CHAPTER II

BACKGROUND INFORMATION

History of Fireclay

Ceramics is a science which refers to the manufacture of products from earth material by the application of high temperature.

The history of ceramics goes back to prehistoric times, when man learned to make the use of fire. He apparently learned that heat would fix the shape of earth materials and would tend to make them stable in the presence of water. Crude pottery was made as early as 700 B.C., while glazed pottery dates back to 5000 B.C. Early producers of fired earthenware, learnt their art by experience. They experienced that all the earth materials or clays did not have the same properties and only certain clays were usable.

As the clay particles are very very small, their exact nature could not be studied with the analytical tools available then. Before 1920, the studies on clay were carried out by means of chemical method only, which was not very satisfactory because clays of different chemical compositions were having similar ceramic properties and vice versa.

Vogt (1906) studie~~s~~d the composition of clay minerals and identified kaolinite in the clay used as refractory material.

Thiebaut (1925) concluded that the refractory clay contains kaolinite and is not a marine deposit. In fact, kaolinite was the only known and well defined clay mineral because of its presence in the ceramic and refractory earths.

Studies on clays by chemical methods alone, resulted in making distinctions between the constituents of different facies thus inducing studies on the genesis of clays.

Ross and Kerr (1931a, 1931b, 1934) critically studie~~s~~d kaolinite group and proved that its SiO_2/Al_2O_3 ratio was nearly equal to two. Grim, Bray and Brindley (1937) confirmed that refractory argillaceous rocks, used in ceramics, were essentially kaolinitic in nature.

In early 1920 the development of X-ray diffraction, electron microscopy infra-red adsorption and differential thermal analysis helped, ceramist for the first time with adequate analytical tools to determine the precise nature of the raw materials.

Termier (1890) was the first to describe leverrierite from black carbonaceous shales near St. Etienne, France. It was named after the mining engineer Le Vertier. Dana (1892) recognized the similarity of leverrierite with kaolinite, as did Cayeux (1916). Ross and Kerr (1931) studied the original type material and concluded that it was kaolinite. De Lapparent in 1934, restudied more of the type material and found a mixture of alternating plates of kaolinite and muscovite. There seems to be no doubt, that the name leverrierite should be discarded.

At the London Congress in 1948 several names for these minerals were proposed, such as "Mellorite " by Brindley, for the less well crystallized material, thinking that there was a specific degree of such disorder. Grimshaw and Roberts (1958) proposed "Livesite". According to some authors, the degree of disorder is too variable and that a group name is preferable. Most of the authors have accepted "fireclay minerals" or "fireclays", but Brindley (1961) has suggested the use of the terminology "disordered kaolinites". Zvyagin (1962) and Brindley (1963) have investigated in detail the various possible polymorphic forms of the kaolinite minerals and qualifying symbols, for example 1 Tc, D, 2 Mz have been suggested to designate the forms.

Kaolinite from fireclays is composed of layers of kaolinite type but the staking of the layers is disordered due to shift of layers parallel to the b-axis.

The structure of kaolinite was first suggested by Pauling (1930). Some detailed work was done by Gruner (1932) and later it was revised by Brindley and his colleagues (1946, 1951). More recently, the structure of kaolinite group has been studied in detail by Brindley and Nakahira (1958), Zvyagin (1960), Drits and Kashaev (1960), Newnham (1961), Radoslovich (1963) and Bailey (1963).

J. De Lapparent (1937a, 1937b), at the Second World Petroleum Congress, has summarised that kaolinite deposits have accumulated in sedimentary basins close to the region in which tropical climate and vigorous vegetation favoured formation of kaolinite during the weathering processes.

Ross (1945) emphasized the role played by base. From the geological point of view, kaolinite is formed in acid environment under the influence of either humic acid or the oxidation of sulfides, but it can also result from strong leaching.

Keller and Pickett (1949, 1950) are among the pioneer workers, who used infra-red spectra on clays. The text of Barnes et al (1944) and Herzberg (1950) is also interesting for clay geologists. Number of workers have recently used this technique extensively on clays.

Faust (1940) investigated the history of staining techniques in general and summarized much of the early work. Behrens (1871) was the first to apply staining methods to clay minerals. A large number of reagents have been suggested and tried for staining tests of clay minerals. The reaction and resulting color change are slight or absent for kaolinite, which has low adsorption capacity.

