FOUNDRY BINDERS – 3R TO IMPROVE WORKPLACE ENVIRONMENT

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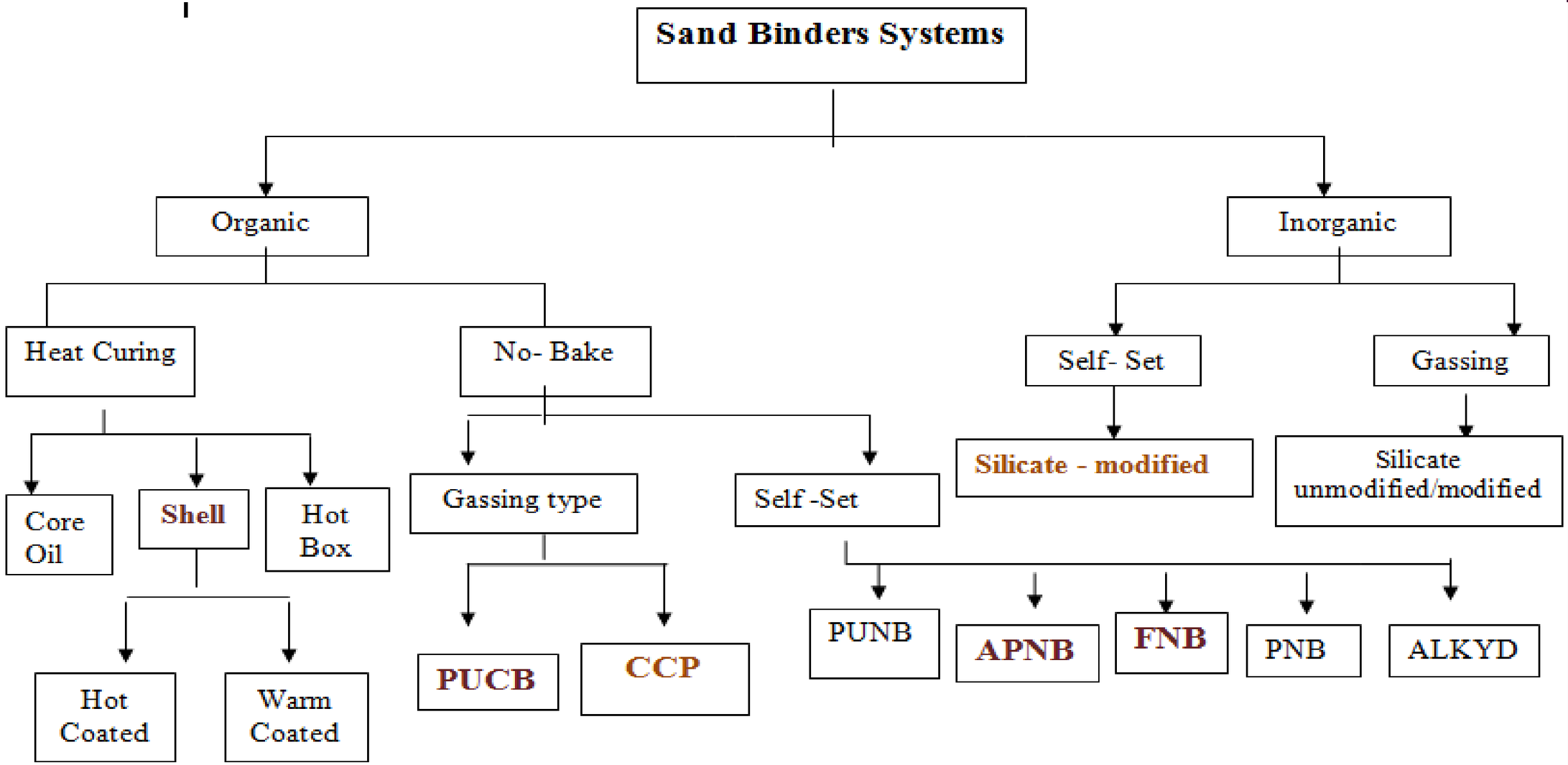
Modern Binders – Quality requirements

- Should be effective at low addition level
- Should meet basic requirements of individual Foundries like :
  - BL , ST, speed of cure, good handling and hot strength, good collapsibility etc.
- Environment friendly
- Good reclaimability
- Favourable economy

Formulating the right Binder systems meeting above requirements is a big challenge to Binder manufacturers

Modern Chemical Binders in use in Foundries in India & Sub- continent



Market Share of Different Chemical Binders In Foundries In India

- Binder systems marked with **Deep Brown** colour are most popular and constitute more than 70% of all synthetic Binder systems in use in India and sub -continent.

- Binders marked with Light Brown colour are of limited use but consumptions are likely to increase, main reason being these offer better work place Environment than many others.

- Among rest of the systems, use of Hot Box in ferrous Foundries no longer exists, but is on rise in non- ferrous Foundries, especially Aluminium and its alloys.

- Self -set version of modified silicate is in process of reintroduction, main reason being this is the most environment friendly system among all Binders.

- Use of PUNB is restricted to handful of Foundries. One or two being manufacturers for steel valve castings ,another is for making cores for automotive castings and one dealing with sand castings for Aluminium and it's alloys.

Why Reclamation ?

Environmental:
Recycling of used sand means less excavation and less demand for new Sand i.e. better protection of ecology.
Lesser demand of binders for reclaimed sand means lesser pollution in work place .

Technical:
Lesser binder in reclaimed sand means lesser evolution of gases during pouring , means lesser gas related defects in castings .

Economical:
More use of recycled sand means lesser use of fresh sand means saving of cost of fresh sand and also cost of disposal of used sand.
Lesser binder demand means reduced cost.

Reclamation Process (For Chemically Bonded Sand)

❖**Mechanical**

➢Mechanical reclamation process usually involves attrition which is most suitable for removal of bonds which are brittle. Furan bonded sand is most suitable for this process. In some cases, primary mechanical process is followed by secondary to get more reuse level of reclaimed sand.

➢Recently, in case of secondary mechanical reclamation ,for better efficiency , a new process called dynamic reclamation has been introduced. This is supposed to be more efficient than secondary attrition.

In mechanical reclamation ,Binder removal is 15-20% of feed value in primary attrition. In secondary attrition, it is as high as 50% of feed value.
For example , in case of Alpha set if LOI of feed sand is 2%,after primary attrition, value will be in range of 1.7%.If same sand is fed to secondary reclaimer, LOI value will drops down to around o.85%.

Reclamation Process (For Chemically Bonded Sand)

❖**Thermal**

➢Thermal reclamation is most efficient among all processes and sand reclaimed in this process becomes as good as or even better than new sand.

➢In this process, crushed molds and cores with chemical bonded sand are usually fed in a heated chamber @ $\geq$ 650˚C where resin particles are burnt preferably with direct flame in fluidized bed.

➢In India, used RCS, used cold box sand, furan and alpha set bonded sand are in operation in some foundries for thermal reclamation.

