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THE EFFECTS OF GLASS AS PARTIAL REPLACEMENT OF FINE AGGREGATE IN CONCRETE

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Abstract:
Waste management is becoming a worldwide major issue . Glass which is non- biodegradable, is not suitable for addition to landfill; as such, recycling opportunities need to be investigated. Due to the high material consumption of the construction industry, the utilization of waste glass as a partial replacement for fine aggregate in structural concrete is particularly attractive. This experiment aims to determine the effect of glass as partial replacement of fine aggregate in concrete. 35 concrete samples were tested at 7, 14 and 28 days, for glass replacement proportions of 0%, 15% and 25% each for two sizes of glass, 2mm and 5mm. Compression strength was done to test their strength. The results proved that highest strength activity given by the waste glass is after 28 days. The compressive strength of specimens with 15% of 5mm waste glass content were 15.16 N/mm2, higher than the concrete control and other specimens. Using glass dust waste in concrete is an interesting possibility for the economy on waste disposal sites and conservation of natural resources.

Keywords: Waste Glass; Concrete; Sustainability; Waste Management; Compressive Strength

1.0 INTRODUCTION

In the modern era of construction industries, many researchers are working towards using waste products as materials in their concrete mixture. The purpose of this work is to utilize environmentally friendly materials by replacing the traditional construction materials. Waste products give a lot of bad effects to the environment. According to Tadić and Tadić, (2009), the waste products affected the environment by causing pollution, loss of biodiversity, litter and pests. Pollution occurs when the landfill site is not properly sealed; the leachate will be leaking to the groundwater and causing environmental problem to animals and plants living downstream. The biodiversity will also be affected by the waste products when the waste becomes uncontrolled and the people need more land to make new landfill sites, resulting in the clearing of vegetation and alteration of natural environment. Besides that, people also throw out the waste products into the sea which cause the sea creatures to be entangled or choked if they accidently mistake the waste products for their food.

So, the waste products need to be reused or recycled to prevent all the effects from happening. The materials of waste products come from a wide variety of sources, such as, municipal and household garbage, agriculture waste and debris from construction. Some of these materials,such as discarded tires, plastic, glass, burnt foundry sand and Coal Combustion By-Products (CCBs) (Bahoria, Parbat, & Naganaik, 2013),are not recyclable, so they are better used as material replacement in the concrete mixture. In this research, waste glass will be used as partial replacement for fine aggregates. The selection of waste glass as partial replacement to fine aggregates is because of its physical characteristics and chemical composition. According to Meyer et al. , (2001), the reason glass is an ideal partial replacement for cement and fine aggregates is because of its characteristics; glass is durable, very hard and it can serve as a pozzolanic material if it is grounded finely. Moreover, less super plasticizers are needed to make high strength concrete by replacing the fine aggregate partially. In fact, Saand et al. (2017) also agreed that glass is the best replacement for aggregate due its physical characteristics and chemical composition. Its physical characteristics which are very hard and durable and if it is finely grounded, it can serve as a pozzolanic material which makes it suitable to replace the fine aggregate.

As for the environment, the usage of waste glass will make incineration cheap and save a lot of landfill space. It is a big problem as according to The Star Online (2005), glass manufacturers in Malaysia produce 600 tonnes of new bottles daily but only 10% of the bottles actually go back to factories and be recycled as new ones. This means that 90% of the waste glass will eventually be thrown at the landfill. Hence, the aim of this research is to focus on replacing the sand as fine aggregates partially in concrete mixture with waste glass. To achieve this aim, the following objectives have been identified:

1. To study the workability of concrete using waste glass as replacement of fine aggregate.
2. To study the compressive strength of concrete using waste glass as a partial replacement of fine aggregates.
3. To study the effect of using two different sizes of waste glass as fine aggregate.

