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Effects of Lumajang sand-bentonite mix on Al-Si casting mechanical properties

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Abstract

The use of sand for metal molds is often found in various places; this research will focus on the type of sand used, namely sand from Lumajang Regency, which is known to be strong for concrete mixes or the like. So the purpose of this research is to find out how Lumajang sand molds will be used as metal casting molds. Testing will be carried out by making three variations of bentonite mixtures: 10%, 15%, and 20%. Later, after knowing the tensile and compressive strengths of each sand mold, casting will be carried out with three variations. For testing, casting objects will use the dye penetration test method. So that a description of the surface smoothness of the casting objects made from the three molds will be obtained and it will be known which variation is good to know about the sand mold and the appropriate metal casting results. From the results of the research conducted, it shows that the bentonite mixture with a percentage of 20% gets the highest compressive value with a value of 26.3 N/cm2 when compared to other bentonite mixture variations. From the tensile testing results, a high tensile strength value was obtained in the 15% bentonite mixture variation with a value of 0.7 N/cm2. While the results of the dye penetrant test were obtained, the results of the variation of the sand mold mixture with 20% bentonite into a mold produced the smoothest workpiece results with a few red spots caused during testing.

***Keywords**: casting; bentonite; casting media; compressive strength; Lumajang sand; tensile strength*

1. INTRODUCTION

Lumajang sand is a fine aggregate with good quality because it is sand derived from a mixture of Mount Semeru vomit, which has very good grain characteristics and gradation (grain size arrangement), with good interlocking power, so that it can affect strength and durability (1). The results of existing research and studies show that volcanic ash contains major elements (aluminium, silica, akalium, and iron), minor elements (iodine, magnesium, manganese, sodium, phosphorus, sulfur, and titanium), and trace levels (aurum, asbestos, barium, cobalt, chrome, copper, nickel, plumbum, sulfur, stibium, stannum, strontium, vanadium, zirconium, and zinc). While the five highest chemical compositions of volcanic ash soils in order are silicon dioxide (55%), aluminum oxide (18%), iron oxide (18%), calcium oxide (8%), and magnesium oxide (2.5%) (2),(3).

Indonesia itself is rich in natural resources in the form of bentonite. Bentonite is a clay containing montmorillonite and aluminia silicate minerals that are layered and consist of tetrahedral networks that form anion networks (4). Bentonite itself has two types, namely swelling and non-swelling. The difference between the two types of bentonite is the suction power of the liquid when dipped in water, which in both bentonite content has a different pH content, as a result of which the liquid absorption power is also different (5). The existence of bentonite in Indonesia itself is spread from Sumatra, Java, Kalimantan, and Sulawesi. Some locations in Indonesia have been exploited, such as those in Tasikmalaya, West Java. Bentonite is another term for clay or mud containing alumina silicate hydrate-type minerals and is included in layered silicate minerals (6). In this research, the problem to be investigated is the bentonite mixture to obtain the better mechanic properties of sand foundry of alumunium-Si. The objectives to be achieved are to obtain data on the compressive strength of molding sand, tensile strength of sand, moisture content in molding sand, sand grain distribution, and prorosity test on aluminum-Si alloy metal castings.

2. METHODS

The process is carried out with the preparation of sand. In the preparation of this type of sand, material is obtained directly from Lumajang, more precisely in Sumberwuluh village, Candipuro District, Lumajang Regency. So that the sand that is obtained is not mixed with other aggregates, such as those bought at building stores or the like. Later, the sand will be mixed with bentonite variations of 10%, 15%, and 20%, and specimens will be made for compressive and tensile testing. Testing the compressive strength and tensile strength will be done on 50 x 50 mm specimens made by compacting sand from the Sand Rammer test style into as many as 3 compressive test specimens. And for the tensile test, it is also done in the same way, but the specimen will be formed with a dog bone model or like a dog bone, with as many as 3 specimens weighing 150 grams per specimen. Figure 1 shows specimens of compressive and tensile tests.

