www.czasopisma.pan.pl PAN www.journals.pan.pl

ARCHIVES
of
FOUNDRY ENGINEERING

ISSN (2299-2944)
Volume 2020
Issue 4/2020

18 – 28

10.24425/afe.2020.133343

3/4

Published quarterly as the organ of the Foundry Commission of the Polish Academy of Sciences

Modern Alphaset (APNB) Flexible Formulations-Enhanced Performance

D.K. Ghosh
Forace Polymers (P) Ltd., India
*Corresponding author. e-mail address: dghosh@foracepolymers.in

Received 20.03.2020; accepted in revised form 13.07.2020

Abstract

APNB (alkaline phenolic no bake), widely known as Alphaset is one of the major sand binder systems used in foundries to make molds and cores without application of heat or gas. This is a two part system comprising of a phenol-formaldehyde resin in alkaline medium as binder and range of esters of dibasic acids and/or polyhydric alcohols as hardeners.
Resin performance varies depending upon formulations. Major variables in formulations are mole ratio of phenol: formaldehyde, total alkali content, ratio of two alkalis (NaOH & KOH) and molecular weight of polymers i.e. chain length.
In present work, one mole ratio of phenol & formaldehyde has been chosen to prepare 8 resins with following details.

Table 1.
Physical and chemical properties of eight (fresh) resins, A to H

Properties	A	B	C	D	E	F	G	H
Viscosity at 30°C (mPs-a)	56	47	66	51	39	44	49	52
Na (%)	5.94	3.21	5.94	3.21	nil	2.73	nil	2.73
K (%)	nil	3.31	nil	3.31	7.18	3.87	7.18	3.87
Molecular weight	Low	Low	High	High	Low	Low	High	High
Gel Time at 121°C, mt-sec	27-0	29-30	24-0	30-0	30-0	27-30	26-30	26-0
Moisture (%)	52.43	52.42	53.01	53.75	55.58	54.12	51.61	54.03
Non-volatile Content (%)	48.74	47.25	49.10	49.35	47.63	47.32	48.06	48.29
Specific Gravity	1.182	1.177	1.183	1.180	1.172	1.184	1.178	1.188
Free Phenol (%)	0.47	0.42	0.44	0.43	0.37	0.27	0.41	0.20

Properties of these 8 formulations have been studied for strength and viscosity over a period of 12 weeks in 4 week interval.
Attempt has been made to develop a simple test for simulating hot & retained strength of molds in laboratory. Process followed for chasing hot and retained strength is described under clause 2.
With more and more understanding of the chemistry of alphaset system in last three & half decades it has been possible to identify role of variables contributing towards specific properties vis a vis developing tailor made formulations to fulfill requirements of individual foundries right from mold making to de coring.

Keywords: Alkaline phenolic no-bake, Variables, Ageing, Strength

1. Introduction

APNB (Alkaline phenolic no bake), FNB (Furan no-bake) & PUNB (Phenolic urethane no-bake) are three commonly used self-sets in foundries across the world. PUNB is not as popular as other two mainly because of content of organic volatiles which emit during mold making and subsequent movement posing threat to pollution of environment.

One of the advantages of PUNB is, it is fastest among self-sets, with strip time as fast as 4 minutes at ambient temperature of as low as 10°C, associated with excellent rigidity of molds, including flask less with total addition level of 1.2% (binder +co binder+ catalyst) by weight of sand. In India, maximum weight of casting (1.5 MT, steel valve) being poured in flask less mold is with PUNB system with MR (mechanically reclaimed):TR (thermally reclaimed) sand =50:50 at facing and MR at backing, weight being close to 3.0 MT for half mold with dimension 1.5x2.6x0.5 meter. APNB and FNB cannot match PUNB to produce similar rigid molds at realistic addition level so quickly.

While comparing with FNB, modern APNB formulations with extremely low free monomer contents are more environment friendly. Although, with European Union regulation [1] modern FNB formulations don't contain more than 25% free FA (Furfuryl alcohol), a potential environment pollutant, subsequent formulations necessitated introduction of phenol as third reactant with Urea & FA (Furfuryl alcohol) to bring down free formaldehyde (another environment pollutant) content of finished resins. These modifications have reduced reclaim ability (mechanical) of used sand and introduction of free phenol in resin formulations which comparatively are much more than in APNB formulations. It's well known that phenol is a potential pollutant to environment and soil. Also residual formaldehyde in APNB formulations are negligible whereas in FNB formulations it may present in % sufficient to cause irritation in mold making area, particularly at high ambient temperature.

APNB undergoes polymerization on its own (heat setting) on storage with elimination of water which is associated with increase in viscosity and finally solidification. Rate of resin advancement depends upon temperature of exposure. Storage at low temperature is recommended to reduce rate of resin advancement. Apart, this system undergoes controlled polymerization (chemical gelation) in presence of weak organic acids released by hydrolysis of esters of polyhydric alcohols or polybasic acids or both, at room temperature. In this stage of curing, partial crosslinking of two dimensional chains to three dimensional give strength to molds good enough for stripping, handling and closing. Probable mechanism for crosslinking at this stage is shown in Fig. 1 [2]. Final curing (crosslinking) takes place by heat at metal pouring temperature offering rigid structure to molds resisting leakage of liquid metal. Mechanism of curing at this stage is typical conversion of resole to resite via resitol.

APNB releases formaldehyde gas, an eye irritant and potential environment pollutant during curing with esters [3] with probable mechanism as shown in Fig. 2. One of the positive features of modern formulations is drastic reduction of formaldehyde concentration in work place by adjusting formulations with slower rate of emission or introduction of chemical scavengers in system. Another attractive development in recent formulations is increase in storage life of resin. Use of aged resin poses problem of proper mixing with sand because of increased viscosity and reduced bench-life and strength of mixed sand. To quantify resin life, individual foundries can study casting quality vs strength of mixed sand with resin ageing and define the time when final strength (24 hours) drops down to 70-80% of fresh resin.

Main reasons for quick acceptance of this system in foundries across the globe are three fold, a) compatibility with all metals, ferrous (CI, SG and Steel) and nonferrous (alloys of Al, Cu, Zn) b) more friendly to workplace environment than other contemporary self-sets and c) unique two stage curing [4] offering production of castings free from defects related to reversible expansion of silica sand at 573^{0}C, associated with 4.74% volume & 1.56% linear (0.015 mm/mm) change [5]. During these three and half decades, chemistry of APNB has been understood more and more. Many foundry men believe, KOH based resin formulations are better than those based on NaOH based. However, one reference [6] available in this regard says Na based formulations are better for MR (mechanical reclamation) and K based for TR (thermal reclamation). One recent publication [7] also says, Na based alkali gives better quality of MR sand where reclaim ability is as high as 60-80%. Otherwise, binders containing only Na based formulations are better for foundries practicing MR. As feed sand for thermal chamber is always MR Sand, it has to be of high quality for efficient reclamation. Thus it stands, judicious blend of Na and K based formulations are appropriate to foundries practicing Thermal reclaimed (TR), Na, for achieving good reclamation by MR and K for better reclaim ability by TR. One reference [8] has mentioned about possibility of use of Li also as another alkali along with Na and K, but in practice author could not find any in formulations used in India. Again, many foundries ask for declaration of % N content in binder. Answer is, this system is free from N, but some manufacturers add N bearing compounds to contain smell of formaldehyde evolved at various stages of mold handling.

