Effects of Glass Powder and Waste Marble Dust on Strength Properties of Concrete

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Abstract

The rapid development of the population has led to a constant increase in industrial waste, which contaminates the environment. The amount that would need to be disposed of might be greatly reduced if industrial waste could be used to make concrete. Waste materials can be used as aggregate or as a cement substitute in cement concrete technology in a variety of ways. As a result, glass powder (GP) was used as an additive at 2% by cement weight in concrete with a water-cement ratio of 0.5, and Waste marble dust (WMD) was evaluated as a partial cement replacement at 0%, 5%, 10%, 15%, 20%, 25%, and 30% replacement levels. When 5% WMD was used as a cement substitute, concrete's compressive strength rose in comparison to the control mix, however adding more than 5% of WMP had the opposite effect. The pattern of split tensile strength was comparable to that of compressive strength. Up to 5% of WMD can be added to cylinders to increase their split tensile strength; after that, the strength tends to decrease as more WMD is applied. By substituting GP and WMD for up to 5% of the cement in a concrete mix, the mechanical properties of concrete can be improved.

Keywords: Compressive strength, Concrete, Glass powder, Marble dust, Workability.

Introduction

Concrete is a mixture that is comprised of weak, loose components known as aggregates that are combined with water and cement to form a homogeneous slurry that can withstand a range of stresses. Each component of concrete serves to provide the necessary strength and maintain favorable design characteristics during the course of the material's lifespan. Cement manufacture is thought to have a major impact on carbon dioxide (CO_2) emissions in the building industry [1], with one ton of cement products producing about 0.8 tons of CO_2 [2]. Finding alternative materials that can replace cement has been seen as a useful way to safeguard the environment. By utilizing more affordable and recyclable materials, the building industry hopes to cut costs while having less of an adverse effect on the environment and the economy. To help meet the rising demand, cementitous ingredients are added [2].

Because marble is so frequently utilized in the construction sector, a ton of marble trash has been generated. With the replacement of cement or fine aggregates in concrete, marble dust, a solid pollutant derived from the marble manufacturing industry, can be used successfully employed as a binding material. Consequently, numerous research have been carried out to investigate the potential use of marble wastes in projects as a means of resolving this issue. [3-6].

Omar et al. [7] investigated the effects of marble waste and lime stone waste on the strength, workability, and elastic modulus of concrete when cement and sand were partially replaced. The presence of limestone waste improved the slump of concrete, while the use of marble waste as a cement replacement increased the concrete's strength. Rodrigues et al. [8] also tested the mechanical performance of concrete using marble waste sludge. Up to 20% of the sludge is used, in increments of 5%. The mechanical characteristics of the freshly laid and cured concrete both decreased during testing. However, it was determined that the ideal dosage was 10% of cement replacement by volume. Topcu et al. [9] studied the fresh and hardened qualities of self-compacting concrete produced utilizing various marble dust dosages. The authors found no difference in slump in fresh state and strength in hardened state for a waste dosage of 200 kg/m3. But after taking the aforementioned amount, there was a reduction in strength. In their study studies, Ofuyatan et al. [10] also used marble dust as a sand replacement, replacing river sand by 0–35%. For both compressive and tensile strengths, they prepared, cured (7, 21, 28, and 56 days), and tested M15 concrete. They saw increases in compressive and tensile strength of 11% and 17%, respectively, at a replacement level of 25%. They also noted that the addition of marble dust powder increased the concrete's hardness. On the other hand, Saghir et al. [11] noted increased porosity and decreased density and compressive strength as a result of the addition of marble dust (from 0 to 15%) to concrete.

