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Testing for Green Compression Strength and Permeability Properties on the Tailing Sand Samples Gathered from Ex Tin Mines in Perak State, Malaysia.

A. Abdullah[1,a], S. Sulaiman[1,b], B.T.H.T. Baharudin[1,c], M.K.A. Ariffin[1,d], T.R.Vijayaram[2,e], M.Sayuti[1,f]

[1]Department of Mechanical and Manufacturing Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 Serdang, Selangor, Malaysia;

[2]Faculty of Engineering and Technology (FET) Multimedia University, Jalan Ayer Keroh Lama, Bukit Beruang, 75450, Melaka. Malaysia

[a]azija656@yahoo.com, [b]suddin@eng.upm.edu.my, [c]tuah@eng.upm.edu.my, [d]khairol@eng.upm.edu.my, [e]vijayaram1@gmail.com, [f]tgk_sayuti@yahoo.co.uk

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Abstract. Permeability and green compression strength are among the important mechanical properties and considered much in the sand casting mould preparation. These molding sand properties play a vital role in determining the optimum moisture content for making green sand casting mould. Tailing sand is the residue mineral from tin extraction, which contains between 94% and 99.5% silica and in abundance in Kinta Valley of state of Perak, Malaysia. In this research work, samples of tailing sands were gathered from four identified ex tin mines located at the Perak State, Malaysia. They were investigated by the standards and testing procedures prescribed by the American Foundrymen Society (AFS). Sand specimens of size Ø50 mm×50 mm in height from various sand–water ratios bonded with 4% clay were compacted on applying three ramming blows of 6666 g each by using a Ridsdale-Dietert metric standard rammer. The specimens were tested for green compression strength using Ridsdale-Dietert universal sand strength machine and permeability number with Ridsdale-Dietert permeability meter. Before the tests were conducted, the moisture content was measured using moisture analyzer. Samples with moisture content ranging from 3 to 3.5% were found to have optimum working range with effective green compression strength and permeability.

Introduction

Tailing sand is the residue mineral from tin extraction, which contains between 94% and 99.5% silica and in abundance in Kinta Valley of state of Perak, Malaysia [1]. The samples were taken from four identified locations, which are Taiping (4.8648532N, 100.7061714E), Tronoh (4.4410824N, 101.0034513E), Batu Gajah (4.447543N, 101.061044E) and Tanjung Tualang (4.2995955N, 101.0588551E) [2]. Study on green compression strength and permeability of tailing sand are vital to identify the working range for making green sand casting mould.

The green compression strength is a study to determine the maximum compression strength that a mixture (tailing sand, clay and water) is capable of sustaining when prepared, rammed and tested according to standard procedure. This is because sufficient strength of moulding sands is required during withdrawal the pattern from the mould and during pouring processes where the mould must retain shape independently without distortion or collapse. Increase in strength occurred because as the clay content of the moulding sand increased, its binding strength also increased which led to increase in strength [3]. Usually, green compression strength for typical moulding sands run from about 6 to 10 Ib. per sq. in (20-80kN/m^2) with moisture content of 3-4% [4].

Permeability is defined by the AFS as that physical property of moulded sand, which allows gas to pass through it. It is determined by measuring the rate of flow of air (2000 cm^3) through the metric standard rammed specimen (Ø50 mm×50 mm in height) under a standard pressure (10 g/cm^2) [5]. A permeability figure of 150 to 200 is normal practice, with moisture content of between 3 and 4 per cent [4].

Clay and water have a significant role in improving the strength and permeability of greensand mould. Clay and water act as control addition to influence mechanical properties of moulding sand. This controlled addition can thus be made in the order of 5-7% clay and 3-3.5% water to produce moulds with better strength and higher permeability [6]. For instances, green sand properties for mould prepared by jolt /squeeze machine are water (3-4%), live clay (5-5.5%), permeability (80-110) and green strength (70-100 kPa) while for mould prepared by high pressure (DISA etc) are water (2.5-3.2%), live clay (6-10%), permeability (80-100) and green strength (150-200 kPa) [7].

