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# Use of Ceramic Waste Powder in Cement Concrete

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## Abstract

Ceramic wall tiles are used as building material in the field of construction. Manufacturing of ceramic tiles require different raw material like clay, potash, dolomite, feldspar, talc and different chemicals like sodium silicate, sodium tripoly, phosphate (STPP) in ceramic production. The temperature in the kiln varies from 200.c to 1200.c.this variation of manufacturing; therefore there is a pozzolanic reactivity in such material.In ceramic industry about 5-10% production goes as waste in various processes while manufacturing (this waste percentage goes down if the technology is installed in new units.) this waste of ceramic industries dumped at nearby places resulting in environmental pollution causing effect to habitant and agricultural lands. Therefore using of ceramic waste powder in concrete would benefit in many ways in saving energy & protecting the environment. The cost of deposition of ceramic waste in landfills will be saved.Raw materials and natural resources will be replaced. Which indirectly helps for reducing the greenhouse gas(co2).there is a large amount of carbon dioxide released in the cement production. In this research study ceramic waste powder from ceramic wall tiles industry is used as replacement to cement in concrete in an incremental order like 0%, 10%.20%, 30%, 40%, 50% and 60% by weight of cement in concrete for M 25 grade.

**Keywords: Ceramic Waste Powder, Pozzolanic Material, Industrial Waste, Cost Effective, Green Concrete**

## I. INTRODUCTION

Environmental issues associated with ceramic tile and sanitary ware manufacturing primarily includes the following:

1) Air Emissions, Greenhouse Gases, and Energy Efficiency
2) Wastewater
3) Solid waste

Each year thousands of tones of wastes are disposed of in landfills which effects occupation and degradation of valuable land. Depletion of natural resources is a common phenomenon in developing countries like India due to rapid urbanization & industrialization, involving construction of infrastructures and other amenities.

Indian ceramic production is 100 Million ton per year. In the ceramic industry, about 15%-30% waste material generated from the total production. This waste is not recycled in any form at present. However, the ceramic waste is durable, hard and highly resistant to biological, chemical, and physical degradation forces. The Ceramic industries are dumping the powder in any nearby pit or vacant spaces, near their unit although notified areas have been marked for dumping. This leads to serious environmental and dust pollution and occupation of a vast area of land, especially after the powder dries up so it is necessary to dispose the Ceramic waste quickly and use in the construction industry. As the ceramic waste is piling up every day, there is a pressure on ceramic industries to find a solution for its disposal. The advancement of concrete technology can reduce the consumption of natural resources. They have forced to focus on recovery, reuse of natural resources and find other alternatives. The use of the replacement materials offer cost reduction, energy savings, arguably superior products, and fewer hazards in the environment.

## II. DESCRIPTIONS OF MATERIALS

### *A. Cement:*

The Ordinary Portland Cement of 53 grades conforming to IS: 8112 is be use. Physical property of cement is as per table 1.

Table – 1
Test Result for Cement

| | | |
|---|---|---|
| *Initial setting time* | | *180min* |
| *Final setting time* | | *240 min* |
| *Compressive strength* | *3 days* | *37 N/mm$^2$* |
| | *7 days* | *48 N/mm$^2$* |
| | *28 days* | *59 N/mm$^2$* |

***B. Ceramic Waste:***
Ceramic material is hard, rigid. It is estimated that 15 to 30% waste are produced of total raw material used, and although a portion of this waste may be utilized on-site, such as for excavation pit refill. Chemical properties of ceramic waste are as per table 2.

Table - 2

| *CONTENTS* | *w/w %* |
|---|---|
| *$SiO_2$* | *55.24* |
| *CaO* | *28.70* |
| *$Al_2O_3$* | *13.25* |

(Source: MET-CHEM LABORATORIES, VADODARA)

***C. Natural Coarse Aggregate:***
The fractions from 20 mm to 4.75 mm are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock, conforming to IS: 383 is being use. The Flakiness and Elongation Index were maintained well below 15%.

