International Journal of the Physical Sciences Vol. 6(34), pp. 7805 - 7810, 16 December, 2011
Available online at http://www.academicjournals.org/IJPS
DOI: 10.5897/IJPS11.1144
ISSN 1992 - 1950 ©2011 Academic Journals

Full Length Research Paper

Accessing the performance of binders on core strength in metal casting

Popoola A. P.[1] and Fayomi O. S.[1]*

Department of Chemical and Metallurgical Engineering, Faculty of Engineering and Built Environment, Tshwane University of Technology, P.M.B X680, Pretoria, South Africa.

Accepted 9 August, 2011

Poor performance of local binder of foundry core in casting has been a major concern recently. The effect of some local binder on the mechanical properties of a core has been studied in an attempt to develop a suitable core strength using green compression strength, baked compression strength, permeability and collapsibility test. The effect of temperature, water content, baking time, binder quantity and sand fineness on the core behavior strength was observed.The compression strength of baked cores increased with an increase in the quantity of binder added. The collapsibility of the core is a function of the high permeability obtained in the case of Arabic gum. At baking temperature of 200°C and a baking time of 1.5 h the compression strength after baking increases as the percentage of water decreases. The results obtained showed that the binder of molasses, starch and Arabic gum could serve as effective binder of high core strength for core making processes.

Key words: Binders, foundry core, core strength.

INTRODUCTION

The metal casting industry uses a large quantity of binders annually as the total output of metal castings (Fayomi et al., 2011). In recent years some countries has developed rapidly in the use of core binders locally sourcing for industries in order to boost the ailing economy (Fayomi et al., 2011; McGraw, 1980; Paul et al., 2007). Material which holds sand grains together could be classified as a binder. Binders suitable for foundry cores must not only hold the sand grains together, but must also be sufficiently resistant to high temperature, so as not to collapse before the metal solidifies, but after solidification and cooling, they must completely collapse to allow sand to be easily removed from the casting leaving its surface smooth (Nuhu, 2010; Atama, 2009; Olakanmi et al., 2009). The ability of the binder to collapse on cooling is known as breakdown and this property is very important in cored holes which are inaccessible to fettling. The proper selection of core sand is just as important to the foundry in manufacturing satisfactory sand heaps as it is to the core room in maintaining satisfactory core mixture (Mukoro, 2009; Harper, 1993; Ola, 2000). Binders are of various types and each type is used to confer some desired property on a core for a particular use or set of conditions. Core binders serve to hold the sand grains together, impact strength, resistance to erosion and the breakage and degree of collapsibility.

They are divided into two classes, organic and inorganic binders. Cereals resins, proteins pitch oils and molasses are organic binders. Cement, silicates and some esters are inorganic binders (Ola, 2000; Fayomi, 2006; Debussy, 1980; Fayomi et al., 2011). Organic binders are much more expensive than inorganic binders but this is partly offset by the percentage addition being much lower. Less than 2% compared to the more than 3% for the inorganic binders. All organic binders have excellent breakdown which makes them ideal for the cores of casting where accessibility for fettling is difficult and the reduced fettling cost make these binders economical. However, inorganic binders comprises of clays, aqueous sodium silicates, bentonite, silicon flour and iron oxide. They are used to obtain additional green strength retard or increase the collapsibility of a core and to prevent cutting or penetration. Clay materials most

*Corresponding author. E-mail: fayomio@tut.ac.za.

Abbreviations: GFN, Grain fineness number; **AFS,** adaptive frequency sampling.

Table 1. Sieve analysis of sand as received.

Ota silica sand Total weight of sample = 100 g					
Serial no.	**Aparture (mm)**	**B.S.S no.**	**% Retained**	**%CUM**	**Product**
1	1.40	14	0.05	0.05	0.35
2	1.00	18	0.34	0.39	4.76
3	0.71	25	0.36	0.75	6.48
4	0.50	35	1.26	2.01	31.50
5	0.355	45	3.78	5.76	132.3
6	0.250	60	13.06	18.85	587.7
7	0.180	80	28.06	46.91	168.3
8	0.125	120	39.76	86.67	3180.8
9	0.09	170	8.45	95.12	1014
10	0.063	230	1.72	96.84	292.4
11	PAN	PAN	1.20	98.04	276
Total			98.04		7209.89

Table 2. Sieve analysis of sand washed by BS 410: 1986 series for degree of sand fineness.

