

## L.5 : FERROUS CASTINGS - MOULD, CORE, PATTERN MATERIALS AND PROCESSES

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Any amount of care in melting and pouring of metals and alloys cannot help in producing good quality castings if no proper attention is paid in preparation of moulds and cores. In fact, mould and core production may account for one-third of the cost of finished castings. No economy measure is complete without proper selection of moulding materials and maintaining their specification through control tests. Choice of the right type of raw materials for preparation of moulds and cores and specification control ensure a mould or core of uniform quality and minimises the number of defective castings, and this is considered as an important aspect in productivity.

Depending on the specific use, dimensions, accuracy required, ease of operation and above all economic considerations, several moulding methods have been developed over the years - like, sand clay-water system, shell moulding, no-bake processes etc. In all these cases, basic mould/core moulding materials had been sand with different binders. The sand, too, in majority of the cases is silica sand. The basic ingredients, thus, in case of mould or core preparations are sand, binders, additives and coatings.

### S A N D S

**Silica Sand :** Foundry sands, in general, are composed of grains of quartz or quartzite, crystalline forms of silica or other minerals of highly siliceous character which may be found associated with some form of clays. These sands as they occur in nature, may not be suitable for foundry use. It may be necessary to prepare the sand by washing, grading or mixing. The element silica has a density of 2.4 g/cc and a melting point of 1420°C, where

as quartz, the principal constituents of silica sand has a density of 2.66 g/cc and a melting point of about 1750°C. Quartz is in the stable form of silica at room temperature. On heating a series of allotropic changes occur which are accompanied by volume changes. The greatest drawback of silica sand for use as a mould material is the sudden expansion that occurs at 575°C and it is this expansion which governs the tendency of mould face to spall at some stage during casting causing scabs and sand inclusions. Silica sand which is essentially SiO<sub>2</sub> also contains various percentages of impurities like iron oxide, lime, magnesia, potash, alumina etc. The influence of these constituents on the properties of sand is shown in Table-1. Silica sands can be broadly classified as :

- Natural moulding sands

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- Crude silica sands
- High silica sands

Natural moulding sands contain appreciable amount of clay of unspecified mineralogical constituents and they are normally used directly for preparation of mould and cores. The foundry properties of natural moulding sands depend on the clay mineral present. The quantity of clayey matter associated with natural moulding sand is usually in excess of the actual requirements for developing required strength in the sand mixture. It is therefore, customary to blend such natural moulding sands with relatively clay free river sand to get optimum properties in sand mixture.

Crude silica sands are obtained from river beds, sea coasts and dunes. Owing to this nature of origin and occurrence, they contain low percentage of clayey matter. These sands are used for mould making after blending with natural moulding sand.

High silica sands are usually obtained by processing loosely consolidated sand deposits of sedimentary origin. Majority of these sands do not require elaborate processing and some of them may even be available with

requisite grading and can be used as mined. Those that are not sufficiently well graded, are washed and sieved for grading into fine, medium and coarse fractions. High silica sands may also be produced artificially by crushing quartzite sand stones with subsequent washing and grading. High silica sands are usually high in silica and contain very little clayey matter. Depending on the silica content, high silica sands are divided into following grades :

Grade A :  $\text{SiO}_2$  content over 98%

B :  $\text{SiO}_2$  content above 95% and upto 98%

C :  $\text{SiO}_2$  content above 90% and upto 95%.

**Special Sands** : The use of special sands like zircon, chromite, olivine etc. is to overcome the limitation of silica sands. High thermal expansion and phase change of silica sand can lead to expansion defects particularly when fine grained sands are employed. Special sands can be grouped under three major headings :

(a) Zircon sand, (b) Chromite sand, and (c) Olivine sand

**Zircon Sand** : Zircon ( $\text{ZrSiO}_4$ ) occurs together with other heavy minerals - notably rutile and ilmenite in certain beach sands. Zircon is believed to dissociate into  $\text{ZrO}_2$  and  $\text{SiO}_2$  at elevated temperature, but this does not appear to affect its performance in foundry. Its low and regular thermal expansion provides high resistance to scabbing defects. The grains tend to be rounded and sand is free from clayey material. The sand offers high resistance to metal penetration and excellent surface finish owing to fine grain size, high refractoriness and low thermal expansion.

