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Investigation on Different Compositions of Clay and Water to the Permeability of the Silica Sand Used in Greensand Casting Mould

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ABSTRACT

Greensand casting is a casting process that uses mixture of silica sand with addition of control additions which are bentonite clay and the presence of water. Control additions influence the mechanical properties of greensand casting mould, for this study focuses on the permeability. Bentonite clay acts as a binder and activated by water to develop strength and plasticity thus the greensand casting mould can be formed. Permeability is ability of gas to pass through the moulding mixture aggregates in order to reduce the defects due to trapped gasses in mould cavity such as blow holes or pin holes. The objective of this study is to investigate the effect of control addition (water and clay) on the permeability number of silica sand sample (tailing sand) from former tin mine site in Tronoh, Perak. Experiments are conducted according to American Foundrymen Society (AFS) standard of procedures. Sand sample is sieved using mechanical sieve shaker to size of 425 µm. Cylindrical test pieces dimensioning of Ø50 mm×50 mm in height from various mixtures of sand-clay–water ratios are compacted by applying three ramming blows of 6666 grams using Ridsdale-Dietert metric standard rammer. The test pieces are tested for permeability with Ridsdale-Dietert permeability meter. The results show that clay and water have affected the permeability of silica sand sample and when more water and clay added, into the moulding mixture, the permeability is found decreased. The appropriate allowable water and clay content are crucial for permeability number of greensand casting mould.

Keywords: Permeability; moulding mixture; silica sand; sand casting and greensand casting mould

INTRODUCTION

Sand casting is a process in which a molten metal is poured into a mould cavity of sand mould. Sand mould consists of sand, binder, and other additives, and then allowed to solidify to form the desired shape. Greensand casting is a sand casting technique that combines pure silica sand (85-95%) with binder which is bentonite clay (4-10%) and water (2-5%) as a wetting agent (Siddique et al., 2009). Siddique et al. (2009) also mentioned that 90% of casting products are produced by greensand casting and according to Paluszkiewicz et al. (2008), 70% of ferrous castings were made from greensand casting.

Apart from zircon, olivine, and chromite, the most common sand used in metal casting moulds is silica sand. The two types of silica sand that can be generically categorised based on their chemical makeup are clay-free sand (synthetic sand) or washed sand and clay-bearing sand (naturally-bonded sand). According to Mackay (2000), tailing sand which contents of high silica sand, was formed during the extraction of tin in former tin mines, where soil was washed away using gravel pumps and the sand left behind is called tailing sand. This technique produced a large amount of tailing sand with a silica content of 94% - 99.5%.

Permeability is a physical feature of a sand mixture's moulded mass that allows gas to travel through it. It is determined by calculating the rate of flow of air (2000 cm^3) through a typical cylindrical sand test piece (Ø50 mm × 50 mm in height) under standard pressure (10 g/cm^2). Because of its porosity, a high-permeability sand mixture provides good venting qualities. The degree of permeability is influenced by the grain size, grain shape, and the grain distribution sand. Other factors are the type, quality and amount of binder, the density to which the sand is rammed, and the percentage of moisture content (AFS, 1963).

Howard (1958) mentioned that in normal practice permeability number is ranging 150 to 200 with moisture content of between 3% and 4%. According to Brown (2004), the permeability for iron foundries is 80-110 when prepared with a jolt/squeeze machine, and 80-100 when prepared with high pressure, according to Salmon and Simon (1966), cast iron has a permeability number of 10-80, bronze is 35, aluminium is 20-40, and steel has a permeability number of 150-300. The permeability value for a mixture of synthetic sand and 8% Ogharaki clay from Delta state, Nigeria, is 55.5 (Eze et al., 1993). Moulding sand from Mansfield Sand

Company when mixed with 6% water has permeability number of 21 (Bolger, 1996). According to Beadle (1971), sand no. 95 from King's Lynn, Norfork, has a green permeability of 61 when mixed with 5% Montmorillo-nite clay and 3.5% moisture, Redhill No. 65 sand has a green permeability of 120, and Chelford 50 sand has a green permeability of 220.

Clay and water, which are control additives, have an important function in enhancing the strength and permeability of greensand casting moulds. Clay is used as a binder in the production of greensand mould. For this study, bentonite clay was employed which is most commonly utilised in the foundry. Due to the low refractoriness of bonding materials, the amount of clay must be obtained with the smallest possible, of the order of 5-7% (Webster, 1980). The presence of appropriate water is required to activate the bonding action of clay. According to Jain (2008), the greatest thickness of water layer that clay can keep determines its bonding quality. Rao (2009) explained the development of necessary plasticity and strength happened when water activates the clay thus Webster (1980) mentioned that the amount of water used should be kept under strict control. According to Beatle (1971), general-purpose synthetic greensand for iron castings contains 5% clay, 6% coal dust, and a moisture content of 3.5%. The water films thicken as the water content of the sand increases, causing the clay to become less rigid and the sand grains to be kept more apart. The water films thicken, and the clay softens to the point where it can no longer hold the grains apart, reducing permeability. Excess moisture should be avoided at all costs, as it lowers permeability and increases the chance of a casting defects. Gas entrapment and sand washing by molten metal are encouraged by low permeability and green compression strength (Griffiths, 1990). Figure 1 shows the effect of water on the permeability of mixture bonded with two types of binder which are bentonite and fireclay and Figure 2 shows the permeability for two amounts of clay. The permeability of both binders decreases as the moisture content rises in both figures.

