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Study of Variation of Binder Materials On Permeability Of Foundry Green Sand

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***Abstract*—The preparation of standards and procedures for the production process in the manufacturing industry plays an important role in achieving acceptable products and in accordance with the desired quality. Based on the data from the quality control report of a foundry company, casting defects slightly exceed the maximum reject rate. It was found that the moisture content in the molding sand produced according to the procedure exceeded the maximum water content in the molding sand. The research was conducted as an effort to improve the quality of the company's production in reducing reject products. Permeability values of molding sand and quantitative area of cast defects will be compared, as a variations of bentonite and molasses binders , in three variations of the percentage addition of binder, respectively: 1, 3, and 5%. The Anova Two Way approach was used to statistically assess the results of the permeability test of the test specimens to ensure the effect of the predictor variables on the response. The results indicated that the more molasses, 5% added to the molding sand, gave the highest permeability of 53.50 ± 0.50 cm3/minute and gave the lowest cast defect area of 11.97%. The addition of bentonite binder produces a phenomenon that is inversely proportional to the addition of molasses binder.**

Keywords—Permeability, Bentonite, Molasses

I. INTRODUCTION

Metal casting is a manufacturing industry that is still widely used in Indonesia. According to the official page of the Indonesian Metal Foundry Association (Aplindo), there are 52 foundry companies registered as members of Aplindo. Then there are 33 large iron-based foundry companies, nine alloy steel-based companies, 16 large companies and 20 small-medium scale companies (IKM) for aluminum (non-ferrous) in Indonesia[1]. Due to the large number of foundry companies in Indonesia, entrepreneurs must compete and be competitive by increasing the quality of the company. One way to improve the quality of the company is to reduce the percentage of failed products.

PT. AAK is a national private company engaged in metal casting and is located in Ceper District, Klaten Regency, Central Java. According to the results of the company's production and quality control reports, it was found that the casting defects slightly exceeded the maximum reject rate. It was also found that the water content of the printed sand produced according to the procedure exceeded the maximum water content limit of 6% [2]. In addition, the company's quality targets for 2020 and 2021 have also decreased from a maximum reject production of 3.5% to 3%. The company every year tries to reduce the percentage of rejected products, which means improvements need to be made to continue to improve the quality of the company. From the results of observation and data collection, there are two types of defects that often occur in companies, namely porosity defects and mold loss. The defect is thought to have arisen due to the mismatch of the molding sand composition. So that research is needed on the exact composition of molding sand between sand and its binder.

Based on research conducted by Muhammad Akmal[3] and Sofudiman Lubis[4], variations in the type of binder produce different values of hardness, density, and permeability. So in this study will compare the permeability of molding sand and casting results of two different types of binders available at the company, namely bentonite and molasses. Variations in the composition used are 1%, 3% and 5%. The results of the permeability test of the test specimens will be statistically analyzed using the Anova Two Way method to determine the effect of predictor variables on response. Then the product resulting from the casting was analyzed for the area of the defect with the help of software, namely Image J. From the results of the statistical analysis and the area of the defect it can be seen which binder has the most influence on the permeability of the molding sand. The results of this study are expected to be a recommendation for foundry companies in determining the composition of molding sand.[5] [6]

II. METHOD

This research was conducted using the experimental method and then compared the permeability of sand molding and casting results from two types of binder additions namely Bentonitee and molasses as well as one control specimen. Variations in the composition used are 1%, 3% and 5%. The results of the permeability test of the test specimens were analyzed by the Two Way Anova

