Partial Replacement of Cement in Concrete using Ceramic Waste

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***Abstract*: Waste and find the solution of resulting it the most serious problem of the word today. Waste utilization has become an attractive alternative to disposal now days. There are number of researches, for use of waste in industry most of them related to use these waste in construction are or use of waste in concrete to develop new type of concrete. Use of waste producing is not only makes it economical but also a very good and attractive solution of disposal problem. Ceramic waste from ceramic industry is used to produce a new type of concrete by replacing the cement. According a report in India 30% of the daily production goes on waste during the manufacturing, usages and transportation. Ceramic waste increases day by day because of its usages in construction, so it is necessary for ceramic industry for diminishing the waste dump at ceramic industries is recycling, reusing and substitution of concrete ingredients. Ceramic waste produce from industry is durable, hard, and highly resistant to biological, chemical and physical degradation forces. Ceramic waste powder can be used to produce lightweight concrete, without affecting. The compressive strength of concrete of the concrete improved by the use of optimal dosage of ceramic tile powder.**

Keywords:-Ceramic waste, properties of ceramic waste, partial replacement of cement.

1. INTRODUCTION

Introduction:- in India ceramic industry, in which wall floor tiles, sanitary ware, bricks and roof tiles refectory materials and ceramic materials for domestic and other use is produce 100 million tons per year, out of which 15-30% material is waste. Ceramic industry dump these waste powder in nearby pit or any vacant space. Ceramic waste consider as a non hazardous solid waste and possess pozzolanic properties. Use of non hazardous material in construction field is gaining in India day by day. After recycling ceramic waste can be used in different construction application. Researches used ceramic waste to generate green concrete by using 20% replacement of natural aggregate. It can be shown that the concrete produce from ceramic waste is good workable and achieve characteristic strength [9, 10, 11, 12].

Researchers found that the addition of ceramic waste has improved the compressive strength, split tensile strength.

The cube strength increases to extant of 30% at w/c ratio of 0.46 with replacement of 20% ceramic waste [1]. Ceramic waste found suitable as a substitution for fine and coarse aggregate and partial substitution in cement production [2]. Ceramic waste can be used as a filler material in flexible pavement [3]The ongoing research has interest in ceramic waste from different ceramic based industry which includes wall floor tiles, sanitary ware, bricks and roof tiles etc. The waste generated from thee industry dump in a pit or nearby vacant space which is not a best option and also neglect the concept of sustainable development, and hence need to find out the alternative solution for this problem and use of ceramic waste which is generated in a huge amount in India per year or worldwide in a positive manner

2. MATERIALS USED FOR MIX DESIGN M30

Ceramic Waste:- Ceramic waste comes from the ceramic industry in which the waste of wall and floor tiles, sanitary ware, bricks and roof tiles are included ceramic waste consider as a non-hazardous solid waste and possess pozzzolanic properties. Ceramic waste is hard and durable.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 [3].

Properties of Ceramic Powder:-

I. Inorganic
II. Highly resistant to chemical and biological forces
III. Mainly composed of silica (69.4%) and alumina (18.2%), High strength
IV. Good frictional behaviour
V. Thermal expansion coefficient similar to cement
VI. Corrosion resistance in acids and alkalis
VII. Modulus of elasticity is similar to steel.

Cement (OPC):- The Ordinary Portland Cement of 33 grades conforming to IS: 8112 is being used. Ordinary Portland Cement (OPC) is manufactured by grinding a mixture of limestone and other raw materials like argillaceous, calcareous, gypsum to a powder. This cement is available in three types of grades, such as OPC 33 grade, OPC 43 grade and OPC 53 grade. OPC is the most commonly used cement in the world. This type of cement is preferred where fast pace of construction is done. However, the making of OPC has reduced to a great extent as blended cement like PPC has advantages, such as lower environmental pollution, energy consumption and more economical.

