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Utilization of marble dust powder in concrete

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Abstract. The economic costs of construction have become largely unbearable today. In a bid to mitigate these costs, civil engineering faculties and stakeholders across the world have endeavoured to produce recyclable and resource saving concrete for construction purposes. Most of the environmental problems are caused by the deposit of waste to the environments in which marble shaping is part. Both stone slurry and solid wastes are generated from the marble stone slurry and with the huge discharge of marble waste locally, emphasizes has been placed on the reuse of the waste material. This research investigates the utilization of marble dust powder in concrete, where marble dust at varying percentage (0%, 15%, 25% & 35%) with replacement by sharp sand was added in M15 grade and water cement ratio 0.50 was kept constant in the concrete mixes. The quality, performance and reliability of the concrete where tested by the compressive and split tensile strength of 7, 21, 28 and 56 curing days. The results of the laboratory work showed that marble dust powder replacement with cement increased in strength up to 25% for both resistance to compressive load and tensile strength of concrete.

1. Introduction

Concrete is a composite material made up of loose materials known as aggregates that provide strength and are formed into a homogenous mixture using water and a binder in the form of cement to withstand loads of various forms. The ability to use recycled waste material to form concrete brings in a new dimension to construction and helps for sustainability of the built environment. In the housing, transportation and energy infrastructure, Portland cement is a material most widely used in construction. Industry and academia have come together to develop stronger concrete, raw material used as filler and admixture or aggregate in concrete. The essence of each of the constituents of concrete is to provide adequate strength throughout its life cycle and maintain favourable design properties. PCC (Portland Cement Concrete) is made up of raw materials such as limestone, shale, clay for cement production, river sand which is the Fine aggregates, granite stones as the coarse aggregates and are diminishing as a result of continuous and enormous usage in construction activities [1]. New methods of construction must be devised due to the thinning of various resources from overuse and a lack of subsequent replenishment. With the use of more economical and recyclable materials in building, the construction industry aims at cutting costs and reducing disposal costs of the used wastes from other industries. Certain materials when used in concrete produce favourable results in comparison to regular use concrete while saving on several environmental and financial fronts. Supplementing Cementous materials helps to meet the increase demand of cement also reducing green gas emission [2].

Green concrete should not be taken as a specific color of concrete. This term serves to describe concrete which is eco-friendlier and releases less amount of greenhouse gases compared to conventional concrete. In green concrete less harm is afflicted on the environment and minimum amount of energy is required, it resembles the conventional concrete [3]and [4] describe green concrete as a concrete which its production does not lead to environmental destruction, has high performance, lifecycle sustainability and uses at least one waste material as its component. Green concrete improves the social, environmental and economic impacts of sustainability. The eco-friendly nature of green concrete is brought about using recycled, cheap and eco-friendly materials in the concrete like fly ash, Marble sludge powder etc. (Supplementary Cementitious Materials) or SCM. When identifying a green concrete; the quantity of the Portland cement used, the mineral admixture and method of manufacturing are important factors to be considered. The strength & utility of "green" concrete for building have been the subject of various research works in the past which investigated key parameters in concrete use. [5] designed the preliminary concrete mix for self-compacting concrete to find the relationship between the hardened and fresh properties of the SCC, marble being a building material since ancient times was used as marble dust which was used as replacement (marble dust) in this research. [6] mix design on monogram was adapted to the SCC mix. Marble powder was used as partial replacement of sand and cement at 0, 25, 50, 75 and 100% by [6] and [7] with 10% fly ash, 10 %slag, 7.5% silica fume and 1% superplasticizer in concrete. Result obtained indicated that considerable advantage in plastic and dry shrinkage of marble powder and beneficial effect on mechanical properties. 5, 10, 20, 30, 40 and 50% of stone slurry waste where studied by [8] as replacement of pozzolana Portland cement of M25 grade. Stated that marginal replacement had beneficial effect on the mechanical properties of the concrete. [8] used statically analysis to determine the dataset on predictive compressive strength models of SCC. They concluded that water cement ratio, aggregate combination, superplasticizer and binder combination are variables that affect compressive strength for 7, 28 and 90 days. [9] researched concrete durability of palm oil fuel ash at 14, 28 and 90days of water absorption on the specimen also tested for acid and sulphate resistance, from the result it is observed mixes with ash had low resistance to the acid and sulphate test compared to SCC with palm oil fuel ash which had high values [10] assessed the strength properties of cassava peel ash concrete. Cassava peel ash was used to partially replace cement at varying percentages and curing days. It was seen that the concrete can be used for light construction works where high strength is not a major requirement. The aim of this study is to investigate the effect of marble sludge powder on the strength properties of concrete, to compare the mechanical properties of the varying mix concrete with marble dust.

