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The Effect of Sand Grain Size and Water on The Green Compression Strength for Greensand Casting Mould Mixture

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ABSTRACT

The focus of this research is to investigate the effect of water content and sand grain size on the green compression strength of a greensand casting mould mixture. Grain size is a major determinant of mould and core green compression strength and surface finish of the greensand casting product. Water influences the efficiency of binder which is bentonite clay in bonding the sand grain particles thus improving the green compression strength. The objective of this study is to study the effect of grain size and water on the green compression strength. The specimen is prepared by mechanical size grading and graded into three sizes which are 425 µm, 300 µm and 150 µm. Experiments are carried out in accordance with American Foundrymen Society (AFS) guidelines. Three ramming blows of 6666 grammes with a Ridsdale-Dietert metric standard rammer compact cylindrical test pieces with dimensions of Ø50 mm×50 mm in height made from varied sand grain size–water ratios bound with 5% bentonite. The test pieces are tested for green compression strength with Ridsdale-Dietert Universal Sand Strength Machine. The sand grain size of 150 µm is found to have superiority in green compression strength compared to two other sizes, and 3% water content gives the maximum green compression strength for all three sand samples sizes.

Keywords: Sand casting, green compression strength, greensand casting mould.

INTRODUCTION

Sand casting is one of the most effective metal forming processes, and it is widely used for complex ferrous and nonferrous metal casting. The process incorporates greensand, dry sand and chemically bonded sand. According to Siddique et al. (2009), generally, 90% of casting products came from greensand casting and Paluszkiewicz et al. (2008) mentioned that greensand casting produces about 70% of ferrous castings. Rao (2009) stated that in a greensand casting mould, the main ingredients are sand such as silica and zircon, a binder such as bentonite clay where with the addition of water, activate the clay and provide plasticity and strength. The major constituents of the greensand casting mould, according to Siddique et al. (2009), are silica sand (85-95% SiO_2) combined with bentonite clay (4-10%) and water (2-5%).

Identification of the size of the sand grain is crucial to determine the usage of sand as a moulding medium for making the greensand casting moulds. Mould and core green compression strength, surface finish, and casting quality are all influenced by grain size. Greensand and shell moulding demand finer sands for a good finish, but coarser sands are utilised in instances where higher gas permeability is necessary to eliminate casting defects such as blowholes and pinholes. The finer the sand grain the better the green compression strength compared to coarser sand grain. This is due to the greater inter-particle friction. Greater inter-particle friction creates a larger repose angle where finer particles have a larger repose angle than coarse particles. The angle of repose, as shown in Figure 1, is the angle generated by a pile of sands as they are poured from a narrow funnel, and it shows inter-particle friction. Greater inter-particle friction between particles is indicated by larger angles. Friction and angles are often stronger with smaller particle sizes. According to Edoziuno et al. (2017), the quality of casting products depends on the grain size distribution and the grain size of the sand. Metal might penetrate the mould due to the distribution of coarse-grained sands, resulting in a poor surface finish on the castings.

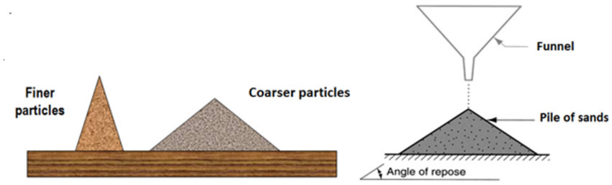

FIGURE 1. Relationship between particles size, friction and angle of repose (Groover, 2020)

Figure 2 shows the influence of the fineness of sand particles on the green strength where the figure indicates that finer sand gives greater green strength due to the greater surface friction that they have.