**Chromite Sand** : Natural chrome ore from which foundry sands are obtained contains 44 to 50%  $\text{Cr}_2\text{O}_3$ . The other constituents are serpentine, Pyroxene, feldspar, quartz, chlorites and carbonates. Suitable foundry sands are therefore produced by crushing, removing the gangue and

screening to the desired grades. High refractoriness and low regular thermal expansions are characteristics of chromite sand which makes it resistant to thermal cracking, spalling or scabbing. Chromite sand shows lower wetting property in contact with steel or metal oxide and exhibit exceptional penetration resistance in comparison to zircon or silica sand. When bonded with acid catalysed furan resins, the sand, however poses problem due to its slow hardening rate. In such cases, sand with consistently low acid demand value requires to be selected. Chromite sand also forms a very strong sintered layer (Frit) at the metal - mould interface.

**Olivine Sand :** Olivine sand is essentially a solid solution of two silicates : Magnesium orthosilicate (forsterite,  $Mg_2SiO_4$ ) and iron orthosilicate (fayalite,  $Fe_2SiO_4$ ) with impurities like serpentine, pyroxene, chlorites, talc etc. The quality of sand is dependent upon the ratio of forsterite to fayalite - the higher the amount of forsterite, the better. Its bonding with clays are satisfactory, in fact, less amount of bentonite is required in comparison to silica sand. Limitation lies in its use with acid catalysed furane resin binder due to its basic nature.

**Chamotte Sand :** It is calcined clay fired so that clay fuses together in hard lumps. The lumps are then ground and screened to size suitable for moulding. The sand quality is dependent on firing and quality of clay. The better is the grade of chamotte, the less is the danger of mould surface fracture.

The average chemical composition of special sands and their properties are shown in Table-2 and Table-3 respectively.

## **BINDERS**

The basic requirements of the raw materials for mould making is that the sand particles should bond together in such a way that the desired shape is easily formed, which should be strong enough to support and hold the molten metal, yet weak enough for casting to be knocked out of the mould

easily. The binder provides this bond. The moulding process when classified based on the materials used, differs due to adoption of binders to bond the sand grains. In general, the binders used for the moulding processes can be categorised as :

- a) Inorganic binders
- b) Organic binders
- c) Synthetic resin binders

**Inorganic Binder** : Most widely used binder of this group is **clay** - which is essentially used for making moulds. Clays are group of minerals in which chief constituent is hydrated silicate of alumina. Of all the clay groups 'bentonite' clay is most common. Bentonites have 75% or more crystalline clay like minerals ( $\text{Al}_2\text{O}_3 \cdot 4\text{SiO}_2 \cdot x\text{H}_2\text{O}$ ) montmorillonite or beidellite. Table-4 lists characteristics of some clay minerals used for bonding moulding sands.

When sand and clay are milled together, each sand grain is evenly coated with clay. So far as the bonding mechanism is concerned, each flake can be regarded as a thick structural unit. At the initial stage of mulling, most of the water molecules are randomly oriented. As the mulling progresses, the clay aggregates breakdown into individual flakes, thus increasing surface exposed to water. The water films now gets coated uniformly and distributed in a regular fashion. The coating thickness becomes thinner and more stable, and result in more cohesion between clay and sand particles bringing in a developed strength. The optimum water requirement to develop strength however, differs from one type of clay to another.

**Sodium Silicate** : Aqueous sodium silicate ( $\text{Na}_2\text{O}$ ,  $\text{SiO}_2 \cdot x\text{H}_2\text{O}$ ) is another type of inorganic binder which is used in conjunction with a hardener to bond the sand grains and develop strength.