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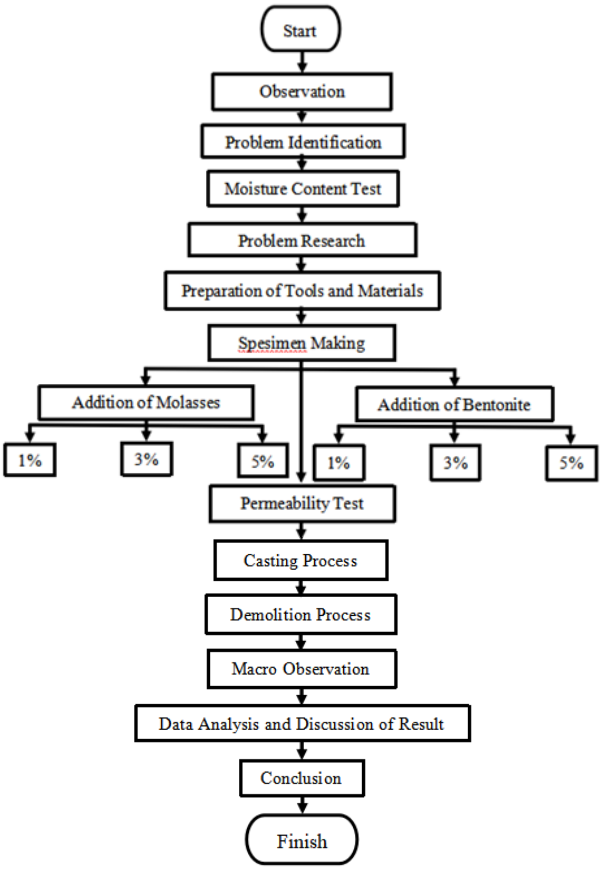

Figure 1.Flowchart

method using Minitab 19, then the results of the metal casting were observed for the types of defects and the calculation of the area of the defects with the help of Image J software. The following are the steps in this study.

2.1. Research variable

The variables used in this study are as follows:

a. Independent variable: Type and composition of the molding sand binder
b. Dependent variable: Permeability of molding sand
c. Fixed variables: Liquid metal composition, type of sand, pattern, molding frame, and gating system

TABLE 1.
RESEARCH MATRIX

Type of Binder	**Binder Composition**		
	1%	**3%**	**5%**
Bentonitee	1	2	3
Molasses	4	5	6

Information :
1: Addition of 1% Bentonitee composition
2 : Addition of 3% Bentonitee composition
3 : Addition of 5% Bentonitee composition
4 : Addition of 1% molasses composition
5 : Addition of 3% molasses composition
6 : Addition of 5% molasses composition

d. Control specimens: Molded sand with a composition of sand and water with a normal moisture content of 6%

Table 3.1 below is a research matrix showing that there were 3 specimens for the Bentonitee mixture and 3 specimens for the molasses mixture. So that there are a total of 7 specimens with the addition of 1 control specimen in this study.

III. RESULTS AND DISCUSSION

In this study, 7 types of molding sand composition were used, namely 1 molding sand without binder which was used as a control specimen. 3 specimens of molding sand with the addition of Bentonitee binder of 1.3 and 5% and 3 specimens of molding sand with the addition of molasses binder of 1.3 and 5%. The percentage of binder addition is calculated in weight percent.

3.1 Calculation of the Required Composition of the Test Specimen

Determination of the need for binder and water in the manufacture of permeability test specimens, is based on the need for sand required during the test. The test was carried out at the Ceper Manufacturing Polytechnic which required 2000 grams of sand for each test. The percentage addition of binder and water is calculated in weight percent. The mass requirement of binder and water for each specimen is presented in Table 1.

TABLE 2.
COMPOSITION NEEDS CALCULATION RESULTS

No	Sample Code	Komposition(gram)	
		Water	Binder
1	Control Speciment	120	-
2	Bentonitee 1%	120	20
3	Bentonitee 3%	120	60
4	Bentonitee 5%	120	100
5	Molasses 1%	40	20
6	Molasses 3%	40	60
7	Molasses 5%	40	100

3.2 Molding Sand Permeability Test

Permeability is the ability to expel air or expel gas from the molten metal or gas produced from the reaction between the mold itself and the molten metal through the holes in the mold at a certain speed and time when the molten metal freezes [7].

