Technical Paper

ACCELERATOR FOR FASTER INVESTMENT SHELL MAKING AND ITS EFFECT ON THE PROPERTIES OF INVESTMENT MOULDS

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This paper highlights the usage of colloidal silica (commercially known as SILOX) as a binder for the investment casting process. This binder provides more strength to the investment shells and it is environmentally friendly. It can be easily mixed with refractory powders or grains to give brushable and sprayable slurries. The filler material used to prepare the investment slurry was zircon powder. It has the advantage of high refractoriness, low thermal expansion, resistance to wetting by molten metal and a fine particle shape. The stuccoing of the investment shells was made by using high refractory sand with AFS grain fineness number of 120 & 35 respectively for primary and secondary coats. The investment shells made with these materials were tested for bending strength and permeability. The effect of slurry viscosity, air drying time between coats and addition of electrolyte (ammonium acetate) on the properties of bending strength and permeability was also studied. The results of the investigation indicate that the addition of electrolyte (ammonium acetate) increase the viscosity of the slurry thus increasing the bending strength. The bending strength of the shells found increased with the increase in the viscosity of the slurry and also with the air drying time between the coats. The permeability of the shells decreased with the increase in the air drying time.

INTRODUCTION

In investment casting process an investment slurry is applied around a disposable pattern, usually wax, and allowed to harden to form a disposable casting mould[1,2,3]. The term disposable means that the pattern was destroyed during its removable from the mould and the mould was destroyed to recover the casting.

In this investigation, colloidal silica (commercially known as silox) was used as the binder. Zircon powder was used as the refractory filler material in the investment slurry. The primary and secondary stucco sands were high refractory silica sand obtained from Mangalore. The grain fineness number of 120 and 35 AFS numbers was used for primary and secondary stucco respectively. Ammonium acetate was used as an accelerator which neutralises the negatively charged silicon particles and imparts fast gellation of the slurries.

OBJECT OF THE PRESENT STUDY

The binder, Colloidal Silica, is commercially available for several years in our country[4]. But a clear understanding of the shell mould preparation is not available. Hence in the study the effects of the following factors are studied;

1} Effect of filler to binder ratio on the slurry properties,

2) Effect of air drying time between the coats of shell making,

3) Effect of accelerator on the reduction of shell making time.

SHELL MAKING PROCESS

The summary of shell preparation is shown in fig.1 in table 1 the binder specification i.e., colloidal silica is given.

Table 1: The constituents of silox

Silica (SiO_2) wt%	=	30 to 32
pH at 25^{0}C	=	9.5 to 10
Titratable Alkali (Na_2O_3)	=	0.3 to 0.6
Chlorides/Sulphates	=	Traces
Specific Gravity	=	1.20 to 1.23
Specific Surface area, m^2/g	=	250 to 400

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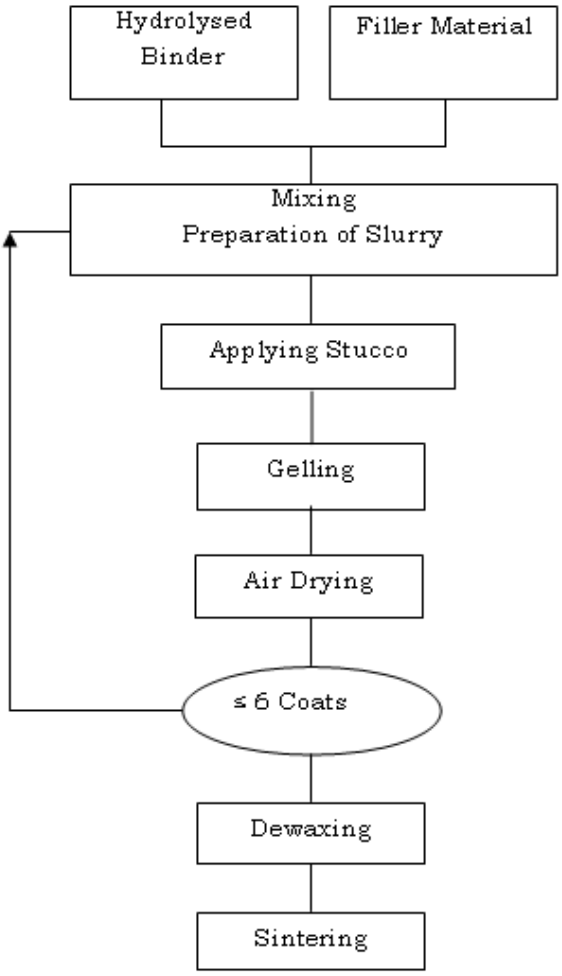

Fig.1 Steps in shell making process

PREPARATION OF THE SLURRY

The investment slurry was prepared by mixing thoroughly a weighed quantity of filler material (Zircon powder) and colloidal silica for 5 minutes to form homogeneous slurry. This is indicated by filler to binder ratio and given by the amount of filler to the volume of binder[5] and is indicated in table 2.

