Moulding Sands

Dr. Serhat ACAR

- Sand: Mineral grain (Grain size: 0.05 – 2 mm)
- In sand mould casting, for 1 ton cast part production average sand requirement is 4-5 tons.

The refractory moulds used in casting consist of a particulate refractory material (sand) that is bonded together to hold its shape during pouring. Although various sands can be used, the following basic requirements apply to each.

- Dimensional and thermal stability at elevated temperatures
- Suitable particle size and shape
- Chemically unreactive with molten metals
- Not readily wetted by molten metals
- Freedom from volatiles that produce gas upon heating
- Economical availability
- Consistent cleanliness, composition, and pH
- Compatibility with binder systems

Many minerals possess some of these features, but few have them all.

Moulding sand mixtures

Natural sands

- Includes natural clay as binder and used as extracted. In case of some bentonite addition its called semi synthetic sand.
- Natural sands do not have regular properties, they are variable.

Synthetic sands

- Washed (cleaned) and sized sands. Clay content is decreased to very low levels with washing.
- Used with bentonite addition for green sand moulding.

Types of sand binders

- **Inorganic binders** (generally for moulds)
  - **Clay** (Natural Clay, Bentonite, Fire Clay)
  - **Inorganic resins** (Sodium silicate + CO_2)
  - **Cement**

- **Organic binders** (for moulds and cores)
  - **Air set (No bake) resins**
  - **Heat cured (Hot box) resins**
  - **Gas set (Cold box) resins**

Green sand → Sand + Clay + Water
(Temper water+ free water)

Types of sands

- **Silica sand (SiO_2)**
- Zircon sand ($ZrSiO_4$)
- Chromite sand ($FeCr_2O_4$)
- Olivine sand ($MgFe_2SiO_4$)
- Aluminium silicate sand (Al_2SiO_5)

Synthetic sands are preferred because of:

- More uniform grain size
- Higher refractoriness
- Need less water
- Need less binder
- Need smaller storage places
- Properties can be controlled easily

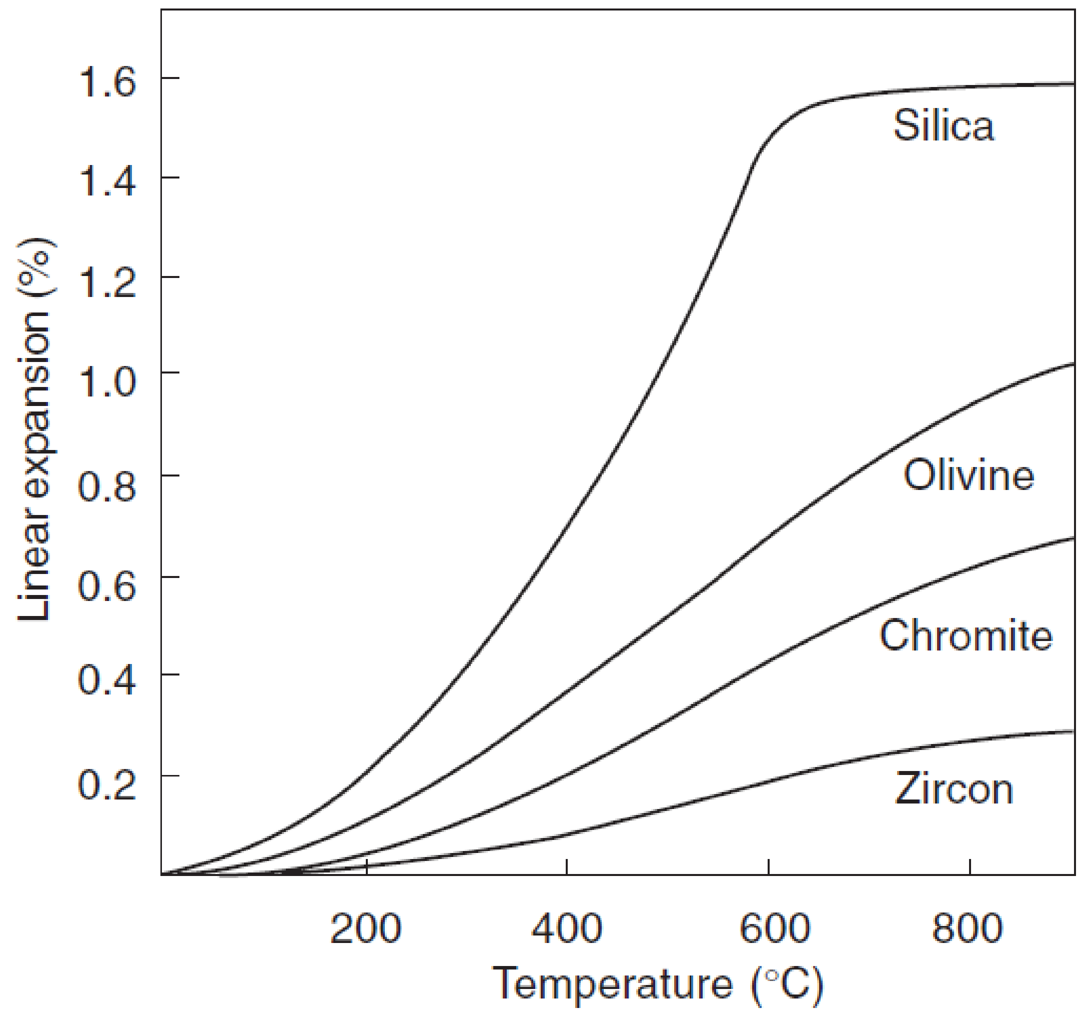
Silica sand

Zircon sand

Chromite sand

Olivine sand

Aluminium silicate sand



Thermal expansion characteristics of zircon, chromite and olivine sands compared with silica sand.

Silica Sands

Most green sand moulds consist of silica sands bonded with a bentonite-water mixture. (The term green means that the mould, which is tempered with water, is not dried or baked.) The composition, size, size distribution, purity, and shape of the sand are important to the success of the mould making operation.

Sand	*Sintering point* (°C)
High purity silica sand, >99% quartz	1450
Medium purity silica sand, 96% quartz	1250
Sea sand (high shell content)	1200
Natural clay bonded sand	1050–1150

Zircon

Zircon is zirconium silicate ($ZrSiO_4$). It is highly refractory and possesses excellent foundry characteristics. Its primary advantages are a very low thermal expansion, high thermal conductivity and bulk density (which gives it a chilling rate about four times that of quartz), and very low reactivity with molten metal. Zircon requires less binder than other sands because its grains are rounded. The very high dimensional and thermal stabilities exhibited by zircon are the reasons it is widely used in steel foundries and investment foundries making high-temperature alloy components.