The hardening mechanism of sodium silicate binder suggests that strength in sand aggregates is imparted due to (a) chemical reaction - responsible for formation of silica gel as a result of reaction with hardener

and (b) a physical reaction -causing dehydration responsible for further increase in strength values with time, making the process dependent on time (self set process).

In fact,  $\text{SiO}_2 : \text{Na}_2\text{O}$  ratio influences strength as stability of silica in sodium silicate is in a state of delicate balance and largely depend on solids to water concentration. Silica gel is precipitated when this balance is lost. With high ratio silicates, precipitation of silica gel could be even due to the evaporation or dehydration of water. The gelation in lower ratio silicates is generally accelerated by chemical reactions with hardener. The most common hardener which are in use for strength development are Carbon dioxide, Ferrosilicon, Dicalcium silicate, and portland cement.

**Cement** : Cement as binder finds specific use and claim economy for the production of large castings like ingot moulds and general engineering castings. The moulding mix consists of sand with 8 to 12% cement and 4 to 6 % water. The sand develops great hardness and strength by the setting action of portland cement. The characteristic slow curing rate of cement sand process is accelerated by use of molasses. The molasses as an additive also imparts a better collapsibility to the mix which is otherwise exhibits a poor breakdown.

**Organic binder** : Organic binders are combustible in nature, thus collapsibility is improved when organic binders are used. In fact organic binders are mainly used in core-making processes. These binder systems may be categorised based on material used as listed below :

- (a) Oil
- (b) Phenolics
- (c) Polyurethane
- (d) Urea formaldehyde
- (e) Furan

**Oil Binder :** Linseed oil and alkyd oil are the binders extensively used for core making. The linseed oil consists of glycerides of unsaturated fatty acids. A typical composition consists of 22% oleic acid, 17% linoleic acid and 51% linolenic acid. The oxygen attacks the point of unsaturation and polymerises the oil to a solid, cohesive, flexible gel which binds the sand grains.

The alkyd oil consists glyceryl-phthalate-ester-linked linseed oil. The curing is through oxidative polymerisation of the oil similar to linseed oil. The reaction is generally initiated by an oxidizing agent, viz. sodium perborate and catalysed by a metallic dryer, viz. cobalt or lead naphthanaite. Alternatively, the curing can be achieved by isocyanate also.

**Phenolic binder :** Phenol formaldehyde resins belong to this category. These resins are prepared by the condensation of phenol with formaldehyde. Depending on condition used, two types of PF resins are in use.

- (a) Novolac (Phenol: Formaldehyde :: 1:0.7)
- (b) Resol (Phenol: Formaldehyde 1: 1.5 to 1.3)

Novolac resin is also termed as shell resin finds application in fluctuating humidity and temperature conditions. In its curing, it is mixed with 'Hexa', which is a mixture of hexamethylene tetramine and calcium stearate in the ratio of 70:30. When the precoated shell sand comes in contact with the heated mould or core box at  $(245^{\circ} \pm 15^{\circ}\text{C})$ , the hexamine decomposes and reacts with the residual water in resin to liberate ammonia and formaldehyde. The formaldehyde reacts with novolac resin, produces cross-linked phenolic polymer which bonds the sand grains. Calcium stearate improves the flowability of the mix and ease the core or mould withdrawal.

**Urethane Binders :** This group of binders derive it name as the developed bond is through urethane polymer. The binder system consists of phenolic resin (Novolac) and isocyanate (Diphenyl methane di-isocyanate : MDI)

which is gassed through amine gas (TEA, Triethyl amine; or DMEA, Dimethyl ethyle amine). The process is a no-bake process and popularly known as 'cold-box' process of core making.