The technique of differential thermal analysis was used in the study of clay minerals by Spiel et al (1945), Kerr and Kulp (1948), Arens (1951), Boersma (1955), Decg (1956) etc. Among the recent workers, Mackenzie (1957), Evans et al (1958), Grim, R.E. (1947), Allison (1955), Kacker et al (1964) and number of other workers have done extensive work on clays. F.H. Norton (1939) is one of the pioneer workers who used D.T.A. techniques to identify clay minerals and phases.

Thermo gravimetric analysis was used Keller (1955), Torker et al (1962) and Hodgson (1963). Kloss (1974) published a text on "Differential Thermal Analysis, Application and Results in Mineralogy", in which he has given method of finding out disorder in kaolinite using differential thermal analysis.

Bragg (1933, 1937), Buerger (1942), James (1948), Wilson (1949), Bragg et al (1944) etc. are the workers who used X-ray methods in general. Brindley (1961) discussed experimental methods used in clay mineralogy. Brindley, grim and Clerk (1937) described a method of forming well oriented clay sample.

Electron microscopy was applied to study clay minerals by Ardenne (1940), Eitel (1940), Middel (1940), Humbert (1941), Shaw (1942), Marshall (1942), Alexander (1943), Moore (1947) and their various collaborators. Replica technique was initially adapted for the study of clay surfaces by Bates and Comer (1955) and has since been used by many others. Recently Electron Diffraction Techniques are used to study clay minerals. Extensive study in this direction was done by Zyvagin (1955, 56, 57, 58 to 1962) who also prepared a valuable text.

In recent years, advanced X-ray techniques, Transmission electron microscopy, scanning electron microscopy, electron diffraction, differential thermal analysis, thermal gravimetric analysis and detailed chemical work has thrown more light on the structure, characteristics, and genesis of clays. These modern techniques are used by the clay based industries to control the qualities of their raw material.

Origin, Occurrence and Composition of Major Fireclay Deposits of India.

Fireclay is generally found as bedded deposits in the coal measures. Fireclays in India may be either aluminous or siliceous. Usually they burn buff. The aluminous variety burns dense and is more refractory while siliceous one is an open firing clay. The color of fireclays when raw is usually greyish, bluish or blackish. Fireclays are plastic and are harder than China clays, their hardness being 5. Specific gravity varies from

2.6 to 2.75. They are usually fissible, practically non-magnetic and have a low electrical conductivity. A good fireclay must be plastic and must not fuse below 1600°C in oxidising atmosphere. Indian fireclays contain an appreciable quantity of organic matter which keeps the atmosphere enveloping the clay more or less reducing until the organic matter is burnt off.

Most of the Indian fireclays are of drift origin. Some in situ (residual) fireclays are also found in Jabalpur district, M.P. Strictly speaking, fireclay is of sedimentary origin and is commonly found as bedded deposits in the coal measures.

The best fireclay deposits are found in the coal measures of Assam, Bengal, Bihar, Orissa, M.P., A.P. Gujarat. Most important fireclay deposits occur associated with coal seams of Jharia and Raniganj coal fields in Bihar and West Bengal and Korba coal fields of Madhya Pradesh and lignite field of South Arcot district of Tamilnadu. In Gujarat, fireclay occurs intercalated with Dhrangadhra sandstone of Jurassic age. Besides these, important refractory fireclays are also reported from Orissa, Rajasthan, Tripura and Maharashtra States.

TABLE II.1

Fireclay - Annual Production (India)

Year	Production		Number of Mines
	Quantity (tonnes)	Value (Rs.'000)	
1969	598,957	4,217	
1970	611,242	4,484	140
1971	611,724	5,482	149
1972	732,732	6,753	174
1973	717,753	7,040	181
1974	802,000	10,236	185
1975	672,000	9,669	188
1976	617,000	9,303	195
1977 (Upto Aug.)	386,431	5,343	

(Mineral Year Book and Mineral Statistics of India.)

