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The Effects of Windscreen Glass Waste (WGW) as Sand Replacement on The Compressive Strength of Mortar

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Abstract: Nowadays, most of developing country having serious problems facing shortage of post consumers disposal waste site. Due to this problem, it has been suggested to regenerating and using waste glass product as ways of replacing sand as construction materials and prevents the environmental pollutions. Therefore, this paper is conducted to investigate the properties of the mortar, which contain windscreen glass waste as an admixture. During the research, 60 specimens of mortar were prepared by using different proportions of windscreen glass waste, which are 10%, 20% and 30%. The entire specimen was designed with w/c ratio of 0.5 and partial replaced the sand with windscreen glass waste. This research focuses on the compressive strength of the mortar. The specimen was cast in cube mould with the dimension of 50mm x 50mm x 50mm. Then, the specimen was tested for 7, 14 and 28 days of curing. The result of compressive strength test for the specimens which contain windscreen glass waste partial replacement of sand has compared with the control sample. Based on the results obtained the windscreen glass waste in preparing the mortar improved the strength of the mortar with partial replacement of 30% of windscreen glass waste.

Keywords: Sand replacement, compressive strength, windscreen glass waste, mortar

1. Introduction

According to Bentchikou et al (2017), it was estimated that various tons of waste glasses are produced annually worldwide due to the rapid growth of population, increasing in the standard of living, industrialization and urbanization. Hence, the utilization of waste glasses has become a serious issue worldwide. The main sources of waste glasses are window glasses, windscreen glasses, glass container, tube lights, bulbs, and other things.

In fact, the glass can be considered as a pozzolanic - cementitious material according to the chemical requirement in ASTM C 618, (2012). The alkali content of glass is a typical concern for its use in mortar. According to Harrison et al (2020) the lower glass of powders showed very good with a pozzolanic reactivity and can be used as a cement replacement and the pozzolanic activity will increased if the fineness increased.

Du & Tan (2013) conducted a study as the used of waste glass in replacing sand and reported that there is a potential of windscreen waste glass powder to be used as a Supplementary Cementitious Material (SCM) in the cement matrix. Jani & Hogland (2014) studied the effect of the particle size of the waste glass on the properties of the produced cement. Reducing the particle sizes of the waste glass increases the pozzolanic properties and leads to producing a cementitious.

The major problems for municipalities everywhere are come from recycling, disposal and decomposing of waste glass possesses. This problem can be greatly removed by reusing waste glass as a sand replacement in mortars. According to Hongjian Du (2014) due to limitation of the availability of aggregate and minerals used for making cement, it is required to reduce energy consumption and emission of carbon dioxide (CO_2) effect from construction processes.

The glass also is a unique inert material that could be recycled many times without changing its chemical properties. In Malaysia, due to high number of accident on roads, therefore the collection of windscreen of the car can be collected for recycling or reuse as the partial replacement of cement. The windscreen will be crushed into a fine powder of finesses passing 90μm. Recently, many studies have focused on the use of waste glasses as partial replacement of natural aggregate in concrete. The combined usage of waste glass with industry product can be more suitable instead of using it alone in mortar (Liu et al., 2016).

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This study focuses on the effects of using glass as fine aggregate in mortar on the strength of the mortar, due to the high mechanical strength. It is believed that mortar composed of glass will be a practical solution for construction while offering a solution to recycling of waste glass.

2. Research Method

The automotive windscreen glass was obtained from nearby workshops in Terengganu, Malaysia. The Los Angeles machine was used to grind windscreen glass up to 5000 revolutions using 30 steel rod to produce the automotive windscreen glass waste (WGW). Figure 1 shows the flow of the preparation of WGW.

Automotive windscreen glass waste

Grinding at 5,000 revolution

Windscreen Glass Waste

Figure 1. Preparation of automotive windscreen glass waste (WGW)

The study was carried out by 60 sample of mortar cube specimens with dimensions of 50mm x 50mm x50mm. The mortar mix proportion cement to sand (C:S) of 1:3 with water to cement (w/c) ratio 0.5. Three mix proportion were adopted comprising various percentages of WGW (10%, 20% and 30%) by weight of sand. The mortar cube specimens were water cured until the day of the compressive testing at 7, 14 and 28 days.

The compressive strength was conducted in accordance to ASTM C:109 American Society for Testing And Materials.,(2013) at the Concrete Laboratory of Civil Engineering Faculty, UiTM Shah Alam. The strength was assessed using cube specimens of dimensions 50mm x 50mm x 50mm taken at 7, 14, and 28 days. Five replicates were used for each batch.

3. Results And Discussion

The result for compressive strength of mortar cube made of windscreen glass waste powder has been collected. Compressive strength test results were recorded for 7 days, 14 days and 28 days. The results for the compressive strength showed that there are increased of strength replacement with 10% of WGW until 30% of WGW. Figure 2 shows the result of compressive strength in 7 days, where 30% WGP showed the highest strength than other replacement. The results showed that increased in the percentage of replacement resulted in increased in the compressive strength and prolong of the curing time resulted in increased in strength. These results can be seen as drawn in figure 2, figure 3 and figure 4 for 7, 14 and 28 days respectively.

