Investigation of Ceramic Waste as Supplementary Cementitious Material in Concrete

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Abstract
This paper presents a research and study of one of the major topic regarding Investigation of ceramic waste as supplementary cementitious material in concrete. Due to the demanding of need of high amount of cement in construction it's require to reduce the production of cement by partially replacing the cement with another materials. If the waste material has been used in the production of cement with partially the cost decreases and in environment good impact will found. In the production of cement, the amount of cement produced the same amount of carbon di-oxide has been released and 1.5 times of lime stone has been required for that, so it's a very bad impact for the environment. The aim of this work is that to reduce the environmental impact, reduce the cement consumption in the concrete by the replacement of ceramic material as a supplementary cementitious material. In this work first investigate the pozzolanic activity of ceramic electrical insulator waste material by three test i.e. strength activity test, frattini test and saturated lime test. According to these result in ceramic electrical insulator material pozzolanic activity of material has been found and it can be replaced in mortar and for that exact limit further investigation is required i.e. durability etc. After that its successful in mortar gives pozzolanic activity test result, here research work is done in concrete for the same ceramic electrical insulator material partial replacement with cement in the concrete and check its mechanical properties, workability, durability and microstructure (by FE-SEM test only). In the concrete cement has been partially replaced by 5%, 10%, 15% and 20% of ceramic waste. For utilization of these ceramic waste investigate the test performance in the concrete, here workability test (by slump cone test), mechanical properties test (compressive strength test, flexural strength test, split cylinder tensile strength), durability test (water absorption and water penetration test) and micro-structure analysis (by FE-SEM test images) has been tested in the replacement of the ceramic waste material.

Keywords: ceramic waste, pozzolanic activity, electrical insulator waste, strength activity test, frattini test, microstructure, FE-SEM test

Introduction

What is ceramic?
Ceramics as well as other insulators like paraffin, rubber, plastic, paper and artificial marble are fired in a kiln, they can be fashioned into a wide variety of shapes with excellent heat resistance and durability. For these reasons, ceramics have long been used as insulators and give their services. Generation of large amount of ceramic insulator waste has been found in electricity board due to heavy voltage insulator becomes breaks. These ceramic insulator wastes have not been reused after breaking. In this research area these ceramic waste has been utilised for the replacement with fine or coarse aggregate.

Environmental issues and studies:
History of construction has witness that construction industry increases with increase in development of construction and due to high volume of raw material used in construction the environmental has been affected. High amount of waste generated in the construction industries, with respect to development of construction the waste material and pollution has been generated continuously. It's requiring to reuse the waste material in any purpose to reduce the environmental impact.

Infrastructure development continuously increasing simultaneously the environmental impact has also increases with. Utilization of high amount of cement and other raw materials has the bad effect in sustainability, due to the high cement used in the construction industries high amount of carbon dioxides released at the manufacturing time of cement.

CO_2 has increases the greenhouse gases and forming the global warming effect. Global warming is the main issue or problem for the world, so it's require to control the global warming and other environmental issue.

In the research field the waste has been used in concrete to reduce the environmental impact. Currently fly ash, silica fume and other waste material has been frequently used as a construction material up to a certain level, similarly in research field ceramic insulator waste has be the increasing number of environmental regulations has led the waste producers in whole world to the choice of recycling and reuse, as the disposal cost is very high and in some cases it may require controlled landfills, especially for ashes, which may be rich heavy metal contaminants, such as Cd and lead Pb. Finding utilization pathways for this type of waste is an important aspect, because processes that would convert the oxide content of the combustion wastes to value-added products are necessary for the profitability of the recycling process. It reduces permeability which prevents from ground water recharge. If these particles become airborne, they can readily cause air pollution causing unfavorable surroundings for humans, animals, vegetation and machinery and also used in concrete with the replacement of fine and coarse aggregate. If ceramic waste has been utilized in the concrete than it is environment and eco-friendly for our eco system.

Different test:

Frattini test is the direct method to determine the pozzolanic activity of the material, in these test Ca^{2+} and OH^- concentration has been determined. According to concentration define the pozzolanic activity of these material.

Saturated lime (SL) test is the modified version or simplified method of frattini test. SL test is also a direct method and number of days will be increase compare to frattini test.

The strength activity test is the indirect test method to find the pozzolanic activity of the material. In SAT test compare the strength of the control with respect to the waste material.

