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Experimental Study of Ceramic Waste Electric Insulator Powder Used as a Partial Replacement of Cement in Concrete

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ABSTRACT
The consumption of ceramic materials in construction industries is increasing day by day in the form of tiles, sanitary fittings, electrical insulators etc. But around 30% of ceramic materials changes into wastage during processing, transporting and fixing due to its brittle nature which is not recycled at present. These ceramic waste has better mechanical behavior and shows pozzolanic nature .Therefore by using these wastes in to the concrete can be improved the properties of concrete. The pozzolanic reactivity of ceramic waste insulator collected from JUET campus was evaluated and its suitability as a partial replacement of cement using ordinary Portland cement 43 grade was analysed. Hence, the ceramic waste insulator powdered passing from 90 micron sieve were used in concrete as a partial replacement of cement with 10%, 20%, 30%, 40% by weight of cement. Concrete mixtures were produced, tested and compared in terms of compressive strength to the conventional concrete. These tests were carried out to evaluate the mechanical and durability properties for 7, 14 and 28 days.

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Introduction

Aggregate and Cement, which are the most important constituents used in concrete production, are the essential materials needed for the construction industry. This certainly led to a continuous and increasing demand of natural materials used for their production. The overall size of the Indian ceramic industry is about Rs 18,000 crores producing 100 Million tons per year. The production during 2011-12 stood at approx. 600 million square meters. However, the ceramic waste is durable, hard and highly resistant to biological, chemical and physical degradation.

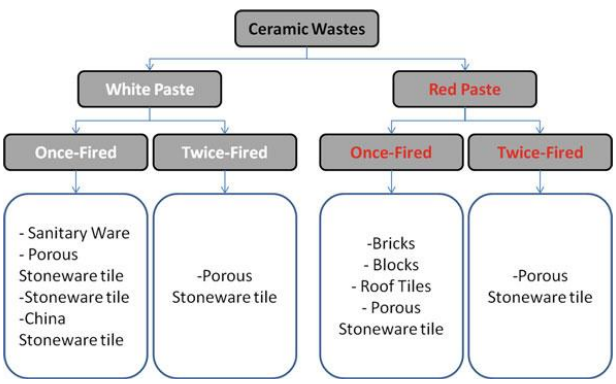

Figure 1: Classification of ceramic wastes by type and production process [1]

Figure 1 shows the classification of ceramic waste which is classified under two category white and red paste. Each category is again classified in to once fired and twice fired. The twice fired ceramic waste has more toughness and rigidity and less porous and susceptible for heavy loads as compared to once fired.

In the ceramic industry, nearly 15%-30% waste material generated from the full production. These wastes are not recycled in any course at present owning a problem in present-day society. Thus, a suitable form of management is required in society to attain sustainable growth. These industries are dumping the ceramic waste like (marble dust, stone dust, pieces of tiles, electric insulator etc) in any nearby pit or vacant spaces, near their unit, although notified areas have been marked for dumping. This contributes to severe environmental and dust pollution and occupation of an immense expanse of solid ground, especially after the powder dries up and then it is necessary to throw out the ceramic waste quickly and employ in the construction industry.

Construction and Demolition (C&D) wastes contribute the highest percentage of wastes worldwide about 75%. Furthermore, ceramic materials contribute the highest percentage of wastes within the C&D wastes about 54%. The global production of ceramic tiles during 2011-12 in the world is about 11,166 million square meters [2]. Ceramic waste is seen as non-hazardous solid waste and possesses Pozzolanic properties. Therefore, after recycling can be reused in different building construction application [3, 4, 5, and 6]. The objective of this study is to assess the durability of concrete using ceramic waste electrical insulator converted into powdered form by some processing and sieving through 90micron and partially replaced by ordinary portland cement in concrete by investigating their permeation characteristics through the determination of saturated water absorption, volume of voids, Sorption and Chloride diffusion and effect of sulphate on their compressive strength, their hardened properties like compressive strength and tensile strength.

