Replacement of Fine Aggregates by Mixture of Ceramic and Marble Powder in Concrete

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***Abstract*— This paper investigates the effect on the compressive strength and tensile strength of concrete by partial and full replacement of fine aggregate by mixture of ceramic and marble powder in equal proportions. The reason for using ceramic and marble as fine aggregates is that both of them are waste materials in the form of broken insulators and marble chippings respectively, with marble powder also possessing cementitious properties. For conducting the tests, initially a portion of conventional fine aggregate was replaced by equal proportions of ceramic and marble powder till all of fine aggregate was replaced. The results obtained from various tests conducted on concrete of grade M25 are analyzed and ultimately compared to that of the M25 grade. It was observed that with the increase in the percentage of ceramic and marble powder the compressive and tensile strength of the concrete mix increased, with its maximum value at full replacement of conventional fine aggregate by ceramic and marble powder.**

Keywords: Compressive strength, Split cylinder test, Slump test, Water-Cement ratio, Ceramic and marble mixture, Mix design.

I. INTRODUCTION

Ceramic electrical insulators are used in electrical equipments to support and separate electrical conductors without allowing current through them. More often or not these ceramic insulators fail by many causes like cracking of insulators, defective insulation material, porosity in insulating material, flashover across insulator, etc. Because of failure of these insulators they can no longer be used and are kept as waste materials. In the same manner marble chippings produced from construction sites and cutting processes near marble quarries. Marble waste leads to serious environmental problems. So, using ceramic insulators and marble chippings as a replacement of fine aggregate in concrete will solve the problem of disposal of wastes as well as will make the construction economical by utilizing waste materials. In order to use ceramic and marble mixture as fine aggregate in concrete these materials need to be grinded to obtain there powdered form. Concrete of grade M25 was prepared at a water cement ratio of 0.45 and part of its fine aggregate was replaced by ceramic-marble mixture in equal proportions starting from 20% (10% ceramic + 10% marble) in specimen B1 for compressive strength test and specimen C1 for Split cylinder test. Further the percentage of ceramic-marble mixture was increased to 40% (20% ceramic +20% marble) for specimen B2 and C2,60% for specimen B3 and C3,80% for specimen B4 and C4,and finally 100% for specimen B5 and C5.

For conducting compressive strength test specimens were prepared in the form of cubes and in the form of cylinders for split cylinder test. Specimens were prepared by hand mixing; casted, cured. Workability of concrete was measured by carrying out the slump test of fresh concrete mix. The respective tests were carried out at the age of 7 days and 28 days. Moreover, compression testing machine was (CTM) was used for carrying out compression and split cylinder tests. There was increase in compressive and tensile strength with the increase in percentage of ceramic-marble mixture. The maximum value of compressive strength and tensile strength was obtained for specimen C5 and S5 respectively. However, there was decrease in slump value as the percentage of ceramic-marble mixture was increased i.e. slump value was minimum for specimen C5 and S5 and maximum for C1 and S1.

II. MATERIALS USED

A. Cement

Cement is a powdery binding substance made by calcining lime and clay, mixed with water to form mortar or mixed with sand, gravel and water to make concrete. Cement is one of the most ingredients of concrete. Portland cement is the most common type of cement in general use around the world, used as a basic ingredient of concrete, mortar, stucco and most non-specialty grout. The most common use for Portland cement is in the production of concrete. Concrete is a composite material consisting of aggregate (gravel and sand), cement, and water. Ordinary Portland cement of grade 53 with 32% normal consistency conforming to IS: 12269-1987. Initial and final setting time of cement was found to be 110 minutes and 290 minutes respectively. Specific gravity and Fineness modulus of cement was 3.14 and 2.9% respectively.

TABLE I. PHYSICAL PROPERTIES OF CEMENT

Name of cement	Ambuja cement
Grade of cement	53 OPC
Consistency	32%
Initial setting time	110 minutes
Final setting time	290 minutes
Sp. Gravity	3.14
Fineness Modulus	2.9%

B. Sand

Sand is a naturally occurring granular material composed of finely divide rocks and mineral particles. It is defined by size being finer than gravel and coarser than slit. River sand locally available confirming to grading zone III of IS: 383-1970 was used in the study. Specific gravity of sand was found out to be 2.605. The composition of sand varies, depending on the local rock sources and conditions, but the most common constituent of sand in inland continental settings and non-tropical coastal settings is silica (silicon dioxide), usually in the form of quartz.