Frattini test, saturated lime test and strength activity test is the test related to mortar for determine the pozzolanic activity of the material

In the concrete to compare the density and strength of the material different types of test has been adopted (i.e. mechanical properties test)durability test and carbonation test and also find microstructure properties of the material etc. In concrete adopted mechanical properties and durability test of concrete that which amount of ceramic waste material has been used for the replacement with cement, both test has a physical properties of the material that indicate the strength and durability of concrete.

In mechanical properties of concrete do the test of compressive strength test, flexural strength test and split cylinder test also analyses the workability of concrete. A mechanical property has been related to strength of concrete that define structural stability after years ago. Also the workability of concrete has been important role plays that the concrete has workable or not in the field. For workability of concrete two test has mainly used i.e. slump cone test and compaction factor test, compaction factor test has given the better accurate with less error result but not used in the field because of heavy instrument. In the field adopted the slump cone test for workability of concrete because its takes quick time for result and easy to handle.

Durability test of concrete relates the durability of concrete structure in construction industries. There are the different test in disabilities i.e. sulphate attack test, acid attack test, carbonation test, chloride penetration test, water absorption and water penetration test etc. are available. Water penetration test gives the permeability of concrete and perform according to DIN 1048.

Aim of study

The objective of this study to replace ceramic insulator waste material with cement in mortar and concrete for its utilization. In the mortar check the pozzoalnic activity of the material, if material gives the pozzolanic activity then it can be replaced by cement up to 20% as per British standard and test for pozzolanic activity is strength activity test, frattini test and saturated lime test. Similarly in the concrete several tests are adopted for the replacement i.e. mechanical properties test (Compressive, flexural, split tensile and non-destructive test), durability test and also microstructure investigation on the material.

Scope of study

The study of these material to helps the optimum percentage of replacement with cement in concrete and also if its gives pozzolanic activity then it can be replaced up to 20% in the mortar. These study reduce the environmental impact by the utilization of waste and high consumption of cement in mortar as well as in concrete. For the use of this type other waste material further research work is required.

Literature reviews

Researchers are trying to decrease the used of cement in the concrete and mortar, for that purpose used different types of waste materials in the concrete with partial replacement of cement i.e. fly ash, rice husk, slag, glass waste, industrial waste etc. In this experiment work partial replacement of cement by ceramic waste material 6 to 20 %.

Dima M. Kannan have performed to "High performance concrete incorporating ceramic waste powder as large partial replacement of Portland cement". They have used the ceramic waste powder as partial replacement with cement, according to these performance or research work ceramic waste powder has been replaced large amount 10 to 40%. As per these research work replacement of ceramic waste powder used up to 40% for that confirmation mechanical, durability and microstructural investigation of high performance concrete mixtures were performed and microstructure shows that incorporating

ceramic waste powder did not make significant difference in cement hydration compared with cement without ceramic waste powder.

Amr S. El Dieb have analyzed the research work at the "Ceramic waste powder an alternative cement replacement – Characterization and evaluation". According to that ceramic waste powder gives the better result up to 20% of replacement with cement. In this study ceramic waste powder replaced up to 10 % to 40% and its gives better result in mechanical and durability properties in concrete up to the 20% of replacement with cement.

Luiz Renato Steiner have performed the research work for the "Effectiveness of ceramic tile polishing residues as supplementary cementitious materials for cement mortars". According to these research work the sludge coming from the polishing process of ceramic tiles, particularly 'porcellanato' and 'monoporosa', results in a large amount of waste that requires disposal in controlled landfills. These ceramic waste material have been replaced up to 15 % with cement that is based on the result of compressive strength, pozzolanic activity index, thermal behavior (calorimetry) and autogenous shrinkage.

Salman Siddique have studied the research work in the "Durability properties of bone china ceramic fine aggregate concrete". According to his research work bone china ceramic fine aggregates (BCCFA) can be used for structural applications up to 40% replacement of BCCFA. In this research work the BCCFA was utilised as 0%, 20%, 40%, 60%, 80% and 100% partial replacement of fine aggregate. The hydration products were assessed by X-ray photoelectron spectroscopy. The water based properties of concrete such as percentage voids, apparent density, water absorption, water permeability (DIN) and chloride ion permeability were obtained for concrete samples.

Wioletta Jackiewicz-Reka has researched on the "Properties of cement mortars modified with ceramic waste fillers". According to these research work partial replacement of fine aggregate with sanitary ceramic fillers up to 20% of cement by weight improves compressive and flexural strength and reduces shrinkage. The test results were discussed in the lights of the literature data on influence of ceramic waste on properties of fresh and hardened concretes. Their influence was evaluated with respect to workability (consistency, plasticity and pores volume), mechanical properties (compressive and flexural strength) and freeze-thaw resistance.