Investment Shell Making

Investment shell moulds were made by applying a series of ceramic coatings to the wax patterns. The pattern was dipped into the investment slurry. It was removed from the slurry and excess slurry adhering to the pattern was drained off to produce an uniform coating of slurry on the pattern. The wet layer was immediately stuccoed by sprinkling fine sand particles on it and it was dried to get the first primary coat. The first two coats were stuccoed with finer sand and later four coats with coarser sand. After six coats, the pattern was removed the shells into boiling water for 15 minutes and fired in a muffle furnace (810^0C for one hour) to remove moisture, to burn off residual wax as well as the sinter the ceramic shell.

The test specimens and investment shells were prepared with and without the addition of ammonium acetate. Ammonium acetate neutralizes the negatively charged silicon particles in the silox.

TESTS CONDUCTED

Figure 2 shows various tests conducted on the binder, the investment slurry and on the investment shell in the present investigation[6,7,8].

RESULTS AND DISCUSSION

Binder

Percent Silica Content

To ensure the quality of the binder used, for every batch of experiment the silica content of binder was determined. The procedure is; take 12.22802 g of colloidal silica and completely dry it in an oven at 110^0C. The final residue was weighed. Then the percent weight of silica in the colloidal silica was given by

$$\frac{\text{Weight of silica residue}}{\text{weight of colloidal silica}} \times 100$$

Silica (as SiO_2) wt% = 31.399%.

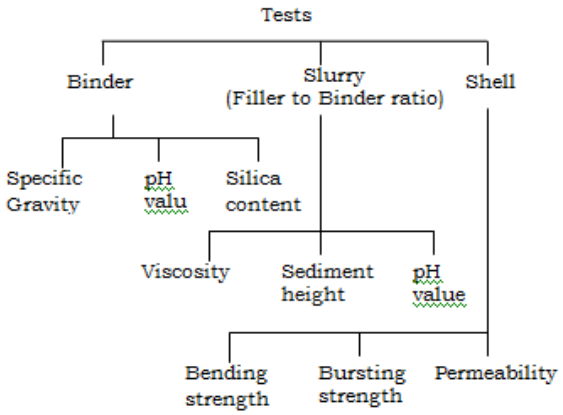

Fig.2 Tests conducted

The specific gravity of silox is

$$\text{Specific gravity of silox} = \frac{\text{Density of silox}}{\text{Density of water}} \times 100$$

$$= \frac{1.22802}{1.0}$$

$$= 1.22802$$

pH of Silox

The pH value of silox was measured using pH meter. The pH of silox was found to be 10.5 at 30^0C.

Slurry Viscosity

Ford cup[9] was used to measure the flow times of the slurries. The flow time was used to calculate the viscosities of slurries with the help of the equation. The pH variations of slurries were monitored with the help of pH paper.

Effect of Filler to Binder ratio and Aging time on the Viscosity of Slurries

The slurry once prepared will be used for several hours. Hence the influence of aging time on the slurry viscosity is necessary. Kinematic viscosities of slurries are given in table 2 for different filler to binder ratios and different aging times of slurry. The variation of kinematic viscosity in centi stokes with the filler to binder ratio is also shown in the table. It can be observed that the kinematic viscosity increased with increasing filler to binder ratio. The extra zircon powder makes the slurry denser and therefore, it takes a longer time for the slurry to pass through the orifice of Ford 2B cup.

