Determination of the Physical Properties of Sand Moulding Bonded with Composite of Ipomoea Batatas and Bentonite with Casting Application

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Abstract - *Nowadays all over the world face the silica sand scarcity problem. But traditionally the foundry field produces casting with sand moulding so in this research try to enhance the silica sand utility and also reduce the environmental pollution by using new organic binder Ipomoea batatas. The effect of the local binder named bentonite and Ipomoea batatas gum addition with silica sand was investigated in this study by varying binder concentration. Aluminium casting was produced by this research. Grain fineness of the sand and mechanical properties, such as green/dry compressive strengths and permeability were tested. The results show good properties when combining Bentonite and Ipomoea batatas binder and also good casting in non-ferrous metals when applied the optimum binder combination. Then the quality of casting was analyzed by hardness test, surface roughness test and ultrasonic test.*

Keywords— Foundry, Silica sand, Bentonite, Ipomoea batatas, Compression strength, Permeability, Casting, Ultrasonic test

1.INTRODUCTION

Green sand moulding process has been traditional for long time, but it is common in practice because of its advantages. When investigated on Stress strain curve behavior of sample and also indicated that sample from naturally bonded sand has highest tensile strength with superior ductility. Best surface finish than cement mould. Impact strength is high when compared to cement and Co_2 mould. For those reasons sand moulding was selected [1]. Silica sand is costly nowadays. So effectively using the silica sand is very much important. Foundry industry successfully run with may category of binders. But only some of the binders have reduced the production cost, environmental friendly and also giving good properties of moulding, good casting. When review all this points, the organic binder was introduced in this research named Ipomoea batatas. Previously some of the researches were conducted using starch based binders. Dry and green compression strength will increase with increase starch binder and shows good properties for casting non-ferrous metals [2-8]. And also Sweet potatoes having some good engineering properties those are the highest value of compressive strength [9]. That why Ipomoea batatas binder was selected for this research. Using only the starch binder was gave moderate physical properties so adding one more binder to enhance the physical properties of moulding; the sand gave good mechanical properties when bonded with kaolin or bentonite clay, with kaolin giving better bond properties. The mechanical properties analysis of the sand was compared to existing foundry standard and it was discovered to be very suitable to all types of non ferrous alloy castings [10-13] so here bentonite binder was added with Ipomoea batatas binder. Silica sand was collected at the place of river bed and the grain finesse number was found by sieve analysis test [14, 15]. The physical properties of moulding sand like permeability, green compression strength, and dry compression strength were tested [16]. Optimum binder combination was found by the testing methods and castings were done on the appropriate combination moulding. In this research aluminum was selected for the casting process. After the casting process, the quality of the casting was tested by the methods like hardness test, surface roughness test and ultrasonic test.

2. MATERIALS

In this research, moulding sand preparation was done by three raw materials those are natural silica sand, bentonite and Ipomoea batatas. There are many types of moulding method available, but here green sand moulding method was selected.

2.1 Natural Silica Sand

Sand is divided into two broad types that are natural and synthetic. In this research Natural silica sand was collected at the place of Amaravathi River in the state of Tamilnadu, India. River bed sand is most probably green sand which was opted for foundry application. Most of the green sand molds composed of silica sands bonded with a clay-water mixture in different proportion with respect of the places at where we collect silica sand. The composition, size, size distribution, shape and purity of the sand are important to the success of the mold making operation. The best foundry sands having good grain finesse number and also good shapes that is round shaped sand having good permeability, flowability and also good bonding and compressive strength. So grain size is an important factor. Grain finesse number of the sand is ≈ 36. Moisture content present in the green sand is also important which already derived 5-8% [5]. And it is having good damping capacity

