Chapter Two

OCCURRENCE

The raw materials used in the foundry industry for the preparation of moulds and cores can be broadly classified into the following groups:

(i) Natural moulding sands
(ii) Bank sands including dune sands
(iii) High silica sands
(iv) Special sands like zircon, sillimanite, olivine, etc.
(v) Bonding clays like bentonite, fullers' earth, etc.
(vi) Core oils and special additives.

With increasing demand for castings of close tolerance limits and of high melting point alloys, a wide range of foundry moulding materials has been developed to suit the different types of foundry practices commonly adopted, namely, green sand, dry sand, oil sand, shell moulding, precision investment processes, Shaw process, etc. But basically the composition of moulding sand mixtures remains the same in most of the cases, namely, a graded sand of the requisite refractoriness, bonded with a binder or an admixture of 2 or 3 types of binders such as clays, dextrine, molasses, etc. to secure the optimum combination of properties at room and elevated temperature.

MOULDING SANDS

In India, the principal moulding sands employed at present for foundry moulding purposes are: Damodar and Barakar sands, available from Damuda series near Raniganj and Barakar area in Bengal-Bihar border ; Oyaria sand, occurring near Oyaria railway station in Bihar State ; Batala sand, occurring near Batala town in Gurdaspur district in Punjab ; Bhavnagar sand in Saurashtra ; Londa sand from the Deccan traps in South Satara district in Bombay State ; "Gigata Mannu" occurring near Secunderabad in Andhra Pradesh and Avadi and Veeriyambakam sands quarried from areas adjoining Avadi and Villivakkam in Madras State.

All the above sands are naturally occurring moulding sands, medium to medium-fine grained. Except for Damodar and Barakar sands, all other sands are being used by foundries as they occur locally.

Natural Moulding Sands

These sands, as they occur in nature, contain appreciable amounts of clay which acts as bond between the sand grains. The mineralogical constituents of the clay may belong to the kaolin group like dickite, kaolinite, nacrite, halloysite or montmorillonite or to the secondary mica group ; each group has its own characteristic properties. Natural moulding sands can, therefore, possess strength, plasticity and refractoriness to varying extent depending upon the clay minerals present. These sands are usually processed by crushing and milling soft yellow sandstones, carboniferous rotton rocks, etc. During milling, the clayey aggregates break down and the clay particles get uniformly distributed over the sand grains. Usually, the clay bond present may be too high in proportion to what is generally required to give the requisite strength to the sand mixture. It is, therefore, customary to blend the natural moulding sands with river sand, dune sand, etc. which are relatively clay-free, so as to get the optimum properties desired in the sand mixture. By and large, natural moulding sands find application in iron and non-ferrous foundry practice because of economic considerations and their availability in close proximity to the foundries.

The characteristics that determine the quality of a moulding sand are refractoriness, plasticity, strength, permeability, durability, flowability, etc. These properties are governed by grain shape, size, distribution and surface characteristics and mineralogical constitution of the sand and clay grades. An ideal moulding sand should consist of only two grades, viz. the sand grade (particle size, 1-0.1 mm. diam.) and the clay grade (particle size, <0.1 mm.). The sand grade should be composed mostly of quartz grains of round to subangular shape. The clay bond should be plastic and refractory in character and should be present as a uniform thin coating around the sand grains. Non-bonding minerals like quartz, muscovite, feldspar, siderite, dolomite, gypsum, iron pyrites, marcasite, calcite, and carbonaceous matter should be present in low percentages as they impair the bonding capacity of the clay. Fluxing constituents like lime and magnesia, including alkalies, should be low. Naturally occurring moulding sands partly satisfy these requirements, but their resources in any country are limited. To overcome this difficulty, the modern practice is to prepare synthetic mixtures from silica sand by bonding it with clays like bentonite, fullers' earth, etc. In the preparation of synthetic sand mixtures, the mineralogical and geological characteristics of the sand and clay grades are of fundamental importance.

Bank Sands including Dune Sands

These sands contain low percentages of clay grade matter and are obtained from river beds, sea coasts, dunes and estuaries and geologically they are of recent origin. These sands are mainly used for blending natural moulding sands for increasing their permeability and reducing the strength of the sand mixtures and also for core making in admixture with suitable binders.

The common practice in most of the foundries in India is to use river sand available locally. Thus, the foundries in West Bengal make use of the 'Mogra' sand available from Baghmaidar, Pandua, in Hooghly district, Amta river sand from Midnapore district and the sand from Barakar near Begunia. Foundries in Jamshedpur use the local Swarnarekha sand and those in Jamalpur use the Kiul sand, occurring locally. Foundries in Western India use Shohagpur sand and Saurashtra beach sand while in the south, the sands from local rivers like Cauveri and Coleron are used.