Olivine

Olivine minerals (so called because of their characteristic green color) are a solid solution of forsterite (Mg_2SiO_4) and fayalite (Fe_2SiO_4). Their physical properties vary with their chemical compositions; therefore, the composition of the olivine used must be specified to control the reproducibility of the sand mixture. Care must be taken to calcine the olivine sand before use to decompose the serpentine content, which contains water. The specific heat of olivine is similar to that of silica, but its thermal expansion is far less. Therefore, olivine is used for steel casting to control mould dimensions. Olivine is somewhat less durable than silica, and it is an angular sand.

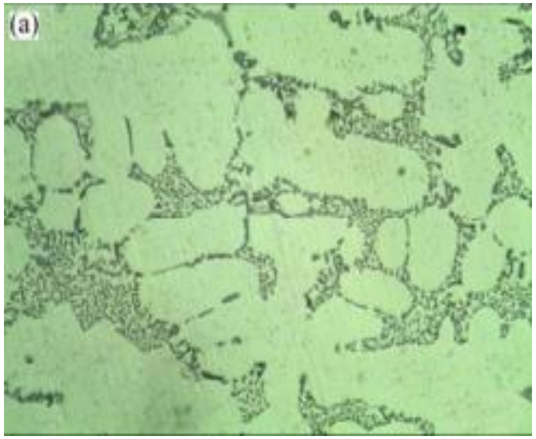
Chromite

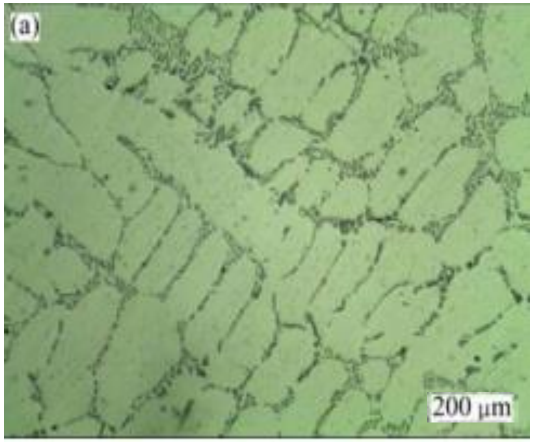
Chromite ($FeCr_2O_4$), a black, angular sand, is highly refractory and chemically unreactive, and it has good thermal stability and excellent chilling properties. However, it has twice the thermal expansion of zircon sand, and it often contains hydrous impurities that cause pinholing and gas defects in castings. It is necessary to specify the calcium oxide (CaO) and silicon dioxide (SiO_2) limits in chromite sand to avoid sintering reactions and reactions with molten metal that cause burn-in.

Aluminum Silicates

Aluminum silicate (Al_2SiO_5) occurs in three common forms: kyanite, sillimanite, and andalusite. All break down at high temperatures to form mullite and silica. Therefore, aluminum silicates for foundry use are produced by calcining these minerals. Depending on the sintering cycle, the silica may be present as cristobalite or as amorphous silica. The grains are highly angular. These materials have high refractoriness, low thermal expansion, and high resistance to thermal shock. They are widely used in precision investment foundries, often in combination with zircon.

A356 alloy – 40 mm wall thickness



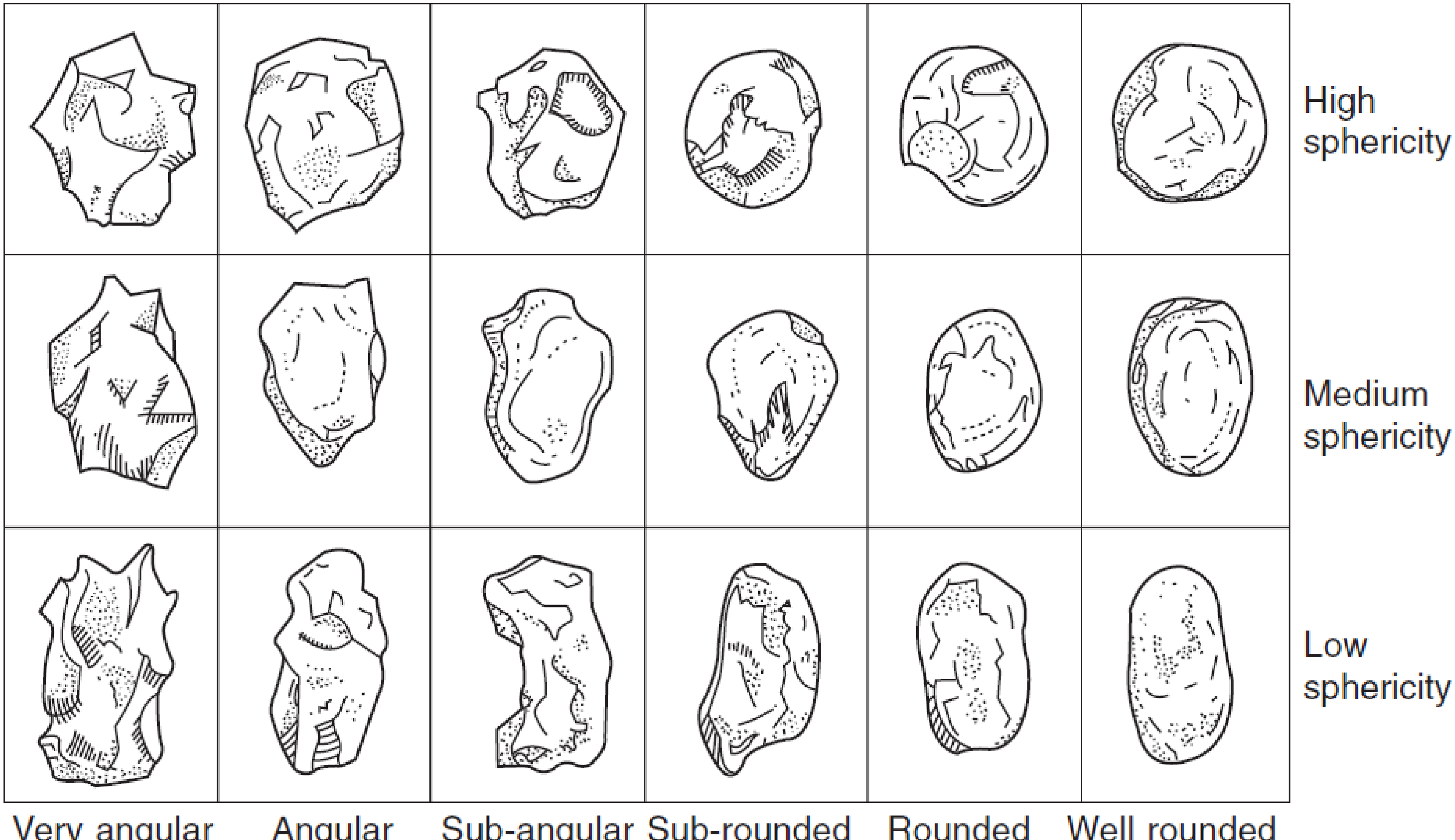


Silica sand

Chromite sand

Effects of moulding sands and wall thickness on microstructure and mechanical properties of Sr-modified A356 aluminum casting alloy, SUN Shao-chun, YUAN Bo, LIU Man-ping, Transactions of Nonferrous Society China, 22, 2012, 1884-1890