TABLE II.2

Fireclay - Export Data

Y e a r	Quantity (Tonnes)	Value (Rs. '000)
1969	49	11
1970	10	2
1971	2	-
1972	58	24
1973	2,297	298
1974	142	74
1975	941	160
1976	266	145

TABLE II.3

Fireclay - Import Data

Year	Quantity (Tonnes)	Value (Rs.'000)
1969	23	75
1970	4	23
1971	-	2
1972	1	7
1973	5	16
1974	12	50
1975	NA	NA
1976	186	760

B I H A R

It is the largest producer of fireclay in India. The total inferred reserves of fireclay are about 316 million tonnes, out of which Bihar reserves are 30.04 m.t. Fireclay deposits of Jharia and Raniganj coal fields of Bihar and West Bengal are extensively worked out.

In Palamau district, deposits of fireclay occur at Rajhara in the Daltonganj coal field. It is a good plastic fireclay useful for mixing with harder clays from the Raniganj coal field. Good fireclay also occurs near Tupu Kalan and Mungor in Latehar sub-division of Palamau district. In Manbhum district, fireclays occur in association with the coal seams of the Jharia and Raniganj coal fields. The best clays occur in the Barakar series. In the Jharia coal field the clays occur close to the edge of the coal field in Jharia, Pathardih, and Tisra areas. In the Bihar portion of Raniganj coal field, fireclays occur near Damodar and Barakar rivers. Similar to Raniganj, fireclay occurs south of Rujabasa. In Bhagalpore ~~district~~ and Santal Parganas district fireclay beds occur in the rocks of Damuda age in coal fields lying towards the western side of Rajmahal hills. They all dip at low angle due east and average three feet in thickness.

Burn and Co. Ltd., Bengal, Bihar Brick and Pottery Works (P) Ltd., Bihar Firebricks and Potteries Ltd. and Kumardhubi Fireclay and Silica Works Ltd. are the chief manufacturers of firebricks in Bihar.

GUJARAT

It was the largest producer of fireclay in the year 1970 accounting for 187,000 tonnes i.e. 31 percent of the total output. Since then, it remains second in production. The fall in production during 1972 and 1973 was mainly due to the removal of over-burden and less off take from some of the captive mines. Out of 125 mines in India; Gujarat has 66 open cast mines. Surendranagar district with 29 open cast mines, gives the highest production. There are 22 open cast mines in Rajkot district, 4 in Balsar, 4 in Sabarkantha, 2 in Panchmahals, 2 in Surat, 2 in Mehsana and 1 in Kutch district. In Surendranagar and Rajkot districts, fireclay occurs in Dhrangadhra Formation near Than, Palasa, Sudala, Velala, Vagodia, Matel, Jambudia and Makansar.

The Parshuram Pottery Works of Morvi, Wankaner and Than use fireclay for the manufacture of drainage pipe, sanitary wares, tiles, firebricks, pottery and stove nozzles. Other pottery and ceramic works using fireclay from Surendranagar and Rajkot districts are at Surendranagar, Rajkot, Chotila and Vagadia. In Mehsana and Sabarkantha districts the sedimentary formations of Himmatnagar series contain intercalations of fireclay. The more important of these occurrences are on the banks of the Sabarmati and Hathmati rivers near Pedhamli and Derol.

A reserve of one lakh tonnes of clay has been estimated at Derol, where the clay beds are 3.5 m thick. In Panchmahals district occurrence of a 1.2 m thick bed of fireclay is associated with Intra-trappean sandstones of Rajpura. The fireclay bed is approximately 400 meter in length. Another deposit is reported near Bulatia. Reserves of fireclay in Gujarat State is estimated at 0.98 m.t.

O R I S S A

In Gangpur State fireclays occur in variegated colors and burn buff and bluish grey and withstand to

1400°C. In Sambalpur district, fireclay occurs at Jorabaga, Darlipali, Rampur, Bundia, Katabaga, Kudopali, Chualiberma and Talabira. These clays are hard, plastic and refractory. In Cuttack district, beds of good fireclay varying from 0.1 m to 2.5 m thickness occur along with coal seams near Patrapara. The clay is usually hard, fine and plastic and does not fuse upto 1400°C.

Orissa stands third in the production of fireclay with usually 14 to 18 percent of the total production of India. Reserves of fireclay in Orissa, is about 59.34 m.t.

