PREPARATION AND STUDY OF ACID-PROOF BRICKS FROM INDIGENOUS RAW MATERIALS

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A number of compositions for acid-proof bricks were formulated and tested for properties like firing shrinkage, water absorption, bulk density, crushing strength and acid resistance. Successful compositions possess properties far superior to the minimum standard specifications.

Acid proof bricks and cement find considerable use in the chemical industry of Pakistan. All requirements are at present being imported. A suitable cement has already been successfully prepared.[1] This communication deals with the preparation of white stone-ware type acid-proof bricks.

Hard porcelain and some stoneware which closely resembles the former, are the most acid-resisting materials.

The main requirements for suitable acid proof bricks are: (a) a total linear shrinkage of not more than 8%;[2] (b) a crushing strength of at least 10,000 lb/in^2; (c) a maximum average water absorption of 6% and 1% for types H and L* respectively;[3] (d) a weight loss in sulphuric acid not greater than 20% for type H and 8% for type L respectively. The degree of acid-resistance is largely governed by the water absorption and the extent of vitrification.[4]

The essential raw materials namely siliceous clay, feldspar and quartz are abundantly available in the country. This investigation was, therefore, undertaken with a view to developing and exploiting the indigenous sources.

Materials and Methods

Fire clay (–150 B.S. mesh) from Musakhel (District Mianwali), feldspar and quartz (–200 B.S. mesh) from District Hazara were used in this investigation. These materials have already been described[5,6] and their chemical composition is given in Table 1.

Weighed quantities of the ingredients were thoroughly mixed and bricks of size $2\frac{1}{2}$in. × 2in. × $1\frac{1}{2}$in. were prepared by the semi-dry process in a mechanical press. The bricks were first air-dried and then fired at different temperatures. The rate of heating in each case was 150°C/hr.

*Type H is intended for use where thermal shock is a service factor and type L is intended for use where minimum absorption is required and thermal shock is not a service factor.

Table 1.—Chemical Analysis of the Raw Materials.

	Clay (Mianwali)	Quartz (Abbot-abad)	Feldspar (Abbot-abad)
Ignition loss	7.4	0.21	0.15
SiO_2	66.4	97.13	66.69
Al_2O_3	21.19	1.395	17.57
Fe_2O_3	0.81	0.035	0.21
CaO	Traces	0.88	1.24
MgO	Nil	0.35	—
Alkalies	—	—	13.93

Fired linear shrinkage at different temperatures was determined by the usual method of measuring the difference of shrinkage marks after firing.

Bulk density, water absorption and acid resistance were determined by ASTM methods.[7,8] Cold crushing strength of the bricks was determined on a Universal Testing Machine "Avery" Model 7110 with 50 tons load capacity.

Results and Discussion

A preliminary study was first made on five compositions S1 to S5 (Table 2) containing 40–60% clay and 15–35% feldspar, quartz being constant at 25%. This work indicated that the bricks fired below 1200°C did not possess any satisfactory property and in particular, the crushing strength was too low. Further work was, therefore, confined to working temperatures of 1200°C and above and the composition range was extended to include sample S6, S7 and S8 (Table 2).

Examination results obtained on firing at 1200°C for 1 hr (Table 2), it may be seen that in samples S2 to S6 the bulk density increases with a decrease in feldspar content and a complementary increase in clay content. Crushing strength also follows the same pattern. These results are contrary to expectations in view of the fact that with

TABLE 2

Sample	Composition (%)			Soaking time (hr)	Firing shrinkage (%)		Bulk density (g/cm3)		Water absorption (%)		Crushing strength (lb/ in.^{2})		Acid resistance (%)
	Clay	Quartz	Feldspar		1200°C	1250°C	1200°C	1250°C	1200°C	1250°C	1200°C	1250°C	1250°C
S1	40	25	35	1	—	6.8	2.05	2.19	2.50	0.17	5600	23600*	99.34
				2	6.2	7.4	2.17	2.20	0.84	0.18	8190	9730	99.50
S2	45	25	30	1	—	6.9	2.00	2.02	3.08	0.34	6400	23600*	99.21
				2	6.2	7.4	2.00	2.30	1.10	0.25	8641	19000	99.32
S3	50	25	25	1	—	6.2	2.01	2.04	2.54	0.29	8000	23600*	99.36
				2	4.9	7.0	2.03	2.26	1.37	0.30	9900	11264	99.65
S4	55	25	20	1	—	6.2	2.14	2.29	4.26	0.17	9083	23600*	99.34
				2	4.9	7.2	2.22	2.38	1.88	0.15	10240	23600*	99.48
S5	60	25	15	1	—	6.0	2.20	2.30	5.27	0.40	11000	23600*	99.48
				2	5.6	6.2	2.24	2.33	1.53	0.24	23400	23600*	99.58
S6	40	35	25	1	—	5.4	2.19	2.30	5.27	0.40	14784	23600*	99.78
				2	4.5	6.1	2.25	2.30	4.44	0.32	11872	9250	99.50
S7	55	20	25	1	—	6.8	—	2.16	—	0.33	—	23600*	101.70
				2	5.6	6.9	2.14	2.36	1.04	0.29	10180	11200	100.50
S8	60	15	25	1	—	6.2	—	2.12	—	0.28	—	23600*	99.80
				2	4.9	7.0	2.10	2.32	2.36	0.32	8800	23600*	99.00

*The brick did not break at this pressure.

the increase of feldspar in clay-quartz felspar mixture, the amount of liquid formed at the eutectic temperature increases as a result of which greater vitrification takes place at lower temperatures.[9] It is, however, known that the rate of sintering and consequent densification is increased with an increase of finer particle sizes.[10,11] The above-mentioned increase in bulk density and crushing strength are, therefore, presumably due to the increase in the clay content which enhances densification due to a large proportion of finer particles.