The permeability test of molding sand was carried out at the Laboratory of the Ceper Manufacturing Polytechnic. A total of 7 specimens were tested with 3 repetitions to obtain a deviation value so that confidence in the average data value resulted from several repetitions was obtained. Prior to the permeability test, the specimens were first weighed. The sample weight allowed to be tested is a sample that has a weight in the range of 138-180 grams. After weighing, the weight of the sand permeability test sample to be tested is in the range of 147-150 grams, so the sand sample can be tested for permeability. Testing the permeability value of sand is carried out by putting sand into a cylindrical container, then compacting the sand using a sand rammer, and installing it in a permeability tester. Sand permeability values are presented in Table 2.

From the data from the permeability test results shown in Table.2 which is used as a graph in Figure.1 it is found that, the greater the addition of molasses type binder, the resulting sand permeability value also increases, with a maximum permeability value of 53.5 ± 0.5 cm3/minute. Whereas the addition of Bentonitee binder, the more addition of Bentonitee, the lower the permeability value, with the lowest sand permeability value of 40.8 ± 0.76 cm3/minute.

TABLE 3.
PERMEABILITY SAND VALUE

Sample Code	**Permeability(cm^3/min)**	**Permeability ± Dev**
Control Specimen	50	50,00±0,00
	50	
	50	
Bentonitee 1%	48	48,00±0,00
	48	
	48	
Bentonitee 3%	45	45,33±0,58
	45	
	46	
Bentonitee 5%	40	40,8 ± 0,76
	41	
	41,5	
Molasses 1%	43	43,1 ± 0,29
	43,5	
	43	
Molasses 3%	44	44,50±0,87
	45,5	
	44	
Molasses 5%	54	53,50±0,50
	53	
	53,5	

When compared with control specimens, the permeability value of sand with the addition of molasses binder increased the permeability value by 6.54%. The addition of Bentonitee binder with the highest percentage reduced the permeability value of sand by 18.34%. Only the addition of 5% molasses binder gives a sand permeability value above the sand permeability value of control specimens or molding sand which is only bound by water, so the addition of a Bentonitee type binder to the molding sand composition used in the casting process at the company is considered not more effective from the use of molding sand which is only bound by water.

3.3 Macro Observation of Types of Casting Defects

Macro observations were made using a DSLR camera with 5X magnification, carried out on the cast product which had been separated from the gating system section. Molten metal solidified in sand molds with variations in composition and binder is the same and comes from the same furnace. Molten metal is poured with the same pouring height, pouring time parameters, which are in accordance with the SOP used by the company. The dimensions of the casting used as the quantitative area of the cast defects are 150 x 50 x 15 mm. The molding sand used for molding each test sample weighs 6000 grams, which is put into the flask. From visual observation, 4 types of defects were identified, namely porosity, erosion, deformation, and shrinkage. Figure 1 (a-g) is the result of metal casting products using different molding sand compositions.

Based on Figure 1 above, the area marked with the letter A is an area with porosity defects caused by the presence of trapped air, the permeability of molding sand which does not match the characteristics of molten metal makes the air that enters the pouring process not have enough time to diffuse out and eventually trapped in the casting during the solidification process takes place.

The area marked with the letter B is an area with erosional roughness defects caused by the release of mold sand due to the flow of molten metal on the surface of the mold so that the sand sticks to the casting. Printing sand that is less dense and the pouring speed is too fast can cause erosion defects to occur.

Areas marked with the letters C and D respectively are deformation and shrinkage defects which occur with the addition of 5% Bentonitee. It appears that there are additions and depreciations in the results of the castings. The detected area has increased dimensions due to the lack of compressive strength of the sand so that the molten metal presses into the small cavities in the molding sand. The area that is experiencing shrinkage is caused by the low permeability of the sand which causes the process of heat transfer and air diffusion to not take place properly, resulting in shrinking castings. Increasing the Bentonitee content will increase the formation of lumps due to the reaction between Bentonitee and water, so that the mixing and compaction of the molding sand is not uniform.