2.0 LITERATURE REVIEW

In the study, the author highlighted on many sub-topics such as, Glass as Replacement in Construction Materials, Glass as Aggregates for Concrete, Alkali Silica Reaction (ASR) Problem in Glass Concrete and Relevance of Relative Measure of Materials in Concrete. However for this paper, the author will only be focusing on the Relevance of Relative Measure of Materials in Concrete which can be discussed in to another sub-topic which are based on the size of waste glass and the percentage of waste glass in fine aggregates. Although this paper includes sub-topics, such as, Glass as Replacement in Construction Materials, Glass as Aggregates for Concrete, Alkali Silica Reaction (ASR) Problem in Glass Concrete and Relevance of Relative Measure of Materials in Concrete, the main focus of this literature review is on the Relevance of Relative Measure of Materials in Concrete. This will be discussed with other sub-topics that include literature on the size of waste glass and the percentage of waste glass in fine aggregates.

2.1 Size of waste glass

According to Aphale (2016), many attempts have been made by various researchers to use waste glass as rough aggregate, fine aggregate or as partial replacement for cement. Investigations have been conducted with variations in size and proportion of particles using a variety of concrete types. Based on the lists of researchers' experiments, it can be concluded that when waste glass is used as aggregate, the tendency for the concrete to face ASR problem is high. However, as the particle size of waste glass reduces, it helps in enhancing strength of concrete because particles size less than 0.075mm show more pozzolanic activities.

A study carried out by Atwan (2017) also showed the same results when the researcher used three different sizes of waste glass which are 0.06mm, 2.36mm and 4.75mm respectively. From this study, it is found that at the size of 0.06mm, it is more capable to increase compressive and flexural strength up to 18.64% and 5.87% respectively at 28 days of curing, compared to original specimen. The replacement of fine glass by fine aggregate at level 10% by weight has a considerable effect on the comparison and flexion properties. Beyond this percentage, it can be noted that the concrete is decreasing in terms of its properties. The presence of waste glass in the mixes as coarse glass leads to a decrease in compressive and flexural strength as the percentage of glass is increased. However, up to 20% of substitution, the reduction is not significant. While, the maximum negative effect on compressive strength and modulus of rupture was at the ratio of 30% of coarse glass, where the reduction in compressive strength was at 28.52% compared to 22.12% for modulus of rupture at the age of 28 days. The glass powder can be used as a partial replacement of fine aggregate since a finer glass particle size exhibits comparatively better results than coarser glass particle size.

2.2 Percentage of waste glass in fine aggregate

A lot of research have been carried out to find out what is the best percentage of waste glass to be put into the concrete mixture in order to prevent the ASR from occuring. Also, how many percent of the waste glass is needed to strengthen the concrete properties- in terms of compressive strength. According to an experiment done by Ibrahim (2017), the strength of the concrete went to the peak at 15% of waste glass but eventually dropped down starting from 20%. And from 20% to 40%, the strength reduces consistently. Rahim et al. (2014) found that the best strength of the concrete is in 28th day of curing from

10% waste glass mixture with a strength of 13.6% stronger than the control concrete. The report added that the 10% waste glass concrete mixes showed compressive strength values that are higher than those of the plain mixes, except for the 20% and 50% concrete mixes. The low compressive strength of the 20% and 50% waste glass concrete has been attributed to the decrease in the adhesive strength between the surface of the waste glass aggregates and the cement paste. Addition of glass dust waste of less than 10% into the mix has the potential benefit of increasing the compressive strength of concrete. The higher percentage of waste glass in the mix contributes to more water because glass dust does not absorb water as fine aggregate.

A study undertaken by Saand et al. (2017), shows that the compressive strength of concrete is increased with a replacement of fine aggregate with 4% to 12% of waste glass. The peak of the concrete strength is at 12% which is 36.85% of the control concrete. However, as some other experiments, the more the percentage of waste glass, the less strength the concrete has. It can be seen from the result that from 16% to 40% of waste glass, the strength reduces significantly.

