Greensand mould

MME **345**, Lecture **A:04**

Moulding and Casting Methods

2. Greensand moulding system

Ref:

[1] Heine, Loper & Rosenthal, Principles of Metal Casting, McGraw-Hill, 1976
[2] Beeley, Foundry Technology, Butterworth-Heinemann, 2001

Topics to discuss today …

1. Introduction
2. Greensand moulding aggregates
3. Ingredients of greensand moulding aggregates

1. Introduction

- The tonnage of sand which must be handled in sand casting foundry is large.
  - sand moulds for making a ton of castings may require 4 to 5 tons of moulding sand aggregate
  - this sand-metal ratio may vary from **10:1** to **0.25:1** depending on the type and size of castings and moulding methods employed

- The property requirements of moulding materials are generally determined by moulding and casting conditions.
  - A foundry sand moulding mixture passes through 4 main production stages: (1) **preparation and distribution**, (2) **mould and core production**, (3) **casting**, and (4) **cleaning and reclamation**.
  - for integrated sand systems, the **preparation and reclamation** stages are also considered.

- The properties of moulding aggregate in sand moulding system at different stages of casting are crucial to the production of sound, dimensionally accurate castings.
  - the **quality must be controlled** to make good defect-free castings.
- Thus, **selection** and **testing** of moulding material and moulding aggregate constitutes one of the vital steps in founding.

1.1 Functional requirements of sand moulding material

- From a general viewpoint, the moulding sand aggregate must have adequate **flowability** and **strength** so that it must be **readily mouldable** and the mould cavity should **retain its shape** till the molten metal solidifies to produce **defect-free casting**.
- However, certain **specific properties** are identified that are required at different stages of mould making and casting and standard testing procedures are developed for their measurement.

1. **At the moulding stage:**
   - **Flowability** – ability of the material to be compacted to a uniform density
   - **Green strength** – ability to retain the shape of mould during handling

2. **During casting:**
   - **Thermal stability** – ability to retain shape at high temperature
   - **Refractoriness** – ability to withstand high temperatures without fusion
   - **Dry strength** – to withstand erosive forces and pressure of liquid metal
   - **Hot strength** – to withstand distortion and deformation at high temperature
   - **Collapsibility** – ease to break down in knockout
   - **Permeability** – a path for the escape of gases
   - **Fineness** – to prevent metal penetration and produce smooth casting surfaces

3. **At storage:**
   - **Bench life** – ability to retain moulding properties on standing or storage
   - **Durability** – capacity to withstand repeated cycles of heating and cooling (reusability)

2. Greensand moulding aggregates

- Greensand moulding process has a long history.
- A large production of small and medium sized castings is cast using greensand moulding system.
- Uses natural sand as the main ingredient for moulding.

- Typical green moulding sand mixture/aggregate contains:

  sand + clay + water + additives

  - **Sands** – granular materials normally obtainable or artificially produced by the disintegration or crushing of rocks
  - **Clays** – residual or weathered products of various kind of silicate rocks, added as the principal source of strength and plasticity of moulding sand
  - **Water (a.k.a. moisture)** – added to activate bonding action of clay
  - **Additives** – added to impart special properties in mould (e.g., collapsibility)

- As oppose to greensand system, **dry sand systems** use pure silica or other refractory materials.
- Besides clay, **organic binders** (e.g., dextrin, molasses, glutrin, pitch, or resins) are also used to impart bonding in sand.
- **Moisture** content is thoroughly dried; the moulds are baked in ovens prior to pouring to drive out the moisture.
- Dry sand moulds are generally **stronger** than green sand, and they usually have **better dimensional stability** than green sand in larger castings.

- There are strong economic incentives to use this low cost greensand system, but hardened moulds (dry sand system) are preferred in many cases, particularly for heavier castings.

- Typical **advantages of greensand practice:**

1. Low material costs and avoid the additional costs of mould hardening (as used in dry sand process).
2. High suitability for mechanised systems (rapid turnround of moulding boxes, smooth moulding and casting cycle).
3. Sand is readily reconditioned (as there is little dehydration of clay bond).
4. Reduced risk of hot tearing in casting (due to low-compression strength moulds, which offer less resistance to contraction than hardened moulds).
5. Moulds joint closely, leaving little flash for removal by fettling.
6. The process is environmentally friendly.

