# A Study of Properties of Concrete Making Partial Replacement of Cement by Ceramic waste Powder

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***Abstract** - Concrete is the most widely used construction material all over the globe next to water. The present challenge for civil engineers is to produce large volume, good performance, durable and sustainable concrete at lowest possible cost. In the ceramic industry, nearly 15%-30% production goes as waste. The replacement of cement with Ceramic Waste Powder (CWP) produces a substantial modification in compressive strength, making them suitable for the fabrication of eco-efficient concrete. Using $M_{30}$ grade concrete, ceramic powder concrete produced by replacing cement in 5%,10%,15%, 20%,25%,and 30% by weight of cement. Concrete mixtures were produced, tested and compared in terms of compressive strength, split tensile strength and flexural strength to the conventional concrete These tests were carried out to evaluate the mechanical properties after 7, 14 and 28 days. Results showed that 15 % replacement of cement by ceramic powder makes a considerable increase in compressive strength, split tensile strength and flexural strength.*

***Key Words***: Ceramic Waste Powder (CWP),Compressive strength, Split tensile strength, Cement, sustainable concrete

## 1.INTRODUCTION

In India, a number of waste materials are produced by different manufacturing companies, thermal power plant, municipal solid wastes and other wastes. Solid as well as liquid waste management is one of the biggest problems of the whole world. Disposal of waste in to the land causes serious impact on environment. Nowadays large amount of tile powder is generated in tile industries with an impact on environment and humans. Use replacement materials offers cost reduction, energy savings and few hazards in the environment. . Concrete is nothing but a combination of aggregates both fine and coarse, Cement and water. Compare to all other ingredients in concrete, cement the most expensive material. This is because cement is manufactured using energy-intensive process. Cement is one of the major producers of carbon dioxide, which is the main cause of global warming. During the manufacturing process of cement the formation of clinker can be achieved only by heating the cement at very high temperature. This leads to the release of enormous amounts of carbon in the atmosphere. This was one among the major problems identified for climatic changes. Various research works have been carried out for the cost reduction in construction with some of the locally available materials as partial or full replacement material for cement. Over the last few decades supplementary materials like fly ash, rice husk, silica fume, egg shell, groundnut shell, etc. are used as a replacing material. These supplementary materials have proven to be successful in meeting the needs of the concrete in construction. In India ceramic production is 100 million ton per year. The tile industry has about 15% to 30% waste material generated from the total production. The tile waste which is dumped in land filling or vacant spaces causes the environmental pollution which is dangerous for human health. This waste is not recycled in any form at present. However, the tile waste is durable, hard and highly resistant to biological, chemical, physical degradation forces. The tile waste which is dumped in land filling or vacant spaces causes the environmental and dust pollution which is dangerous for human health. As the ceramic waste is piling up every day, there is a pressure on tile industries to find a solution for its disposal. Concrete is considerably the world's largely adaptable and well-liked material produced each year in the construction.

## 2. SCOPE AND OBJECTIVES OF THE STUDY

The main scopes of the study are,

- To examine the effectiveness of using Ceramic Waste Powder (CWP), as partial replacement of cement by studying strength parameters.
- To study the necessity of consumption of the waste material for manufacturing of sustainable concrete for construction. To use locally available material and to reduce the cost of producing concrete.
- To overcome the problems faced by cement industries to a little extent.

The experimental investigation was proposed to work out the suitability of addition of Ceramic Waste Powder (CWP), as partial replacement of ordinary Portland cement in concrete with the following objectives.

- To investigate the compressive strength and split tensile strength of concrete with CWP to that of normal concrete.
- To prepare high strength, eco-friendly and cost effective concrete

## 3. MATERIALS USED

The material used in this study included ordinary Portland cement, fine aggregate, coarse aggregate, water and super plasticizer.

### 3.1 Cement

Ordinary Portland cement 53 grade was used throughout the study. The standard consistency, setting time and specific gravity were tested in the laboratory. All the tests were carried out in accordance with procedure laid down in IS 12269 – 1987.

### 3.2 Fine aggregate

Fine aggregates are basically sands. Fine aggregates are the materials that pass through 4.75 mm IS sieve. Manufactured sand (M sand) was used as fine aggregate. The tests such as specific gravity and gradation were carried out to determine the physical properties of fine aggregate.

