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Studies on the Use of Non-Conventional Binders and their Effect on Moulding Sand Properties

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***Abstract*: Casting is one of the oldest methods of manufacturing and invariably the first step in the sequence of manufacturing a product. In this process, metals/alloys are heated to the desired temperature until they attain the molten condition and poured into the mould cavity where it takes the desired shape. This solidified cooled object is called casting. Moulds are usually made from Green sand, which is a plastic mixture of sand grains, binder (clay), water and other additives. Desirable properties of the moulding sand include good permeability, strength, refractoriness, plasticity, collapsibility, etc. Clay is the most widely used binder in foundry, as it caters to the requirements of moulding sand properties.**

Information relating to the properties of moulding sand using different binder systems namely clay-water, molasses system and CO2 systems is available. But very less information is available with respect to the property studies using conventional household materials which can effectively be used as binders for preparing moulds. In this direction, successful attempts were made to use jaggery, tamarind powder, all-purpose-flour (maida), in different proportions as binders. Combinations of these binders and their effects on the properties have also been evaluated. Property assessments such as compression strength, shear strength and mould hardness have been carried out in detail. The results will be useful to the foundry men and researchers to select particular material for preparing the moulds.

***Keywords*: Non-Conventional Binders, Compression and Shear Strength, Hardness and mould properties**

1. Introduction

Manufacturing processes or Production Technology mainly deal with the conversion of raw materials into useful product. The steps which are involved in converting a raw material into a useful product is called processing and the mechanism followed to get an end product is referred to as manufacturing.

Casting is one of the manufacturing processes which make use of the fusibility property of the material. It is one of the oldest methods of manufacturing and invariably the first step in the sequence of manufacturing a product. In this process, material is heated to the desired temperature and poured into the mould cavity where it takes the desired shape. After the molten metal solidifies in the mould cavity, the product is taken out to get the casting.

In sand moulding, only small amounts of additives are needed each time the sand is mulled. It is not necessary to use expensive reclamation systems to recycle the sand. This results in sand moulding being the least expensive process [1].

The mixture is moistened, typically with water to develop strength and plasticity of the binder. A binder or binding agent is any material or substance that holds or draws other materials together by adhesion or cohesion. The performance and profitability of a foundry mainly depends upon the quality, availability and cost of the binders [2].

Different types of binders that are commonly used are listed below:

- Organic Binders - linseed oil, vegetable oil, mineral oil etc.
- Inorganic Binders - fire clay, bentonite clay, sodium silicate etc.

Most commonly used binder is clay-water system. Oils, resins and sodium silicate are other binders, having their own advantages and disadvantages and are hence accordingly used.

Many researches have been carried out to use other potential substances as binders, to obtain better moulding properties of sand.

Moulding sands are defined by characteristics/properties such as refractoriness, compression strength, shear strength, permeability, mould hardness etc.

2. Aim of the Research

Information relating to the properties of moulding sand using different binder systems namely clay-water, molasses system, CO_2 systems is available. Also, bio-based inorganic binders for core preparation are available [3]. Very less information is available with respect to property studies using conventional household materials which can effectively be used as binders for preparing moulds. In this direction, successful attempts were made to use jaggery, tamarind powder, all-purpose flour (maida), in different proportions as binders. Effects of the combinations of these binder systems on the compression strength, shear strength and mould hardness have been carried out in detail. The main objective of the presented work is to examine the above mentioned properties of the selected binders and its sustainability for usage for foundry purposes and compare them with the conventional binders. The results of the investigation will be beneficial to the foundry men and researchers to select particular materials for preparing low-cost moulds.