CONSTITUENTS OF OPC CEMENT:

The chief chemical constituents of Portland cement are as follows:

Lime (CaO)	60 to 67%
Silica (SiO2)	17 to 25%
Alumina (Al2O3)	3 to 8%
Iron oxide (Fe2O3)	0.5 to 6%
Magnesia (MgO)	0.1 to 4%
Sulphur trioxide (SO3)	1 to 3%
Soda and/or Potash (Na2O+K2O)	0.5 to 1.3%

Table 2.1 chemical constituents of Portland cement

The above constituents forming the raw materials undergo chemical reactions during burning and fusion, and combine to form the following compounds called BOGUE COMPOUNDS.

Compound	Abbreviated designation
Tricalcium silicate (3CaO.SiO2)	C_3S
Dicalcium silicate (2CaO.SiO2)	C_2S
Tricalcium aluminate (3CaO.Al2O3)	C_3A
Tetracalciumaluminoferrite (4CaO.Al2O3.Fe2O3)	C_4AF

Table 2.2 Bogue Compound

Aggregate:- Aggregates are the important constituents in concrete. They give body to the concrete, reduce shrinkage and affect economy. One of the most important factors for producing workable concrete is a good gradation of aggregates. Good grading implies that a sample fraction of aggregates in required proportion such that the sample contains minimum voids. Samples of the well graded aggregate containing minimum voids require minimum paste to fill up the voids in the aggregates. Minimum paste means less quantity of cement and less water, which are further mean increased economy, higher strength, lower shrinkage and greater durability. We used the Coarse Aggregate of 4.75-10mm whose Specific gravity was 2.69 and the fineness modulus was 2.42, & the course aggregate of 10-20mm having Specific gravity 2.67 and fineness modulus was 7.9.

3. MIX DESIGN OF M30 GRADE DESIGNED AS PER IS 10262:2009 & IS 456:2000

Proportioning:

1) Grade designation : M30
2) Type of cement : OPC 43 Grade conforming IS 12269
3) Maximum nominal size of aggregate : 20mm
4) Minimum cement content : 320 kg/m3 (IS 456:2000)
5) Maximum water-cement ratio : 0.45 (Table 5 of IS 456:2000)
6) Workability : 70-100mm slump
7) Exposure condition : Moderate (For Reinforced Concrete)
8) Method of concrete placing : Pumping
9) Degree of supervision : Good
10) Type of aggregate : Crushed Angular Aggregates
11) Maximum cement content : 360 kg/m3

Test Data For Materials:

1) Cement used : OPC 43 Grade conforming IS 12269
2) Specific gravity of cement : 3.15
3) Specific gravity of
   a) Coarse aggregate : 2.7
   b) Fine aggregate: 2.31
4) Sieve analysis:
   a) Coarse aggregate: Conforming to all in aggregates of Table 2 of IS 383
   b) Fine aggregate : Conforming to Grading Zone II of Table 4 of IS 383

Target Strength for Mix Proportioning:

f'ck = fck + 1.65 s

where

f'ck = Target average Compressive Strength at 28 days,

fck = Characteristics Compressive Strength at 28 days, and

s = standard deviation.

From Table I of IS 10262:2009, Standard Deviation, s = 5 N/mm2.

Therefore, target strength = 30 + 1.65 x 5 = 38.25 N/mm2.

Selection of Water-Cement Ratio:

Adopted maximum water-cement ratio = 0.45

Selection of Water Content:

From Table 2 of IS 10262:2009, maximum water content for 20 mm aggregate = 186 litre (for 25 to 50 mm slump range) Estimated water content for 75 mm slump = 186+ (3/100 *186) = 191.58litre.

(Note: If Super plasticizer is used, the water content can be reduced up to 20% and above.)

Calculation for Cement Content:

Adopted w/c Ratio = 0.45

Cement Content = 191.58/0.45 = 425.73 kg/m3

Proportion of Volume of Coarse Aggregate and Fine Aggregate:

From Table 3 of (IS 10262:2009) Volume of coarse aggregate corresponding to 20 mm size aggregate and fine aggregate (Zone II) for water-cement ratio of 0.50 =0.62 .

In the present case water-cement ratio is 0.45. Therefore, volume of coarse aggregate is required to be increased to decrease the fine aggregate content. The proportion of volume of coarse aggregate is increased by 0.01 (at the rate of -/+ 0.01 for every ± 0.05 change in water-cement ratio).