➢In case of APNB, pre-mixing of used sand with some additive in water base slurry form is necessary before entering hot chamber for effective removal of in-organic portion of the Binder.

➢ However Thermal reclamation process is costlier than Mechanical & usually feed sand is Mechanically reclaimed and is not fed directly form knock out area for purpose of better economy.

Reclamation Process (For Chemically Bonded Sand)

❖Thermo Mechanical

- Comparatively new process and is applicable to Sand bonded with modified silicate, self- set
- Steps involved are :

- Heating used sand at about 150^0C to remove moisture and increase bitterness
- Cooling and attrition to remove cured silicate film

Green sand reclamation – Necessity & Challenge

- Foundries using both moulds of cores out of synthetic Binders, reclamation is easy and common practice.
- Approximately 70% of total ferrous metal cast are in Green Sand process
- In automotive Foundries, usually moulds are made of Green Sand and Cores are either with PUCB and or RCS
- In most of the cases used cores are scrapped and used for land filling

Thus biggest challenge to Foundries following Green Sand process is to reclaim Green Sand and Chemically bonded sand simultaneously and bringing the quality up to the standard of usability of same for making cores to protect ecology and environment by way of reduction of excavation of new sand and disposal of chemically bonded sand.

Waste Generation in Green Sand Foundries, a serious Environmental issue
A hypothetical Case

- Foundries producing Automobile castings, use approx. 85% molding sand (green sand) and 15% cores made from synthetic Binders, mostly PUCB, RCS or both.

- At shakeout, physical loss of molding sand is 2.5% and inclusion of core sand is 50% of total.

- Thus, from 100 kg sand from mold (85 kg)/core (15kgs) assembly, generated molding sand is 85x97.5%=83 kg (rounded off) and core sand going into system is 7.5 kg (50% of total), making total of 90.5 kg.

- Disposable green sand quantity becomes (90.5-85) =5.5 kg .Disposable core sand=7.5 kg. Disposable total sand becomes 5.5+7.5=13 kg

- Assuming sand to metal ratio of 6:1, casting produced out of 100 kg (Mold / Core) sand is 100/6 i.e.16.66 kg.

- **In a 1000 MT/month Foundry, disposable sand quantity becomes 13/16.66 x 1000=780 MT/month**

- **Requirement for new sand for making cores = 15/16.66x1000= 900 MT**

Combined Reclamation of Green & Chemically Bonded Sand

Attempts for reclaiming green sand suitable for use with chemical binders did not materialize till 1994, when a technical paper presented in GIFA (June 1994) titled **"Using Reclaimed Sand for Chemically bonded Cores**" by Steven E. Clark, Charles W. Thomas, Robert Williams and Mary Beth Krysiak, based on their studies at R.H Sheppard Co., Hannover, Pennsylvania showed hope.

- The paper claims that by using a combination of heat and abrasion can bring back properties of used green sand for re-use in chemically bonded system.

- As per the publication, green Sand reclaimed by above process could successfully be used with PUCB, FNB and so called Beta Set Binders either fully or in combination with new Sand without increasing addition level of binders or sacrificing core quality.

- One more technical paper titled " ***Reclaimed clay bonded sand used to make superior chemically bonded sand cores*** " presented by **Roger A. Hayes** in IIF transactions 1997 on 25th – 27th Jan, Mumbai has given details of Combined reclamation of Green Sand moulds and cores made with hot box and cold box

- In Indian Foundry Congress held in Kolkata between 3rd to 5th of Feb'17, one exhibitor exhibited PUCB cores made with reclaimed green sand with addition level of 0.9:0.9 as per their claim, which is not excess of what is used in new sand from sources in different parts of India.

Photographs of PUCB cores made from Reclaimed Green Sand moulds and cores from PUCB & RCS

Addition level - 0.9:0.9 (as claimed)

Exhibited in 65th IFC Kolkata, India held between 3rd to 5th Feb' 2017

Chemical Binders & Reclamation of used sand

- Among self-sets FNB & APNB are most commons in Foundries in India & its sub-continent.

- Most of the Foundries using self-sets use CSM for mixing and reclaim used sand Mechanically.

- Primary attrition is most common for FNB, whereas primary followed by secondary are followed by few.

- Moulds constitute both flaskless and flasked.

- Small and medium size moulds are made in loop line or carousal.

- CI Foundries prefer FNB over APNB whereas steel Foundries prefer APNB.

Modified Silicate, Self – Set

Emerging as complete self-set

The System

- Two Part System

- Part One (Binder): Sodium Silicate modified with Organic additives.

- Part Two (Curative) : A blend of specialty Organic chemicals.

Curing

Sand + Liquid Hardener + Binder $\longrightarrow$ Cured Mould / Core

Range of Hardeners are available to suit specific BL & ST requirements of mixed sand

Typical BL and ST of molds using various Hardeners @10-15 % addition (by wt. of Binder) @ RT of 32 DC and RH of 70% in Cochin sand:

Hardener	Fast	Medium	Slow
BL (mts –secs)	2-30	6-30	25-0
ST (mts-secs)	7-30	20-0	95-0