For making green sand mould, clay acts as binder. Bentonite clay has been used for this research. Bentonite is the clay predominantly used by the foundry industry. Because it develops favourable bond characteristics strength can be developed with relatively low additions. Without the addition of water to clay no strength would be achieved, as the sand and clay would be just two dry materials. The clay adsorbs the water up to a limiting amount. Only that water rigidly held (adsorbed) by the clay appears to be effective in developing strength [8]. Too little water fails to develop adequate strength and permeability. With suitable water content, it is the principal source of the strength and permeability of the molding sand. Since bonding materials are not highly refractory, the required strength must be obtained with the minimum possible addition [9] and due to this reason addition of 4% bentonite has been selected. The development of bond strength between grains depends upon hydration of the clay, the green strength and permeability of a moulding mixture increases with water content up to an optimum value determined by the proportion of clay. Above this value, additional free water causes permeability to diminish due to the increasing on thickness of the water films, so that the clay becomes soft, lose its bonding power and less stiff and the sand grains are held further apart thus decrease the strength [10].

Therefore excess moisture must be avoided since it lowers permeability and increases the chance of a blown casting. At the same time plasticity and deformation of the mould will occur. Low permeability and green compression strength encourage entrapment of gas and the washing away of sand by molten metal [6].

Figure 1 shows the influence of moisture content on the green compression strength and permeability.

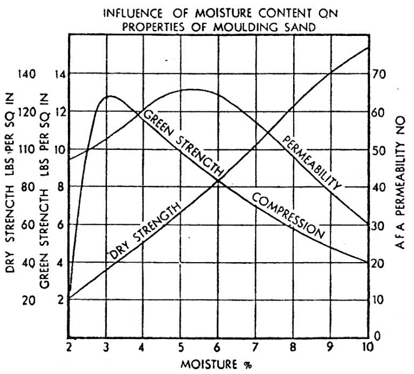

Fig. 1: Influence of moisture content on properties of moulding sand [5].

Materials And Methods

The sand mixture was prepared by mixing 1000 grams of dry sand with 40 grams of bentonite clay, and subjected to milling for 5 minutes. Then, water was added to the mixture and it was started with 20 ml addition (approximately 2% moisture). The mixture was milled appropriately for 3 minutes and then the samples were tested for the moisture % by using a moisture teller shown in Fig. 2(a).

A test piece Ø50 mm×50 mm in height was prepared for green compression test and permeability using Ridsdale-Dietert Metric Standard Rammer as shows Fig. 2(b). A test piece of Ø50 mm×50 mm in height was prepared by weighing out specimens rainging from 138 grams to 150 grams depending on the sand/clay/water ratio [5]. Then, the mixture was transferred to the Ridsdale-Dietert Metric Standard Rammer to form a test piece Ø50 mm×50 mm in height. The specimen test piece was stripped using strip block and removed from the tube carefully as shows in Fig. 2(c) and tested using Ridsdale-Dietert Universal Sand Strength Machine as shows in Fig. 2(d). A test piece for permeability was prepared with same method but the test piece was not stripped out and tested using Ridsdale-Dietert permeability meter as shows in Fig. 2(e).

After the readings were obtained, addition of 20 ml water was added and green compression strength and permeability were tested until the readings start to decrease where the condition of mixture becomes so wet and unmouldable.


(a)


(b)


(c)


(d)


(e)

Fig. 2: Equipments for foundry sand testing. (a) Moisture analyzer, (b) Ridsdale-Dietert metric standard rammer, (c) Strip block and specimen test piece, (d) Ridsdale-Dietert universal strength machine and (e) Ridsdale-Dietert permeability meter.

RESULTS

The results of the tests on the green compression strength (GC) and permeability number (PN) of the tailing sand–clay mixture is in Table 1 and presented graphically in Figures 7-10.

Table 1: Green Compression Strength (GC) and Permeability Number (PN) of tailing sands bonded with 4% Clay.

