# SUSTAINABLE CONCRETE USING CERAMIC WASTE AND MARBLE DUST

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***ABSTRACT: Concrete is the most widely used construction material in civil engineering industry throughout the world because of its high structural strength and stability, where the fine aggregate is generally natural sand. Common river sand is expensive due to excessive cost of transportation from natural sources. On the other hand cement is having not only economical but also environmental implications. Hence any research contributing to the reduction the use of both these material is greatly appreciated by the construction industry. Disposal of both ceramic waste and marble powder is one of the major environmental problems worldwide today. In this research study the (OPC) cement has been replaced by ceramic waste powder in the proportion of 0%,5%, 10%, 15%, 20%, 25%,30% ,35%,40%,45% & 50% and fine aggregate replaced by waste marble powder in the proportion of 0%,5%,10%, 15%,20%,25%,30%,35%, 40%,45% & 50% by weight of M-20 grade concrete. The present investigation has been undertaken to study the effect of ceramic waste and marble powder on the mechanical properties of concrete. The main parameters investigated were cube compressive strength, split tensile strength and flexural strength. In this work, M20 grade concrete mix was developed using IS method of mix design. For evaluation of strength parameters of each grade of concrete samples are prepared in the form of cubes, cylinders and prisms and cured for 28 days before testing. From the results it was observed that the compressive strength, split tensile strength and flexural strength increases with the increase in percentage of ceramic waste and marble powder up to 20%. But beyond 20 % the compressive strength, split tensile strength and flexural strength decreases. So the replacement of cement with ceramic waste and fine aggregate with marble dust is optimum at 20 percent only.***
***Keywords: Marble Dust, Ceramic Waste, Concrete, Mechanical Properties.***

## I. INTRODUCTION

### *1.1 GENERAL*

Concrete is a widely used material in the world. Based on global usage it is placed at second position after water. Cement based material are the most abundant materials in the world. Due to the high in demand of natural resources engineers & architect have growing interest in sustainable development by choosing the material which is more sustainable that is why the green building concept is emerging in our country. It is very eco-to use waste products generated by industries in construction industry. It is also realistic that technology can be developed to use the waste material which can reduce the carbon dioxide emission related to concrete production. Common river sand is expensive due to excessive cost of transportation from natural sources. Also large-scale depletion of these sources creates environmental problems. As environmental, transportation and other constraints make the availability and use of river sand less attractive, a substitute or replacement product for concrete industry needs to be found. River sand which is most commonly used fine aggregate in the production of concrete poses the problem of acute shortage in many areas. The global consumption of natural sand is too high due to its extensive use in concrete. The use of sand in construction results in excessive sand mining which is objectionable. Due to rapid growth in construction industry, the available sources of natural sand are getting exhausted, causing depletion of natural resources resulting increase in scour depth and sometimes flood possibility. Also, good quality sand may have to be transported from long distance, which adds to the cost of construction. Therefore, it is necessary to replace natural sand in concrete by an alternate material either partially or completely without compromising the quality of concrete. In India the marble & ceramic are the most thriving industries.Waste marble dust is one such material which can be used to replace sand as fine aggregate. The present study is aimed at utilizing waste marble powder as fine aggregate in concrete, replacing natural sand. Marble is a metamorphic rock produced from limestone by pressure and heat in the earth's crust due to geological process [1]. In INDIA, the marble processing is one of the most booming industries. Marble industries in India grow more than 3500 metric tons of marble powder slurry per day. India is among the top world exporters of marble rock. The Indian marble industry has been rising steadily at an annual pace of about 10% per year. 20 to 30% of marble blocks are changed into powder. 3,172 M tons of marble dusts were produced in year 2009-10. Marble is one of the most important materials used in buildings since ancient times, especially for decorative purposes.[2-4] The marble is widely used in buildings due to its beauty, strength & resistance to fire. Sustainable construction mainly aims at reduction of negative environmental impact resulted by construction industry which is the largest consumer of natural resources. Over a period of time, waste management has become one of the most complex and challenging problem in the world which is affecting the environment. The rapid growth of industrialization gave birth to numerous kinds of waste by products which are environmentally hazard and creates problems of storage. Always, construction industry has been at forefront in consuming these waste products in large quantities. The utilization will also reduce the strain on supply of natural fine aggregate, which will also reduce the cost of concrete.[5-7] Rapid urbanization in developing countries such as India is creating a shortage of adequate housing in cities. Using artificial aggregates for quality concrete is a natural step to mitigating this problem. The world wide consumption of fine aggregate in concrete production is very high, and several developing countries have encountered difficulties in meeting the supply of natural fine aggregate in order to satisfy the increasing needs of infrastructural development in recent years. To overcome the stress and demand for river fine aggregate, researchers and practitioners in the construction industries have identified some alternative materials such as fly ash, slag, limestone powder and siliceous stone powder, marble dust etc. The utilization of such alternative materials will also reduce the strain on supply of natural fine aggregate, which will also reduce the cost of concrete.[8-9] In addition to marble powder, silica fume, fly ash, pumice powder and ground granulated blast furnace slag are widely used in the construction sector as a mineral admixtures instead of cement Marble dust can be used either to produce new products or as an admixture so that the natural sources are used more efficiently and the environment is saved from dumpsites of marble waste. Many studies have been conducted in literature on the performance of the concrete containing waste marble dust or waste marble aggregate, such as its addition into self compacting concrete as an admixture or sand as well as its utilization in the mixture of asphaltic concrete and its utilization as an additive in cement production. Hanifi Binici et al[10] found that marble-dust concrete has higher compressive strength than that of the corresponding lime stone -dust concrete having equal w/c and mix proportion. The results indicated that the Marble dust concrete would probably have lower water permeability than the lime stone concrete. As non-pozzolanic fines it is at present the limestone and dolomite ones which are most frequently used to increase the content of fine particles in self compacting concretes. Billberg [11]Compared to normal plain concrete of the same w/c ratio and the same cement, the concrete having high limestone filler content of suitable particle-size-distribution generally improves the strength characteristics.[12-13] Sachin [14] used Marble Powder and artificial sand or manufactured sand as partial replacement for natural sand to conduct their study on mechanical behaviour of concrete.[15]