Background

The pozzolanic reactivity of real ceramic waste from different tile manufacturing companies was evaluated and its suitability as a partial Portland cement replacement was analyzed. Compressive strength results for the mortars with increasing TCW additions, cured for 3–90 d. Although a significant reduction in strength with increasing TCW

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contents was observed at short curing ages (3 d and 7 d), the values came closer to that of the control mortar after curing for 90 d[7]. Research Conducted on the use of wastes from sanitary ware as partial substitute for coarse aggregates in concrete (15 to 25%), and produced positive results. The increase in partial substitution resulted in lower density in concrete, and higher compressive and tensile strength. The concrete produced was suitable for structural use [8]. The basic trend of permeation characteristics of the ceramic electrical insulator waste coarse aggregate concrete is similar to those of the conventional concrete. The permeation characteristic values increase with increase in water–cement ratio for both the ceramic electrical insulator waste coarse aggregate concrete and the conventional concrete [9]. Both the ceramic electrical insulator waste coarse aggregate concrete and the conventional concrete behave in a similar way and water absorption increases with increase in water–cement ratio. Water absorption is defined as the transport of liquids in porous solids caused by surface tension acting in the capillaries [10]. Also, the increase in the amount of added ceramic waste caused increase in the compression strength of investigated concretes. The highest compressive strength (increased by 12.3% compared to the control sample) showed concretes containing 30% of ceramic waste. This concrete after 150 cycles freezing and defrosting showed that strength loss of 10% compared to the control samples. Using the post-production ceramic wastes for production of concrete will give a good results (a higher compressive strength) and made economic concrete (production of 1 m3 of concrete containing the ceramic waste allow to save 5% of natural aggregate and 20% of cement [11]. The compression split tensile and flexural strength of M30 grade concrete increases when the cement is replaced with tile powder up to 30% and further replacement of cement with tile powder decreases the strength gradually. Tile powder concrete has increased durability performance [12].

Experimental

Figure 2 Show the bigger waste pieces were processed into the small size pieces with the help of compression testing machine. The small size pieces ranging from 50mm-80mm are fed in the Los Angeles abrasion machine to convert it in to powdered ceramic. In ball mills in contains the powdered ceramic and 20-40 mm size rounded shape ceramic waste aggregate. After separating the ceramic waste aggregate the final powdered ceramic is obtained by sieving through 90micron sieve size. Chemical composition of ceramic waste electric insulator powder is shown in Table 1.

Table 1: Chemical composition of ceramic waste electric insulator powder

Property	% of Ceramic powder
SIO_2	55.24
CAO	28.70
Al_2O_3	13.25
MgO	0.82
SO_3	0.10
NA_2O	0.75
Fe_2O_3	4.28

Cement- Cement is a fine grey powder. It is mixed with water and materials such as sand gravel and crushed stone to make concrete . The cement and water form a paste that binds the other material together as the concrete hardens . The ordinary cement contains two basic ingredients namely argillaceous and calcareous. In argillaceous materials clay predominates and in calcareous materials calcium carbonate predominates. Various Results of Tests Conducted On Cement have been summarized in Table 2.

Table 2: Various Results of Tests Conducted On Cement [13]

Physical property	Result obtained	IS: 8112 - 1989
Specific gravity	3.12	3.15
Fineness	2.90 m2/kg	-
Soundness	2 mm	-
Normal consistency	27.5%	-
Initial setting time	110 minutes	30 minutes
Final setting time	180 minutes	600 minutes

Fine Aggregate- In this research work natural river sand has been used which is conforming to IS: 383 -1970 it lies in Zone II. Natural river sand is sieved from 4.75 mm sieve is being used [14]; Coarse Aggregate- The fractions from 20 mm to 10 mm sieve are used as coarse aggregate. The Coarse Aggregates from crushed Basalt rock confirming to