TABLE II. PHYSICAL PROPERTIES OF SAND

Grading Zone	Zone III conforming to IS : 383-1970
Sp. Gravity	2.605

C. Coarse Aggregate

Coarse aggregate conforming to the IS: 383-1970 was used in the form of crushed angular stone. Coarse aggregate passing through the 20mm sieve and retained on 4.75mm sieve was used. For better workability, graded Aggregates of 20mm and 10mm were used. Specific gravity of 20mm and 10mm aggregates was found to be 2.885 and 2.912 respectively.

TABLE III. PHYSICAL PROPERTIES OF COARSE AGGREGATE

Sp. Gravity of 20mm aggregates	2.885
Sp. Gravity of 10mm aggregates	2.912
Sp. Gravity of combined aggregates	2.899

D. Ceramic

Ceramic materials are inorganic, non-metallic materials made from compounds of a metal and a non-metal. They are mainly made of clay and hardened by very high temperature. . Ceramic materials are brittle, hard, and strong in compression, weak in shearing and tension. Ceramic materials are found in the form of insulators, crockery, showpieces, roof tiles, tableware, disc brakes, etc. A less technical way to define failure is to say that an insulator has failed whenever it is removed from service either because of degradation revealed by inspection or because of unsatisfactory service experience. These insulators fail by radial cracking, pin corrosion, flashover, brittle facture, spontaneous shattering, etc. After failure these insulators become waste and useless. In this study ceramic was collected from a local grid station in the form of broken insulators. The ceramic insulators were in the form of pin and suspension insulators and thus needed to be brought to the powdered form through grinding.

Fig. 1. Ceramic wastes in the form of insulators

Fig. 2. Ceramic wastes in the form of insulators.

E. Marble

Marble is a rock resulting from metamorphism of sedimentary carbonate rocks most commonly limestone or dolomite rocks. Marble is an extremely hard, metamorphic stone composed of calcite(CaCO3). It is formed as a result of recrystallization of limestone under the intense pressure and heat of geological processes. Compressive strength of marble is in the range of 115 N/mm^2. Presently large amounts of marble dust are generated in natural stone processing plants with an important impact on environment and humans. Marble was collected from a local construction site in the form of chippings and broken pieces. They were also grinded to the desired powdered form. Due to marble dust, it proved to be very effective in assuring very good cohesiveness of mortar and concrete.

Fig. 3. Marble waste collected from construction site.

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F. Water

Potable water was used for mixing and curing of specimens. Water used was free from suspensions and other impurities. pH value of water was within the limits as prescribed by IS: 456-2000 i.e. not less than 6. Water serves the following purposes. To wet the surface of aggregates to develop adhesion because the cement pastes adheres quickly and satisfactory to the wet surface of the aggregates than to a dry surface. To prepare a plastic mixture of the various ingredients and to impart workability to concrete to facilitate placing in the desired position and Water is also needed for the hydration of the cementing materials to set and harden during the period of curing. The quantity of water in the mix plays a vital role on the strength of the concrete. Some water which have adverse effect on hardened concrete. Sometimes may not be harmless or even beneficial during mixing. So clear distinction should be made between the effect on hardened concrete and the quality of mixing water. The common specifications regarding quality of mixing water is water should be fit for drinking. Such water should have inorganic solid less than 1000 ppm. This content lead to a solid quantity 0.05% of mass of cement when w/c ratio is provided 0.5 resulting small effect on strength.

III. MIXING AND CASTING

A. Concrete Mix Design

In this study, M25 grade was used. A standard M25 was prepared according to IS: 10262-2009, the various components Cement: Fine Aggregate: Coarse Aggregate were calculated as (1:1.6:2:97) by adopting water-cement ratio of 0.45.The mix was prepared by hand mixing. Cement content of 382 kg/m^3 was calculated which is greater than 300 kg/m^3 as prescribed by IS: 456-2000.Five trial mixes were prepared by varying percentage of fine aggregate by replacing it with ceramic and marble mixture.

TABLE IV PROPORTIONING OF TRIAL MIXES

Trial mix	Cement (%) (kg)	Sand (%) (kg)	Ceramic (%) (kg)	Marble (%) (kg)	Coarse Agg .(%) (kg)	W/C ratio
B1	100	80	10	10	100	0.45
B2	100	60	20	20	100	0.45
B3	100	40	30	30	100	0.45
B4	100	20	40	40	100	0.45
B5	100	0	50	50	100	0.45

B. Mixing of Ingredients

Hand mixing was employed for the study; hand mixing is mainly desirable for small concrete works. As mixing by hand is not thorough and efficient 10 percent more cement was added to cater for the inferior concrete produced by this method. Mixing was done on a steel tray by using masonry trowel. A uniform mixture was produced by turning dry mixture over and over again. After dry mixing water was added in small quantities till uniform, homogenous concrete was produced.