Table – 3

| *Property* | *Natural Coarse Aggregate* |
|---|---|
| *Specific Gravity* | *2.74* |
| *Water Absorption* | *1.45%* |
| *Moisture Content* | *Nil* |

***D. Fine Aggregate:***
Those fractions from 4.75 mm to 150 microns are termed as fine aggregate. The river sand is used in combination as fine aggregate conforming to the requirements of IS: 383.

Table – 4

| *property* | *Natural fine Aggregate* |
|---|---|
| *SPECIFIC GRAVITY* | *2.64* |
| *WATER ABSORPTION* | *1.0%* |
| *MOISTURE CONTENT* | *NIL* |

## III. WORKABILITY TESTS

***A. Slump Test:***
Slump is the most commonly used test for measuring workability of concrete at site as well as in the laboratory. The apparatus for slump test consists of a metallic mould in the form of a frustum of a cone with internal dimension as follows, Bottom dia. = 20cm, Top dia. = 10cm, Height = 30cm. Internal surface of mould is thoroughly cleaned and kept it on horizontal surface. Filled the concrete in four layer and tapper it with 16mm diameter rod, the mould is removed by lifting it slowly and carefully in a vertical direction. This allows the concrete is measured. This difference in height in mm is taken as slump of concrete.

## IV. TESTS FOR CONCRETE

***A. Test for Compressive Strength of Concrete Cubes:***
Compressive strength is the most common test conducted on hardened concrete. It is very easy and simple to perform and partly because many of the desirable properties of concrete are qualitatively related to its compressive strength. Compression test

specimens are used: cubes, cylinder and prisms. Take required quantities of material and mixed it by hand or by machine mixing. Concrete should be filled in mould in three equal layers. Each layer should be compacted for 25 times with a 16mm dia. rod. After hardened the specimens are taken out and cured in clean, fresh water. Curing is done until the required days of testing. The test should be carried out immediately upon the removal of specimen from water curing and after that finding out the compressive strength by compressive machine.
Compressive strength=maximum load/area =P/A

### *B. Test for Split Tensile of Concrete Cylinder:*

Tensile stress is likely to develop in concrete due to drying, shrinkage, corrosion of steel reinforcement or due to temperature gradients. The determination of flexural tensile strength is essential to estimate the load at which the concrete members may cracks. It is of a great importance while designing liquid retaining structures and prestressed concrete structures. The cylinder is placed with its axis horizontal between the platens of a testing machine, and the load is increased until failure by splitting along the vertical diameter takes place. Narrow packing of plywood strip or rubber is used to reduce the magnitude of high compressive stress immediately below load. If such strips are not provided then the observed stress will be reduced for up to 8%.
Horizontal Tensile Stress = $\frac{2P}{\pi LD}$
Where, P = Compressive load on the cylinder
L = Length of cylinder
D = Diameter of cylinder

### *C. Test for Flexural Strength of Concrete Beams:*

The normal tensile stress in concrete, when cracking occurs in a flexure test is known as modulus of ruptures, i.e. flexural strength. The standard test specimen is a beam of size 150mm × 150 mm × 700mm size. The specimen should be should be cast and cured in the same manner as for casting of cubes. The specimens should be immediately tested on removal from the water. The flexural strength can be finding out by universal testing machine. The flexural strength can be found out by central loading as well as the load is applied through two similar rollers mounted at the third point of the supporting span. The flexural strength can be found out by formula as follows

$F_{cr} = (P.L)/bd^2$
Where, P = Fracture load for beam
L = Span
b = Width of the beam
d = Depth of the beam

### *D. Durability Test on Concrete:*

Acid attack is one of the most important aspects for consideration when we deal with the durability of concrete. Acid attack is particularly important because it primarily causes corrosion of reinforcement. Statistics have indicated that over 40 per cent of failure of structures is due to corrosion of reinforcement.