MADHYA PRADESH

Good quality fireclay has been located in the rocks of Jabalpur stage of the Gondwana formation. The localities are Dubar and Piparia in Jabalpur district. Fireclays are highly plastic and refractory. There are two varieties, grey and whitish. Both the fireclays are useful for the manufacture of refractories. In Narsinghpur district, fireclays in the same formation have been reported at Salichauka reserved forest south of Manegaon, Saoneri, Badhai reserved forest, valleys of Sukker and between Kodali and Saoneri and at Bijori near Sukhadongar. The Salichauka fireclay is better than the Soaneri fireclay in possessing better plasticity, and not showing sign of fusion at 1,250°C. These fireclays are suitable for the manufacture of refractory bricks. In Chhindwara district, fireclay occurs in Jubbulpore stage. Near Muria thickness of fireclay bed is about 20 ft. Fireclay is fine grained, highly refractory in character and burns buff. In Raipur district, a low grade variety of fireclay occurs at Murkatola in association with Chandrapur sandstone. Fireclay occurs in the Bisrampur coal field in Surguja district. The thickness of the bed ranges from 30 cm to 3 m. Fireclay has also been reported from near Chendra in Bansar coal field. Fireclay occuring in Durg district is used for firebricks used in Bhilai Steel Plant. Reserves of fireclay in Madhya Pradesh is confined to Narsinghpur, Shahdol, Raipur, Jabalpur, Chhindwara, Hoshingpur, Betul and Bilaspur districts. Madhya Pradesh has large researves of fireclays.

Classification of Fireclays

Klinefelter and Hamlin (1957) list the following commercial classes of Fireclays based on relative plasticity and hardness which give good indications of relative refractoriness.

1. Plastic
2. Semiflint
3. Flint
4. Nodular flint

<u>Plastic Fireclay</u> : It resembles ball clay. The main use of plastic fireclay is as bond clay in making saggers, glass pots, crucibles, mortars, refractory cement etc. Alumina content in plastic fireclay is 25 to 30 percent. On firing, plastic fireclays show more decrease in porosity and greater increase in shrinkage as compared to flint clays. Plastic fireclays soften at pyrometric cones 26 to 30.

<u>Semiflint and flint Fireclay</u> : Non-plastic fireclay is often classed as flint clay. It is hard and dense, has a waxy luster and breaks with a concoidal (flinty) fracture. Clay which is flint like in character but develops some plasticity when ground finely and mixed with water is called semiflint fireclay. Clay whose properties are intermediate between semiflint and plastic clay is called semiplastic.

The flint fireclay is the most refractory and so the most valuable of all clays for the refractory manufacturer. Most flint clays soften at pyrometric cones 35 to 36, but some soften at cones 37 to 38. The semiflint usually soften at pyrometric cones 30 to 35. Fine grinding of flint fireclay increase the plasticity. On firing, flint fireclay shows small changes in porosity and volume shrinkage, which are of the order of about five percent. Vitrification is also very gradual. High alumina clay shows a gradual increase in shrinkage and requires a long baking at high temperature for eliminating shrinkage.

Nodular flint clay : It is a sub-division of the flint clay. It is essentially a flint clay which is somewhat harder and more refractory than pure flint flay, due to presence of nodules of gibbsite or other hydrous aluminium oxides. There is however, no sharp division between these classes.

The classification of fireclay is a matter of individual judgement. It is not difficult to distinguish between flint and plastic fireclay but it will be very difficult to place a dividing line between flint and semiflint, semiplastic and plastic fireclay. It is not uncommon to find all four varieties in a single bed of a few feet thick deposit. The strata may vary from top to bottom grading from a flint or semiflint clay to a plastic clay.

Fireclays are also grouped as

Siliceous

Kaolinitic and

Aluminous

This classification depends upon the proportions of alumina and silica present in the clays. Pure flint fireclay approaches the composition of the mineral Kaolinite (Al_2O_3 $2SiO_2$ $2H_2O$). All Kaolinite clays are of this composition. When silica content exceeds 70% fireclay contains excess silica usually in the form of finely divided quartz. These clays are called siliceous clays. Aluminous clay is that which contains alumina in excess of the ratio of Al_2O_3: SiO_2. The excess alumina is present as inclusions of small crystals of either gibbsite (Al_2O_3 $3H_2O$) or diaspore Al_2O_3 H_2O.

TABLE II.4

Classification of Fireclays according to their fusibility.

(ASTM :C 27 - 1958)

Class	Temperature of Fusion (P.C.E.) Orton Cone	Temperature of Fusion (°C)
1 High Refractory Clay	33	1949
2 Refractory Clay	31-33	1680-1740
3 Semi-Refractory Clay	27-30	1640-1665
4 Clay of Low Refractoriness	20-26	1565-1621

Purdy and Moore (1936) classified clays according to changes in porosity and specific gravity at different temperatures.