3. Materials and Methods used

A. Binder material and properties

- *Jaggery*: Jaggery is prepared by concentrating the sugarcane juice and it is available in the form of solid blocks. The hygroscopic nature of granulated jaggery leads to stickiness [4].
- *Tamarind powder*: Tamarind fruit is a brown pod-like legume which contains a soft acidic pulp, many hard-coated seeds and fiber in a pod. The seed of tamarind comprises of seed coat or testa (20–30%) and the kernel or endosperm (70–80%). The seeds are an important source of carbohydrates, protein, fat and valuable amino acids. The tamarind kernel powder (TKP) made from tamarind seeds is majorly used in industries [5].
- *All purpose flour*: A protein called 'gluten' is present in wheat flour. Gluten gives wheat its elasticity and stretch ability. Refined flour/ maida is very sticky and elastic. It contains higher contents of fat (4%) and carbohydrate (32%), therefore, the water absorption capacity of all-purpose flour can be attributed to the presence of fat and carbohydrates in it, which leads to stickiness [6].

B. Method

1) Preparation of Sand Specimen

Basic ingredients

1. Silica Sand
2. Binder
3. Water

Test specimen for the assessment of moulding sand properties were prepared by varying amounts of the binder content and water. The following table gives the details of the proportions of binders added to prepare the specimen. Initially 200 gram of total sand mixture was prepared using the below composition and standard rammed specimens were obtained for the compositions.

Table 1
Preparation of binders

S. No.	Binder Materials used	Proportions by weight basis	
		Water	Binder
1	Clay	6-8%	8-12%
2	Jaggery	6-8%	8-14%
3	Tamarind	6-8%	8-14%
4	All-Purpose flour	6-8%	8-14%

2) Preparation of mixture

A mixture of 200g is prepared using silica sand, binder (for ex: Jaggery) and water. Amounts of water and binder are calculated by fixing their percentages of composition. The calculations are shown below.

Composition of mixture:

Water = 6%
Jaggery=12%
Weight of water = (6/100)*200 = 12g
Weight of jaggery = (12/100)*200 = 24g
Weight of sand = 200-12-24 = 164g

200g	=	164g	+	24g	+	12g
Mixture		Silica sand		Jaggery		Water

Other specimens were obtained by varying the amount of binder and keeping the water content constant.

3) Preparation of specimen

The specimen is prepared using the Sand Rammer. It consists of a calibrated sliding weight actuated by cam, a cup, a specimen stripper and a specimen tube.

The sand rammer is used to prepare a standard 50mm dia x 50mm height (1" dia x 1" height) specimen.

- Around 150-170g (depending on water content) is filled into the tube supported by the base block.
- This is mounted on the rammer and rammed thrice using the sliding weight.
- The specimen is checked for the dimensions to be within the tolerance lines marked on the equipment.
- The specimen is then removed using the stripper.

Fig. 1. Prepared Specimen

C. Experimentation

This includes the step-wise procedure of the various tests performed on the specimens. Universal Sand Strength Machine is used for carrying out the experiments. It consists of a loading frame, loading mechanism, force measuring mechanism, facility to accommodate accessories and a digital strength indicator. The values/results can be directly read from the indicator. Compression strength and shear strength tests have been performed on this machine, which have further been described.

1) Compression strength test

i. Compression shackles are fitted on the sand strength testing machine.
ii. The specimen is mounted between the shackles.
iii. The machine is set to read compression strength and the value is reset to zero.
iv. The specimen is then loaded until the specimen ruptures; after which it starts unloading.

v. The value is directly read from the digital indicator.

2) Shear Strength Test

i. Shear shackles are fitted on the sand strength testing machine.
ii. The specimen is mounted between the shackles.
iii. The machine is set to read shear strength and the value is reset to zero.
iv. The specimen is then loaded until the specimen ruptures; after which it starts unloading.
v. The value is directly read from the digital indicator.

3) Mould hardness test

A mould hardness tester is used to test the hardness of the mould. It consists of an analog indicator and a special geometry plunger to read hardness of mould from 0 to 100 Nos. Mould hardness test was carried out at different locations on the prepared mould. An average of 6 readings recorded across the cross-section of the mould has been considered for the analysis.

i. The plunger is placed on the surface of the prepared mould.
ii. Pressure is applied until the hemispherical plunger plunges up and the flat surface of the tester touches the flat surface of the mould.
iii. The reading is noted down.

