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EVALUATING PERMEABILITY AND MECHANICAL PROPERTIES OF WASTE MARBLE DUST MIX CONCRETE AND BENTONITE MIX CONCRETE

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In this research attempt is made to examine Waste Marble Dust Mix (WMD) Concrete and Bentonite Mix Concrete. For physical and chemical properties of both concrete mixes, cylinders were examined in the laboratory for permeability testing, scanning electronic microscopy test, slump test, compressive strength test, and split tensile test. Cylinders were prepared in the ratio 1:2:4 with varying marble dust and bentonite content with 5% increment up to 20%. At 28 days with 10% replacement of marble dust and bentonite with cement, the permeability of WMD and Bentonite concrete were decreased by 21% and 34%. Increasing the percentage of WMD and bentonite from 10 to 20%, the MD concrete permeability was drastically increased. After crossing 10% limit it starts working as over burdening additives and allows water to flow through the cylinders, while with bentonite mix concrete by 20% replacement with cement, the permeability was further decreased up to 43%. The compressive and split strength test results of both mixes were totally different from each other. The compressive strength of WMD mix concrete decreased as the percentage of WMD was increased. At 28 days with 10% replacement, the compressive and split tensile strength were reduced by 8.9% and 2.1%. Whereas in bentonite mix, the concrete compressive and split strength were increased by 7.2% and 1.45 and were furthermore increased up to 20% replacement.

Keywords: Concrete strength, Consistency, Impermeable concrete, Environment.

1 INTRODUCTION

In the last few decades, the marble industry has generated a large amount of waste marble dust (WMD). About 50% of marble is wasted due to blasting, poor quality product, unskilled workforce, and largely unrecognized market. This wasted/leftover material, known as waste marble dust, needs permanent dumping because it is harmful for human health by polluting the environment, affecting the agricultural land, water and air due to its alkaline properties. Therefore, the reusing of these extract products from the marble industry needs to be managed permanently in any form, so that their effects may be minimized.

Bentonite clay (Montmorillonite clay) is a geological material having pozzolanic/cementitious properties, mined from earth, formed after volcanic ash in the presence of water with passage of time. Bentonite clay has many uses in the construction industry as a partial replacer to cement because it has pozzolanic properties. Pozzolanic material when reacted with water, forms products that has cementitious properties. Many researchers have made attempts to utilize the WMD and bentonite as a partial replacer to cement.

According to a previous research, in which the WMD and Dolomite (pozzolanic material combination of calcium and magnesium carbonates $CaMg(CO_3)_2$), as a partial replacement of cement, was added up to 20% to study the mechanical properties. According to their conclusion, for to 15% replacement, the flexural strength of concrete mix was improved by 11% whereas the compressive strength was increased by 42% with 10% replacement (Ergun 2011). While in another research, focused on the study of the physical properties (consistency) of waste marble dust mix concrete, it was discovered that as the percentage of marble dust was increased, the slump value of the concrete was increased. So, according to their recommendation, WMD can be used in self-compaction concrete (Alyamac and Ince 2009).

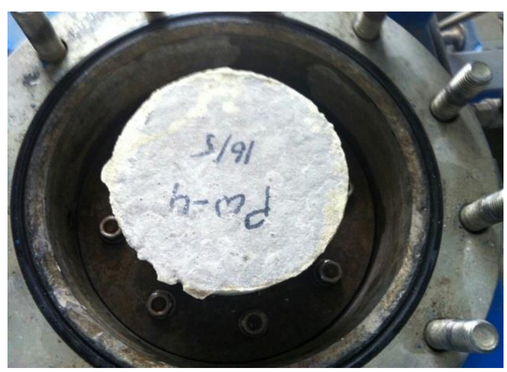
2 METHODOLOGY

This research methodology consists of three phases, which are briefly explained below.

The **first phase** consists of fabrication of concrete specimens according to ASTM C192 (2016) standard. Concrete cylinders in molds having dimensions of 150mm x 300mm were prepared to investigate the mechanical and physical properties of both the concrete mixes.

The **second phase** is lab experimentation: the following tests were performed to investigate the mechanical properties – (i) splitting tensile strength test, (ii) tensile strength at 28 days for 30 cylinders for both WMD and Bentonite mix concrete samples by Universal Testing Machine under ASTM C496 (2017) standard, (iii) compressive strength test for 60 cylinders were tested to find out crushing strength for 7 and 28 days for both WMD and Bentonite mix concrete samples in the Universal Testing Machine under ASTM C39 (2018) standard, (iv), slump test was performed to find the consistency under ASTM C143 (2015) standards, (v) the water permeability test was performed by Blain's apparatus, shown in Figure 1(a) under the ASTM C204 (2018) Standard. After preparing and placing the concrete specimen in the apparatus shown in Figure 1(b), the sample was then fully saturated with water leaving no bubbles on its surface. 30 bar pressure was applied to the specimen for a defined time. The water shall penetrate through the sample with pressure and get collected in a beaker underneath. Then the coefficient of permeability can be derived by Eq. (1).