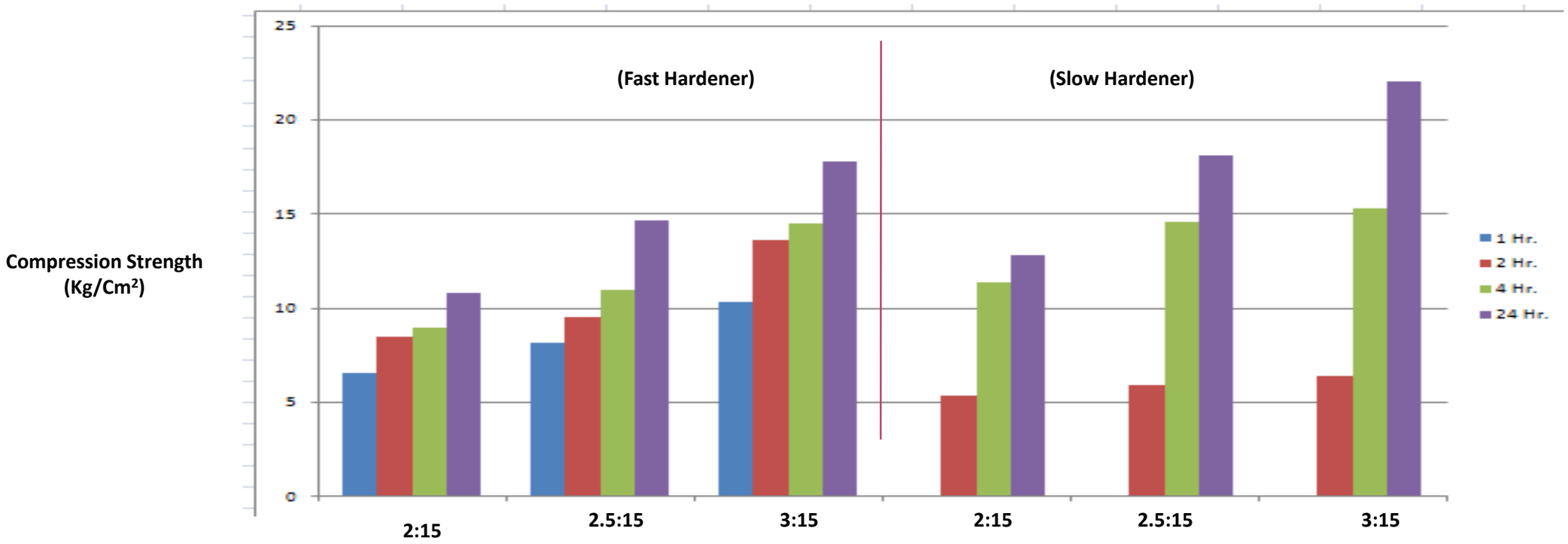
Salient Features

- Works at additional level of 2.0–3.5 : 10 – 15.
- Offers cleanest work place environment among all self-sets.
- Compatible with wide range of refractory sands.
- Offers wide range of BL and ST of mixed sand.
- Applicable for floor molding as well as in loop line with flask less moulds.
- Cores and moulds made out of it are humidity resistant.
- Excellent hot and retained strength.
- Reclaim ability level is up to 70%.
- Compatible with aqueous and thinner based coatings.

Typical Sand Test Results of Modified Silicate Self Set

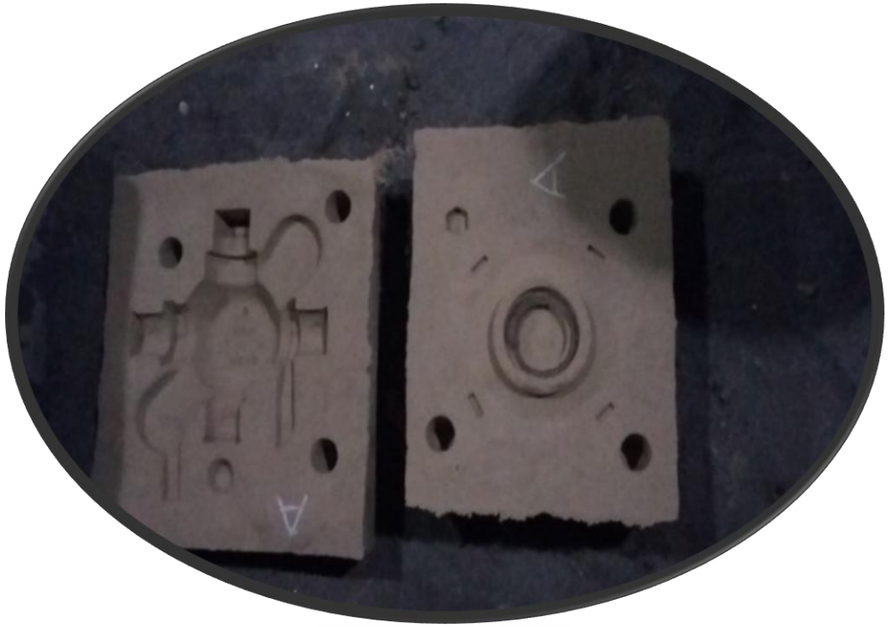
Compressive Strength of Modified Silicate-Ester, Self set in different addition level/ different grade of Hardeners in a typical Indian sand.

RT (°C) -30-32
RH (%) – 60-65



Silica sand of AFS = 55

Two Mould halves made with 2.5:15 in Modified Silicate Ester in Fresh Thiruthuraipondi Sand
Casting : CF8M grade (SS)



Reclamation

Recycling of same sand again and again

Thermo mechanical process of reclamation has been found to be effective for this self set. Steps involved are:

- Heating of used sand in fluidized bed at 150°C which removes moisture from silicate film on sand surface and increases brittleness.

- Mechanical attrition removes silicate film from surface of sand.

- Finally cooling, classification and de dusting is done in fluidized bed.

- ***(Source :Paper presented at 59th IFC (11th to 13th Feb 2011Chandigarh), Chandigarh by Cozicarlo of Sogemi ,Italy).***

ALKALINE PHENOLIC NO BAKE (APNB)

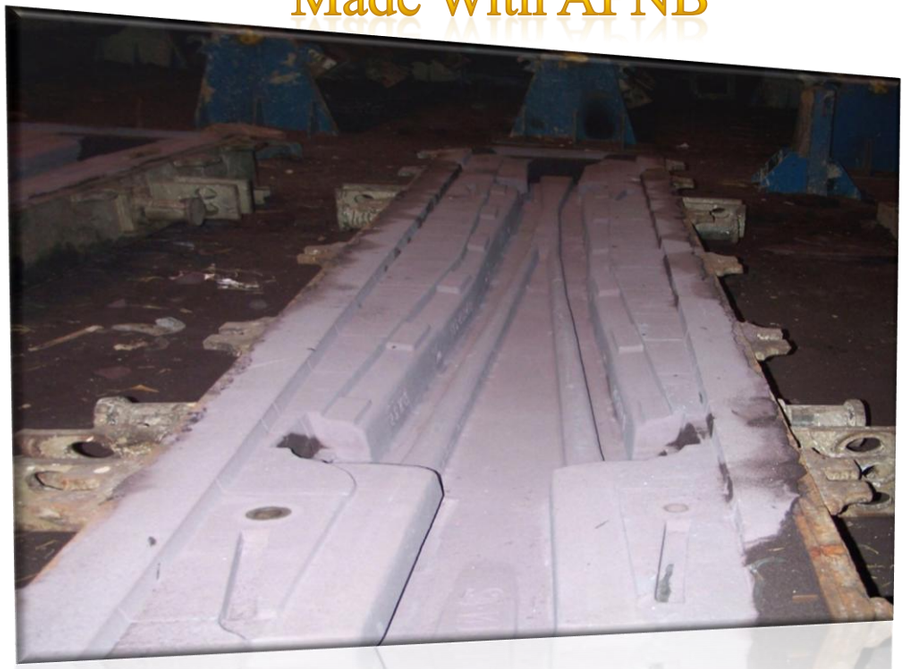
The System

- Two Part System
- Part One (Binder): Aqueous solution of Alkaline Phenol Formaldehyde Resin.
- Part Two (Curative): Single or blend of esters with varying hydrolysis constant.

SALIENT FEATURES

- Work with addition level as low as 1.0 : 20 in good quality sand.
- Resin is water soluble and Ester is non corrosive.
- Thorough curing system.
- Good reclaim ability.
- Offers clean environment at mixing, core making and pouring stages.
- System is free from nitrogen sulphur and phosphorus.
- No tendency for moulds and cores to stick to pattern.
- Produces metallurgic ally sound castings (castings are generally free from scabs, erosion, veins and hot tears)
- Good collapsibility.
- Less sensitivity of moulds/cores to atmospheric degradation.
- Lowest gas evolution when compared to other self setting systems.
- System performs well in low carbon steel, Manganese Steel, Aluminium, Bronze, Brass, Malleable iron and Ductile iron.
- Compatible with silica, zircon, olivine and Chromite sand.
- Compatible with aqueous and solvent based washes.
- Usable with batch as well as continuous mixers.