4. Results and Discussion

A. Compression strength

1) Varying the binder content (Water content constant)

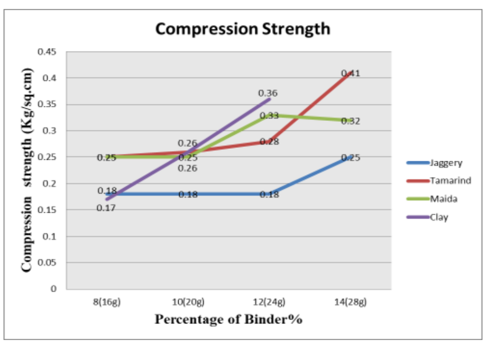

Fig. 2. Variation of compression strength v/s percentage of binder

Figure shows the variation of compression strength versus different amounts of binder addition. It can be observed from the figure that an increase in the binder content has resulted in an increase in the compression strength for all the binder materials and for all proportions of binder addition carried out. Maximum compression strength of 0.41 kg/sq.cm is observed for 14% of tamarind powder and 8% of water addition. Minimum strength of 0.25 kg/sq.cm is observed for the specimen made using jaggery as binder.

2) Varying the water content (binder content constant)

Figure shows the variation of compression strength versus different amounts of water addition. It can be observed from the figure that an increase in the water content has resulted in a decrease in the compression strength for the binder materials and for all proportions of water addition carried out. Maximum compression strength of 0.41 kg/sq.cm is observed for 12% of tamarind powder and 6% of water addition. Minimum strength of 0.25 kg/sq.cm is observed for the specimen made using jaggery as binder.

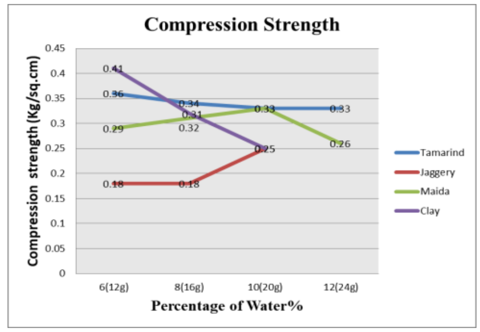

Fig. 3. Variation of compression strength v/s percentage of water

B. Shear Strength

1) Varying the binder content (Water content constant)

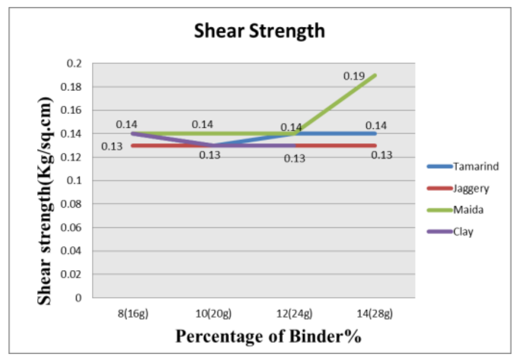

Fig. 4. Variation of shear strength v/s percentage of binder

Figure shows the variation of shear strength versus different amounts of binder addition. It can be observed from the figure that an increase in the binder content has resulted in an increase in the shear strength for all the binder materials and for all proportions of binder addition carried out. Maximum shear strength of 0.19 kg/sq.cm is observed for 14% of all-purpose flour and 8% of water addition.

2) Varying the water content (binder content constant)

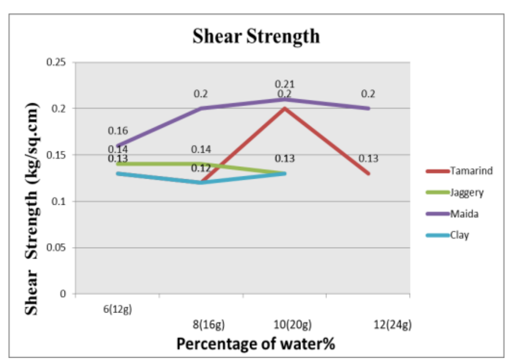

Fig. 5. Variation of shear strength v/s percentage of water

Figure shows the variation of shear strength versus different amounts of water addition. It can be observed from the figure that an increase in the water content has resulted in an initial increase followed by a decrease in the shear strength for the binder material and for all proportions of water addition carried out. Maximum shear strength of 0.21 kg/sq.cm is observed for 12% of all-purpose flour and 10% of water addition. Minimum strength of 0.13 kg/sq.cm is observed for the specimen made using jaggery as binder.