- As compared to greensand system, **advantages of drysand practice** :

1. Hardened moulds offer maximum resistance to mould distortion and erosion.
2. Venting problem is reduced (in the absence of moisture).
3. Metal penetration is reduced (by using finer sands and mould coatings).
4. Surface chilling is greatly reduced, facilitating metal flow in thin sections.
5. Problems of drying-out during delays in casting is reduced, leading to surface friability.

3. Ingredients of greensand moulding aggregates

3.1 Sand

- Granular materials of size 0.10 – 2.00 mm produced from disintegrated or crushed rocks

Size (mm)	Type of particle
2.00 - 1.00	Very coarse sand
1.00 - 0.50	Coarse sand
0.50 - 0.25	Medium sand
0.25 - 0.10	Fine sand
0.10 - 0.01	Silt
< 0.01	Clay

- **Natural sand** – principally consists of sand, clay and organic materials (from tree, weeds, etc.)
- **Synthetic sand** denotes a class of several minerals:
  (1) silica, (2) zircon, (3) olivine, (4) chromite
- Typical properties of sand:
  (1) size, size distribution and shape, (2) refractoriness and thermal stability, (3) thermal expansion, (4) hardness, (5) pH

Comparison of natural and synthetic sand systems

	Natural sand	Synthetic sand
Moulding material	Natural sand and water	Sand, bentonite (clay), starch, coal
Sand treatment	Usually not necessary	Necessary.
Moulding	Easy	Easy
Repair of mould	Easy	Relatively difficult
Shake out	Easy	Easy
Reclamation	Easy (only needs water adjustment)	Easy (although mixing is necessary)
Life of sand	Limited	Not limited
Effects on casting	• Mould swelling • Sand adherence • Gas defects	Similar to natural sand but to a lesser degrees (method is good for rather large size castings).

Comparison of properties of different sands

Properties	Silica	Zircon	Olivine	Chromite
Typical composition	>90% SiO_2	$ZrO_2.SiO_2$	46 MgO, 9 Fe_2O_3, 43 SiO_2	45-55 Cr_2O_3, 13-25 Al_2O_3, Rest - Fe_2O_3, MgO,
Colour	White	Brown	Green	--
Specific gravity	**2.28-2.65**	**4.4-4.8**	**3.2-3.4**	**4.4-4.5**
Melting point, C	**1720**	**2660**	**1880**	**1550**
Hardness, Moh's scale	**6.0-6.5**	**7.5**	**6.5-7.0**	--
Thermal expansion at 900 C, %	**1.56**	**0.25**	**1.0**	**0.4-0.7**
High temperature reaction	Acidic	Slightly acidic	Basic	Neutral to basic

3.2 Clay and water

"Particles of sand having a diameter of 20 micron or less and, when suspended in water, fails to settle at a rate of 25 mm per min" – AFS.

- Clays are hydrated aluminosilicates obtained as residual or weathered products of various silicate rocks
  - **plate or flake structures of particle size 20 to 0.10 micron**
  - **when tempered with water, produces a plastic/semi-plastic mass**

- Added 2 - 50 % of sand as a binder in the greensand aggregate; plasticity and bond are developed by the addition of water.
  - **in some mineral deposit, sand and clay occur mixed in proper proportion and can be used directly in foundry; these are called natural moulding sand.**

- Foundry grade clays:

  (1) **Kaolinite**, $Al_2O_3.2SiO_2.2H_2O$ (**fireclay**, ball clays, china clays); Limited use in foundry as bonding properties not high – require higher additions (10-20 %)

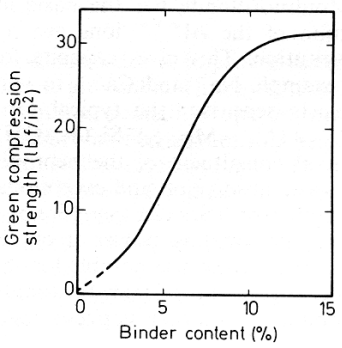
  (2) **Montmorillonite**, $Al_2O_3.4SiO_2.H_2O$, with Al^{3+} partially replaced by Mg^{2+} (**Na and Ca-bentonites**); possess exceptionally favourable bonding capability – require only 3-5 % addition

  (3) **Illite** (weathered product of mica) – principal bonding source in natural moulding sand.