2.2 Bentonite

Bentonite is an absorbent aluminium phyllosilicate, necessarily impure clay composing mostly of montmorillonite content. The absorbent clay was given the name Bentonite by Wilbur C. Knight in 1898, after the Cretaceous Benton Shale near Rock River, Wyoming [15]. Bentonite having different types, some of the types is potassium (K), sodium (Na), calcium (Ca)& aluminium (Al). Bentonite usually forms from weathering of volcanic ash, most often in the presence of water. But the term bentonite, as well as similar clay called tonstein. For industrial application, two main type of bentonite preferred those are sodium and calcium bentonite. But here sodium bentonite was selected because of its advantages, easy availability and economical. Bentonite is highly preferable clay binder for the foundry sand especially for the both ferrous and non-ferrous industries. Sodium bentonite used for medium and large castings. Only small percentage of bentonite can made very good binding with good compressive strengths. The ionic surface of bentonite has a useful property in making a sticky coating on sand grains. This is the property which is used to create sand moulding. The self-stickiness of bentonite allows high-pressure ramming or pressing of the clay in molds to produce hard, this property is used to enhance the refractoriness, hardness and also flow ability. Bentonite which was applied in this research had 75 to 53 micron sizes.

2.3 Ipomoea Batatas

Common name of Ipomoea batata is sweet potato. Sweet potato having lot of varieties, but in this research NASPOT 1 variety was selected having skin colour of pale yellow, flesh colour of white, 67% moisture content, 33% dry matter , 23.5% starch content [16] and also the availability and economical reason. Not only this common reason but also this variety of sweet potato having high starch content which is essential for binding property. Commonly starch binders having good compression strength, that's why we choosing starch binder. While prepare the Ipomoea batatas flour following steps to be followed those are cleaning and trimming, washing, slicing, drying, milling. Ipomoea batatas having the grain size of 103- 75 microns.

3. METHODOLOGY

In this research Ipomoea batatas binder is used as in gum state. Took 400 grams Ipomoea batatas flour binder mixed with 100 ml. Now the mixer was boiled in a pan at the temperature of 120^{0}C. The cooking time was 1 hour 20 min. After 1 hr 20 min the gum was cooled 3 hours thoroughly. Now the gum was ready for using as a binder. Ipomoea batatas gum binder containing 5% moisture content [3].

4. RESUTS AND DISCUSSION

The results and discussion sections present the research findings and analysis of those findings. It also contains a conclusion section, which focuses on practical application or provides a short summary of the research.

4.1 Seive Analysis Test for Natural Silica Sand

Sieve analysis is the method of finding the different grain size of the sample sand. Un wanted and very big substance which were presented in the sand removed by this method. These sieves are stacked in sequence with the coarsest sieve at the top and placed in a sieve shaker. The sieve shaker is inbuilt with mechanical vibrator. About 200 grams sand is placed at the top sieve and, after 15 minutes of vibration, the weight of the sand retained in each sieve is obtained. The AFS grain fineness number of the sand tested can then be determined by taking the percentage of sand retained on each screen, multiplying each by a multiplier (which is simply the next available sieve old mesh number greater than the one being weighed out), adding the total, and then dividing by the total percentage of sand retained on the sieves.

S.No	Sieve size(μ)	Sieve No	Weight retained (g)	Weight retained %	Cumulative weight (g)	Product
1	2057	8	15.20	7.6	7.6	0
2	1680	10	5.18	2.59	10.19	20.72
3	1003	16	16.84	8.42	18.61	84.2
4	710	22	14.10	7.05	25.66	112.8
5	500	30	52.44	26.22	51.88	576.84
6	355	44	6.38	3.19	55.07	95.7
7	250	60	15.28	7.64	62.71	336.16
8	150	100	69.86	34.93	97.64	2095.8
9	103	150	2.68	1.34	98.98	134
10	75	200	1.20	0.6	99.58	90
11	53	300	0.72	0.36	99.94	72
12	-53		0.12	0.06	100	18
					∑3636.22	

Chart 1: Sieve Analysis of Natural Silica Sand

In this graph, sieve size of the natural silica sand is taken in X-axis and percentage of the sand retained is taken in Y-axis. From this graph, it is clearly that 150 and 500 microns size has more amounts of sand present in natural silica sand.