(a)



(b)

Figure 1. (a) Blain's Apparatus (b) top view having cylinder placed in Blain's apparatus.

$$K = (Q \,.\, X) / (A \,.\, h) \tag{1}$$

Where; Q = Volume flow rate (m^3/s), A=Cross-sectional Area (m^2), h= head of water (m), X= Specimen thickness in the direction of thickness (m), K= Permeability coefficient.

To determine the elemental composition of waste marble dust and bentonite, Scanning Electron Microscopy (SEM) apparatus was used, shown in Figure 2(a). SEM is a type of electron microscope that produces pictures of a sample by scanning the area with a confined beam of electrons. The electrons intermingle with the sample of the atoms and provides a surface variation, composition, and topography of the area by producing various signals. The chemical properties obtained from the examination of Electron Microscopy (SEM/ EDS analysis) for marble dust and bentonite fall under under ASTM E2809 (2013) standards.

The **third phase** is the analysis of results of all the lab experimentation mentioned in phase two, and is briefly explained below.

(a)

(b)

Figure 2. (a) SEM apparatus (b) Chemical composition of WMD.

2.1 Compressive Strength Test Results

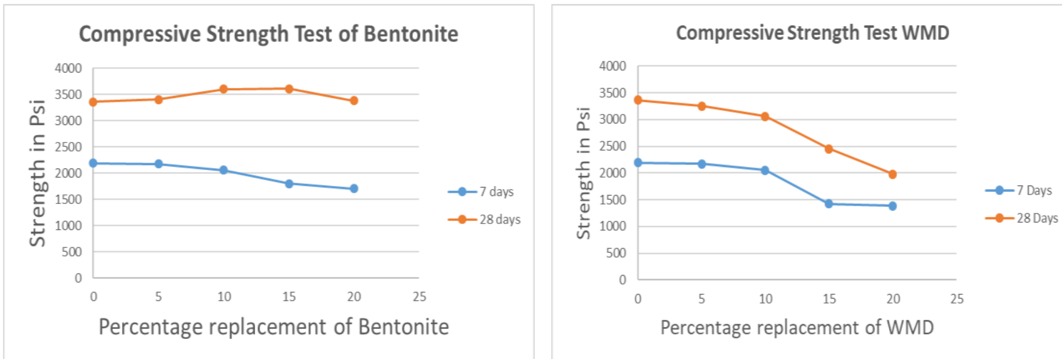
The results shown in Figure 3(a) elaborates that as the percentage of Waste Marble Dust was increased, the compressive strength of the concrete kept decreasing. At 28 days with 20% replacement of cement with waste marble dust, strength gradually decreased from 3361 psi to 1979 psi.

While at 28 days, the Bentonite mix concrete strength was increased. The strength increased from 3361 psi of control sample to 3606 psi at 15% replacement of cement with bentonite, while at 20 % replacement the strength dropped as compared to other replacement, but still was 0.5% as that of control sample as shown in Figure 3(b).

2.2 Splitting Tensile Strength Results

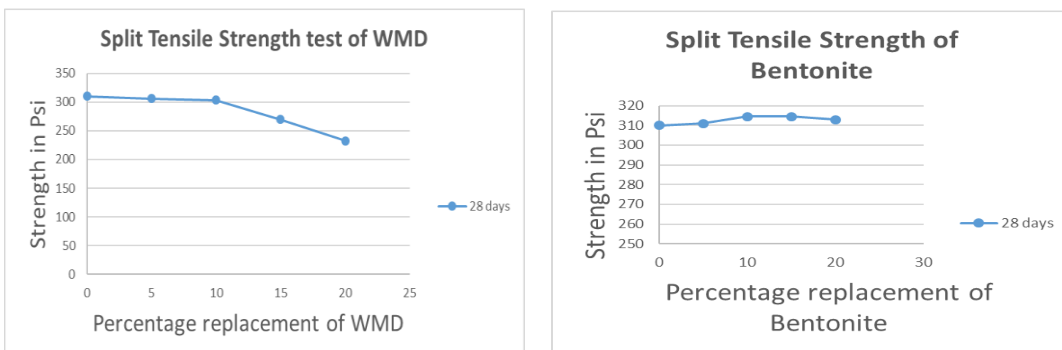
The results show that as the percentage of Waste Marble Dust was increased, the tensile strength of the concrete kept decreasing. At 28 days with 20% replacement of cement with waste marble dust, strength gradually decreased from 310.1 psi to 232.8 psi. Results are shown in Figure 4(a).

But, at 28 days the Bentonite mix concrete strength was increased from 310.1 psi of control sample to 315.2 psi at 15% replacement of cement with bentonite. But at 20% replacement, the Split strength decreased by 0.47% to that of 15% replacement of Bentonite, as shown in Figure 4(b).



(a) (b)

Figure 3. (a) WMD Compressive Strength Test graphs of 7 and 28 days, (b) Bentonite Compressive strength test graphs of 7 and 28 days.