### *1.2 PRODUCTION OF MARBLE DUST*

Marble waste powder is produced from processing plants during the sawing and polishing of marble blocks and about 25% of the processed marble is turn into powder form. Marble waste when dumped on open land affects adversely the productivity of land as it reduces the porosity and affects ground water recharge. Disposal of the waste marble powder from the marble industry is one of the environmental problems worldwide today. Recently, marble dust powder has been employed in the construction industry and research has been carried on to examine their fruitful result. The production of cheaper and more durable concrete using this waste can solve to some extent the ecological and environmental problems. The various applications of Marble Powder are as follows:

1. Power coating, paints and ceramic industry
2. Reinforced polyester glass fiber
3. Leather cloth and flooring applications
4. Detergent applications
5. Glass industry (in manufacturing sheet & optical glasses)

### *1.3 ADVANTAGES OF MARBLE DUST POWDER*

1. Marble powder can be used as filler in concrete and paving materials and helps to reduce total void content in concrete.
2. Marble powder can be used as an admixture in concrete, so that strength of the concrete can be increased.
3. We can reduce the environmental pollution by utilizing this marble powder for producing the other products.
4. Marble dust is mixed with concrete, cement or synthetic resins to make counters, building stones, sculptures, floors and many other objects.
5. Marble dust gives an iridescent feel to the object because of the crystallized particles present in the dust from the marble. These cultured marble objects are often seen in luxury settings. Synthetic marble objects made with marble dust are more commonly used than 100 percent solid marble objects.
6. Marble dust is also used to make paint primer for canvas paintings, and as paint filler.
7. Used as a component for manufacture of white cement.
8. The marble powder is also used to create carbonic acid gases which are used in the bottling of beverages.

### *1.4 PRODUCTION OF CERAMIC WASTE*

Ceramic waste is most commonly produce from ceramic industry, this waste is in the form of pest and hard form, pest waste is known as the filter waste or slurry waste, which is produced at the end of polishing and finishing of ceramic tiles. The overall size of the Indian ceramic industry is about Rs 18,000 crores producing 100 Million tons per year. However, the ceramic waste is durable, hard and highly resistant to biological, chemical and physical degradation.
Different types of ceramic products are:

- Wall And Floor Tiles
- Bricks And Roof Tiles
- Table-And Ornamental ware (Household Ceramics)
- Refractory Products
- Sanitary ware
- Vitrified Clay Pipes
- Tiles used in the Space Shuttle program
- Gas burner nozzles
- Missile nose cones
- Coatings of jet engine turbine blades

### *1.5 OBJECTIVE OF THE PRESENT WORK:*

The basic objective of this study is to identify alternative source of good-quality aggregates, as well as a good substitute to replace the cement without compromising the

  

strength.
For this use of Ceramic waste as partial replacement to cement and marble powder as a partial replacement to sand were identified.
In this work it is proposed to explore the mechanical behaviour of the hardened concrete with the above mentioned replacements of ingredients.
It is also planned to compare the results with conventional concrete.