2. Experimental Study

2.1 Materials

The basic materials used in this experimental study are, sharp sand, granite, marble dust, Ordinary Portland Cement (OPC) of grade 42.5 [11] and water [12]. The fine aggregate used.in the production of the mix was locally sourced from Ota, Ogun state. The coarse aggregate used in the production of concrete was locally sourced granite stones from suppliers in Ota according to [13], [17]. The average diameter of the stones was about 12.5 mm and was washed before using to remove dirt and unwanted materials. Marble waste sludge used was gotten from marble processing industries, in sludge form and dried for 72 hours to produce fine powder. Potable water was gotten from the school water supply system according [16].

2.2 Concrete Proportions

A concrete mix ratio of 1:2:4 was used and was achieved during the experiment through the Weight method. For each mix, a total of twelve concrete specimens were produced with three concrete pieces being taken per curing age (7, 21, 28 and 56 days). A total of thirty-six cubic specimens (150 x 150 x 150) mm were cast in order to determine the compressive strength. A standard weight scale with an accuracy of 0.5 kg was used to batch.

Table 1. Physical and chemical composition of waste marble dust

Chemical analysis	**SPG**	**C**	**CaO**	**SiO_2**	**Al_2O_3**	**Fe_2O_3**	**Mgo**	**SO_3**	**K2O**	**Na2O**
Marble dust	2.71	White	52.46	1.29	0.39	0.78	0.54	–	0.11	-

SPG- specific gravity, C- colour

Table 2. The required weights of concrete constituents

W/C	Cement	Fine aggregate	Coarse aggregate	Mix ratio
0.45	$16kg$	31kg	63kg	1: 2: 4

Table 3. Mix proportion

Mix	Marble	Sand (kg)	Waste marble (kg)	Mix proportion
1	0%	31	0	1: 2: 0: 4
2	15%	26.35	4.65	1: 1.7: 0.3: 4
3	25%	23.25	7.75	1: 1.5: 0.5: 4
4	35%	15.5	15.5	1: 1: 1: 4

Workability tests mainly slump tests was carried out on trial batches of concrete produced. Compressive strength analysis was carried out on cured and hardened concrete samples.

2.3 Slump Test
Slump test was performed on each mix ration of the fresh concrete made. Concrete was placed in the slump test cone in three layers, with each layer compacted by tamping with a tamping rod 25 times each. The top was then levelled out and the cone was removed. The depth of slump was measured and recorded. Figure 2 shows the slump at 25% waste dust marble content according to [18],[19] and [20].

2.4 Moulding and curing
For the compressive test, the specimen was cubical in shape and size of 150 x150 x 150 mm and for the Split tensile test the specimen was cylindrical in shape and diameter of 150 mm by 300 mm height. The concrete cubes were demoulded and placed in curing ponds filled with potable water. Curing was made to last for 7, 21, 28 and 56 days after which the cubes were dried and tested.

Figure 1. Moulding batch of WMD Concrete

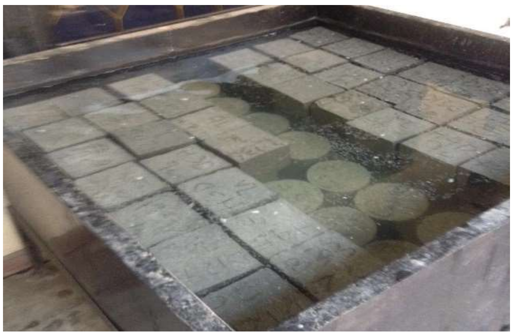

Figure 2. Samples placed in the curing pond

2.5 Compressive Strength Test
The compressive strength test was performed on the cubes after they had been removed from the curing pond and allowed to dry for about one hour. The compressive strength test was done with an automatic analogue electrical compression machine at a fixed rate. Each specimen was crush to failure with the failure load recorded in kN. The samples were placed in the compressive strength testing machine with the smooth surface of the cubes in contact with the plates of the machine.

2.6 Split Tensile Strength Test
This determines the tensile strength of concrete using a concrete specimen of 0.15 m by 0.30 m (6-in. by 12-in.) concrete cylinder is subjected to a load [15] at a constant rate which increases continuously until it splits across the vertical diameter. After failure due to tension developed in the transverse direction the maximum applied load indicated at the testing machine is noted and appearance of fracture

3. Result and Discussion

3.1 Workability of the Resulting Concrete

The workability of the concrete produced using three different replacement percentages 0%, 15%, 25% and 35% of Waste marble dust concrete was tested using the slump test. An arbitrary water-cement ratio of 0.45 was used. Table 4 presents the recorded slump values of the investigation conducted.