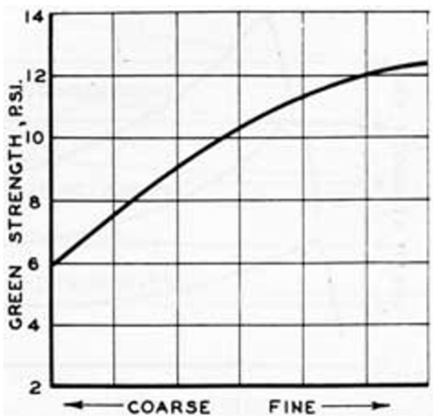

FIGURE 2. Green strength as affected by the fineness of sand (Foundry Manual, 1958)

The effect of the sand grain size of the sample on the green compression strength is studied by conducting mechanical sieve grading. According to Brown (2004), since the acceptance of ISO metric sieves as a standard, grain size is now stated in micrometres (μm). Sand as foundry sands has a grain size distribution of 150-400 μm, with 220-250 μm being the most commonly utilised. In the United Kingdom, the majority of sand castings are in the range of 150-300 μm, with ferrous castings in the range of 210-300 μm and non-ferrous work in the range of 170-270 μm.

Water is a control addition besides clay that influences the mechanical properties of the greensand casting mould. The bonding action of clay only occurred with the existence of the necessary amount of water. Jain (2008) said the thickness of water films influences the bonding quality of clay. Rao (2009) explained that water activates the clay, causing it to produce the requisite plasticity and strength, hence the amount of water used should be carefully monitored. This is due to the fact that a certain amount of water absorbed by the clay aids in bonding and boosting strength, but too much water reduces strength. Webster (1980) explained the addition of water will increase the strength because water activates the bonding power of clay, but excessive water will deteriorate the bonding power, thus reducing the strength of mould.

Parkes (1971) stated that the American Foundry Association began first published the systematic methods for foundry sand testing to identify the mechanical properties which are moisture content, permeability, strength and 'fineness' in 1924. They published the American Foundry Society (AFS) Foundry Sand Handbook to describe the details of the test, testing procedures and equipment used, which have been accepted as a standard for foundry sand testing. According to Parkes (1971), the green compression strength of a greensand mould is the maximum compressive strength a moulded mixture is capable to sustain the shape, and always measured in compression for routine reasons. Olasupo and Omotoyinbo (2009) stated the common practical value of green compression strength is 20-80 kN/m² while Loto (1990) stated it as 30 to 150 kN/m2. According to Ademoh (2008), the green compression strength of Niger River sand with the addition of 3% bentonite clay is 28 kN/m² while Andrew (1989) stated that Ottawa silica has green compression strength ranging 59-69 kN/m² at the moisture of 3.3% added with 6.5% clay. Research conducted by Abdullah et al. (2012) on tailing sand from former tin mine tailing sand in Perak, Malaysia found that the effective green compression strength is at moisture content ranging from 3 to 3.5%. Ameda & Jimoh (2009) found the relationship between water content and green compression strength from sand from Ilorin and Ilesha, Nigeria as shown in Figure 3 where the green compression strength intensity increases with the increase of the percentage of water added but when the water is excessive, the strength starts to decrease.

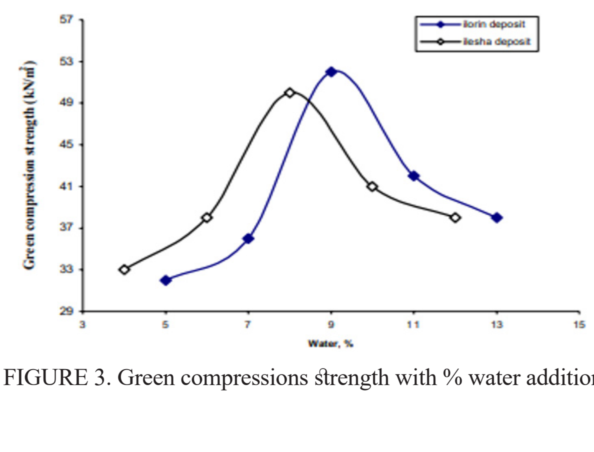

FIGURE 3. Green compressions strength with % water addition

METHOD

Figure 4 shows the flow process of the testing. In the beginning, the sand sample for this study is tin mine tailing sand, collected from a former tin mine in Batu Gajah, Perak, Malaysia.