## II. METHODOLOGY

### *2.1 METHOD ADOPTED*

In this study, concrete of M20 grade is considered as a reference mix with a W/C ratio of 0.50. To evaluate the strength characteristics of concrete in terms of compressive strength, split tensile strength and flexural strength, M20 mixes were tried with different percentages of both marble dust and ceramic waste at 0%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, 50%. For this, each percentage, 3 samples were planned to be tested. Likewise, 30 Cubes of size 150 x 150 x 150 mm and 30 cylinders of 150 mm diameter & 300 mm height and 30 flexural beams of size 500 x 100 x 100 mm were cast and tested for each percentage of replacement. The results were compared and analysed. The following sections present a brief description of material properties.

### *2.2 MATERIAL USED*

Cement: Ordinary Portland Cement (43 grade) with specific gravity of 3.13 was used for this experimental investigation.
Coarse aggregate: Natural granite aggregate having density of 1500 kg/m3 and fineness modulus (FM) of 6.65 was used. The specific gravity was found to be 2.78 and maximum size of aggregate was 20mm.
Fine aggregate (Natural river sand): Locally available river sand having density of 1550 kg/m3 and fineness modulus (FM) of 2.55 was used. The specific gravity was found to be 2.67 the fine aggregate was found to be confirming to zone – II as per IS 383:1970. Fine aggregate are basically sands won from the land or the marine environment. Fine aggregates generally consist of natural sand or crushed stone with most particles passing through a 9.5mm sieve. As with coarse aggregates these can be from Primary, Secondary or Recycled sources.
Marble Dust: The Marble dust powder was collected from the locally available suppliers in Krishna District, India. Specific gravity of marble dust powder is 2.64 and water absorption is 0.97%. The Chemical properties were given in Table 3.7

Figure 2.1 Marble Dust Powder

Table 2.1 Chemical Properties of Marble Dust Powder

| S.No. | Materials | Marble Powder (%) |
|---|---|---|
| 1. | Loss of Ignition (L.O.I) | 43.63 |
| 2. | CaO | 43.20 |
| 3. | Fe2O3 | 1.90 |
| 4. | Al2O3 | 2.50 |
| 5. | SiO2 | 13.8 |
| 6. | MgO | 2.70 |
| 7. | SO3 | 0.07 |
| 8. | K2O | 0.60 |
| 9. | Na2 O | 0.90 |
| 10. | CL | 0.03 |

Ceramic Waste: The Ceramic waste powder was collected from the locally available suppliers in Krishna District, India. Specific gravity of ceramic waste powder is 2.84 and water absorption is 0.92%. The Chemical properties were given in Table 2.2

Figure 2.2 Ceramic Waste Powder

Table 2.2 Chemical Properties of Ceramic Waste Powder

| S.No. | Materials | Ceramic Powder (%) |
|---|---|---|
| 1. | $SiO_2$ | 63.29 |
| 2. | $Al_2O_3$ | 18.29 |
| 3. | $Fe_2O_3$ | 4.32 |
| 4. | CaO | 4.46 |
| 5. | $K_2O$ | 2.18 |
| 6. | $Na_2O$ | 0.75 |
| 7. | MgO | 0.72 |
| 8. | $P_2O_5$ | 0.16 |
| 9. | $Mn_2O_3$ | 0.05 |
| 10. | CL | 0.005 |
| 11. | $SO_3$ | 0.10 |
| 12. | Loss of Ignition (L.O.I) | 1.61 |

*Water*
Potable fresh water, which is free from concentration of acid or organic substances, was used for mixing the concrete.
*Casting*
According to IS 516-1959: The cubes were casted in steel moulds of having dimensions 150 x 150 x 150mm, the cylinders having dimensions of 150mm diameter and 300mm height and finally, the flexural beams were casted in 500 x 100 x 100 mm. For all test specimens,

  

moulds were kept on table vibrator and the concrete was poured into the moulds in three layers simultaneously vibration was effected by table vibrator. The moulds were removed after twenty four hours and the specimens were kept immersed in clean water tank. After curing the specimens in water for a period of 28 days the specimens were taken out and allowed drying under shade.

