Original Research Article

THE USE OF WASTE MARBLE DUST AS PARTIAL REPLACEMENT FOR CEMENT IN CONCRETE

ABSTRACT

An experimental study was carried out to investigate the strength properties of concrete produced with waste marble dust (WMD) as partial replacement for cement. Concrete specimens (cubes, cylinders and prisms) were cast and tested for compressive, split-tensile and flexural strengths at 0% (control mix), 10%, 20% and 30% replacement of cement by weight with WMD with a mix ratio of 1:2:4 and water/cement ratio of 0.45 after curing in water for 28 days. The results obtained reveal that the replacement of cement with WMD had appreciable impact on the compressive, split-tensile and flexural strength of concrete. An optimum of 20% replacement of cement with WMD is therefore recommended for concrete production.

Keywords: waste marble dust, cement, concrete, strength

1. INTRODUCTION

Concrete is the most widely used construction material in the world. The global population growth has led to an increase in the demand for infrastructure. This has led to a higher demand for construction materials such as cement and natural aggregates (fine and coarse). The production of cement has resulted in emission of carbon (iv) oxide (CO_2) which is a major contributor to greenhouse gases which deplete the ozone layer. The production of 1 ton of cement results in the emission 1 ton of CO_2 in the atmosphere.

The disposal of industrial wastes has also become an issue of great concern over the years. Marble dust is one of such industrial wastes generated from marble producing industries.

The increased demand for concrete has resulted in an enormous depletion of natural resources (without replenishment) leading to environmental issues such as erosion, landslides, etc.

All of these have necessitated the need to source/harness alternate raw materials to reduce environmental pollution and reduces the depletion of natural deposits of raw materials like limestone for cement production. The use of waste materials in the production of concrete results in the profitable utilization of waste materials and enhances the sustainability of the built environment.

Omisande and Onugba [1] carried out an investigation on the combined effect of the using marble dust (MD) and iron filings (IF) as partial replacements for fine aggregates on the compressive strength of concrete. The results obtained indicated that the combination of MD and IF has beneficial effects on the compressive strength of concrete.

Ofuyatan, et al [2] in their research, partially replaced sand (by weight) with marble dust powder at 0%, 15%, 25% and 35% in concrete. They recommended a 25% optimal replacement of sand with WMD.

Seghir, et al [3], carried out research to evaluate the effect of partially replacing sand with WMD on the physical and mechanical properties of air-cured mortar. Their findings revealed that replacing sand with WMD negatively affects the properties of air-cured mortar. They however recommended the use of WMD in lightweight cement-based materials used for non-structural elements.

Sakalkale, et al [4] investigated the strength properties of concrete produced by replacing sand with WMD. They replaced sand with WMD at 0%, 25%, 50% and 100% replacement levels. Their results indicated increments in the compressive and flexural strengths when sand was replaced with WMD up to 50% and decrease in the split-tensile strength when sand was with WMD in concrete. They recommended an optimum of 50% replacement of sand with WMD in concrete.

This present research investigated the possibility/suitability of the use of waste marble dust as a partial replacement of cement in the production of concrete.

2. MATERIALS AND METHODS

2.1 Materials

The following materials were sourced and used for this study:

2.1.1 Cement

Portland-Limestone Cement, CEM II/B-L, Grade 42.5, (purchased in Idah, Nigeria), manufactured in conformity to Nigerian Industrial Standard (NIS) 444-1 [5], which is equivalent to BS EN 197-1 [6] was used for this research. Table 1 shows the results of the specific gravity and consistency of the cement.

Table 1: Basic properties of the cement

Tests conducted	Result Obtained	Code Limit	Test Method
Specific gravity	3.15	3.15	ASTM C188 [7]
Initial setting time (minutes)	97	Min. 45	BS EN 196 Part 3 [8]
Final setting time (minutes)	231	Max. 375	BS EN 196 Part 3 [8]
Soundness (minutes)	3.7	Max. 10	BS EN 196 Part 3 [8]

2.1.2 Waste Marble Dust

The WMD used was gotten from Jakura Marble Industry, Lokoja, Nigeria. WMD passing through BS sieve size 0.075mm was used for this research. The specific gravity and colour of the WMD is 2.81 and cream respectively. Figure 1 shows a sample of the WMD used.

Fig.1: Sample of Waste Marble Dust used

2.1.3 Fine Aggregates

Sharp river quartzite sand that is free of clay, loam, dirt and any organic or chemical matter, and maximum size of 4.75mm, having a specific gravity of 2.62 and water absorption of 0.61; sourced from Idah environs, Idah, Nigeria was used for this research.