However, conflicting results have been obtained in a study by Abdallah and Fan (2014). The strength of the concrete is obvious during the first 7 days of curing when the concrete containing 5% of waste glass which is higher than the control concrete. At 15%, the strength decreases as expected but suddenly the strength increases again with 20% of glass waste. The result of this experiment is completely different from other experiments. This is because other experiments showed that once the strength is increased, then the strength will decrease constantly. The result's trend is the same for 14 days of curing. But for 28 days of curing, a different result was observed. The strength of the concrete with 5% waste glass was slightly dropped from the control concrete's reading but increased with 20% of glass waste in the mixture. It can be concluded that the percentage would increase in compressive strength as age overall would also increase with the increment of glass aggregate replacements. This may be attributed to the Pozzolanic reaction that appears to offset this trend at a later stage of hardening and as such, contributes to an improvement in the compressive strength at 28th day

3.0 METHODOLOGY

There are two phases in doing this research. First is writing the literature review and second, conducting the experiment. The steps in conducting the experiment are:

3.1 Materials Preparation

Materials used in this research are cement, fine aggregates, coarse aggregates, water and waste glass. The cement that is used is ordinary Portland cement which is available at the concrete lab. The fine aggregate used is 4.75 sieved sand free from any inorganic materials and the coarse aggregate used is crushed stone free from any unwanted substances and has a maximum size of 19mm. The waste glass used as partial replacement of fine aggregates is collected at trash shops. It is crushed and sieved into two sizes which are 5mm and 2mm.

3.2 Mix Proportions

The concrete is mixed with 0.7 cement water ratio. For this ratio, two sizes of waste glass are used as a partial replacement for fine aggregates, which are 5mm and 2mm. For each size, three experiments are carried out where in every experiment two measures of Waste Glass Fine Aggregate (WGFA) substitution for the fine aggregates used are at 15% and 25%. This amount taken is based on previous studies by other researchers, namely, Ibrahim, (2017); Rahim et al., (2014); and Saand et al. (2017) who found that the ideal quantity of waste glass to be added into the mixture is around 10% to 15%.The mixture proportions used in laboratory for experimentation are shown in table below:

3.2. Waste glass size 2mm and below

Table 1: Mix proportions of materials for 2mm size waste glass

Substances	**WC 0.7(kg/m3)**	**Total (kg)**
Cement	295 x 0.001 x 10 Cubes	2.95
Water	205 x 0.001 x 10 Cubes	2.05
Aggregate	800 x 0.001 x 10 Cubes	8.0
Sand	1115 x 0.001 x 10 Cubes	11.15
Waste Glass 15% Sand 85%	11.15 x 15% 11.15 x 85%	1.673 9.477
Waste Glass 25% Sand 75%	11.15 x 25% 11.15 x 75%	2.788 8.362

3.2.2 Waste glass size 5mm-2mm

Table 2: Mix proportions of materials for 5mm size waste glass

Substances	**WC 0.7(kg/m3)**	**Total (kg)**
Cement	295 x 0.001 x 10 Cubes	2.95
Water	205 x 0.001 x 10 Cubes	1.05
Aggregate	800 x 0.001 x 10 Cubes	8.0
Sand	1115 x 0.001 x 10 Cubes	11.15
Waste Glass 15% Sand 85%	11.15 x 15% 11.15 x 85%	1.673 9.477
Waste Glass 25% Sand 75%	11.15 x 25% 11.15 x 75%	2.788 8.362

3.3. Testing Methodology

To test the workability, a slump test is done. The fresh concrete is poured into the slump cone and the difference in level between the height of the cone and the highest point of the subsided concrete is measured and reported. To test on hardened concrete, a cube test is done. The fresh concrete is poured into the cube moulds with the size of 100mm x 100mm x 100mm and is cured for 7 days, 14 days and 28 days. Then, the concrete undergoes a compressive test to see its strength.

4.0 ANALYSIS AND FINDINGS

As this paper is being written, the concrete test result is not completely obtained. Only the test for 7 days is complete. So, in this section, the 7 days results and expected results for another 2 days are revealed and discussed.

