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Investigation of the addition of Resin Coated Sand (RCS) waste as a greend sand Substitution on the Characteristics of Sand Moulding

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Abstract
The current era of industrialization has become a severe problem regarding the handling of waste, which causes a threat to the environment. From a benefits standpoint, all waste can be processed and utilized to provide value and economic benefits. RCS moulds in the foundry industry cannot be used repeatedly, so their use is limited and tends to produce waste that cannot be reused as moulds, thus potentially polluting the environment. This type of sand used as moulding sand with a binder has been widely studied, with research results affecting the permeability and strength values against compressive-shear loads. This research aims to determine the effect of adding RCS to greensand sand on the characteristics of moulding sand. Variations in the use of RCS in this study were 0%, 20% and 20% in the greensand mixture, with five test objects for each variation. In this study, three tests were carried out: Permeability, shear testing and compression testing. The results of this study indicate that the more addition of RCS, the lower the permeability value. Whereas the results of the compression and shear tests have the same tendency, with the results of adding RCS up to 20%, it will increase compared to without adding RCS and then with an addition of 40%, it will decrease.

Keywords: Resin coated sand, greensand, zero-waste manufacturing, foundry

Introduction
The current era of industrialization has become a severe problem regarding the handling of waste from the manufacture of a product, so that waste treatment must be carried out from the beginning of manufacture to the end until it becomes a product so that it does not pose a threat to the environment or pollution. However, on the other hand, treating waste is quite expensive, so this will be a problem for small industry players. When viewed from the benefit side, all waste can be processed and utilized to provide value and economic benefits for industry players and those who can use the waste. Utilization of waste from the beginning to the end of the product manufacturing process to minimize the amount of waste is a process known as industrial zero-waste manufacturing [1].

One type of sand used is RCS (Resin Coated Sand), which consists of silica sand bound with resol or novolac resins, as shown in Figure 1. Metal casting using RCS sand moulds is capable of producing a smoother cast surface than cast sand [2]. However, The use of RCS sand moulds cannot be used repeatedly, so their use is limited and tends to produce waste that cannot be reused as moulds, as shown in Figure 2, thus potentially polluting the environment.This type of sand used as moulding sand with this type of binder has been widely studied, with research results affecting the strength of the moulding sand itself and the quality of the cast results. The strength of the sand is affected by the composition of the sand with the binder [3], the water content in the mould [4], and the fastener type [5].

In terms of the quality of the cast results, the differences in moulding sand are based on the type [6], will affect the characteristics of the sand mold which includes the strength of the sand, the conductivity of the sand, and the ability to flow molten metal or permeability [4]. Furthermore, the conductivity of the sand will directly affect the cooling rate of the molten metal after the pouring process, this cooling rate will affect the shape of the microstructure and the mechanical properties of the cast object [7].

While the permeability of sand is affected by the size and shape of the molding sand used, this will affect the air movement in the mold during the pouring process. It will also affect the formation of air cavity defects in the castings [8].

Fig 1: Moulding from resin coated sand

Fig 2: Mould waste from resin coated sand

One type of moulding sand often used today is greensand, with a high permeability value, easy to cast and can be used any time [9]. In its use as a mold, greensand sand is combine with a binder to compact the mold, the material as a binder for greensand sand can use bentonite or water glass [5]. A binder is required when using sand as a metal mould, while moisture content required for the binding between sand and binder. Wijayanto and Sunyoto, (2019) [10] investigated the effect of bentonite binder composition on the hardness of cast specimens. The bentonite composition is a percentage of the sand casting used, namely 0%, 8%, and 16%, with silicon Aluminium as the metal to be cast. The results of this research show that the hardness value of the 8% bentonite composition yielded the highest value of 84.26 VHN, followed by the 16% and 0% bentonite composition with 78.17 VHN and 72.53%, respectively. Aji, (2018) [4] examined the level of water content that affects the results of metal casting. This research found that at a moisture content of 4% and 10%, there were product defects in the form of shrinkage defects and fallout defects, whereas at a moisture content of 7%, no shrinkage defects or fallout defects were found. In addition to the type of sand used, the mechanical properties of the mould are affected by the grain size of the sand Prihadianto dkk., (2021) [11] conducted research on the effect of grain size on the mechanical properties of moulds with variations without large sieving, grain size < 300 µm, and grain size ≥ 300 µm. This research showed that grain size < 300 µm had a compressive strength value and greater shear strength than without a sieve and grain size ≥ 300.