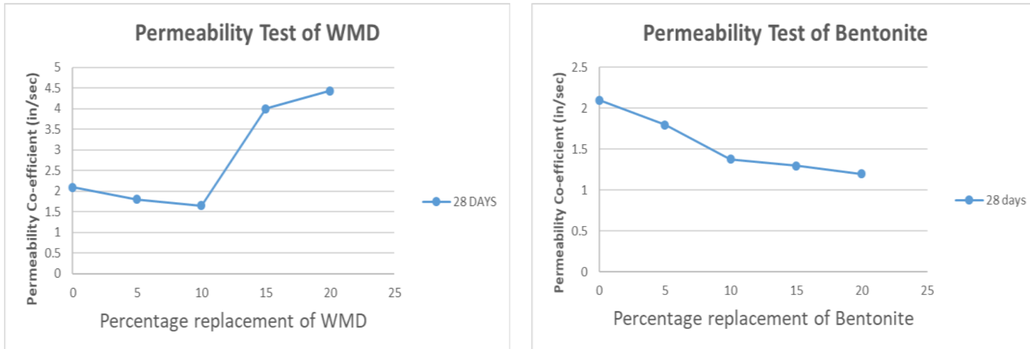
(a) (b)

Figure 4. (a) WMD 28 days split tensile strength graph, (b) Bentonite 28 days split tensile strength graph.

2.3 Permeability Test Results

The permeability results show that as we keep increasing the percentage of marble dust from 0 to 10%, the permeability of concrete mix was improved/decreased by 21%. The reason is that marble dust acts as a filler and dust makes the concrete compacted, and stops the ingress of water through the sample. But after crossing 10% and reaching 20%, the permeability was increased (not improved). After 10% replacement of marble dust it starts acting as an over burdening material. Results are shown in Figure 5(a).

While in the bentonite mix concrete up to 20% replacement, the permeability was gradually improved/decreased by 43% as compared to the control sample as shown in Figure 5(b).



(a) (b)

Figure 5. (a) WMD 28 days permeability test graph, (b) Bentonite 28 days permeability test graph.

2.4 Scanning Electron Microscopy

The chemical composition of the both the waste marble dust and bentonite are examined via SEM test. The increase in the strength of Bentonite mix concrete is due to the high percentage of calcium oxide (74.9%). The chemical composition of both the waste marble dust bentonite samples are shown below in Tables 1 and 2.

Table 1. SEM analysis of bentonite.

Composition	Content (wt. %)
SiO_2	14.13
Al_2O_3	4.9
Fe_2O_3	2.32
MgO	3.11
CaO	74.9
Na_2O, TiO_2, K_2O	Where less than 1% each.

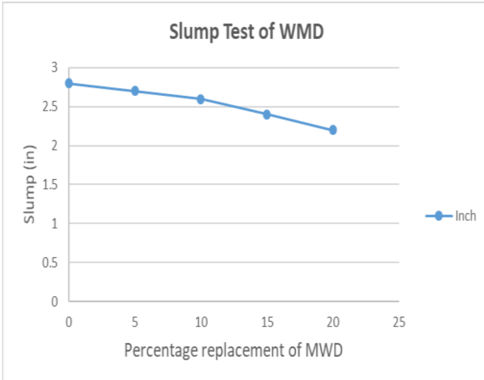
Table 2. SEM analysis of WMD.

Composition	Content (wt. %)
CaO	26.1
SiO_2	10.5
MgO	12.1
Loss in ignition	43.5
K_2O, Na_2O, Fe_2O_3, Al_2O_3	Where generally less than 1% each

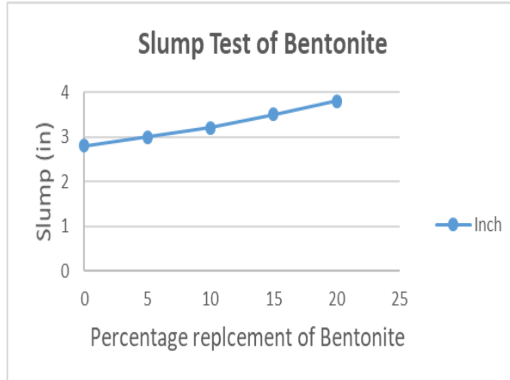
2.5 Slump Tests

The slump test results show that as the percentage of marble dust was increased in the mix, the slump value decreases. Because marble dust doesn't absorb water actually, it entraps it, and as a result, the concrete workability is decreased as shown in Figure 6 (a).

While in the bentonite mix concrete, the slump value was continuously increasing as the percentage of bentonite was increased, the reason is that bentonite particles have the tendency to absorb water thus resulting increasing the workability of concrete as shown in Figure 6 (b).



(a)



(b)

Figure 6. Slump test of WMD and bentonite samples.

3 CONCLUSIONS

Foregoing experimentations show that for initial optimum replacement of cement: the compressive strength and tensile strength decreases with Waste Marble Dust (WMD) and increases with Bentonite; the permeability decreases/improves with WMD and decreases/improves with Bentonite; the slump decreases with WMD and increases with Bentonite.

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