Types of clays	Minerals	Properties	
Ball clay, china clay, fire clay	Kaolinite	• Good refractoriness • Poor bonding, higher binder content required • Irreversible dehydration at 400 – 650 C • Limited use in foundry	
Western (or, soda) bentonite	Montmorilonite	• High water absorption capacity • Very good bonding properties • Bonding regenerated by water addition • Thermally more stable than other clays • Irreversible dehydration at 550 – 700 C	• High swelling capacity, low plasticity, low GCS, high DCS and HCS
Southern (or, calcium) bentonite	Montmorilonite		• Low swelling capacity, high plasticity, high GCS, low DCS and HCS
Illite (or, natural) clays	Illite	• Principal source of bond in natural moulding sand • Moderate bond strength • Irreversible dehydration at 500 – 550 C	

Effect of clay

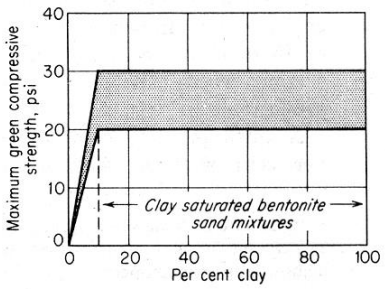
- The basic function of clay is bonding.
- Clay forms a thin coating around each grain and produce cohesion between the grains.
- if the layers become continuous and then progressively thicker, further increase in bonding cannot be achieved.



bentonite-bonded silica sand

Dry compressive strength developed:

- Western bentonites : > 80 psi
- Southern bentonites : 40 – 80 psi
- Fire clays (kaolinite) : moderate
- Fire clay plus western bentonite : > 200 psi



bentonite clay-sand-water mixtures

Clay requirement for saturation

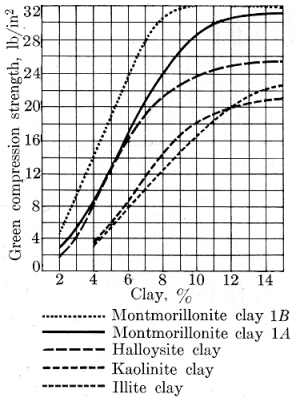
- Depends on purity and type of clay, base sand, and additives
- 8 – 12 % bentonites; 20 – 25 % fire clay (Sand fineness AFS 60–100)

Clay-saturated sands

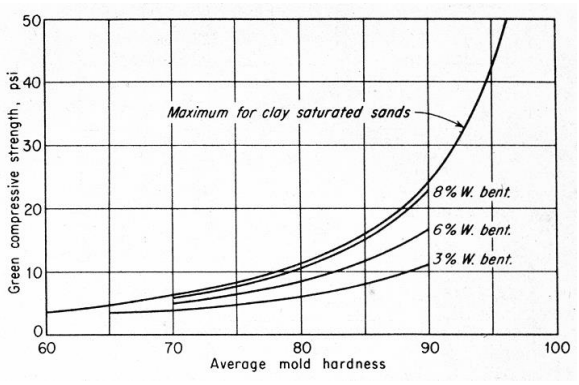
- The most versatile greensand
- Eliminates or reduces casting defects due to sand expansion, erosion etc.
- High strength (GCS = 14–20 psi)
- Require adequate ramming to generate such high strength (> 85 mould hardness)

Clay-unsaturated sand systems

- 4 – 9 % bentonites; 10 – 15 % fire clays
- Used for lighter castings where expansion defects, erosion etc. are lesser problems.



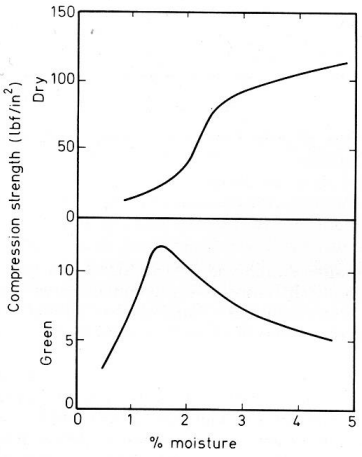
effect of different clay content on green compressive strength



effect of clay content on relationship between mould hardness and green compressive strength

Effect of water

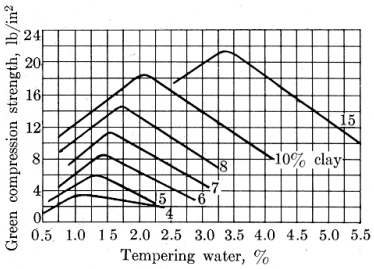
- About **1.5 - 8 % moisture** is added to activate the clay in the sand, causing the aggregate to develop plasticity and strength.