S.M.A. El-Gamal Sayed has done the experiment on the "Ceramic waste as an efficient material for enhancing the fire resistance and mechanical properties of hardened Portland cement pastes". According to this research utilization of industrial by products like ceramic waste (CW) for enhancing the microstructure and mechanical properties as well as the fire resistance of hardened ordinary Portland cement (OPC) pastes is the main goal of this research. Different cement blends were prepared by partial replacement of OPC with 5, 10 and 20 CW (mass %). According to these result the ceramic waste has been replaced up to 15 % based on result of mechanical properties and thermal resistance compressive strength values at 1, 3, 7, 28 and 90 days of hydration.

P.O. Awoyera have done the research work on the "Suitability of mortars produced using laterite and ceramic wastes: Mechanical and microscale analysis". According to these research work a mortar sample containing 10% ceramic powder and 100% ceramic aggregate as replacements for cement and sand respectively, gave higher strength values than the reference and other mixes. Microstructural analysis of the best mix revealed that it has larger proportions of ettringite, portlandite and calcite than the reference mix, and this could be responsible for the strength gained. Thus, despite the apparent low reactivity of crushed ceramic material, this can improve bonding in cement-based mixture, when used at an appropriate concentration.

Serkan Subas have studied on the "Utilizing of waste ceramic powders (WCP) as filler material in self-consolidating concrete". According to his research work it can be used up to 15% and it can be concluded that finely ground WCPs could be evaluated up to 15% for production of self-consolidating concretes as a filler material if the strength and flow ability parameters are evaluated together. In his research work using filler materials finer than 0.125 mm is quite effective on the fresh state properties, strength and durability of self-consolidating concrete. In this study, usability of granulated waste ceramic powder as filler material in selfconsolidating concretes was investigated. Properties of self-consolidating concretes produced with 550 kg/m3 dosage and cement was replaced with (WCP) in the amounts of 5%, 10%, 15% and 20% (by weight) were determined in the fresh and hardened phases.

Khuram Rashid have done the research work on the "Experimental and analytical selection of sustainable recycled concrete with ceramic waste aggregate". According to these research work that the 30% partial replacement of ceramic waste aggregate with conventional aggregate provides the highest compressive strength, less environmental impacts and is selected as sustainable concrete, which is also verified by analytical hierarchy process (AHP) and technique for order preference by similarity to ideal solution (TOPSIS). In the research work the experimental and analytical investigation is conducted to develop a sustainable recycled concrete by incorporating ceramic waste as coarse aggregate. In order to achieve the designed goal, conventional aggregate is replaced by different amounts of ceramic waste aggregate. Fresh and hardened properties of conventional as well as ceramic waste aggregate concrete are assessed concrete.

Characterization of materials:

Cement

In all experiment work use OPC 43 grade of ultratech cement passing through 90 micron sieve.

Ceramic

In the electricity board due to high voltage the insulator has been break. Insulator has made by the ceramic material. We can use these waste ceramic insulator material as a cement replacement.

Figure 1: Ceramic Material (Insulator) break due to high voltage.

Procedure to find the ceramic material in powder form:

Waste Insulator has been taken than break by hammer into the 20 to 40 mm aggregate size. These material has been taken in the Los Angeles abrasion machine for 4 hour than find out the mix form of powder and aggregate size material. Sieving these material by different sieves and use the ceramic material that is sieved by the 90 micron sieve.

Physical properties of ceramic waste

Ceramic waste generated due to high voltage of electrical insulator breaks, for utilization of this brick make it powder for by any method adopted and found the following physical quality parameter of ceramic material.

Table 1: Physical properties of ceramic insulator waste materials:

S.N.	Physical quality parameters	Ceramic waste quality parameter result
1.	pH	9.92
2.	Specific gravity	2.287
3.	Bulk density (natural/ Loose)(kg/m^3)	610.6
4.	Void ratio (kg/lit)%	75.45

Chemical properties of electrical insulator (ceramic) waste material

The following chemical composition is found in the ceramic electrical insulator material according to "A. Roulal, K. Boudeghdegh, N. Boufafa".

Table 2: Chemical composition of ceramic waste

S.N.	Chemical oxides compounds (from test)	Test result (in %)
1.	$Al2O_3$	50
2.	ZrO_2	0.0
3.	BaO	7.79
4.	$(NaK)O_2$	2.65
5.	SiO_2	39.25
6.	Rest.	0.78

Sand

In this experimental work Zone 2 sand used for all the concrete mix.

Coarse aggregate

10 mm and 20 mm coarse aggregate used in the concrete and individual amount in concrete has half of the total aggregate means 50% – 50%.

