مجلة العلوم البحثة والتطبيقية
Journal of Pure & Applied Sciences
www.Suj.sebhau.edu.ly ISSN 2521-9200
Received 12/11/2017 Revised 05/2/2018 Published online 30/06/2018

Suitability of Different Local Sands as Moulding Sand in Foundry Industry

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Abstract Moulds that are made of sand are relatively cheap, and sufficiently refractory for high temperature use. In addition to the sand, a suitable binder is mixed with the sand. This paper presents a comparative study on the usability and suitability of different local sands and binders for metal casting operations. Four different types of sands and three binders were combined successfully in different design mixtures. The sands under study were Red sand (Ashkida), silica sand (Zallaf), red well sand and white well sand. Soil texture determination method was carried out to determine the type of sand. The binders used in the mixtures were sugar solution, dates extract and local clay. Certain properties concerning sand casting were investigated which were; the mixture strength, collapsibility, refractoriness, permeability and availability. The experimental results show that the best mixture for casting is (silica + clay) which tolerate a temperature of about 1373.15 K, and compression strength of 750 N. In addition, the silica sand has the highest value of permeability (2.31 K (cm/h) as compared with the other types of sands.

Keywords: Availability, Binders, Collapsibility, Moulds, Metal, Permeability, Refractoriness, Sand.

مدى ملائمة الرمال المحلية كقوالب سباكة رملية في صناعة سباكة المعادن

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الملخص قوالب السباكة المصنوعة من الرمال تعتبر رخيصة الثمن نسبيا، وتستخدم كقوالب في صهر المعادن عند درجات الحرارة العالية. بالإضافة إلى الرمل، يتم خلط الرابط المناسب مع رمل السباكة. تقدم هذه الورقة دراسة مقارنة حول قابلية استخدام وملاءمة الرمال المحلية والروابط المختلفة لعمليات السباكة. تم الجمع بين أربعة أنواع مختلفة من الرمال وثلاثة روابط مختلفة. انواع الرمال التي درست في هذا العمل كانت رمل احمرمن منطقة (أشكدة) ،رمل السيليكا (زلاف) ،رمل بئر (أحمر اللون) ورمل بئر (أبيض اللون). وكانت الروابط المستخدمة في التجارب: محلول السكر، الطين و رب التمر. تم فحص بعض الخصائص المتعلقة بقوالب السباكة الرملية والتي كانت؛ قوة القالب، قابلية الانهيار، الصمود عند درجات الحرارة و وفرة المواد. لظهرت النتائج العملية ان افضل قالب سباكة هو (السليكا + طين) الذي قاوم درجة حرارة وصلت الى حوالي 1373.15 K ، وقوة ضغط 750 N . بالاضافة الى ذلك، فإن رمل السيليكا له أعلى قيمة للنفاذية 2.31 cm/h بالمقارنة مع الأنواع الأخرى من الرمال ومتوفر بكثرة.

الكلمات المفتاحية: الروابط، القوالب، المعادن، الرمل، خصائص السباكة الرملية.

1. Introduction

The casting process basically involves pouring molten metal into a mold patterned after the part to be manufactured, allowing it to solidify, and removing the part from the mold [1].

1.1 Sand Casting: Over 70% of all metal castings are produced via a sand casting process. Sand casting is one of the most popular and simplest types of casting. Some examples of sand casting products are engine blocks, machine tool bases, cylinder heads, pump housings, and valves. Most sand casting operations use silica sand (SiO2). Great advantages of sand in manufacturing applications are that sand is inexpensive and very resistant to elevated temperatures. Usually sand used to manufacture a mold for the casting process is held together by a mixture of water and clay [2], [3].

1.2 Use of Binder in Sand Casting: In sand casting, the sand must contain some type of binder that acts to hold the sand particles together. Organic resins and inorganic bonding may be used to hold the sand together and in order to improve mold properties [4], [5].

1.3 Properties of Sand Casting Mixture

Strength: It is the ability of the sand casting mixture to hold its geometric shape under the conditions of mechanical stress imposed during the sand casting process.

Collapsibility: The ability of the sand mixture to collapse under force. Collapsibility is a very important property in this type of casting

manufacture to collect the casting part after solidification.

Refractoriness: This is the ability of sand to withstand high temperature without fusing or breaking down.

Permeability: The ability of the sand mold to permit the escape of air, gases, and steam during the sand casting process [4], [5].

Availability: The availability and cost of the sand is very important because for every ton of metal poured, three to six tons of sand is required [6].

Several studies have investigated sand and binders and their suitability for sand casting process as a cores. For instance [7] studied the composite binder consisting of collagen, sodium silicate and Sodium polyphosphate which was used to create a sand core. Another study [8] used appropriate foundry sand and found that good quality cores can be successfully produced using cassava starch singly. Furthermore, A. Oyetunji [9] used cassava starch singly in combination with clay as a binder to produce a good core. Other reported work [10] found that very convenient cores can be made using rubber seed oil as a binder. In his study, the author stated that there is a great potential for the production and use of rubber seed oil as core oil in the foundries [10].