Batu Gajah	Moisture(%)	2.28	3.03	4.86	5.48	7.33	7.95	8.50	9.08
	GC (kN/m^2)	26.8	30.2	32.2	32.2	30.5	30.8	30.2	29.3
	Moisture(%)	1.27	2.21	3.01	4.10	5.52	6.43	7.15	8.05
	PN	46.0	71.0	91.0	94.0	93.0	88.7	82.0	77.0
Taiping	Moisture(%)	2.34	3.16	3.91	4.64	5.22	6.50	7.73	8.33
	GC (kN/m^2)	25.7	30.5	31.2	30.3	29.0	27.3	24.3	23.7
	Moisture(%)	1.69	2.85	3.91	4.99	6.33	7.27	8.10	8.84
	PN	212.0	234.7	235.0	232.0	212.0	198.0	185.0	167.0
Tanjung Tualang	Moisture(%)	2.37	3.84	4.15	4.83	5.22	6.25	6.41	6.79
	GC (kN/m^2)	23.7	28.3	28.5	25.0	24.0	20.3	19.7	19.5
	Moisture(%)	1.96	3.18	4.40	5.61	6.60	7.59	8.24	9.09
	PN	219.0	253.0	253.0	240.3	226.0	219.0	209.7	202.7
Tronoh	Moisture(%)	2.74	3.24	3.50	4.65	5.88	6.36	6.94	7.38
	GC (kN/m^2)	25.0	26.7	26.3	25.2	24.8	23.3	23.0	22.2
	Moisture(%)	1.74	2.63	3.47	5.00	5.87	7.56	8.01	8.84
	PN	120.0	142.0	144.7	140.7	134.0	123.0	120.0	109.3

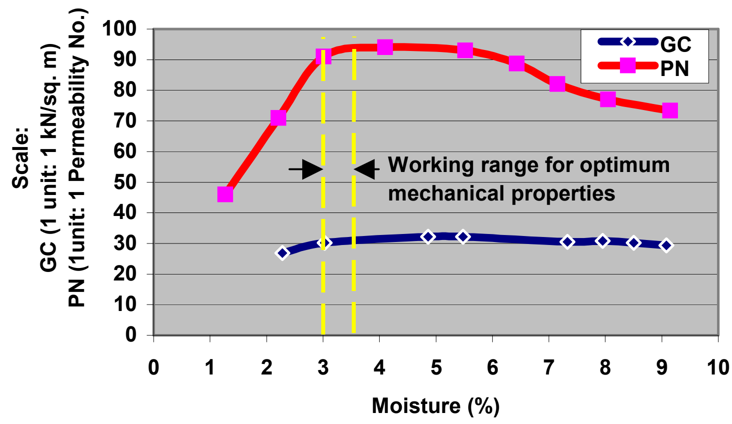

Fig.7: Effect of moisture on green compression (GC) strength and permeability number (PN) of tailing sand from Batu Gajah bonded with 4% clay.

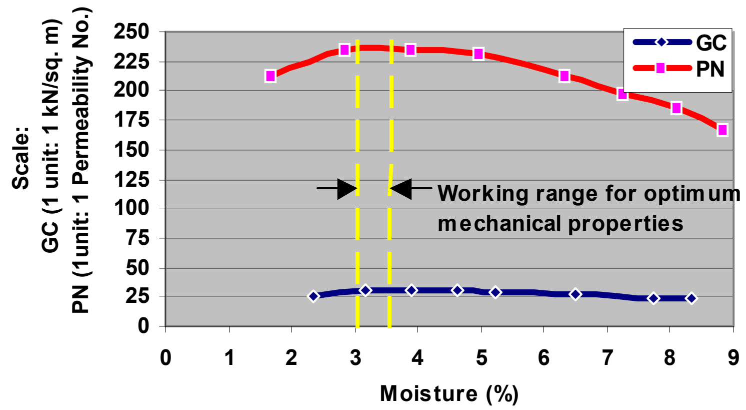

Fig.8: Effect of moisture on green compression (GC) strength and permeability number (PN) of tailing sand from Taiping bonded with 4% clay.

