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Evaluation of the Performance of Normal Concrete Produced by Marble Waste

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Abstract: **The marble industry produces a lot of marble waste which is an environmental burden. It is necessary to recycle this waste in the concrete industry. Cement manufacturing is a risk to the environment due to the emission of Co2. The use of marble waste as cement substitution presents environmentally friendly concrete. Five different concrete mixes were prepared. Cement was replaced with marble waste (MW) at the ratios of 0, 5%, 10%, 15%, and 20% by weight. The constant water to cement ratio was 0.5. The compressive strength, the flexural strength, and the splitting tensile strength of concrete made with waste marble powder were recorded at the curing ages of 7, 28, and 56 days. The rate of water absorption and density were evaluated. The slump test was carried out on the fresh concrete to measure its workability. The results were analysed and revealed that mechanical properties of concrete are improving by using MW as a partial replacement of cement. A replacement ratio of 10% by weight of cement with marble waste is an ideal ratio to enhance the mechanical properties of concrete and after this replacement ratio, the mechanical properties of concrete decreased. The workability and the rate of water absorption decreased with the increase in MW replacement ratio. The values of density increased with the increase in MW content compared to the control mix.**

Keywords: Marble waste, compressive strength, flexural strength, rate of water absorption

I. INTRODUCTION

Marble waste is produced from the marble industry and is an environmental problem. The manufacture of cement causes the emission of carbon dioxide. The reusing of marble waste as a substitute for cement offers a solution to the environmental problem. The specific gravity of MW is 2.6 while 3.15 for cement, this reduces the weight of structures. A different percentage of marble waste was used as a substitute for cement. The destructive and non-destructive tests were used for the evaluation of concrete samples. The compressive, tensile, and flexural strengths for samples were recorded at different ages of curing. The results of ultrasonic pulse velocity (UPV) and rebound hammer compared with the values of destructive compressive strength test. The results revealed that the workability decreases because MW absorbs water in the concrete mix. The mechanical properties improve up to 10% replacement level of cement weight. After 10% replacement level, the strengths of concrete decrease because of the lack of cement. The results of the Schmidt rebound numbers agreed with the compressive strength results. The ultrasonic pulse velocity test showed that velocity increases with the increase of the replacement level of MW. This increase is due to the fineness of MW particles [1]. Marble waste was used as partial replacement of cement at the ratios of 0, 5%, 10%, 15%, 20%, 25%, and 30% of cement weight to improve compressive strength and coconut fiber was used at ratios of 0.5%, 1.0%, 1.5%, 2.0%, 2.5%, and 3.0% of cement weight to enhance tensile strength. The compressive, flexural, and splitting tensile strengths were evaluated. The acid attack resistance, carbonation resistance, and water absorption were determined to evaluate durability properties. The results showed that marble waste and coconut fiber decreased the workability of fresh concrete. The mechanical properties of hardened concrete enhanced by MW and coconut fiber up to 20% and 2% replacement ratio of cement weight, respectively. There is a significant improvement in durability properties with partial replacement of cement by marble waste and coconut fiber [2]. Seven different concrete mixes were prepared by partial replacement of cement and sand with MW at ratios of 0%, 10%, and 15% by weight both alone and together. The compressive strength, flexural strength, and splitting tensile strength of concrete produced with marble waste were determined at 7, 28, and 90 days of curing. The durability properties of specimens were studied via ultrasonic pulse wave test, absorption, and sorptivity. The results revealed improvement in the mechanical properties of concrete at specific proportions of marble waste [3]. The objective of the work is to make partial replacement of sand with marble waste in concrete as this mixture will preserve the ecosystem. The concrete mixes were prepared by partial replacement of sand with marble waste of 10%, 20%, 30%, 40%, 50%, and 90% by volume. The compressive strength values were recorded after 7, 28, and 90 days of curing. The tensile strength values, water absorption, and abrasion resistance values were also determined. Feasibility was investigated using slump test, compressive strength test, sorptivity, abrasion resistance, and the cost was calculated. The results showed that a replacement level up to 40% of marble waste by volume gives satisfactory results [4]. The unit weight, workability, compressive strength, splitting tensile strength, and water penetration were determined. The sand was replaced with marble waste at the ratios of 0, 20%, 40%, 60%, and 80% by weight. The constant water to cement ratio was 0.62 for all mixes. The compressive strength, and splitting tensile strength were determined at 14, 28, and 70 days of curing. The results revealed that the workability and unit weight of concrete decreased with a