3.4 Quantitative Assessment of Defective Areas of Cor

Quantitative calculation of the area of cast defects is calculated using the help of Software Image J for each defect area and then summed to determine the total area of defects in each product. The surface area of the area of interest is 7500 cm2. Furthermore, further calculations are carried out to determine the percentage of the defect area. The resultant defect area obtained for each variable is shown in Table 4.

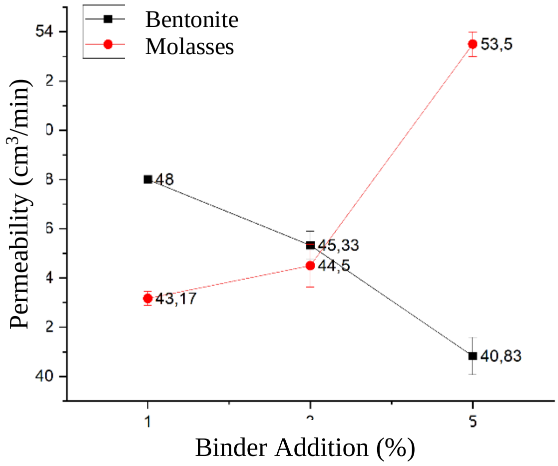

Figure 2. Graph Of The Relationship Of Permeability Of Molding Sand On Variation Of Composition And Type Of Binder

From the description of the types of defects that occur in each product as well as the calculation of the percentage area of defects presented in Table 4 which is used as a graph shown in Figure 3, it is concluded that along with the addition of molasses binder in the molding sand composition it produces the least quantity of defects, namely 11, 97% and along with the addition of Bentonitee produces the largest quantity of defects covering an area of 49.68% of the area of interest.

Unbound molding sand compositions also give test specimens that have defects. It was recorded from the results of a quantitative assessment of cast defects, sand molds without a binder gave 12.09% cast area where the addition of 5% molasses binder succeeded in reducing 1% of the cast defect area, where the addition of other types of binder with various compositions resulted in a larger cast area than the mold. This confirms that the use of other types of binders with various compositions, other than 5% molasses, is considered no more effective than the use of molding sand which is only bound by water.

3.5 Statistical Test

In this study, a statistical data processing test was carried out using the Two Way Anova method. The method was chosen based on the number of variables in this study which amounted to more than one. Before analyzing the data from the ANOVA test, it is better to do the normality and homogeneity tests first to find out whether the residuals are normally distributed and are homogeneous.

1. Normality Test

The normality test is carried out to find out whether the residuals are normally distributed or not. Before conducting the test, the initial hypothesis needs to be made in order to conclude the results of the test.