**Urea formaldehyde binders :** These resins are prepared by reacting urea and formaldehyde in mildly alkaline condition. These resins can be crosslinked using acid catalyst, e.g. ferric chloride. The hot strength and resistance to thermal stress are however low.

A combination of phenolic cresol (PF) Urea formaldehyde (UF)/Furan resin (FA) gives better binder performance and are the most common 'hot-box' binders. However, owing to presence of nitrogen, it is not used for steel castings.

**Furan Binders :** These resins are made from furfuryl alcohol. The binders reaction is polymerisation of these chains alongwith a certain amount of cross-linking. Mildly acidic chloride salts promote the setting reaction.

Based on material used and method of curing, the organic binders can be grouped as follows :

#### Heat cured

- a) Phenolic novolac (Shell process)
- b) Linseed Oil
- c) Phenolic hot box
- d) Alkyd oil isocyanate

#### Gas cured

- a) Silicate.-  $\text{CO}_2$
- b) Phenolic/isocyanate/Amine (Urethane bond)
- c) Phenolic/ $\text{SO}_2$
- d) Furan/ $\text{SO}_2$



### No bake

- a) Alkyd/isocyanate
- b) Furan/acid
- c) Phenolic/isocyanate
- d) Phenolic/acid
- e) Phenolic/ester
- f) Silicate/ester, ferrosilicon, dicalciumsilicate

The organic binder systems and their comparative properties are given in Table-5 and Table 6 respectively.

### ADDITIVES :

Additives are the materials generally added to sand mixtures to develop some special property in moulding sand. The 'additives' particularly have influences on green, air set, dry and hot properties.

The type of additives and their effects are listed below :

<i>Materials</i>	<i>Type</i>	<i>Effect</i>
Cellulose material (Wood flour)	Cushioning additives	<ul style="list-style-type: none"><li>• Improves surface finish</li><li>• reduces hot, dry, retained strength and spalling</li></ul>
Carbonaceous materials (Coal dust, pitch, oil, carbon)	Facing additives	<ul style="list-style-type: none"><li>• Retards expansion</li><li>• increases hot deformation</li><li>• creates reducing atmosphere</li></ul>
Silica flour, iron oxide, alumina flour, fly ash	Fine additives	<ul style="list-style-type: none"><li>• Increases green, dry hot and retained strength</li><li>• Prevents erosion</li><li>• controls finning and pinholing</li></ul>
Dextrin, corn flour	Cereals	<ul style="list-style-type: none"><li>• Improves surface finish</li><li>• Reduces penetration</li><li>• Improves toughness, green, airset, dry and hot strength</li></ul>
Sodium chloride Sodium carbonate	Chemical additives	<ul style="list-style-type: none"><li>• Controls inclusions</li><li>• improves surface finish</li></ul>

## **PATTERN MATERIALS**

A pattern is basically a model 'job', which is used for making a cavity to receive the molten metal which on subsequent solidification forms the casting.

The materials which are normally used for pattern making are :

- Wood : Pine, Teak, Mahogany
- Metal : Cast iron, aluminium alloys, brass and bronze
- Plaster : Plaster of paris
- Wax or mercury : (Investment casting)
- Plastics : Thermosetting resin, Foam Polystyrene

There are several factors which have influence on selection of particular type of pattern material. These are :

- \* Number of castings to be produced
- \* Moulding method adopted
- \* Accuracy and surface finish required
- \* Wall thickness of casting required

Several allowances and tolerances need to be incorporated in preparation of pattern to obtain the specified dimension of the casting. The usual tolerances are :

- Allowance for shrinkage
- Allowance for machining
- Allowance for draft
- Allowance for rapping or shake
- Allowance for distortion
- Allowance for mould wall movement

## **PROCESS CONTROL**

The most important basic characterisation required for a ferrous foundry sand are the following :

- a) Chemical analysis
- b) Mechanical grading and grain fineness number (GFN)
- c) Grain shape
- d) Refractoriness

These tests are carried out in an operating foundry as routine test to select the raw material for the system-sand to be prepared, as each individual character influence the property of sand mix.