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decrease in marble waste replacement level. At the replacement level of 40% of sand, the compressive strength had the highest value. Splitting tensile strength was slightly improved at a replacement level of 20% of sand. The permeability decreased with an increase in marble waste replacement level [5]. Mortars samples were prepared by partial substitution of hydrated lime with marble waste at ratios of 0%, 25%, 50%, 75%, and 100%. The results demonstrated the possibility to use MW up to 50% replacement ratio though 100% replacement level was impossible [6]. The basic objective of this investigation is to examine the characteristics of concrete using marble slurry as binding material in proportions 5%, 10%, 15%, 20%, 25%, and 30% by weight of cement. The results observed from the various studies depict that replacement of marble slurry to a certain extent enhances strength properties of the concrete but simultaneously decreases the slump value with the increase of replacement level of marble slurry [7]. Four concrete mixes were prepared by substituting the fine sand with MW at ratios of 0, 25, 50, and 100% by weight. The results indicated that the replacement of the fine material passing through a 0.25 mm sieve at specific ratios by MW improved compressive strength. Marble waste is produced during the manufacture of marble and causes pollution in the environment. Recycling marble waste will prevent this pollution particularly in largely producing areas of marble. Recycling marble waste also reduces the consumption of natural resources because MW is utilized as a partial replacement of sand in normal concrete [8]. Three concrete mixes were prepared by partial substitution of sand, gravel separately and combined with marble waste. The water to cement ratio was constant in concrete mixes. The results indicated that the mechanical properties of concrete samples involved MW agree with the concrete production specifications and partial replacement of sand and gravel by MW improves the strength of concrete up to 75% replacement ratio [9]. The characteristics of concrete containing marble powder and scoria were investigated. The ratios of marble: scoria were 2:1, 1:1, and 1:2. The combined fraction of marble powder and scoria in concrete was increased from 33 to 67 and 100%, respectively. The chemical properties of marble powder revealed that it consisted of CaO and SiO2 and scoria consisted of SiO2, Al_2O_3, Fe_2O_3, CaO, and MgO. The compressive strength improved with partial replacement of sand by marble waste and scoria comparing the compressive strength of the control mix. The compressive strength and workability decreased with an increase in marble waste replacement level and scoria. The concrete composed of marble waste and scoria saves up to 4.5% of the concrete cost and the weight of concrete decreases up to 5%. The best replacement ratios for marble waste and scoria were 22.5%, and 44.5%, respectively [10].

II. WORK OBJECTIVE

This study aims to evaluate the performance of normal concrete containing MW as a partial substitution of cement.

III. EXPERIMENTAL WORK

Materials

Cement: The studies were conducted on cement 42.5 N OPC (CEM-I) conforming to the specifications specified in Egyptian Standard requirements (4756-1/2007).

Fine Aggregate: The fineness modulus of the used sand was 2.85 conforming to the specifications specified in Egyptian Standard requirements (ECP.1109/2002).

Coarse aggregate: Coarse aggregate used in this investigation was dolomite whose maximum nominal size was 19 mm.

Water: Potable water.

Plasticizer: Sikament- 163M is used as a highly effective water-reducing agent.

Marble waste: Marble powder from the marble industry was obtained.

TABLE I: THE CHEMICAL CHARACTERISTICS OF MARBLE POWDER

Chemical characteristics%	**Values (%)**
SiO_2	7.27
Al_2O_3	0.11
Fe_2O_3	.45
CaO	50.87
MgO	0.84
SO_3	0.37

TABLE II: THE PHYSICAL CHARACTERISTICS OF MARBLE WASTE

Physical characteristics	
Color	White
LOI (%)	38.33
Fineness (m^2/kg)	492
Loose bulk density (kg/m^3)	1375
Specific gravity	2.71

Concrete Mixes

Five concrete mixes included a control mix have been prepared by using a different percentage of marble waste as a partial replacement of the cement. The water to binder ratio was 50%. The used dosage of Sikament- 163M was 2% of the total cementitious materials weight. Cement was replaced with MW at the proportions of (0%, 5%, 10%, 15%, and 20%) by the weight of cement. Mixture proportions of concrete mixes are shown in TABLE III.