The purpose of this study was to determine the effect of adding 0%, 20%, 40%, and 60% RCS sand to greensand moulding on the characteristics of the moulding sand. This research is directly beneficial for reducing RCS sand moulding waste, increasing the economic value of RCS sand moulding waste, and reducing production costs for moulding sand preparation. In addition, this research also contributes to supporting the government in implementing the concept of zero waste manufacturing industry on large, medium and small scales.

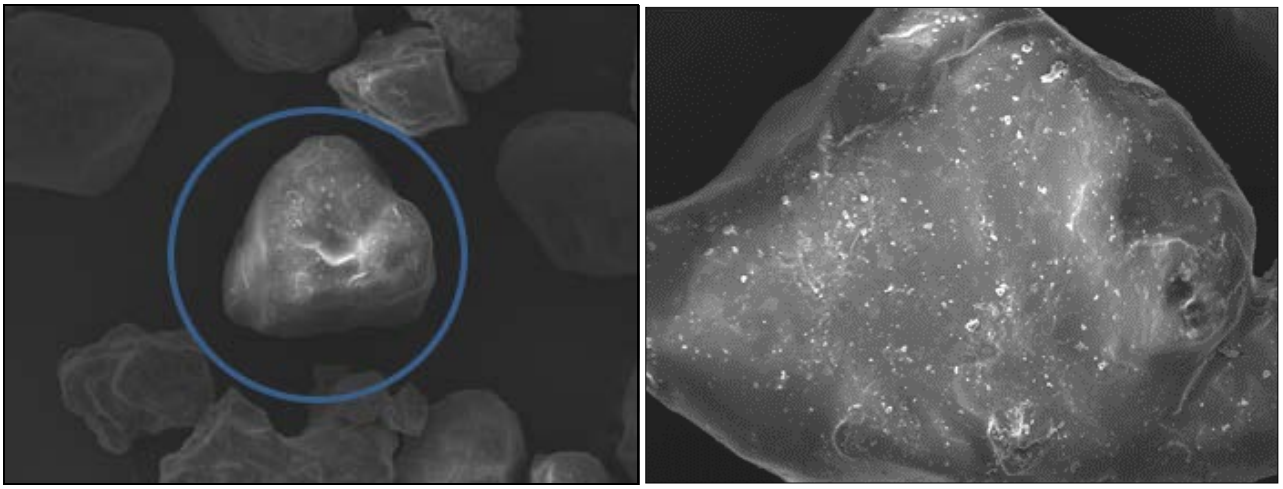
Materials and Methods

This research was conducted to obtain the composition of RCS sand moulding waste with 0%, 20%, and 40 for grend sand to the characteristic of the sand moulding.

The morphological shape of the RCS from Scanning Electron Microscopy (SEM) observations in Figure 3a with a magnification marked with a circle of 1000 times in Figure 3b. The results of scanning using EDS on RCS are shown in Figure 4, the element C, which is the primary element that makes up resin (polymer), reaches 54.09%, as well as the elements Si and O, which make up SiO2, with 13.07% and 32.84%, respectively. Meanwhile, the morphology of silica sand based on the results of Banganayi *et al.*, (2017) [14] is shown in Figure 5, with the dominance of SiO_2 compounds reaching 95.98% using X-ray Fluorescence (XRF) analysis.