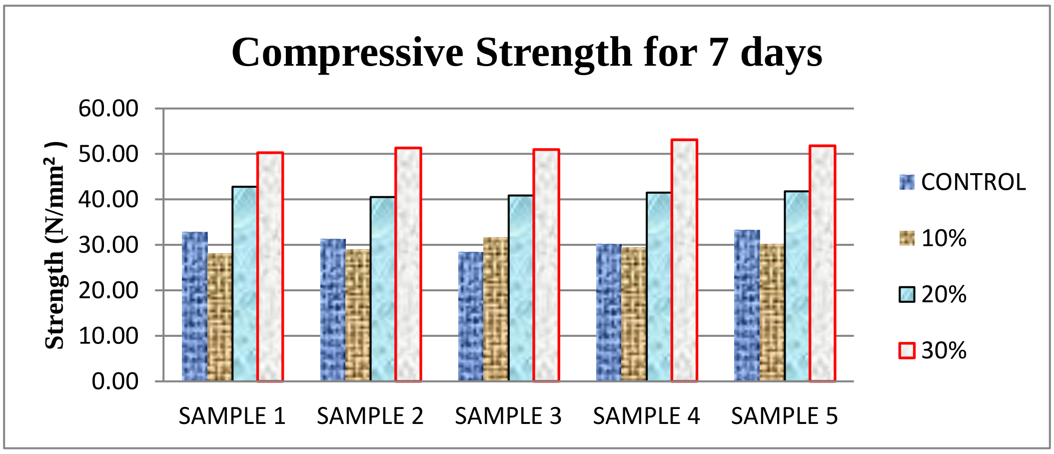

Figure 2. Compressive Strength for 7 days

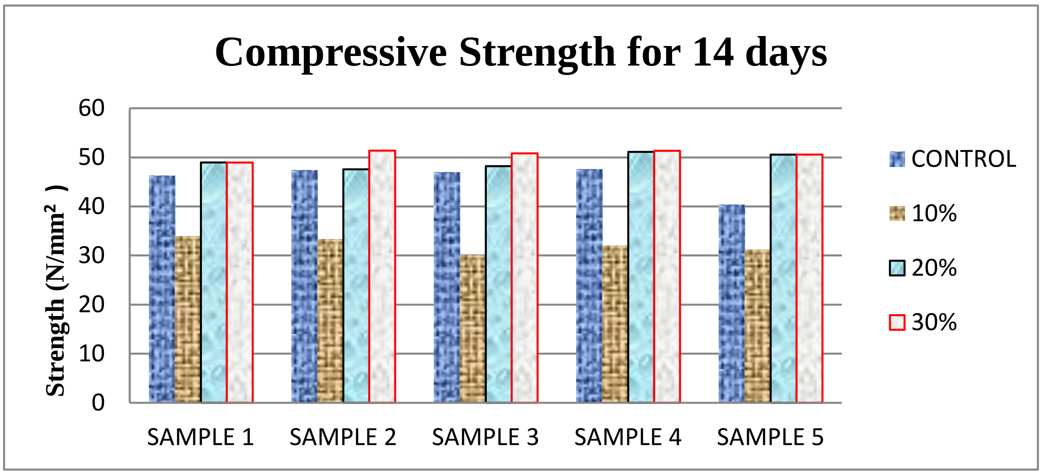

Figure 3. Compressive Strength for 14 days

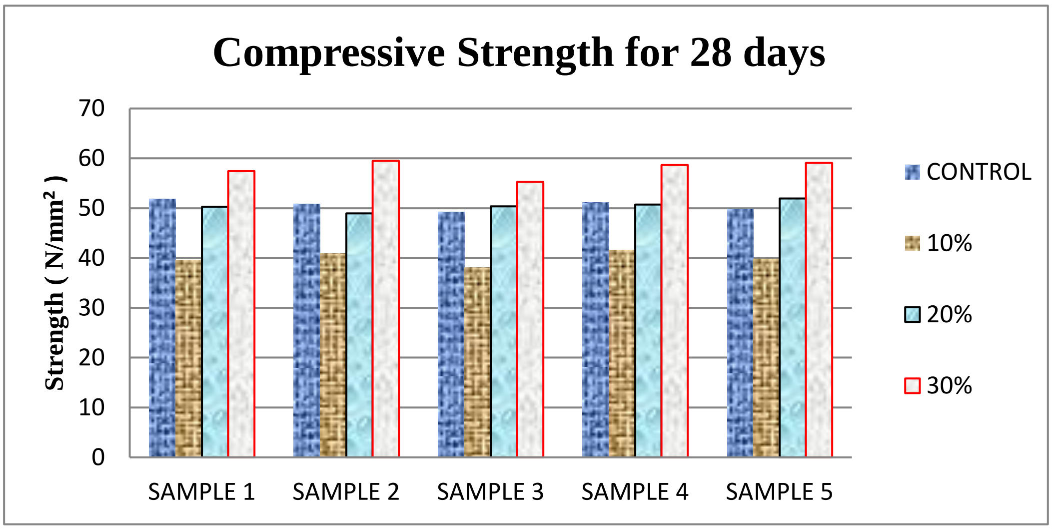

Figure 4. Compressive Strength for 28 days

From this study, the compressive strength of the mortar cube increases from 10% of glass powder content to the 30% of glass powder content in the mortar mixture. The 30% of glass powder contained in the mortar mixture has the maximum compressive strength compare with other glass powder content. The increased in compressive strength of mortar cube with glass powder is due to the pozzolanic reactivity. The glass powder has an active pozzolanic particle due to high silica content. Pozzolanic reaction happens in the cement paste when the glass powder mixed with calcium hydroxide to form a second form of calcium silicate hydrate (CSH). According to Loo & Poon (2018), the silica content is possibly similar to calcium hydroxide in the mix design with a percentage of 30% of WGW, so that the pozzolanic reaction occurs is at the maximum. Thus, this reaction can improve the properties of mortar including the strength of mortar.

Figure 5 shows the bar chart of average stress for each curing day. It was highlighted that the strength of mortar depends on the period of the curing process. It showed that the usage 30% of WGW gave a highest strength of specimen. The average percentage of strength for all different days of curing process for the 10% of WGW was lower than the control specimen. While, the average percentage of strength for specimen that used 20% of WGW was suddenly increased around 15% than the 10% of WGW. For specimen that used 30% of WGW also increased around 10% of the average percentage of strength. Based on figure 5 it can be summarized that the 30% of WGW replacement sand showed increased strength in the mortar mix.