It's well established phenomenon that thermal reclamation of FNB sand slows down in reaction with acids compared to that of new sand, a phenomenon attributed to buildup of alkali metal ions used during processing of FNB. Finally, author has experienced absolutely no setting of FNB in TR sand generated out of combined PUCB and FNB sand, whereas no issue of setting of PUCB in same sand, reason is yet to be understood. Again, it has been found that stable TR sand generated from APNB does not work with PUNB and PUCB as well.

It wouldn't be irrelevant to mention that with growing consciousness on protection of ecology and improvement in work place environment, foundries are looking for inorganic binders as replacement of organic ones. In self-set sector, modified water glass along with liquid hardeners is a viable alternate to APNB and FNB in meeting requirements including de coring and reclamation, but short bench life of mixed sand particularly at temperature of 35°C or more remains major constraint. A publication [9] says use of butylene carbonate can fulfil bench life requirement & through curing to water glass bonded sand but this chemical is not so far available commercially. In short, APNB with modern environment compliant formulations will continue to be one of the most widely used self-sets in foundries until one or more inorganic self-sets are available.

Present APNB with flexibility of formulations associated with availability of series of organic esters with varying hydrolysis constant are capable of meeting bench life, strip time and strength requirements of all foundries at various stages right from stripping to post pouring.

There are more than one publications defining bench life and strip time of mixed sand in case of self-sets. One of those [10] define bench life as time in minutes required for a standard AFS 50X50 mm cylindrical core to achieve a compression strength of 0.1 0.009 MPa and strip time is time to reach AFS 50X50 cylindrical core to achieve compression of 0.68 MPa. Whereas bench life for faster systems like PUNB can't be measured by this process where a more practical approach will be to use laboratory grade mold hardeners. For strip time it will highly depend on the molding practice of individual foundries. For example, as stripped compression strength of small boxed molds can be as low as 0.14 MPa and same can be as high as 0.73 MPa for big flask less molds in roll over strip.

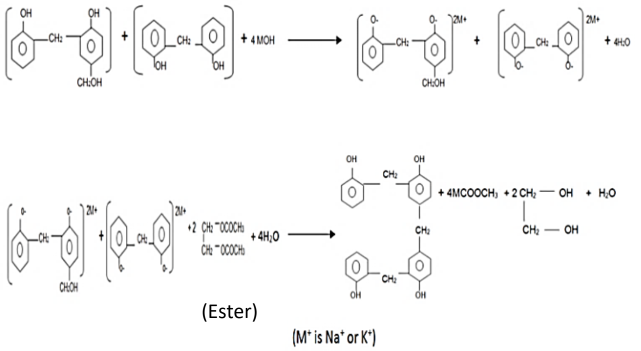


Fig. 1. Probable mechanism at 1st stage of curing

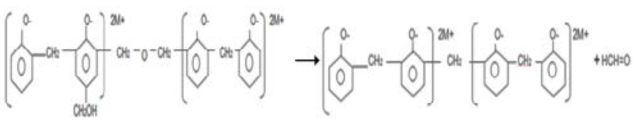


Fig. 2. Probable mechanism of release of Formaldehyde (HCHO) during 1st stage of curing

2. Materials And Methods for sand test

One Sand of north Indian origin was chosen. Sieve distribution (Fig. 5) and cumulative % retention (Fig. 6) of same are given in form of graph. Mixing was done in laboratory mixer with required dosage of Hardener and Resin with specific cycle. Discharged sand was checked for bench life (BL) manually. Small mixed sand on discharge was kept tightly in a polythene bag. Strip time (ST) was recorded as the time it became sufficient hard by feel. Immediate stripped samples were allowed to air dry for 5 minutes, put in oven at120^{0}C for 5 minutes, cooled to room temperature, applied with thinner based coating and lighted off. Two warm samples were tested for compression. Another two samples were tested for compression when those attained room temperature. Cold samples were soaked in furnace at 450^{0}C for 5, 10 and 15 minutes and tested for compression in hot (hot strength) as well as cold (retained strength). Some of these properties were repeated with up to 12 weeks of resin ageing. Many of the sand test properties followed in this paper are unconventional, but author feels, those can be simulated with strength requirements of individual foundries during mold movement (stripping, handling in manipulator, wash degradation, closing, pouring, post pouring and de-coring) using simple and non-expensive equipment to have better control on quality of molds and finally castings.

Pattern of strength development of samples simulating mold stripping to post pouring via preheating, coating application (thinner based) lighting off, post baking, closing, pouring and decoring simulating mold movement of a typical foundry is shown schematically in the Fig. 17.

Further, reclaimed sand samples, both mechanical (MR) and thermal (TR) from few foundries have been quantitatively analyzed for Na and K and tested for different properties including sand mix. Case studies documented in this paper has unearthed factor contributing towards stability of thermally reclaimed Alphaset bonded sand, a question, un answered for quite long time.

Equipment used

Kelsons Engineers & Fabricators, Kohlapur, India was used for testing compression strength of samples.

Systronics India Ltd., Flame photometer was used for testing of Na and K.

Thermo Fischer Scientific, Gas Chromatography was used to check free phenol.