Grain finesse number (GFN)
= 3636.22/100
=36.3622 AFS

Average grain finesse number (AFN)
=3636.22/99.94
=36.53 AFS

Normally 50 GFN size is preferred for the casting process. But here 36.5 GFN size only derived, so the sand which was used in this research having average grain finesse number.

Table – 1: Sieve Analysis Test Result for Silica Sand

4.2 Permeability Test

Permeability test was done by permeability meter. Permeability meter has manometer gauge. The gauge reading denotes the permeability number of the test specimen. Test specimen must have standard size which is already in the practice derived by the AFS. Permeability of the sand specimen prepared was determined by passing a given volume of air through the sand. This test was taken in the permeability meter. The amount of air passing through the specimen was to be showed in the manometer reading. The permeability number should neither low nor high. The entire tests choose 5% water which is optimum value for good binding.

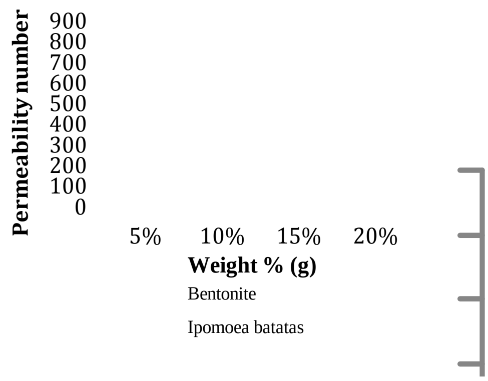

Chart – 2: Permeability Tests of Bentonite and Ipomoea Batatas Binders

In both cases, when increase the binder, the permeability was decreased. Low permeability will create the defects like porosity, blow hole like that. High permeability will create poor surface finish. So, moderate permeability was chosen for good casting. In this graph 5% of binders show high permeability number, 20% of binders show low permeability number. The reason of decreasing permeability number with increasing binder is when binder % increase at the time lot of small particles occupied in between the sand particles.

4.3 Green/dry compression test (GCS/DCS)

Green and dry compression strength test is done by using universal sand strength machine. Permeability test and green/dry compression strength are done with the same test specimen standard. The test specimen at which point break when giving load to that piece that particular point is noted as a strength of the specimen. If the specimen is in the wet state means that are called green compression strength. If the specimen is in the dry state means that are called dry compression strength. This test is held in sand strength machine. Prepare a specimen and test the specimen with sand strength machine to know the green strength of the specimen.

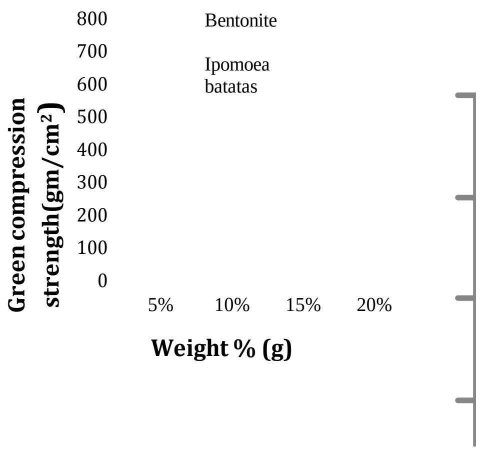

Chart – 3: Green Compression Strength of Bentonite and Ipomoea Batatas

DCS test was held after the GCS test. The same specimen was naturally dried in 48 hours and takes the test in sand strength machine and calculates the dry compression strength (fig. 4).