Most of these sands are medium to medium-fine grained, subangular in shape and assay 80-85 per cent silica and 8-12 per cent alumina ; they are contaminated with appreciable amounts of feldspar and iron oxide.

High Silica Sands

In India, the principal high silica sands used by the steel foundries are Rajmahal sand from Santhal Parganas in Bihar State, quartzitic rock sand occurring near Jamshedpur, Allahabad sand occurring near Shankergarh Station on the Central Railways, Jubbulpore sand, Hyderabad silica sand and silica sand from Vengurla, Malvan and Kudal taluks of Ratnagiri district in Maharashtra State.

Sands of this group are usually high in silica and contain very little clay usually less than 2 per cent. Alkalies, calcium, magnesium and iron oxides and alumina are considered as impurities. These sands are usually obtained by processing loosely consolidated sand deposits of sedimentary origin. Dunes blown inland from the sea coasts, accumulated deposits in estuaries and rivers and deposits of geologically recent origin are other sources of the sand. Majority of the sands from the above sources do not require elaborate processing and some of them may even be available with the requisite grading and can be used as such in foundry practice. Those which are not sufficiently well graded in the natural state are washed to remove silt and clay and then passed through sieves for grading them into fine, medium and coarse fractions.

High silica sands may also be produced artificially by crushing quartzitic sandstones with subsequent washing and grading to yield a sand grade of requisite distribution. But in these cases, a knowledge about the petrological features of the sandstone is important, as the grain size, distribution and shape of the sand grains are greatly influenced by the composition of quartzitic aggregates which in turn affect the moulding characteristics of a sand mixture. Thus, quartz has no cleavage and normally milling has little effect on the size of the grain. If the quartz grains are tightly packed and the interstices are completely filled or intricately sutured together as in the case of sandstones of compact texture, these aggregates do not break down on crushing into their constituent grains and each aggregate fractures independently of the original grain boundaries to give composite grains and mixtures of coarse angular particles and fines which are not well suited to normal foundry practice and can be used only for silica brick manufacture.

It can, therefore, be seen that the texture of the quartzitic type of sandstones is very important. It should be open type, capable of being crushed easily by simple hammering or milling to give maximum yield of sand grade of the requisite grading and size. Such sources of silica sands can be economical only if they are situated close to the consuming foundries.

High silica sands are composed wholly of quartz. Hence, their refractoriness is very high and they find wide application in steel foundry practice. During the last two decades, synthetic sand mixtures made by milling together a high silica sand and a bonding clay such as bentonite, have been increasingly employed in view of the fact that the base sand can be varied to suit the job on hand independently of the clay bond, while the quantity of clay can also be varied to the extent necessary for imparting the requisite strength. The properties of synthetic sand mixtures can, therefore, be controlled accurately and hence they are preferred in mechanized foundries.

In the evaluation of high silica sands for use in foundry practice, their mineralogical constitution, mechanical grading and grain size and shape are of importance. These are the characteristics which differentiate a silica sand suitable for foundry use from the one suitable for the refractory industries. A sand may contain more than 98 per cent silica and yet it may not be suitable for foundry practice if the size, shape and distribution of the grains are not up to requirements. For use in foundry practice, a silica sand should have a well defined grading of preferred shape and size, besides having the desired chemical composition.

A draft Indian Standard Specification has been evolved for foundry moulding sands based on the characteristics of sands, available and used at present by Indian industries.

Silica sands have been classified into the following six grades in respect of mechanical grading: 70 per cent or more of the sand grains being retained on 20-30-40 (Gr. I), 30-40-50 (Gr. II), 40-50-70 (Gr. III), 50-70-100 (Gr. IV), 70-100-140 (Gr. V) and 100-140-200 (Gr. VI) of the U.S. sieves respectively, percentages of sand grains retained on upper and lower sieves have also been specified.

On the basis of chemical analysis, high silica sands have been divided into 3 grades in respect of percentage of silica, viz. (i) over 98 per cent, (ii) above 95 to 98 per cent and (iii) above 90 to 95 per cent.

Special Sands

As the name implies, sands of this category, such as zircon, sillimanite and olivine sands are used in foundry practice for moulding sand mixtures, cores and also for mould dressings for the production of castings in special alloys of high melting point.