Experimental

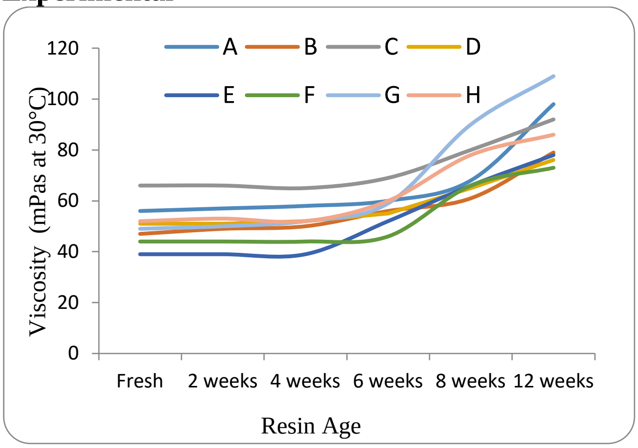


Fig. 3. Resin age vs Viscosity, up to 12 weeks

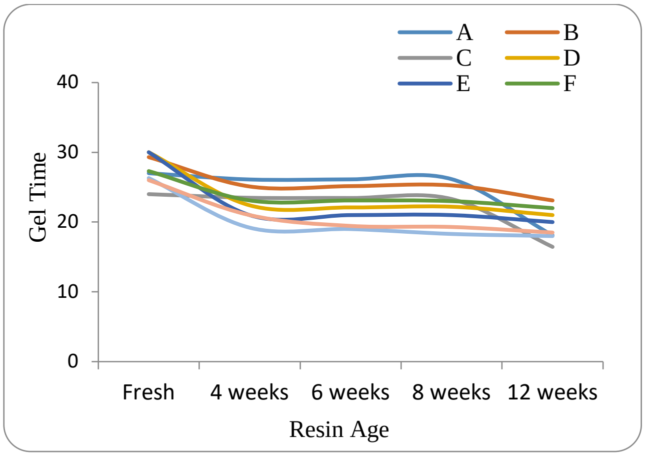


Fig. 4. Resin age vs Gel time (minutes-sec) at 121^{0}C

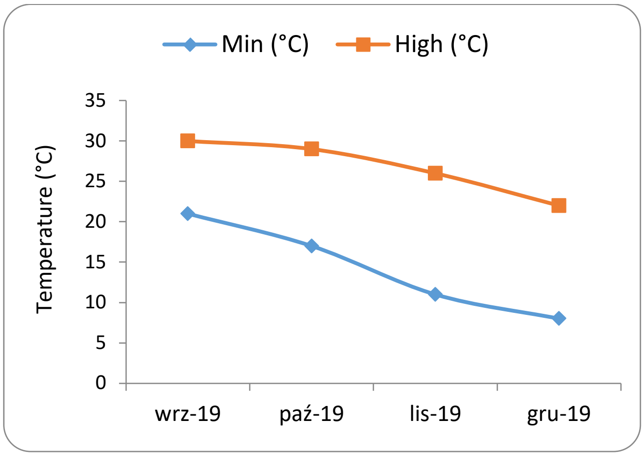


Fig. 7. Maximum and minimum temperature during 12 weeks of experiment done

Silica sand used for testing

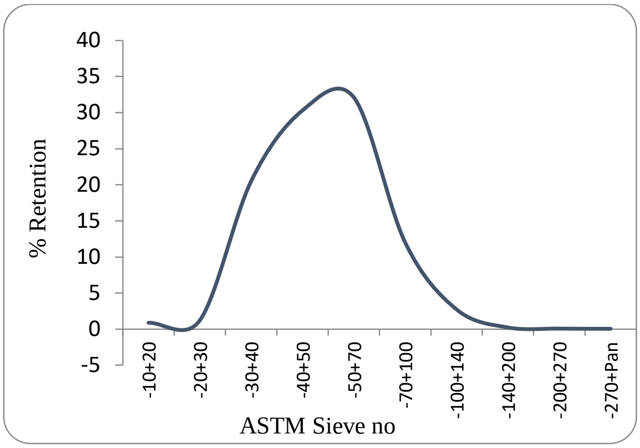


Fig. 5. American Society for Testing & Materials (ASTM) Sieve no vs % Retention

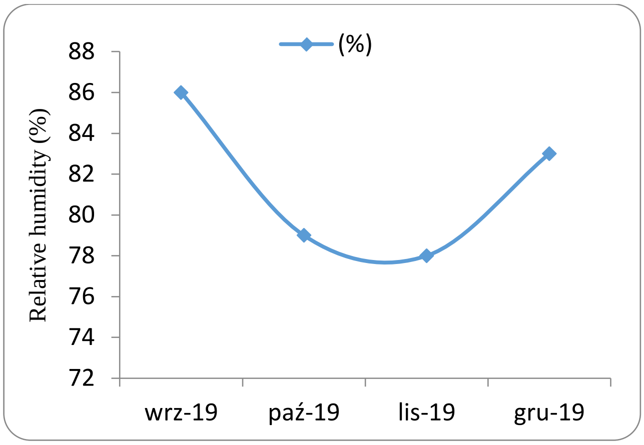


Fig. 8. Relative humidity (%), during 12 weeks of experiment done

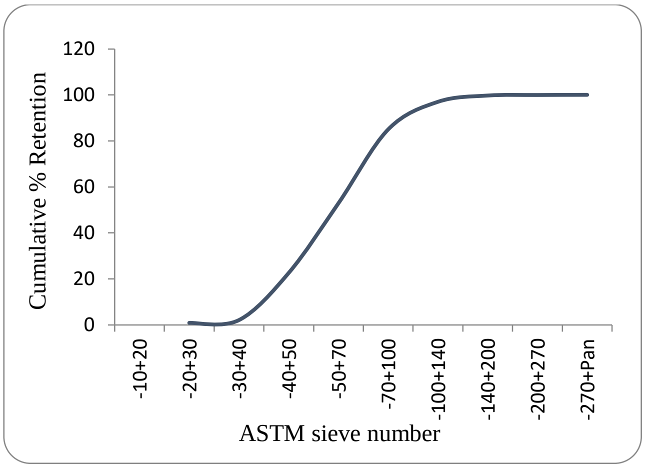


Fig. 6. ASTM sieve number vs cumulative % retention

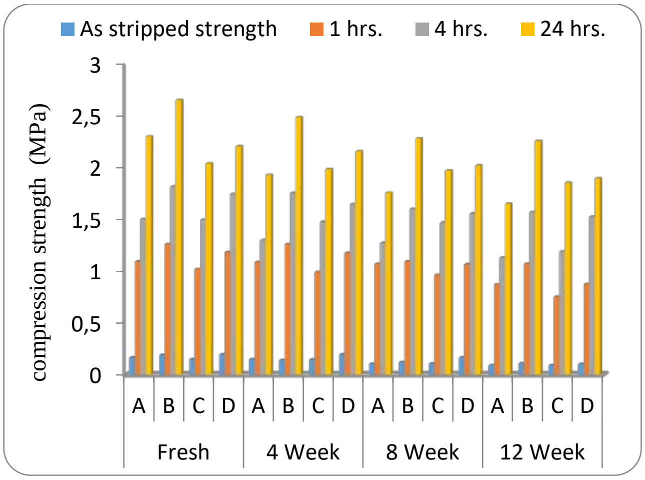


Fig. 9. Hourly dry compression strength of samples made using fresh and aged Resin (A-D)