The cubes were cast and kept at a temperature of 27OC± 2OC and at relative humidity of about 90% for 24 hours. After 24 hours the cubes were removed from the mould and immersed in clean and fresh water until they were taken out for testing. After 28 days of curing, the cubes were taken out, weighed accurately and were immersed in a 5% concentrated sulphuric acid(H2SO4) & 5 % hydrochloride acid(HCL) for another 28 days. After 56 days from the date of casting cubes are removed from acid curing and worst surfaces of cube were removed. The specimens were weighed again and the weight difference before and after acid curing was determined. After that specimens were taken for compressive testing to measure their strength loss due to acid attack.

## V. RESULTS

The mix proportion for M 25 is and W/C ratio of 0.46 was casted. Slump test was tested when the concrete in fresh concrete. The cubes, beams and cylinders were tested for compressive strength, split tensile strength and flexural strength. These tested were carried out at age of 7 days, 14 days and 28 days.

Table – 5
Various Concrete Mixes

| *MIX 1* | *MIX 2* | *MIX 3* |
|---|---|---|
| $X_0$<br>*0%CWP+100%CMT* | $Y_0$<br>*0%CWP+100%CMT+1%*$Na_2SiO_3$ | $Z_0$<br>*0%CWP+100%CMT+2%*$Na_2SiO_3$ |
| $X_1$<br>*10%CWP+90%CMT* | $Y_1$<br>*10%CWP+90%CMT+1%*$Na_2SiO_3$ | $Z_1$<br>*10%CWP+90%CMT+2%*$Na_2SiO_3$ |

| | | |
|---|---|---|
| *$X_2$ 20%CWP+80%CMT* | *$Y_2$ 20%CWP+80%CMT+1%$Na_2SiO_3$* | *$Z_2$ 20%CWP+80%CMT+2%$Na_2SiO_3$* |
| *$X_3$ 30%CWP+70%CMT* | *$Y_3$ 30%CWP+70%CMT+1%$Na_2SiO_3$* | *$Z_3$ 30%CWP+70%CMT+2%$Na_2SiO_3$* |
| *$X_4$ 40%CWP+60%CMT* | *$Y_4$ 40%CWP+60%CMT+1%$Na_2SiO_3$* | *$Z_4$ 40%CWP+60%CMT+2%$Na_2SiO_3$* |
| *$X_5$ 50%CWP+50%CMT* | *$Y_5$ 50%CWP+50%CMT+1%$Na_2SiO_3$* | *$Z_5$ 50%CWP+50%CMT+2%$Na_2SiO_3$* |
| *$X_6$ 60%CWP+40%CMT* | *$Y_6$ 60%CWP+40%CMT+1%$Na_2SiO_3$* | *$Z_6$ 60%CWP+40%CMT+2%$Na_2SiO_3$* |

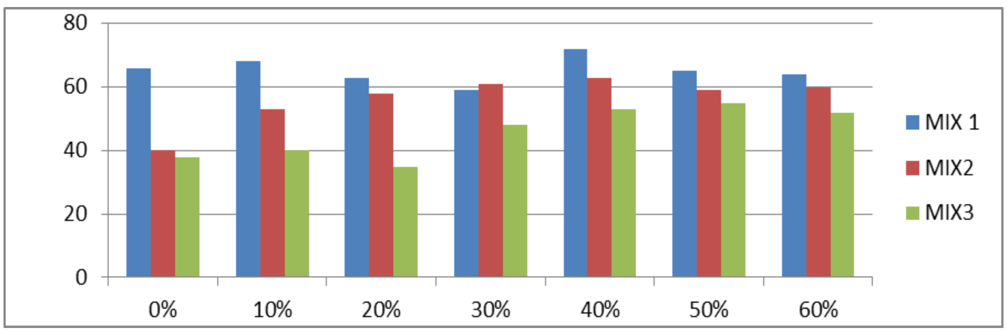
1) Coarse aggregate and fine aggregate are as per designed mix in all three mixes
2) CMT – Cement
3) CWP – Ceramic Waste Powder
4) Mix1, Mix2, Mix3 are of same water-cement ratio 0.46