Table 4. Shows the slump values for the resulting concrete mixes

Mix	Green concrete	Slump (mm)	Slump Type
1	0% marble	15	True
2	15% marble	20	True
3	25% marble	25	True
4	35% marble	20	True

From the figures above it is realized that 25% has the highest degree of slump and 15 and 35% recorded the lowest slump values due to the fineness of marble dust and its high binding properties.

Figure 3. Slump test of WMD concrete.

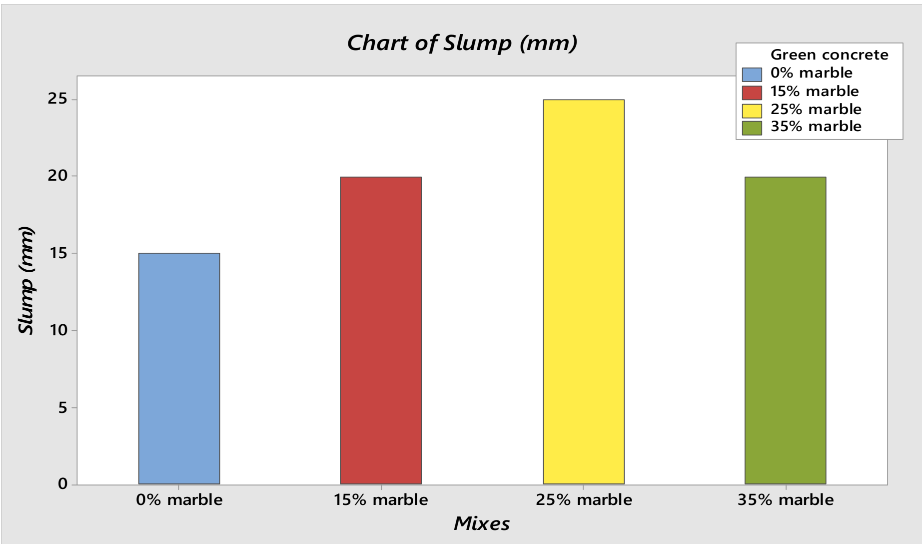

Figure 4. Graph showing slump value of concrete samples for each percentage mix of WMD (0% - 35%)

Table 5. Showing the compressive strengths and split tensile of various mix of marble dust concrete cubes for respective days of curing

Mix	Compressive Strength				Mix	Split Tensile Strength			
	7days	21days	28days	56days		7days	21days	28days	56days
0% marble	13.4	19.3	22.8	27.5	**0% marble**	2.22	2.56	3.07	3.54
15% marble	14.5	22.05	24	30.7	**15% marble**	2.34	2.8	3.2	3.68
25% marble	17.5	23.71	26.4	32.8	**25% marble**	2.45	3.14	3.56	3.82
35% marble	14.3	21.6	25.84	29.2	**35% marble**	2.27	3.05	3.42	3.71

From the result obtained it was observed that the compressive strength of M15 grade of waste marble dust at the respective curing days increased with marble dust powder up to 25%. Further increase in percentage reduced the compressive strength of concrete (35% marble dust). It was found that the split tensile strength of M15 grade concrete at both 7 and 28 days increases with the increase in the percentage of marble dust powder for up to 35%. The split tensile strength of concrete improved by 15.55 % and 17.95 % for M15 grade concrete at 7 and 28 days respectively. However, there is a relationship between Tensile strength and the percentage replacement. This increase in strength is due to the filling capacity of the marble dust and its cohesive properties within the concrete mix