The control tests, however, is a measure on sand mix to have a specific property, it also provides information when there is deviation from the specific property. The usual routine control tests are :

- a) Determination of compactability
- b) Determination of moisture
- c) Specimen weight determination
- d) Permeability determination
- e) Active clay determination (M.B.Test)
- f) Green compression strength determination
- g) Splitting strength determination

### **Compactability**

Compactability testing has significance and relevant influence on :

- a) Preparation of moulding sand
- b) Determining of the squeeze pressure
- c) establishing mould properties as a base reference.

Compactability values are sensitive to water addition and mulling time. During preparation of moulding sands, particularly in mulling operations, non-uniform distribution of water causes wet lumps to form, keeping bulk of sand dry. Absolute moisture percentage in those cases is an unreliable measure of degree of temper, while compactability acts as a measure of effective degree of temper.

During compaction, for full energy transfer, the sand must be dry enough to produce a final height which is above the travel limit of squeeze element. In actual foundry moulding, the facing sand should be kept considerably wetter in comparison to back up sands to facilitate complete energy transfer which results in high mould density.

Compactability determines moisture and can be adopted as a routine control test by establishing reference curves for moisture-compactability data on sand mix.

### **Moisture**

At a constant compactability, a change in the moisture level of sand mix influences the property. In fact, every additive in a system sand has a moisture requirement of its own. At a constant compactability, the moisture requirement will increase in case of those sands with oolitic grains or inert fines. Sand grains, on continued use, becomes coated with porous, fused or dry bonded material which absorb water that is readily released by the heat of metal.

**Specimen weight :** Specimen weight is influenced by specific gravity of the material and packing of the sand. If there is a gradual reduction in specimen weight over a period of time, this may indicate the formation of oolitic grains which have a specific gravity well below that of silica. To derive maximum benefit from test data, the specimens should be prepared to a length of 2 in  $\pm$  0.010 in rather than the 1/32 in tolerance accepted in the past.

## **Permeability**

The actual packing of the sand grains is reflected through achieved permeability. In this respect it is a realistic measure than the AFS screen analysis. An increase in permeability indicates a more open structure and can lead to rough casting surface, burn-in and metal penetration. A decrease in permeability is indicative of too tight a packing indicating moulds are prone to blow holes, pin holes, and gas roughened surface.

## **Active clay determination**

In system sand a part of bentonite becomes inactive or dead in continuous cycle. The estimation of live clay is necessary to estimate fresh clay addition. The Methylene blue test provides three clay values that can be used in control of system sand. These are total live clay - which is determined by using ultrasonic scrubber; the dispersed clay - determined using only a disc agitator and suppressed clay - which is difference between total clay and dispersed clay. The suppressed clay is the amount of live clay entrapped in lumps or otherwise not responding to methylene blue. Suppressed clay indicates the effectiveness of mulling operation, and the degree of interaction of additives. System sand formulation requires special attention when the suppressed clay is observed greater than 0.7%.

## **Green Compression**

The green compression test is in practice for primary sand control in foundries. It is considered that proportion of clay present has a direct bearing on G.C.S value though there are other factors too, which influence the GCS. The degree of mulling, the compactability and additives also have influence on GCS. The test is best applied in conjunction with some other mechanical test to derive an effective clay value.

## **Splitting Strength**

The splitting strength is not affected as much by the presence of inert fines as is the case with GCS test. In this test, the specimen is loaded on its side between two plane surfaces. With the splitting strength test, the plane of rupture is at right angles to the plane of rupture in the older, green tensile strength. Fig-1 shows the relationship between compression and splitting strength for lines of constant effective clay. The splitting strength is not affected by some of the factors that alter the green compression and the ratio between the two test results can be used as a control in its own right.