Therefore, corrected proportion of volume of coarse aggregate for the water-cement ratio of 0.45 = 0.63

NOTE – In case the coarse aggregate is not angular one, then also volume of coarse aggregate may berequired to be increased suitably based on experience & site conditions.

For pumpable concrete these values should be reduced up to 10%. Therefore, volume of coarse aggregate =0.65 x 0.9 = 0.585.

Volume of fine aggregate content = 1 – 0.63 = 0.37

Mix Calculations:

The mix calculations per unit volume of concrete shall be as follows:

a) Volume of concrete = 1 m3

b) Volume of cement = [(Mass of cement) / (Specific Gravity of Cement)] x (1/1000)
= 425.73/(3.15 x 1000)
= 0.135m3

c) Volume of water = [(Mass of water) / (Specific Gravity of water)] x (1/1000)
= 191.58/(1 x 1000)
= 0.192m3

d) Air Content = 2% of total volume of concrete
= 0.02 x 1
= 0.02m3

e) Volume of all Aggregate = [a - (b + c + d)]
= [1 - (0.135 + 0.192 + 0.02)]
= 0.653m3

e) Mass of coarse aggregate = Volume of all aggregate x Volume of Coarse Aggregate x Specific Gravit of coarse aggregate x 1000
= 0.653 x 0.63 x 2.7 x 1000
= 1110.75 kg/m3

f) Mass of fine aggregate = Volume of all aggregate x Volume of Fine Aggregate x Specific Gravity of Fine aggregate x 1000
= 0.653 x 0.37 x 2.31 x 1000
= 558.12 kg/m3

Mix Proportions:

Cement = 425.73 kg/m3
Water = 191.58 l/m3
Fine aggregate = 558.12 kg/m3
Coarse aggregate = 1110.75 kg/m3
Water-cement ratio = 0.45

Note – Aggregates should be used in saturated surface dry condition. If otherwise, when computing the requirement of mixing water, allowance shall be made for the free (surface) moisture contributed by the fine and coarse aggregates. On the other hand, if the aggregates are dry the amount of mixing water should be increased by an amount equal to the moisture likely to be absorbed by the aggregates. Necessary adjustments are also required to be made In mass of aggregates. The surface water and percent water absorption of aggregates shall be determined according to IS 2386.

Mix Design calculation for 6 cubes:
Cement = 8.5 kg
Water = 3.83 litre
Coarse aggregate = 22.2 kg
Fine Aggregate = 11.16 kg

Compressive Strength of Mix Grade M30:

7days
Sample 1
Compressive load = 540 KN
Compressive Strength = $\frac{540X1000}{150X150}$
= 24 N/mm2

Sample 2
Compressive load = 550 KN
Compressive Strength = $\frac{550X1000}{150X150}$
= 24.44 N/mm2

28 days
Sample 1
Compressive load = 780 KN
Compressive Strength =$\frac{780X1000}{150X150}$
= 34.67 N/mm2

Sample 2
Compressive load = 800 KN
Compressive Strength = $\frac{800X1000}{150X150}$
= 35.55 N/mm2

Compressive strength

S.No	7 days strength in N/mm2	28 days strength in N/mm2
1.	24	34.67
2.	24.44	35.55

Table 3.1 compressive strength of M30 cube

4. **Partial Replacement of Cement by Ceramic powder**

5% Replacement of Cement by Ceramic Powder:

Mix Design calculation of M30 for 6 cubes:
Cement = 8.5 kg
Water = 3.83 litre
Coarse aggregate = 22.2 kg
Fine Aggregate = 11.16 kg
By replacing 5% of cement by ceramic waste –
5% of 8.5 = 0.425 kg
Therefore,
Final Mix for 5% replacement:
Cement = 8.5 – 0.425 = 8.075 kg
Water = 3.83 litre
Coarse Aggregate = 22.2 kg
Fine Aggregate = 11.16 kg
Ceramic waste = 0.425 kg

7 days
Sample 1
Compressive load = 555 KN
Compressive Strength =$\frac{555X1000}{150X150}$
= 24.67 N/mm2