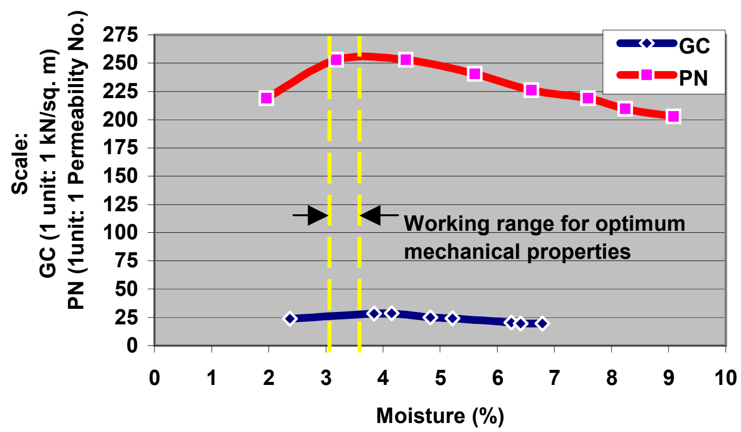

Fig.9: Effect of moisture on green compression (GC) strength and permeability number (PN) of tailing sand from Tanjung Tualang bonded with 4% clay.

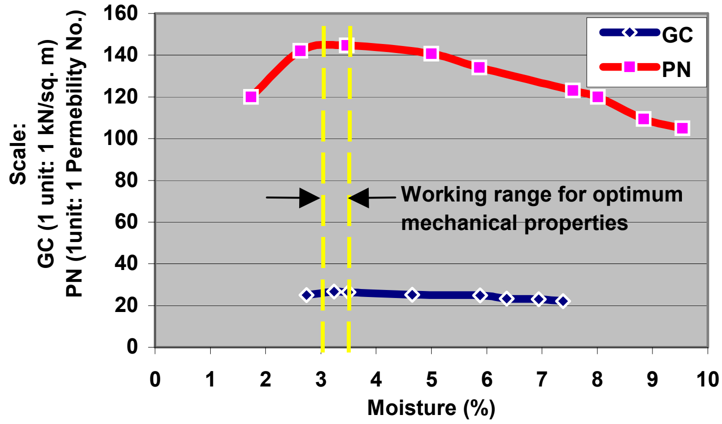

Fig.10: Effect of moisture on green compression (GC) strength and permeability number (PN) of tailing sand from Tronoh bonded with 4% clay.

Discussion

The results show the green compression strength and permeability for all samples bonded with 4% bentonite clay increased incrementally with the increasing percentage of water in mixtures between 3-4% moisture before they start to decrease. Green compression strength for sample from Batu Gajah, increases to maximum value at moisture of 4.86% and the permeability is maximum at 4.10%; for sample from Taiping, both mechanical properties are maximum at the same moisture which is 3.91%; sample from Tanjung Tualang, green compression strength at moisture of 4.15% and permeability at moisture of 3.18% and Tronoh is at 3.24% and 3.47% respectively. These show that the samples will not give superiority on green compression strength and permeability at the same percentage of moisture except sample from Taiping, therefore the optimum values are used to determine the working range with suitable moulding properties. Figures 7-10 show the working range for optimum moisture content, green compression strength and permeability for all samples. The optimum moisture content for optimum green compression strength and permeability for samples is at range of 3-3.5% and this is acceptable because water required is about 3 to 4% in normal practice [4]. This range indicates, at this percentage of moisture, clay has absorbed the water up to a limiting amount to produce effective strength with good permeability and suitable for making green sand mould. The figures also show when the moisture is beyond 4.0%, the strength and permeability become low and poor and not suitable for making mould. At this stage, mixture becomes wet and thicker the water thus the clay becomes so soft and unable to hold the grains together hence decreases the strength and at the same time reduced the capability of gas to pass through.

Summary

Moisture content influences the green compression strength and permeability of tailing sands. The amount of water addition and working range for optimum green compression strength and permeability is determined by plotting the control graph. The finding shows tailing sand bonded with 4% bentonite clay has working range with effective strength and permeability at moisture ranging from 3% to 3.5% and this is congruent to produce moulds with better strength and higher permeability.

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