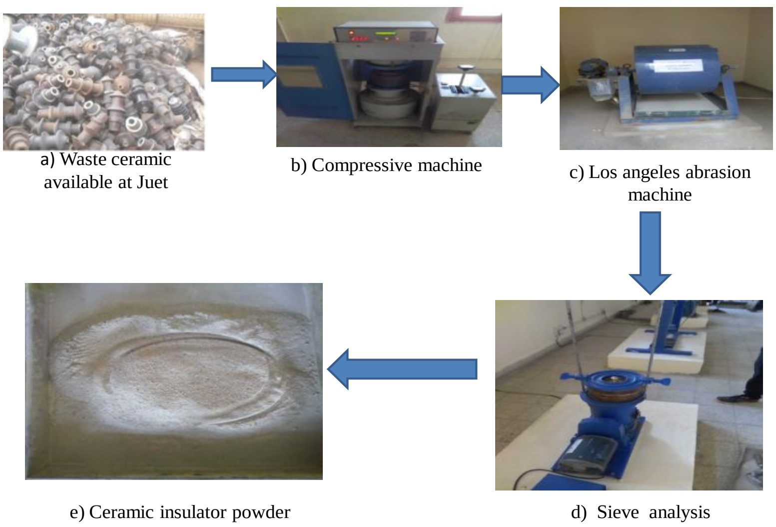

Figure 2: Process of converting large size ceramic waste insulator to powdered form

IS: 383-1970 [14]. Table 3 is shows the properties of aggregate.

Table 3: Properties of aggregate [15]

Aggregate	Specific gravity	Fineness modulus	Bulk density	Water absorption
Fine aggregate	2.7	2.8	1670 kg/m^3	0.85%
Coarse aggregate	2.8	6.85	1690 kg/m^3	1.3%

Water – Generally water that is suitable for drinking is satisfactory for used in concrete. Water from lakes and streams that contain marine life also usually is suitable Water is an important ingredient of concrete as it actually participates in the chemical reaction with cement. Since it helps to from the strength giving cement gel, the quantity and quality of water are required to be looked into very carefully.

Concrete Mix design

A mix M25 grade was designed as per Indian Standard method (IS 10262-2009) and the same was used to prepare the test samples. The design mix proportion 1:1.58:2.48 and water cement ratio as 0.45 as replaced by cement used ceramic powder 0%, 10%, 20%, 30% and 40% in concrete [16].

Table 4: Sample preparation

S. No.	% Replacement	Cement (Kg/m³)	F. A (Kg/m³)	C A (Kg/m³)	Water	Ceramic powder
1	0%	437 kg	682 kg	1177 kg	197 lit	0 kg
2	10%	393 kg	618 kg	1177 kg	197 lit	44 kg
3	20%	349 kg	602 kg	1177 kg	197 lit	88 kg
4	30%	306 kg	586 kg	1177 kg	197 lit	131 kg
5	40%	262 kg	570 kg	1177 kg	197 lit	175 kg

Testing Procedure

Strength Activity Index Test [17]

The purpose of these evaluations is to investigate the suitability of ceramic material as a replacement for cement in concrete mortar mixes. Our objective is determining the pozzolanic activity of the material. The pozzolanic activity is based upon a comparison of the compressive strength of mortar cubes containing pozzolans as a partial replacement for Portland cement to reference mortar cubes containing only Portland cement as binder. The mortar cubes are prepared, cast, cured and tested. The ceramic material which has a strength index greater than 80% with respect to normal mortar cube result is called "pozzolonic material" and it has a very good contain of reactive silica which is responsible for higher strength as well durability criteria of concrete.

Processes of test

Figure 3 shows the preparation of lime reactivity test in which the above materials put in steel bowl and fit in planetary mixture machine add approximate water about 360 ml. Mix for two minutes immediately place the mortar in flow table mould and flow should cone 70.5 % with 10 drops in 6 seconds take another weight material as above make mortar from a same procedure and fill it in 6 no's 50 mm cube mould, keep it is moist chamber 65.5% relative humidity and 27+2C temp For 48 hours. After 48 hours removes the specimens from the mould and keep it for curing in humidity control oven for 8 day. Humidity and temperature should be maintained 90% minimum and 50+2C respectively.