Railway Crossing Mould With Olivine Facing Made With APNB



Semi Machined Railway Crossing (Mn- Steel) Made In APNB

Reclamation

- Reclaim ability by primary attrition is as highest 70% which goes up to 85% when primary attrition is followed by secondary.

- 100% mechanically reclaimed sand can be used as backing sand.

- LOI of reclaimed sand can be controlled at 2% level by attrition.

- Alkali build up levels off at about 10% of total LOI.

- Mechanical attrition followed by thermal reclamation by addition of a chemical can give practically 100% reclaim ability and the sand is as good as new sand which can be used in PUCB process.

Modern FNB

The System

Its two part system, Part A or Binder being a Resin where FA is one of the major constituents, condensed with Formaldehyde, Phenol &/ or Urea. The grades are called :
UF / FA, PF / UF / FA or PF/FA

SALIENT FEATURES

- Works at addition level as low as 0.8 : 30.
- Low Binder viscosity.
- Low variation of viscosity of Binder with Temp.
- Long storage life of Binder.
- Flexibility for adjusting work time and strip time.
- High out of box and handling strength of cores and moulds.
- Fast curing system.
- Excellent reclaim ability of used sand.
- Thorough mixing with sand in shorter cycle.
- Less number of calibrations in CSM.
- No necessity for storing at cold room.
- Better economy, better casting finish, better control over environment protection.
- Can be used in batch as well as continuous mixers, suitable for cores and moulds of any size.
- Suitable for flask less molds in CSM with rollover strip.
- Faster productivity.
- Better economy, good control over environment protection.

Reclaimability

Best among all organic Binders, as high as 95% Reuse level is also as high as 95%, i .e Reclaimed :Fresh=95::5, if not more.

Rigidity of moulds - One of the best among all commonly used self sets ie PNB, APNB , PEPSET and FNB making it absolutely suitable for Flask less moulds in loop line.

Mixers – Both batch and Continuous Mixers are used, continuous mixers are preferred..

Casting finish- Usually free from hot tears and shrinkage defects. Surface finish is comparable with other commonly used self set systems.

Quality of Binder-Depends on FA, water and N content. More the FA and less the N and water, better is the Binder ,of course pushing cost on higher side.. FA content usually varies from 65 – 95%. N content varies from Nil to approx 8%. Uses are as follows :

N – content (%) in Binder	**Recommended application (metal)**
Nil to 2	Steel and large DI
2 to 5	CI and SG
≤ 5	CI and Non-Ferrous

In fact N – content of sand (fresh or system) coming in contact with liquid metal is important for deciding the grade of metal to be cast.

For CI and SG	it should be		$\leq 0.15\%$
For Steel and heavy SG	"	"	$\leq 0.1\%$
For Heavy Steel Castings	"	"	$\leq 0.05\%$

PUCB / Amine cured cold Box

The system

•Three Part System.
•Part One (Binder): Phenol formaldehyde Resin in a blend of polar and non-polar organic solvents.
•Part Two (Co- Binder / Hardener) is a single or blend of bifunctional isocyanates in complex organic solvent system .
•Part Three (Catalyst) :Single or blend of volatile tertiary amines.

Salient Features

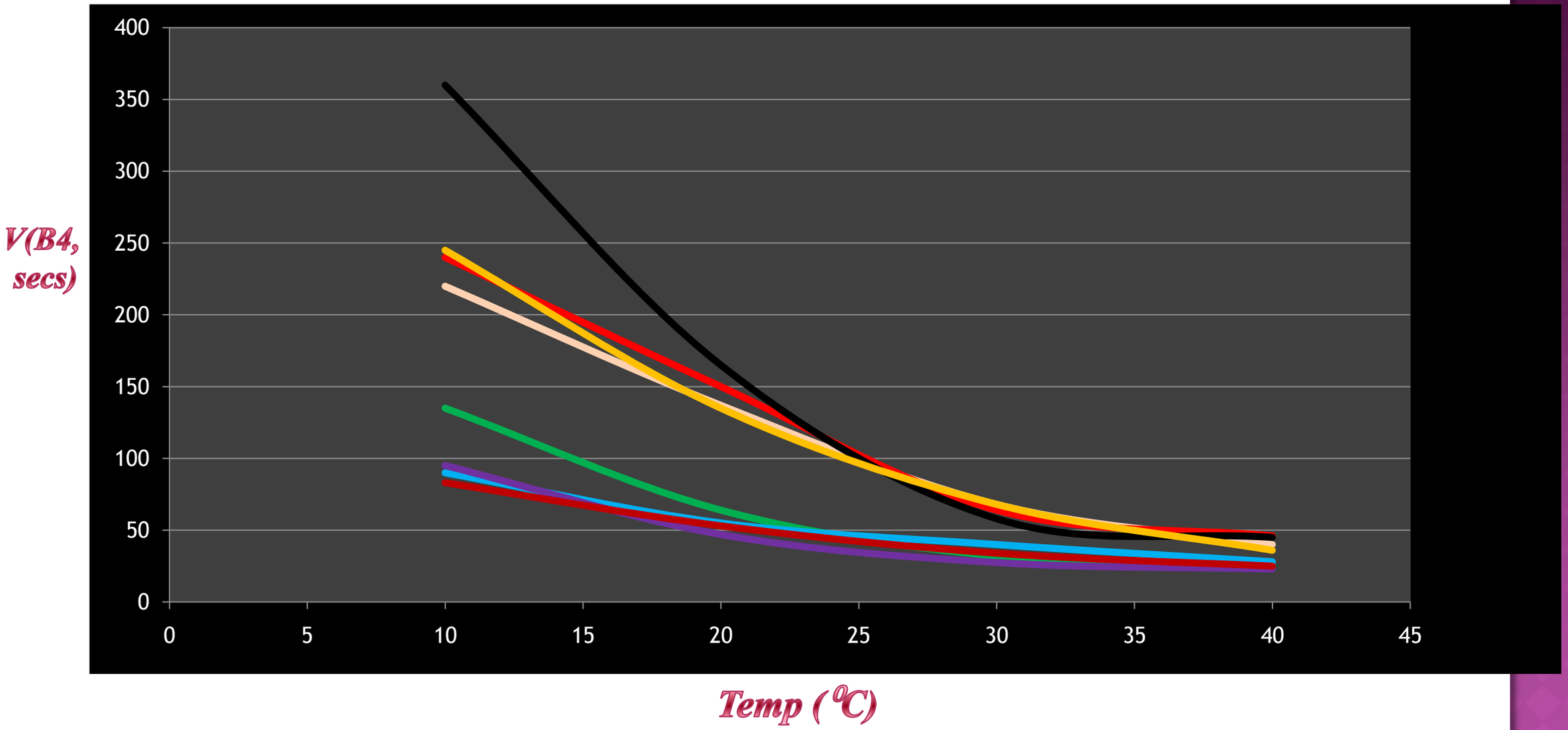
- Works with total Binder content of as low as 1.4 % by wt. of sand in Indian sands.
- No- bake process.
- Rapid Curing cycle
- Good and adjustable out of box strength.
- Good handling strength of cores.
- Long storage life of all three components.
- Good dimensional accuracy of cores.
- Low tooling cost.
- Compatible with Chromite, zircon and olivine sand .
- Suitable for both Ferrous and non ferrous casting.
- Works over wide temperature range (5- 40 ˚c).