### *2.3 MIX DESIGN PROCEDURE*

Test results of mix design
(a)Characteristic Comp. Strength required in the field at 28 days = 20 Mpa
(b)Max. size of aggregate= 20 mm
(c)Degree of workability (specified or not)= 50 –80 mm
(d)Type of exposure = Moderate
(e)Min. Cement (if specified) = 300kgs
Test data for materials:
Cement Used =OPC 53Grade
Specific Gravity of 1) Fine Aggregate = 2.58
2) Coarse Aggregate – 20mm = 2.81
Specific Gravity of Cement= 3.13
Sand corresponds of Zone= Zone II
The target mean strength is determined using following relation

$$f_t = f_{ck} + (t * S)$$

Where $f_t$ = Target Mean Strength@ 28 days $f_{ck}$=Characteristic Compressive Strength @ 28 days t=A Statistical value depending upon the results and no. of tests. S = Standard deviation shown from IS: 10262-2009. Assuming not more than 5% results are expected to fall below the characteristic compressive strength. In which cases the value of 't' is 1.65. Standard deviation for M20 Grade of concrete is 4.

$$f_t = 20 + (1.65*4) = 26.6 \text{ Mpa}$$

- Target mean Strength of Concrete = 26.6 Mpa
- Selection of w/c ratio corresponding to the target mean Strength of 26.6 Mpa = 0.50 ( From Table 5 of IS 456, maximum water-cement ratio = 0.55)
- From Table-2 IS: 10262-2009 for nominal maximum size of aggregate 20mm, the maximum water content is 186 liters per cubic meter.
- From Table-3 IS: 10262-2009 Volume of coarse aggregate per unit volume of concrete for zone–II fine aggregate is 0.62.
- For change in value of w/c ratio the following adjustments are required according to IS: 10262-2009 in water content and percentage of sand in total aggregate.
- Selection of water and sand content water per cubic meter for 20mm maximum size aggregate and sand of zone II water content per cubic meter of concrete is 170 kg and sand content(as % of total aggregate) = 37%Therefore required Sand content as percentage of total aggregate by absolute Volume = 37- 2.00 =35%.
- Determination of Cement content : Water / Cement ratio = 0.50; Required Water content = 170 Lts /m³; Cement content = 340 Kgs. This Cement is adequate for moderate exposure condition.
- Determination of Coarse and Fine Aggregate content: For 20mm Maximum size of aggregate the amount of entrapped air in the fresh concrete is 2 percent.

$$0.98 = [170 + 340/3.13 + ((1/0.35) \times Fa/2.58)] \times 1/1000 ; \quad Fa = 633.34 \text{ Kg/m}^3$$

$$0.98 = [170 + 340/3.13 + ((1/0.65) \times Ca/2.81)] \times 1/1000; \quad Ca = 1282 \text{ Kg/m}^3$$

Mix Proportion by weight is: 1 :1.86 :3.77.
Comp. Strengths of Concrete Cubes at 28 days with the above proportions were obtained as:
1)22.50MPa 2)22.60MPa 3)23.00MPa
Slump observed 75mm, Hence, the Mix Proportion of above trail is recommended.

## III. EXPERIMENTATION

Concrete specimens were casted using 0%, 10%, 15%, 20%, 25%, 30%, 35%, 40%, 45%, and 50%, replacement of fine aggregate with both marble powder and ceramic waste. The specimens are tested for compressive strength, flexural strength and split tensile strength for 28 days curing.

