AN EXPERIMENTAL APPROACH TOWARDS PARTIAL REPLACEMENT OF CEMENT WITH MARBLE POWDER

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Abstract:

This research article represents various experimental parameters in the analysis of partial replacement of cement with marble powder in percentile substitution. The chemical compositions shows higher % of CaO, while loss of ignition found 43.21 during the analysis. The cubes were prepared by replacing cement with marble powder (MP), from 0 %, 10 %, 20 % and 30 % respectively. Several tests such as density, slump cone, split tensile strength, flexural strength and compressive strength were performed. From the test results obtained, it is recommended that the replacement of cement by the MP waste up to 10% is favorable for the concrete making without adversely affecting the structural behavior of concrete. The concrete improved its compressive strength, split strength and flexural strength respectively by replacing cement with marble powder.

Key words- Marble Powder, Cement, compressive, flexural, split tensile strength

I. Introduction

Innovations are much needed to meet the increasing demand for new and quality materials. Concrete is an essential building material that is widely used in the construction of infrastructure such as buildings, bridges, highways, dams and many other facilities. The concrete made by using cement, coarse aggregate, fine aggregate and water. The advancement of concrete technology can reduce the consumption of natural resources and energy sources and lessen the burden of pollutants on environment. There is a limit on the availability of natural aggregate and minerals used for making cement, and it is necessary to reduce energy consumption and emission of carbon dioxide resulting from construction processes, solution to this problem are sought through usage of MDP as partial replacement of Portland slag cement. Presently large amounts of marble dust are generated in natural stone processing plants with an important impact on environment and humans. In India, the marble andgranite stone processing is one of the most thriving industry the effects if varying marble dust contents on the physical and mechanical properties of fresh and hardened concrete have been investigated.

Waste marble powder is generated as a by-product during cutting of marble. The waste is approximately in the range of 20% of the total marble handled.

The environmental problems attributed by waste marble powder impose threat to ecosystem, physical, chemical and biological components of environment. It is therefore very important to reuse the waste marble powder which shall solve most of the problem. This project describes the feasibility of using the waste marble powder as a partial replacement of cement. This replacement helps to increase the strength of concrete and reduce the quantity of cement in concrete.

Utilization of marble waste in various industrial sectors, especially the construction, agriculture, glass and paper industries would help to protect the environment. The worldwide consumption of cement in concrete production is very high, so maximum areas are facing acute shortage of good quality of cement. The main objective of the present work is to investigate the usability of the marble powder as partial replacement of cement in concrete. Effect of waste marble powder in concrete has been investigated by experimental tests on conventional concrete without marble powder and with varying quantities of marble powder by replacing the cement partially.

The marble is a metamorphic rock which is formed during metamorphism of limestone. Marble is one of the most important materials used in buildings since ancient times, especially for decorative purposes. However its powder has bad effects on the environment, soil, water andhealth problems. Marble powder is produced from processing plants sawing and polishing of marble blocks. Some factories have water recycling plants containing flocculation tank and filterpress unit. About 25% of the processed marble is turn into dust or powder form about 7,000,000 tons of marble have been produced in the world. Disposal of the marble powder material of the marble industry is one of the environmental problems worldwide today.

II. Objectives

The Main Objectives of this research study is to study the influence of partial replacement of cement with marble powder, and to compare it with the compressive, flexural and tensile strength of ordinary M20 concrete. We are also trying to find the percentage of marble powder replaced in concrete that makes the strength of the concrete maximum.

III. Material study

A] Concrete

Concrete is the important material in the construction other than steel and timber. The word concrete originates from the Latin word "Concretus", which means to grow together. Concrete is the material which is largely consumed in world. It plays very important role in civilengineering work. A composite material that consists essentially of a binding medium, such as a mixture of Portland cement and water, within which are embedded particles or fragments of aggregate, usually a combination of fine and coarse aggregate.

Concrete is by far the most versatile and most widely used construction material worldwide. It can e engineered to satisfy a wide range of performance specifications, unlike other building materials, such as natural stone or steel, which generally have to be used as they are. Because the tensile strength of concrete is much lower than its compressive strength, it is typically reinforced with steel, in which case it is known as reinforced concrete.

B] Factors affecting strength of concrete

Concrete strength is affected by many factors, such as quality of raw materials, water/cement ratio, coarse/fine aggregate ratio, age of concrete, compaction of concrete, temperature, relative humidity and curing of concrete.

i. Cement:-

A cement is a binder, a substance use in construction that sets and hardens and can bind other materials together. Ordinary Portland cement of 43-grade of ACC brand was used in this project conforming to IS: 8112-1989. It was fresh and without any lumps. The most important types of cement are used as a component in the production of mortar in masonry, and of concrete, which is a combination of cement and an aggregate to form a strong building.