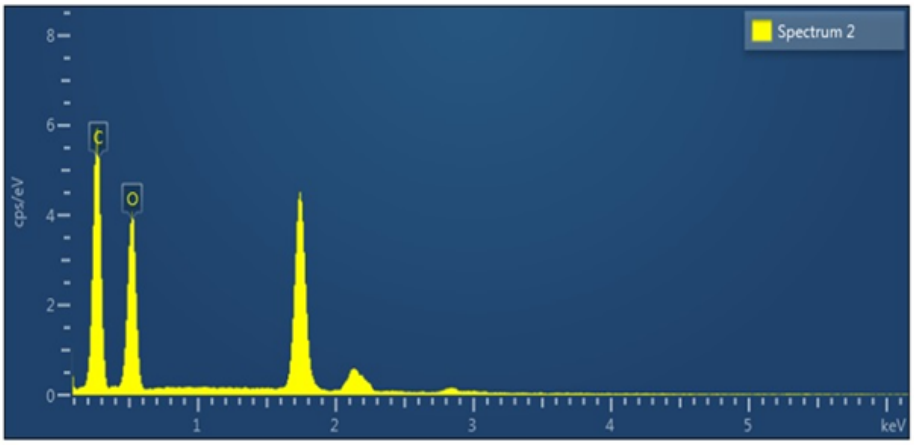
The bentonite composition used in this research refers to the study of Wijayanto and Sunyoto (2019) [10], with a percentage of 8% of the total weight of moulding sand, the water content used by Aji (2018) [4] with a ratio of 7% of the total weight of sand casting, and the grain size of sand used by Saputra *et al.*, (2018) with a size that passes through mesh 80 which is retained by mesh 100. After making the sand composition according to the variation is ready, make a sand mould specimen and test the sand mould's characteristics. Variations in the composition of the RCS 0%, 20% and 20% in the mixture of greensand sand moulding, with five specimens in each variation.

In this research, three testing were carried out, namely sand moulding testing, which included permeability testing which referred to research by Dwi Hartono, (2012) [13], shear testing and compression testing with procedures referring to the study of Prihadianto *et al.* (2021) [11]. The specimen made and formed by sand rammer with the dimensions of the specimen shown in Figure 3.



A B

Fig 3: Scanning Electron Microscopy of RCS (a) 50 times magnification (b) 11000 times magnification



Spectrum 2				
Element	Line Type	Weight %	Weight % Sigma	Atomic %
C	K series	54.09	0.35	64.14
O	K series	32.84	0.33	29.23
Si	K series	13.07	0.14	6.63
Total		100.00		100.00