Fig. 3. Mixing of ingredients

C. Casting of Specimen

Specimens were cast in two forms i.e.; Cubes and cylinders. Cubes of dimension 150mm x 150mm x 150mm and cylindrical specimens of 10mm diameter and height equal to 20mm were casted in standard steel moulds. Moulds were cleaned before pouring concrete in them a thin layer of oil was applied on the surfaces of moulds to facilitate the easy removal of specimens from moulds. The test cube specimens were made as soon as practicable after mixing and in such a way as to produce full compaction of the concrete with neither segregation nor excessive laitance. The concrete was filled into the moulds in layers approximately 5cm deep. Compaction was done by using a vibrating table. While finishing off the surface of the concrete, if the mould is too full, the excess concrete should not be removed by scraping off the top surface as this takes off the cement paste that has come to the top and leaves the concrete short of cement. The correct way is to use a corner of the trowel and dig out a fair sample of the concrete as a whole, and then finish the surface by trowelling.

Once a specimen has been compacted, it should not be left standing on the same bench as another specimen that is being compacted. If this is done, some vibration will be passed on to the first specimen and it will be more compacted than the other. In extreme cases some re-arranging of the particles may result and segregation will occur.

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Fig. 4. Casting of specimens

D. Curing

Curing is defined as the creation of favorable environment during the early period for uninterrupted hydration. Curing is done mainly to keep hydration of cement continuously. Curing is the process in which the concrete is protected from loss of moisture and kept within a reasonable temperature range. This process results in concrete with increased strength and decreased permeability. Curing is also a key player in mitigating cracks, which can severely affect durability. Curing is also a key player in mitigating cracks in the concrete, which severely impacts durability. Cracks allow open access for harmful materials to bypass the low permeability concrete near the surface. Good curing can help mitigate the appearance of unplanned cracking. All the specimens were cured by water curing by immersion in curing tank for 7 to 28 days for 7 days and 28 days strength tests respectively.

IV. TESTS AND RESULTS

A. Slump test and Compacting Factor test

Slump test is an empirical test that measures workability of fresh concrete. The test measures consistency of concrete in that specific batch. It is performed to check consistency of freshly made concrete. Consistency refers to the ease with which concrete flows. This test is popular due to the simplicity of apparatus used and simple procedure.

The compacting factor test is primarily used in laboratory for concrete mixes of low workability. This test is more precise and sensitive than slump test. In this test we need to calculate Compaction Factor which gives us idea about workability of concrete.

Fig. 5. Slump test

TABLE 5. RESULTS OF SLUMP TEST AND COMPACTING FACTOR TEST

Trial mix	Slump in mm	Compacting Factor	Degree of workability
B1	67	0.89	Medium
B2	52	0.86	Medium
B3	35	0.81	Low
B4	21	0.79	Very low
B5	12	0.76	Very low

