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Research Article

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Investigation of Gum Arabic and Its Suitability as a Composite Binder for Core Production

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Abstract

Gum Arabic, exudates of several species of acacia, is typical of gum that contains Arabin. Gum Arabic of finest quality is obtained from Acacia Senegal and A. Arabica found in western and northern Africa. The Gum forms a clear thick solution in water. In this work, the foundry properties of Gum Arabic were investigated to ascertain its suitability as a composite binder for core production. Various percentages of Gum Arabic and some conventional foundry binders were prepared and their binding properties determined. Since the binder has low limit hydration, it does not require the use of much water during mixture preparation. For the purpose of this work, 4%-6% of the Gum Arabic was used with conventional binders like bentonite, water glass, industrial starch, linseed oil to prepare core mixtures. A higher percentage (13-15%) of Gum Arabic alone was also used. Foundry properties like permeability, scatter index; mouldability index, moisture content, compressive strength tests and refractoriness were examined. The results revealed that the binder has a low refractoriness of 1200°C. This has the advantage of enhanced and good collapsibility during knock out.

Keywords: Gum arabic; Composite; Binder; Core production

Introduction

Raw materials development is very important for any society that wants to develop technologically, Nigeria is a country endowed with a lot of solid minerals and material resources. The slow pace of technological development in Nigeria is attributable to inadequate attention to raw material development. Gum Arabic (E 414, Acacia gum is prepared from exudates of several species of trees is typical of gum that contain Arabin) [1]. Gum Arabic of finest quality is obtained from Acacia Senegal and A Arabic found in the northern Africa. The Gum forms a clear thick solution in water. The Gum can also be collected from the stem and branches of sub-Saharan Sahel zone, Acacia Senegal and Acacia seyal (leguminosae) trees and produced naturally as noodles with brown and white colours or sometimes in powdery form during a process called gummosis. It is a less consistent material than other hydrocolloids. Gum Arabic is a complex and variable mixture of Arabinogalcutain, Oligosaccharides, Polysaccharides and glycoprotein [2]. Gum Arabic consists of a mixture of lower molecular weight Polysaccharides (M.Wt 0.25×10^6 major component) and higher molecular weight hydroxyproline –rich glycoprotein (M.Wt 2.5×10^6), minor component. Gum Arabic glycoprotein possesses a flexible but compact conformation. It is readily soluble to give relatively low viscosity Newtonian solutions, even at higher concentration (20%-30%wt/wt). The objective of this work is to determine the foundry properties of Gum Arabic and to investigate its suitability as binding material for production of cores.

Experimental Procedure

Materials and equipment

The Gum Arabic, a composite material for this work, was collected from the Northern part of Nigeria. (Acacia tree from Gindiri, in Plateau State). Quartz sand was collected from the stock of sand being used for preparation of moulding and core mixtures in the Foundry shop of the Ajaokuta Steel Company Limited. Distilled water and water from the tap were also used.

The equipment used for the experiment were Laboratory mixer, Test tubes, Pneumatic rammer, Electric universal strength testing machine, Moisture content meter, shaker-mouldability and collapsibility indexes, permeability tester, sieve analysis equipment and drying oven [3].

Procedure

Physical and mechanical properties of the binders were investigated. Gum Arabic was used alone and at other conditions, mixed with some conventional binders at various percentages. Core mixtures were prepared with the Gum Arabic, using laboratory mixer. Weighed core mixtures of 150 g were taken for test specimen preparation, using the specimen rammer dropping a load of 6.35 kg weight fall three times to give a sample of 50 ± 0.2 mm diameter and 50 ± 0.8 mm height prepared with split sleeve [4]. A total of thirty-six (36) specimens were prepared for tests covering green and dry compression strength, for each core mixture. Tests for core mixture moisture content scatter index and mouldability index, permeability, and bulk density were also carried out.

Results and Discussion

The Gum Arabic binder requires little water 3% to 5% by weight for a given bonding strength of the core mixture. It satisfies all the properties required for foundry cores like collapsibility , greater swelling ability, and good binding ability, hence it can used in the foundry industry as a binder for production of cores [5].

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Effect of gum Arabic composite binder on the production of cores

Table 1 gives some properties of Gum Arabic as a composite binder. The composition is varied from 13% to 15%, quartz sand varied from 84%-82% and water at 3%. As the binder increased both the Green and Dry compression strength were seen rising and falling. The rising of both strength is quite in order at 100° C, as it exhibits the characteristics and the binding strength of the binder as being used in foundry technology.