Grain shape



High sphericity
Medium sphericity
Low sphericity
Very angular
Angular
Sub-angular
Sub-rounded
Rounded
Well rounded

- Grain shape is defined in terms of angularity and sphericity. Sand grains vary from well rounded to rounded, sub-rounded, sub-angular, angular and very angular. Within each angularity band, grains may have high, medium or low sphericity. The angularity of sand is estimated by visual examination with a low power microscope and comparing with published charts.
- The best foundry sands have grains which are rounded with medium to high sphericity giving good flowability and permeability with high strength at low binder additions. More angular and lower sphericity sands require higher binder additions, have lower packing density and poorer flowability.

Size distribution

The size distribution of the sand affects the quality of the castings. Coarse grained sands allow metal penetration into moulds and cores giving poor surface finish to the castings. Fine grained sands yield better surface finish but need higher binder content and the low permeability may cause gas defects in castings. Most foundry sands fall within the following size range:

Grain fineness number	50–60 AFS	Yields good surface finish at low binder levels
Average grain size	220–250 microns	
Fines content, below 200 mesh	2% max	Allows low binder level to be used
Clay content, below 20 microns	0.5% max	Allows low binder levels
Size spread	95% on 4 or 5 screens	Gives good packing and resistance to expansion defects
Specific surface area	120–140 cm^2/g	Allows low binder levels
Dry permeability	100–150	reduces gas defects

Chemical purity

SiO_2	95–96% minimum	The higher the silica the more refractory the sand
Loss on ignition	0.5% max	Represents organic impurities
Fe_2O_3	0.3% max	Iron oxide reduces the refractoriness
CaO	0.2% max	Raises the acid demand value
K_2O, Na_2O	0.5% max	Reduces refractoriness
Acid demand value to pH_4	6 ml max	High acid demand adversely affects acid catalysed binders

Acid demand

The chemical composition of the sand affects the acid demand value which has an important effect on the catalyst requirements of cold-setting acid catalysed binders. Sands containing alkaline minerals and particularly significant amounts of sea-shell, will absorb acid catalyst. Sands with acid demand values greater than about 6 ml require high acid catalyst levels, sands with acid demand greater than 10–15 ml are not suitable for acid catalysed binder systems.

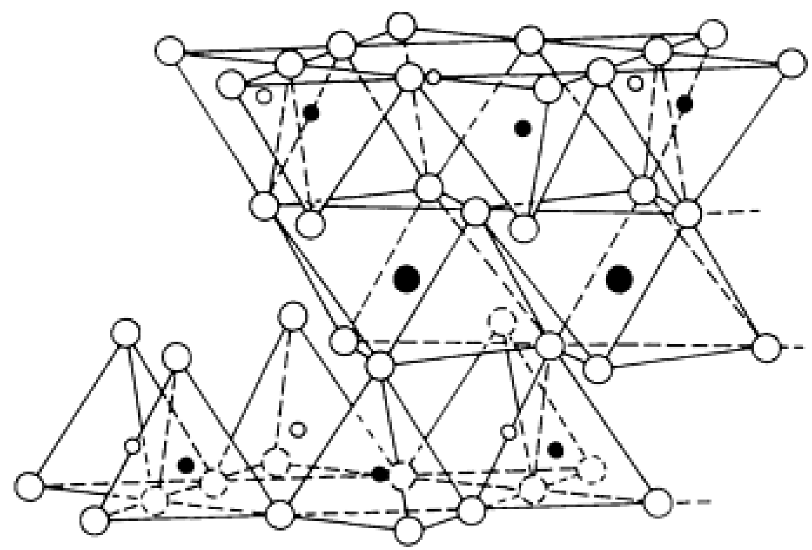
Clays

Bonds in green sand moulds are produced by the interaction of clay and water. Each of the various clays has different properties, as described below.

Bentonites

The most common clays used in bonding green sand moulds are bentonites, which are forms of montmorillonite or hydrated aluminum silicate. Montmorillonite is built up of alternating tetrahedra of silicon atoms surrounded by oxygen atoms, and aluminum atoms surrounded by oxygen atoms. This is a layered structure, and it produces clay particles that are flat plates. Water is adsorbed on the surfaces of these plates, and this causes bentonite to expand in the presence of water and to contract when dried.

There are two forms of bentonite: Western (sodium) and Southern (calcium). Both are used in foundry sands, but they have somewhat different properties. Sodium bentonite has higher dry and hot strength while calcium bentonite has higher green strength.



Structure of montmorillonite. Large closed circles are aluminum, magnesium, sodium, or calcium. Small closed circles are silicon. Large open circles are hydroxyls. Small open circles are oxygen

Fireclay

Fireclay consists essentially of kaolinite, a hydrous aluminum silicate that is usually combined with bentonites in moulding sand. It is highly refractory, but has low plasticity. It improves the hot strength of the mould and allows the water content to be varied over greater ranges. Because of its high hot strength potential, it is used for large castings. It is also used to improve sieve analysis by creating fines whenever the system does not have an optimum wide sieve distribution of the base sand. However, because of its low durability, its use is generally limited. In addition, the need for fireclay can usually be eliminated through close control of sand mixes and materials.

Properties of moulding sands

Main properties

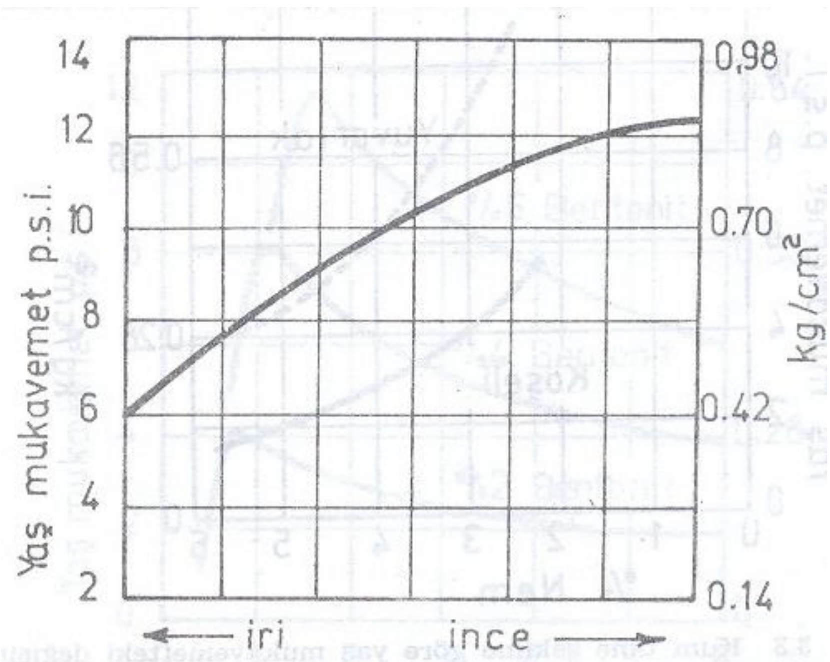
- Green strength
- Dry strength
- Permeability
- Moisture content
- Clay content
- Grain size and distribution