Super plasticizer

Aura mix 350 used as a super plasticizer in concrete.

Preparation of mould and mixing of mortar

After testing the physical properties of ceramic material now for the test strength activity test perform the flow table test and find out the workability means water quantity in the mortar proportion. Prepare the mould of size 50*50*50 mm^3 and make the mortar cubes for 7 and 28 days of testing

Table 3: Mix proportion for the mortar

S.N.	Materials	Quantity required for mortar mixing (in gm)
1.	Sand	1500
2.	Cement	400
3.	Pozzolana	100
4.	Water	325

Methodology in concrete mix

Methodology of these work is explained that the cement replaced by the ceramic insulator material (size passing through 90 micron sieve) with the percentage of 5%, 10%, 15%, 20% means compare the control mix with these percentage replacement. The test has been performed for 7 days and 28

days also micro-structure analysed. In these work different test i.e. mechanical properties (compressive strength, flexural strength, split cylinder strength etc.), durability properties (water absorption and water penetration) performed also the micro-structure of concrete (FE-SEM test and XRD test) has been analysed. Concrete mix has been performed at different percentage of ceramic insulator waste is replaced in place of cement.

Water cement ratio 0.43 are constant for all the concrete mix and it is designed as per IS 456 and IS 10262-2009, other concrete properties are compared with respect to this water cement ratio.

Mix proportion of concrete

Ceramic waste material is replaced by cement with 100 % replacement is inconvenient for the concrete and structure and there is no any specific code to design for these material. The concrete mix design takes in the basis of trial mixes. In this research work not design the grade of concrete only to fix the water cement ratio and other parameters change the percentage replacement. Water cement ratio is taken 0.43 and mix has based on IS 456 and IS 10262-2009 is listed below following table:

Table 4: IS Codes for different test performed in this concrete project work

S.N.	TEST	IS CODE
1.	Specific gravity (fine aggregate)	IS 2386 (PART-III) 1963
2.	Specific gravity (coarse aggregate)	IS 2386 (PART-III) 1963
3.	Specific gravity (cement)	IS 2720 (PART-III) 1980
4.	Sieve analysis or Gradation	IS 383-1970

Table 5: Mix design at water cement ratio of 0.43 with different percentage of ceramic waste.

Sn.	Replacement (%)	Water (kg/m^3)	Cement (kg/m^3)	Ceramic (kg/m^3)	Aggregate (10mm) (kg/m^3)	Aggregate (20mm) (kg/m^3)	Sand (kg/m^3)	Admixture (0.5%)
1.	Control or 0	180	418.60	0	545.87	545.87	787.10	2.09
2.	5	180	397.67	20.93	545.87	545.87	787.10	2.09
3.	10	180	376.74	41.86	545.87	545.87	787.10	2.09
4.	15	180	355.81	62.79	545.87	545.87	787.10	2.09
5.	20	180	334.88	83.72	545.87	545.87	787.10	2.09

Process of preparation of specimen

The preparation of the specimen is being carried out by prepare the mould 100*100*100 mm^3, 150*150*150 mm^3 and beam 100*100*500 mm^3 also the cylinder 150 mm diameter with 300 mm height for the concrete filling. Before filling the concrete material in the mould do the proper oiling in all inner side of the mould because to remove the concrete adhesion in the moulds. Concrete materials filled with 2 or 3 layers with each layer is vibrated by vibrating table machine.

Process of curing of specimen

Process of curing is being carried out after the 24 hours of casting first demoulding the specimen then taken into the curing tank for curing bath for the required duration i.e. 7 days, 28 days, 56 days and 90 days etc.

Conclusion:

In the mortar according to test of the pozzolanic activity test the ceramic insulator waste has been given the positive result, it shows the pozzolanic activity in saturated lime test, strength activity test and frattini test. So according to British standard code if waste material gives the pozzolanic activity in these test then it can be replaced by cement up to 20% and for the use of these waste material other research work will be required like durability etc.

In concrete according to the test result of mechanical properties and durability test of ceramic insulator waste material replacement has been successful up to the limitation of 15 % replacement with cement.

Future scope:

In future it can be increase the percentage of replacement of ceramic material So according to these research work cement replaced by ceramic waste also further investigation is required for that these replacement to find exact percentage replacement limit in future utilization

In the concrete ceramic replace by performing of mechanical properties and durability test i.e. water absorption and penetration test, but for the confirmation of that replacement other durability test i.e. acid attack test, chloride attack test, carbonation test and micro-structure study are required.

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