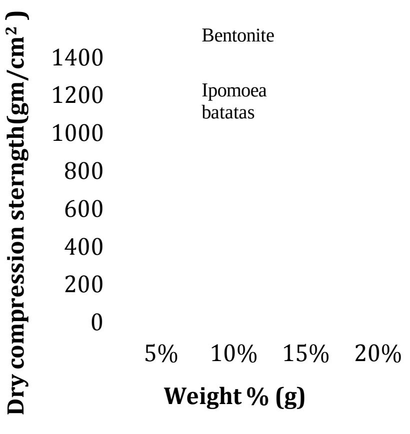

Chart – 4: Dry Compression Strength of Bentonite and Ipomoea Batatas

Y axis denotes the green compression/ dry compression strength and x axis denote the weight percentage. From the graph it can be realize that addition of bentonite binder is directly proportional to green compression/ dry compression strength. If Ipomoea batatas binder increased the GCS also increased up to 15% then it is come down in 20% of binder addition. Bentonite shows the good results than ipomoea batatas flour binder. Increasing both binders also increases the DCS upto 20%. Hear Bentonite was gave good results than Ipomoea batatas.

4.4 Permeability, GCS, DCS Tests With 5% Bentonite and Ipomoea Batatas Flour Binder (5-20%) Combination

Y axis denotes permeability, GCS, DCS & X axis denotes 5% Bentonite and varying % in five multiples of Ipomoea batatas. The blue line indicates permeability, red line indicates green compression strength and green line indicates DCS. From the graph it can be find that the permeability is reduced in the addition of binders & increased GCS and DCS upto 5% Bentonite and 15% Ipomoea batatas combination, then came decreased in 5% Bentonite and 20% Ipomoea batatas combination (fig. 5).

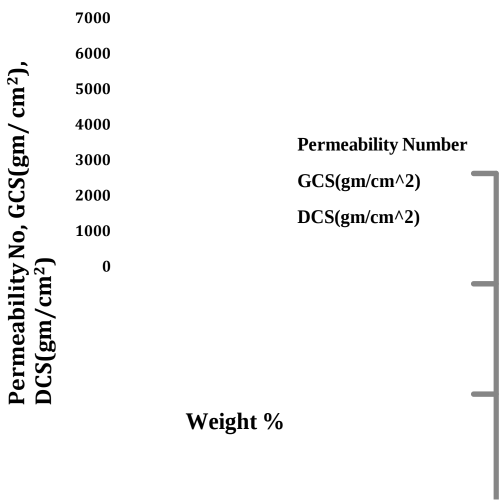

Chart – 5: Permeability, GCS, DCS Tests of Combining Bentonite (5%) and Ipomoea Batatas

4.5 Permeability, GCS, DCS Tests With 10% Bentonite and Ipomoea Batatas Flour Binder Combination

In the graph Y axis denotes permeability, GCS and DCS & X axis denotes 10% bentonite and varying % of Ipomoea batatas. The blue line indicates the permeability. Red line indicates the green compression strength. Like that green line indicates DCS. From the graph we can know that, if binder increased permeability is reduced & GCS, DCS is increased.

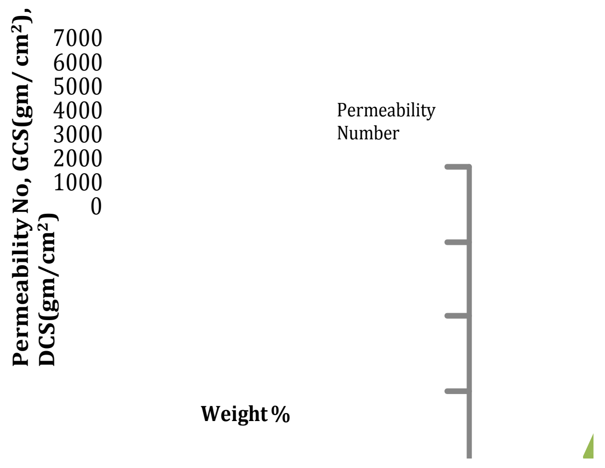

Chart – 6: Permeability, GCS, DCS Tests of Combining Bentonite (10%) and Ipomoea Batatas