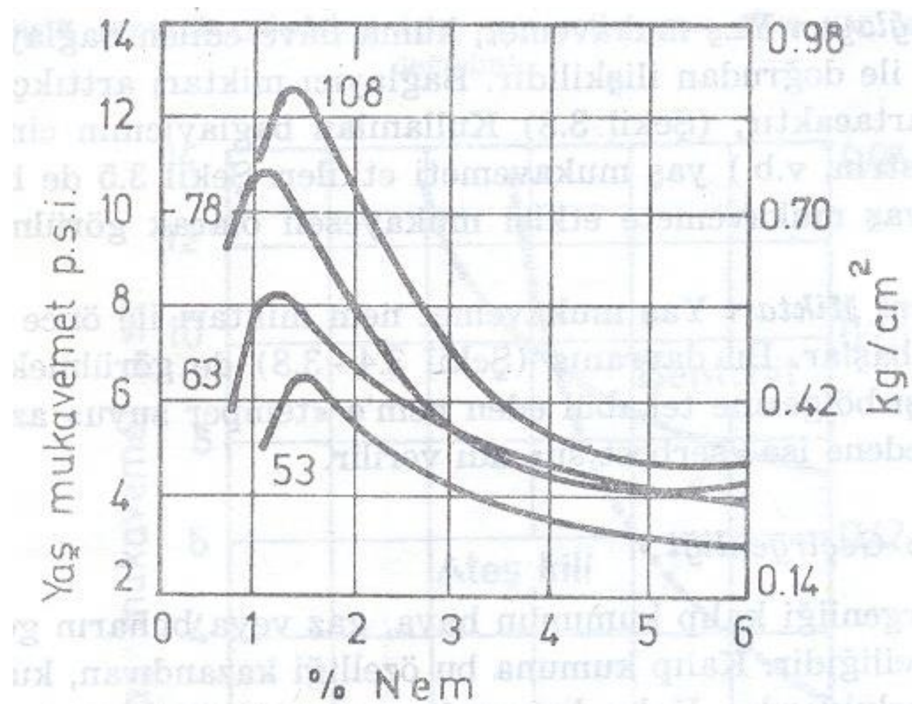
Other properties

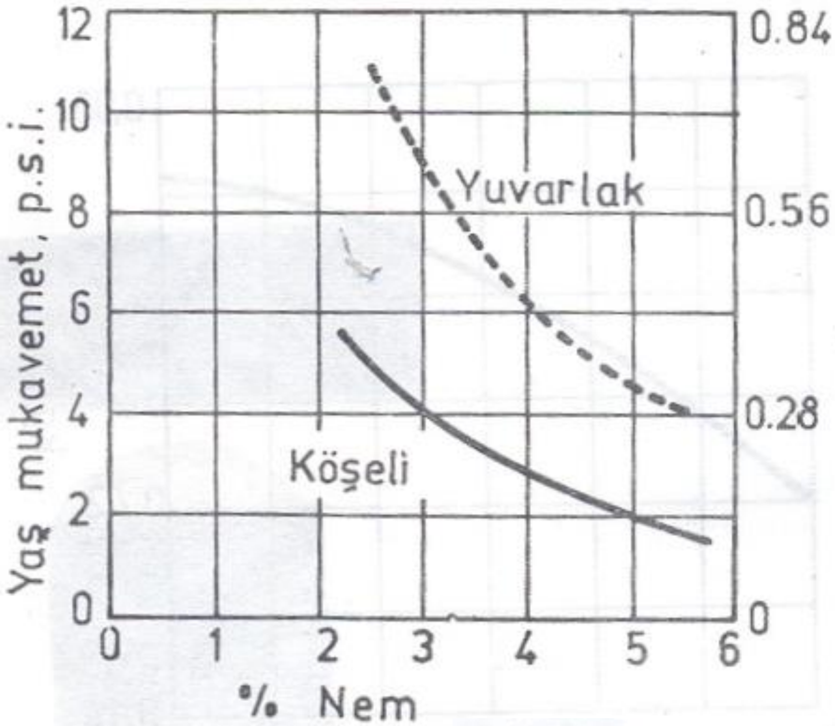
Hot strength, sinter point, thermal stability, flowability and plasticity, collapsibility, ability of reuse

Green strength: Strength of the moulding sand just after addition of tempering water.

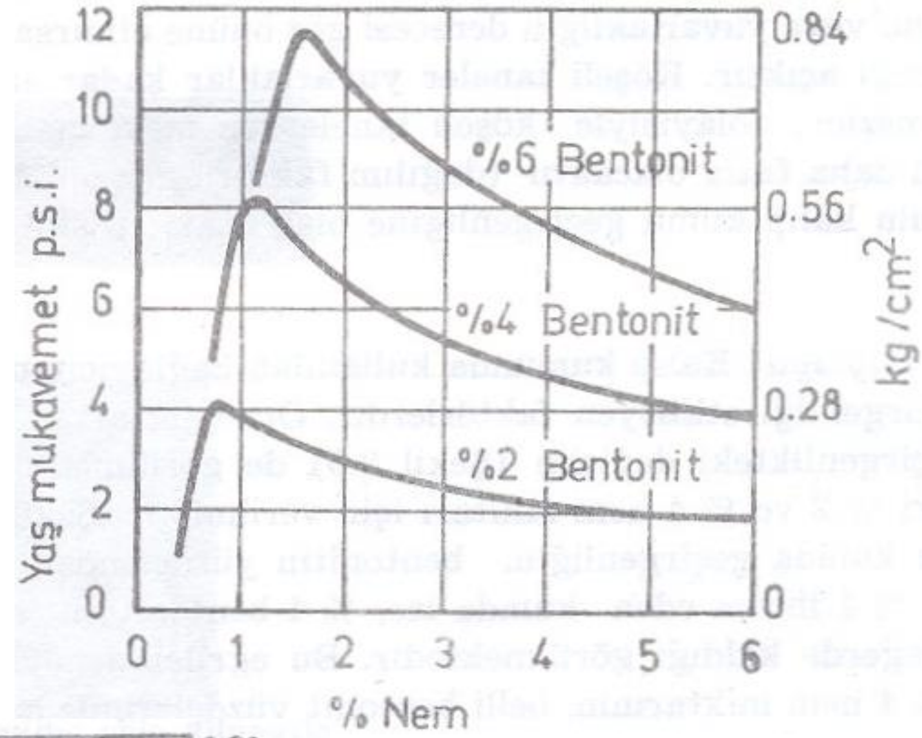
Factors effects green strength:



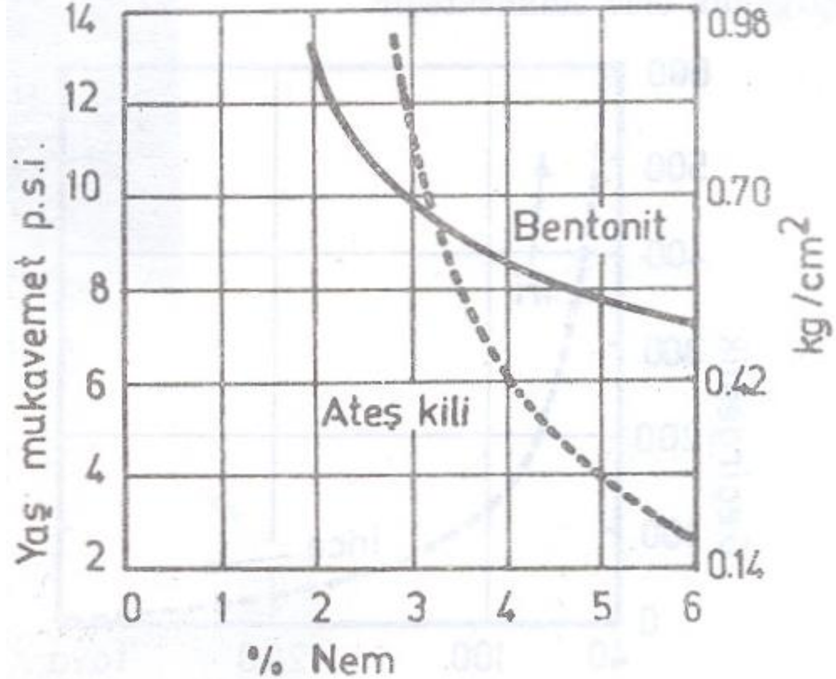




Yaş mukavemet, p.s.i.
kg /cm²
Yuvarlak
Köşeli
% Nem
0 1 2 3 4 5 6
0 2 4 6 8 10 12
0 0.28 0.56 0.84



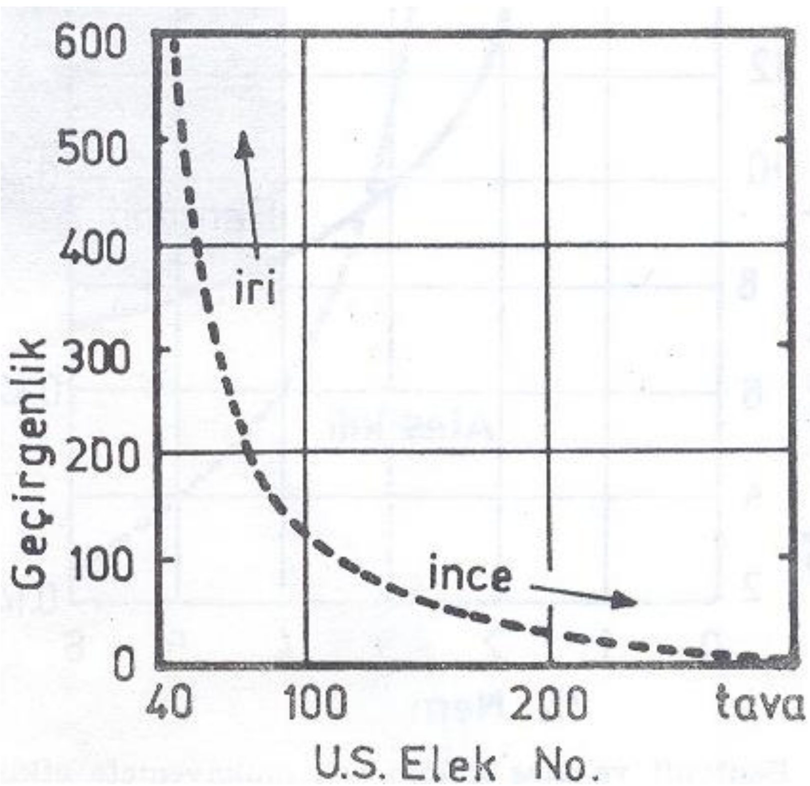
Yaş mukavemet p.s.i
kg /cm²
%6 Bentonit
%4 Bentonit
%2 Bentonit
% Nem
0 1 2 3 4 5 6
0 2 4 6 8 10 12
0 0.28 0.56 0.84