Of these, zircon sand, mostly a silicate of sodium, is a cream coloured sand and has recently been found to be highly suitable for use in foundries. Deposits of this sand are found at Quilon in Kerala State. The sand is obtained as a by-product of the beneficiation of monazite sands. Although at present the production of zircon sand is dependent on the production of monazite, it is likely that with sufficient development of the steel and alloy casting industry in the country, the need for zircon sands may justify its production for its own sake.

The distinguishing features of zircon sand are its usually small particle size, low linear expansion (0.0032 in.), which is about one-sixth that of silica sand, high thermal conductivity, high density, high refractoriness and chemical inertness. The sand can be used with a fineness range from 110-116 A.F.S. fineness number for all types of castings. The lower the expansion of the sand the finer the sand may be without causing the defect of mould wall fracture. The thermal conductivity of zircon sand is 14.5 Btw/ sq. ft/sq. in. thickness which is about twice that of silica sand. By virtue of its high density (*c.* 172 lb./cu. ft) as compared to 98 lb./cu. ft for silica sand, zircon sand can abstract much more heat than silica sand. This in turn causes the formation of a solidified metal layer at the metal sand interface of the mould which prevents metal penetration. On account of its chemical inertness, it does not wet easily or reach with molten metal and hence, does not burn on to the castings.

Olivine sand is obtained by processing forsterite and fayalite. One advantage of its use is that those who handle it are free from the hazard of silicosis. Olivine sand is used in Norwegian foundries for casting iron, aluminium and copper ; recently, its use has been extended to steel castings. Casting defects such as scabs and rat tails are minimized with olivine sand owing to its low expansion characteristics. Likewise, sillimanite also has low expansion (*c.* 0.002 in.) and castings have been made using sillimanite sand with very little surface defects. However, these sands are used to a limited extent in foundry practice owing to their high cost.

BONDING CLAYS

Bonding clays are finding increasing use in the preparation of synthetic sand mixtures and as boosters in natural sand systems, particularly in mechanized foundries. With the advent of mass production technique in the preparation of moulds and cores by pneumatic moulding machines, sand slingers and core-blowing machines, exacting controls over the characteristics of foundry sand mixtures have to be exercised. Since moulding sands occur in nature with a wide diversity in chemical and physical characteristics, they have to be suitably processed to obtain optimum combination of properties. Further, the resources of good quality natural moulding sands anywhere cannot be unlimited. Hence, there is increasing stress on the need for finding substitutes for natural moulding sands. Upgrading of inferior sand by bonding them with bonding clays is an obvious solution and is being widely practised. Among the bonding clays, bentonite, fullers' earth (Fulbonds) and fireclays containing kaolinite or illite are the ones commonly used. Of these, bentonite possesses the best bonding properties, as is evident from Table 1 wherein comparative bonding characteristics of the different bonding materials are presented.

Bentonite

Bentonite is a clayey mineral of volcanic origin and finds wide use in foundries by virtue of its fine particle size, expanding layer lattice structure, remarkable water absorption properties and high base exchange capacity. The bulk of the particles in bentonite are of colloidal size, viz. less than a micron. By virtue of this fine grain size, the clay particles have a large specific surface and are, therefore, able to spread readily as a thin adhesive film around the sand grains without filling up the spaces in between the grains. Hence, only very small percentages of the order of 3 to 5 per cent are required to be added in a sand mixture as compared with 7 and 15 per cent respectively in the case of illite and kaolinite type of clays.

Deposits of Bentonite in India. In India, the known deposits of bentonite are confined only to a few places in Rajasthan, Kashmir and Bihar. In Rajasthan, bentonite deposits of workable quality occur at Hathi-ki-Dhani, Akli, Bhadres, Giril and Sonri in Sheo and Barmer districts. These bentonites are light green in colour. They are primarily of sodium base, but their base-exchange capacity is rather poor. The chemical compositions of a few typical samples are shown in Table 2.

In Jammu and Kashmir State, deposits of bentonite are found at Bhimbar in Mirpur district. The average chemical composition of Kashmir bentonites

TABLE 1—RELATIVE BONDING VALUES OF DIFFERENT BONDING CLAYS

(Values expressed in arbitrary units)

Clay	Green Bond	Dry Bond
Southern bentonite	100	70
Western bentonite	75–80	100
Fulbond No. 1	75–80	55–60
Fulbond No. 2	75	70–80
Col-bond	50–60	40–50
Fireclay	30–35	25–30