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TABLE III. MIXTURE PROPORTIONS (kg/m^3)

Mix ID	Marble waste MW	Water	Cement	Coarse aggregate	Fine aggregate	Plasticizer
Control (C)	-	175	350	1228	614	7
M1(5%MW)	17.5		332.5			
M2(10%MW)	35		315			
M3(15%MW)	52.5		297.5			
M4(20%MW)	70		280			

IV. TESTING

Fresh Concrete

Slump Test

A slump test was carried out for fresh concrete to determine the workability of a concrete mixture prepared at the laboratory. It is considered the simplest workability test for concrete because it is low cost, and gives results immediately. The slump is achieved according to the procedures in ASTM C143 [11].

Hardened Concrete

Compressive Strength Test

The compressive strength test was conducted on all the concrete mixes at the curing ages of 7, 28, and 56 days. The cube specimens with dimensions 150*150*150 mm were tested for determining compressive strength. All samples were cured in water. Three samples were prepared for each age. All specimens were tested in the compression testing machine. The capacity of the compression machine was 1500 kN [12].

Flexural Strength Test

A flexural strength test was conducted on beams with dimensions 100*100*500 mm at the curing ages of 7, 28, and 56 days on a bending testing machine. Three samples were prepared for each age. The flexural strength was determined for different mixes [13, 14].

Splitting Tensile Strength

The cylinder specimens were tested for determining splitting tensile strength with dimensions of 150*300 mm. Three samples were prepared for each age. The splitting tensile strength was recorded for 7, 28, and 56 days. The tensile strength was calculated for different mixes [15].

The Rate of Water Absorption

The cube specimens with dimensions 100*100*100 mm were tested for determining the rate of water absorption at the age of 7, 28, and 56 days of curing. The cube specimens were placed in an oven at a temperature of 100°C for 24 hours. After 24 hours, the samples were removed from the oven and cooled in the air. The dry mass (A) was determined. Specimens were submerged in water for 48 hours. After 48 hours, the samples were dried and wet mass (B) was calculated. The rate of water absorption was calculated from the following equation [16].

Absorption after immersion%= [(B-A)/A] *100

Density

The cube specimens of size 150*150*150 mm were used to determine the density. The weight of the cubes was determined After 28 days of curing with water. The density was calculated for all concrete mixes[17].

V. RESULTS & DISCUSSION

Fresh Concrete

Slump Test

The workability of fresh concrete for all mixtures was evaluated by slump test. The results are summarized in Fig. 1. The higher the replacement rate of MW, the lower the slump value. This decrease in the slump values is due to the MW particles are absorbing water because their increased surface area, which leads to lower workability.

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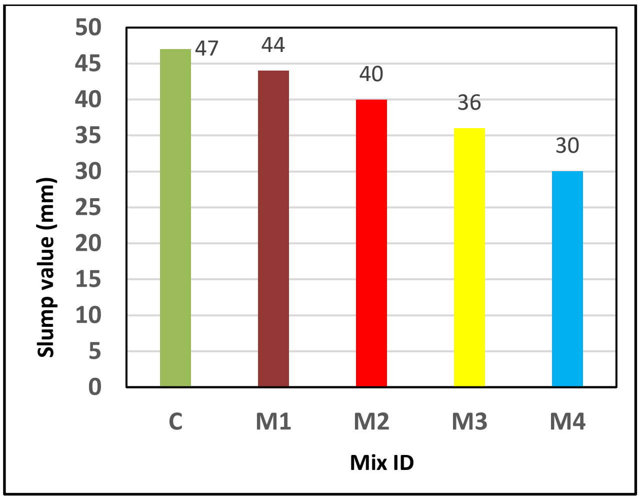

Fig. 1. Slump values for mixes

Hardened Concrete
Compressive Strength Test

The obtained values of concrete compressive strength according to the different percentage MW are summarized in TABLE IV and Fig. 2. The higher the percentage of marble replacement, the higher the compressive strength, up to 10% replacement ratio. The results revealed the highest compressive strength for mix M2. It was 10.4%, 9.03%, and 9.4% compared to the compressive strength of the control mix at 7, 28, and 56 days curing periods, respectively. The increased compressive strength was due to pore filling achievement by MW because of the increased fineness of MW particles which leads to an increase in the density of the concrete mixture. MW particles have higher absorption of water which leads to a decrease in the ratio of water to cement and thus increases the compressive strength. Further replacement of cement up to 10% with MW resulted in decreased compressive strength. This is due to reduced binder content and dilution of available cement content.