### 3.3 Coarse aggregate

Locally available crushed stone aggregate of 20 mm size was used throughout the experimental study. The tests such as specific gravity and gradation were carried out to determine the physical properties of coarse aggregate. The coarse aggregate is chosen by shape as per IS 2386(Part I) 1963, surface texture characteristics of aggregate is classified as in IS 383-1970.

### 3.4 Water

This is the least expensive but most important ingredient of concrete. The water which is used for making concrete should be clean and free from harmful impurities such as oil, alkali, acid, etc. Potable water was used for the experiment.

### 3.5 Ceramic Powder

The principal waste coming from the ceramic industry is the ceramic powder, specifically in the powder forms. Ceramic wastes are generated as a waste during the process of dressing and polishing. It is estimated that 15 to 30% waste are produced and a portion of this waste may be utilized on-site, such as for excavation pit refill, The disposals of these waste materials require large land areas and remain scattered all around, spoiling the aesthetic of the entire region. It is very difficult to find a use of ceramic waste produced. Ceramic waste can be used in concrete to improve its strength and other durability factors. Ceramic waste can be used as a partial replacement of cement or as a partial replacement of fine aggregate sand as a supplementary addition to achieve different properties of concrete:-


**Fig-1**: Ceramic powder

### 3.5 Super plasticizer

Ceraplast-300 M, a naphthalene base super plasticizer which is compatible with blended cements, especially with slag cements. Ceroplastic- 300 is a new generation, high grade, and high -performance retarding super plasticizer specially designed for concrete with replacement of cement up to 70-80 percent by slag. 0.2 % of super plasticizer used in each replacement to achieve desired workability

## 4. METHODOLOGY

### 4.1 Material testing

a) Specific gravity test

The specific gravity is normally defined as the ratio between the weight of a given volume of material and weight of an equal volume of water. Specific gravity of cement, fine aggregate and coarse aggregate are tested.

**Fig-2:** Specific gravity test on a) cement b) fine aggregate c) coarse aggregate

b) Sieve analysis

- Sieve analysis of Fine Aggregate

Sieve analysis is done as per IS 2386 (Part I)-1963. The first step involves arranging the IS sieves in the order of4.75mm-2.36mm-1.18mm-600µ-300µ-150µ as shown in FIG-3. 1kgs of fine aggregate is taken and placed on the top most sieves.

Sieving is done for fifteen minutes and weight retained on each IS sieve is found.

- Sieve analysis of Coarse Aggregate

Particle size distribution in a sample of aggregate is done by sieve analysis using a sieve shaker. It is the operation of dividing a sample of aggregate into various fractions, each consisting of particles of same size. Experiment was done as per IS 2386-Part I-1963,IS:383-1970 and the gradation curve was plotted.

**Fig-3:** Sieve shaker

c) Fineness of cement

Fineness test was conducted on cement using 90 micron sieve. Fineness is an important property of cement which affects the rate of hydration of cement. Finer cement offers a greater surface area for hydration and hence faster the development of strength. The test was conducted by sieving 100 gm. of cement through IS 90 micron sieve continuously up to 15 minutes.Fig-4 shows fineness test.

**Fig-4:** Fineness test

d) Consistency of cement

Ordinary Portland cement of grade 53 was used in the casting of the specimens. Consistency limit test is done to determine the standard water requirement for setting time, the test was done under standard condition as mentioned in IS: 4031-1988.Fig-5 shows consistency test.

**Fig-5:** Consistency test

e) Bulk Density, Void Ratio and Porosity of Fine and Coarse Aggregate

Bulk density is the density of dry aggregate. This is required to determine the amount of aggregate in concrete mix. Container having 3L capacity, tamping rod and weighing balance were used for determining the bulk density, void ratio and porosity of aggregate.

**Fig-6**: Test on aggregate

e) Initial and final setting time of cement

Vicat apparatus with 1mm square needle was used for initial setting time test and another needle with annular attachment was used for final setting time test of Ordinary Portland cement. In this test 400 gm of cement was mixed with 0.85 times the percentage of water as determined in the consistency test. The time required to penetrate the needle to a depth of 5 mm to7mm from the bottom of the mould was noted as initial setting time and the time required to make an impression on the test block was noted as final setting time.