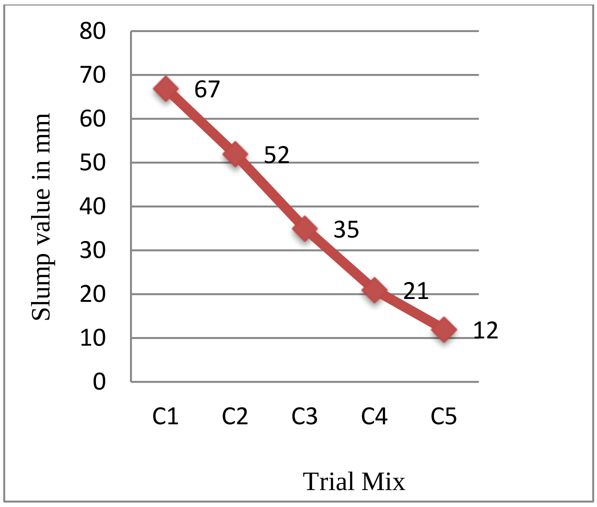

Fig.6 Result of Slump Test

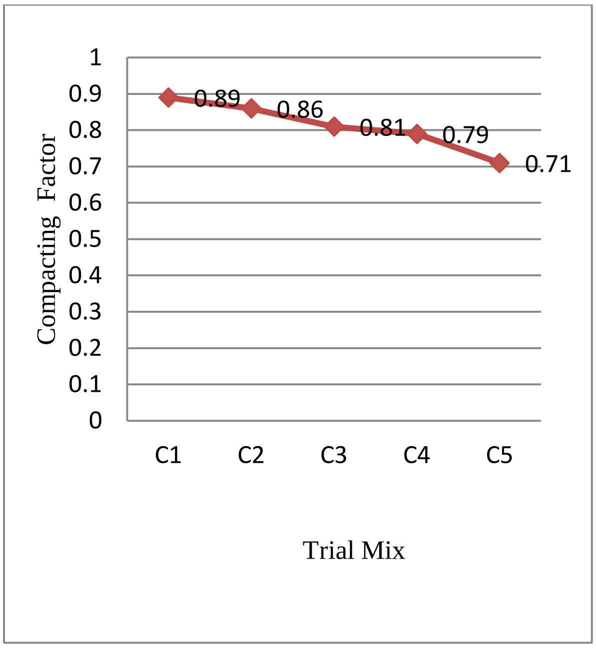

Fig 7. Results of compacting factor test

B. Compression Test

Compression test is the most common test conducted on hardened concrete, partly because it is an easy test to perform, and partly because most of the desirable characteristic properties of concrete are related to its compressive strength. Compression testing machine was used to carry out the tests. Compression tests were carried out at the age of 7 days and 28 days. Load at failure divided by the area of specimen gives the compressive strength of concrete specimen. Loads should be applied at the rate of 140kg/cm^2 per minute till the specimens fails. Procedure of compression test are as follows, Remove the specimen from water after specified curing time and wipe out excess water from the surface. Take the dimension of the specimen to the nearest 0.2m. Clean the bearing surface of the testing machine. Place the specimen in the machine in such a manner that the load shall be applied to the opposite sides of the cube cast. Align the specimen centrally on the base plate of the machine. Rotate the movable portion gently by hand so that it touches the top surface of the specimen. Apply the load gradually without shock and continuously at the rate of 140kg/cm^2/minute till the specimen fails.

Record the maximum load and note any unusual features in the type of failure.

(a)

(b)

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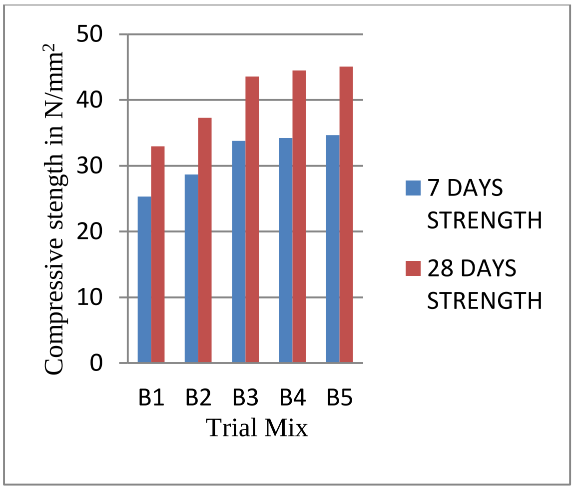
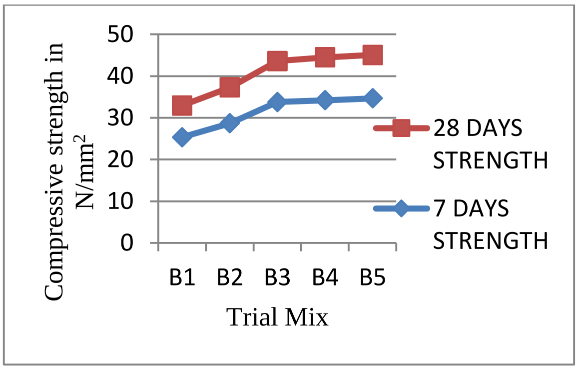
(c)

(d)

Fig 8. Compression test and failure of samples



(a)



(b)

Fig 9. (a) Compressive strength at 7days and 28 days (b) Variation of compressive strength at 7 days and 28 days

TABLE VI. COMPRESSIVE STRENGTH OF CONCRETE

TRIAL MIX	7 Day compressive strength in N/mm²	28 day compressive strength in N/mm²
B1	25.33	32.93
B2	28.67	37.27
B3	33.77	43.58
B4	34.20	44.46
B5	34.67	45.07

C. *Split Tensile Strength Test*

Tensile strength of concrete is one of the basic and important property. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete. Concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

This test is also known as "Brazilian Test". This test is an indirect measure of tensile strength of concrete. The test is carried out by placing a cylindrical specimen horizontally between the loading surface of compression testing machine and the load is applied until failure of the cylinder along the vertical diameter takes place. Narrow packing strips of suitable material are placed between the specimen and the loading platens of the testing machine. Take the wet specimen from water after 7 days of curing. Wipe out water from the surface of specimen. Draw diametrical lines on the two ends of the specimen to ensure that they are on the same axial place. Note the weight and dimension of the specimen. Set the compression testing machine for the required range. Keep are plywood strip on the lower plate and place the specimen. Align the specimen so that the lines marked on the ends are vertical and

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centered over the bottom plate. Place the other plywood strip above the specimen. Bring down the upper plate to touch the plywood strip. Apply the load continuously without shock at a rate of approximately 14-21kg/cm^2/minute .Note down the breaking load P.
Split Cylinder Strength = 2P/Π dl.
Where, P= Breaking load.
π=3.14
d= Diameter of cylindrical specimen.
l= Height of cylindrical specimen.