2.1.4 Coarse Aggregates

Crushed granite coarse aggregates of 20 mm maximum size, having a specific gravity of 2.68 and water absorption of 0.45; free from impurities such as dust, clay particles and organic matter, etc, sourced from Idah environs, Idah, Nigeria, was used for this research.

Table 2: Physical properties of coarse aggregates

Test conducted	Result obtained	Code Limit	Test Method
Aggregate crushing value (%)	23.6	Max. 25	BS 812 Part 110 [9]
Aggregate impact value (%)	16.8	Max. 25	BS 812 Part 112 [10]
Los angeles abrasion value (%)	18.8	Max. 30	ASTM C131 [11]
Specific gravity	2.68	2.55 - 2.75	ASTM C127 [12]
Aggregate moisture absorption (%)	0.45	Max. 2	BS 812 Part 2 [13]
Flakiness Index	27	<35	BS 812 Part 105 [14]

Table 3: Combined aggregate gradation

Sieve Size (mm)	Percentage Retained	Cumulative Percentage Retained	Cumulative Percentage Passing
25.00	-	-	100
19.00	2.7	2.7	97.3
12.50	9.7	12.4	87.6
9.50	9.2	21.6	78.4
6.30	12.7	34.3	65.7
4.75	10.3	44.6	55.4
2.36	10.9	55.5	44.5
1.18	12.0	67.5	32.5
0.60	10.0	77.5	22.5
0.30	7.7	85.2	14.8
0.15	6.2	91.4	8.6
0.075	2.1	93.5	6.5
Pan	6.5	100	-

2.1.5 Water

Fresh, colourless, odourless and tasteless potable water that is free from injurious amounts of oils, alkalis, salts, sugar organic matter or any other substances, was used for this research.

2.2 Experimental Investigation

Experimental investigations were carried out to evaluate the strength properties of grade M30 concrete mixes in which cement was partially replaced with WMD. The compressive, split-tensile

and flexural strength of the specimens after replacing the cement by 0% (control), 10%, 20% and 30% with WMD (by weight) was investigated after 28 days of curing.
The concrete cubes (150 mm X 150 mm X 150 mm), concrete cylinders (Φ150 mm X 300 mm) and concrete prisms (100 mm X 100 mm X 500mm) were cast for conventional mix as well as other mixes.

2.2.1 Mix Proportioning

The concrete mix design was proposed to achieve the compressive strength of 30N/mm^2 after curing for 28 days in the case of cubes, cylinders for split-tensile strength and prisms for flexural strength. The concrete mix proportion was 1:2:4 with a water/cement ratio of 0.45. Table 4 shows the mix proportions of waste modified concrete mixes

Table 4: Mix proportions of waste modified concrete mixes

Mix ID	Percentage of WMD	Cement (kg/m^3)	WMD (kg/m^3)	Sand (kg/m^3)	Coarse Aggregate (kg/m^3)	Water/ Cement ratio
M1	0	16.95	0	35.27	75.25	0.45
M2	10	15.25	1.70			
M3	20	13.55	3.40			
M4	30	11.85	5.10			

2.2.2 Casting and testing of specimens

Three specimens each of waste modified and control concrete were cast for compressive, split-tensile and flexural strength tests respectively. Casting, compaction and curing of the specimens were conducted in accordance to B.S. EN 12390 [15-16]. The compressive, split-tensile and flexural strengths tests were carried out in accordance to B.S. EN 12390 [17-19]. The average compressive, split-tensile and flexural strength of the specimen was recorded after 28 days of curing. Figure 2 showing a specimen been tested.

Fig. 2: Specimen been tested

3. RESULTS AND DISCUSSION

3.1 Workability

The slump values are presented in Table 5. The slump values increased as the volume of WMD was increased in the concrete mix. All the concrete mixes produced true slump and the slump values were within the normal range for good workable concrete. The addition of WMD to the concrete mixes therefore had positive impact on its workability.

Table 5: Slump Test Result

MIX ID	SLUMP VALUE (mm)
M1	60
M2	62
M3	64
M4	65

3.2 Compressive, Split-Tensile and Flexural Strength

The compressive, split-tensile and flexural strength tests results are presented in Table 6. The results showed that as WMD was used to replace cement at 10%, 20% and 30%, the compressive strength of concrete increased as compared with the control mix. However, further increase in the percentage replacement of cement with WMD, resulted in a decrease of the compressive, split-tensile and flexural strength of concrete as compared with the 10% and 20% replacement.