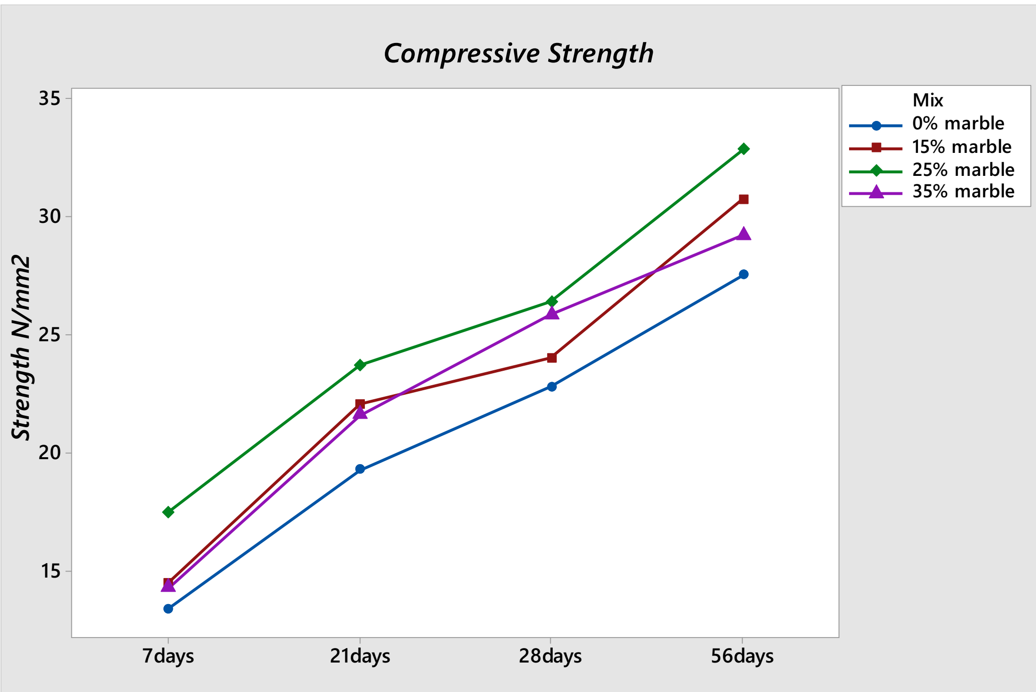

Figure 5. Graph showing the curing days of compressive strength of each series replacement with marble dust

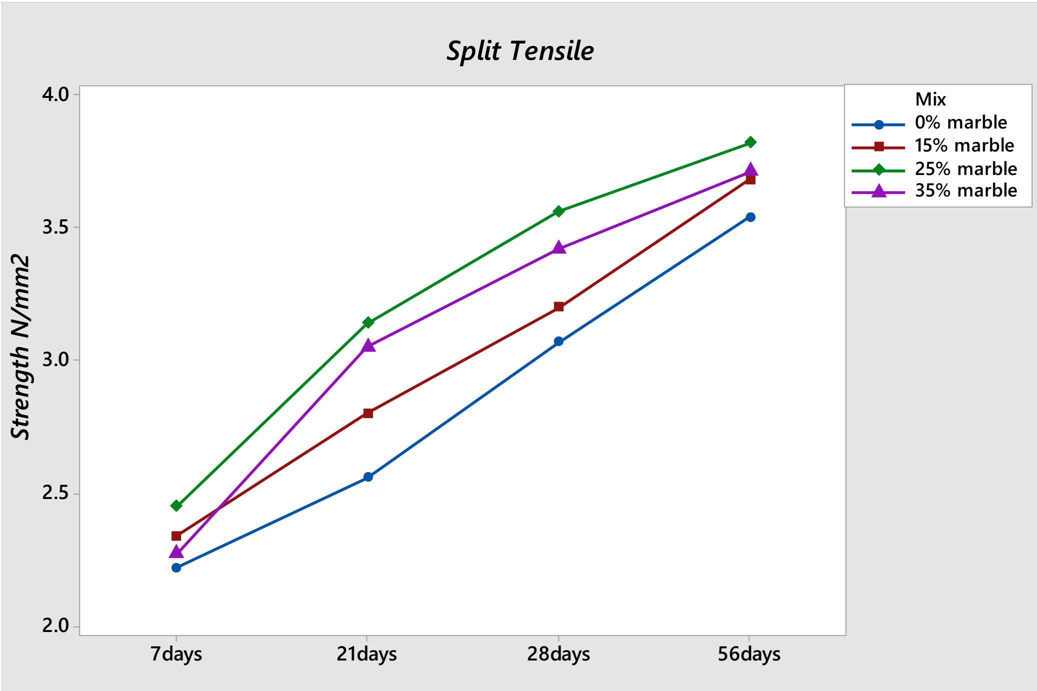

Figure 6. Graph showing the Tensile strength of each series replacement with marble dust

4. Conclusion

The addition of waste marble dust as a constitutive material of concrete had a good slump of fresh concrete. At 25%, marble dust had a strength greater than the control at 56days. However, the addition of waste marble dust increased the tensile strength by 17% at 25%.

The addition of waste marble dust increased the compressive strength of concrete by 11% at 25% Marble dust content. The optimum percentage for replacement of sand with Marble waste is at 25% for both cubes and cylinders. This research put forth a simple and effective way to minimize costs incurred in the production of concrete since Waste Marble Dust is cheaply available. Based on the observations gotten from the test results and analyses of WMD concrete, the integration of waste marble dust in making green concrete would be a promising strategy to improve the performance of concrete. The significant improvement in toughness allows WMD concrete resist greater amount of stress and hence, concrete structures made of WMD concrete have greater load bearing capacity.

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