4.1 Compressive test result for 7 days.

Table 3: Compressive test result for 7 days.

WG Size (mm)	WG Percentage (%)	Compressive Test Result (N/mm2)
0	0	7.234
2	15	8.146
2	25	8.348
5	15	10.01
5	25	8.779

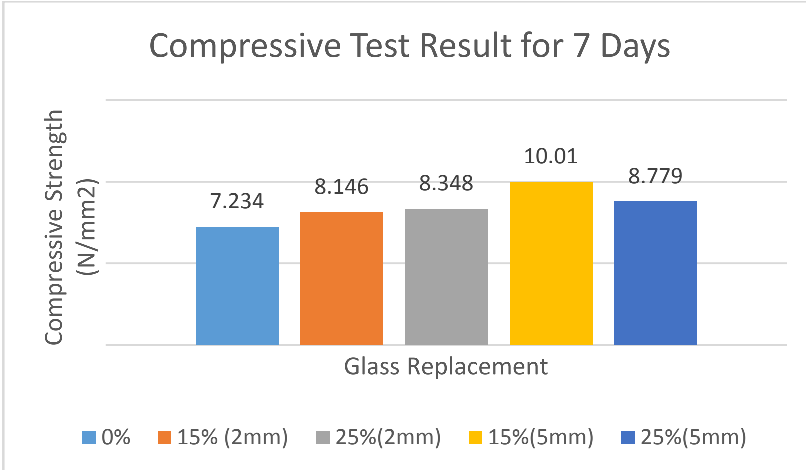

Figure 1: Chart for Compressive Test Result for 7 Days

From the result, it is observed that with the addition of waste glass, the concrete strength increased. The highest reading is at 15% replacement of fine aggregate when the reading reaches up to 10.01 N/mm2 from the controled reading which is only 7.234 N/mm2. There is an increase of 38.37% . But the result is expected to change after14 and 28 days. This is because based on previous research, the reading with15% waste glass would increase up to 20% while the 25% reading would decrease lower than the 15% reading. However, the first reading at 7 days is beyond the expected result as the reading for 5mm of waste glass is higher than 2mm. According to Meyer et al. (2001), the finer the waste glass is, the stronger the concrete would be. However, the reading shows otherwise.

4.2 Compressive test result for 14 days.

Table 3: Compressive test result for 14 days.

WG Size (mm)	WG Percentage (%)	Compressive Test Result (N/mm2)
0	0	8.563
2	15	10.28
2	25	8.734
5	15	11.60
5	25	10.82

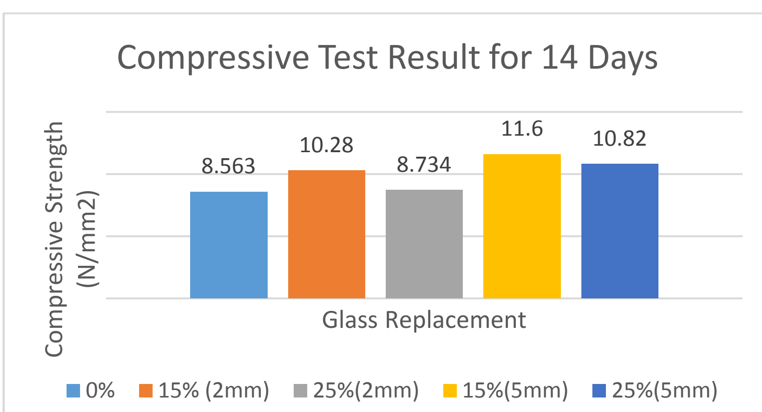

Figure 2: Chart for Compressive Test Result for 14 Days

After curing for 14 days, the highest reading obtained is at 15% of waste glass for 5mm size: the strength increased to 11.60N/mm2 compared to 10.01 in 7 days. The increase is 15.88%. It is followed by 25% of 5mm of waste glass where the reading increased up to 23.25% from the 7-day reading. All of the readings increased between 5% to 25% of strength. From these test readings, it can be seen that the strongest concrete is by using 5mm size of waste glass.