Fig 4: EDS observation results

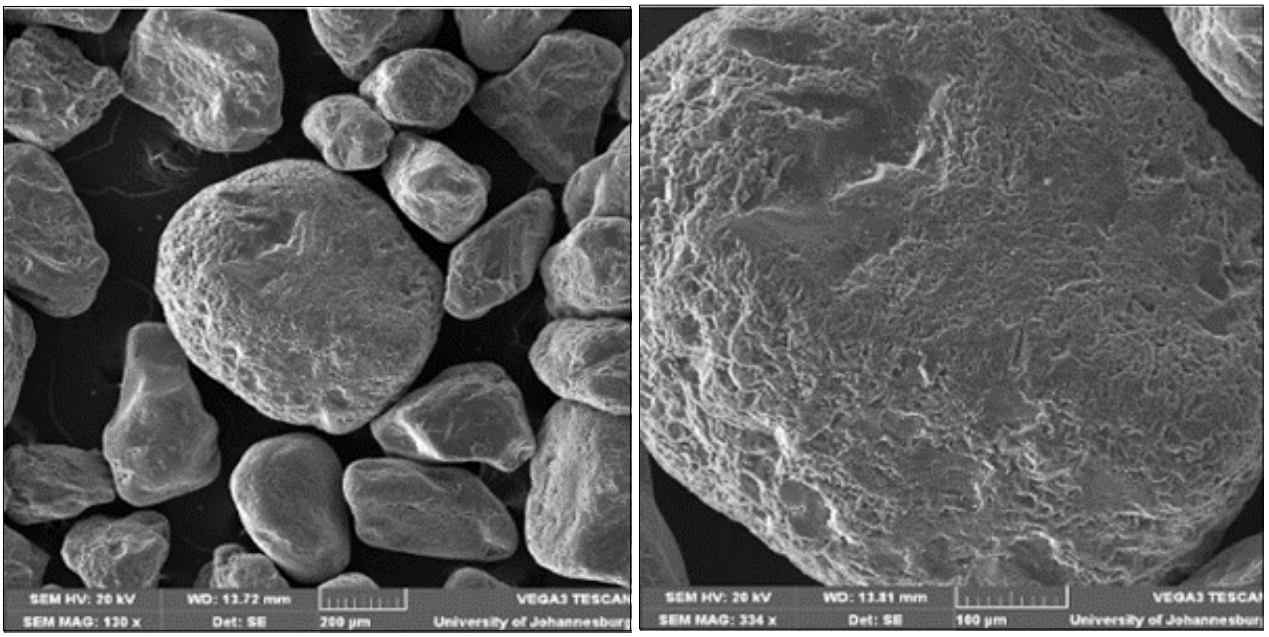


Fig 5: Scanning Electron Microscopy of silica sand for 130 times magnification [13]

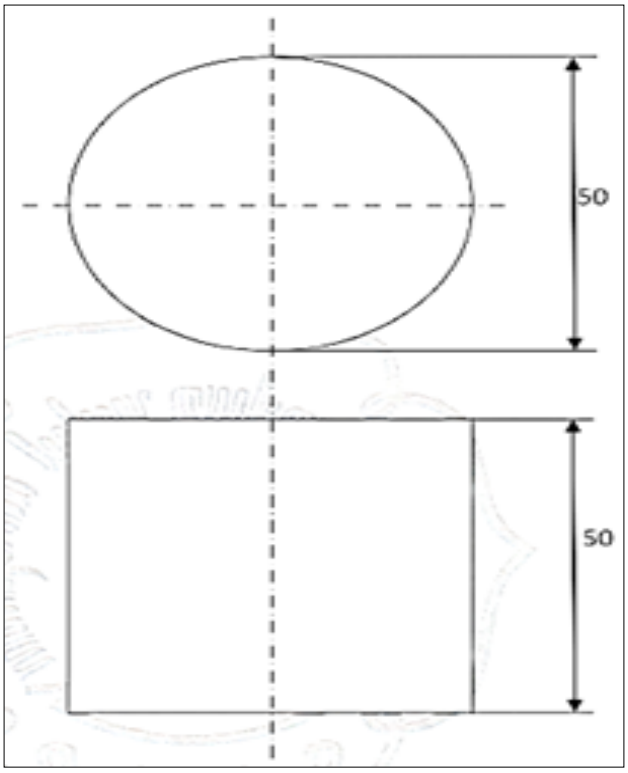


Fig 6: Sand mould testing specimen dimensions [11]

Result and Discussion

The results show a graph of the effect of the RCS composition on the moulding sand's characteristics, including density, permeability, compressive stress and shear stress. Figure 7 shows the composition of RCS as a substitute for greensand in the moulding sand foundry, which directly affects the permeability value, increasing the RCS composition, the permeability value will decrease with the respective values at composition 0%, 20%, and 40%, respectively 216.4 mm 3 min, 110 mm3/min, and 53.4 mm3/min. Silica sand in greensand foundry, which has an uneven surface on the grain surface (Figure 5) which functions as pores, whereas in RCS, it is sand whose grains are coated by resin or polymer (EDS results in Figure 4), This layer will cover the pores of the silica sand grains (Figure 5) so that the more closed pores will reduce the gas flow ability while pouring molten metal into the mould [14]. In addition, Figure 7 also shows the use of RCS as a substitute material for greensand moulding sand with compositions of 0%, 20% and 40%, which have density values that tend to be the same in the range of 150 grams/cm3, This trend with the same value is because RCS is sand with the primary element silica oxide coated with resin, as shown by the results of the EDS composition in Figure 4. At the same time, the composition of greensand sand is also dominated by silica oxide. Banganayi *et al.*, (2017) [14].

While the value of the strength of the sand mould to resistance to the flow of molten metal when poured is indicated by the characteristics of resistance to compressive stress and shear stress, as shown in Figure 8. In general, the RCS composition values have the same trend in the maximum compressive stress and shear stress that the mould can be resistant.