2. Experimental preparation

2.1 Soil texture determination: Four different types of sands were collected from difference areas of Sebha and Shati cities and were selected for the present study, which are: (i) Red sand (Ashkida), (ii) Silica sand (Zallaf), (iii) Well sand (red), (iv) Well sand (white). Soil texture determination by mechanical and chemical Analysis aims at separating the soil granules in mechanical and chemical ways so that we obtain a homogeneous suspension from the individual primary granules, then find the particle distribution and determine the soil texture [11]. Figure (1) illustrates soil texture triangle determination to determine the class of soil.

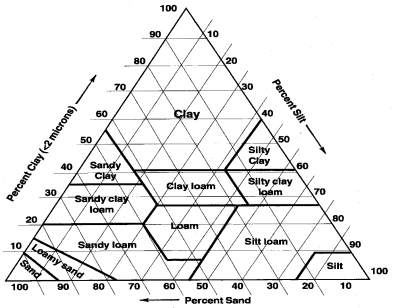

Figure (1) Soil texture triangle determination [11].

2.2 Proposed mixtures and properties tested: After determining the type of sand, binders that were used as link between sand boundaries are: (i) Clay, (ii) Sugar Solution, (iii) dates Extract. In sand casting the mold must have certain properties to be applicable for metals casting. These properties were explained in section 1.3. In this work, the properties of the new designed mixtures were tested to find out their suitability for foundry industry. The properties are listed as followed: (i) Strength, (ii) Collapsibility, (iii) Refractoriness. (iv) Permeability. For each mixture (type of sand + type of binder) designed in this work, three (3) samples were made for the compression and thermal collapse tests. Specimens were made with 92% of sand of the total mixture, and 8% as content of binder [6]. The samples that were prepared for all tests were made in cylindrical shape as shown in figure (2).

Figure (2) - The samples after drying

3. Result and discussion

3.1 Soil Texture Determination: Soil texture determination by mechanical and chemical Analysis was carried out to determine its texture by applying equations used by Black et al. [11]. The results are shown in Table (1).

Table (1) - Calculation of soil texture

No.	Type of Sand	Soil Wt. Dry	Silt Ratio	clay Ratio%	Sand Ratio%	Soil texture
1	Ashkida sand (red)	50	10	37.8	52.2	Sandy clay
2	Well sand (white)	100	7	27.9	65.1	Sandy clay loam
3	Well sand (red)	100	1	20.9	79.1	Sandy clay loam
4	Silica sand (zllaf)	100	1	13.9	85.1	Sandy

3.2 Strength: At least 2-3 samples of cylindrical shape of each mixture design were examined under compression to find out their failure strength. The results will provide direct indications into the resistance of these types of sand/binder mixture to external forces that may be imposed on moulds during casting operation. Table (2) shows the average strength results from the compression tests.

Table (2) – The average strength results from the compression tests

No.	Type of Sand + Binder	Average force N
1	Red sand (Ashkida) + sugar solution	700
2	Red sand (Ashkida) + clay	900
3	Red sand (Ashkida) +dates extract	750
4	Silica sand (Zallaf) + sugar solution	0
5	Silica sand (Zallaf) + dates extract	0
6	Silica sand (Zallaf) + clay	700
7	Wells sand (red colour) + clay	450
8	Wells sand (red colour) + dates extract	750
9	Wells sand (red colour) + sugar solution	300
10	wells sand (white colour) + sugar solution	1650
11	Wells sand (white colour) + dates extract	800
12	Wells sand (white colour) + clay	750

The average results for failure strength are included in Table (2). The highest strength resistance for each group were wells sand (white colour) plus sugar solution with average value of 1650 N, red sand (Ashkida) plus clay with average value of 900 N, wells sand (red colour) plus dates extract with average of 750 N and Silica sand (Zallaf) plus clay with average of 700 N.

3.3 Collapsibility: The results for collapsibility test are shown in Table (3). The highest resistance of collapsibility among each group were red sand (Ashkida) plus clay with average of 4.39 Kpa, Silica sand (Zallaf) plus clay with average of 3.29 Kpa, wells sand (red colour) plus sugar solution with average of 3.33 Kpa and wells sand (white colour) plus sugar solution with average of 7.62 Kpa.

Table (3) - Collapsibility tests of sand samples

No.	Type of Sand + Binder	Collapsibility Kpa
1	Red sand (Ashkida) + sugar solution	3.18
2	Red sand (Ashkida) + clay	4.39
3	Red sand (Ashkida) +dates extract	1.32
4	Silica sand (Zallaf) +sugar solution	0
5	Silica sand (Zallaf) + dates extract	0
6	Silica sand (Zallaf) + clay	3.29
7	Wells sand (red colour) + clay	2.08
8	Wells sand (red colour) + dates extract	3.33
9	Wells sand (red colour) + sugar solution	1.36
10	wells sand (white colour) + sugar solution	7.62
11	Wells sand (white colour) + dates extract	3.63
12	Wells sand (white colour) + clay	3.57

3.4 Refractoriness

Samples of each type of sand/binder mixture was tested thermally in a furnace. The results provide direct indications into the resistance of these types of sand/binder mixtures to high temperatures, which are expected during casting operations. Table (3) shows the thermal resistance temperature for each of them.