C. Mould Hardness

1) Varying the binder content (Water content constant)

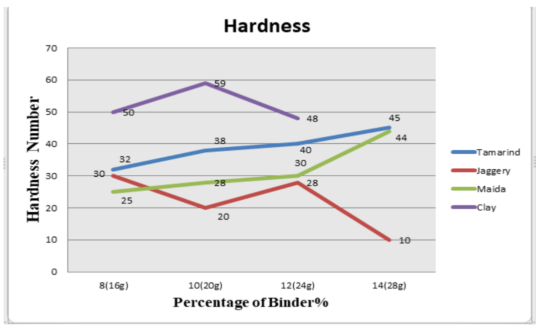

Fig. 6. Variation of Hardness v/s percentage of binder

Figure shows the variation of mould hardness strength versus different amounts of binder addition. It can be observed from the figure that an increase in binder content has resulted in an increase in mould hardness for tamarind and all-purpose flour. Maximum mould hardness of hardness number- 45 is observed for 14% of tamarind powder and 8% of water addition. Minimum hardness number of 10 is observed for the specimen made using jaggery as binder.

2) Varying the water content (binder content constant)

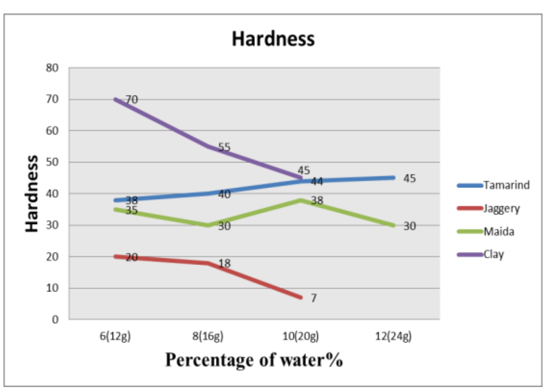

Fig. 7. Variation of Hardness v/s percentage of water

Figure shows the variation of mould hardness versus different amounts of binder addition. Maximum mould hardness of hardness number 45 is observed for 14% of tamarind powder and 12% of water addition. Minimum hardness number of 7 is observed for the specimen made using jaggery as binder.

5. Conclusion

Different binder systems such as Jaggery, Tamarind and all-purpose flour (Maida) have been successfully tried as binders for moulding sand.

The values of the highest strength obtained using various binder systems are listed below:

Compression strength:

- Jaggery -0.25 kg/sq.cm
- Tamarind Powder- 0.41 kg/sq.cm
- All-purpose flour(Maida) - 0.33 kg/sq.cm

Shear strength:

- Jaggery- 0.14 kg/sq.cm
- Tamarind Powder- 0.14 kg/sq.cm
- All purpose flour(Maida)- 0.21 kg/sq.cm

Mould hardness:

- Jaggery- 30.
- Tamarind Powder- 45.
- All-purpose flour (Maida)- 44.

It can be seen from above that, Tamarind system exhibits better compression strength and hardness compared to the other two systems. Whereas, All-purpose-flour (Maida) exhibits better shear strength.

The properties may further be enhanced by baking them in ovens. All the specimens tested contained only the main binder and water. No special additives were added. Thus, different additives can be added along with these binders and further tested to obtain better properties.

6. Scope for future work

The results of the investigation are quite encouraging to take up further studies on binder systems.

a) Other properties namely permeability, gas evolution property, friability tests can be carried out.
b) Castings can be made using these binder systems.

Using the binder systems, castings can be made and the hot strength property, refractoriness property and other properties like sand burn-on, etc. can be studied.

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