The addition of 20% RCS to moulding sand will increase the value of resistance to compressive stress and shear stress compared to without the addition of RCS, but this resistance value will decrease with the addition of 40% RCS. The increase in stress resistance in the mould without RCS and 20% RSC is because the RCS grains are generally finer than silica sand grains, so the number of bonds between grains at the addition of 20% RCS will be more than without RCS. However, at the addition of 40% RSC, the value of resistance to compressive stress and shear stress will decrease, this is due to the more RCS composition, and the more sand grains will also be, while the amount of bentonite as a binder is the same, so the number of gaps between grains that can be bound by bentonite will decrease.

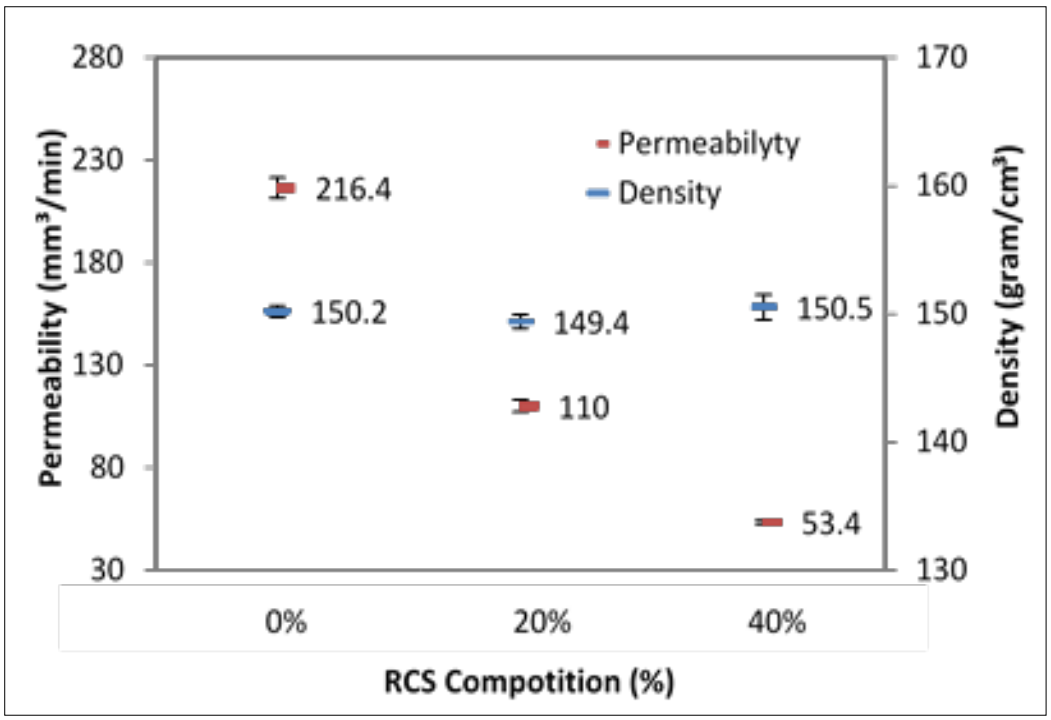


Fig 7: RCS composition on permeability and density