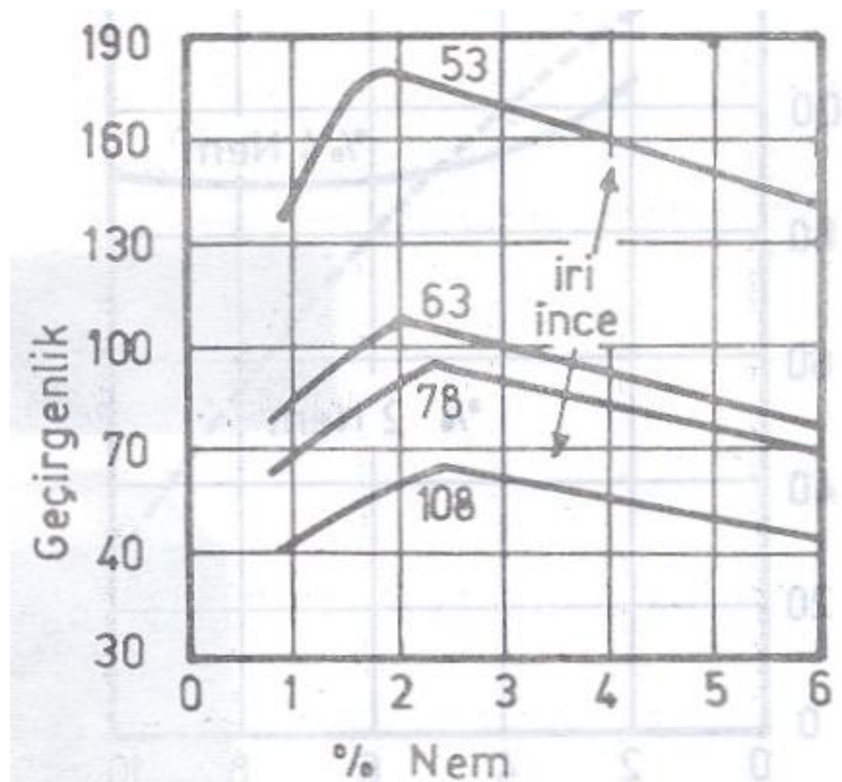


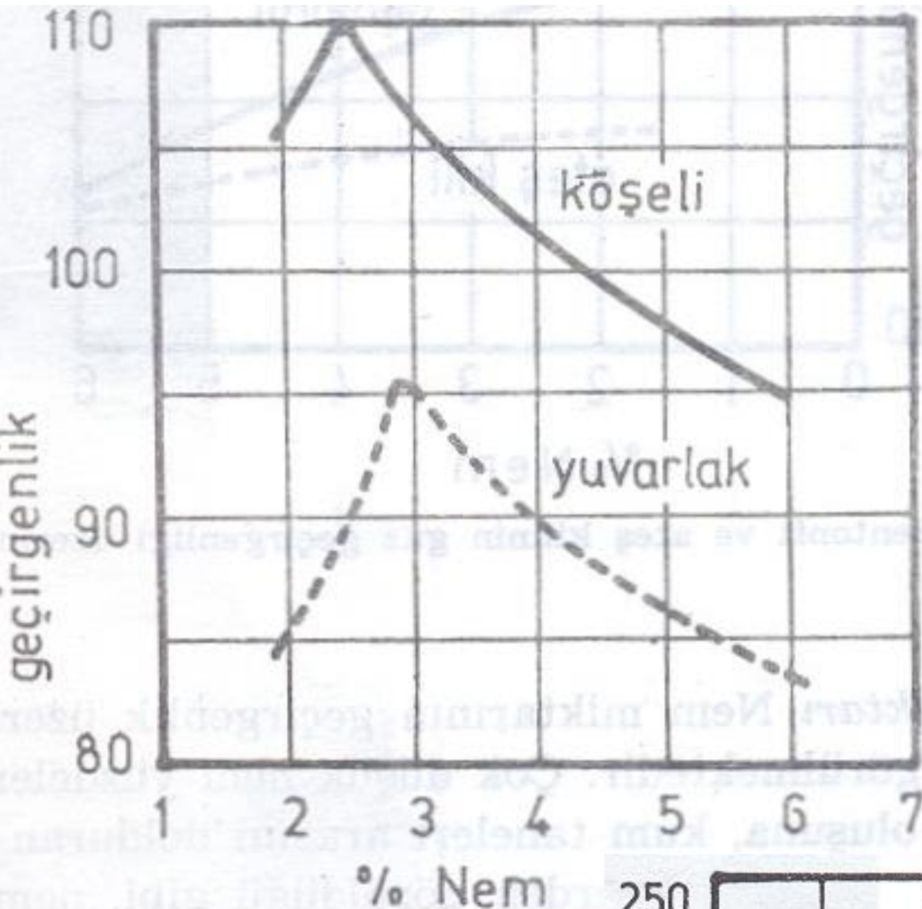
Yaş mukavemet p.s.i
kg /cm²
Bentonit
Ateş kili
% Nem
0 1 2 3 4 5 6
2 4 6 8 10 12 14
0.14 0.42 0.70 0.98

Permeability: Passing ability of air, gas and vapour through the mould wall.

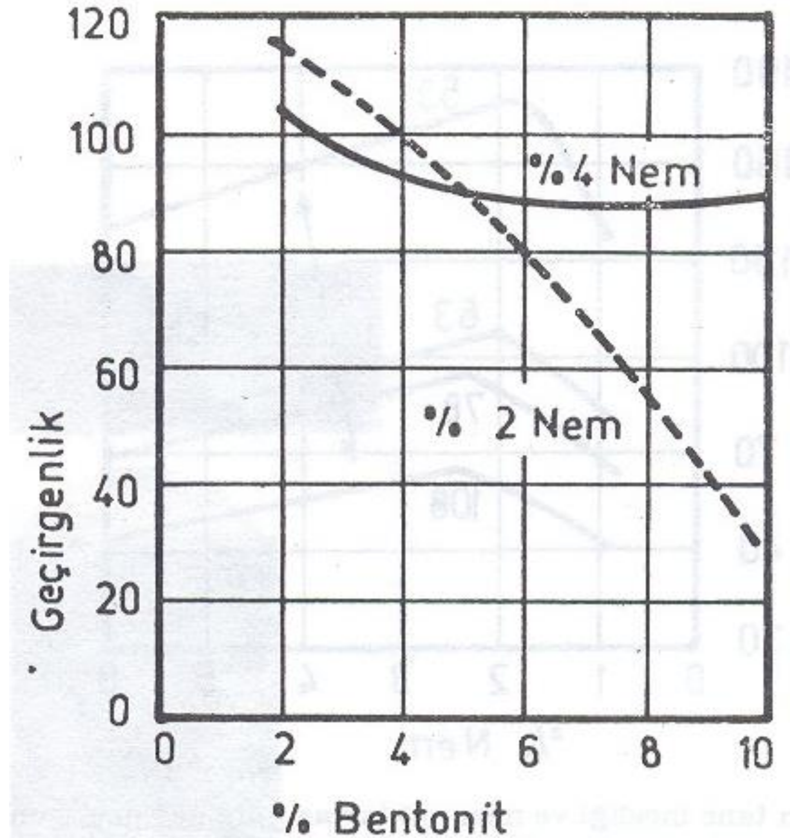
Factors control permeability:



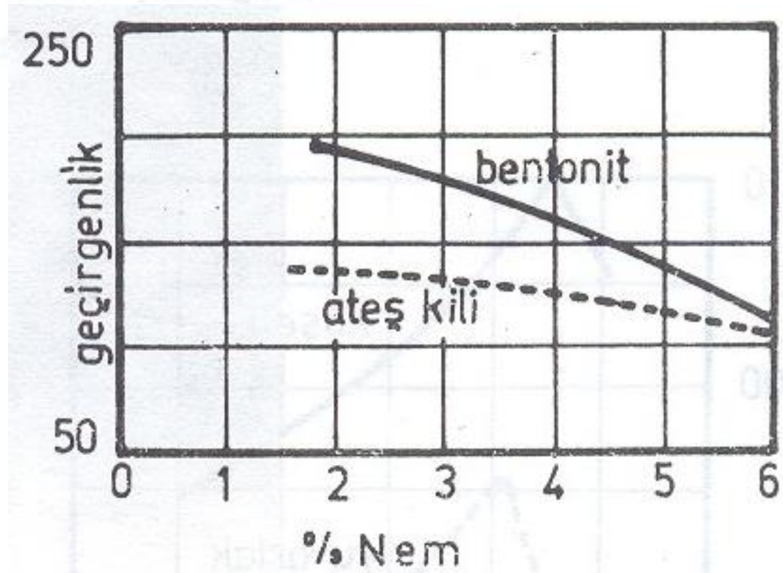




110
100
90
80
1
2
3
4
5
6
7
köşeli
yuvarlak
geçirgenlik
% Nem



120
100
80
60
40
20
0
0
2
4
6
8
10
% 4 Nem
% 2 Nem
Geçirgenlik
% Bentonit



250
50
0
1
2
3
4
5
6
bentonit
ateş kili
geçirgenlik
% Nem

Moulding sand additives

- **Silica powder**. Increase hot strength.
- **Iron oxide** (Grounded hematite ore (Fe_2O_3). Increase hot strength. Iron oxide loose oxygen during casting and decrease volume and stress.
- **Fuel oil.** Decrease free water content and improve moulding ability.
- **Cereals** (Corn flour, dextrine, and other starches)**.** Act as binder and increase green and dry strength.
- **Pulverized coal.** Prevent sintering of sand grains, generates gas barrier between sand grains.