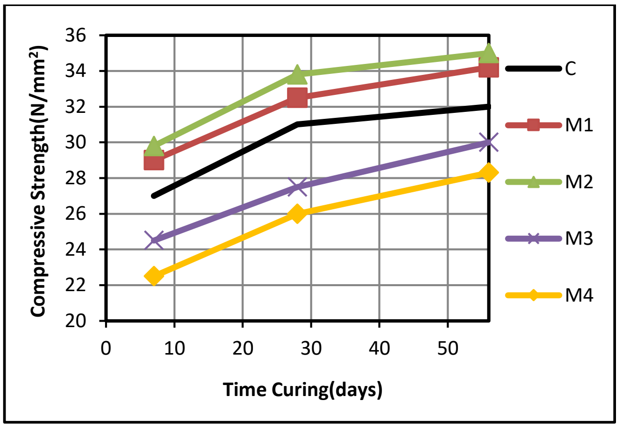

Fig. 2. Compressive strength values

TABLE IV. COMPRESSIVE STRENGTH (N/ mm ^{2}) FOR MIXES

Mix ID	Compressive strength Ages		
	7 days	28 days	56days
C	27	31	32
M1	29	32.5	34.2
M2	29.8	33.8	35
M3	24.5	27.5	30
M4	22.5	26	28.3

Flexural Strength Test

The flexural strength test was evaluated. The obtained results of the flexural strength are indicated in TABLE V. and Fig. 3. It had the same trend of compressive strength and improved until the substitution ratio of marble waste up to 10% addition and beyond 10% it decreases. The results revealed the highest flexural strength for mix M2. It was 7.5%, 8%, and 7.06% compared to the flexural strength of the control mix at 7, 28, and 56 days curing periods, respectively. The improvement of results was due to low porosity for blended cement concrete incorporating marble powder as a micro-fine filler product.

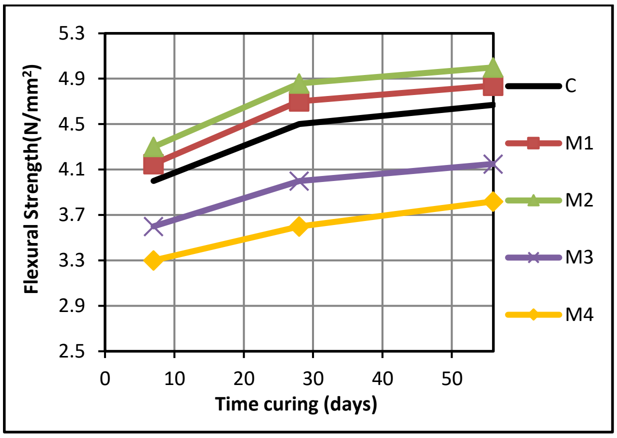

Fig. 3. Flexural strength values

TABLE V. FLEXURAL STRENGTH (N/MM ^{2}) FOR MIXES

Mix ID	Flexural strength Ages		
	7 days	28 days	56days
C	4	4.5	4.67
M1	4.15	4.7	4.84
M2	4.3	4.86	5
M3	3.6	4	4.15
M4	3.3	3.6	3.82

Splitting Tensile Strength Test

It can be observed from TABLE VI & Fig. 4. , on partially replacing 10% cement with marble powder, at the curing ages of 7, 28, and 56 days, splitting tensile strength increased by 20.45%, 18%, and 22.3% respectively. The splitting tensile strength was also improved up to 10% replacement ratio and afterward, it decreases. It can be

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noticed that due to a decrease in porosity there is a significant increase in the splitting tensile strength.