No.1. Fireclays show a small but regular decrease in porosity from the beginning of firing to above cone 11.

No.2. Fireclays show increase in loss of porosity with consequent early vitrification, the change beginning at about cone 02 and becoming marked with increasing temperature.

No. 3. Fireclay show a marked change with increasing porosity at cone 4 and seldom have a fusion point above cone 16.

Another practical classification of fireclays given Mathews (1949) is based on the following results.

"<u>Incipient Vitrification</u>":-

1. Some of the constituents, which fuse to a glass and cement the more refractory grains together.

"<u>Complete Vitrification</u>":-

2. Sufficient fusion closing all the pores and developing maximum shrinkage.

"<u>Viscosity</u>" :-

3. Much fusion of the body so that it is no longer self supporting.

Mathews grouped the clays as follows :

a) Clays for which the interval between incipient and complete vitrification is more than that between complete vitrification and viscosity.

b) Those for which the range is approximately half of the total range from incipient fusion to viscosity.

c) Those for which the range from incipient to complete vitrification is less than that from vitrification to viscosity.

INDUSTRIAL APPLICATIONS

Refractories

Fireclay refractory bricks are most commonly used in all places of heat generation, especially in boiler furnaces, glass melting furnaces, chimney linings, pottery kilns and most extensively in blast furnaces, and reheating furnaces. It is estimated that 85% of the refractories manufactured and consumed in India are of fireclay. Most of the fireclay bricks used are either high duty or super duty containing excess of alumina. A wide range of fireclay refractories are manufactured depending upon the alumina content, which may vary from 30% to 70%.

In blast furnaces, the lining is done almost entirely with fireclay bricks. Pouring refractories like sleeves, nozzles, stoppers and tuyers are made of fireclay. There are over 55 units manufacturing fireclay bricks in the country making all types and shapes of bricks to suit different purposes.

During 1975, 55 units were engaged in the production of fire bricks and high alumina bricks with a total installed capacity of 861,500 tonnes. The production of fire bricks and high alumina bricks during the year 1975, was 409,174 tonnes.

Iron and steel industry is the major consumer of fireclay - refractories, which consumes 70 - 75% of the total refractories manufactured. The upcoming capacity for fireclay refractories in respect to some of the more important scheme is given below :

	Tonnes
1. Bhilai Refractory Plant	60,000
2. Tamil Nadu Industrial Development Corporation Ltd.	40,000
3. U.P. State Industrial Development Corporation Ltd.	40,000
4. D. C. M. Ltd.	30,000
5. Vidarbha Development Corporation Ltd.	21,000

Regular consumption of refractories in the steel industry includes periodic replacing of laddle bricks, relining of open hearth furnaces and convertors, hot rèpairs etc. Relining of blast furnaces is normally done once in 5 years and rebuilding of coke oven batteries is done once in 15 years.

Considering the existing level of steel manufacture in the country as also the projected expansions of Bhilai and Bokaro steel plants as well as coming into being of the new envisaged plant at Salem, Visakhapatnam and Hospet, a production level of 12.57 million tonnes and 24.25 million tonnes of steel was anticipated by 1975 and 1980 respectively by the raw materials sub-committee of Ministry of Steel and Mines. Requirements of fireclay refractories alone, in the iron and steel manufacture, were anticipated to be, around 502,000 and 941,000 tonnes by the end of 1975 and 1980 respectively as against the existing requirement of 385,000 tonnes. Considering the requirements of other non-users of fireclay refractories the consolidated requirements of these refractories at the end of 1975 and 1980, are placed at 630,000 and 1,180,000 tonnes respectively. However, the steering group on metallurgical industries has subsequently scaled down the targets of production of steel ingots to 9.81 m.t. and 15.12 m.t. by 1975-76 and 1980-81 respectively. The requirements of fireclay refractories therefore will be proportionately lesser than the quantities anticipated by the raw materials sub-committee.

The demand picture of fireclay refractories indicate that half million tonnes mark was reached early in 1975 and one million tonnes mark will reach by 1980. However, the envisaged availability of fireclay refractories indicates quite a dismal position. A short surplus of about 25,000 tonnes was estimated for 1973. Subsequently, the gap between the demand and availability would continuously widen since the capacity would stagnate at around 661,000 tonnes from 1977 onwards.

