A Review on the Performance of Waste Glass as Partial Replacement of Fine Aggregate

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Abstract. Waste glass is one of the biggest contributors in waste production in Malaysia which can be used as partial sand replacement in concrete. Silica exists in waste glass components made it becomes a pozzolanic material and suitable to be used in a concrete mixture. The performance of the waste glass as fine aggregate was reviewed by considering the workability of fresh concrete, the strength, and the splitting tensile of hardened concrete. The range of the replacement waste are 0%, 10%, 20% and 30%. The influence of the waste glass on the microstructure of the concrete also have been evaluated. A total of seventeen previous research papers were collected and review based on the parameters selected. The results shows that replacement of waste glass in concrete give a positive impact for all selected parameters with 20% replacement represent as an optimal percentage replacement. The microstructure of the waste glass concrete resulting that more voids created after 20% replacement of waste glass which affects the compressive strength and split tensile strength of the concrete thus make the optimum replacement percentage is 20% replacement.

1. Introduction
Concrete is one of the main construction materials besides steel and timber. Typical concrete mix composed of 10% - 15% cement, 60% - 75% aggregate, 15% - 20% of water, and lastly 5% - 8% of entrained air. From there, it is clear that more than half the volume of concrete was made from aggregate. Glass is one of the waste materials that were study as partial fine aggregate in concrete mixture. Some researcher has done laboratory experiment in order to evaluate the properties of fresh concrete and hardened concrete consists of waste glass as a partial replacement of fine aggregate [1][2]. The findings shows that the workability, compressive strength, and split tensile strength give a positive impact until certain replacement percentage.

Glass is a material that can be recycled several times because it can maintain its purity and quality, [3]. Recycling glass in daily live will drives into energy saving and lowering glass disposal cost [4]. Silica that exists in glass makes it pozzolanic cementitious and can improve the bond between cement-aggregate [5].

Waste glass is one of the best materials to replace natural sand because both waste glass and natural sand share lots of similarities in its physical properties [6]. Waste glass able to improve the fresh concrete properties as it has smooth surface and low water absorption that can influence the workability of concrete [7]. Replacement of sand with waste glass has been done in the past and all of this was done to evaluate the waste glass potential but a certain limitation has been applied since severe segregation with bleeding and inferior mechanical performance can be detected if the 100% replacement was done [8]. An optimum percentage of waste glass can increase the hardened concrete
properties such compressive strength and split tensile strength. The replacement percentage of the waste glass in the concrete are 0%, 10%, 20%, 30% and this study aims on determining the optimum percentage of waste glass replacement. Environmental issue has increase due to large amount of waste glass disposal at the landfills. This study is important as it can help to decrease the percentage of overall glass waste in the landfill area thus led to the decrease of waste disposal [9].

2. Methodology
Planning is the first step of this project to make sure that the project was done systematically without missing an important part. All the important sub-topic such as the parameters that considered to be reviewed were list out in this process. The parameter chosen were workability of fresh concrete, compressive strength, and split tensile strength of hardened concrete and lastly, the microstructure of the concrete after replacing the sand with waste glass. The research papers that were related to this study were collected and reviewed. Most research papers that were collected is the research papers that were published in the past 5 years (including this year) but several papers are much older.

Seventeen research papers were taken to collect the data for workability, compressive strength, and split tensile strength while there are only three research papers were collected to get the microstructure results. Only the data for 0%, 10%, 20%, and 30% waste glass replacement were selected.

2.1. Workability
Table 1 represent the workability data that has been selected for concrete grade 20 and 25 from previous research.

| References | Grade concrete | Workability of concrete (mm) |
|------------|----------------|-------------------------------|
|            |                | 0%   | 10% | 20% | 30% |
| [1] 20     | 65             | 68   | 73  | 60  |
| [2] 250    | 270            | 290  | 260 |
| [3] 52     | 48             | 60   | 59  |
| [4] 97     | 92             | 75   | 65  |
| [5] 52     | 38             | 43   | 48  |
| [6] 250    | 280            | 290  | 300 |
| [7] 25     | 35             | 53   | 65  | 72  |
| [8] 25     | 29             | 34   | 40  |

2.2. Compressive strength
Table 2 present the compressive strength data that has been selected for concrete grade 20 and 25 on 28 days.

| References | Grade concrete | Compressive strength (MPa) |
|------------|----------------|----------------------------|
|            |                | 0%   | 10% | 20% | 30% |
| [1] 20     | 30.33          | 31.33| 31.00| 29.66|
| [2] 22.77  | 25.88          | 29.84| 24.66|
| [3] 26.00  | 27.10          | 27.50| 28.80|
| [4] 23.57  | 26.88          | 27.11| 27.76|
| [5] 25.00  | 36.80          | 25.80| 24.00|
| [6] 33.80  | 35.60          | 38.40| 34.25|
| [7] 37.00  | 35.90          | 34.20| 28.88|
| [8] 29.66  | 29.33          | 30.00| 29.66|
| [9] 29.68  | 33.03          | 27.14| 25.11|
| [10] 27.30 | 29.25          | 30.25| 29.90|
| [11] 28.07 | 33.69          | 35.11| 30.82|
2.3. Split tensile strength
Table 3 present the split tensile strength data that has been selected for concrete grade 20 and 25.