Ota silica sand Total weight of sample = 100 g					
Serial no.	**Aparture (mm)**	**B.S.S no.**	**% Retained**	**%CUM**	**Product**
1	1.40	14	0.00	0.00	0
2	1.00	18	0.01	0.01	0.14
3	0.71	25	0.20	0.21	3.6
4	0.50	35	0.60	0.82	15
5	0.355	45	2.40	3.22	84
6	0.250	60	11.00	14.21	495
7	0.180	80	26.80	41.01	1608
8	0.125	120	41.50	82.51	3320
9	0.09	170	10.51	93.02	1261.2
10	0.063	230	2.27	95.29	385.9
11	PAN	PAN	2.60	97.89	598
Total			97.89		7770.98

widely used binders are kaolinite (Fayomi, 2006; Debuessy, 1980; Fayomi et al., 2011). In this study, it is anticipated that locally available binders carried out in this research (gum arabic, molasses and cassava starch) will enhance the casting surface finish for foundry core.

MATERIALS AND METHODS

The base material which is silica sand used for this studies is ota silica sand from Ogun state, Nigeria. The binders used are gum arabic, molasses and cassava starch. Gum arabic from acacia tree was found in Birnin Kebbi, Kebbi State, Nigeria. Molasses is sold in the market, cassava starch is found mainly in the Southern parts of Nigeria where lots of cassava is grown.

Sieve analysis and core mixture

About 500 g of ota silica sand collected contain a lot of impurities and are allow to pass through a standard sieve test of Bs 410: 1986 series to remove all coarse particles. 100 g of fine sand was removed and placed on a shaker for 15 min. The weight of the sample of sand that had settled on each sieve obtained and the values were used to calculate the grain fineness number (GFN) and percentage fines. This test determines the suitability of the sand for core making. The experiments for sand testing were carried out in two stages, it was then washed and the results are tabulated in Tables 1 and 2, respectively.

$$G.F.N = \frac{Total Product}{Total\ \%\ tage of retained grain} = \frac{7209.89}{98.04} = 73.54$$

Fines = 1.72 + 1.20 = 2.92

Clay content = 50- 47.51 = 2.49 or 4.98%

$$G.F.N = \frac{Total Product}{Total\ \%\ tage of retained grain} = \frac{7770.98}{98.89} = 79.385$$

Table 3. Core mixture parameter using Arabic gum, molasses and starch for core making.

Mix	A	B	C	D	E
Sand (g)	**560**	**560**	**560**	**560**	**560**
Starch (%) (g)	2% (17g)	3% (26 g)	4% (34 g)	6% (51 g)	8% (68 g)
H_2O (%) (g)	6.5%	5.2%	3.8%	2.4%	1.7%
Apparent density (g)	160	160	160	160	158
Permeability	95	110	156	150	140
Green compression strength (KN/m^2)	1.4	1.9	2.8	1.3	0.9
Moisture %	0.7	0.5	0.4	0.4	0.3
Sand (g)	**560**	**560**	**560**	**560**	**560**
G/Arabic (%) or (g)	2% (17g)	3% (26 g)	4% (34 g)	6% (51 g)	8% (68 g)
H_2O (%) (g)	6.5%	5.2%	3.8%	2.4%	1.7%
Apparent density (g)	152	153	154	160	158
Permeability	280	300	310	150	280
Green compression strength (KN/m^2)	1.0	1.2	1.4	1.3	0.7
Moisture %	0.3	0.4	0.4	0.4	0.3
Sand (g)	**560**	**560**	**560**	**560**	**560**
Molasses % (g)	2% (17g)	3% (26 g)	4% (34 g)	6% (51 g)	8% (68 g)
H_2O (%) (g)	6.5% (47.68 g)	5.2% (35.76 g)	3.8% (23.84 g)	2.4% (11.92 g)	1.7% (5.96 g)
Apparent density (g)	154	155	156	160	160
Permeability	240	1260	280	150	222
Green compression strength (KN/m^2)	0.7	0.6	1.3	1.3	0.4
Moisture %	0.3	0.3	0.3	0.4	0.2

Fines = 2.27 + 2.60 = 4.87
Clay content = 2.11%

Mixing procedure and core making

Gum arabic is grounded into smaller sizes using a muter and pestle so as to hasten dissolution in water. 100 g of gum arabic was put to dissolve in 500 ml of hot water, 560 g sand was weighted and the gum with different composition as indicated in the Table 3 was mixed with the sand in a laboratory mixer and a corresponding amount of water was added to temper mix, the mixer was allowed to operate for a period of 5 min. This was also prepared for in the case of starch and molasses. 20 g sample of tempered mix was put in a pan and the pan contains most samples that are placed in the machine. The timer switch was turned on to allow the sample dry and then the dried sample was reweighted. Loss in weight between moist and dry sample divided by 2 is the moisture content in the sample.