Properties of Range of Amines used worldwide

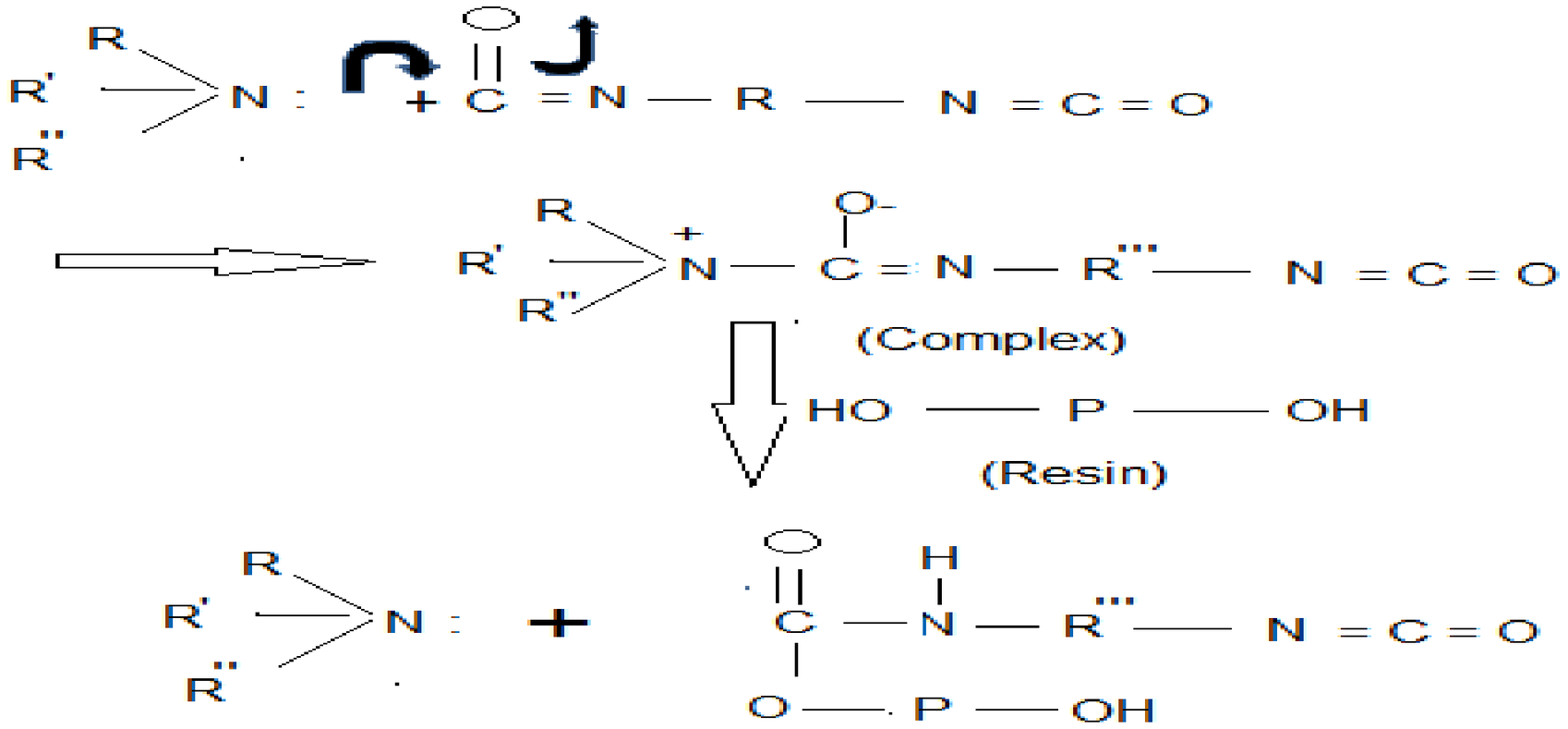
Properties	TEA	DMEA	DMIA	DMPA
Vapourization Temp (^{0}C)	87-89	36-38	65-68	66-67
Odor	Ammonia	Stronger than TEA	Lowest	Ammonia
Amine Demand (Approx.ml/100 kg Sand)	125	50% of TEA	70% of TEA	50% of TEA
Cure Rate	Standard	Fastest	Faster	Faster

DMEA is faster curing than TEA

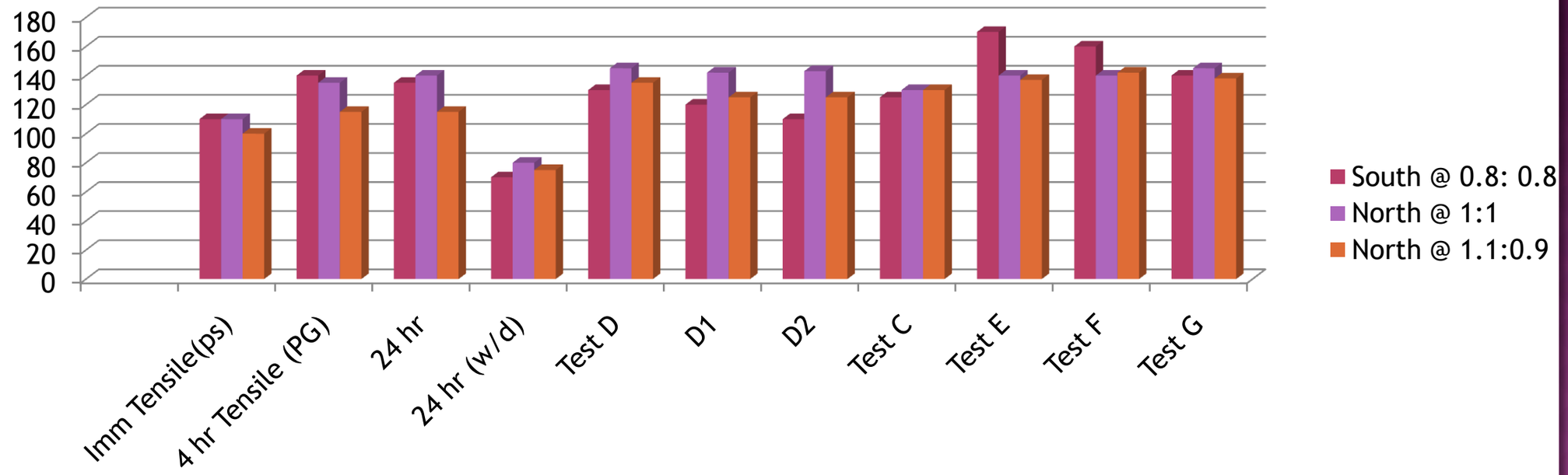
Viscosity V/s Temperature (PUCB, Resin)



Chemistry of curing



Test Conditions
RT= 30-31.5 ˚C
RH = 69 - 72 %



Test D : Immediately gassed samples dipped in water based coating (A1- Silicate) of ºBe 50-52, baked in oven @ 150ºC for 1 hr cooled for 1 hr, tested for tensile
Test D1: Above samples tested after 4 hours
Test D2 : Above samples tested after 24 hours
Test C: 24 hrs tensile specimen dipped in water based coating , baked @ 150 ºC for 1 hr. Cooled for 1 hour and tested
Test E : 24 hrs. Water desiccators samples coated and baked in oven @ 150ºC for 1 hour, cooled for 1 hour and tested
Test F : 24 hrs W/D samples baked for 30mts in oven @ 150ºC, cooled and tested (no coating)
Test G : Samples F coated and baked in oven for 1 hr @ 150ºC, cooled for 1 hr and tested.