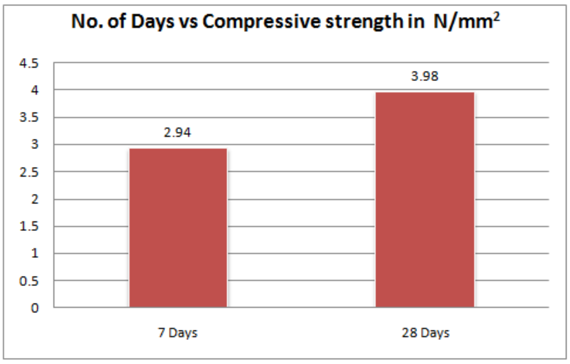

Figure 4: No of day's v/s compressive strength of lime mortar cube

Figure 4 shows the 7 days and 28 days compressive strenth of lime cubes in N/mm² to evaluate the pozzolanic reactivity of powdered ceramic.

Figure 3: Steps perform during lime reactivity test

Methdology

The evaluation of ceramic waste electric insulator powder for use as a replacement of cement material begins with the concrete testing. Concrete contains cement, water, fine aggregate, coarse aggregate and grit. With the Control concrete, i.e. 10%, 20%, 30%, 40%, of the cement is replaced with ceramic waste which is denoted by A0, A1, A2, A3, A4, the data from the ceramic waste is compared with data from a standard concrete without ceramic waste. Three cube samples were cast on the mould of size 150 x 150 x 150 mm for each 1:1.58:2.48 concrete mixes with partial replacement of cement with a w/c ratio as 0.45. After about 24 hrs the specimens were de-molded and water curing was continued till the respective specimens were tested after 7, and 28 days.

Results and Discussion

Compressive strength

Compressive strength tests were performed on compression testing machine using cube samples [18]. Three samples per batch were tested with the average strength values reported in this paper. The loading rate on the cube is 35 N/mm² per min. The comparative studies were made on their characteristics for concrete mix ratio of 1:1.58:2.48with partial replacement of cement with Ceramic waste as 10%, 20%, 30%, 40% Based on experimental investigations concerning the compressive strength of concrete. Table 5 is shown the average compressive strength.

Table 5: Average compressive Strength of Concrete at Various % Replacement

Concrete Types	Average Compressive Strength (N/mm²)		
	7 days	14 days	28 days
A0	21.55	27.64	32.61
A1	18.98	26.44	30.43
A2	16.38	24.64	28.14
A3	14.6	20.33	22.48
A4	12.48	17.24	19.98

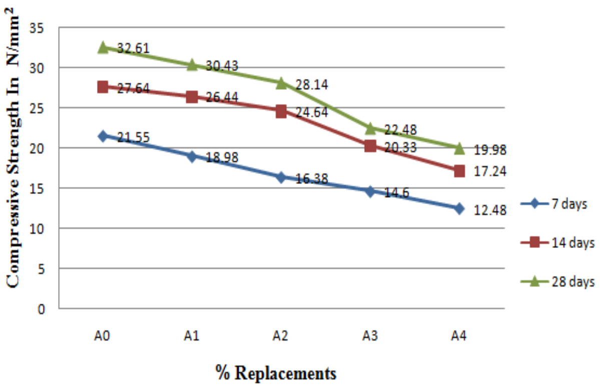

Figure 5: Percentage Replacement v/s Compressive strength

Figure 5 shows the 7, 14, and 28 days compressive strength at various percentage replacement of ceramic waste in concrete. As all above three graphs showing the same trend as we are increasing the percentage of ceramic waste the compressive strength is also decreasing. But up to the 30% replacement level the compressive strength for 28 days of curing is close to the characteristics strength of concrete. This is due to less percentage of silica SiO_2 in the powdered ceramic [Table no.1].