Materials and methods

For the research, it is necessary to get concrete materials including sharp sand, granite, cement, glass powder, and waste marble dust. In order to ascertain the qualities of cement, numerous tests were conducted on Dangote Portland Cement, which was purchased in Ilaro and produced in accordance with Nigerian Industrial Standard (NIS) 444-1:2003. In this study, waste marble dust (WMD) was used, which was gathered from the industry sector in Abeokuta, Ogun State. The MWP used had particle size smaller than 75 m. Table 1 shows WMD chemical constituents. Glass Powder (GP) was created by grinding up glass bottles into powder, thereafter utilized as an additive in the mix. The chemical constituents of GP is shown below in Table 1.

Table 1: Chemical Composition of Cement, WMD and GP

Oxide composition	Cement (%)	WMD (%)	GP (%)
Fe_2O_3	2.99	0.08	0.37
SiO_2	18.99	0.20	70.16
Na_2O	-	-	13.05
Al_2O_3	2.09	0.15	1.10
CaO	60.75	59.2	9.17
MgO	2.31	0.89	4.36
SO_3	2.54	0.031	-
Cl	0	-	-
L.O.I	-	-	17.21

Casting, Curing and Crushing

Standard cube specimens measuring 150 mm x 150 mm x 150 mm and a cylinder measuring 150 mm x 300 mm were cast at weight replacement rates of WMD 5%, 10%, 15%, 20%, 25%, and 30% for cement and 2% for GP as an additive. A total of 3 cubes were cast for each percentage replacement of WMD. After 24 hours of casting, the samples were demolded and put in a water curing tank where they were left for the following days before being weighed, dried, and crushed to test their compressive strength and split tensile strength at 7, 14, and 28 days of curing.

Result and Discussion

Sieve Analysis

Table 1: Particle size distribution of sand

Sieve Size	weight retained	% weight retained	For (sand) cumulative percentage retained	Cumulative % passing
4.76	4	0.4	0.4	99.6
2.36	41	4.1	4.5	95.5
1.18	407	40.7	45.2	54.8
0.6	304	30.4	75.6	24.4
0.3	216	21.6	97.2	2.8
0.15	17	1.7	98.9	1.1
0.075	7	0.7	99.6	0.4
Pan	4	0.4	-	0
Total	1000	100.00	321.4	

Table 1: Particle size distribution of granite

Sieve Size	Weight retained	% Weight retained	For (sand) cumulative percentage retained	Cumulative %
2.5	127	12.7	12.7	87.3
19	341	34.1	46.8	53.2
13.2	208	20.8	67.6	32.4
10	163	16.3	83.9	16.1
8	9	9	92.9	7.1
6.7	22	2.2	95.1	4.9
5.6	32	3.2	98.3	1.7
4.75	17	1.7	-	0
Total	1000		497.3	

The material utilized was coarse crushed granite with a specific gravity of 2.72 and a maximum particle size of 19 mm that was devoid of contaminants including biological matter, etc. It is poorly graded because of its 1.59 coefficient of curvature, 1.72 coefficient of uniformity, and 4.875 fineness modulus. Sand that was used in this study has a maximum particle size of 4.75 mm, a specific gravity of 2.65, and a fineness modulus of 3.214. The sand is poorly graded since it has a coefficient of curvature of 0.97 and a coefficient of uniformity of 2.5.

Workability of concrete

The workability findings of concrete are displayed in figure1. The workability of concrete mixes was observed to diminish as compared to control as the percentage of WMD in concrete mixes increased from 0% to 30%, causing the mix to harden. This is attributable to the WMD's replacement of the cement, which also resulted in a decrease in the amount of cement paste. More specifically, the high fineness modulus of the marble will tend to raise the requirement for water in the concrete mix.