There are many different kinds of cements. In concrete, the most commonly used is Ordinary Portland cement, a hydraulic cement which sets and hardens by chemical reaction withwater and is capable of doing so under water. Cement is the "glue" that binds the concrete ingredients together and is instrumental for the strength of the composite.

ii. Chemical composition of cement:-

The raw material used for the manufacture of cement consists mainly of lime, silica alumina and iron oxide. These oxides interact with one another in the kiln at high temperature toform more complex compounds. The relative proportions of these oxide compositions are responsible for influencing the various properties of cement, in addition to rate of cooling and fineness of grinding.

Table No. 1: Approximate oxide composition limits of ordinary Portland cement

Oxide	Content in %
CaO	60 -67
SiO_2	17 -25
Al_2O_3	3 – 8.0
Fe_2O_3	0.5 – 6.0
MgO	0.1 – 4.0
Alkalis (K_2O, Na_2O)	0.4 – 1.3
SO_3	1.3 – 3.0

iii. Aggregate

Aggregates are the important constituents in concrete. They give body to the concrete reduce shrinkage and effect economy. Earlier aggregates were considered as chemically inert materials but now it has been recognized that some of the aggregates are chemically active and also that certain aggregates exhibit chemical bond at the interface of aggregate and paste The mere fact that the aggregates occupy 70~80 per cent of the volume of concrete, their impact on various characteristics and properties of concrete is undoubtedly considerable. To know more about the aggregates this contributes major volume in concrete.

iv. Marble Dust Powder

Marble is a metamorphic rock resulting from the transformation of a pure limestone. The purity of the marble is responsible for its colour and appearance: it is white if the limestone is composed solely of calcite (100% $CaCO_3$). Marble is used for construction and decoration; marble is durable, has a noble appearance, and is consequently in great demand. Chemically, marbles are crystalline rocks composed predominantly of calcite, dolomite or serpentine minerals. The other mineral constituents vary from origin to origin. Quartz, muscovite, tremolite, actinolite, micro line, talc, garnet, osterite and biotite are the major mineral impurities whereas SiO_2, limonite, Fe_2O_3, manganese, $3H_2O$ and FeS_2 (pyrite) are the major chemical impurities associated with marble. The main impurities in raw limestone (for cement) which can affect the properties of finished cement are magnesia, phosphate, leads, zinc, alkalis and sulphides. Leaving these waste materials to the environment directly can cause environmental problem.

During some the industrial process stone slurry generated during processing corresponds to around 20% of the final product from stone industry. Therefore the scientific and industrial community must commit towards more sustainable practices. There are several reuse and recycling solutions for this industrial by-product, both at an experimental phase and in practical applications.

Table No.2: Chemical composition of marble powder

Oxide compounds	Marble powder (%)		Oxide compounds	Marble powder (%)
CaO	36.44		SO3	0.12
SiO2	8.86		Na2O	0.78
Al2O3	1.79		K2O	0.74
MgO	8.95		Fe2O3	1.12
LOI Loss of Ignition: 41.34				

v. Water

Water is an important ingredient of concrete as it actively participates in the chemical reaction with cement. Since it helps to form the strength giving cement gel, the quantity and quality of water is required to be looked into very carefully. Since quality of water affects the strength, it is necessary for us to go into the purity and quality of water. The pH value of water should be in between 6.0 and 8.0 according to IS 456-2000.

IV. Specific Gravity test

In concrete technology, specific gravity of aggregate of in design calculations of concrete mixes. With the specific gravity of each constituent known, its weight can be converted into solid volume and hence a theoretical yield of concrete per unit volume can be calculated. IS :2386(Part III)1963 is refer to perform this test. During the tests the result of the specific gravity of coarse aggregate is 2.56.

V. Bulk density test

When dealing with aggregates it is important to know the voids that presents between the aggregate particles, so that we decide whether to fill them with finer aggregate or with cement paste. We all know that the Density we often deal with equals the mass divided by the volume, when using this law to measure the density of aggregates the volume we use in the volume of aggregate +the volume of the voids and in this case we get a new quantity called the Build Density. Density = Mass of the aggregate / Volume of aggregate particles with voids between them. This build density is used to convert

quantities by mass to quantities by volume. Bulks density depends on several factors: Size distribution of aggregates, shape of particles and degree of compaction. There are two methods this quantity is measured by Loose method & Compaction method. During the tests the result of the Dry loose bulk density found 1.72gm/ml.