**Fig-7:** Initial and final setting time test Plunger

### 4.2 Mix design

Mix design is done as per IS 10262:2009 specifications. The concrete mix of $M_{30}$ grade concrete is adopted with a water cement ratio of 0.5.

### 4.3 Preparation of specimen

The cube moulds of size 150mmx150mmx150mm ,cylinders mould of size 150mm diameter and 300mm length and beam of size 500 mm x100mm x 100mm were filled with the mix. The specimens were tamped by tamping rod for around 25 times and the surfaces of moulds were leveled properly. The specimens were kept for 24 hours; de- moulded and then set for curing

**Fig-8:** Stages of preparation of specimen (a) Mixing (b) Casting

### 4.4 Curing

The curing was allowed until the date of testing i.e., for 7th, 14th, and 28th. Then after the days of curing, the cube specimens were taken out and tested under testing machine.

### 4.5 Workability test

Slump test and compaction factor test were conducted on fresh concrete to determine the workability of concrete as per IS 456 – 2000.Workability testing apparatus as shown in Fig-9.


Fig-9: Workability test (a) Slump cone test (b) Compaction factor test

### 4.6 Compressive strength test

Compressive strength of concrete is a measure of its ability to resist static load. 7, 14 and 28 day compressive strength test were conducted on three specimens having size 150x150x150 mm and the average strength was taken as the cube compressive strength of concrete.Fig-10 shows the compression testing machine. The optimum percentage of ceramic powder was determined by conducting compression test on cubes. Cubes were made with partially replaced CWP at various percentages such as 5%, 10%, 15%, 20%, 25%and 30%. The tests were conducted by using compression testing machine. From the results of the compression tests, the optimum percentage of CWP to be added is determined as the one which renders the maximum compressive strength. The cube specimen was taken out from the curing tank after specified curing time and were allowed to dry and the weight of each specimen as well as the dimension of the specimen were noted. The specimens were placed in the machine such that load was applied to the opposite sides of the specimen, and the specimens were aligned centrally on the base plate of the machine. The movable portion was rotated gently by hand so that it touches the top surface of the specimen. The load was applied gradually till the specimens failed and the maximum load at failure of specimen were recorded. The compressive strength of the specimen was calculated by dividing the failure load by the cross-sectional area of the specimen.

**Fig-10**: Compression testing machine

### 4.7 Split tensile strength test

Tensile strength is one of the basic and important properties of the concrete. The concrete is not usually expected to resist the direct tension because of its low tensile strength and brittle nature. However, the determination of tensile strength of concrete is necessary to determine the load at which the concrete members may crack. The cracking is a form of tension failure. The usefulness of the split cylinder test for assessing the tensile strength of concrete in the laboratory is widely accepted and the usefulness of the above test for control purposes in the field is under investigation. The standard has been prepared with a view to unifying the testing procedure for this type of test for tensile strength of concrete. The load at which splitting of specimen(150x300mm) takes place is recorded. The compression testing machine was used for testing split tensile strength of the concrete cylinders.

**Fig-11:** Split tensile strength testing machine

### 4.8 Flexural strength test

Flexural strength testing on beam was carried out in universal testing machine (UTM). Standard beams of size 100 x 100 x 500 mm were supported symmetrically over a span of400mm and subjected two point loading till failure of the specimen.

**Fig-12:** Universal testing machine

## RESULTS

### 5.1 Test on cement

**Table-1:** Properties of cement

| Test | Results |
|---|---|
| Fineness Test | 2.6% |
| Specific Gravity | 3.12 |
| Standard Consistency test | 32% |

### 5.2 Test on aggregate

#### a) Coarse Aggregate

**Table-2:** Properties of coarse aggregate

| Test | Results |
|---|---|
| Fineness modulus | 3.17 |
| Specific gravity | 2.78 |
| Water absorption | 0.69% |
| Bulk density | 1574kg/m$^3$ |
| Void ratio of coarse aggregate | 0.8 |
| Porosity of coarse aggregate | 0.445 |

#### b) Fine aggregate

**Table-2:** Properties of fine aggregate

| Test | Results |
|---|---|
| Fineness modulus | 2.7 |
| Specific gravity | 2.5 |
| Water absorption | 2.3% |