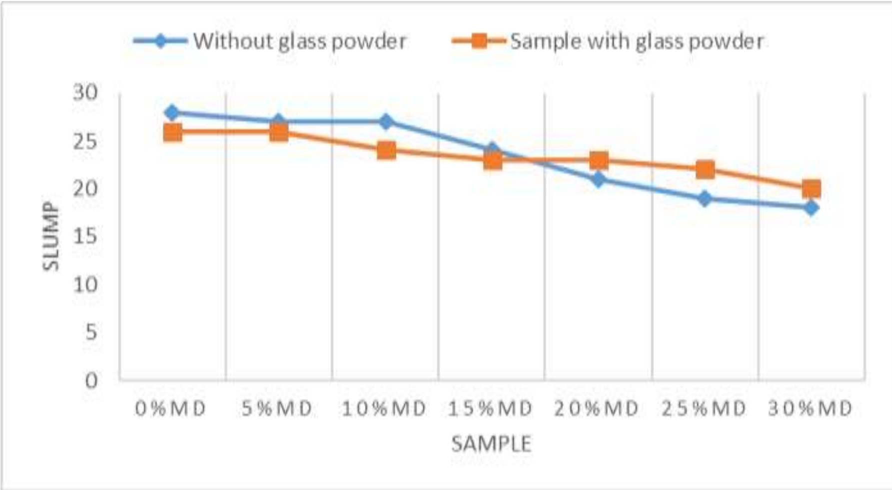
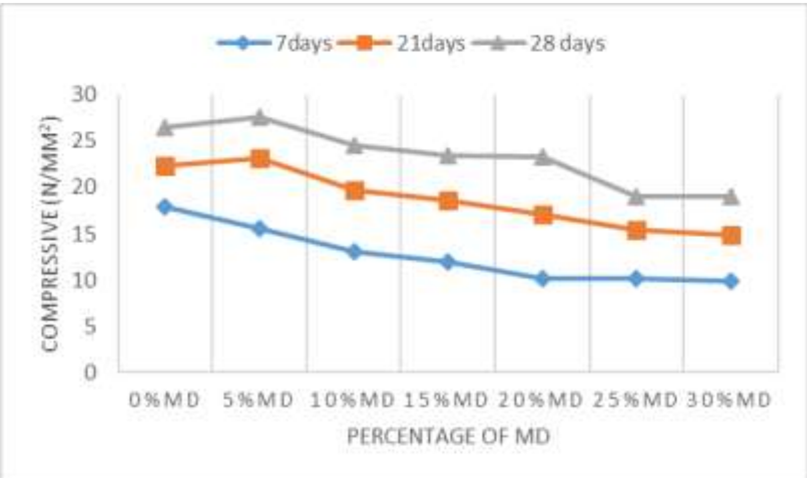


Figure 1: Workability of concrete.

Compressive strength of concrete

When 5% WMD is used, concrete's compressive strength at 28 days of curing age increases by 3.9% in comparison to control mix. In comparison to the control specimens, the concrete age strength at 28 days for 5% replacement is higher. The increase in strength can be credited to the filler effect of a few very small particles of WMD in the mixture that enhances the particle packing of the cement, balancing out the drop in strength anticipated due to cement reduction. Beyond 5% replacement range, however, the 28-day strengths are lower with WMD added than they are in the corresponding control specimens, with reductions increasing as the percentage of WMD is increased. This is due to the cement being replaced by MWP, which results in the dilution of dicalcium and tricalcium silicates, which are responsible for the development of strength. The same pattern was found when GP was used as an additives.



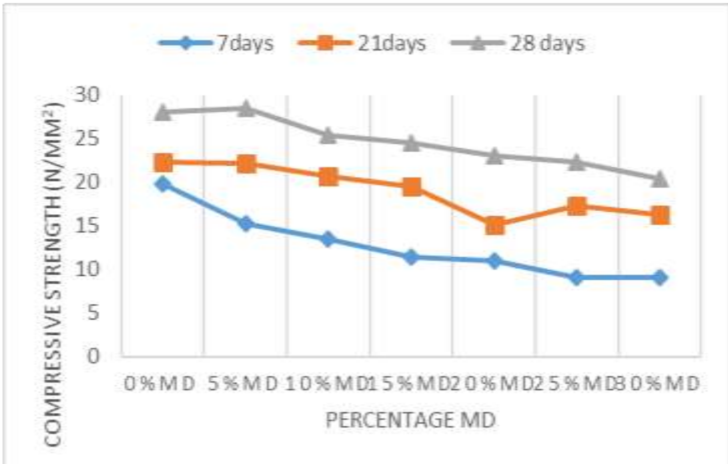


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Figure 2: Compressive of concrete without GP **Figure 3: Compressive of concrete with GP**