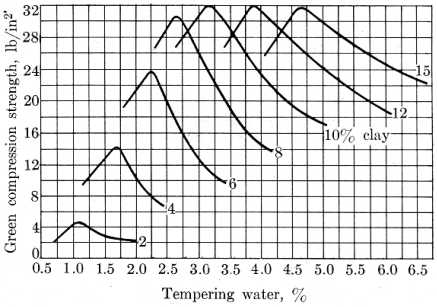
bentonite-bonded silica sand

- The green strength of a moulding mixture increases with the temper water content up to an optimum value determined by the proportion of clay.
- Above this value, additional free water causes the green strength to diminish again.
- Dry strength continues to increase due to improved distribution of the binder and the higher bulk densities attainable.

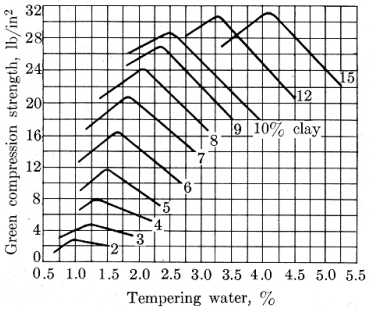
Combined relationship between clay and water contents and bond strength



kaolinite – sand mixture



southern bentonite – sand mixture



western bentonite – sand mixture

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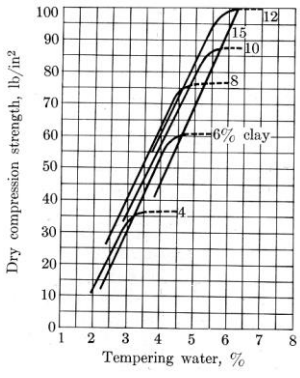
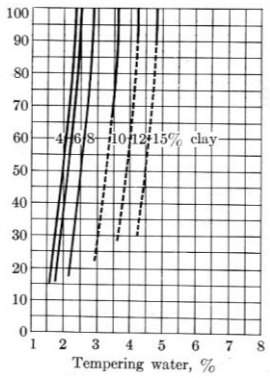
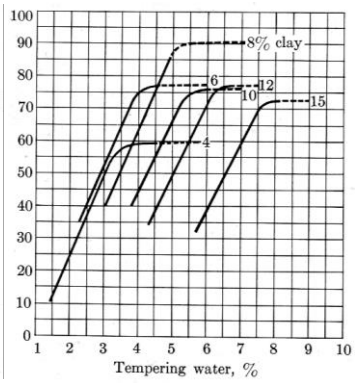


southern bentonite – sand mixture



western bentonite – sand mixture



kaolinite – sand mixture

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Summarising the effect of water

- For a given clay type and content, there is an optimum water content which form the greatest number of clay-water-quartz bonds.
  - **Too much water causes excessive plasticity and dry strength.**
  - **Too little water fails to develop adequate strength and plasticity.**
  - **control of moisture in the moulding sand to develop the best properties is a necessary basis of sand control**

3.3 Additives

- Different **organic or inorganic materials** are added in small quantities to moulding and core making sands to **impart certain special properties** such as improved hot strength, preventing metal penetration, improved collapsibility, improved surface finish, etc.
- The additives may be of **reducing** or **fibrous** nature, or may act as **binding agents**.
- It is necessary to select the **right type** and determine the **correct proportion** of the additive for any given moulding and casting conditions so as to enable the production of flawless castings.

Purposes	Additives
As binder	Cereal, molasses, resin, linseed oil, water glass
Increase collapsibility	Cereals, molasses, fibrous materials
Reduce expansion problems	Cereals, coal dust, fibrous materials
Increase green strength	Coal dust, molasses
Increase dry strength	Cereals, resin, molasses, coal dust
Increase hot strength	Iron oxide, silica flour
Reduce metal penetration	Coal dust, iron oxide, silica flour
Improve surface finish	Coal dust, resin
Increase flowability	Resin, fibrous materials
Increase bench life	Cereals, resin, molasses

Next Class

MME **345**, Lecture **A:05**

General Methods of Moulding Casting

3. Greensand system: Pt.2 – Sand bonding and thermal aspects