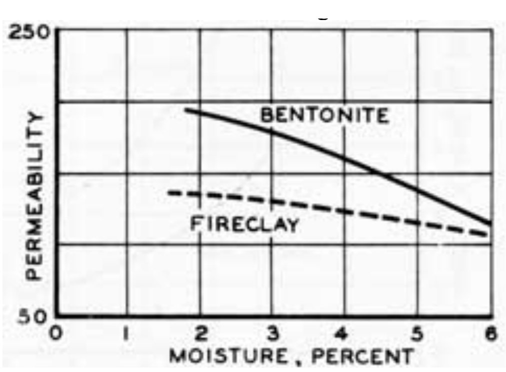

FIGURE 1. The effect of moisture content on the permeability of sand mixture bonded with bentonite clay and fireclay (Foundry Manual 1958).

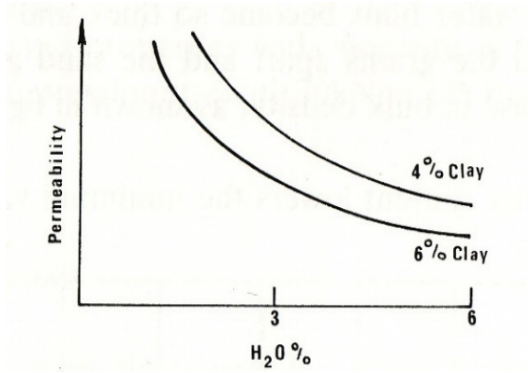

FIGURE 2. Permeability number of sand mixture bonded with 4% clay and 6% clay (Heine et al, 1967)

METHOD

The method of testing is shown in Figure 3. Sand sample for sampling is taken from former tin mine in Tronoh, Perak, Malaysia. It is graded using mechanical sieve shaker into size of below 425 µm. This size is selected due to its medium size foundry sand which is between 250 µm to 500 µm (Salmon & Simons, 1966) and acceptable size for foundry sand according to Brown (2004) where mentioned that generally average grain size of foundry sands is 150 – 400 µm.

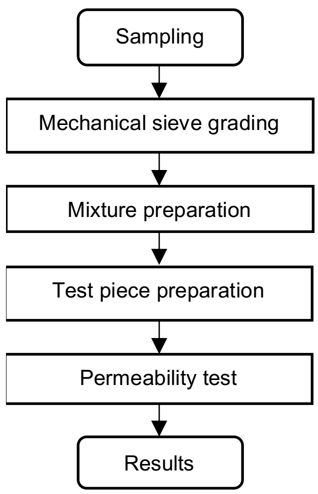

FIGURE 3. Flow prosess of the testing.

Preparation mixture for the effect of water: 1000 grams from sand sample is bonded with 4% of bentonite clay and then water is added starting with 1% of water which is 10 millilitres (ml). Specimen mixture then weighed ranging from 138 grams to 150 grams, depends on the ratio of sand, clay and water for test piece preparation. Cylindrical test piece of Ø50 mm x 50 mm is prepared by compacting three ramming blows of 6666 grams using Ridsdale-Dietert Metric Standard Rammer as shown in Figure 4. Test piece is tested for permeability number using Ridsdale-Dietert permeability meter as shows in Figure 5. The procedures are repeated for sand bonded with 8% bentonite clay.

Preparation mixture for the effect of clay: 1000 grams from sand sample is added with 3% of water which is 30 ml or 30 grams and then bentonite clay is added starting with 1% of bentonite clay which is 10 grams. Specimen mixture then weighed ranging from 138 grams to 150 grams (depends on the sand / clay / water ratio) for test piece preparation. The cylindrical test piece is prepared and test are conducted with similar procedures as mentioned earlier. The procedures are repeated for sand added with 5% water.

FIGURE 4. Ridsdale-Dietert Metric Standard Rammer for test piece preparation

FIGURE 5. Ridsdale-Dietert Permeability meter

RESULTS

Figure 6 shows the result for permeability number for sand when water is incrementally added and bonded with 4% and 8% clay addition. Figure 7 shows the permeability number when sand is added with 3% and 5% water with the increasing of clay content.