4.6 Permeability, GCS, DCS Tests with (15%) Bentonite and Ipomoea Batatas Flour Binder Combination

In our graph Y axis is denote permeability, GCS, DCS & X axis denote 15% Bentonite and varying % of Ipomoea batatas. From the graph we can know that, if binder increased permeability is reduced & GCS, DCS is increased. When compared to 5%, 10% Bentonite combination 15% Bentonite combination gave good strength. But permeability became too low than 5%, 10% Bentonite combination. When review the green compression strength (GCS) result, 15% bentonite and 15% Ipomoea batatas binder combination was gave highest strength like 650 gm/cm^2. The next highest GCS strength 640 gm/cm^2 was given by two various combinations those are 10% bentonite and 15% Ipomoea batatas binder & 15% bentonite and 10% Ipomoea batatas binder (fig. 7). These three combinations having the permeability range of 150-250. Because of these reasons this three particular combinations were selected for the casting process.

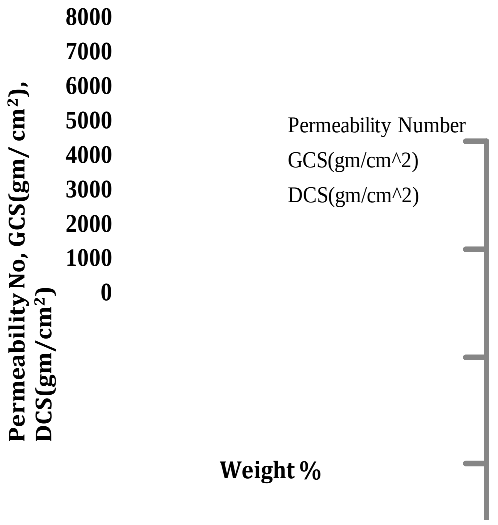

Chart – 7: Permeability, GCS, DCS Tests of Combining Bentonite (15%) & Ipomoea Batatas

5. CASTING SAMPLE

Best moulding combinations samples were selected. Three selected sample moulds were prepared and aluminium material was selected for casting process. This is the best casting samples among three set of casting (fig. 8). The binder combination 10%Ipomoea Batatas, 15%Bentonite was gave good casting.

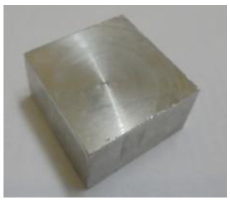

Fig – 1: Casting Sample after Machining Process

6. TESTINGS

In this research hardness test, surface roughness test and ultrasonic test were done to know the casting quality.

6.1 Hardness Test

Hardness may be defined as the ability of a material to resist scratching, abrasion, cutting or penetration. The hardness test is performed on a material to know its resistance against indentation and abrasion. The three most commonly used hardness tests are Brinell hardness test, Vickers hardness test and Rockwell hardness test [18]. In this research we consider Rockwell hardness test only. The best moulding combination sample was gave the good hardness range.

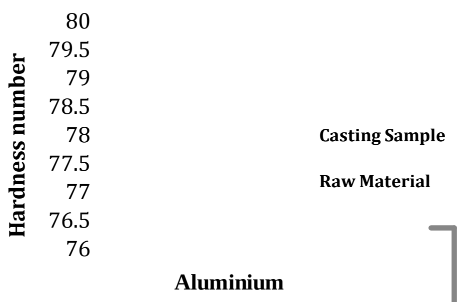

Chart - 8: Rockwell B- scale (15% Bentonite, 10% Ipomoea Batatas)

From the (fig .9) hardness of the aluminium was tested. From the graph the materials which were casted by this research having approximately equal hardness to the same raw materials. So the casting process which was held in this research not reduces the strength of the materials. So this binder combination is opted for non ferrous casting.