Green compression strength test

Green compression strength test were performed on the core made sample. Adaptive frequency sampling (AFS) specification was used to make the standard test specimen; a sufficient measured quantity of the tempered sand from the prepared hot is used. The mix was placed with the specimen pedestal in place and specimen container with sand mix was rammed three times to the tolerance mark. Then the green core permeability test was carried out by fixing the rammed specimen on the perimeter before removing the specimen from the specimen container. For green compression, the specimen was removed from the container and fixed unto the compressive strength testing machine.

Core hardness test

The hardness was made to correctly determine the surface hardness of a core. The surface hardness largely determines how a core will withstand shocking and handling, it is also a property of a core that determines the amount of loose sand that is on the core surface.The hardness measured by means of a scratch test with degree of hardness being designated by depth of scratch.

Baked core test

Standard AFS sample was made with different compositions as in the green state and the binder was used as received, prepared and baked.The samples were made and allowed to stand in air for 30 min before being placed in the oven. The temperature of the oven was set at 200°C and the core was allowed to cool for 45 min and the cold strength test was carried out using the compression strength test machine.The compression strength of baked cores is a good index for measuring the resistance that core offers to shrinkage of casting and cooling. In using starch as a binder after the extraction from cassava, it was ground using a laboratory motor and passed through a sieve of 1.25 mm. The same composition was used as with gum arabic and molasses and these cores were subjected to the same test, at both green and baked states.

Core collapsibility test

The collapsibility test were performed by subjecting the specimen

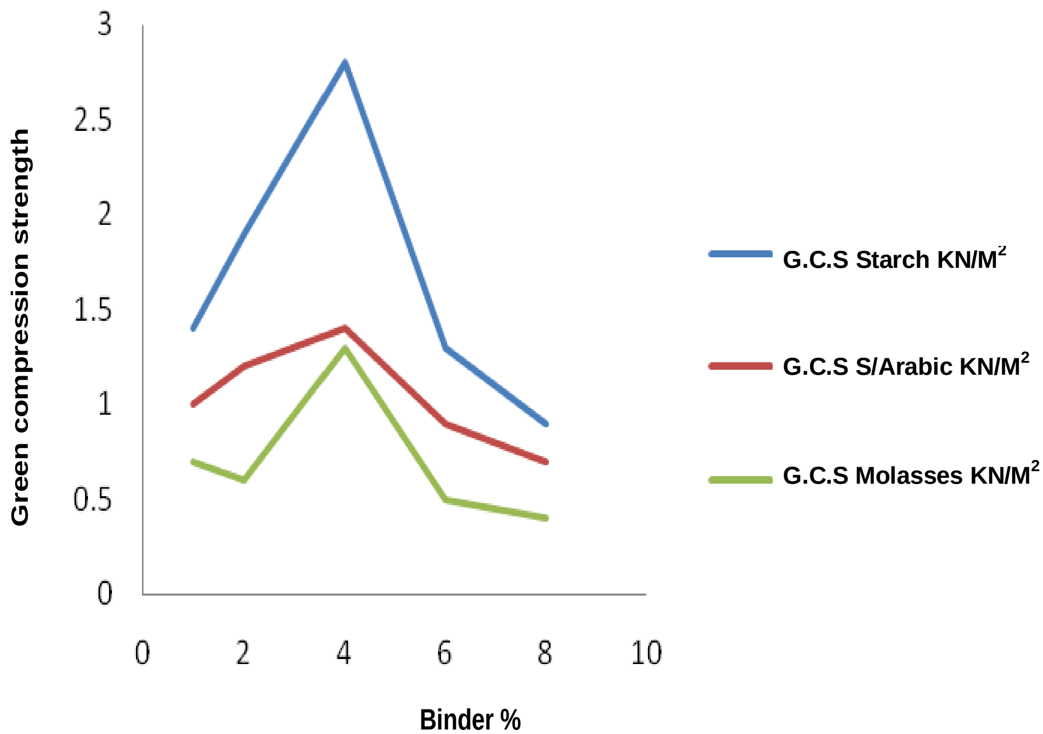

Figure 1. Binder effects on the green compression core strength.

test to a furnace temperature of 1095°C with a ceramic material weighing 197 Kg, placed over the core specimen. A stop watch was then used to determine time required for the core to collapse.