Table (3) - Results of refractory testing

No.	Type of Sand + Binder	Notes during heating	Refractoriness K
1	Red sand (Ashkida) + sugar solution	Surface cracking With the rise of the combustion fumes	573.15
2	Red sand (Ashkida) + dates extract	Cracks on the surface	1143.15
3	Red sand (Ashkida) + clay	Surface cracking , increase brittleness	923.15
4	Wells sand (red color) + sugar solution	Cracks on the surface, brittle	573.15
5	Well sand (red color) + dates extract	combustion	673.15
6	Well sand (red color) + clay	Crack due to elevated temperature	773.15
7	Wells sand (white color) + dates extract	Cracking during solidification	1143.15
8	Wells sand (white color) + sugar solution	Burning start at 663.15 k, with rise of fumes	663.15
9	Wells sand (white color) + clay	Burning start at 653.15 k	623.15
10	Silica sand + clay	It withstand up to 1273.15 k	1373.15

11	Silica sand + dates extract	combustion	423.15
12	Silica sand + sugar solution	combustion	473.15

Three samples registered the highest temperature resistance which were Silica sand + clay with average of 1373.15 K. The reason for this is that silica contain quartz element that has high melting point of about 1943.15K [3]. The other two types of sands were Red sand (Ashkida) + dates extract with average of 1143.15 K, and Red sand (Ashkida) + dates extract with average of 1143.15 K, Notes during heating process were listed in the table.

3.5 Permeability Author [12] studied the permeability, porosity and granular distribution found that increasing the degree of bonding between the soil granules leads to a decrease in the permeability coefficient. Thus the bigger the size of granular, the greater the coefficient of permeability .The coefficient of permeability (k) is calculated for the four different sands studied in the present work by the method mentioned in ref. [13] and the results are shown in Table 4.

Table (4) - Result of permeability test

No.	Type of Sand	Permeability (cm/h)	K
1	Red Ashkida sand	0.51	
2	Well sand (white color)	2.06	
3	Well sand (red color)	2.20	
4	Silica sand (Zallaf)	2.31	

From the table 4, it is noticed that the highest value of permeability (2.31 cm/h), was recorded for the silica (Zallaf) sand. This is because this type of sand has the biggest granular size among all other types of sands. The lowest permeability was recorded for the Red Ashkida sand with value of 0.51 (cm/h), which can be attributed to high content of clay. The clay ratio for this type of sand was recorded in table (1) as 37.8 %, which is the highest value as compared with other types of sands.

3.6 Availability: All types of sands that were used are available for free, but charge may be applied for some types of binder. It can be clearly seen that each type of these local sand require certain binder to give the best combination of properties required for metal casting operations. For instance, it is noticed that the sample made from wells (white color) sand/ sugar solution binder have the highest strength resistance and collapsibility with a value reaching 1650 N and 7.62 Kpa. However, this type of mixture cannot withstand high temperatures because it failed at a very low temperature of 663.15 K. This is because the melting point of sugar is lower than that of sand. Contrary to this, the best recommendation for sand/binder mixture for casting is (silica + clay) since this type tolerates a temperature of about 1373.15 K, and compression strength of 700 N. This can be explained by the fact that silica sand contains sandy texture (see table 1). Sandy texture originally is a quartz contains SiO2 of about 50-90 % and clay of about 2-8 % [14]. Quartz is well known of tolerating high temperature which has high melting point of about 1943.15K [3], and the clay is a strong binder. In addition, the silica sand has the highest value of permeability (2.31 cm/h). The new second best mixture was the sample with mixture of (the white well sand + dates extract). This type of sand/binder mixture can endure a temperature as high as 1143.15, and has strength of 800 N. This can be related to the strong chemical bond that may be formed between both sand and binder. The white well sand has the second best permeability with a value reaching 2.06 (cm/h).

4. Conclusions: This work aims to provide a comparative study on the usability and suitability of different local sands and binders for metal casting operations. The aim was to focus on investigating certain properties that are of great importance for sand casting. The findings can be summarized as follows:

1. Four different types of sands and three binders were successfully combined in different design mixtures.

2. Experimental results show that the best recommendation for sand/binder mixture for casting is (silica + clay) since this type tolerates a temperature of about 1373.15 K, compression strength of 700 N, collapsibility of about 3.29 Kpa, highest permeability of 2.306 cm/h since its particle size is bigger comparing with the other types, and it is readily available. Further investigation can be done by adding different binders to the sand mixture.

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