| References | Grade concrete | Split tensile strength (MPa) |
|------------|----------------|-----------------------------|
|            |                | 0%  | 10%  | 20%  | 30%  |
| [1]        | 20             | 2.30| 2.52 | 3.21 | 3.1  |
| [12]       |                | 3.75| 3.27 | 3.55 | 3.29 |
| [7]        |                | 2.90| 3.83 | 3.80 | 3.24 |
| [3]        |                | 2.80| 2.87 | 2.90 | 2.98 |
| [4]        |                | 3.45| 3.40 | 3.46 | 3.04 |
| [10]       | 25             | 2.40| 2.20 | 2.40 | 1.90 |
| [13]       |                | 2.55| 2.48 | 2.30 | 2.16 |

2.4. Microstructure
Scanning electron microscope (SEM) analysis is an analysis that has been done to analysed by referring to the changes in the microstructure of the waste glass concrete [14].

3. Results and discussion

3.1. Workability
Figure 1 and figure 2 shows the slump value result for waste glass concrete grade 20 and 25.

![Slump Value Result](image)

**Figure 1.** Value of slump test of waste glass concrete with different percentage of replacement of glass for G20.
From the graph in figure 1, 20% - 30% waste glass replacement shows highest result. The positive result of the workability is due to the smooth surface of the waste glass that absorb less water during mixing process. Figure 2 shows that slump value for [10] appears to be lower than [12] and the reason for this difference is the water-cement ratio used for the design mix proportion. Different water-cement ratio of 0.55 and 0.45 resulting this situation. The overall workability result from both figures shows positive achievement especially at 20% of waste glass replacement. It shows that 20% of waste glass replacement is the optimum replacement to increase the workability of the fresh concrete. The amount of admixture added in the waste glass concrete increase with the increase of waste glass percentage used in order to maintain the compaction factor value. This shows that the workability of waste glass concrete can be increased by and adding admixtures in the mix design proportion [13].

3.2. Compressive strength
Figure 3 and figure 4 shows the compressive strength result for waste glass concrete grade 20 at 28 days.
Concrete was projected to achieve approximately 100% of its strength in 28 days. From the result in figure 3, all the results have obtained a minimum compressive strength of 28 days for concrete grade 20. However, there is only one sample continuously drop as the percentage replacement of waste glass increases which due to texture of glass aggregate has a smoother texture relative to sand, thereby minimizing the concrete mixture's paste-aggregate bond [12]. The poor resistance to aggregate fracture since the glass is easily broken and fragile. Besides that, most of the compressive strength results for waste glass concrete is higher than control concrete.

Figure 4 showed that all of the results have achieved the minimum compressive strength of concrete with grade 25 since all the results were higher than 25 MPa. This proves that waste glass can increase the compressive strength of concrete and produce concrete with higher strength compared to control concrete.

3.3. Compressive strength
Figure 5 and figure 6 shows the split tensile strength result for waste glass concrete grade 20 and 25 at 28.
Figure 5 shows that Elavasran [1] has the highest result at 20% waste glass replacement while Pratheba [7] have the highest split tensile strength at 10% waste glass replacement. Premalatha [3] results increase marginally along with the increase in the replacement of waste glass. Most results in figure 5 shows the positive split tensile strength mostly at 10% - 20% waste glass replacement. The graph shown in figure 6 were based on the results of split tensile strength for concrete grade 25 on 28 days. Both results do not meet the minimum split tensile strength that should be reached with a grade of 25 for concrete. After 28 days, the split tensile strength at 20% waste glass replacement increases and have the same strength as control concrete [12]. This can be concluded that the optimum waste glass replacement percentage to increase the split tensile strength of grade 25 concrete is 20% [12].

3.4. Microstructure

Figure 7 shows the result of Scanning Electron Microscopy (SEM) analysis [15].

From figure 7, the image for the concrete without waste glass shows a boundary between the cement and aggregates but the boundary become more invisible after 18% waste glass replacement. This is due to the waste glass that was dispersed uniformly in the concrete structure thus creating denser concrete and helps to improve the compressive strength and split tensile strength of the waste glass concrete. However, voids started to appear in the images of 18% waste glass replacement and 20% waste glass replacement. The number of voids increased as the waste glass replacement increased and cracks can be seen when the replacement percentage is higher than 20%. The existence of the cracks will be one of the reasons for the decrease of compressive strength and split tensile strength.
4. Conclusion

The optimum replacement percentage of waste glass in concrete mixture is 20% replacement. 20% replacement. The results for the workability, compressive strength, split tensile strength and microstructure shows positive result at 20% replacement. Voids start to appear in the concrete structure when the replacement percentage is more than 18% as in the microstructure result. Cracks start to form when the replacement percentage is higher than 20% thus effecting the compressive strength and the split tensile strength of the concrete.

5. References

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