Split tensile strength

The standard test specimen is a cylinder of size 100mm × 100 mm × 200mm size. The specimen 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. After 7, 28 days for test Split tensile strength is determined at 7 and 28 days after successful curing period. Due to high percentage of silica oxide in ceramic waste its core Split tensile strength is achieve at replacement of ceramic waste concrete. Further research on it is preferred.

Figure 6: Test cylinder for split tensile strength

Figure 6 shows the crack pattern observed in a specimen under the split tensile strength test. The observed crack is along the longitudinal direction. Table 6 shows the average tensile strength.

Table 6: Average Tensile Strength of Concrete at Various % Replacement

Concrete types	Average tensile Strength (N/mm²)	
	7 day	28 day
A0	1.614	2.856
A1	1.583	2.444
A2	1.567	2.189
A3	1.529	1.989
A4	1.479	1.734

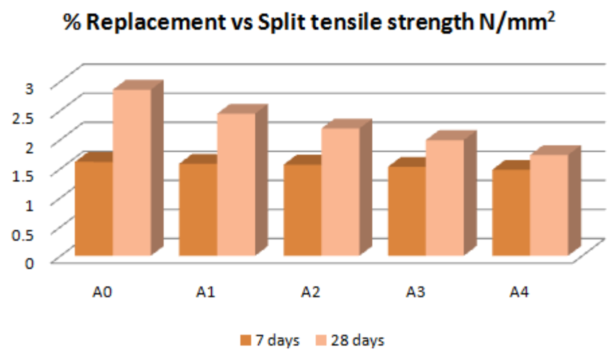

Figure 7: Percentage Replacement v/s split tensile strength

Figure 7 shows the 7, 14, and 28 days split tensile strength at various percentage replacement of ceramic waste in concrete. As we are increasing the percentage of ceramic waste in concrete the split tensile strength is also decreasing. But there is little change in the value of split tensile strength at various percentage replacements.

Water absorption test

The tests were performed to record water absorption on blocks. The main agents of deterioration require the presence and movement of water within the material itself. The presence of water can cause freeze-thaw the absorption of the product has a great effect on its durability. From the results obtained it is noted that the water absorption. Water absorption 100mm X 100mm X 100mm cube casted and tested after 28 days continuous curing period. Then after cube specimen were oven dry for 24 hours at 100^{0}C. This weight should be measured Then after specimens were kept in water for 24 hours, this wet weight noted is % of water absorption should be calculated is weight as a replacement of cement in concrete.

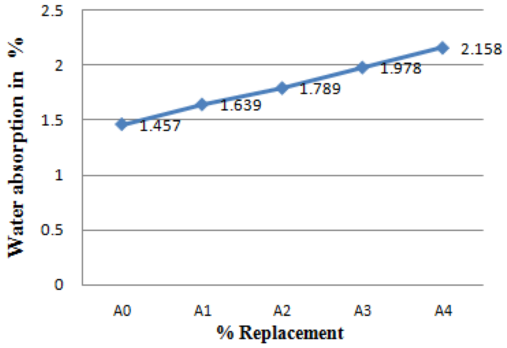

Figure 8: Percentage Replacement v/s water absorption in percentage

Figure 8 shows the water absorption with various percentage of ceramic waste after 28 days of curing. As the waste ceramic insulator powder shows low reactive pozzolanic property. This will result in less compacted and less dense concrete causes more internal voids. But the water absorption is increases with a lesser value with increase in the percentage of powdered ceramic.

Effect of sulphate on compressive strength of concrete [19]

The standard test specimen is a cube of size 100mm × 100 mm × 100mm size. The specimen should be cast and cured in the same manner as for casting of cubes. The 5% magnesium sulphate is mixed up in 1 liters of water and mixed at the time of preparing concrete and casting of cubes. The specimens should be immediately tested on removal from the water and after found out strength in concrete. Solution of the sulfates of various bases including sodium, potassium, magnesium and calcium react with hydrated cement paste forming gypsum or a compound called ettringite (sulphoaluminate) which leads to the expansion and disruption of the concrete and mortar this process is referred as sulphate attack. The consequences of sulfate attack include not only disruptive expansion and cracking, but also loss of strength of concrete due to the loss of cohesion in the hydrated cement paste and of adhesion between it and the aggregate particles. Sulfates combines with the C-S-H, or concrete paste, and begins destroying the paste that holds the concrete together. As sulphate dries, new compounds are formed, often called ettringite. These new crystals occupy empty space, and as they continue to form, they cause the paste to crack further damaging the concrete.