Sand Test recipe: 1.6:20

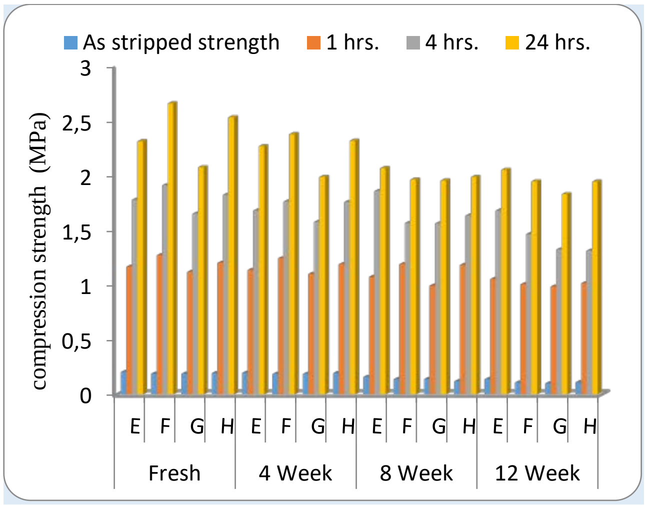


Fig. 10. Hourly dry compression strength of samples made with fresh and aged Resin (E-H)

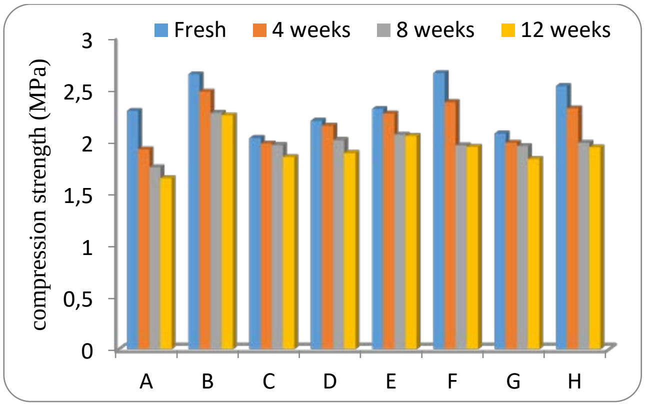


Fig. 11. Resin age vs 24 hours compression Strength

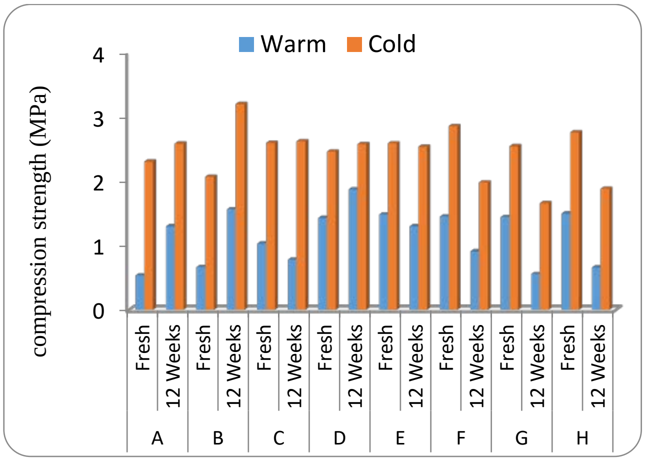


Fig. 12. Strength of warm & cold samples after coating & lighting off

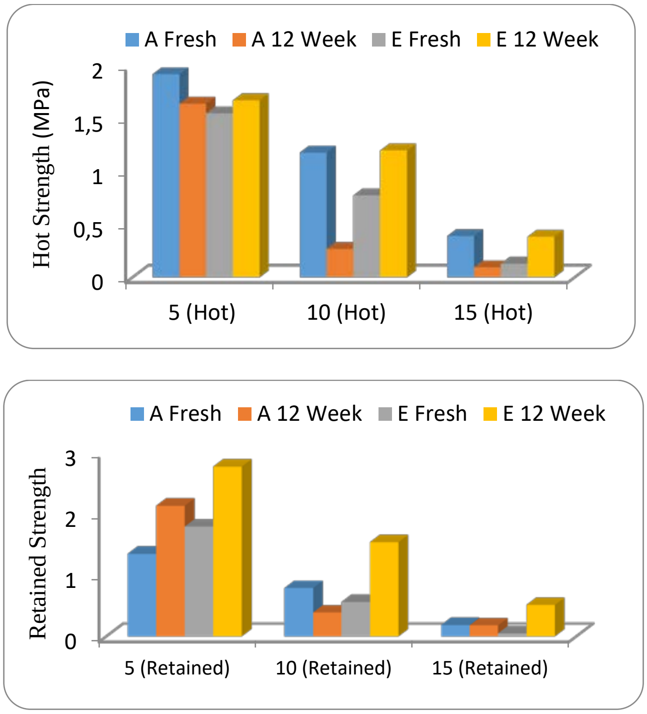


Fig. 13. Hot & retained strength of samples made with fresh & 12 weeks aged resin for A & E

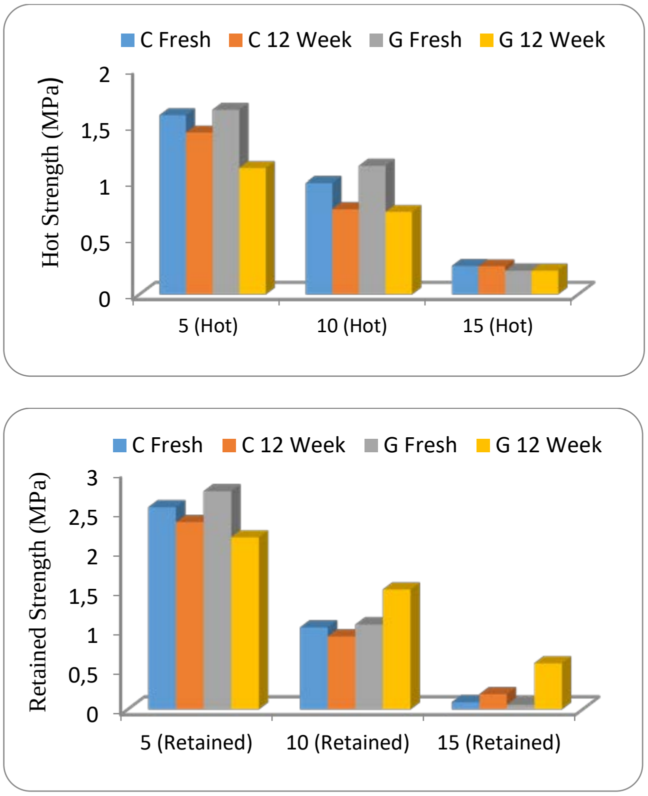
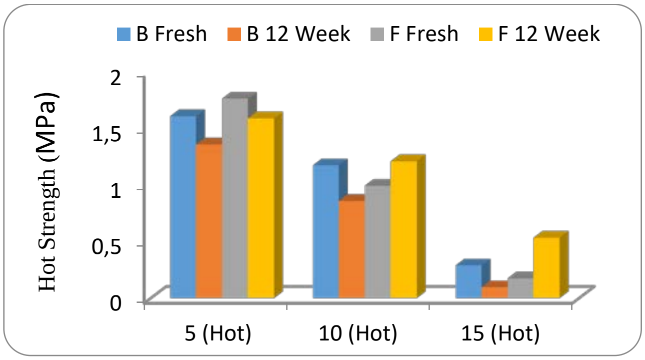