TABLE 2—RAJASTHAN BENTONITES: CHEMICAL ANALYSIS*

CHEMICAL CONSTITUENT	BENTONITE FROM			
	Hathi-ki-Dhani	Bhadres	Akli	Giril
SiO_2, %	52.76	51.07	47.0	50.4
Al_2O_3, %	23.36	24.18	23.3	19.8
Fe_2O_3, %	6.61	3.97	6.95	9.2
TiO_2, %	2.82	2.50	—	—
CaO, %	0.37	0.87	0.75	2.0
MgO, %	1.62	2.48	Traces	2.4
$Na_2O + K_2O$, %	0.6	0.83	5.92	4.8
Loss on ignition, %	11.86	14.10	13.50	11.4

* Data supplied by the Director of Mines and Geology, Government of Rajasthan

is: SiO_2, 48.64 ; $Fe_2O_3 + Al_2O_3$, 11.15 ; CaO, 1.83 ; MgO, 8.67 ; and loss on ignition, 29.91 per cent.

Recently, new deposits have been located in Jammu near the village Rattanpur Sarrara. These bentonites are of calcium base and have a high base-exchange capacity, equivalent to that of the American Wyoming bentonite. They bond well, 3–5 per cent addition being sufficient for use in normal synthetic sand practice.

In Bihar, bentonite is mined at Tinapahar in the neighbourhood of Rajmahal hills of Santhal Parganas. These deposits have been recently discovered.

Mining and Quarrying. Most of the deposits of bentonite in India are worked by shallow inclines and tunnels. In some cases, e.g. at Bhimbar in Kashmir, due to the gentle inclination of the rocks and thick overburden of sandstones, bentonite deposits are worked through a number of adits and drives into the hill sides. In Jodhpur, excavation is done by quarrying with pick and shovel.

Treatment. Bentonites should be processed by drying, crushing and grinding in hammer or Raymond mill, and air-floated to about -200 mesh, to get the best results. In addition, some bentonites need a desanding treatment to remove gritty impurities.

Scope for increasing the Use of Bentonites in India. Prior to World War II, bentonite was used only to a limited extent in some Indian foundries which used Wyoming bentonite imported from the U.S.A. The stoppage of imports during the war gave an impetus to the use of Indian bentonites. But, even today, bentonites are not as much in use as their excellent characteristics would warrant.

One reason for this antipathy was that most of the Indian foundries were at one time unmechanized, with little attention being paid to scientific and systematic foundry sand control and testing along modern lines. There were very few steel foundries, the majority being iron and non-ferrous foundries. Quite a few Indian foundries are now fully mechanized along modern lines and new steel foundries are being installed at various places.

In modern steel foundry, production of steel castings by green sand moulding is being increasingly adopted on account of its obvious advantage of increased output through elimination of stoving of moulds. It will, therefore, be in the interest of Indian foundries to adopt green sand moulding. Mechanized iron foundries will also doubtless find it to their advantage to employ Indian bentonite as a booster to their circulating sand systems and for making cores, mould paints and core washes.

Fullers' Earth

Deposits of fullers' earth are known to occur in Tikaria, Lodhihera and Borgaon (Madhya Pradesh) and Gudha, Hatundi and Thok Malyan in Ajmer Tehsil ; Kesarpura, Bharratpura, Kalatkhera and Khera Dauti in Beawar Tehsil in Dewa district and Kapurdi and Pargan Mallain (Rajasthan). Although these deposits have been known to exist for a long time, so far no use has been made of fullers' earth in Indian foundries.

Like bentonites, fullers' earth consists essentially of the clay mineral, montmorrillonite with calcium as the exchangeable cation. The principal impurity calcite, which acts as a diluent just like quartz in bentonite, slightly impairs its plasticity and green and dry strengths of synthetic clay-sand mixtures. However, it is amenable to base-exchange treatment. By treating it with sodium carbonate, calcium can be replaced by sodium with resultant improvement in certain characteristic physical properties, particularly dry strength, plasticity and swelling capacity.

The approximate chemical composition of fullers' earth samples collected from Madhya Pradesh is as follows : SiO_2, 67.1 ; Al_2O_3, 18.4 ; CaO, 2.7 ; K_2O, 6.4 ; and Na_2O, 7.1 per cent.

In view of the limited resources of bentonite in India it would be worth while exploiting the resources of fullers' earth.

CORE OILS AND SPECIAL ADDITIVES

Core oils and other special additives like, rosin, pitch, synthetic resins, dextrine, molasses, wood flour, are used in foundry practice for imparting certain specific properties like green, air-set, dry and hot strength to the moulds and for improving the surface finish of the castings and reducing surface defects. They are added to the sand mixtures in definite proportions, depending upon the extent to which the specific properties are required to be modified for obtaining sound castings. A large number of additives are now at the disposal of the foundryman.