## **SUMMARY**

While qualitative assessment of sand is the basis of sand selection for specific application in a ferrous foundry, routine check for incoming raw materials, in general, ensure homogeneity and consistency. The specific requirements may vary depending on the process adopted. For example, a green strength of 15 to 16 psi with a green deformation of 0.016 to 0.02 in/In considered to be ideal in the production of iron castings weighing between 20 and 140 kg, when conventional jolt squeeze machine is used. Castings of similar range when produced by high pressure moulding, operating between 120 to 150 psi squeeze pressure, needs a green compression strength of 25 to 32 psi. The standard for specific process thus need to be set and constant monitoring through control test is essential for adopting modern and improved methods of production for producing quality castings to specification at competitive price.

In the present scenario of global liberalisation, the 'development' and 'quality' are key words for survival. With the firm belief that industrial development is the back bone for prosperity of a country, the challenges of modern technological developments in foundry is being met by National Metallurgical Laboratory, Jamshedpur and its foundry units at Ahmedabad, Batala, Howrah and Madras, with a motto to provide R&D support and ensuring quality by choice only.

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TABLE : 1

**CHEMICAL ANALYSIS AND  
PROPERTIES RELATION**

Silica sand is analysed for :

- SiO<sub>2</sub>      High SiO<sub>2</sub> — High Refractoriness.
  - Al<sub>2</sub>O<sub>3</sub>
  - TiO<sub>2</sub>
  - Fe<sub>2</sub>O<sub>3</sub>
  - CaO
  - MgO
  - K<sub>2</sub>O
  - Na<sub>2</sub>O
- Presence in small quantities no serious effect .  
 → Higher quantities — lower hardening rate with self set binder  
 → Higher quantities — lower refractoriness

TABLE : 2

**AVERAGE CHEMICAL ANALYSIS OF SPECIAL SANDS**

Chemical Constituents %	SANDS		
	ZIRCON	CHROMITE	OLIVINE
ZrO <sub>2</sub>	65 to 67	—	—
Cr <sub>2</sub> O <sub>3</sub>	—	46 to 47	—
SiO <sub>2</sub>	27.6 to 33.5	0.9 to 1.5	40.5 to 42.0
Fe <sub>2</sub> O <sub>3</sub>	0.06 to 0.96	23.5 to 28.2	6.0 to 8.5
Al <sub>2</sub> O <sub>3</sub>	0.18 to 2.8	15.0 to 20.0	0.2 to 2.0
MgO	—	10.00 to 12.0	46.0 to 49.0
CaO	—	—	0.1 to 0.8
TiO <sub>2</sub>	0.05 to 2.0	—	—



**TABLE : 3**  
**PROPERTIES OF FOUNDRY BASE SANDS**

	SILICA	OLIVINE	CHROMITE	ZIRCON
Colour	White-light brown	Greenish grey	Black	White-brown
Dry Bulk density g/ml	1.57-1.74	1.8-2.1	2.5-2.7	2.9-3.2
Specific Gravity	2.65	3.20	4.50	4.60
Grain shape	Angular/rounded	Angular	Angular	Rounded/angular
Grain distribution	2-5 screen	3-4 screen	4-5 screen	2-3 screen
AFS-GFN ranges	25-180	40-160	50-90	95-160
Expansion at 900°C(%)	1.56	1.02	0.65	0.25
Fusion Point°C	1425-1760	1538-1760	1760-1982	2038-2204
Chemical reaction	Acid-neutral	Basic	Neutral-basic	Acid-Neutral
Resistance to metal penetration	Moderate, consistent with grain size	Good	Excellent	Moderate, consistent with grain size
Bonding Characteristics	Excellent with all types of bond	Satisfactory except with acid catalyst system	Good with all types of bond	Excellent with all types of bond