Fig. 14. Hot & retained strength of samples made with fresh & 12 weeks aged resin for C & G



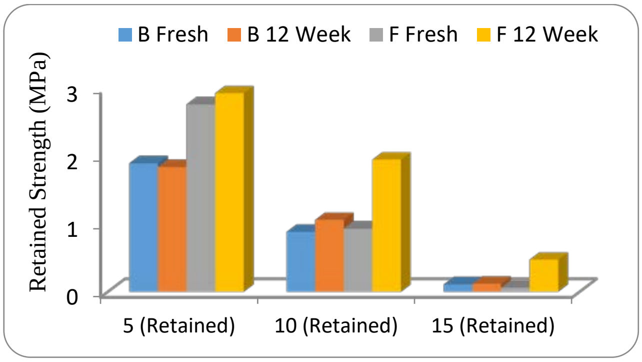
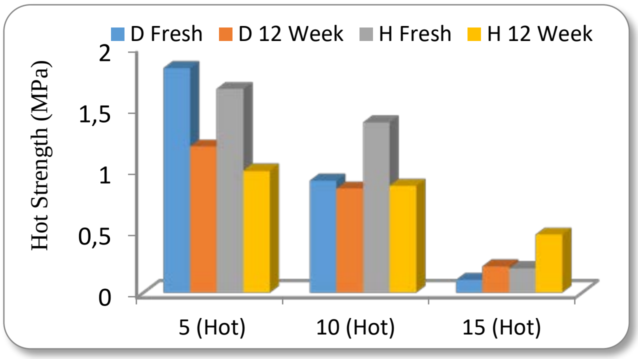


Fig. 15. Hot & retained strength of samples made with fresh & 12 weeks aged resin for B & F



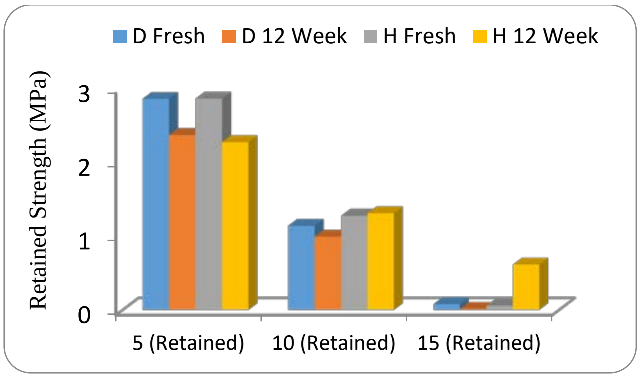


Fig. 16. Hot & retained strength of samples made with fresh & 12 weeks aged resin for D & H

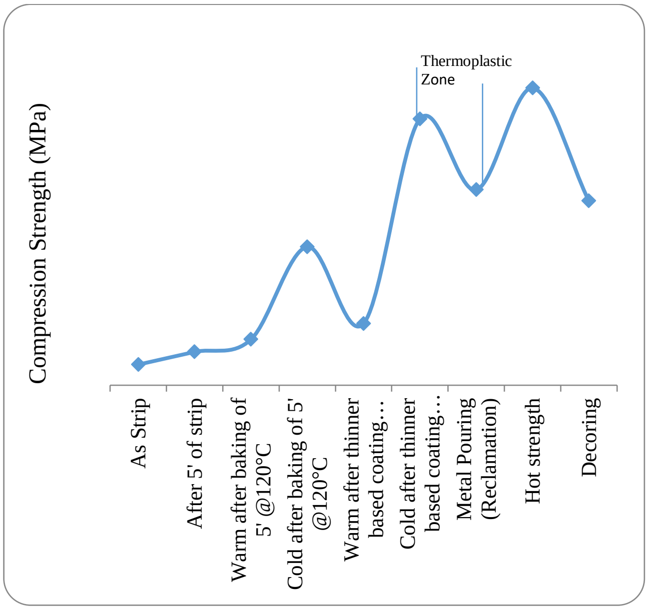


Fig. 17. Pattern of compression strength variation at different stages from strip to 5 minutes at Furnace (450°C)

3. Results and Discussions

3.1. Physical & chemical properties of different formulations

1. Formulations using Na based alkali offer more viscosity in fresh resin than K based. Same is trend with mixed alkali also.
2. Viscosity of all formulations remains fairly stable over initial period and then rise. Total K based formulations indicate more rate of rise during period of study and prevailing ambient temperature.

3.2. Sand Mix Properties

1. **Dry strength**
   Values for compression in 1 hour and to some extent 4 hours have been influenced by change in climatic during ageing. Thus, it’s more rational to compare only 24 hours results while comparing strength deterioration on ageing of samples made with various resin formulations. Total variation in strength of samples made with fresh resin A-H is close to 25%, B and F being maximum, C and G being minimum. Drop in strength during the period of study varied approximately between 10-28% in samples made with A-H. A being maximum and E minimum. Samples made using B shows not only consistency in results but also having highest values during period of study. Samples made using fresh resins, C and G show comparatively lower strength but shows maximum resistance to deterioration on

ageing. Fresh resins F and H show good strength but drop is more on ageing.

2. **Hot and retained strength**

a) Fresh resins

Values and drop of hot strength for all compression samples made using fresh resin are quite close during soaking period of 5 to 15 minutes. Corresponding retained strength values for 5 minutes samples show increase followed by drop in case of samples made using resins of higher molecular weight i.e. C, D, G and H. Only exception is F which is of lower molecular weight. For E, values for 5 minutes are close. In other 2 cases drop is from very beginning.

b) Aged Resins

Hot strength values for all are lower than corresponding values made using fresh resins up to 10 minutes. In case of 15 minutes, some show values more than samples made using fresh resins. These can be taken as scope within experimental error.

Retained strength of samples made using resins A and E show increase in 5 minutes and then subsequent drop. Drop is drastic in case of A. Values for 10 and 15 minutes in case of E continue to be higher than corresponding values of fresh resin. In case of F, 5 minutes value is at par but subsequent values are more. In case of G and H, 5 minutes values are lower, but others are more than corresponding values of fresh resins. It stands, in case of aged resins, samples made with resins E, F, G and H show more retained strength than other four. These resins are either K based or predominately K based.