Reclamation

- Reclaimability is poor by mechanical attrition.
- Thermal reclamation is done when cores are made with PUCB and or PUNB like socket cores of spun pipe.
- Combined reclamation with green sand has already been discussed.

CCP

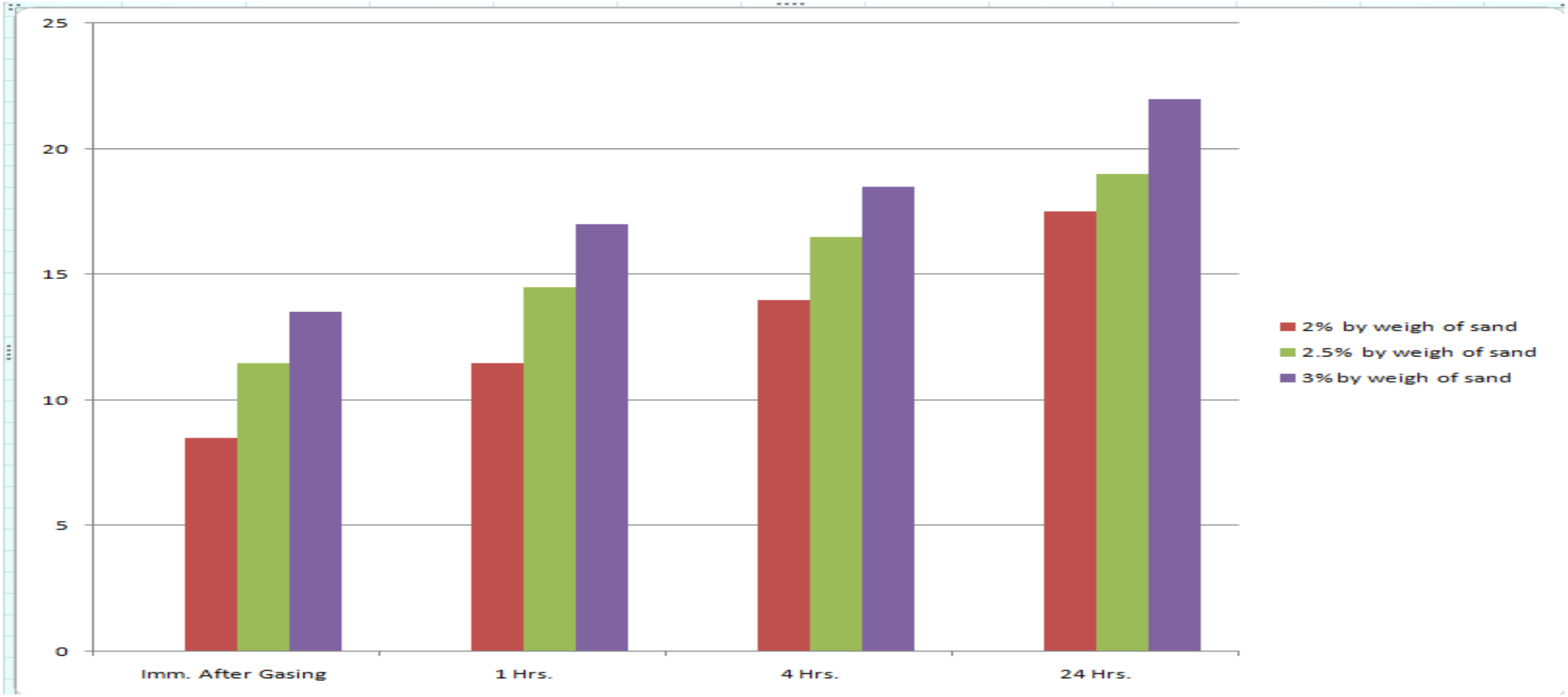
The System

- Two Part System
- Part One (Binder): Alkaline Phenol formaldehyde Resin in aqueous solution.
- Part Two : CO_2 gas

SALIENT FEATURES

- Binder Demand, 2.0 – 3.5 % by wt. of Sand, CO_2 – 1 – 4% by wt. Of Sand
- Resin is water soluble
- Compatible with Silica, Zircon ,Bauxite and Chromite sand
- Short curing cycle
- Good flow ability of mixed sand
- Unique storage stability of mixed sand – more than 12 hours in covered condition
- Water based coatings are preferred
- Long shelf life of binder –six months in ambient conditions
- Molds/cores are resistant to atmospheric degradation
- Suitable for batch as well as continuous mixers
- Over gassing does not reduce strength of molds/cores
- Binder is non flammable
- N, S and P free system
- Suitable for Ferrous as well as non Ferrous metals
- Castings are usually free from veining and lustrous carbon defects
- Excellent post casting breakdown properties
- Excellent work place environment
- Viable economy

Compressive Strength of Co_2 cured system at different addition level
(CO2 pressure 3 kg/sq cm,15 secs gassing) in a typical Indian sand of AFS - 52
RT (^oC) -18-24
RH (%) – 60-70



Crushed quartz sand of AFS 50-52

Top half of mold made with 3% CCP facing and 5.5% CO2/ silicate sand

Bottom half of mold made with 3% CCP facing and 5.5% CO2/ silicate sand

Core made with 3% CCP sand

Valve body casting (Steel , WCB) using above mold/core assembly

Bottom mold core assembly

Reclamation/Reuse/Disposal

- Emissions during core making and pouring while using this system is comparatively less compared to many of the organic binder systems.

- Application of this system so far is limited to very few Indian Foundries. In one or two cases this is used for making cores as alternate system for PUCB with green sand moulds for automotive castings. During knockout, 10-20% of core sand goes into system, which is recirculated . Rest is disposed for land filling.

- In specific cases, few foundries use this for making mould facing and cores, mould backing being CO_2-Silicate sand.

- Used sand is reused as mould backing after crushing.

- One more possible field of application for this system is as cores for APNB moulds. Used sand can be reclaimed along with molding sand and reintroduced into the system.

- Limited application of this system is the hindrance for going for reclamation of used sand as a whole.