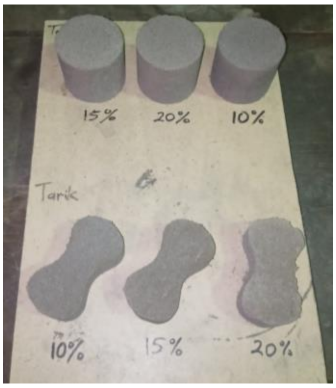


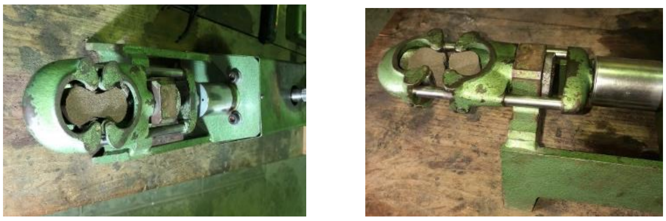
Figure 1. Specimens for compressive and tensile tests of 10%, 15%, and 20% bentonite blends

The test equipment to be used in the process of compressive and tensile tests is a universal strength machine. Where the test specimen will be placed on the universal strength machine test head, which is then given a load by rotating the handwel slowly and constantly until the specimen is destroyed or broken. The figure 2 shows the compressive test process for sand.

a. Before b. After

Figure 2. Sand Specimen Pressing Test

For tensile testing, a specimen with a dog-bone shape is needed, where the specimen will be clamped with a test head that is different from the head of the compressive test tool. Then turn the handwheel slowly and constantly until the specimen is cut off. The following tensile test process is shown in Figure 3.



a. Before b. After

Figure 3. Tensile Test of Sand Specimens

Metal casting process was conducted after testing process. The fixed bentonite variation mixture is divided into 3 specimens, namely 10%, 15%, and 20%, to determine the results of metal casting objects for each specimen. Sand mold was chosen as the mold material, and defect identification was carried out and confirmed by comparing the experimental simulation results. In making the mixture of sand and bentonite needed in a mold with a volume of 5300 cm^3, Approximately 6,000 grams per mold of sand and bentonite mixture will be made. The raw materials used can be found in Table 1.

Tabel 1. The raw material requirement for sand mold

No	Specimen	Sand	Bentonite	Water
1.	10%	5.400 gr	600 gr	480 ml
2.	15%	5.100 gr	900 gr	480 ml
3.	20%	4.800 gr	1200 gr	480 ml

Water added to the sand mixture can increase the formability of the sand because the water will be absorbed by the clay so that it becomes clayey and has binding properties on the sand. The criteria for printing sand is a moisture content between 6% to 12% (7). The lack of moisture content in the mold will cause the mold sand to fall off easily and loose, and the formation of the mold will be difficult (8). Then molding is carried out using the gravity casting method. Where this casting process is carried out without being given pressure when pouring metal liquid into the mold, the weight of the metal liquid will flow by itself into the mold pattern that has been made. In casting raw materials, researchers use aluminum-Si materials. Aluminium Si alloy was chosen because of its excellent properties and ability to melt at low temperatures around 660.3 ^{o}C, and it can be applied to various commercial objects (9).

For testing casting objects, the dye penetrant test method was used. This method is used to find defects (discontinuity) in the open surface of solid components, both metal and non-metal (10). Through this method, defects in the material will be seen more clearly. To assist vision, a liquid that easily penetrates into the defect and is brightly colored is used. This method cannot be applied to components with rough, coated, or porous surfaces. The dye penetrant testing is shown in figure 4.

a. *Cleaner spraying* b. *Red Penetrant spraying* c. Red Penetrant wipping d. *Developer spraying*

Figure 4. Dye Penetrant Test procedure

3. Result and Discussion

3.1 Lumajang Sand Distribution Test

After the specimen is tested for sand distribution using a shieving machine, the results are found in Table 2 below:

Table 2. Sand distribution

Mesh	Specimen 1 Weigth (grams)	Specimen 2 Weigth (grams)	Specimen 3 Weigth (grams)
0,560	40,33	35,40	34,27
0,400	3,54	5,98	6,74
0355	1	1,20	1,39
0,200	2,30	3,46	4,13
0,180	0,30	0,59	0,60
0,160	0,40	0,48	0,50
0,140	0,26	0,44	0,51
0,125	0,25	0,33	0,24
Sisa	0,62	2,12	1,62
Total (∑)	**50**	**50**	**50**