The following industries depend upon fireclay refractories :

1. Iron and Steel
2. Non-Ferrous Metals
3. Glass
4. Gas

5. Steam Power
6. Ceramics
7. Gasturbine and Jet Propulsion
8. Nuclear Power
9. Cement and Lime Manufacturer
10. Incinarators
11. Paper Mills
12. Enamelling
13. Domestic Heating

A large number of major industries are dependent on a process using heat and are therefore dependent on heat resisting structure. Refractories are of major importance to them. Technical advances are frequently influenced by the availability of better refractories.

Refractories prepared from fireclay are fireclay bricks, Aluminia-Diaspore bricks, Semisilica fireclay bricks, Insulating fire bricks, Pouring pit refractories, Refractory mortars, Ramming mixtures, Plastic fire bricks and castables.

A. Fireclay Bricks

Fireclay bricks (9" x 4½" x 2½") are the standard material of construction for all kilns and furnaces.

The general structure is built of these bricks and the various shapes includes arches, wedges, keys, skews, jams and various patented designs are used when needed. The chemical and physical properties of fireclay vary between wide limits and hence, fireclay bricks with widely varying combinations of properties are available. This fact accounts for their suitability for service under widely different operating conditions.

I. <u>Super Heat Duty Fireclay Bricks</u> : Conform to Pyrometric cone equivalent (P.C.E.) not lower than cone 33 on the fired product, not more than 1% linear shrinkage in the permanent linear change test schedule (1600°C, 2910°F) and not more than 4% linear shrinkage in the panel spalling test (Preheated at 1650°C, 3000°F). They show the following characteristics : Stability of volume at high temperature, excellent resistance to thermal spalling, fair resistance to highly acid slags and somewhat lower resistance to basic slags.

II. <u>High Heat Duty Fireclay Bricks</u> : Conform to only one of the following requirements; P.C.E. not lower than cone 31-32 or not more than 15% deformation in the 1350°C (2480°F) load test. They show the following characteristics : Relatively high spalling resistance and thermal insulation value, fair resistance to acid slags and fluxes, and relatively lower resistance to basic slags and fluxes.

III. Intermediate Heat Duty Fireclay Bricks : Conform to only one of the following requirements; P.C.E. not lower than cone 29 or not more than 3% deformation in the 1350°C (2460°F) load test, modulus of rupture not less than 500 Psi.

IV. Low Heat Duty Fireclay Bricks : Conform to P.C.E. not lower than cone 19 and modulus of rupture not less than 600 Psi.

V. Alumina - Diaspore Fireclay Bricks : The following classes of Alumina-Diaspore bricks are not sharply defined because the fireclays from which they are made, differ only in the amount of impurities that they contain. All clays are essentially kaolinite (Al_2O_3 $2H_2O$) with a certain amount of impurities. Although it is theoretically possible to have a fireclay with a P.C.E. 35, this is never attained in commercial fire bricks because of the ever present impurities. A fireclay with a P.C.E. 34 is about the best obtainable.

(a) <u>50% Alumina-Diaspore Fireclay Bricks</u> have diaspore or nodular fireclay as an essential original ingradient, alumina content 50 $\pm$ 25% and P.C.E. not lower than 34.

(b) <u>60% Alumina-Diaspore Fireclay Bricks</u> have diaspore or nodular fireclay as an essential original ingradient, alumina content 60 $\pm$ 25% and a P.C.E. not lower than cone 35.

(c) <u>70% Alumina-Diaspore Fireclay Bricks</u> have diaspore as an essential original ingradient, alumina content of 70 $\pm$ 25% and P.C.E. not lower than cone 36.

(d) <u>80% Alumina-Diaspore Fireclay Bricks</u> have diaspore as an essential original ingradient, alumina content of 80 $\pm$ 25% and P.C.E. not lower than cone 37.

VI. <u>Semi-silica Fireclay</u> : are characterised by, rigidity under load at high temperatures; resistance to structural spalling; volume stability; resistance to penetration and attack by alkalies, and high temperature of incipient vitrification.

VII. <u>Insulating Fire Bricks</u> : retard the flow of heat through furnace walls and thereby promote the thermal efficiency of furnaces. These bricks can be heated and cooled quickly and their capacity for the storage of heat is low. Through the use of insulating fire bricks in place of the heavier fireclay bricks, the time required for heating or cooling a furnace is greatly shortened.