### A. *Workability Test Results:*

1) *Slump Test:*

Table - 6
Comparison of Slump Values

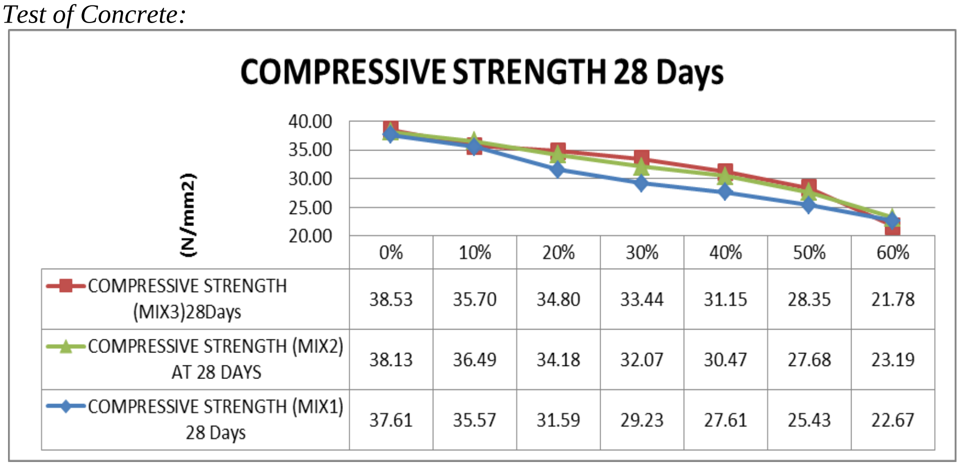
| *MIX* | *SLUMP FOR MIX 1* | | *SLUMP FOR MIX 2* | | *SLUMP FOR MIX 3* | |
|---|---|---|---|---|---|---|
| | *VALUE (mm)* | *VARIATION (%)* | *VALUE (mm)* | *VARIATION (%)* | *VALUE (mm)* | *VARIATION (%)* |
| *0%* | *66* | *0* | *40* | *39.3* | *38* | *42.4* |
| *10%* | *68* | *-3.03* | *53* | *19.6* | *40* | *39.3* |
| *20%* | *63* | *4.5* | *58* | *12.1* | *35* | *46.9* |
| *30%* | *59* | *10.6* | *61* | *7.5* | *48* | *27.2* |
| *40%* | *72* | *-6.06* | *63* | *4.5* | *53* | *19.6* |
| *50%* | *65* | *1.51* | *59* | *10.6* | *55* | *16.6* |
| *60%* | *64* | *3.03* | *60* | *9.09* | *52* | *21.2* |



Graph 1: Comparisons of Slump Values

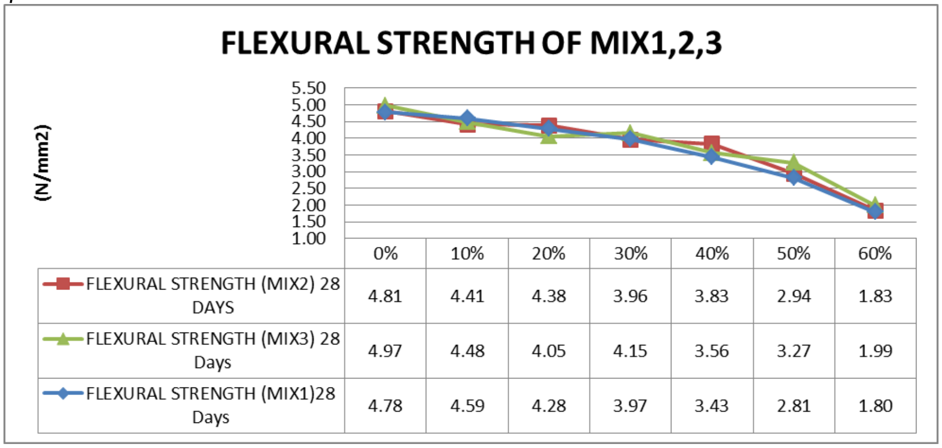
### B. *Effect on Hardened Properties of Concrete:*