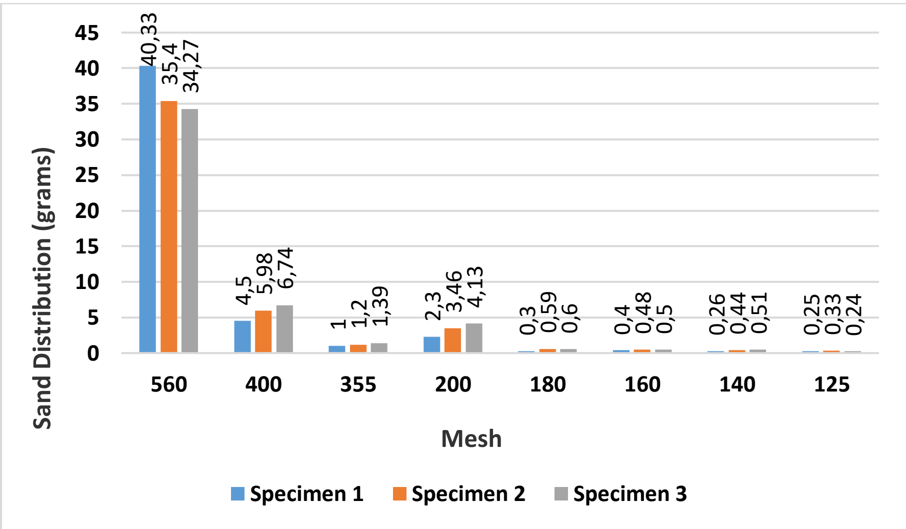


Figure 5. Sand distribution graph

In figure 5, it can be seen that the amount of Lumigan sand grains with mesh 560 gets higher, so it can be said that only a few grains of sand can be taken as fine aggregate from the sand used, so more sand is needed if it is used for metal casting.

3.2 Grain Fineness Number (GFN)

Based on the American Foundry Society, as shown in Table 3, the calculation of these parameters is the weight of sand on each sieve (grams), the percentage of sand remaining on each sieve (%), the product, and how to find the grain distribution of sand / GFN (Grain Fineness Number).

1. **Weight of sand per sieve (Grams)**
   Equation used for all sieve sizes:

$$M\ (gr) = Mk - Mt$$

Where

M = net weight of sand per sieve (gr)
Mk = empty weight of sieve (gr)
Mt = weight of sand and sieve (gr)

Mk = 349.6
Mt = 386.26
M = 386.26 - 349.6
= 36.66 gr

2. Percentage of sand per sieve (%)

This formula is used for all existing sieves, so the percentage of sand per sieve can be found using the formula:

$$P\ (\%) = \frac{M(gr)}{Ms}\ x\ 100\%$$

Where:
P = Percentage of sand per sieve (%)
M = Weight of sand per sieve (gr)
Ms = Specimen Weight

P (%) = $\frac{36{,}66\ gr}{50\ gr}$ x 100%
P (%) = 73,32 %

3. GFN calculation of each sieve

This equation is used on all existing sieves to find the product value,:

$$Pr = M\ (gr)\ x\ F\ (Multiplier)$$

Where
Pr = Product (the result obtained on each sieve)
M = Weight of sand per sieve (gr)
F = Multiplier factor

Pr = 36,66 x 10
Pr = 366,6

4. GFN (Grain Fineness Number)

The following formula is used to calculate the grain number of sand fineness.

$$GFN = \frac{Total\ Product}{weigth\ of\ specimen}$$

Table 3. GFN Calculation results(Grain Fineness Number)

U.S Sieve Number	Grams	%	Multiplier	Product
6	0,00	0	3	0
12	0,00	0	5	0
35	36,66	73,32	10	366,6
40	5,75	11,5	20	115
45	1,19	2,38	30	35,7
70	3,29	6,58	40	131,6
80	0,39	0,98	50	24,5
100	0,46	0,92	70	32,2
120	0,4	0,8	100	40
120	0,27	0,54	140	37,8
270	0,00	0	200	0
Pan	1,49	2,98	300	447
Total	**50**	**100%**	**……..**	**1.229,8**