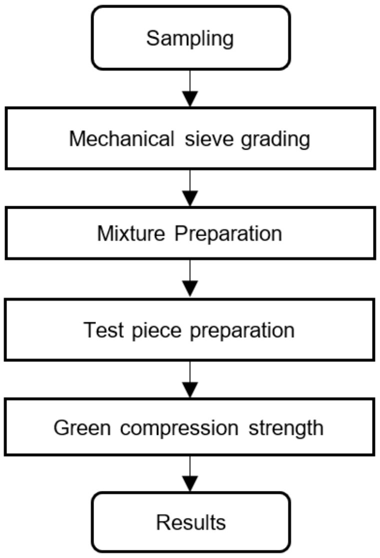

FIGURE 4. Flow process of the testing

It's graded using a mechanical sieve shaker machine as shown in Figure 5 into three specimen sizes which are 150 µm, 300 µm and 425 µm. These sizes are selected based on standard sieve size for grain size distribution and within the required size which is 150 – 400 µm (Brown, 2004).

FIGURE 5. Mechanical sieve shaker machine

The mixture is prepared by mixing 1000 grams from each specimen size with 5% of bentonite clay which is 50 grams, and then water is added starting with 1% of water which is 10 millilitres (ml) or 10 grams. The specimen mixture was then weighed for test piece preparation, ranging from 138 grams to 150 grams depending on the sand/clay/water ratio. As shown in Figure 6, a test piece of Ø50 mm × 50 mm is made by compacting three ramming strokes of 6666 grams with the Ridsdale-Dietert Metric Standard Rammer.

FIGURE 6. Ridsdale-Dietert Metric Standard Rammer with strip block

The test piece was then properly stripped with a strip block before being tested for green compression strength using the Ridsdale-Dietert Universal Sand Strength Machine, as shown in Figure 7, three times to obtain the average value. The test is repeated by adding 1% more water until the mixture reached 6% water in order to ensure the flow process of the mechanical sieve grading is completed with the permeability test. The result shows at 3.0 green compression strength for sand grain size and the water effect when addition.

FIGURE 7. Ridsdale-Dietert Universal Sand Strength Machine

RESULTS

Figures 8-10 show the result for green compression strength when water is added to the sand bonded with 5% bentonite clay.

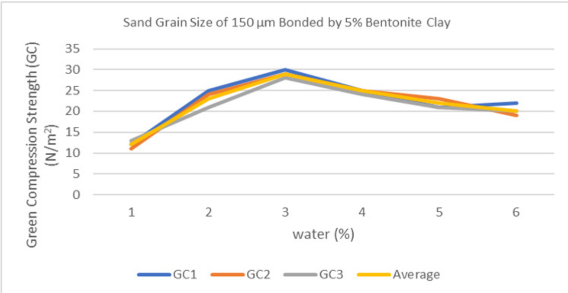

FIGURE 8. Green Compression Strength for Sand Grain Size of 150 µm Bonded by 5% Bentonite Clay with the Addition of Water Content

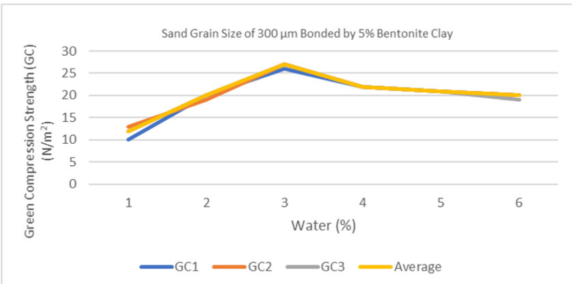

FIGURE 9. Green Compression Strength for Sand Grain Size of 300 µm Bonded by 5% Bentonite Clay with the Addition of Water Content

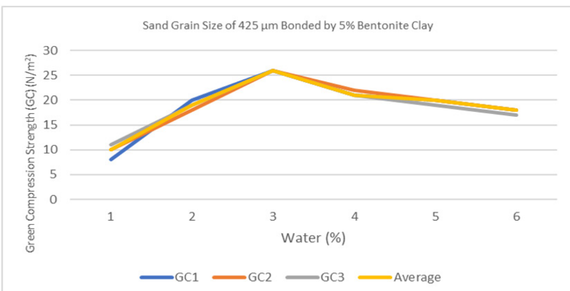

FIGURE 10. Green Compression Strength for Sand Grain Size of 425 µm Bonded by 5% Bentonite Clay with the Addition of Water Content

Figure 11 shows the effect of the addition of the water content on the green compression strength for sand grain sizes of 150 µm, 300 µm and 425 µm bonded with 5% bentonite clay.