6.2 Surface Roughness Test

Surface roughness, often shortened to roughness, is a component of surface texture. It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth. Roughness is typically considered to be the high-frequency, short-wavelength component of a measured surface [18].

Table-2: Surface Roughness Value for Different Materials

Metals	Surface Roughness of Raw Material in mm	Surface Roughness of Casting Sample in mm
Aluminium	0.09	0.01

Here good surface finish in micron level finish was achieved. Good machinabiliy of the materials are definitely giving good surface finish. The casting samples surface finish is better than raw material finish. Aluminium having 1 micron finishes. From this table the result which is come to know that the moulding combination and the casting process which were held in this research are not affect the surface finish of the casting samples

6.3 Ultrasonic Test

When analyses the ultrasonic test result of aluminium from the report which show clearly that this combination of mould was gave best casting when compare to other two mould combination castings with negligible defects. And very good surface finish. Why because this combination having good green compressive and also good permeability range.

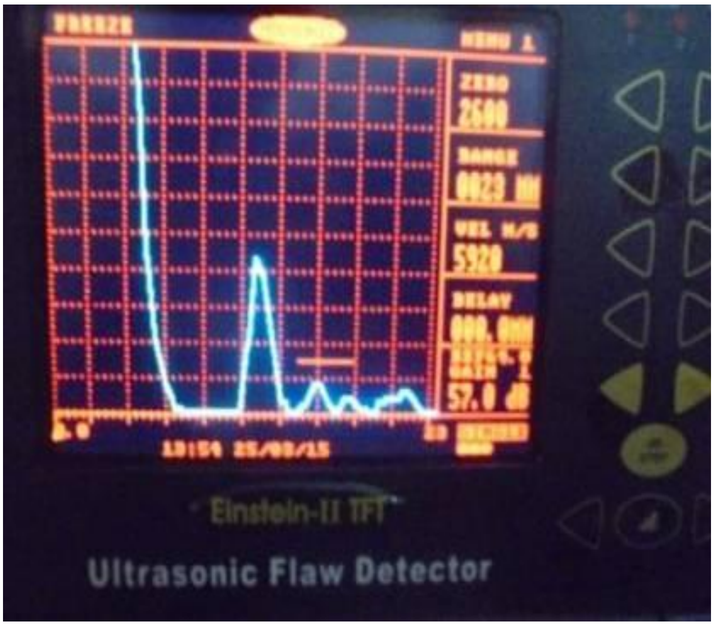

Fig-2: Ultrasonic test result

7. CONCLUSION

From the analysis conducted, we can conclude that green compression strength of the molding sand and Bentonite increase in strength when compared to moulding sand in practice. Ipomoea batatas binder with moulding sand gave moderate strength. But the combination of Bentonite and ipomoea batatas binders with moulding sand was given excellent strengths in both GCS and DCS. Permeability value decreased when moulding sand along with increasing percentage of Bentonite and also flour binder. Casting was done with aluminium sample with three particular combinations like 15% bentonite binder & 10% Ipomoea Batatas binder, 10% bentonite binder & 15% Ipomoea Batatas binder, 15% bentonite binder & 15% Ipomoea Batatas binder. When review the hardness test, surface roughness test, ultrasonic test of the casting sample we can conclude that 15% bentonite binder & 10% Ipomoea Batatas binder combination were gave good result because of its good strength (640gm/cm^2) and also the permeability number range (243). So our new binder was not affecting the moulding sand strength which is in practice and also the casting quality. This binder combination was increasing the moulding sand strength and also the casting quality. Ipomoea batatas has self degradable in nature, so environment friendly. Production cost of the moulding, casting, finishing were reduced. Silica sand was utilized effectively. Non- ferrous castings were done successfully. In Future Molding sand will be reused effectively. For the above reasons in future this type of organic binders are going to be used for the core making and also moulding purposes. Comparison of the fresh sand mould properties and used sand mould properties. And try to utilize the used moulding sand.

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