RESULTS AND DISCUSSION

Effect of sand fineness

In order to obtain a smother surface finish of casting through a core processing, standard sieve analysis were performed by standard test sieves of BS 410: 1986, as seen from Tables 1 and 2. Silica sand was found to have a fitness number of 73.54% and a fine number of 2.92% with clay content of 4.95%, while the washed sand has grain fitness number of 79.38% fines of 4.87 and clay content of 2.11%. The fineness of sand affects many properties of a core. The amount of binder required to produce a given strength increases as the sand become finer, hence, the amount of binder for the washed sample would have to be more than as received. The fineness number also affect the permeability, rate of core collapsibility, hardness rate of baking and green strength.The greater the permeability of a core, the better the core is baked which implies that the binder will produce less gas on pouring. As the core sand become coarser the permeability of the core increases which causes the heat to travel through the core to burn up faster, creating a fast rate of generation for the quantity of gas contained in the core.

Effect of quantity of binder

To evaluate the stability and effectiveness of binder, green and cold compressive strength test were carried out on core sample as seen from Figure 2. The quantity of binder added to a core mixture also influences the total quantity of gas evolved in a core leaving defect. In using arabic gum as binder, the permeability of the sample rose to 310 and at green state. However, it is within acceptable limit between 200 and 300. The volume of core gas may be kept to a minimum which accounts for why binders in this analysis were not used above 8%.

Effect of water quantity

The variation of water content added to core produce for temper was considered and not made above 4% for practical reasons as observed in Figure 1. The permeability of a core is slightly affected by the water content of the mix as shown in Table 4 and 5. The permeability of a core to a certain point drops slightly with an increases in the amount of binder and decrease in water content.

A baking temperature of 200°C with a baking time of 1.5 h was used in studying the effect of water in the core mixture. The compression strength after baking increases as the percentage of water added decreased as indicated in Table 5.

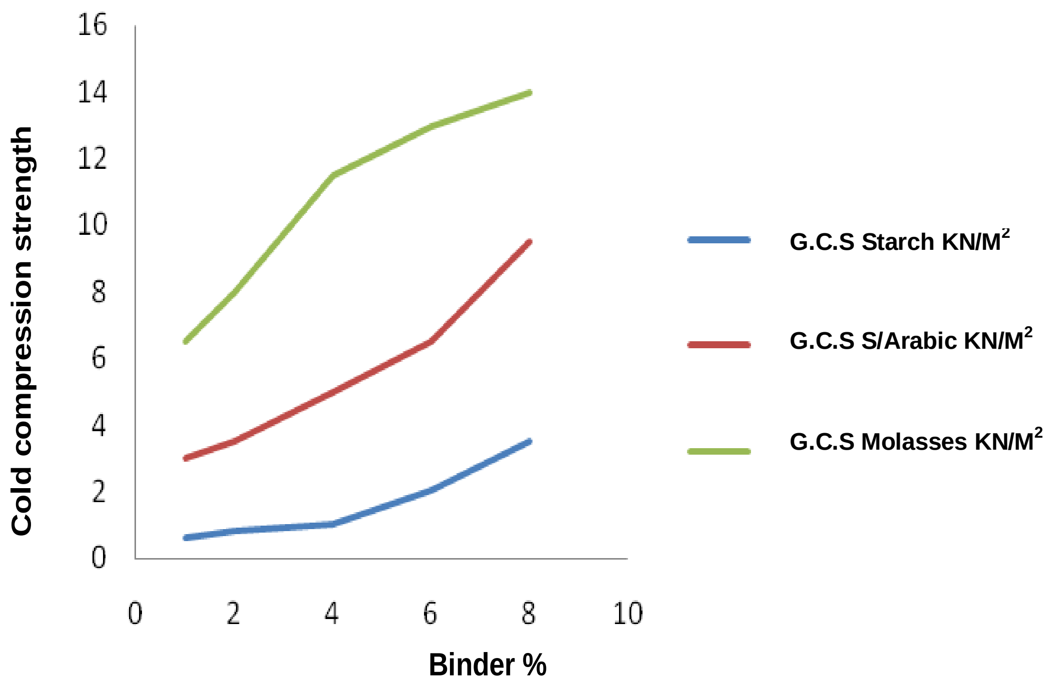

Figure 2. Plot showing the effect of binder on the compression strength of a core.

Table 4. Testing green compression strength of core and core sand mixtures using various binders.