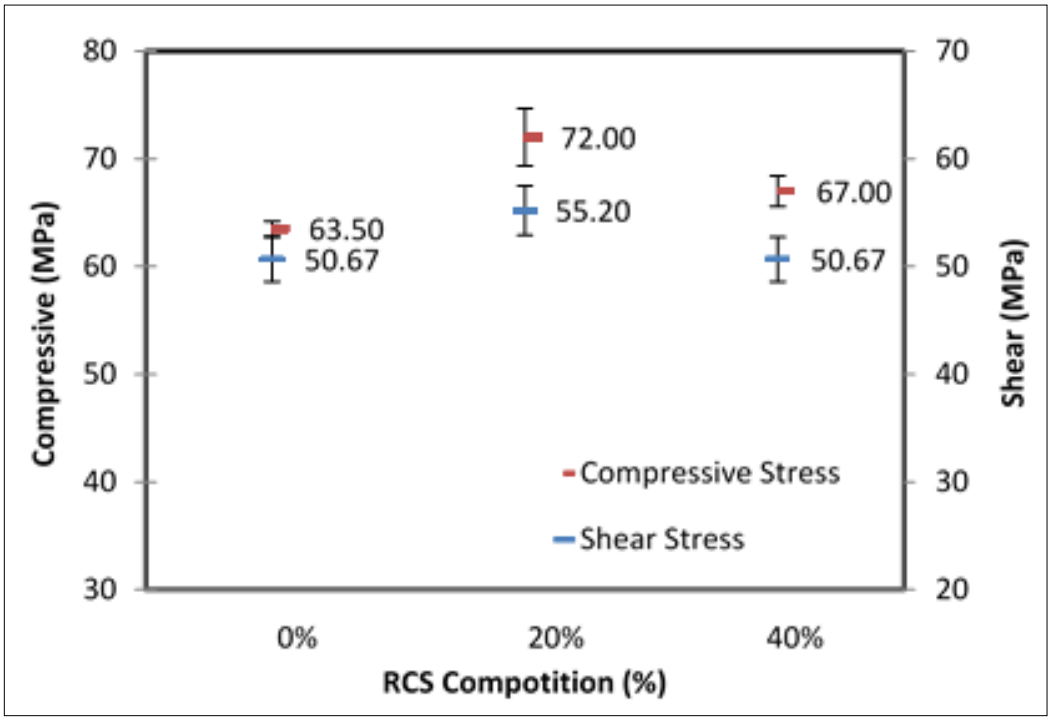


Fig 8: Composition of RCS on compressive stress and shear stress

Figure 9 shows the morphology of the bonding of moulding sand at a composition of 40% RCS and 60% greensand using SEM at 50 times magnification. The figure shows that the smaller RCS covers the pores of the silica sand, filling the gaps between the larger silica sand sizes that are bond by bentonite. So that the more RCS composition in the moulding sand, the narrower the pores and gaps between the sand grains. While Figure 10 shows the morphology of bonding between RSC grain and silica grain by bentonite at 500 times magnification, this shows that the use of 40% RCS bonds between grains using bentonite will tend to close the gap further. Narrowing and tend to close this gap causes the gas flow ability or permeability characteristic to decrease, as shown in Figure 7.