Sample 2
Compressive load = 550 KN
Compressive Strength = $\frac{550X1000}{150X150}$
= 24.44 N/mm2

28 days
Sample 1
Compressive load = 820 KN
Compressive Strength = $\frac{820X1000}{150X150}$
= 36.44 N/mm2

Sample 2

Compressive load = 795 KN
Compressive Strength = $\frac{795X1000}{150X150}$
= 35.33 N/mm2

Compressive test of 5% replacement cubes:

S.No	7 days strength in N/mm2	28 days strength in N/mm2
1.	24.67	36.44
2.	24.44	35.33

Table 4.1 Compressive Strength of M30 with 5% Replacement

10% Replacement of Cement by Ceramic Powder:

Mix Design calculation of M30 for 6 cubes:
Cement = 8.5 kg
Water = 3.83 litre
Coarse aggregate = 22.2 kg
Fine Aggregate = 11.16 kg
By replacing 10% of cement by ceramic waste –
10% of 8.5 = 0.85 kg
Therefore,
Final Mix for 10% replacement:
Cement = 8.5 – 0.85 = 7.65 kg
Water = 3.83 litre
Coarse Aggregate = 22.2 kg
Fine Aggregate = 11.16 kg
Ceramic waste = 0.85 kg

7 days
Sample 1
Compressive load = 570 KN
Compressive Strength =$\frac{570X1000}{150X150}$
= 25.33N/mm2
Sample 2
Compressive load = 560 KN
Compressive Strength = $\frac{560X1000}{150X150}$
= 24.88 N/mm2

28 days
Sample 1
Compressive load = 850 KN
Compressive Strength =$\frac{850X1000}{150X150}$
= 37.7 N/mm2
Sample 2
Compressive load = 830 KN
Compressive Strength = $\frac{830X1000}{150X150}$
= 36.88 N/mm2

Compressive test of 10% replacement cubes:

S.No	7 days strength in N/mm2	28 days strength in N/mm2
1.	25.33	37.7
2.	24.88	36.88

Table 4.2Compressive Strength of M30 with 10% Replacement

15% Replacement of Cement by Ceramic Powder:

Mix Design calculation of M30 for 6 cubes:
Cement = 8.5 kg
Water = 3.83 litre
Coarse aggregate = 22.2 kg
Fine Aggregate = 11.16 kg
By replacing 15% of cement by ceramic waste –
15% of 8.5 = 1.275 kg
Therefore,
Final Mix for 15% replacement:
Cement = 8.5 – 1.275= 7.225 kg
Water = 3.83 litre
Coarse Aggregate = 22.2 kg
Fine Aggregate = 11.16 kg
Ceramic waste = 1.275 kg
7 days
Sample 1
Compressive load = 590 KN
Compressive Strength =$\frac{590X1000}{150X150}$
= 26.22 N/mm2
Sample 2
Compressive load = 600 KN
Compressive Strength = $\frac{600X1000}{150X150}$
= 26.67 N/mm2

28 days
Sample 1
Compressive load = 870 KN
Compressive Strength =$\frac{870X1000}{150X150}$
= 38.67 N/mm2
Sample 2
Compressive load = 855 KN
Compressive Strength = $\frac{855X1000}{150X150}$
= 38 N/mm2

Compressive test of 15% replacement cubes:

S.No	7 days strength in N/mm2	28 days strength in N/mm2
1.	26.22	38.67
2.	26.67	38

Table 4.3Compressive Strength of M30 with 15% Replacement

20% Replacement of Cement by Ceramic Powder:
Mix Design calculation of M30 for 6 cubes:
Cement = 8.5 kg
Water = 3.83 litre
Coarse aggregate = 22.2 kg
Fine Aggregate = 11.16 kg
By replacing 20% of cement by ceramic waste –
20% of 8.5 = 1.7 kg
Therefore,
Final Mix for 20% replacement:
Cement = 8.5 – 1.7 = 6.8 kg
Water = 3.83 litre
Coarse Aggregate = 22.2 kg
Fine Aggregate = 11.16 kg