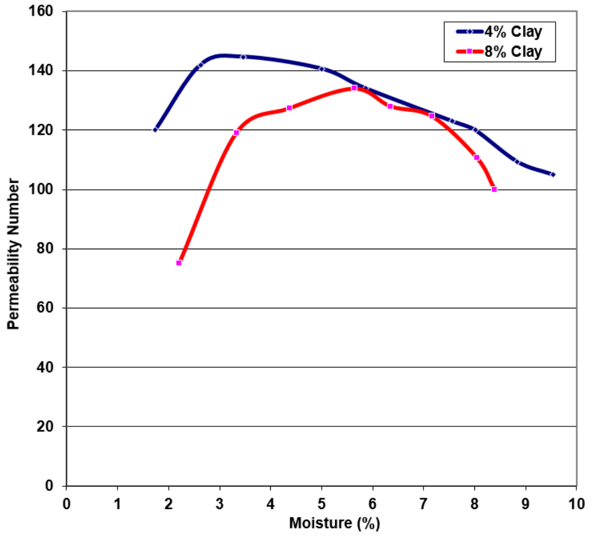

FIGURE 6. Permeability number of mixture bonded with 4% and 8% bentonite clay.

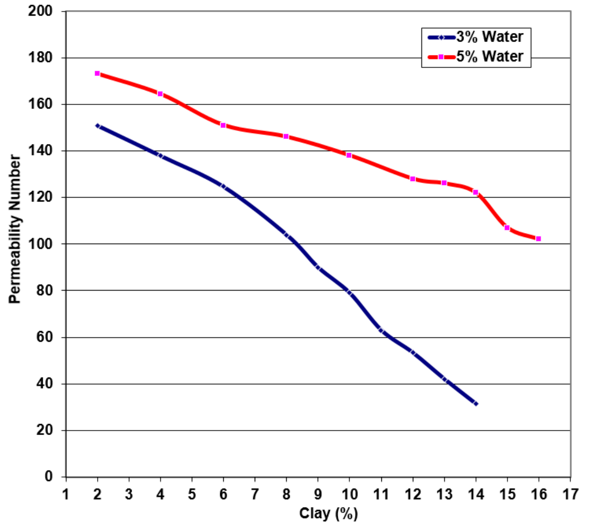

FIGURE 7. Permeability number of mixture added with 3% and 5% water.

DISCUSSION

Figure 6 indicates that with the addition of water gradually from low water content, the permeability is increased. This is because water started to develop water films and activates the bonding power of bentonite clay as mentioned by Jain (2008) and Rao (2009). The thickness of the water films thicken as the water content in the clay grows, causing the clay to become less stiff and the sand grains to be kept farther apart, improving permeability. The maximum permeability is reached at around 6% moisture (sample bonded by 8% clay) and 3% moisture (sample bonded by 4% clay). Mixture with higher clay content requires more water to activate the bonding power of clay. As the water content increases, the permeability decreases because the water films become too thick and the clay becomes too soft to hold the grains apart, causing the sand grains to become closer together and the permeability to drop. Thus, amount of water should be properly controlled (Webster, 1980). Mixture bonded with more clay which is 8% clay means more water are required to develop sufficient permeability So, it needs to absorb more water to achieve maximum permeability number. The graph also shows that a mixture bonded with 4% clay has a higher permeability value than a mixture bonded with 8% clay, where the curve is above the 8% clay curve. This is because a mixture bonded with 4% clay contains fewer small particles (clay), allowing gas to pass through the sand particles more easily and therefore enhancing permeability.

Figure 7 shows that increasing the amount of bentonite clay in the both mixtures (3% water and 5% water additions) will decrease the permeability. This is due to the gaps between sand particles are filled by the finer particles of clay thus gasses are not easy to pass through therefore reduced the permeability. When more clay is added in the both mixtures, the finer of clay will occupy all the available spaces between the sand particles thus the permeability continue to decrease. Mixture bonded with 5% water possess good permeability compared to 3% mixture because of it has excessive water to absorb addition of clay and its water films is appropriate to let gasses pass through. While for mixture with 3% water has less water to be absorbed by clay thus the mixture still dry when clay is continuing to be added. As a result, sand particles become closer together and reduce the permeability.

CONCLUSION

Clay and water, which are used as control additions in this study, are found to be important in determining the permeability of greensand casting moulds. To ensure that sand is suitable for use as moulding aggregates, the amount of water and clay allowed must be determined. Poor permeability can cause defects such as blow holes and pin holes due to gasses produced during the casting process are entrapped inside the mould cavity. Results from this study proved that control additions influenced the permeability of sand from Tronoh and must be controlled for be used a foundry sand.

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DECLARATION OF COMPETING INTEREST

None

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