Table 2: Slurry Viscosities with Filler to binder ratios and Aging time

Sl No.	Filler to Binder ratio (*)	Kinematic Viscosity, cst				
		Aging 0 hr	Aging 1 hr	Aging 2 hr	Aging 3 hr	Aging 4 hr
1	2.0	30.25	30.25	32.67	36.30	41.14
2	2.5	39.93	41.14	43.56	50.82	65.34
3	3.0	59.29	59.29	61.71	68.97	88.33
4	3.5	108.90	121.00	157.30	205.70	350.90
5	3.7	193.60	215.38	279.09	508.20	810.70
6	4.0	350.90	544.50	715.90	1101.10	1936.00

* $\frac{\text{Weight of filler (g)}}{\text{Volume of binder (ml)}}$

Effect of Ammonium Acetate on Kinematic Viscosity of the Slurry

Ammonium acetate was added to the slurry to accelerate the gelling time by neutralizing the negatively charged silicon particles in the silox. The kinematic viscosities of the slurries are given in table 3. It is observed from the table that the kinematic viscosity increases with the increase in the quantity of ammonium acetate. This effect can occur due to the neutralization of silicon particles in the silox that results in the rapid gellation of the slurry.

Sedimentation of Zircon Powder in the Slurry

The specific gravity of colloidal silica is 1.7 times lower than that of zircon powder. Hence high density zircon particles tend to settle down as sediment. The extent of sedimentation was recorded in terms of sedimentation height[8] i.e. the height of sedimentation of zircon powder in the slurry at different intervals of time. The results are given in the table 4. It can be observed that the sedimentation height increases with the increase in settling time of up to 45 minutes. thereafter it became constant. The maximum extent of sedimentation occurs within first 30 minutes. to overcome this problem it is necessary to continuously agitate the liquid slurry.

Table 3: Slurry Viscosities with Filler to binder ratios and Aging time

Sl No	Filler to Binder ratio	% ml of Ammonium Acetate to Binder	Kinematic Viscosity, cst				
			Aging 0 hr	Aging 1 hr	Aging 2 hr	Aging 3 hr	Aging 4 hr
1	3.7	0.0	193.6	209.1	237.2	248.5	481.6
2	3.7	0.2	188.8	208.1	244.4	399.3	601.4
3	3.7	0.3	194.8	194.8	226.3	274.7	468.3
4	3.7	0.4	196.0	232.3	317.0	599.0	851.8
5	3.7	0.5	205.7	286.8	530.0	1003.1	1531.9
6	3.7	0.6	214.2	348.5	913.6	1770.2	3690.5

* $\frac{\text{Weight of filler (g)}}{\text{Volume of binder (ml)}}$

Table 4: Sedimentation height of Zircon powder

Time (min)	Sedimentation height (mm)
15	18
30	20
45	21
60	21
75	21

PROPERTIES OF INVESTMENT SHELL

Bending Strength of Shells

The shell was built around a perspex sheet of 100mm x 30mm x 5mm as a pattern. Six coats

were given around the perspex pattern. The slurries were aged. The variables were filler to binder ratio, air drying time and addition of electrolyte.

Effect of Slurry Viscosity

Effect of slurry viscosity on the bending strength of investment shell is shown in figure 3. A study of the figure indicate that the slurry having kinematic viscosity value equal to 193.6 cst the bending strength was found to be maximum. At higher viscosities the bending strength of the shell was found to decrease and it can be related to this larger amount of zircon particles in the slurry for a given binder content.

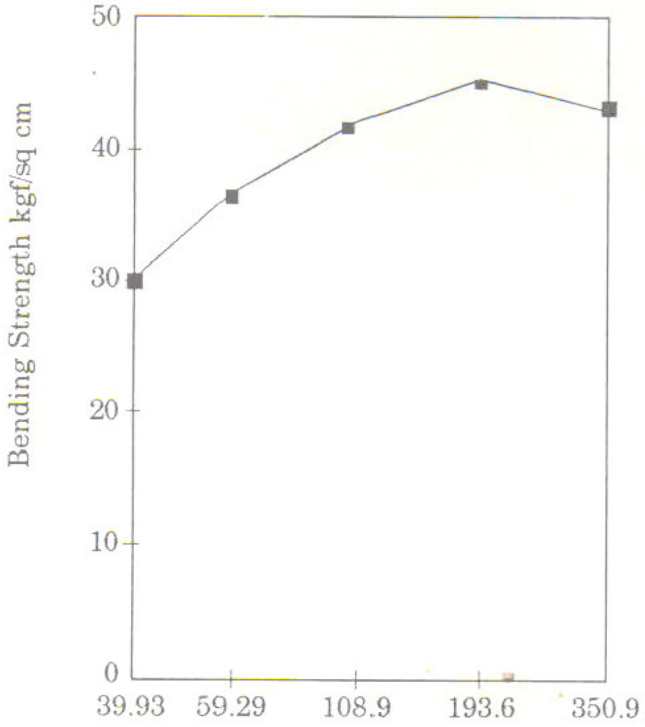

Fig. 3 Effect of viscosity of slurry on the bending strength of investment shell

Effect of Air Drying Time

The variation of bending strength with air drying time10 of the individual coats is shown in figure 4. Shell bending strength was found to increase with air drying between each of the individual coat. It was found to be increase with air drying time between each of the individual coat. It was established that greater the removal of water from the binder, higher was the strength. The water removal is facilitated during the longer air drying time and hence improved