**TABLE: 4**

**Characteristics of some clay minerals used for bonding molding sand**

Clay mineral type	Composition type	Base Exchange	Refractoriness (softening point)	Swelling due to water	shrinkage due to loss of water	Particle size and shape
Montmorillonite class 1A	$(OH)_4 Al_4 Si_8 O_{20} nH_2O$ Ex. 90% montmorillonite 10% Quartz, Feldspar, Mica, etc.	High. Na is adsorbed ion, pH = 8-10	1150-1345°C	Very high gel forming	Very high	Flake size less than .00001in.
Montmorillonite class 1B	$(OH)_4 Al_4 Si_8 O_{20} nH_2O$ Ex. 85% Montmorillonite, 15% quartz, limonite, etc.	High. Ca adsorbed ion pH = 4-6.50	980°C+	Slight little tendency to gel	Very high	Flake size less than .00001 in.
Kaolinite class IV, fire clay	$(OH)_4 Al_4 Si_4 O_{10}$ Ex. 60% Kaolinite, 30% illite, 10% quartz, etc.	Very Low	1650-1700°C	Very low non-gel forming	Low	Fire clays are often ground and therefore may be relatively coarse or may be ground to a flour.
Illite grundite	$(OH)_4 K_\gamma (Al_4 Fe_4 Mg_4 Mg_\delta) (Si_8 - \gamma Al_\gamma) O_{20}$	Moderate	1370°C	Low, non-gel forming	Moderate.	

**TABLE: 5**

**ORGANIC BINDER SYSTEMS FOR POPULAR CORE/MOULD MAKING PROCESS**

PROCESS	BINDER	HARDNER/ CATALYST	CURING TEMP-°C
LINSEED OIL/DEXTRIN	LINSEED OIL DEXTRIN WATER	OXYGEN (AIR)	220 ± 10
ALKYD OIL a) AIR SET	ALKYD OIL	SODIUM PERBORATE ACCELERATOR COBALT NAPHTHANATE	SETTING AMBIENT. FULL CURE : STOVING
b) NO BAKI	1. ALKYD OIL 2. MDI	ACCELERATOR COBALT NAPHTHANATE	AMBIENT
SHELL HOT BOX	PF (NOVOLAK) PF (RESOL) PF/FA, F/UF, UF/FA	HEXAMINE NH <sub>4</sub> CL	245 ± 15 225 ± 25
COLD BOX a) AMINE GASSED	PART-1 : PF (NOVOLAK) PART-2 : MDI	TEA, DMEA	AMBIENT
b) SO <sub>2</sub> GASSED	PF (RESOL) PF/FA	SO <sub>2</sub> , MEKP	AMBIENT
PHENOLIC COLD SET a) ISOCYANATE	PART-1: PF (NOVOLAK) PART-2: MDI	PPP	
b) ACID CATALYSED	PF (RESOL) PF/FA PF/UF/FA UF/FA	PTSA, XSA, BSA, H <sub>3</sub> PO <sub>4</sub> , H <sub>2</sub> SO <sub>4</sub> & THEIR MIXTURES	AMBIENT

**DEFINITION :**

- |   |  |
|---|--|
| BSA - BENZENE SULPHONIC ACID  | DMEA - DIMETHYLETHYLEAMINE                       |
| H <sub>2</sub> SO <sub>4</sub> - SULPHURIC ACID                                   | H <sub>3</sub> PO <sub>4</sub> - PHOSPHORIC ACID |
| MDI - DIPHENYLMETHANE DIISOCYANATE  | MEKP - METHYL ETHYL KETONE PEROXIDE              |
| PF - PHENOLFORMALDEHYDE RESIN   | PF/FA - PHENOLIC FURAN RESIN                     |
| PF/UF/FA - COPOLYMER RESIN, PHENOLFORMALDEHYDE/UREA-FORMALDEHYDE/FURFURYL ALCOHOL | PPP - 4-(3-PHENYL PROPYL) PYRIDINE               |
| PTSA - PARATOLUENE SULPHONIC ACID   | TEA - TRIETHYLAMINE                              |
| UF/FA - UREA FURAN RESIN  | XSA - XYLENE SULPHONIC ACID                      |