Since only composition S5 and S6 gave satisfactory crushing strength when fired at 1200°C for 1 hr the soaking period was increased to 2 hr (Table 2). There is a marked decrease in water absorption and increase in crushing strength (except in the case of S6) with a maximum of 23400 lb/in.^{2} in the case of composition S5. In compositions S1 to S5 crushing strength increases with increasing clay content.

The crushing strength of the test pieces fired at 1250°C for 1 hr (Table 2) showed a remarkable increase and none of these could be broken at a pressure of 23600 lb/in^2. The water absorption also ranges between 0.17 to 0.40% and bulk density between 2.02 to 2.30. Firing shrinkage is between 5.4 to 6.9% and is well within the acceptable limit. The acid resistance of these test pieces is above 99% excepting for composition S6 (98.78%). Composition S7 shows a slight increase in weight when exposed to acid presumably due to some acid being entrapped in the pores.

Searle[2] mentions that the usual composition range for acid proof bricks is clay 45–55%, feldspar 22–28% and flint or sand 22–28%. Although bricks in this range give satisfactory results, equally good samples have also been prepared by extending this range to clay 40–60%, quartz 15–35% and felspar 15–35%. It thus appears that besides composition physical characteristics and firing conditions play an important role. In cases where clay content has been increased at the expense of quartz, the free silica content of the clay appears to have taken over the role of quartz. In other cases where feldspar has been dispensed with in view of higher clay content the additional amount of fine clay particles have possibly produced a more compact and impervious body with equally good acid resistance. This view is strengthened by considering the results of the firing at 1250°C for 2 hr for compositions S4, S5 and S8 with clay contents of 55, 60 and 60% respectively. No deterioration in any of the desirable properties particularly crushing strength and acid resistance takes place. Even in the case of composition S7 containing 55% clay the firing at 1250°C for 2 hr does not reduce the crushing strength below the acceptable limit and there is little effect on its acid resistance. There is a strong indication that higher clay contents should be preferred as these result in a larger working range.

Table 2 shows the result obtained at 1250°C when the soaking period is increased to 2 hr. As expected the firing shrinkage increases as also the bulk density. The water absorption is much the same as in the firing of 1250°C for 1 hr. Acid resistance also shows a slight increase for compositions S1 to S6. The most remarkable change is the decrease in crushing strength in fired samples (S1, S2, S3, S6 and S7). However, the strength, with the exception of compositions S1 and S6, remains above the minium acceptable limit.

Samples 1,2,3,6 and 7 were examined in order to determine the cause of loss of strength. These samples were found to be bloated and rough in comparison with samples fired at 1250°C for 1 hr which had smooth surfaces. On micrographic examination most of the bloated samples were found to contain pin holes in various stages of formation. Although these pin-holes make a definite contribution to the water absorption of the samples, they do not contribute to any appreciable increase in water absorption as most of them exist in the main bulk of the sample and remain closed. Bloating and consequent loss in crushing strength, however, makes it inadvisible to employ soaking time of more than 1 hr at 1250°C. The causes of bloating will be discussed in a separate communication.

TABLE 3

	Imported brick	Prepared brick (S4)
Ignition loss	0.21	0.42
SiO_2	76.89	78.93
Al_2O_3	17.825	16.4
Fe_2O_3	0.675	0.475
CaO	Nil	0.51
MgO	0.805	Traces
Na_2O	1.488	3.265
K_2O	2.115	(by diff.)
Bulk density g/cm^3	2.2	2.29
Water absorption %	0.6	0.17
Acid resistance %	99.18	99.34

An imported acid-resistant brick presently being used in industry was also tested for its properties and chemical analysis are compared with those of composition 4 (Table 3) which may be regarded as a typical composition of this study. Although there is no appreciable difference in the silica and alumina contents of the two samples and also in the total flux content, the CaO content of S4 can be the only probable reason for higher acid resistance. This influence may, however, be negligible in view of the high porosity and water absorption of the imported sample.

Conclusions

Satisfactory acid-resistant bricks can be made in the composition range, clay 40–60%, quartz 15–35% and feldspar 15–35%. Fired bricks possess properties far superior to the minimum standard specifications and are considered suitable for use as Type L as such, and as Type H after the creation of porosity.

Physical characteristics and firing conditions play an important role in determining the final properties of the product. Best results were obtained at 1250°C when fired for 1 to 2 hr.

A high feldspar or clay content produces similar increase in bulk density and crushing strength.

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