1) *Compressive Test of Concrete:*



Graph 2: Comparative Study of Compressive Strength of Mix1, 2, 3

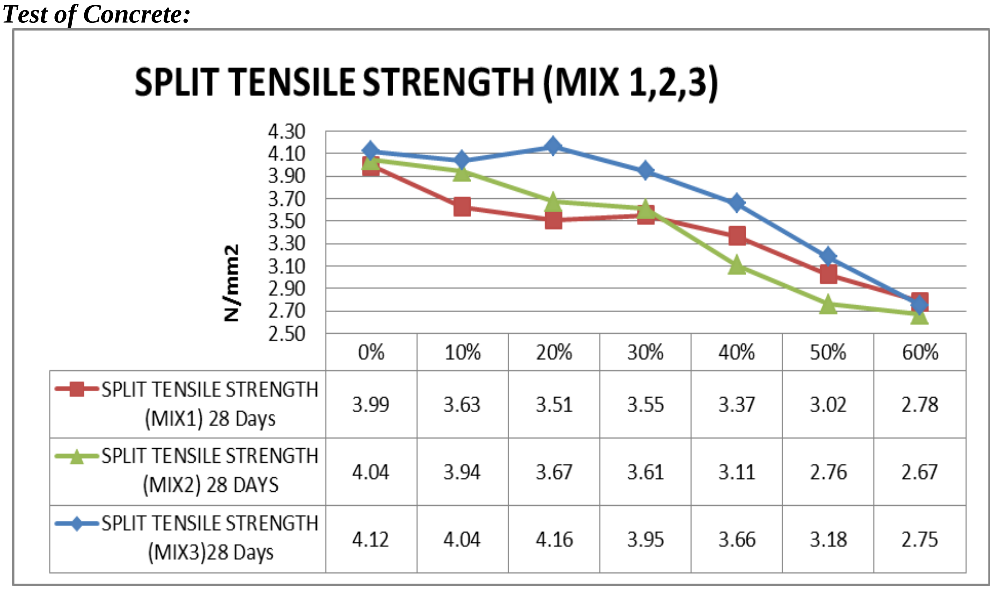
2) *Flexural Test of Concrete:*




| | 0% | 10% | 20% | 30% | 40% | 50% | 60% |
|---|---|---|---|---|---|---|---|
| FLEXURAL STRENGTH (MIX2) 28 DAYS | 4.81 | 4.41 | 4.38 | 3.96 | 3.83 | 2.94 | 1.83 |
| FLEXURAL STRENGTH (MIX3) 28 Days | 4.97 | 4.48 | 4.05 | 4.15 | 3.56 | 3.27 | 1.99 |
| FLEXURAL STRENGTH (MIX1)28 Days | 4.78 | 4.59 | 4.28 | 3.97 | 3.43 | 2.81 | 1.80 |

Graph 3: Comparison of Flexural Strength of Mix 1, 2, 3

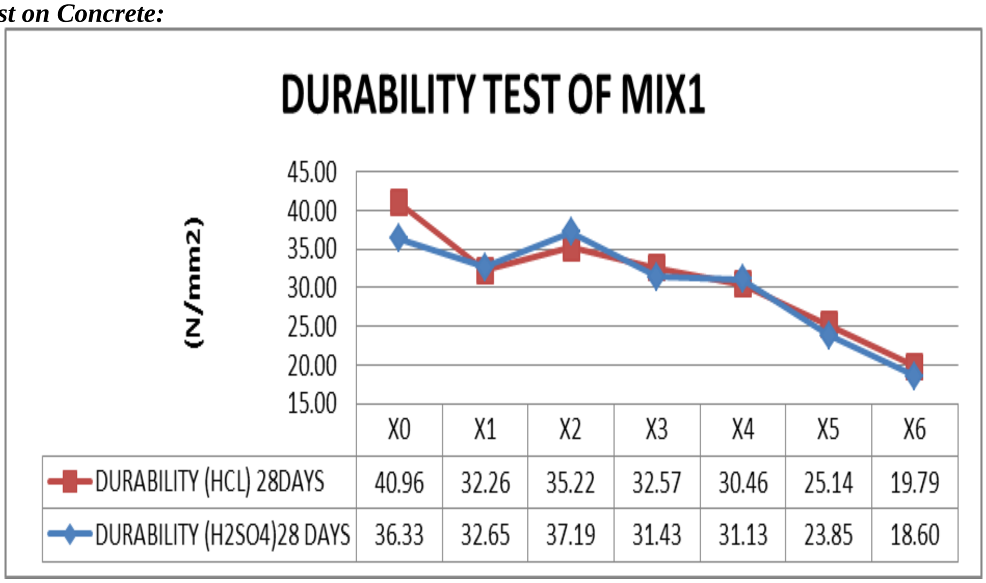
### C. *Split Tensile Test of Concrete:*