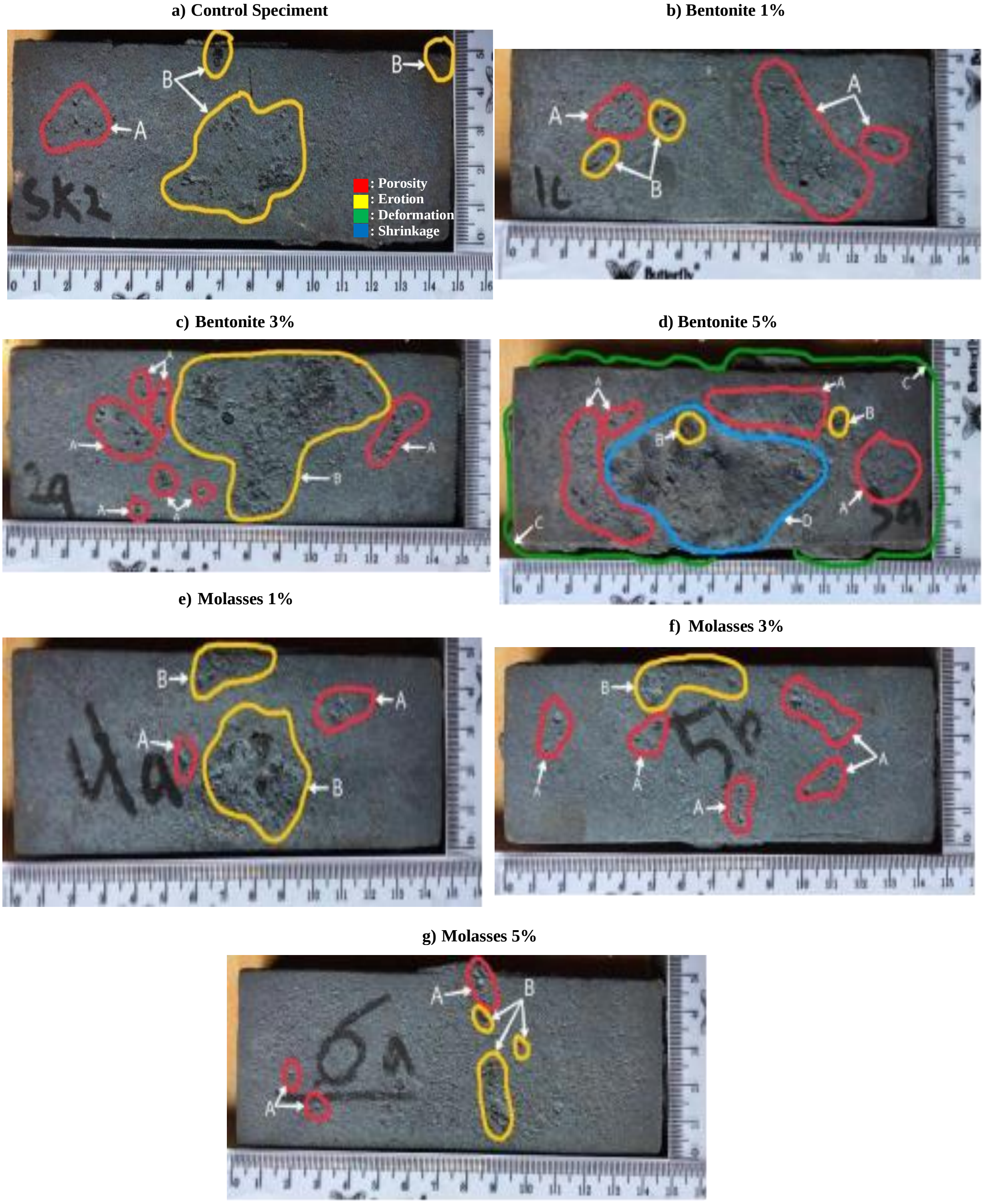

Figure 3. Metal Casting Result

TABEL 4.
CALCULATION OF DEFECT AREA

Composition	*Defect Area (cm²)*	*Persentage (%)*
Control Speciment	9,069	12,09
Bentonite 1%	14,449	19,27
Bentonite 3%	18,510	24,68
Bentonite 5%	37,261	49,68
Molasses 1%	13,833	18,44
Molasses 3%	10,435	13,91
Molasses 5%	8,977	11,97

Initial Hypothesis:
a. H0: residuals are normally distributed
b. H1: residuals are not normally distributed

After making the initial hypothesis, the normality test was carried out using Minitab 19 software, and Figure 3 below is the result of the normality test that has been carried out.

In the normality test performed, the significance value (α) used is 0.05 or 5% and the P-Value shows a value greater than 0.05, which means H0 is accepted. So it can be concluded that the residuals are normally distributed.