VI. Water Absorption Test

Some of the aggregates are porous and absorptive. Porosity and absorption of aggregate will affect the water/cement ratio and hence the workability of concrete. The porosity ofaggregate will also affect the durability of concrete when the concrete is subjected to freezing and thawing and also when the concrete is subjected to chemically aggressive liquids. This test helps to determine the water absorption of aggregates as per IS:2386 (Part III)- 1963. For this test a sample not less than 1000g should be used. During the tests the water absorption of coarse aggregate is found 2% and for fine aggregate it was found 2.83%.

VII. Bulking of Sand & Crushing test

Free moisture forms a film around each particle. This film of moisture exerts what is known as surface tension which keeps the neighboring particles away from it. Similarly, the force exerted by surface tension keeps every particle away from each other. Therefore, no point contact is possible between the particles. This causes bulking of the volume. It is interesting to note that the bulking increases with the increase in moisture content unto a certain limit and beyond that the further increase in the moisture content results in the decrease in the volume andat a moisture content representing saturation point, the fine aggregate shows no bulking. IS : 2386(Part III)1963 is refer to perform this test. During the tests the result of the aggregate impact value was found to be 6.06% and the aggregate crushing value is 19.63%.

VIII. Test on cement

i. Specific gravity of cement

In concrete technology, specific gravity of cement is made use of in design calculation of concrete mixes. With the specific gravity of each constituent known, its weight can be convertedinto solid volume and hence a theoretical yield of concrete per unit volume can be calculated. The specific gravity of cement was found 3.15.

ii. Fineness

Fineness or particle size of Portland cement affects hydration rate and thus the rate of strengthen again. The smaller the particle size greater will be the surface area-to-volume ratio and thus more area available for water-cement interaction per unit volume. Following are two methods used for finding out the fineness modulus of cement. The fineness of cement was found to be 5%.

iii. Consistency of cement

For finding out initial setting time, final setting time and soundness of cement, and strength a parameter known as standard consistency has to be used. The standard consistency of a cement paste is defined as that consistency which will permit a Vicat plunger having 10 mm diameter and 50 mm length to penetrate to a depth of 33-35 mm from the top of the mould.

IX. Replacement of cement by marble powder (0 to 30%):

During the experimental analysis following results were observed while replacement of cement by marble powder (0 to 30%):

i. The normal consistency of a given sample of cement:

1. At 0% replacement of marble powder is 31%.
2. At 10% replacement of marble powder is 32%.
3. At 20% replacement of marble powder is 33%.
4. At 30% replacement of marble powder is 32%.

ii. Setting time of cement

When water is mixed to cement, a reaction start, this reaction is known as hydration. Due to this reaction the mixture of cement of water starts changing from fluid state to a solid state. This is called setting of cement. In the first few minute the setting action is more predominant and after some time hardening action becomes rapid.

It is defined as period of elapsing between the time of water added to the cement and the time when the 1mm sq. section needle fails to penetrate cement block to depth of about 5mm from the bottom of the mould. Generally the initial setting time of cement is not less than 30min.

X. Experimental results:

a) The initial setting tie of cement sample is found to be 30 min.

b) The final setting time of cement sample is found to be 500 min.

XI. Test on marble powder

Specific gravity & Fineness :-

Specific gravity of marble powder is used in design calculation of concrete mixes. With the specific gravity of each constituent known, its weight can be converted into solid volume and hence a theoretical yield of concrete per unit volume can be calculated. The specific gravity of marble powder was found to be 2.25 & the fineness of marble powder was found to be 7%.

XII. Mix design:

It is not possible to predict the strength and other concrete properties solely based on the properties and proportions of the mix components. Therefore, mixes are designed on an empirical basis, often with the help of trial mixes. The objective of the mix design is to assure that the product has specified properties in both the fresh and hardened state. The most important mix design variable is the weight ratio between water and cement, referred to as the w/c ratio. Any excess water creates pores which, together with any air pores, do not contribute to the material strength. The result is a drastic decrease in strength as a function no fine creasing the w/c ratio .On the other hand, too low w/c ratios cause poor workability of the concrete. For practical reasons, the water cement ratio varies between 0.4 and 0.6. The other important mix design variables are the cement-to- aggregate ratio and the one-to-coarse aggregate ratio. Also, the maximum aggregate size is of importance. And since cement is the most expensive bulk ingredient, the mix design will generally aim at the least amount of cement necessary to achieve the design objectives. In the current study OPC 43grade cement were used with a workability 100 mm, minimum cement content 300 kg/m3, maximum WCR 0.5, manual placing etc.

i. Objectives of Mix design:

The purpose of concrete mix design is to ensure the most optimum proportions of the constituent materials to fulfill the requirement of the structure being built. The main objective of this mix design is to achieve the designed / desired workability, strength, durability and economy in the plastic stage.

ii. Selection of water-cement ratio

Maximum water-cement ratio permitted by IS is 0.55, hence on the basis of experience, 0.5 WCR was adopted.