	A	B	C	D	E
Sand (g)	560	560	560	560	560
Binder (%)	1	2	4	6	8
Water (%)	5.5	4.2	2.8	1.4	0.7
G.C.S starch KN/M^2	1.4	1.9	2.8	1.3	0.9
G.C.S S/arabic KN/M^2	1.0	1.2	1.4	0.9	0.7
G.C.S molasses KN/M^2	0.7	0.6	1.3	0.5	0.4

Table 5. Testing cold compression strength of core and core sand mixtures using various binders after baking.

	A	B	C	D	E
Sand (g)	560	560	560	560	560
Binder (%)	1	2	4	6	8
Water (%)	5.5	4.2	2.8	1.4	0.7
G.C.S starch KN/M^2	0.6	0.8	1.0	2.0	3.5
G.C.S S/arabic KN/M^2	3.0	3.5	5.0	6.5	9.5
G.C.S molasses KN/M^2	6.5	8.0	11.5	13.0	14.0

Effect of baking temperature and time

Analytical look at Table 6 shows that gas content of a core is reduced by banking the core at high temperatures with lower baked strength. When baked at a certain temperature of 200°C as in this study, maximum strength was achieved with little reduction of gas. The time of collapse also is a function of the higher permeability, the less time the core takes to collapse. Core with arabic gum binder are fast collapsing since they collapse within the periods of 1 to 2 min, thus accounts for ease of fettling operation, while cores with starch and molasse

Table 6. Effective comparism of collapsibility results showing the effects of high permeability on time of collapse.

Sample	Permeability	Time taken to collapse (minutes)
Cassava starch		
A	95	10
B	110	6.5
C	156	4.5
D	150	5.0
E	140	5.5
Gum arabic		
A	280	1.5
B	300	1.1
C	310	1
D	290	1.5
E	280	1.5
Molasses		
A	240	3.2
B	260	2 Min
C	280	1.5 Min
D	260	2 Min
E	222	3 Min

that have lower permeability are slow collapsing since they take more than 5 min to collapse.

Conclusion

In this work, the highest valuable results for binder performance on core strength were achieved with arabic gum, starch and molasses of 2, 3, 4, 6 and 8%, respectively at 200°C in 1.5 h. Composition of core properties shows that the core hardness/strength is affected by the nature of core treatment before, during and after baking. However, binder above this specification may lead to poor core strength and casting failure because increase in the quantity of binder used, we result in greater volume of gas generated by the core. The amount of binder required to produce a given strength increases as the sand become finer, thereby obtaining a smother surface finish of casting. gum arabic maintain a stable structure strength than other, hence can be used conveniently without the addition of other additives but for effective use of molasses and starch, some additives have to be added to improve their mechanical properties and stability.

ACKNOWLEDGEMENT

The authors gratefully acknowledge the contribution of Mrs. Fayomi Gloria for the provision of all local raw materials use in this research work and for the determination of the mixing procedure.

REFERENCES

Atama EO (2009). Core and Foundry Technology Handbooks, Department of Metallurgical and Foundry Engineering, Federal Polytechnic Idah, Nigeria, pp. 10-17.

Debussy JH (1980). Cast metal and core making technology. J. Mater. sci. technol., pp. 23-29.

Fayomi OSI (2006). Development of foundry core by using local raw material. Research work, Metallurgical and Foundry Department, Federal Polytechnic Idah, Kogi State, Nigeria, pp. 1-20.

Fayomi OSI, Ajayi OO, Popoola API (2011). Suitability of local binder compositional variation on silica sand for foundry core making. Int. J. Phys. sci., 6(8): 1940-1946.

Fayomi OSI, Popoola API, Ojo OI (2011). Investigating Nigeria Ochadamu Silica Sand, Clay and Local oilsfor foundry core making. Int. J. phys. sci., 6(8): 1894-1904.

Harper JD (1993). Small scale foundries for Developing Countries guide to process selection,

McGraw Hill (1980). Encyclopedia of science and Technology, 8 6th ed.

Mukoro EE (2009). Foundry Technology Handbooks, Federal Polytechnic Idah, Nigeria, pp. 5-10.

Nuhu AA (2010). Evaluation of the tensile strength of foundry cores made with hybridized binder composed of neon oil. Int. J. phys. Sci., 5(5): 555-563.

Ola A (2000). Development of oil sand cores, Seminar paper, Ahmadu Bello University Zaria.

Olakanmi EO, Arome AO (2009). Characterization of the core binding properties of fatty based oil. Int. J. Phys. sci., 4(11): 623-628.

Paul A, Jecob J, Hamisu M (2007). The use of LP simplex method in the determination of the minimised cost of a newly developed core. J. Mat. Sci., pp. 155–162.