### 5.3 Test on fresh concrete

**Table-3:** Test on fresh concrete

| Sl.No | Grade | Percentage of replacement of cement with CWP | Workability test | |
|---|---|---|---|---|
| | | | Slump test | Compaction factor test |
| 1 | | 0% | 110 | 0.92 |
| 2 | | 5% | 107 | 0.92 |
| 3 | | 10% | 107 | 0.91 |
| 4 | | 15% | 108 | 0.91 |
| 5 | $M_{30}$ | 20% | 103 | 0.89 |
| 6 | | 25% | 99 | 0.88 |
| 7 | | 30% | 95 | 0.87 |

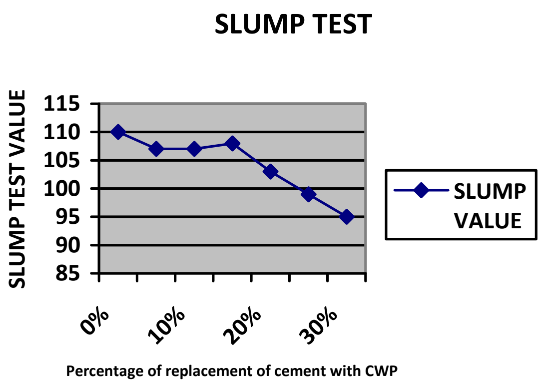


**Chart-1:** Plot between slump value and various percentage of CWP

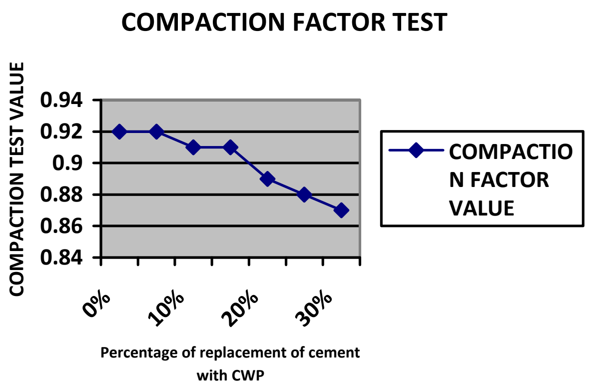


**Chart-2:** Plot between compaction factor value and various percentage of CWP

### 5.4 Compressive strength test

**Table -4:** compressive strength of cube

| SL. No | Percentage of replacement of cement with CWP | Compressive strength after 7 days (N/mm²) | Compressive strength after 14 days (N/mm²) | Compressive strength after 28 days (N/mm²) |
|---|---|---|---|---|
| 1 | 0% | 24.95 | 28.27 | 34.1 |
| 2 | 5% | 25.12 | 29.15 | 35.7 |
| 3 | 10% | 27.02 | 31.8 | 36.4 |
| 4 | 15% | 28.6 | 33.42 | 38.56 |
| 5 | 20% | 25.9 | 29.6 | 33.8 |
| 6 | 25% | 23.07 | 27.96 | 30.61 |
| 7 | 30% | 21.58 | 25.81 | 28.74 |

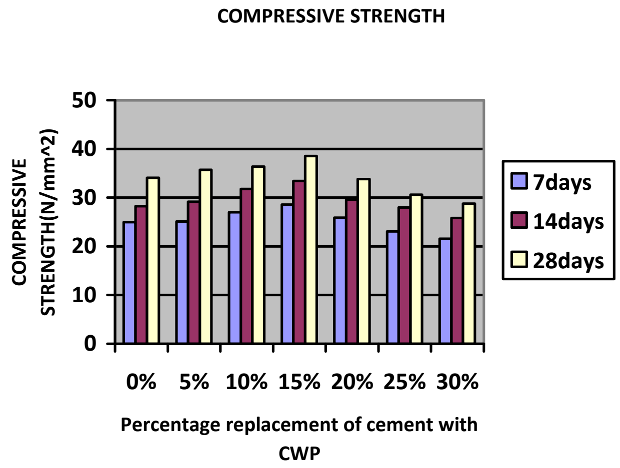


**Chart-3:** Relationship between compressive strength and various percentage of CWP

### 5.5 Split tensile strength test

**Table-5:** split tensile strength of cylinder

| SL. No | Percentage of replacement of cement with CWP | Spilt Tensile Strength after 7 days (N/mm²) | Spilt Tensile Strength after 14 days (N/mm²) | Spilt Tensile Strength after 28 days (N/mm²) |
|---|---|---|---|---|
| 1 | 0% | 3.43 | 3.87 | 4.38 |
| 2 | 5% | 3.51 | 3.96 | 4.44 |
| 3 | 10% | 3.57 | 4.01 | 4.56 |
| 4 | 15% | 3.62 | 4.27 | 4.61 |
| 5 | 20% | 3.48 | 4.15 | 4.33 |
| 6 | 25% | 3.31 | 3.85 | 4.03 |
| 7 | 30% | 3.20 | 3.59 | 3.73 |