3.3 Compressive and Tensile Test Results

In the implementation of the compressive test, as many as three test specimens with differences in the addition of bentonite variations in wet printing sand were used, namely 10%, 15%, and 20%, respectively. The following are the results of the compressive test process that has been carried out:
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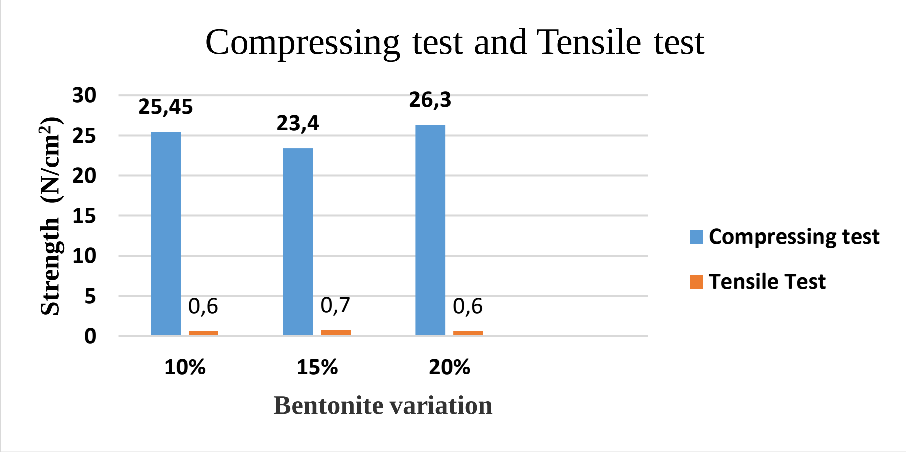


Figure 6. Compressing test and tensile test

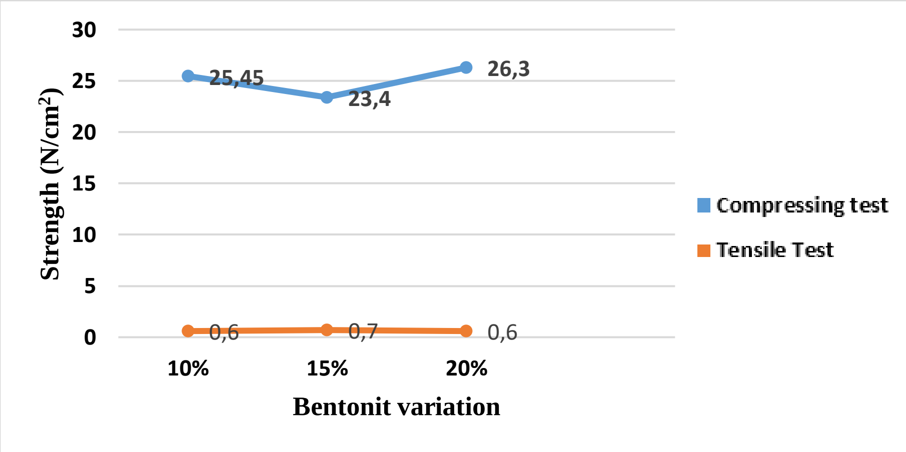


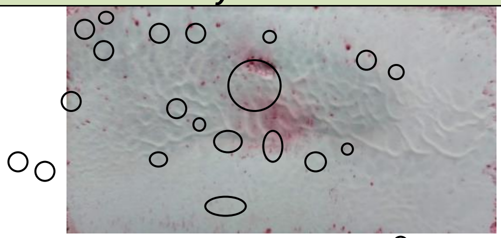
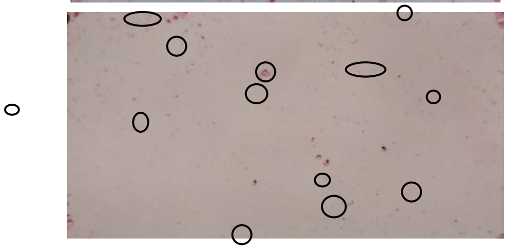
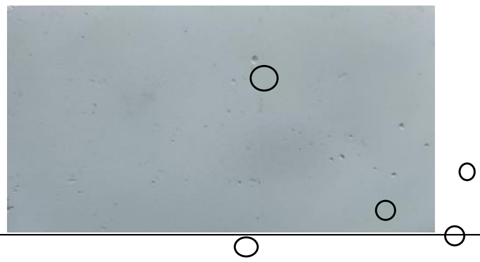
Figure 7. Pressure test and tensile test