TABLE II. 5

Grouping of Insulating Fire Bricks
(ASTM Classification, Designation: 115-57)

Group Identification	Linear Reheat Change Not More than 2% When Tested At	Bulk Density Not Greater Than
Group		
16	1550°F (845°C)	34 lb per cubic feet
20	1950°F (1065°C)	40 " " " "
23	2250°F (1230°C)	48 " " " "
26	2550°F (1400°C)	52 " " " "
28	2750°F (1510°C)	60 " " " "
30	Not included in ASTM	

The group identification number multiplied by 100 gives ultimate temperature in degree Fahrenheit to which the brick may be exposed to service.

B. Pouring Pit Refractories

It includes ladle bricks, hot tops, nozzles, sleeves, stopper, runner bricks and certain other shapes required in transferring molten steel from the furnace to the ingot molds. All of these bricks are made of fireclay except the stopper heads, which generally consist of clay graphite compositions. In general these materials are made from plastic clays uniquely suited for these services but having refractoriness value in lower ranges.

C. Refractory Mortars

Refractory mortars are of two types : (a) Hot setting and (b) Cold setting.

(a) Hot Setting : It has only moderate cold strength. For its ultimate bonding strength, it depends upon a ceramic bond formed at high temperature. Such mortar generally consists of finely ground crude and calcined refractory materials, similar in composition and properties to the brick with which they are to be used. The temperature range of maximum bonding strength usually is somewhere between 2200 to 2600°F.

(b) Cold Setting : It is also called high temperature cement containing bonding agents which impart a rigid set merely upon drying. Upon firing, the strength of the initial bond decreases, while a strong ceramic bond develops. Among the various cold setting mortars, there is a wide range in chemical composition and refractoriness.

D. Ramming Mixture

It consists essentially of ground and sized refractory materials, usually with minor amounts of other materials added to make the mixture workable and self bonding. The base materials of these compositions include silica, fireclay, high alumina minerals, magnesite, chrome, silicon carbide, zircon and others.

Some ramming mixtures are supplied in plastic or ready to apply and others in dry state are prepared for use by mixing the proper amount of water. When rammed into place, they harden upon drying and heating to form dense, well bonded, monolithic refractories.

E. Plastic Fire Bricks

These are shipped in stiffly plastic condition. Various grades are supplied commercially. Some consists of mixtures of fireclays or of fireclay and high alumina minerals. Most plastic fire bricks are hot setting, a few are cold setting, some are of high duty fireclay quality, others of super duty quality. For use, plastic fire bricks are rammed into place to form monolith furnace linings.

F. Castable Refractories

Are supplied in dry form, consisting of ground refractory materials containing added bonding agents. For use, they are mixed with water and cast into place in the same way as ordinary concrete. They develop a strong hydraulic set at room temperature and a strong ceramic bond at high temperatures. The base material or aggregate may be calcined refractory clay and high alumina materials. Alumina silica castables are supplied in five standard grades for use at temperatures varying from 2300°F to 3100°F. Insulating castables are supplied in four standard types, suitable for use at temperatures from 1700°F to 2300°F.

Ceramic Industry

Fireclay, an important component of ceramic industry, is second only to china clay.

There are five broad categories of ceramic products in the country. They are as follows :

1. Porcelain insulators
2. Crockery
3. Structural Clay Products
4. Sanitary wares
5. Stonewares

1. Procelain Insulators : Porcelains of special composition are designed to give high electrical resistance and mechanical strength. Raw materials

used are synthetic mixture of felspar, low grade fireclay and other fluxes.

2. Crockery : The better grade production is made from fireclay that is atleast of semi-refractory nature and of dense burning character. Fireclay used in this industry should have good plastic properties, high strength and low shrinkage. When the body is made from a slip, it must have certain properties of viscosity and thixotropy. Usually low grade fireclay with 25 to 50% calcined material is used as raw materials.

3. Structural Clay Products : Structural clay product is a broad category that includes drain tile, sewer pipe, conduit tiles, glazed tiles, terra cotta etc. Properties of fireclay that are important in the manufacture of structural clay products are plasticity, green strength, dry strength, drying and firing shrinkage, vitrification range and fired color. Low grade fireclay is used for the manufacture of sewer pipe. It becomes dark reddish brown after firing. Salt is used for manufacturing special rectangular shapes

for underground wiring and roofing tiles. Mixtures of low grade fireclay with 20 to 50% calcined material is used for manufacturing terra cotta.