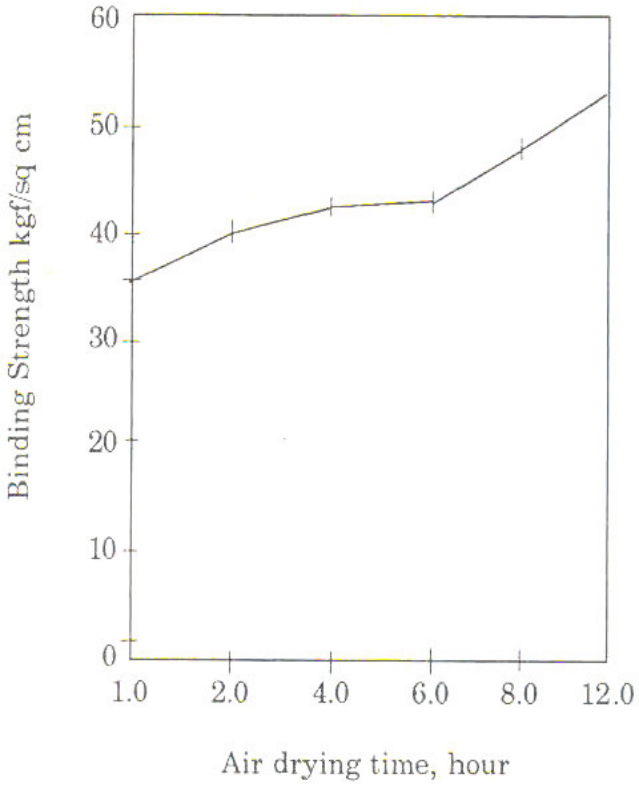

Fig. 4 Effect of air drying time on the bending strength of investment shell

shell strength. It could be seen that the fired strength were low compared to the dewaxed strength. The cause for lower strength of shell could be attributed to loss of binding strength and wax remaining on the shell.

Effect of Ammonium Acetate

The previous results were obtained by making the shells without any accelerator for gelling. But to enhance the production of shells, the air drying time between coats is to be reduced. It is possible by adding components that can shorten gelling time. One such compound is ammonium acetate. The shells to be tested for bending strength were prepared with different amounts of ammonium acetate and filler to binder ratio equal to 3.7. the individual coats were dried for one hour. The variation of bending strength of investment shell with the quantity of ammonium acetate is plotted in figure 5. It can be seen that for 0,4%ml of ammonium acetate, the bending strength was found to be maximum. This might be due to successful neutralization of negative charges on silicon particles of silox in the slurry and rapid gellation of the slurry.

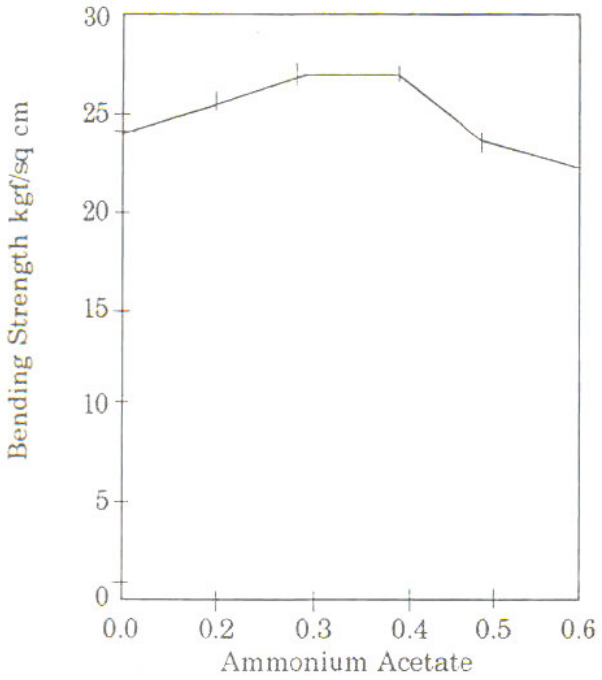

Fig. 5 Effect of ammonium acetate on the bending strength of investment shell

Permeability

The test specimens were prepared following the procedure given in references 8 and 11. These shells were used for testing the permeability[12] following the standard procedure.