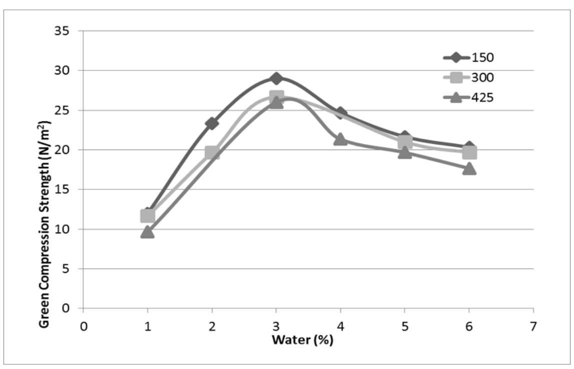

FIGURE 11. The Effect of the Water Addition on the Green Compression Strength for Sand Grain Size of 150 µm, 300 µm and 425 µm bonded by 5% Bentonite Clay

DISCUSSION

Figures 8-10 show the green compression strength of three different sand sizes. At low water content, the green compression strength of all samples is low, owing to the fact that the sand-clay mixture is too dry, and water is insufficient to activate the binder, bentonite clay. Therefore, the binder is unable to hold the grains together thus fails to develop adequate strength and greensand casting mould is difficult to fabricate. When the percentage of water content is increased, water is enough significantly to activate the binder thus improving the bonding power and the green compression strength starts to increase. The maximum green compression strength for all samples is discovered at 3% water where at this water content, clays can hold the grains sufficiently to form a greensand casting mould. Beyond 3% water, the green compression strength for all samples starts to decrease. The decreasing of green compression strength is due to the excessive water content in the mixture where the mixture becomes too wet and deteriorate the bonding power of bentonite clay thus difficult to form a greensand casting mould. Inglethorpe et al. (1993) explained that if the clay were forced to hold an excessive amount of water, the mould would be soft and weak thus becoming unmouldable. Figure 11 shows how water affects the green compression strength of samples of various sizes. The results show that grain sizes of 150 µm have a larger green compression strength than the other two samples, whose curves are at the top. The reason is that finer grain size generally has greater inter-particles friction compared to the coarser grain thus the bonding power between finer particles is higher. These results indicate that sizes of 150 µm and 300 µm are suitable for making greensand casting mould due to the size which is within the recommended size according to Brown (2004) which is 150 – 400 µm. The size of 150 µm has the highest green compression strength and was found to be the most suitable due to its size in reducing metal penetration. In terms of water content, all sand samples sizes have similar water content for maximum green compression strength which is at 3% and suited with the requirement as mentioned by Siddique et al. (2009), which is 2-5% water. The maximum green compression strength for all three samples sizes is found within the recommended range according to Olasupo & Omotoyinbo (2009), which is 20-80 kN/m².

CONCLUSION

This research discovered that sand grain size affected the green compression strength of greensand casting mould mixture. The coarser the grain size, the lower the green compression strength, where the grain size of 425 μm has the lowest green compression strength and the finest size, which is 150 μm, has the greatest green compression strength among the three sizes. Due to their sizes, sample sizes of 150 μm and 300 μm are found to be suitable as medium sand for making greensand casting moulds. Water has a significant impact on the moulding mixture's green compression strength. The results demonstrate that with moisture content within the acceptable range of 20-80 kN/m2 and 2-5 % water content, all sand sample sizes have the maximum green compression strength. The optimum allowable water (moisture) content for optimum mechanical properties of the sand to produce greensand casting mould only can be determined by investigating another mechanical property which is in permeability number and thus, suggested to be conducted in future.

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DECLARATION OF COMPETING INTEREST

None.

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