Shell Resin

The System

•Two Part System for warm coating and three part for hot coating.
•Part One (Binder): Novolak in flake/granular/bead form or solution of Novolak in low boiling alcohols.
•Part Two : Aquaous solution of Hexamine/ mixture of Hexamine and Ca – stearate.
•Part Three : Ca- Stearate (for hot coating).

Salient Features

- Addition level 1.8 - 4.0 : 15 -18.
- Produces castings with tight dimensional tolerance.
- Negligible effect of atmospheric variables.
- Able to produce excellent castings again and again.
- Long storage life of RCS.
- Excellent out of box and handling strength of cores.
- Exceptional resistance of cores to atmospheric degradation.
- Ability to form hollow shells provides ease of handling and better economy.
- Works at low sand to metal ratio.
- RCS is extremely flow able.
- Works without application of refractory coating also.
- Compatible with wide range of metals and alloys, ferrous or non-ferrous, Cu and its alloys, Aluminum and its alloys and so many.
- Most suitable Binder system for making molds/ cores with thin section, intricate geometry and fragile.
- Repeatability of quality of cores with minimum dependence on operator skill.

Reclamation

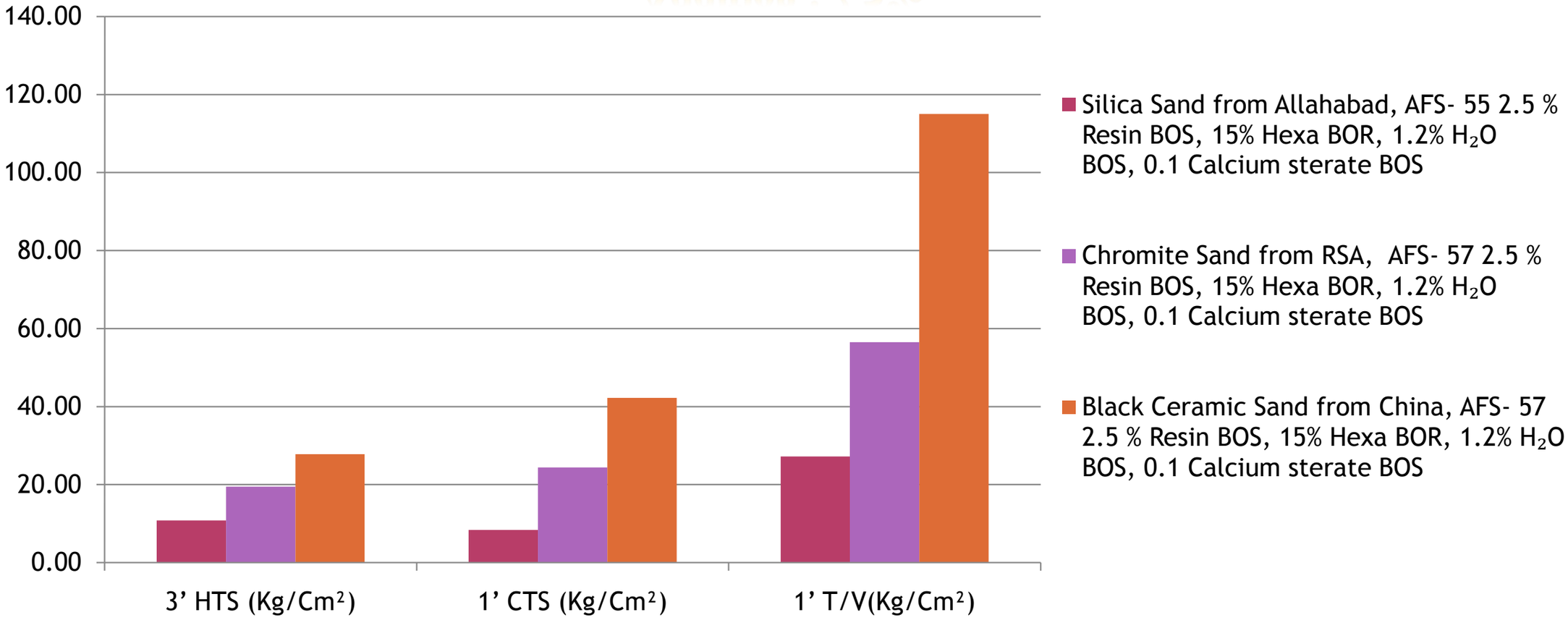
- Although regular grade Shell Resin contains up to 4% free Phenol and Resin addition in RCS is up to 3.5% by wt of sand, analysis of waste sand from pouring area shows leachable Phenol lower than most of other PF resins. Reasons being low sand to metal ratio, high density of cores enhancing heat transfer and increased burn-out .Emissions of Formaldehyde and Ammonia in core making process and shake out are usually within TLV.

- Foundries using RCS for both mold and core making usually reclaim used sand by thermal process

- Thermally reclaimed sand from green sand molds and cores using synthetic binders can be used for making RCS. This is a huge advantage from standpoint of Environmental cleanliness for foundries practicing shell process.

SOME CRITICAL CORES & CASTINGS MADE OUT OF RCS

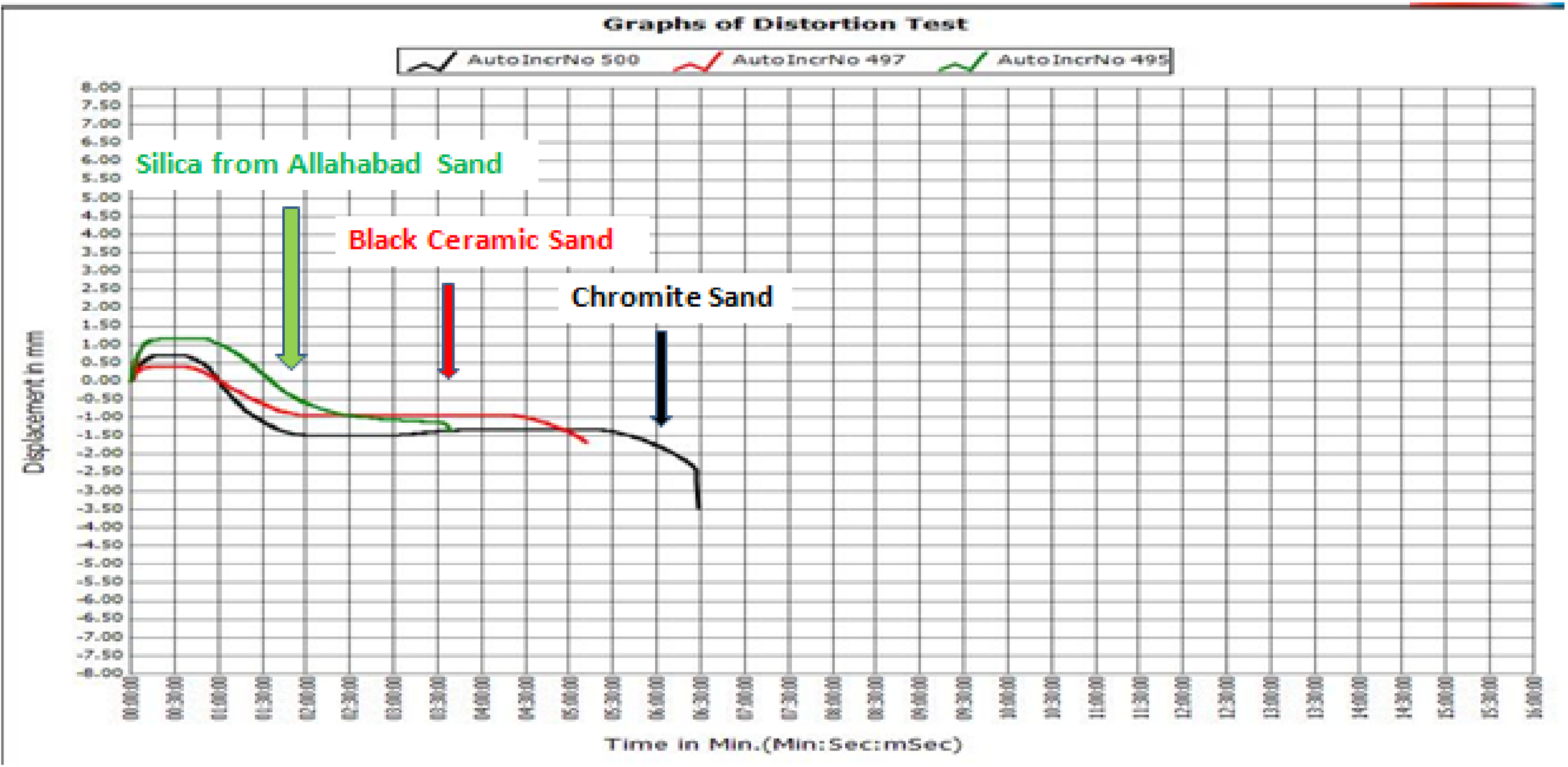
Hot Coating : Same Recipe in different sand of similar AFS
Addition : 2.5%