In Figure 8, it can be seen that the largest compressive test strength is found in the 20% bentonite variation, with the value obtained being 26.3 N/cm2, or about 2.6 kg. This shows that the addition of higher amounts of bentonite has a positive impact on the compressive strength of sand mixtures (1). This could imply that a mixture with 20% bentonite would be more resistant to pressure, which could be a desirable quality, especially in applications where structural stability is important. Although in the tensile test a small value of about 0.6 N/cm2 was obtained, the compressive strength of the sand will play a more important role when pouring metal liquids (11). The 20% blend does not have good resistance to tensile forces. This could be a concern if the mix is to be used in situations where tensile forces also play an important role. In some applications, such as construction, resistance to tensile forces must also be taken into account. In the 10% bentonite variation specimen, a low compressive value of 23.4 N/cm2 and a tensile test value of 0.6 N/cm2 were obtained. Where this value is obtained due to the low level of bentonite used, this bentonite level plays an important role as a binder for each sand aggregate used. This may be due to the lower bentonite concentration. In addition, the tensile test values were also low, indicating that the mix had poor resistance to tensile forces (12). These results underline the importance of bentonite concentration in achieving optimum compressive strength. Analyses suggest that bentonite content acts as a binder for sand aggregates. Therefore, it is important to take into account the important role of bentonite in influencing the mechanical properties of the mix. If the mix is to be used in a project that emphasizes compressive strength over resistance to tensile forces, then a mix with 20% bentonite may be a better choice. However, if tensile strength is also important, adjustments to the mix composition may be required. Further analysis, such as freeze-thaw cycle testing or temperature changes, may be required to better understand the behavior of these mixes under various environmental conditions.

3.4 Dye Penetrant Test

The casting objects have been printed and tested with dye penetrant tests to determine the porosity produced in the casting mold variations with 10%, 15%, and 20% specimens. The following test results are shown in Table 4.

Tabel 4. Dye Penetrant Test Result

No	Spesimen	Hasil *Dye Penetrant Test*
1.	10 %	
2.	15 %	
3.	20 %	

Dari hasil pengujian *Dye Penetrant Test* pada tabel 4 diketahui mendapatkan hasil terbaik oleh spesimen ke 3 dengan sedikit bercak merah yang di tunjukkan pada benda uji yang telah di beri cairan *developer.* Dari spesimen ini dapat diketahui jika campuran bentonit 20 % menjadi campuran dengan hasil benda kerja yang halus dan sedikit rongga.

4. Conclusion

From the research conducted by researchers, the results of sand distribution with a GFN (Grain Fineness Number) value of 24.59 were obtained. Therefore, the large grains of sand get fairly coarse results. From the results of the compressive test obtained, it is known that Lumajang sand with a 20% bentonite mixture gets a value of 26.3 N/cm2, or 2.68 kg/cm2. This compressive strength is useful when later making metal casting mold materials that can withstand the strength of the flow of liquid metal that is still hot, which can cause deformation or loss of molds when poured into metal casting molds. From the results obtained in Figure 4.26, the greatest tensile strength was obtained from a 15% bentonite binder content. In the tensile strength results from diagram 4.45, a value of 0.7 N/cm2 was obtained. From the results of the dye penetrant test in Table 4.8, it is known to get the best results on the third specimen with a little red spot shown on the test specimen that has been given a liquid developer. From this specimen, it can be seen if the 20% bentonite mixture becomes a mixture with smooth workpiece results and few cavities.

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