Ceramic waste = 1.7 kg

7 days
Sample 1
Compressive load = 500 KN
Compressive Strength $= \frac{500X1000}{150X150}$
= 22.22 N/mm2
Sample 2
Compressive load = 520 KN
Compressive Strength $= \frac{520X1000}{150X150}$
= 23.11 N/mm2

28 days
Sample 1
Compressive load = 720 KN
Compressive Strength $= \frac{720X1000}{150X150}$
= 32 N/mm2
Sample 2
Compressive load = 735 KN
Compressive Strength $= \frac{735X1000}{150X150}$
= 32.67 N/mm2

Compressive test of 20% replacement cubes:

S. No	7 days strength in N/mm2	28 days strength in N/mm2
1.	22.22	32
2.	23.11	32.67

Table 4.4Compressive Strength of M30 with 20% Replacement

5. CONCLUSION

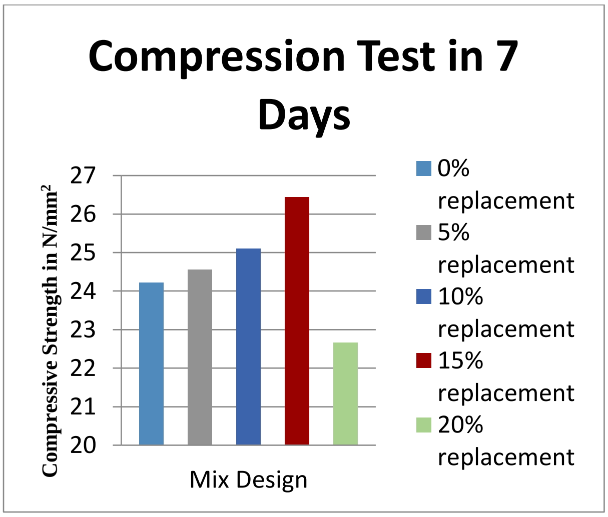

Fig 5.1 Compression Test Result in 7 Days

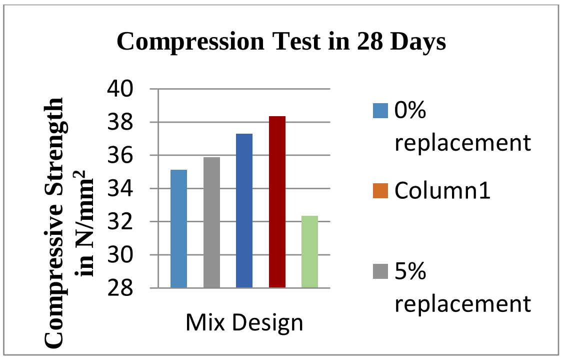

Fig. 5.2 Compression Test Result in 28 Days

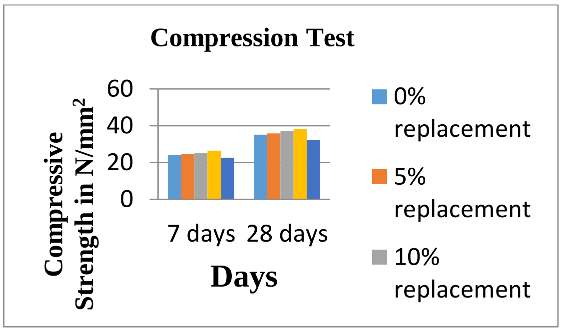

Fig. 5.3 Bar Chart of Compression Test

This study was carried to obtain the results, test conducted on the tile powder modified cement concrete mix, in order to ascertain the influence of tile powder on the characteristic strength of concrete.

I. The most optimal dosage for the partial alternative of cement by ceramic tile powder is 15 %.
II. The compressive strength of concrete decreases, when the addition of dosage is more than 15%. The results show if 20% replacement of cement by ceramic tile powder will affect the strength of concrete.
III. By doing this project we could gave a contribution to the society by making the environment more eco-friendly by utilizing the ceramic waste scientifically. Thus by adopting replacement method we can overcome problems such as waste disposal crisis.
IV. Utilization of tile powder and its application for the sustainable development of the construction industry is the most efficient solution and also address the high value application of such waste.
V. By using the replacement materials offers cost reduction and can overcome few environmental hazards.

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