The effects of increasing gum Arabic quantity on the binding strength

Table 2 shows the results of properties of core mixture with Gum Arabic 4-6%,90-88% quartz sand, starch 3% and 3% water. As the binder quantity increased from 4% to 6%, the green strengths remained 1 N/cm^2, while the dry strength reduced from 17.5 N/cm^2 to 11.0 N/cm^2 and then increased to 14.0 N/cm^2 [6]. Table 3 shows the results of properties of core mixture with Gum Arabic 4-6%, 90-88% quartz sand, Bentonite 3% and 3% water. As the binder quantity increased from 4% to 6%, the green strengths increased from 0.5 N/cm^2 to 1.0 N/cm^2, while dry strength, increased from 2.0 N/cm^2 to 4.0 N/cm^2 and then reduced to 2.0 N/cm^2.

Table 4 shows the results of properties of core mixture with Gum Arabic 12%-14%, 80%-78% quartz sand, linseed oil 5% and 3% water. As the binder quantity increased from 12% to 14%, the green strengths increased from 1.0 N/cm^2 to 1.9 N/cm^2, while the dry strength increased from 1.0 N/cm^2 to 1.2 N/cm^2 and then reduced to 1.0 N/cm^2.

Table 5 shows the results of properties of core mixture with Gum Arabic 12-14%, 80-78% quartz sand, Sodium Silicate 5% and 3% water.

As the binder quantity increased from 12% to 14%, the green strengths reduced from 0.5 N/cm^2 to 0.4 N/cm^2, and then increased to 0.5 N/cm^2 while the dry strength remained at 1.0 N/cm^2 [7].

Table 6 shows the results of properties of core mixture with Gum

Materials	**% Composition of core mixture**				
Quartz sand	90-88	90-88	80-78	80-78	84-82
Gum arabic	4-6	4-6	12-14	12-14	13-15
Starch	3	-	-	-	-
Bentonite	-	3	-	-	-
Linseed oil	-	-	5	-	-
Sodium silicate	-	-	-	5	-
Water	3	3	3	3	3

Table 1: Composition of core mixture.

Core mixture quartz sand (%)	90	89	88
Permeability quartz sand	100.24	38.1	49.3
Green compression strength n/cm²	1	1	1
Dry compression strenght n/cm²	17.5	11	14
Mouldability	75.5	90	95
Shatter index (%)	35	25	25
Moisture content (%)	9.6	9.8	9.8
Bulk density (g/cm)	150	150	150
Brinder a (gum arabic)	4	5	6
Brinder b (bentonite) (%)	3	3	3
Water (%)	3	3	3
Baking temp (°C)	50	100	150/200

Table 2: Gum arabic 4-6%, quartz sand varied 90-88%, starch 3% and water at 3%.

Core mixture quartz sand (%)	90	89	88
Permeability quartz sand	100.24	63.9	50.12
Green compression strength n/cm²	0.5	1	1
Dry compression strenght n/cm²	2	4	2
Mouldability	4.5.0	4.7.0	50
Shatter index (%)	87.5	72.5	75
Moisture content (%)	5	4	4
Bulk density (g/cm)	150	150	150
Brinder a (gum arabic)	4	5	6
Brinder b (bentonite)	3	3	3
Water (%)	3	3	3
Baking temp (°C)	50	100	150/200

Table 3: Gum arabic 4-6%, quartz sand varied 90-88%, bentonite 3% and water at 3%.

Core mixture quartz sand (%)	80	79	78
Permeability	10.7.4	111.3	113.5
Green compression strength n/cm²	1	1	1.9
Dry compression strength n/cm²	1	1.2	1
Mouldability (%)	32.5	50	30
Shatter index (%)	60	75	70
Moisture content (%)	3	3	3
Bulk density(g/cm)	150	150	150
Binder a (gum arabic) (%)	12	13	14
Brinder b (linseed oil) (%)	5	5	5
Water (%)	3	3	3
Baking temp (°C)	50	100	150/200

Table 4: Gum arabic 12-14% quartz sand varied 80-78%, linseed oil 5% and water at 3%.

Core mixutre quartz sand (%)	80	79	78
Permeability	100	85.8	83.5
Green compression stenght n/cm²	0.5	0.4	0.5
Dry compession shenght n/cm²	1	1	1
Mouldability (%)	20	25	27.5
Shatter index (%)	75	71	78
Moisture content (%)	2	2	2
Bulk density (g/cm)	150	150	150
Binder a (gum arabic)	12	13	14
Binder b (sodiuim silicate)	5	5	5
Water (%)	3	3	3
Baking temp (°C)	50	100	150/200

Table 5: Gum arabic 12-14%, quartz sand Varied 80-78%, sodium silicate 5% and water 3%.