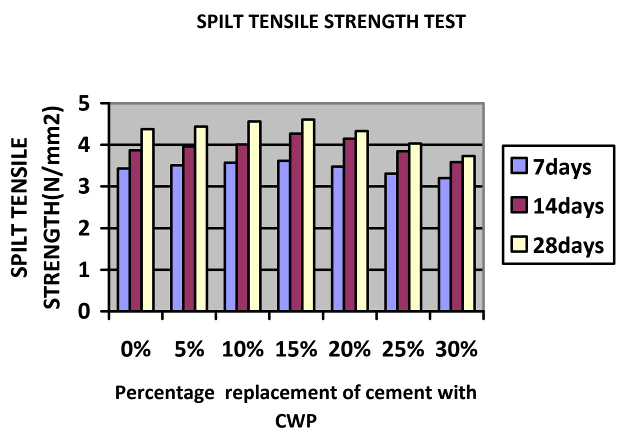


**Chart-4:** Relationship between spilt tensile strength and various percentage of CWP

### 5.6 Flexural strength test

**Table -4:** flexural strength of beam

| SL.No | Percentage of replacement of cement with CWP | Flexural Strength after 7 days ($N/mm^2$) | Flexural Strength after 14 days ($N/mm^2$) | Flexural Strength after 28 days ($N/mm^2$) |
|---|---|---|---|---|
| 1 | 0% | 4.81 | 5.26 | 5.44 |
| 2 | 5% | 5.08 | 5.37 | 5.51 |
| 3 | 10% | 5.21 | 5.56 | 5.77 |
| 4 | 15% | 5.27 | 5.63 | 5.89 |
| 5 | 20% | 4.74 | 5.23 | 5.38 |
| 6 | 25% | 4.61 | 5.15 | 5.21 |
| 7 | 30% | 4.503 | 5.01 | 5.13 |

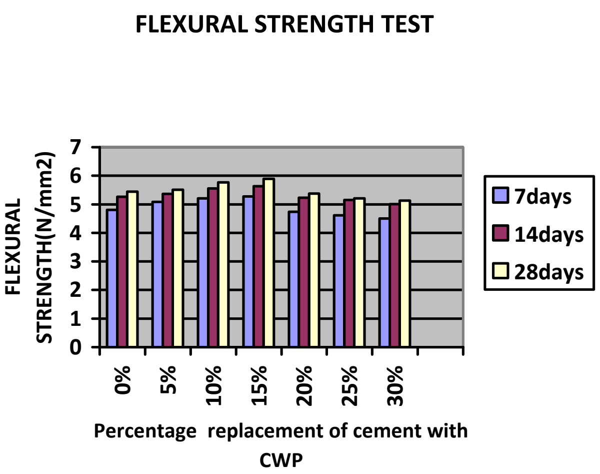


**Chart-5:** Relationship between flexural strength and various percentage of CWP

## 6. CONCLUSIONS

- The workability of concrete had been found to decrease with increase of ceramic powder.
- The use of a super plasticizer can achieve the desired workability.
- The Compressive strength of Concrete increases up to 15% replacement of cement by CWP and further increasing of percentage of CWP leads to decrease in compressive strength of concrete.
- The Split tensile strength of concrete increases up to 15% replacement of cement by CWP & further increasing of percentage of CWP leads to decrease in Split tensile strength of concrete.
- The Flexural strength increases up to 15% replacement of cement by CWP and further increases in the percentage of CWP leads to decrease in flexural strength.
- On 15% replacement of cement with ceramic waste, compressive strength, Split tensile strength and flexural strength obtained is more than those of normal concret and hence it is more economical without compromising concrete strength. It becomes technically and economically feasible.
- Use of a ceramic waste and its application are utilized for the improvement of the construction.
- Using ceramic wastes in concrete can solve several environmental problems

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