Figure 3.1: compression test of cube

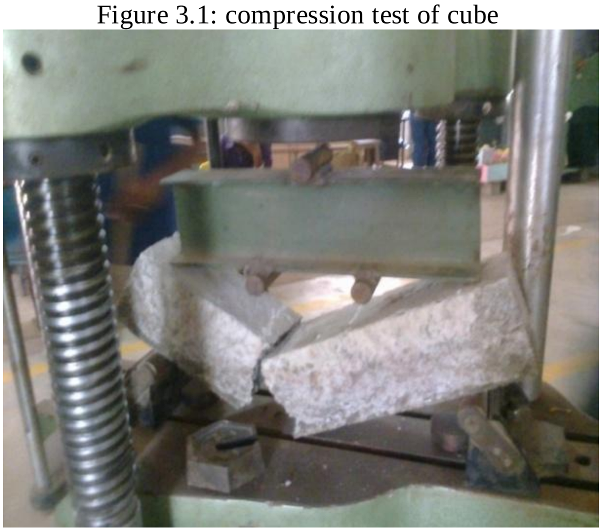
Figure 3.2: flexural strength test

  

Figure 3.3: split tensile strength

## IV. RESULTS AND DISCUSSION

*4.1Compression strength*

The cubes were placed in the compression testing machine and the loads are applied gradually at a rate of 16.3 N/mm2/min. The average value of the compression strength of three cubes was taken as the compression strength.

Table 4.1: Average Compressive Strength of Concrete with marble dust and ceramic waste

| % replacement of cement with marble powder and ceramic waste | Average Compressive strength of the concrete at 28 days (N/mm2) |
|---|---|
| 0% | 31.45 |
| 10% | 32.46 |
| 15% | 33.38 |
| 20% | 34.98 |
| 25% | 32.36 |
| 30% | 30.04 |
| 35% | 28.96 |
| 40% | 26.37 |
| 45% | 23.37 |
| 50% | 20.15 |

The average compressive strength of concrete with marble powder and ceramic waste is shown in Figure 4.1.

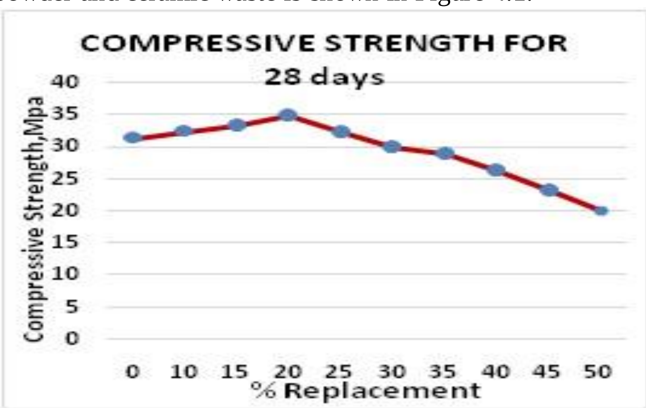


Figure 4.1 average compressive strength 28days

From the table and figure, it can be seen that up to 20% replacement of cement with marble dust and ceramic waste there is a gradual rise of compressive strength but beyond which there is reduction in compressive strength.

*4.2 Split tensile strength*

The cylindrical specimens of diameter 150mm and height 300mm were used to determine the split tensile strength. The specimens were tested in compression testing machine of capacity 2000 kN. (According to IS 5816-1999).Three cylindrical specimens were tested for each percentage of replacement. The cylinders were placed in the machine horizontally. Load was applied gradually at a uniform rate until the specimens failed.

Table 4.2: Average split tensile strength of Concrete with marble dust and ceramic waste

| % replacement of cement with marble powder and ceramic waste | Average split tensile strength of the concrete at 28 days(N/mm$^2$) |
|---|---|
| 0% | 2.62 |
| 10% | 2.72 |
| 15% | 2.81 |
| 20% | 2.94 |
| 25% | 2.69 |
| 30% | 2.51 |
| 35% | 2.54 |
| 40% | 2.48 |
| 45% | 2.41 |
| 50% | 2.39 |

The average split tensile strength of concrete with marble dust and ceramic waste is shown in Figure 4.2

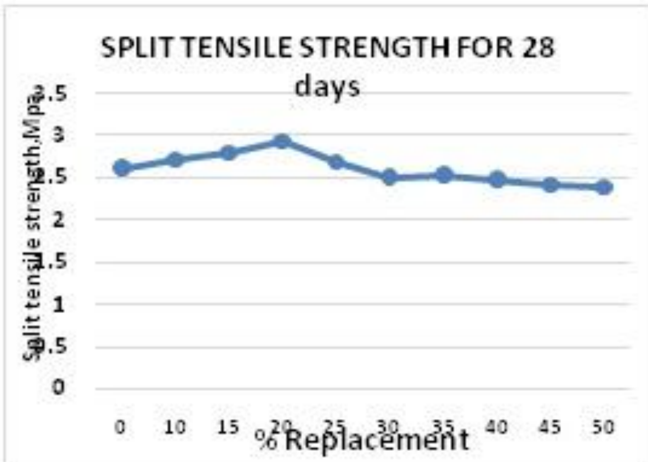


Figure 4.2 split tensile strength for 28 days

From the table and figure, it can be seen that up to 20% replacement of cement with marble dust and ceramic waste there is a gradual rise of split tensile strength but beyond which there is reduction in split tensile strength.