3.3. Case studies

Foundry I (Largest castings with Alphaset in India):

This foundry produces steel castings upto 65 metric ton (MT) in weight. This foundry produces turbine casing of approximately 65 MT and liquid metal weight close to 130 MT. Two halves of molds are made with approximately 90 MT each of sand. Facing sand is new silica na d baking MR. Mixer capacity is 60 MT/Hr, strength values required for facing and baking sand are ≥ 2.94 MPa and 2.45 MPa respectively. Specified bench life is 20 Mts. Throughout the year where variation in temperature is 15-45°C. Addition level for facing and baking are 1.35:20 and 2.35:20 respectively.

Table 2.
ROA of one month aged Resin being used by above Foundry

Property	Unit	Value
Viscosity (Brookfield), 30°C	mPs-a	95
Sp. Gr (30°C)	None	1.24
Gel time at 121^{0}C	Mts-Secs	27-15
Nonvolatile content (2 gm, 2 hr, 120^{0}C, glass Petri dish	%	55.74
Moisture content	%	52.15
Free phenol	%	0.12
Na	%	1.38
K	%	7.15

Table 3.
ROA for MR Sand from above Foundry

Parameter	Unit	Value
AFS no	None	40.72
LOI	%	2.08
Na	%	0.039
K	%	0.25

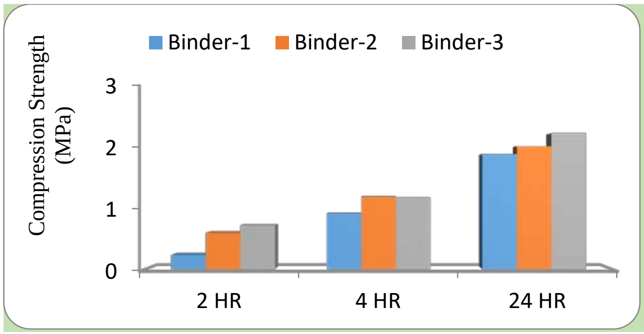


Fig. 18. Compression Strength (MR Sand used at 2.35:20) values of three approved binders in laboratory of Forace Polymers (P) Ltd (Results are lower than specification because of resin ageing, change in testing laboratory or both)

Remarks:

1. Specification for strength requirement shows MR Sand offers much lower strength than New Sand at equal addition level in case of APNB.
2. MR Sand (backing) with (1.96 MPa) compression strength is capable of handling pressure of 128 MT of liquid metal.
3. APNB can handle pressure of 128 MT liquid metal in facing (New) sand with compression as low as (2.94 MPa) because of excellent hot strength.

Foundry II (Largest casting in Alphaset, flask less molds):

Mixer: 30 MT/hr, Reclamation: Mechanical (primary followed by secondary), Castings: Steel, Sand weight: 1780 kg (one half), Half mold dimension 180X140X47 cm, Items: Manganese (Mn) steel and high Chromium (Cr) steel for crushers.

Addition level in facing (new and olivine) as well as backing (MR) 1.6:20. Specs for 1 hr. compression in New Sand is ≥ (0.98 MPa).

Mold making and pouring cycle: Mold filling, stripping in roll over (~45 mts) preheating in IR, flood coating with Mg or Zr thinner based coatings by tilting with help of manipulator, lighting off and passing through hot air oven, approx. 45 mts at 150-250°C. Molds are closed and poured within 18-30 hrs. of making. Castings are cooled for 48-56 hrs. before shifting to knock out chamber. Critical stages:

- BL of mixed sand, particularly MR: Should be ≥5 mts
- Strip strength for roll over strip, close to 45 mts: New Sand compression should be ≥ (0.73 MPa)
- Handling strength at manipulator for coating application: MR sand ≥ (0.98MPa)
- Molds should not collapse post pouring and during cooling of castings to prevent leakage of sand during casting movement to avert (a) loss of sand and (b) cleaning of leaked space. Should have good retained strength.

Table 4.
ROA of one month aged Resin being used by above Foundry

Property	Unit	Value
Viscosity (Brookfield), 30°C	mPs-a	83
Sp. Gr (30°C)	None	1.205
Gel time at 121°C	Mts-Secs	25-20
Nonvolatile content (2 gm, 2 hr, 120°C, glass Petri dish	%	53.08
Moisture content	%	49.82
Free phenol	%	0.33
Na	%	3.99
K	%	3.14

Table 5.
Properties of Sand

Parameter	Unit	Silica Sand	MR, followed by dynamically reclaimed sand
AFS No.	None	44.64	45.39
L.O.I (%)	%	0.589	1.329
Na	%	Not applicable	Not available
K	%	Not applicable	Not available

Remarks:
1. As stripped strength of ≥ (0.73 MPa) is enough for stripping of flask less molds of largest size using APNB in the Country. Maximum strength requirement is at the stage of handling the molds in manipulator for applying flood coating. Same is ≥ (0.98 MPa).. Manipulator grips both facing new sand & backing MR Sand. Thus MR sand also should have good strength.
2. In case of boxed molds, it is desired that system should have good hot strength and low retained strength, but in case of flask less molds, retained strength also should be good where cooling cycle of castings is as high as 56 hrs.

Foundry III (Steel Valves), Reclamation MR followed by TR:
Thermal Reclamation (TR) chemical supplier B (name withhold) Produces steel valves in flask less as well as boxed molds. Mold facing TR: New Sand=85:15, mold backing MR. Addition level 1.3% in facing and 1.6% in backing. TR sand is supposed to be quite stable.

Table 6.
Properties of Resin (2 weeks aged)

Property	Unit	Value
Viscosity (Brookfield, 30°C)	mPs-a	70
Sp. Gr (30°C)	None	1.24
Moisture content	%	49.92
Non-volatile content (2 gm, 2 hr, 120°C, Glass Petri Dish)	%	55.96
Free Phenol%	%	0.27
Gel Time at121°C	Mts-Secs	28-30
Na	%	1.44
K	%	7.38

Table 7.
Properties of MR and TR Sand (Fresh)

Parameter	Unit	New Sand	MR Sand	TR sand
AFS no	None	40.124	44.025	45.30
LOI	%	0.991	0.993	0.69
Na	%	Not applicable	0.092	0.0189
K	%	Not applicable	0.090	0.045

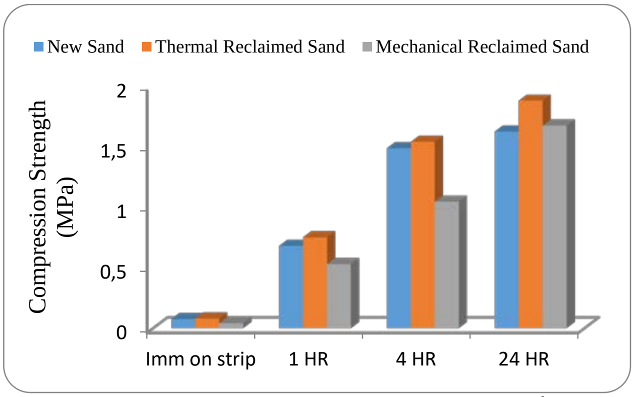


Fig. 19. Compression Strength of New & TR Sand (9th day of generation) at1.3:20 & MR Sand at1.6:20 with medium fast catalyst