Saw dust (wooden). Burns and increase thermal stability.

Graphite. Increase moulding ability and surface quality.

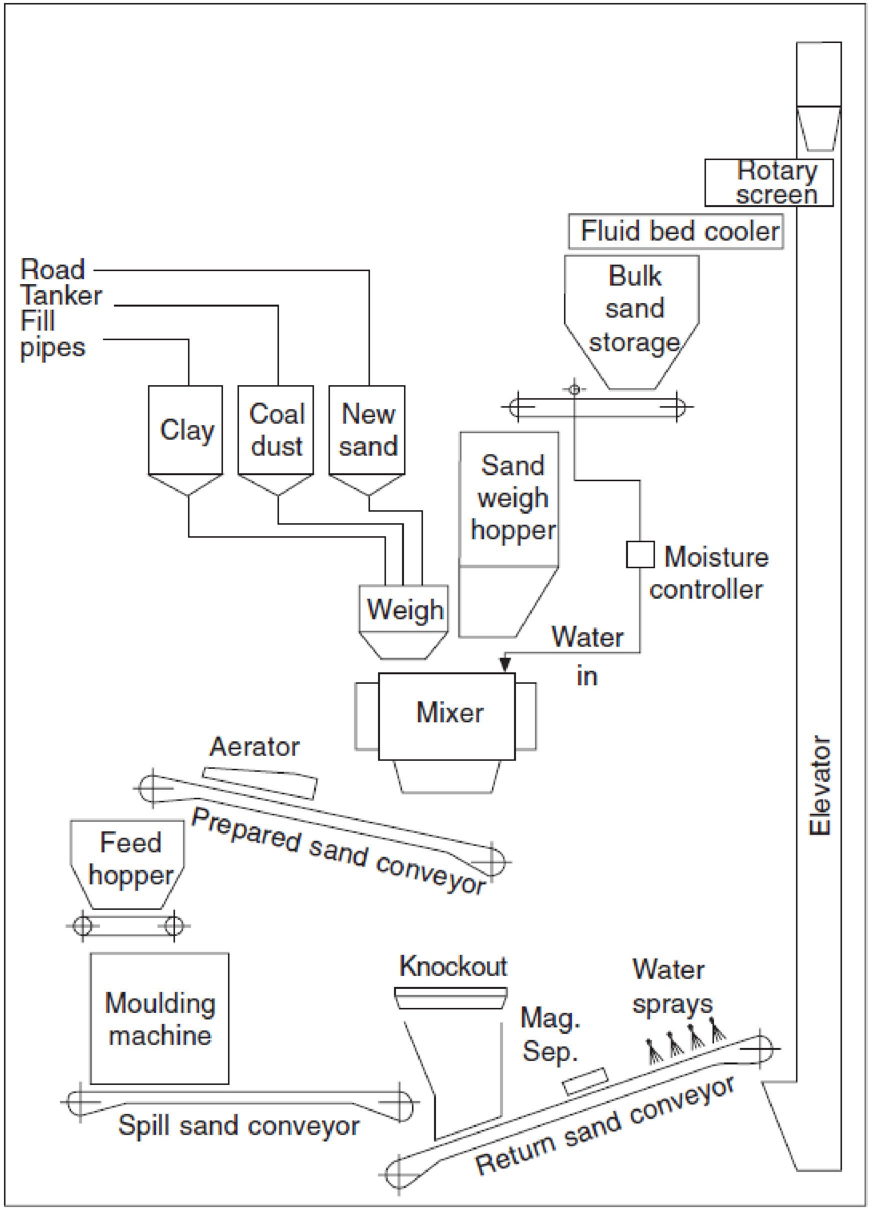
Pearlite. It is a kind of aluminium silicate based mineral used for increase thermal stability.

Typical green sand properties for a iron foundry.

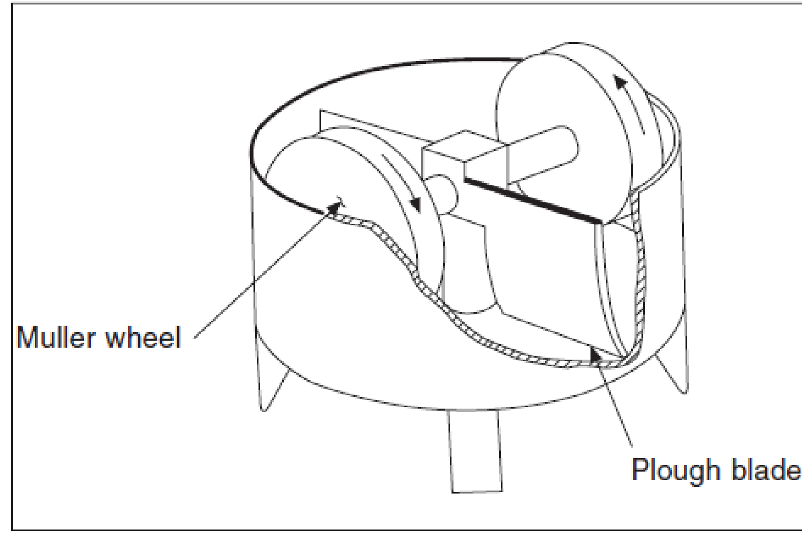
	jolt/squeeze machines	*high pressure (DISA etc.)*
water	3–4%	2.5–3.2%
green strength	70–100 kPa	150–200 kPa
	10–15 psi	22–30 psi
compactability	45–52%	38–40%
permeability	80–110	80–100
live clay	5.0–5.5%	6.0–10.0%
volatiles	2.5%	2.0%
LOI	7.0–7.5%	6.0%

Steel foundries use sand having similar properties except for reduced volatiles and LOI since coal dust is not used.