4.3 Compressive test result for 28 days.

Table 3: Compressive test result for 28 days.

WG Size (mm)	WG Percentage (%)	Compressive Test Result (N/mm2)
0	0	11.47
2	15	14.88
2	25	10.25
5	15	15.16
5	25	13.54

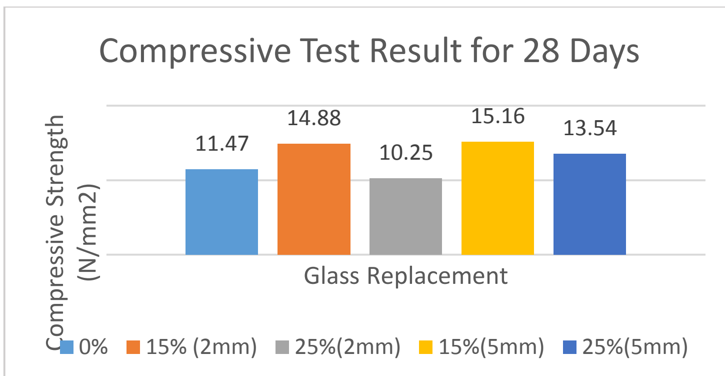

Figure 3: Chart for Compressive Test Result for 28 Days

After 28 days, the results changed dramatically. The strongest reading obtained is still at 15% of 5mm, which increased up to 15.16N/mm2 with 51% of increase from the 7-day reading. The reading of 15% of 2mm waste glass also increased drastically when it reached 14.88N/mm2. The lowest one is 25% of 2mm of waste glass with only 10.25N/mm2 reading and is lower than the controlled concrete. Below is the comparison chart for all concrete readings.

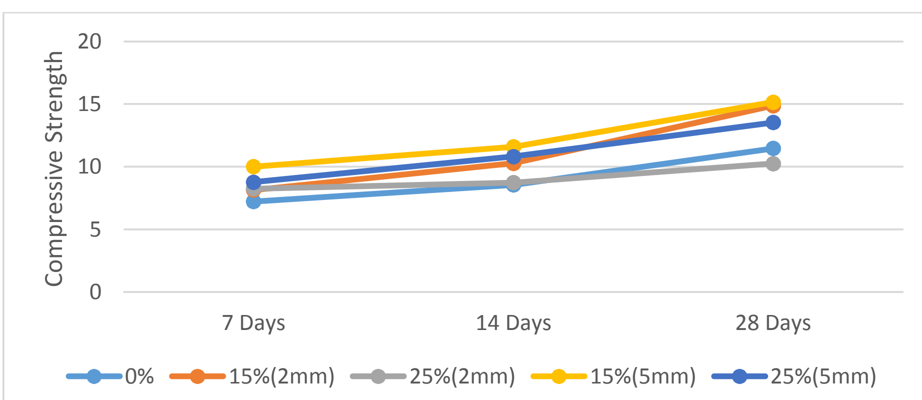

Figure 4: Chart for Compressive Test Result for 7, 14 and 28 Days

So, from the chart in Figure 4 above, in can be concluded that the best size is 5mm of waste glass and the best percentage is 15%. The worst is 25% of 5mm waste glass. The different sizes and different percentage do have different results. So, the size and the percentage need to be controlled from the beginning.

5.0 CONCLUSION

This experimental study seeks to identify the effects of implementing waste glass as a partial replacement for fine aggregate in concrete. The results obtained demonstrate that doing so can in fact increase the strength and workability of the concrete. Moreover, this is in line with the environmental legislation as focusing on sustainable building development may act as an incentive for the construction industry to incorporate this waste material into their practices. Hence, this would result in a twofold benefit for the environment, reducing the consumption of raw materials and diverting additional waste from landfill.

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