2. Homogeneity Test

Homogeneity test was carried out to find out whether the variations in this study were homogeneous. Before conducting the test, the initial hypothesis needs to be made in order to conclude the results of the test.
Initial Hypothesis:
a. H0: variation in each homogeneous group
b. H1: variations in each group are not homogeneous

Table 5 is the result of homogeneity testing for all variations using a significance value (α) of 0.05. The Levene method value is 0.936 or greater than the

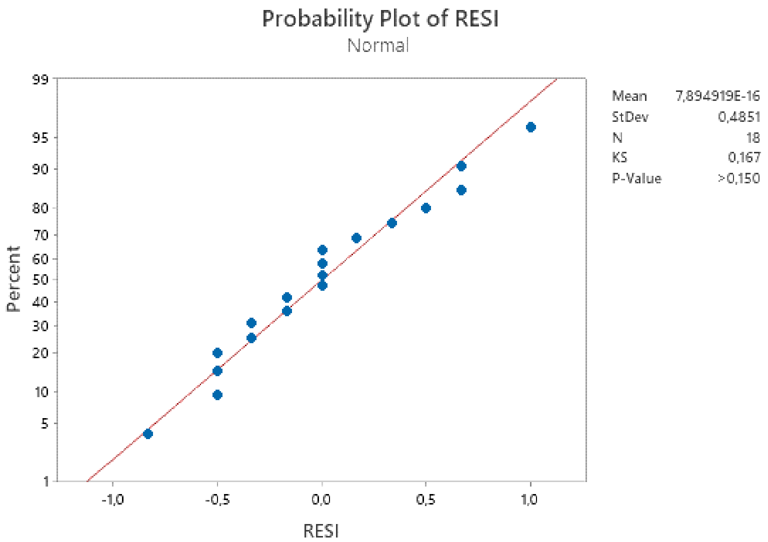

Figure 4. Normality Test Results

TABLE 5.
HOMOGENEITY TEST RESULTS ON MINITAB 19

Method	Test Statistic	P-Value
Multiple Comparations	-	0,598
Levene	0,19	0,936

TABLE 6.
ANALYSIS OF VARIANCE

Source	Adj SS	Adj MS	F-Value	P-Value
Binder	24,500	24,500	73,50	0,000
Composition	16,028	8,014	24,04	0,000
Binder *Composition	252,250	126,125	378,37	0,000
Pure Error	4,000	0,333		
Total	296,778			

significance value (α). So it can be concluded that H0 is accepted or the variation in each group is the same (homogeneous).

3. ANOVA

After the normality and homogeneity tests have been carried out, it can be continued by analyzing the results of the two-way Anova test using Minitab 19. An initial hypothesis needs to be made first in order to be able to conclude the results of the test.

Binding type variable hypothesis:

a. H0: the type of binder affects the permeability of the molding sand
b. H1: the type of binder does not affect the permeability of the molding sand

The compositional variable hypothesis:

a. H0: composition affects the permeability of the molding sand
b. H1: the composition does not affect the permeability of the molding sand

ANOVA testing in this study uses a significance value (α) of 0.05. Based on Table 6 above, it can be seen the F-Value and P-Value. To find out the conclusions from the results of this test, the P-Value value is compared with a significance value of 0.05. If the P-Value is greater than 0.05, then H0 is rejected or H1 is accepted. In the P-Value column of the binder row, the P-Value value is less than 0.05, which means that variations in the type of binder affect the permeability of the molding sand. In the P-Value column for the composition row, the P-Value value also shows less than 0.05, so compositional variations also affect the permeability of the molding sand. Then in the P-Value column the interaction row of binder and composition also shows less than 0.05, so it can be concluded that there is an interaction or difference in effect on the permeability of molding sand in terms of the interaction between the type and composition of the binder.

IV. Conclusion

Based on the data analysis that has been done, it can be concluded that variations in the type of binder and composition affect the permeability value of molding sand ($P<0.05$). The addition of 5% molasses as a type of binder produced the highest permeability of molding sand of 53.50 ± 0.50 cm3/minute with an area of product defects of 11.97%. There is a correlation between the results of the permeability test and the results of the analysis of casting defects. Molding sand added with molasses which has a higher permeability value results in a smaller quantity of product defects. This phenomenon is inversely proportional to the addition of bentonite binder.

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