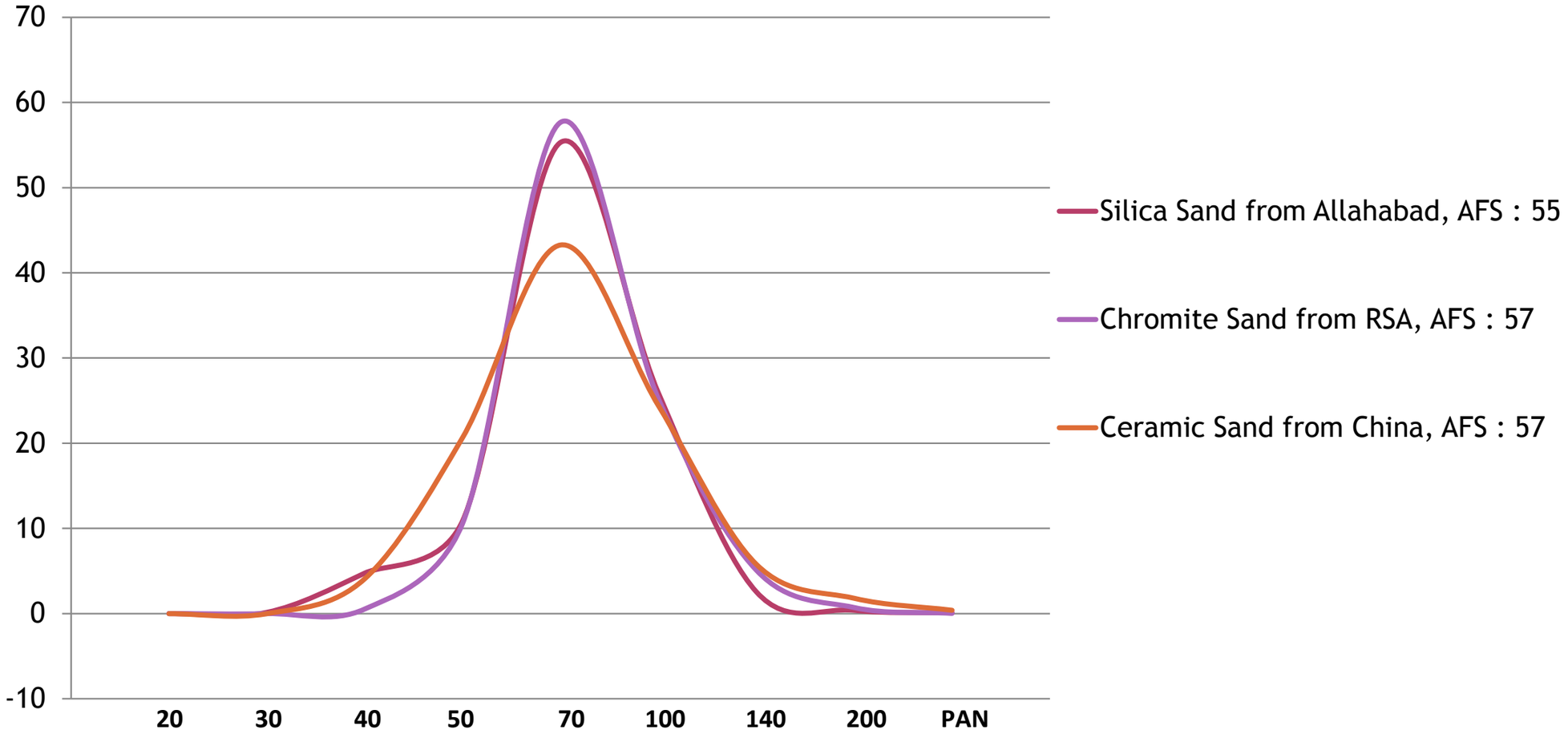


Sand Vs. BD

- **Silica Sand from Allahabad - 1.45 gm/cc**
- **Chromite Sand From RSA - 2.53 gm/cc**
- **Ceramic Sand from China - 2.00 gm/cc**

Addition Level : 2.5%





ASTM Sieve no. Vs. % Retention

Conclusion

- Serious efforts are on to improve workplace environment in Foundries, considered to be one of most polluting Industries in manufacturing sector.

- 3 R – i.e Reduction of addition level of Binder by choosing right formulations and selecting good quality of sand, Reclamation of used sand and reuse of same again & again helps in protecting ecology and requirement of Binder demand improving workplace environment.

- Reclamation of chemically bonded sand is already in practice in Foundries in India & sub continent, however, combined reclamation of used green sand from moulds and chemically bonded sand from cores with quality of reclaimed sand suitable for making cores with chemical Binders has become of absolute necessity to minimize excavation of new sand to protect ecology and leaving bare minimum quantity of sand meeting specifications for environmental regularity authorities for disposal for road filling or application in construction industries.

- Latest work so far in India has shown that combined reclaimed sand is compatible with PUCB and making RCS but not with Furan.

- Lot of work is left to be done on these issue to make Foundries cleaner working place like other manufacturing units and protecting ecology in interest of future generation .

THANK YOU

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