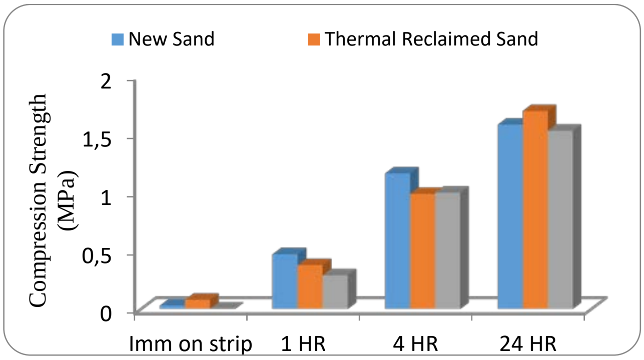


Fig. 20. Compression Strength New & TR (after 8 weeks of generation) Sand at1.3:20 & MR Sand at1.6:20 weight of sand with medium fast catalyst

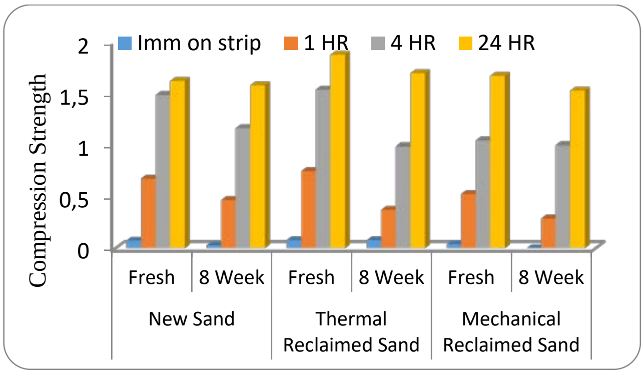


Fig. 21. Storage time vs. compression of MR & TR sand with New sand as reference

Remarks:
TR sand generated using additive of supplier B is stable

Foundry IV (Steel castings for Railways, in boxed as well as flask less molds):
Additive supplier: A
Addition: 1.2% by weight of sand
Resin supplier: Two

Table 8.
Properties of Resins

Property	Unit	Binder Supplier (X)	Binder Supplier (Y)
Resin age (days)	Days	30	27
Viscosity (Brookfield, 30°C)	mPs-a	80	105
Sp. Gr (30°C)	None	1.22	1.223
Moisture content	%	47.68	48.78
Non-volatile Content (2 gm, 2 hr, 120°C, Glass Petri Dish)	%	54.82	54.92
Free Phenol %	%	0.1	0.11
Gel Time at121°C	Mts-Secs	22-40	20-50
Na	%	4.28	8.01
K	%	2.7	0.41

Table 9.
Properties of MR and TR Sand received on 9^{th} day of generation

Parameter	Unit	MR Sand	TR Sand
AFS no	None	41.8	47.0
LOI	%	1.86	0.58
Na	%	0.20	0.013
K	%	0.034	0.011

Sand mix properties of above sands on 10^{th} day of generation

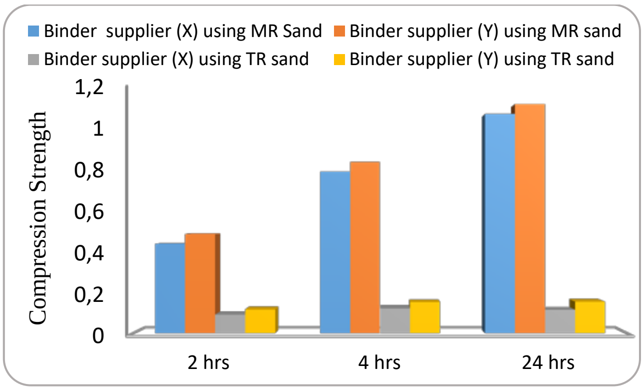


Fig. 22. Compression Strength MR & TR Sand used at1.5:20 with medium fast hardener after 8 weeks of generation

Remarks:
Example of another steel foundry producing railway castings generating TR sand using additive of supplier A. TR sand has become totally in-active in a period within 10 days of generation.

Additional Information and comments:

- TR sand generated when used in mold facing in case of SG Iron of thickness ≤ 30 mm produces castings free from surface defects.
- In case of steel & SG Iron casting of thickness > 30 mm ,this foundry faces sand inclusion and pinhole (up to 6-7 mm from surface) defects in surface. This observation substantiates the fact that repeated thermal reclamation of APNB bonded sand reduces its SiO_2 content vis a vis refractoriness. Reported values are as low as 92% compared to >99% in fresh sand.
- This phenomenon forces the foundry to use only new sand on mold facing in case of steel castings.
- Pouring temperature of SG Iron is 1480°C whereas in case of steel it is 1625°C.

Foundry V (Producing valve body steel castings up to 10 MT, boxed molds):
Sand: Saudi, one of the best qualities available
Reclamation: Mechanical followed by thermal
TR chemical supplier: Originally A then B
History of thermal reclamation:
Through experiments were done with variation on parameters like additive doses, chamber temperature, sand flow rate etc. Original supplier was A. Experiments were continued with additives from couple of other suppliers. Final solution came when experiments were done with additive of supplier B.

Table 10.
ROA of one month aged Resin being used by above Foundry

Property	Unit	Value
Viscosity (Brookfield), 30°C	mPs-a	55
Sp. Gr (30°C)	None	1.124
Gel time at 121°C	Mts-Secs	28-40
Nonvolatile content (2 gm, 2 hr, 120°C, glass Petri dish	%	58.03
Moisture content	%	47.74
Free phenol %	%	0.37
Na	%	0.64
K	%	8.05

Additive supplier: A
Additive: 1.4 % by weight of sand and Sand mix properties in TR sand at1:21

Table 11.
MR Sand (inlet sand in TR chamber) & TR sand (out let from TR chamber) properties

Parameter	Unit	MR Sand (Value)	TR Sand (Value)
AFS no	None	39-42.5	40.51-46.78
ADV	(ml 0.1 N Hcl/100 gm sand)	11.40-12.10	9.90-11.30
LOI	%	1.30-1.50	0.03-0.06%