A typical grading of a sand suitable for iron or steel castings is:



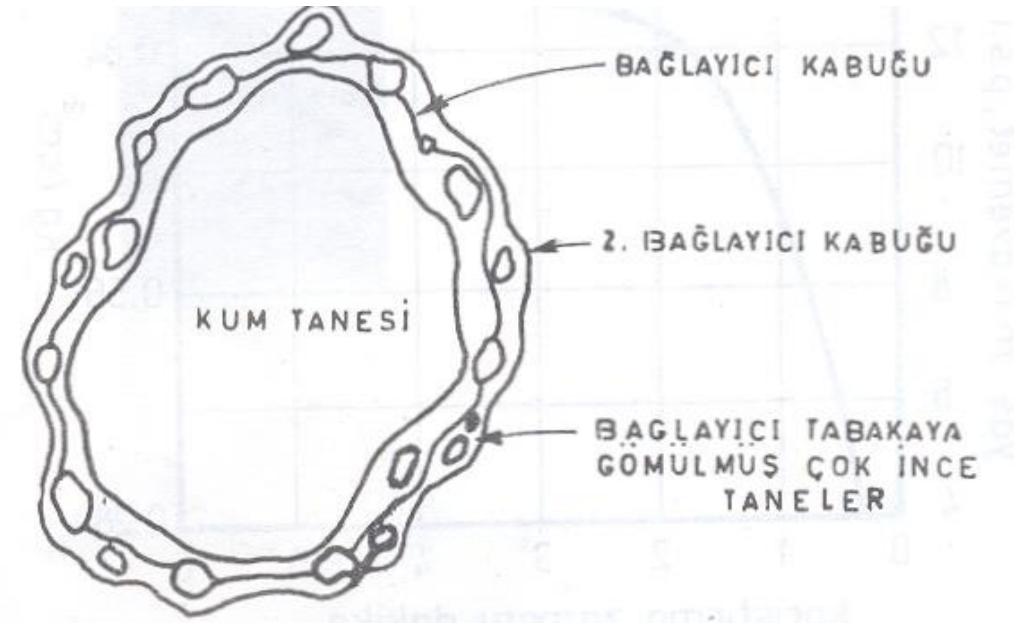
Flow diagram for a typical green sand plant



Sand mixer

Sand reclamation

Reclamation is treatments which are carried out for return properties of used sand to its original form. Reclemation of sand is easiest when only one type of chemical binder is used. Generally sphericity of reclamated sands are increase and angularity decrease.



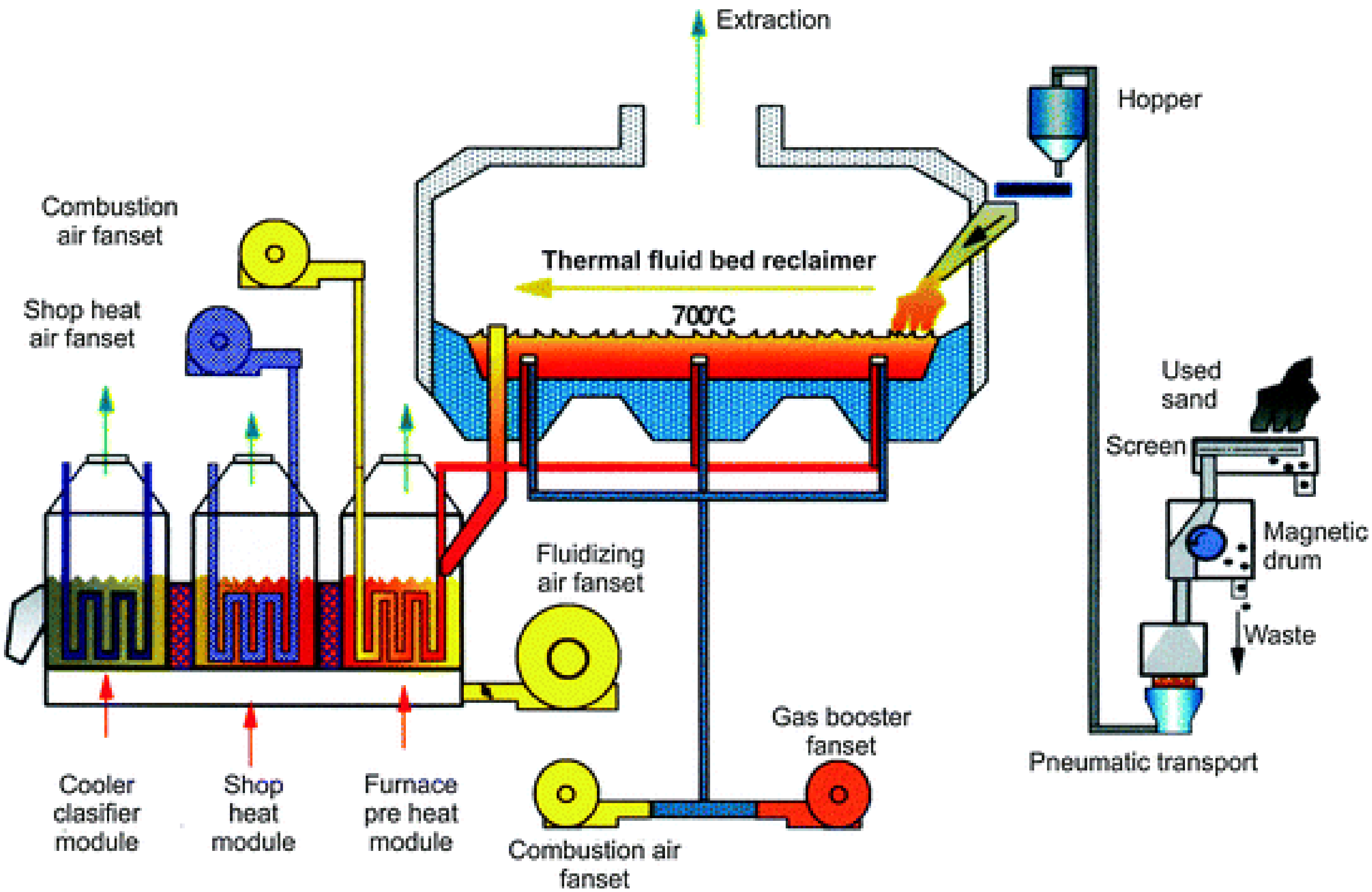
Binder shell layers around the used sand grain

Types of sand reclamation

- Dry reclamation
- Wet reclamation
- Thermal reclamation (650-850 °C)
- **Dry or wet reclamation + thermal reclamation**

Dry and green reclamations remove clay binder shell but organic and carbon based residues cannot be removed.

Thermal reclamation removes organic and carbon based materials however it is not effective on clay shell cover.


Extraction
Hopper
Combustion
air fanset
Thermal fluid bed reclaimer
Shop heat
air fanset
700°C
Used
sand
Screen
Magnetic
drum
Fluidizing
air fanset
Waste
Gas booster
fanset
Pneumatic transport
Cooler
clasifier
module
Shop
heat
module
Furnace
pre heat
module
Combustion air
fanset