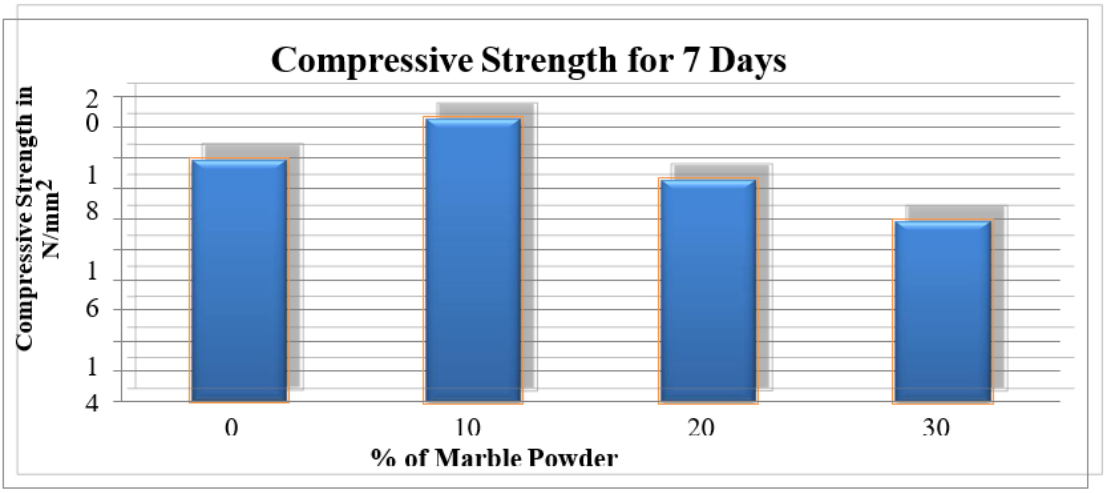
XIII. Experimental results:

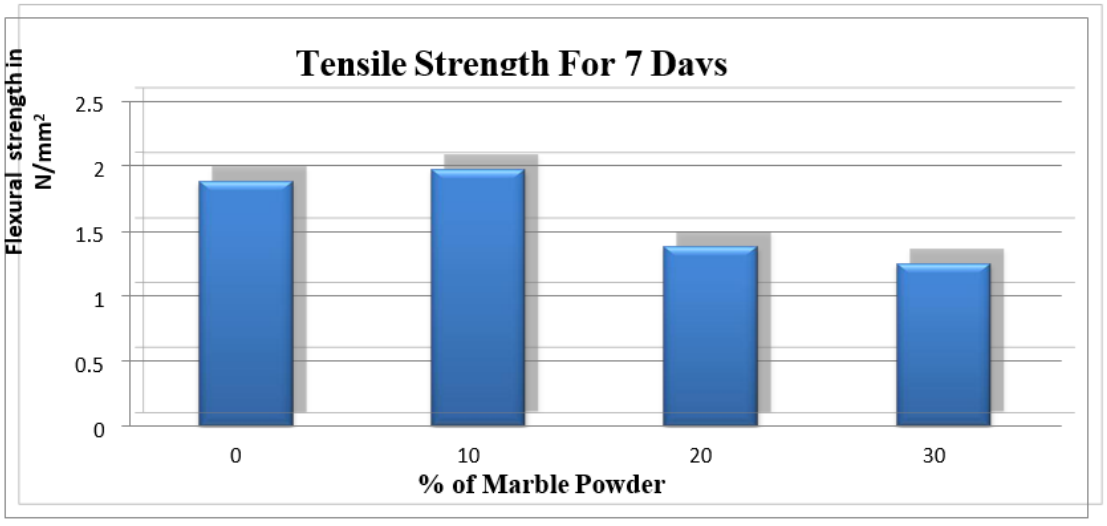
i. Slump Cone Test Value

Table No. 3: Slump Cone Test Value

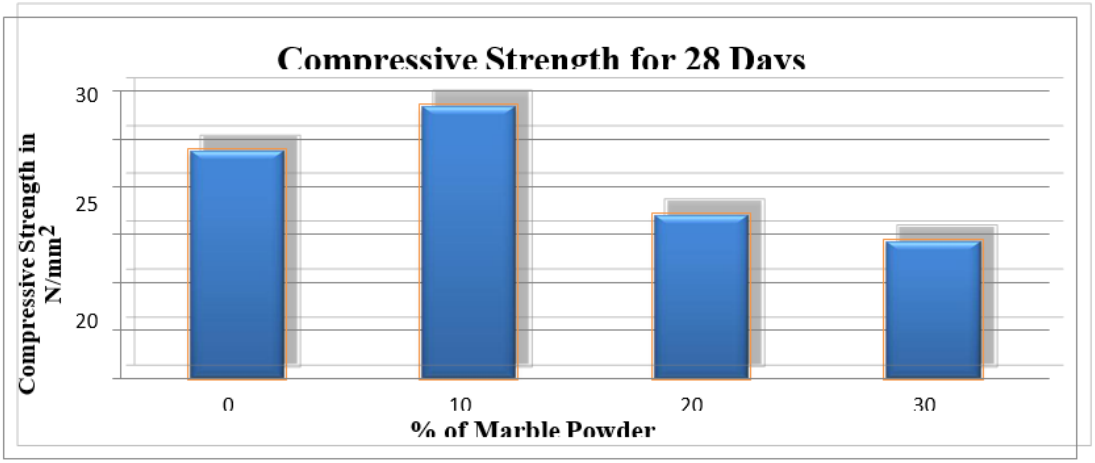
W/C ratio	Replacement of marble powder in %	Slum value in mm
0.5	0%	98
	10%	92
	20%	98
	30%	100

ii. Compression Test:

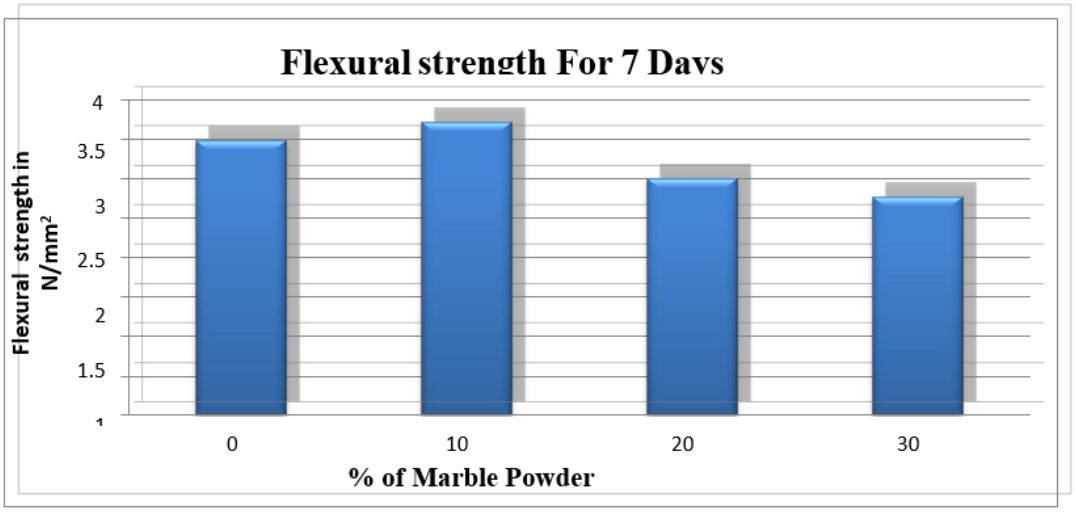




iii. Split Tensile Test:



iv. Flexural Strength:



XIV. CONCLUSIONS:

1. The Compressive strength of Concrete increases up to 10% replacement of cement by marble dust powder and further increasing of percentage of marble dust powder leads to decrease in compressive strength of concrete. The addition of marble dust powder (10% by weight of cement) into the concrete improved its compressive strength by 15.86 % & 28.69 % respectively at 7 & 28 days.

2. The split tensile strength of concrete increases up to 10% replacement of cement by marble waste powder. The split tensile strength of concrete improved by 7 % and 9 % for M20 grade concrete respectively after 7 & 28 days. As the percentage of marble powder increased the split tensile strength of concrete was reduced.

3. The flexural strength of concrete increase up to 10% replacement of cement by marble waste powder. The flexure tensile strength of concrete improved by 9.8 % and 24 % for M20 grade of concrete (10% by weight of cement) respectively after 7 & 28 days. As thepercentage of marble powder increase the flexural strength of concrete was reduced.

4. The results showed that the substitution of 10% of the cement content by marble stone dust induced higher compressive strength, higher splitting tensile strength, and improvement of properties related to durability.

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