At 28 days of curing, for the 20% replacement of cement with WMD, there was an increase of 7.73%, 12.32% and 11.49% in the compressive, split-tensile and flexural strength as compared with the control mix. The results obtained also indicate that there was early strength gain upon the replacement of cement with WMD.

Table 6: Compressive, Split-tensile and Flexural Strength Test Results

% WMD	Compressive Strength (N/mm^2)		Split-Tensile Strength (N/mm^2)		Flexural Strength (N/mm^2)	
	7 days	28 days	7 days	28 days	7 days	28 days
0%	25.09	31.32	2.03	2.84	4.43	5.31
10%	25.43	32.68	2.11	2.99	4.56	5.61
20%	25.57	33.74	2.53	3.19	5.30	5.92
30%	25.20	31.52	2.34	3.10	5.11	5.12

The increase in strength of concrete upon the replacement of cement with WMD agrees with the observations of Ofuyatan et al [2] that the strength increase is due to the filling capacity of marble dust and its cohesive properties within the concrete mix. The porosity of concrete might also be reduced due to the filler effect of waste marble dust.

4. CONCLUSION

The following conclusion can be drawn from the findings obtained from this experimental investigation;

1. Waste marble dust can be used as a partial replacement for cement in concrete.
2. The use of waste marble dust in concrete will help reduce environment pollution and lead to the profitable utilization of wastes.
3. The use of marble dust in construction might be cost effective because this waste is available free of cost.
4. Waste marble dust can be used for the production of structural concrete.
5. An optimum of 20% replacement by weight of cement with waste marble dust is recommended for the production of concrete.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

REFERENCES

1. Omisande, L. A. and Onugba, M. A. (2021). Strength Characteristics of Concrete Produced by replacing Fine Aggregates with Iron Filings and Marble Dust. *International Journal of Innovative Science and Research Technology.* 6(3): 29 – 34
2. Ofuyatan, O. M., Olowofoyeku, A.M., Obatoki, J. and Oluwafemi, J. (2019). Utilization of marble dust powder in concrete. *1st International Conference on Sustainable Infrastructural Development: IOP Conf. Series: Materials Science and Engineering.* 640: 1-7 doi:10.1088/1757-899X/640/1/012053
3. Seghir, N. T., Mellas, M., Sadowski, L., Krolicka, A., Zak, A., and Ostrowski, K. (2019). The utilization of waste marble dust as a cement replacement in air-cured mortar. *Sustainability.* 11 (2215): 1-14; doi:10.3390/su11082215
4. Sakalkale1, A. D., Dhawale, G.D., and Kedar, R. S. (2014). Experimental study on use of waste marble dust in concrete. *International Journal of Engineering Research and Applications.* 4(10): 44 – 50
5. Standards Organization of Nigeria. Cement – part 1: Composition, specification and conformity criteria for common cements. 2003; 444:1
6. British Standards Institution. Cement – part 1: Composition, specification and conformity criteria for common cements. 2000; 197:1
7. American Society for Testing and Materials. Standard test method for density of hydraulic cement. 1995; C188
8. British Standards Institution. Methods of testing cement – part 3: determination of setting times and soundness. 2016; 196:3
9. British Standards Institution. Testing aggregates – part 110: methods for determination of aggregate crushing value. 1990; 812:110
10. British Standards Institution. Testing aggregates – part 112: methods for determination of aggregate impact value. 1990; 812:112

11. American Society for Testing and Materials. Standard test method for resistance to degradation of small size coarse aggregate by abrasion and impact in the los angeles machine. 2006; C131
12. American Society for Testing and Materials. Standard test method for relative density (specific gravity), and absorption of coarse aggregate. 2015; C127
13. British Standards Institution. Testing aggregates – part 2: methods for determination of density. 1995; 812:2
14. British Standards Institution. Testing aggregates – part 105: methods for determination of particle shape – flakiness index. 1990; 812:105-1
15. British Standards Institution. Testing of hardened concrete – part 1: Shape, dimensions and other requirements for specimens and mould. 2000; 12390:1
16. British Standards Institution. Testing of hardened concrete – part 2: Making and curing specimens for strength tests. 2000; 12390:2
17. British Standards Institution. Testing of hardened concrete – part 3: Compressive strength of test specimens. 2002; 12390:3
18. British Standards Institution. Testing of hardened concrete – part 6: tensile splitting strength of test specimens. 2000; 12390:6
19. British Standards Institution. Testing of hardened concrete – part 5: Flexural strength of test specimens. 2000; 12390:5