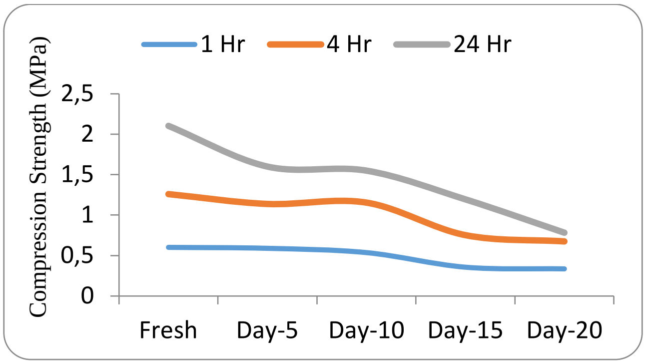


Fig. 23. Storage life Vs compression of TR sand

RT during period of experiment: 29-30°C, RH-59-70% except on 5th day 81% (data collected from foundry)
Additive supplier: B
Additive used 1.19% by weight of sand and Sand mix properties in TR sand at1:21

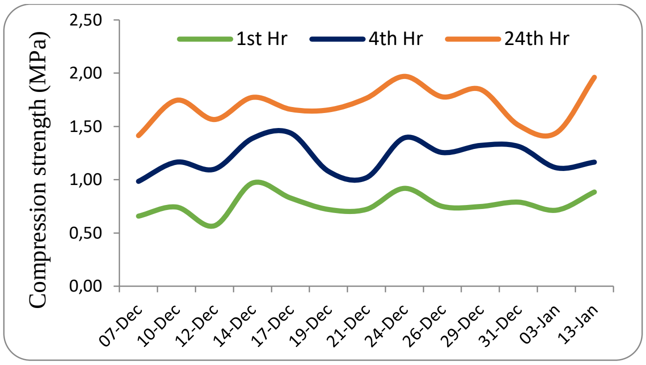


Fig. 24. Compression strength of TR sand studied for a period of 5 weeks (data collected from foundry)

Table 12.
New, TR & MR Sand properties

Parameter	Unit	New Sand	TR Sand	MR Sand
AFS no	None	48.06	43.35	46.31
LOI	%	0.688	0.390	1.83
Na	%	NA	0.019	0.161
K	%	NA	0.018	0.057

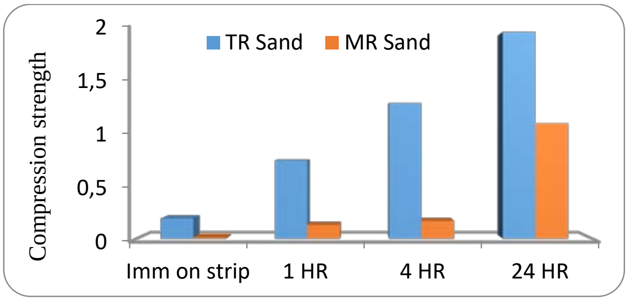


Fig. 25. Compression Strength of TR sand (after one month of generation) at1.0:21 & MR Sand at1.2:21with fast catalyst. RT-10-20^{0}C, RH- 58-73%

Remarks:
1. This foundry uses minimum percentage of binder both in New/TR (1%) and MR (1.2%) Sand. Specification for 24 hour compression are 1.96 MPa & 1.07 MPa respectively i.e. in case of boxed molds, steel castings can be poured in molds with dry compression of as low as 1.96 MPa.
2. Most phenomenal observation is that thermal sand generated using additive of supplier A loses stability on storage, right from day 1 to become inert towards reactivity with binder within a period of as low as a week.

TR sand generated using additive of supplier B is stable. Graphs are shown in Fig. 24 & Fig. 25.

4. Conclusions

1. Modern Alphaset is a complete self-set for producing all types of castings with different metallurgy and size.
2. With better understanding of chemistry, it has been possible to formulate recipe absolutely tailor made to meet specific requirements of individual customers.
3. Two recent developments are reduction of smell of formaldehyde in work place making it more environment friendly than ever before and formulations much more stable than original ones.
4. Regarding role of NaOH & KOH in formulations, both are having advantages and disadvantages. KOH based formulations are effective for thermal reclamation and NaOH based in mechanical.
5. Judicious blend of KOH & NaOH in formulations produces effective compositions.
6. There is no reference available indicating role of specific alkali on quality of castings.
7. It is always advisable to identify need of dry, hot and retained strength requirements of molds in every stage of handling right from stripping to post pouring and develop tailor made formulations to obtain optimum properties.
8. Specifications for dry strength values should be laid down by generating data over a period of time and should be just enough to meet values at different stages of mold handling. It has been found that values as low as 1.96 MPa in TR/new sand and 0.98 MPa in MR Sand are good enough to produce steel castings weighing 10 MT in boxed molds. Specifying strength requirement more than actual demand unnecessarily increases binder demand which in turn produces more gas and pushes the castings towards vulnerability for defects that too with increased cost.
9. There is scope for further studies by changing other variables like Phenol; Formaldehyde mole ratio, reaction conditions, non-volatile content etc.
10. FNB, with EU regulation [EC no 1272/2008] of restriction of maximum free FA content to 25%, finds incorporation of Phenol as third reactant with Urea and FA. Free phenol content of these formulations are much more than that of APNB formulations. On other hand modern APNB formulations are much more environment friendly than ever before. Thus, modern APNB is equally good or even better then FNB in many aspects as sand binder for making molds & cores in green field projects.

References

[1] Regulations (EC) No 1272/2008 of the European Parliament and of the council of 16 December 2008

[2] Ghosh, D.K. (2019). Comparison of Molding Sand Technology between Alphaset (APNB) and Furan (FNB). *Archives of Foundry Engineering*. 19(4). 11-20.

[3] Trikha, Sudhir, K. (2017). International Publication Number WO 2017/105526 A1. Naperville (US). World Intellectual Property Organization.

[4] Mhamane, D. A., Rayjadhav, S.B. & Shinde, V.D. (2018). Analysis of chemically bonded sand used for molding in foundry. *Asian Journal of Science and Applied Technology*. 7(1), 11-16.

[5] Thiel, J. (2011). Thermal expansion of chemically bonded silica sands. *AFS proceedings*. 11-116.

[6] Holtzer, M. (2015). Influence of Reclaim addition to the molding sand matrix obtained in the Alphaset technology on the emission of gases-comparison with molding sand with Furfuryl resin. *Archives of Foundry Engineering*. 15(1),121-125.

[7] Łucarz, M., Drożyński, D., Jezierski, J. & Kaczmarczyk, A. (2019). Comparison of properties of Alkali-Phenolic binder in terms of selection sand for steel castings. *Materials*. 12(22), 3705.

[8] White, K.B.. (2001). US Patent No US 6,232,368 B1. Schaumburg (US). United States Patent

[9] Major-Gabryś, K. et al. (2009). A new ester hardener for molding sands with water glass having slower activity. *Archives of Foundry Engineering*. 9(4), 125-128.

[10] Stevenson, J., Machin, J., Dyke, D.L. (1983). U.S. Patent No. US 4,416,694. England. United States Patent.