  

*4.3 Flexural strength test*

According to IS 516-1959. The prism specimens of size 500 x 100 x 100 mm were used for the determination of the flexural strength. The bearing surface of the supporting and loading rollers were wiped clean and any other loose fine aggregate or other materials removed from the surface of the specimen where they are to make contact with the rollers. The specimen was then placed in the machine and two point load was applied. Load was increased until the specimen failed and the load at failure was recorded and the flexural strength was determined. Flexural strength was taken as the average strength of three specimens. The flexural strength of conventional concrete was found to be 5.61N/mm2.

Table 4.3: Average flexural strength of Concrete with marble dust and ceramic waste

| %of replacement marble powder and ceramic waste | Average Flexural strength of the concrete at 28 days(N/mm2) |
|---|---|
| 0 % | 4.06 |
| 10% | 4.13 |
| 15% | 4.18 |
| 20% | 4.28 |
| 25% | 4.12 |
| 30% | 3.97 |
| 35% | 3.9 |
| 40% | 3.72 |
| 45% | 4.38 |
| 50% | 3.98 |

The average flexural strength of concrete with marble dust and ceramic waste is shown in Figure 4.3.

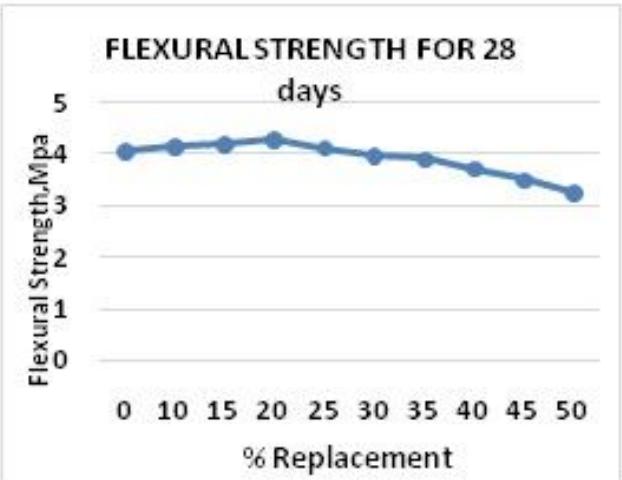


Figure 4.3: Average flexural Strength for 28days

From the table and figure, it can be seen that similar to split tensile strength only marginal increase was observed at 20% replacement of marble dust and ceramic waste and fine aggregate. From the table and figure, it can be seen that up to 20% replacement of cement with marble dust and ceramic waste there is a gradual rise of split tensile strength but beyond which there is reduction in split tensile strength.

## V. CONCLUSIONS

As compared to conventional concrete, on addition of marble dust and ceramic waste its characteristic strength is gradually increased. So the ceramic waste powder has been replaced by up to 20% by weight of cement without affecting the characteristic strength of M20 grade concrete. On further replacement of cement with marble dust and ceramic waste powder, the strength of concrete found decreased. As compared to conventional concrete, on addition of marble dust powder its compressive strength gradually increases up to a certain limit but then gradually decreases. The increase in strength of concrete is due to the fact that certain proportions of waste had been added to the concrete as very fine aggregate substitutes. This is an expected outcome due to the high specific gravity of marble dust powder and also filler effect of marble dust because it has finer particles than fine aggregate. As a matter of fact, marble dust powder had a filler effect and played a noticeable role in the hydration process. Ceramic waste also contains large amount of silica which affects the strength characteristics of concrete. Utilization of ceramic waste or marble dust and its application for the sustainable development of the construction industry is the most effective solution and also speak the high value application of such waste. It is the best possible alternative solution of safe disposal of the Ceramic waste and Marble dust powder thus stepping into a realm of solving the environmental pollution by cement production; being one of the primary objectives of Civil Engineers.

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