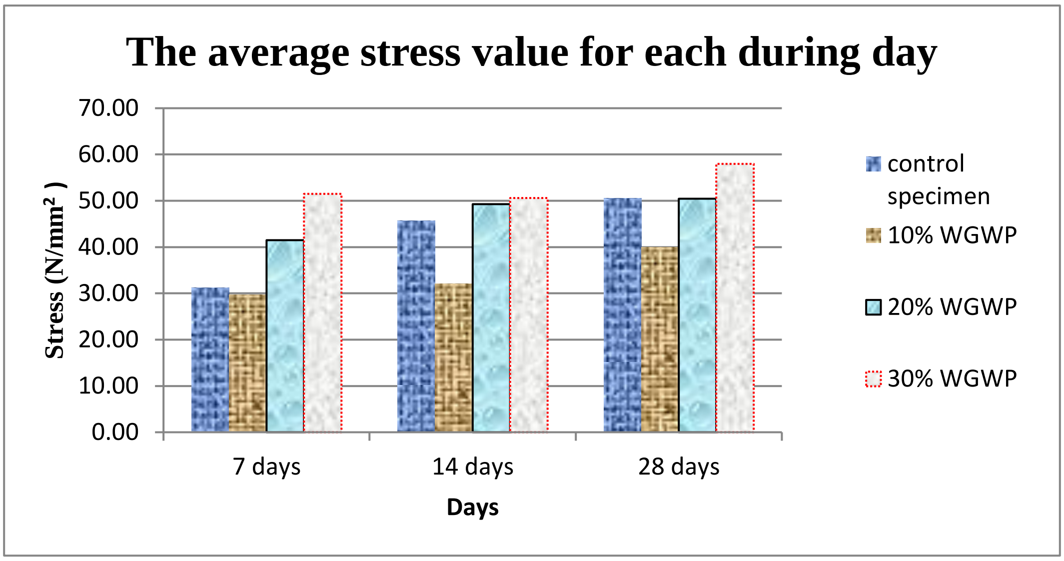

Figure 5. The data of average stress value for each curing day

Other than that, based on Figure 5, the compressive strength of mortar cubes at 28 days for 30% percentage replacement of glass powder increase as the curing age also increased. This may be due to the finely glass powder reacts with calcium hydroxide to form highly stable of complex composition involving calcium, silica and water as suggested by Mohajerani et al (2017). The production of heat hydration and development of strength is also slow when the pozzolanic reaction is slow Islam et al (2017). This indicates that the increase of compressive strength in mortar cause by the faster pozzolanic reaction.

Besides, the particle size of the glass used also the key factor that influencing the development of compressive strength. As stated in previous study by Hajimohammadi, Ngo & Kashani (2018), the compressive strength is highest for the mortar paste when used very fine glass less than 100µm and in this study the particle size of the glass is 90µm. It is noted that the maximum strength occurred for mortar with 30% glass powder as partial replacement of sand.

4. Conclusion

The compressive strength for 30% replacement with WGW showed the highest value compared to 10% and 20% and the strength increased as the period of curing increased. The performance of mortar replacement of sand with WGW much better than conventional mortar however the percentage used is limited to 10%, 20% and 30% WGW. It shows the progressive increased in strength. Additional usage of WGW to the mortar can improve the compressive strength of mortar compared with control specimens. Therefore, in order to achieve the highest rate of the compressive strength of mortar, the optimum usage of WGW in the mortar was only at 30%.

5. Acknowledgement

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