TABLE - 6

## COMPARISON OF PROPERTIES OF CHEMICAL BINDER SYSTEMS

Chemical Binder Systems	Binder in sand mix(%)	Catalyst	Other additives	Strip time mini.(Min)	Max. work time (Min.)	Mini time prior to pouring (hr)	Relative tensile strength
No Bake (Non gassed) Furan acid cured	1.5	H <sub>3</sub> PO <sub>4</sub> TSA, BSA	Boric acid Iron oxide, silica flour	30	45	2	Good
Phenolic acid cured	1.5	H <sub>2</sub> SO <sub>4</sub> TSA*, BSA*	Iron oxide	30	45	2	Good
alkyd/oil urethane	1.8	Amines / Metal driers	Iron oxide, silica flour	5	60	12	Good
Phenolic urethane	1.2	Substituted pyridines	Iron oxide	2	20	1	Good
Silicate ester	3.5	Acetin	--	5	45	1	Good
<b><u>GAS CURED</u></b>							
Silicate CO <sub>2</sub>	4.5	CO <sub>2</sub>	Dextrin, pitch	Immediate	180-240	1	Fair
Phenolic Isocyanate/ Amines	1.5	Triethyl amine(TEA)	Iron oxide	Immediate	180-240	1	Good

\* TSA : Toulene Sulphonic Acid

\* BSA : Benze Sulphonic Acid

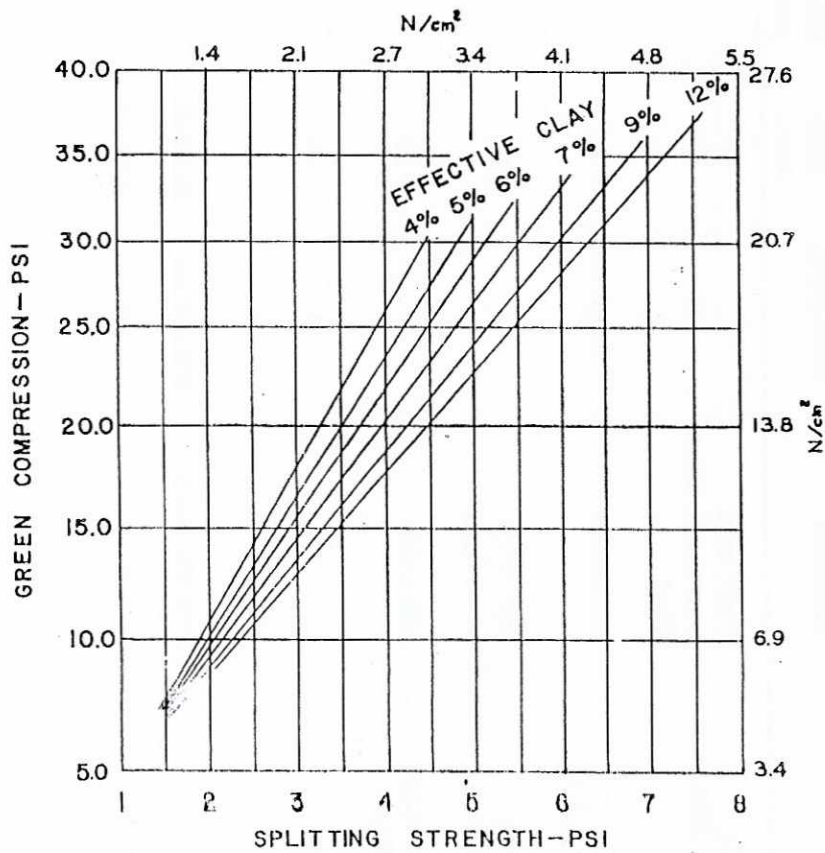


Fig. 1. Effective clay chart based on the relationship between green compression and splitting strength.