Figure 9 shows the 14 and 28 days of compressive strength at various level of percentage replacement of ceramic waste with 5% solution of MgSO4 in concrete. The compressive strength is decreasing by increasing the percentage of powdered ceramic. From the above result the ceramic waste powdered for M25 grade with water cement ration .45 can be replaced by cement up to 20-30%.

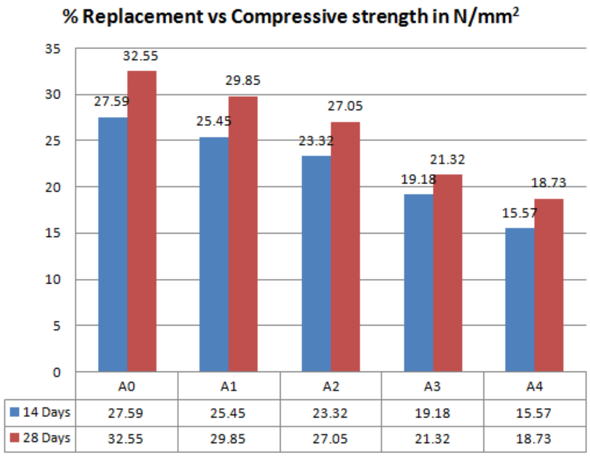

Figure 9: Shows Percentage Replacement v/s compressive strength of concrete at 5% of MgSo4

Conclusions

The process of substituting 0 to 40 percent ceramic insulator waste powder as a partial replacement of cement was studied and then parameters of concrete like hardened properties and durability properties of concrete were observed. Finally, the following conclusions can be derived based on the present work and can be summarized as follows.

1. Ceramic waste electric insulator is mainly formed by siliceous and aluminous compounds. The loss of water due to thermal treatments causes destruction of their crystalline structure, and they are converted into unstable amorphous state. If they are then mixed with calcium hydroxide and water, they undergo pozzolanic reaction and form compounds with enhanced strength and durability. Therefore, they have a potential to be used in mortar and concrete
2. Indirectly, the construction industry is one of the main producers of CO_2 emissions through high temperature kilns for steel production, cement factories, the ceramics industry, or in transport. Therefore, when defective construction material is thrown away, or when a building is demolished, much incorporated energy is wasted. It is necessary to find a practical method of reusing these materials, especially those with the highest levels of incorporated energy.
3. The compression and split tensile strength of M25 grade concrete increases when the cement is replaced with ceramic power of electric insulator powder up to 20- 30% and further replacement of cement with ceramic powder decreases the strength gradually.
4. Ceramic waste insulator powdered concrete partially replaced by cement increases the water absorption as we are increasing the replacement percentage of ceramic waste powder.
5. In lime reactivity test we have observed that the compressive strength of 28 days was comes out to be 3.98N/mm^2. Which show that it is a low reactive pozzolana.
6. As increases in percentage of ceramic waste the compressive strength after 28 days decreases at 5% MgSO4 but up to 20% replacement it is higher than characteristics compressive strength design of M25 grade of concrete.

7. Utilization of ceramic waste insulator powder and its application for the sustainable development of the construction industry is the most efficient solution and also suggest the high value application of such waste.
8. By using the replacement materials offers reduces the cost of concrete and can overcome few environmental hazards.
9. On the basis of result we have observed By conducting lime reactivity test we can suggest that ceramic waste insulator power shows little low pozzolanic activity but it can be considered to used in to the concrete because at various percentage level of replacement like 10%-30% it gives satisfactory results in hardened and durability properties of concrete discussed in this research work.

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