 0.08, while the others show high values. Control of permeability is one of the important factors in deciding the relative value of various refractories for a given purpose. It may be helpful to consider that permeability can be increased or decreased correspondingly by checking the grain size of the grog and the pressure to be applied in the process of shaping the bricks.

7. Spalling tests (Table 1) indicate that all of the bricks tolerated 16 cycles satisfactorily with no cracks even on the surfaces. So it is presumed that the use of the grog ensures best resistance to spalling.

8. Examination of porosities (Table 1) discloses that sample F has the lowest value i.e. 8.82 percent while J is extraordinarily porous having porosity which is equal to 30.78 and so the latter can be ignored. All the other values are in accordance with the required limits. Due to the close relationship between porosity and life of the lining, low porosity is extremely desirable irrespective of other properties.

9. Figures relating to the reburning effect show that only bricks (B,C.) expand while the rest keep their dimensions constant.

In consequence of the dual characteristics and complex inter-relationships of various properties, the following conclusion may be made:

1. Bricks P,Q,R,L, possess over-all better properties as compared with the rest of the bricks. They have (a) high crushing strength (b) low thermal conductivity (c) acceptable thermal expansion and (d) low permeabilities.

2. Brick J is very poor in regard to all the properties and hence can totally be neglected.

3. Comparing with the properties of British and American fire bricks containing 42 to 60 percent alumina (Table 2) it may be concluded that our bricks are comparable.

4. Most of these bricks, and in particular Q,R,P,L, can be employed for general as well as special purposes in the construction of heating furnaces used in industries such as pottery and porcelain, enamel, refractory, metallurgy, open hearth doors, boilers, soaking pits, checkers and cement.

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