Effect of Air Drying Time

The variation of permeability with air drying time is shown in figure 6. The permeability was found to decrease with the air drying time of the individual coat.

Effect of Ammonium Acetate

The shells to be tested for the permeability were prepared with different amounts of ammonium acetate and filler to binder ratio equal to 3.7. the individual coats were dried for one hour. The variation of permeability with increasing quantity of ammonium acetate is shown in figure 7. It is seen that the permeability value decreases marginally with the increasing quantity of ammonium acetate.

CONCLUSIONS

1. Kinematic viscosity of slurries increased with the filler to binder ratio.
2. Viscosity of slurries increased with the aging time of slurries.
3. The shells having viscosity equal to 193.6 cast, the bending strength was maximum i.e., 44.4 kgf/cm^2.

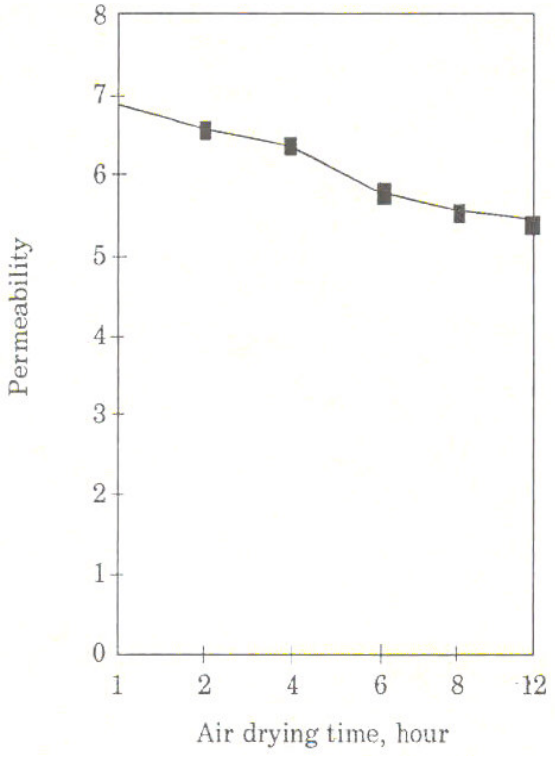

Fig. 6 Effect of air drying time on the permeability of investment shell

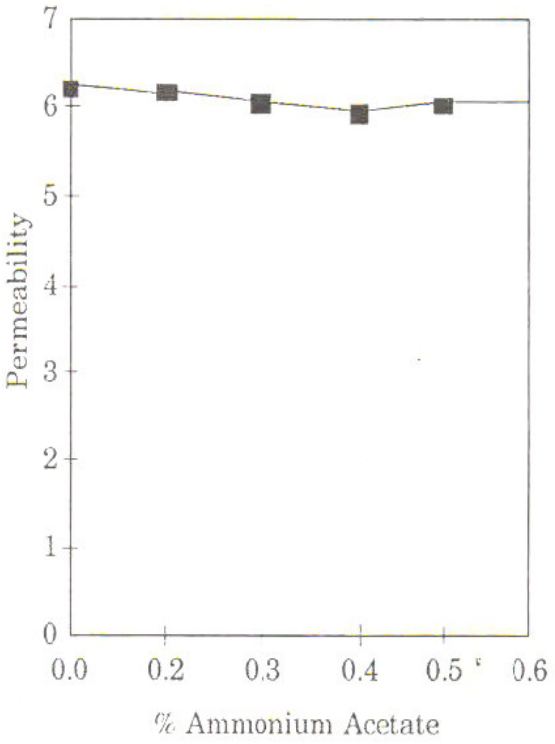

Fig. 7 *Effect of ammonium acetate on the permeability of investment shell*

4. The bending strength of shells increased with the increase in air drying time of shells between the coats.
5. The permeability of shells decreased with the increase in air drying time between the coats.
6. The addition of an accelerator, ammonium acetate, increased the viscosity, bending strength of shells but did affect the permeability of the shell.

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