	1	2	3
Core mixture quartz sand (%)	84	83	82
Core mixture	1	2	3
Permeability	93.9	89.8	85.9
Green compression strenght n/cm²	0.2	0.5	0.2
Dry compression strenght n/cm²	4	3	3
Mouldability (%)	70	75	65
Shatter index (%)	50	60	72
Moisture content (%)	3	3	3
Bulk density (g/cm)	150	150	150
Binder (gum arabic)	13	14	15
Water (%)	3	3	3
Baking temp(°C)	50	100	150/200

Table 6: Gum arabic 13-15% quartz sand Varied 84-82% and water at 3%.

Composition	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Loi	Refractoriness	H_2O
%	95.96	2.04	0.92	0.06	0.08	0.02	1500°C	0.19

Table 7: Chemical composition of quartz sand in foundry shop of ASCL.

Arabic 13-15%, 84-82% quartz sand, and 3% water. As the binder quantity increased from 13% to 15%, the green strengths increase from 0.2 N/cm² to 0.5 N/cm² and, then reduced to 0.2 N/cm². The dry strength reduced from 4.0 N/cm² to 3.0 N/cm². The discussion above indicated that the composition of core mixture with Gum Arabic should be from 12% and above, when used alone and 3% water, but 4% to 6% is appropriate when used with other binders (Table 7).

The results of the experiment

- Varying percentage of quartz sand from 90%-88% with Gum Arabic, 13%-15% could not produce bond; but when the quartz sand percentage was reduced to 84%-82% and using the same 13%-15% Gum Arabic these mixture produced adequate bonding.
- In the core mixtures consisting of Gum Arabic and 5% sodium silicate, the quartz sand needed to be reduced from 90%-88% to 80%-78% before the result could yield bonding effect. In this particular case, both the Gum Arabic and sodium silicate (Na_2SiO_3) were increased in percentage.
- Core mixtures consisting of 12% of Gum Arabic could not be baked at 50°C, but with increase to 13-14%, and with 5% sodium silicate, the baking at the same 50°C was good.
- Core containing 6% Gum Arabic binder with bentonite or industrial starch were brown and hard at 200°C
- Each core particularly the core made from Gum Arabic has the characteristics of air setting when exposed to the atmospheric air for some minutes (60-90 minutes)
- The inlet guide Gum Arabic cores exhibited excellent surface finish, with excellent shake-out characteristics. For the grey cast iron casting, the core material was easily removed by tapping the casting 2-4 times with say a ball Pen hammer. No other secondary core cleaning operations were required to observe the inside casting surface. The outside surface of the casting also had also had smooth finish because the core facing materials was made of Gum Arabic.
- No much fettling work was done on the cast inlet guide. This is deliberately to show or reveal the features of the Casting. The defects were not remedied so as to show the true condition of the casting [8].

Conclusion

The research work investigated the suitability of Gum Arabic as a composite binder for foundry core production, it was obviously confirmed that Gum Arabic is suitable for foundry core production. Different types of experiments conducted, using varying quantities of Gum Arabic revealed that it is possible to produce cores for excellent inside casting surfaces, using Gum Arabic as a binder in the core mixtures. The cored surface, using Gum Arabic cores exhibited an excellent surface finish. On removal of the casting from the Gum Arabic mould facing material, the core exhibited an excellent shake-out characteristics, requiring minimal efforts. The use of Gum Arabic as a composite binder for foundry core production removes or reduces the risks of silicoses from foundry workers {since Gum Arabic are usually employed in food production}. It is however, likely that the limiting use of Gum Arabic as a composite binder for foundry core production lies on the difficulty of procuring large quantities for big cores. Again the cost of large quantities of Gum Arabic places limit on its use, as the cost may be much higher than that of the same quantities of other conventional core binders. Nevertheless, for small size cores meant for limited number of castings, Gum Arabic is essentially suitable, especially where high inside casting surface finishing is required. Gum Arabic can make a good ‘as cast products. On the removal of the casting from the mould prepared with gum Arabic as facing material, it was observed that it has excellent shake-out characteristics, requiring less effort in knocking out of the moulds.

Gum Arabic has a unique air setting property which can dry at room temperature. Cores produced with Gum Arabic as composite binder exhibited excellent surface finish when used for castings. Cast products from the moulds prepared with Gum Arabic has excellent shake out characteristics, requiring less effort in knocking out of the moulds. Gum Arabic does not constitute any health hazard as the risk of inhaling poisonous gases from the reaction of the binder with liquid melt is eliminated [9]. Grey cast iron melted at 1460°C produced with the core exhibited a good surface quality. Gum Arabic is therefore suitable for foundry core production. Gum Arabic does not constitute any hazard and Health as the risk of inhaling poisonous gases from the reaction of the binder with liquid melt. Grey cast iron melted at 1460°C produced with the core exhibited a good surface quality**.**

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