The mix with 5% WMD as a replacement for cement with 2% GP was found to have the best compressive strength when GP was added as an additive. The reactions of cement particles chemically resulted in some heat being created, which could boost the GP particles pozzolanity (capacity for chemical reactions).

Split tensile strength

Tensile strength showed a similar pattern to compressive strength, and the values are shown in Figure 3 and Figure 4.

Figure 3: Split tensile strength without GP

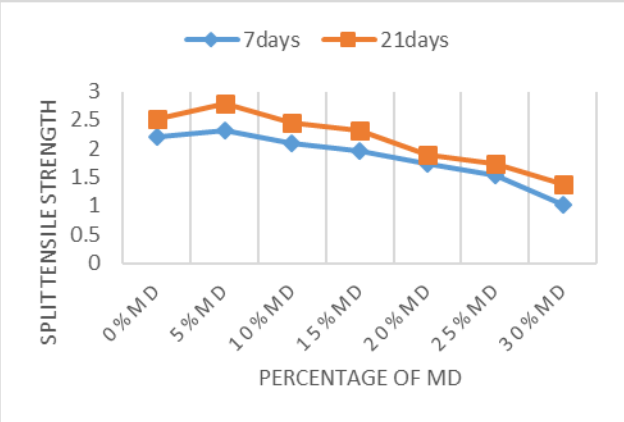
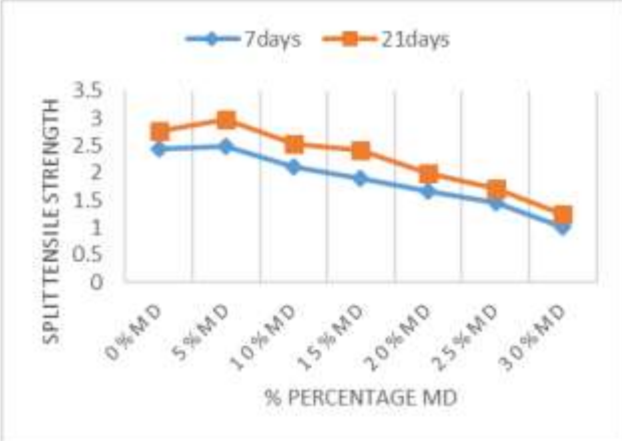


Figure 4: Split tensile strength GP



When WMD is added to the mix, up to 5% of the cement by weight, the tensile strength of the cylinders is improved. On further increase in percentage replacement beyond 5%, the strength of the split tensile tends to decline. Similar to the use of GP, the mix containing 5% WMD and 2% GP had the best split tensile strength. Low porosity for blended cement concrete using WMD as a micro-fine filler product was observed to boost tensile strength.

Conclusion

According to the slump test, workability tends to decline as WMD content rises in the mixture. Given the increased total surface area of mixtures incorporating GP as an addition, the slump value was lower. It was discovered that using 5% WMD as a cement substitute increased the compressive strength of concrete when compared to control mix, while using more than 5% cement replacement had a negative impact. The combination that comprises 5% WMD as a replacement for cement with 2% GP has the best compressive strength, according to research. This is because some heat was generated during the chemical reactions of the cement particles, which may have increased the chemical reaction activity of the GP particles. Split tensile strength showed a similar pattern to compressive strength. The addition of WMD up to 5% replace by weight of cement increases the split tensile strength of cylinders. Similar to the use of GP, the mix containing 5% WMD and 2% GP had the best split tensile strength. The strength of concrete is positively impacted by GP, it has been determined.

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