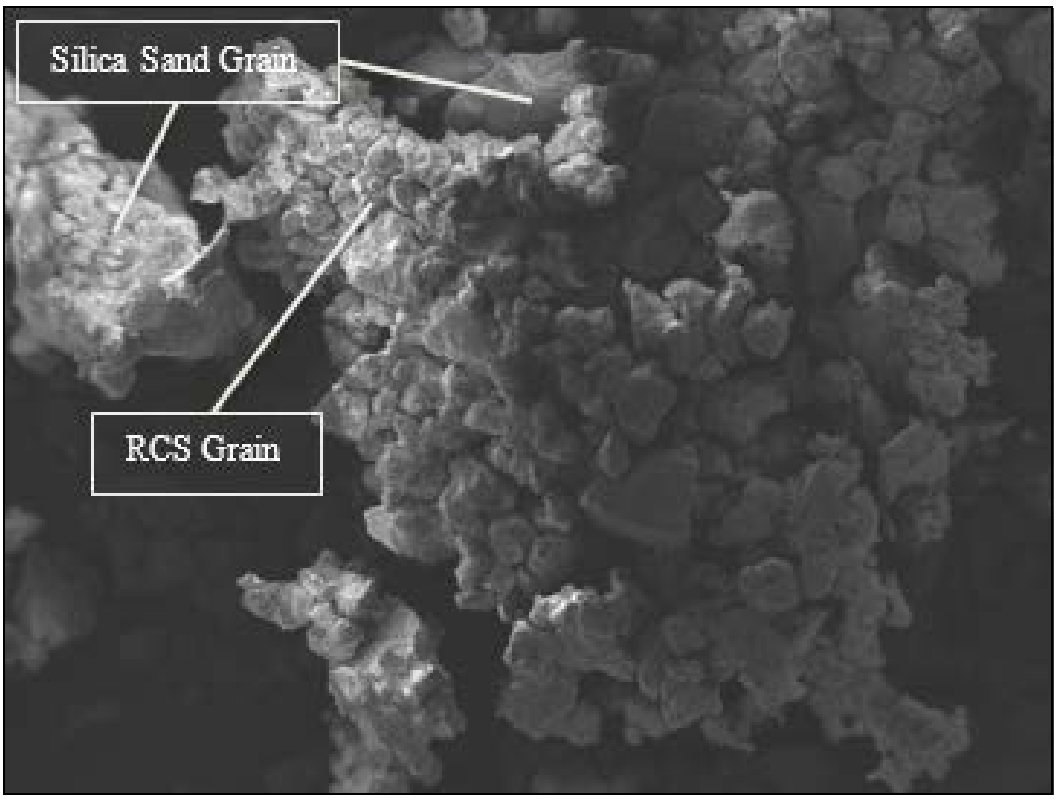


Fig 9: Scanning Electron Microscopy of 40% RCS-Greensand moulding for 50 times magnification

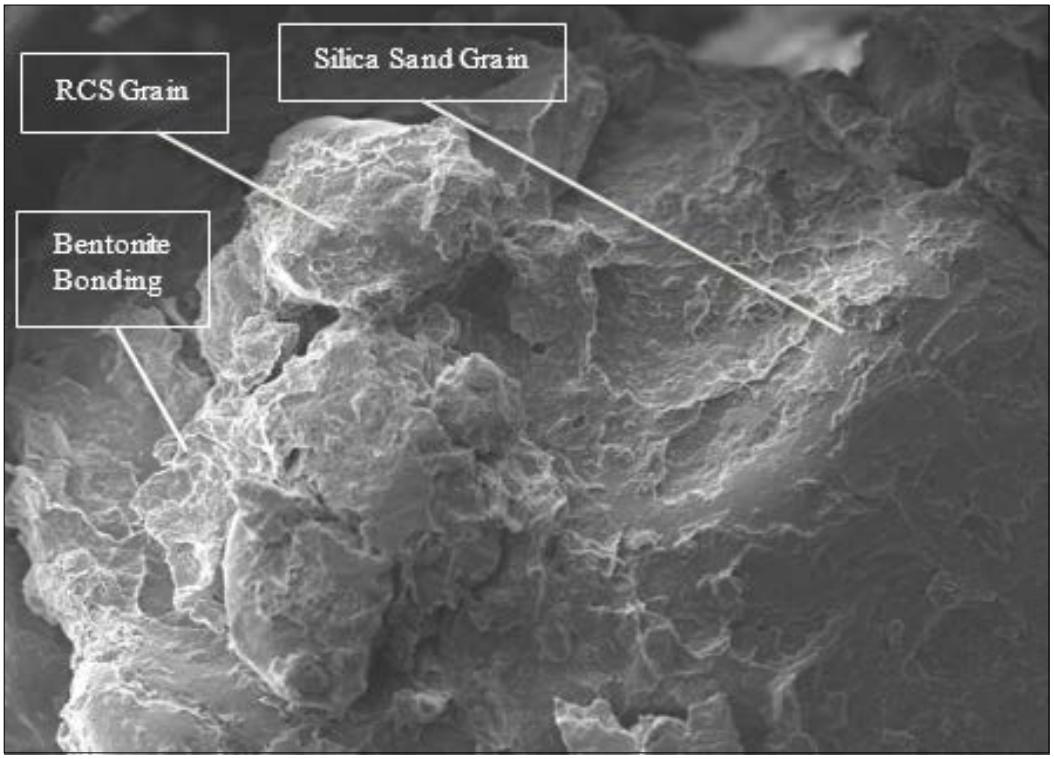


Fig 10: Scanning Electron Microscopy of 40% RCS-Greensand moulding for 500 times magnification

Conclusion

The results of this study indicate that, in general, RSC waste can be used as a substitute for greensand sand in sand moulds. In the permeability test results, the more RCS the addition will reduce the gas flow ability so that the permeability value will decrease. Whereas the compressive and shear resistance tests have the same trend, with the result that adding RCS up to 20% will increase the value of compressive and shear resistance compared to without the addition of RCS, then with the addition of 40%, it will decrease.

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