4. Sanitarywares : Low grade fireclays with 25 to 50% calcined material (a mixture of buff burning grogged bodies) is used as raw material. Sanitarywares are glazed with white opaque enamels.

5. Stonewares : The better grade products are made from fireclays that are atleast of semi-refractory nature and of dense burning character. Fireclays used in this industry should have good plastic properties, high strength, and low shrinkage.

Cement Industry :

In the cement industry fireclays are used as raw materials along with gypsum. The fireclays for this application are used as a source of silica in the portland cement clinker which is mainly a calcium silicate and calcium aluminate. The material is required to be pure, somewhat high in silica content and fine grained for ease of mixing with gypsum or limestone.

Foundry Industry :

Fireclay is used in foundries to bind sands into desired shapes in which metals can be cast. Fireclays used in foundries are composed mainly of the clay minerals, kaolinite and illite. The quantity of fireclay used is approximately two to three times that of bentonite to equal its strength qualities. Sands bonded by fireclays give the metal a smoother surface than those bonded by bentonite. Fireclays are used only when the cost of mining and transportation are low.

Mineral Filler :

Fireclay is used as fillers and pigments in paint, linoleum and oil cloth, insecticides and fungicides, plastics, papers etc.

Miscellaneous :

Fireclay is also used in rotary drilling mud, chemicals and artificial abrasives, etc.

TABLE II.6

Consumption of Fireclay by Industries

Industries	1969	1970	1971	1972	1973
Refractory/Ceramic (Including Iron and Steel Industry)	536,936 (70)	605,153 (76)	698,484 (79)	772,336 (80)	690,874 (78)
Foundry	4,717 (59)	6,001 (66)	6,383 (58)	6,972 (56)	6,892 (55)
Glass	725 (12)	621 (13)	418 (9)	483 (10)	467 (10)
Ferro-alloys and alloy steel	-	216 (1)	362 (1)	1,012 (3)	773 (3)
Insecticide	-	239 (1)	263 (1)	150 (1)	250 (1)
Others: (Including Textiles, Paper, Paints, Sugar, Abrasives, Chemical, Cement, Abbestos Products, Vanaspati, Rubber, Electrical Electrode etc.)	638 (42)	944 (90)	944 (113)	1,823 (120)	1,305 (115)
TOTAL	542,996	613,434	706,884	782,776	700,561

Figures in the brackets show number of units consuming fireclay.

TABLE II.7

Typical Analysis of Fireclays from Different Localities(India)

Locality	SiO_2 (%)	Al_2O_3 (%)	Fe_2O_3 (%)	TiO (%)	CaO (%)	MgO (%)	Alkalies (%)	L.O.I. (%)	P.C.E. Value (°C)
Khasi and Jaintia Hills (Assam)	80.15	13.04	0.51	-	-	0.48	0.96	4.75	1300
Raniganj, (West Bengal)	56.95	28.55	-	-	1.37	0.29	1.43	8.25	1400
Chandia (Madhya Pradesh)	70.54	21.62	0.09	-	0.45	0.41	-	6.64	1400
Jabalpur (Madhya Pradesh)	60.28	36.36	0.81	-	0.77	-	-	9.13	1400
Panchmahals (Gujarat)	64.20	20.00	1.00	1.25	1.10	1.4	0.3	9.09	1400
Thangadh (Gujarat)	53.75	30.65	0.67	0.80	0.74	0.18	0.4	13.49	1650
Rajhara Palamau (Bihar)	60.02	27.65	1.2	1.4	-	0.33	0.12	9.79	1400
Pakuria, Bhagulpur, (Bihar)	39.5	40.63	2.15	-	0.98	0.43	1.34	14.85	1680
Jarabagu (Orissa)	51.98	33.85	3.47	-	0.51	0.18	0.26	9.75	1600
Sambalpur (Orissa)	51.64	31.34	3.14	1.84	0.64	0.46	0.46	10.74	1640
Siddhout, Cuddapah, (Andhra Pradesh)	72.14	14.23	4.51	-	3.80	0.34	0.87	4.11	1500