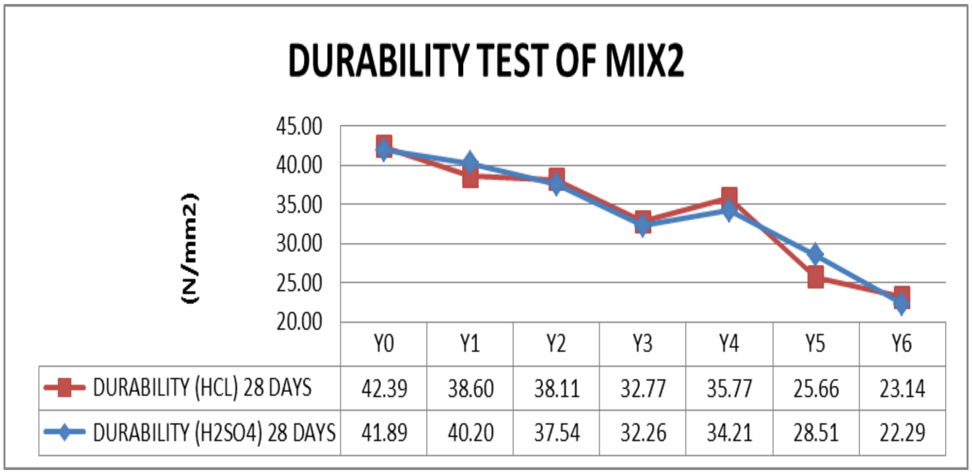

| | 0% | 10% | 20% | 30% | 40% | 50% | 60% |
|---|---|---|---|---|---|---|---|
| SPLIT TENSILE STRENGTH (MIX1) 28 Days | 3.99 | 3.63 | 3.51 | 3.55 | 3.37 | 3.02 | 2.78 |
| SPLIT TENSILE STRENGTH (MIX2) 28 DAYS | 4.04 | 3.94 | 3.67 | 3.61 | 3.11 | 2.76 | 2.67 |
| SPLIT TENSILE STRENGTH (MIX3)28 Days | 4.12 | 4.04 | 4.16 | 3.95 | 3.66 | 3.18 | 2.75 |

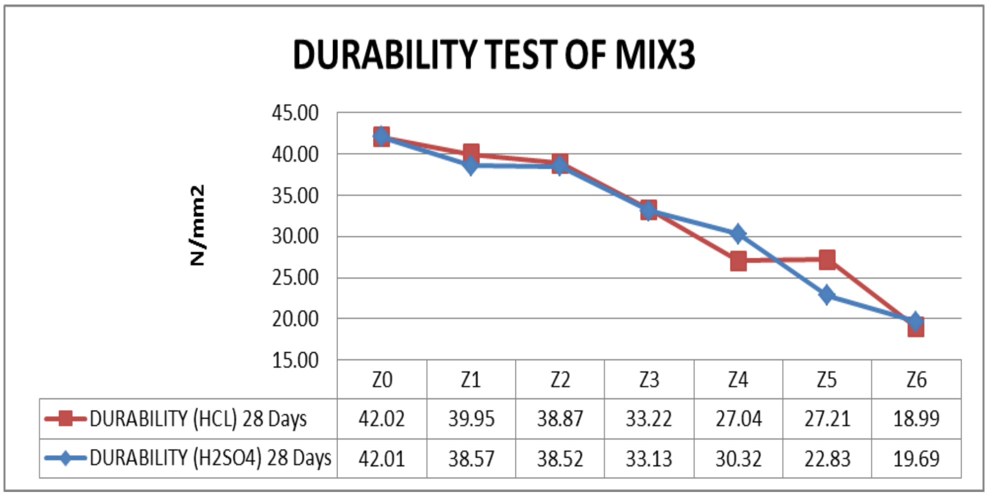
Graph 4: Comparison of Split Tensile Strength of Mix 1, 2, 3