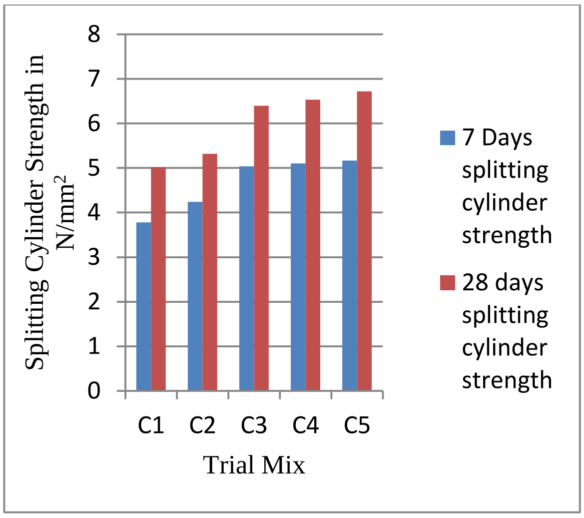
(a)

(b)

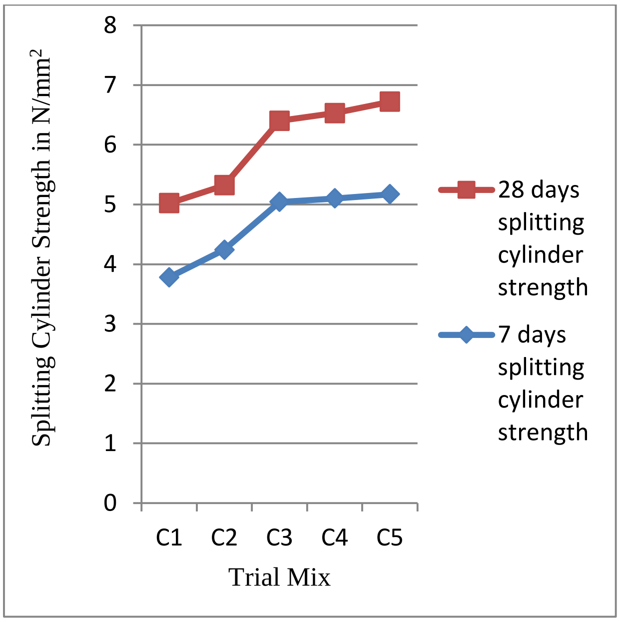
Fig. 10. (a) Failure of cylindrical specimen C2 (b) Failure of cylindrical specimen C4

TABLE VII. SPLITTING CYLINDER STRENGTH OF CONCRETE

TRIAL MIX	7 DAYS SPLITTING CYLINDER STRENGTH IN N/mm	28 DAYS SPLITTING CYLINDER STRENGTH IN N/mm^2
C1	3.78	5.02
C2	4.24	5.32
C3	5.04	6.40
C4	5.10	6.53
C5	5.17	6.72



(a)



(b)

Fig. 11. (a) Tensile strength at 7 days and 28 days (b) Variation of tensile strength at 7 days and 28 days

V. CONCLUSION

Based on the studies conducted on the fresh and hardened concrete by employing mixture of ceramic-marble waste materials it was seen that:

The behavior of concrete with replacement of fine aggregate by ceramic-marble mixture under slump and compaction factor tests shows decrease in workability as percentage of ceramic-marble mixture is increased from 20% to 100%.

There is an increase in compressive strength of concrete from trial mix B1to B5. There is an increase of 13% in compressive strength from B1 to B2, 17% increase from B2 to B3, 1.2% increase from B3 to B4, 1.37% increase from B4 to B5 as calculated from 7days compressive strength. Almost similar trend is showed at the age of 28days strength.

The study revealed that there is an increase in splitting cylinder strength from trial mix C1 to C5. There was an increase of 12% in splitting cylinder strength from C1 to C2, 18 % increase in splitting cylinder strength from C2 to C3, 1.19% from C3 to C4, 1.38% increase from C4 to C5 as calculated from 7 days splitting cylinder strength. Almost similar trend was shown at the age of 28 days.

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