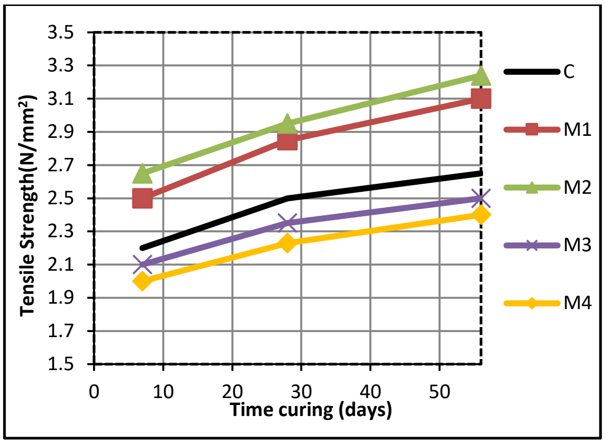

Fig. 4. Splitting tensile strength values

TABLE VI. SPLITTING TENSILE STRENGTH (N/mm^2) FOR MIXES

Mix ID	Splitting tensile strength		
	Ages		
	7 days	28 days	56days
C	2.2	2.5	2.65
M1	2.5	2.85	3.1
M2	2.65	2.95	3.24
M3	2.1	2.35	2.5
M4	2	2.23	2.4

The Rate of Water Absorption Test

Rates of water absorption results for concrete after 7, 28, and 56 days of curing are presented in Fig. 5. The rate of water absorption reduced for all concrete mixtures compared to the absorption rate of the control mixture. The mix M2 achieved the smallest absorption rate at 56 days of curing; it decreased to 2% compared to the control mixture which its rate of water absorption was 2.7%. This is due to the fineness of MW particles and the interlocking of MW within the cement matrix.

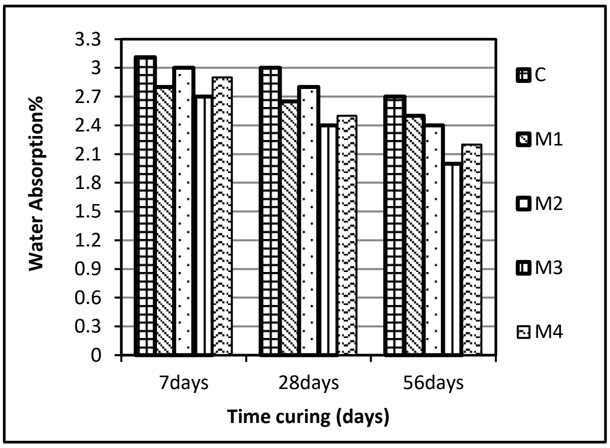

Fig. 5. The rate of water absorption for mixes

Density Test

The density of the concrete after 28 days of curing is summarized in Fig. 6. The values of density increased compared to the control mix. The mix M2 had the maximum density compared to the density of the control mix because of the high surface area of the MW that fills voids as a result the density of the mix increases.

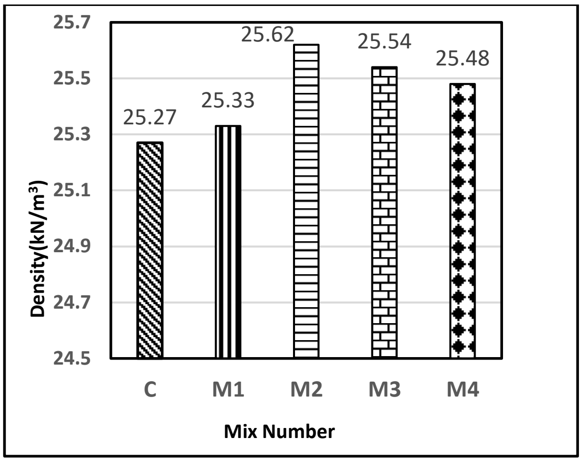

Fig. 6. The density for mixes

CONCLUSIONS

Based on results analysis, it can be concluded that:

1. The marble waste enhances compressive strength up to 10% a replacement ratio by weight of cement and beyond 10% it decreases.
2. The flexural strength and splitting tensile strength have the same trend as the compressive strength. They improved until the substitution ratio of marble waste up to 10% addition and afterward it decreases.
3. Workability decreased with the increase in MW replacement ratio. This is due to MW particles are absorbing water because of their increased surface area, which leads to lower workability.
4. The rate of water absorption reduced by increasing the replacement ratio of MW because of the fineness of MW particles and the interlocking of MW particles within the cement matrix.
5. The values of density increased with the increase in MW content compared to the control mix because of the high surface area of the MW that fills voids as a result the density of the mix increases.

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