### D. *Durability Test on Concrete:*




| | X0 | X1 | X2 | X3 | X4 | X5 | X6 |
|---|---|---|---|---|---|---|---|
| DURABILITY (HCL) 28DAYS | 40.96 | 32.26 | 35.22 | 32.57 | 30.46 | 25.14 | 19.79 |
| DURABILITY (H2SO4)28 DAYS | 36.33 | 32.65 | 37.19 | 31.43 | 31.13 | 23.85 | 18.60 |




Graph 5: Effect on Durability Test (Acid Attack)

## VI. CONCLUSION & FUTURE SCOPE

### *A. Conclusions:*

Various tests are performed in order to know the effect of sodium silicate binder on CWP & cement concrete.
Conclusion is based on results discussed above are as follows:

1) When Sodium silicate used as binder with cement, the setting time of cement get affected.
2) Water gets dehydrated from the mix while testing initial & final setting time of cement but initial & final time fall as per specified in code.
3) Slump value for mix 1 decreases with respect to conventional concrete, while adding 10% & 40% replacement of CWP increases by 3.03% & 6.06% respectively.
4) Slump value for mix 2 decreases with respect to the conventional concrete mix done in mix 1.
5) When in mix 1 CWP only is used in different varying percentage of cement (0% to 60%), compressive strength decrease from 0% to 39.7% respectively.
6) When in mix 2, CWP & 1% sodium silicate of water is used in different varying percentage of cement (0% to 60%) compressive strength decreases from -1.3% to 38.3% respectively with compare to the conventional concrete.
7) When mix 3, CWP & 2% sodium silicate is used in different varying percentage of cement (0% to 60%) compressive strength -1.3% to 42% with respect to conventional concrete.
8) Concrete on 30% replacement of cement with CWP compressive strength obtained is 33.44 N/mm2 of mix 3 (i.e., 30% CWP & 2% Na2SO4) can be recommended.
9) When observing the cost of concrete at this point is reduced up to 16.3% in M25 grade of concrete and becomes economical with compromising the target strength of concrete.
10) By following the same above percentage replacement split tensile strength of mix 3 is 3.95 & only about 1% of loss is observed with compare to conventional concrete.

11) Flexural is observed in mix 3 (i.e., 30% CWP & 1% Na2SO4) as greater than mix 1 & mix 2, while taking mix 3 (i.e., 30% CWP & 2% Na2SO4) as higher side in compression and split tensile strength, we find flexural strength is decreased by 13.1% which is preferable.
12) Durability properties of mix 3 (30% replacement of CWP) is better than mix 1 and mix 2.
13) Finally, this research can be made applicable if it is used in READY MIX CONCRETE PLANTS as quality of concrete is important one.

### *B. Future Scope of Work:*

Further testing and experiment can be done on ceramic waste concrete, as it is highly recommended to indicate strength characteristics of this type of material for application in normal or low rise structural concrete.

Some recommendations made for further studies:

1) Experiment can be done by varying water/cement ratio, to know the varying strength parameters while addition of sodium silicate, in order to get better grip on workability.
2) More investigations and research can be done on the strength characteristics of ceramic waste powder as cementious material which is also a pozzolanic material.
3) Non-destructive testing like Rapid Chloride Penetration Test (RCPT) can be done to support its suitability for structural concrete.
4) Use of waste can sustain environment and eco-system the whole; therefore there is an active research on ceramic waste.

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