Utilization of Ceramic Waste Replacing Coarse Aggregate to Produce Self-Compacting Concrete

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Abstract— Concrete is a versatile engineering composite material made with cement, aggregates and admixtures in some cases. Cement and coarse aggregate are two important constituents of concrete. Several studies were conducted to find an effective replacement for these raw materials of concrete with different goals such as reduced cost, increase workability and gain high strength. Due to the day by day innovations and developments in construction field, the global consumption of natural aggregates is very high and at the same time production of solid wastes from the demolitions and manufacturing units are also very high. Ceramic waste is the least expensive of all the concrete constituents and is much less expensive than natural aggregates and sand, thus the idea is to replace as much of the natural aggregates as possible to save money and to reduce the amount of disposable wastes, as well, but care has to be taken in order not to weaken the concrete by adding too much ceramic. 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 the new units.) This waste of Ceramic Industries dumped at nearby places resulting in environmental pollution causing effect to habitant and agricultural lands. Self-compacting concrete is a highly flow-able type of concrete that spreads into the form without the need for mechanical vibration. Self-compacting concrete is a non-segregating concrete that is placed by means of its own weight. An attempt has been made to study the behavior of SCC with ceramic waste powder and understands the effect of the mineral admixtures on fresh & hardened properties of SCC and also investigates the compatibility of ceramic waste in SCC along with chemical admixture such as super plasticizers.

Key words: Ceramic Waste, Self-Compacting Concrete, Flow Test, Compressive Strength Test, Tensile Strength Test

I. Introduction

Self-compacting concrete is a highly flow-able type of concrete that spreads into the form without the need for mechanical vibration. Self-compacting concrete is a non-segregating concrete that is placed by means of its own weight. The importance of self-compacting concrete is that maintains all concrete's durability and characteristics, meeting expected performance requirements. Self-compacting concrete produces resistance to segregation by using mineral fillers or fines and using special admixtures. Self-compacting concrete is required to flow and fill special forms under its own weight, it shall be flow-able enough to pass through highly reinforced areas, and must be able to avoid aggregate segregation. This type of concrete must meet special project requirements in terms of placement and flow. Self-compacting concrete with a similar water cement or cement binder ratio will usually have a slightly higher strength compared with traditional vibrated concrete, due to the lack of vibration giving an improved interface between the aggregate and hardened paste. Self-compacting concrete has been used in bridges and even on pre-cast sections. One of the most remarkable projects built using self-compacting concrete is the Akashi-Kaikyo Suspension Bridge. This type of concrete is ideal to be used in the following applications:

1) Drilled shafts
2) Columns
3) Earth retaining systems
4) Areas with high concentration of rebar and pipes/conduits.

Concrete made with ceramic electrical insulator waste as coarse aggregate shows good workability, compressive, tensile and flexural strengths and modulus of elasticity.

II. Ceramic Waste and Its Property

In recent decades the ceramic industry has undergone profound technological changes of manufacturing process as well as the characteristics of the final product. Porcelain, a ceramic coating, which has earned a growing role in the consumer market due to technical and aesthetic properties such as water absorption of less than 0.5% and high mechanical strength, came along with those innovations. Porcelain is characterized by a dense microstructure consisting of crystalline phases, mullite and quartz in less amount minority, mostly majority immersed in a glassy phase.

In the civil construction industry is a great generation of rubbish that is landfilled in inadequate area. It is estimated that over 30% of this debris is ceramic waste. It has been reported that fired clay may present pozzolonic activity which improves the performance of mortars and concrete. In addition, it has been cited the feasibility of ceramic tile in the replacement of part of coarse aggregates in mortars and concrete. Calcined clays have been used as pozzolans since distant times. Clays in the raw form do not show pozzolonic activity, but when calcined and ground to an appropriate fineness clays can be used as pozzolonic admixtures for cement.

Some of the highly desirable properties of, ceramic waste, are:

– High Strength – High Fracture Toughness – High Hardness – Excellent Wear Resistance – Good Frictional Behavior – Anti-Static	– Non-Magnetic – Low Thermal Conductivity – Corrosion Resistance in acids and alkalis – Excellent Surface Finish (0.006 µm Ra) – Modulus of Elasticity similar to steel – Thermal Expansion Coefficient similar to cast iron

A. *Physical property*

1) Mass Properties (e.g., density): Ceramics are intermediate (density= 2.00 to 6.00 gms/cm3)
2) Thermal properties: Melting points high (600-4000C). Thermal conductivities are low (insulators). Thermal expansion values are low (1-15 ppm/C).
3) Electrical properties: Electrical conductivity (insulator or semi-conductor).

SR. NO	PROPERTIES	ANALYSIS
1.	Specific gravity	2.50
2.	Water absorption in %	0.18
3.	Impact value in %	22
4.	Crushing value in %	20
5.	Abrasion value in %	19
6.	Bulk Density in kg/m3 Loose state Dense state	 1069 1188

Table 1: physical property of ceramic waste

B. *Chemical property*

1) Chemical / Electrochemical corrosion properties: Very few under normal circumstances.
2) Solubility: Soluble in certain strong acids (HF) and strong bases usually non-crystalline (glassy) phases dissolve first. Capable of selective ion leaching and ion-exchange reactions.

SR. NO	COMPOUND	ANALYSIS RANGE IN %
1.	SiO_2	63.29
2.	Al_2O_3	18.29
3.	Fe_2O	4.32
4.	CaO	4.36
5.	MgO	0.72
6.	P_2O_5	0.16
7.	K_2O	2.18
8.	Na_2O	0.75
9.	SO_3	0.10
10.	CL^-	0.005
11.	TiO_2	0.61
12.	SrO_2	0.02
13.	Mn_2O_3	0.05
14.	L.O.I	1.61

Table 2: chemical property of ceramic waste

III. CONCRETE WITH CERAMIC WASTE

A. *In these research we replace coarse aggregate with ceramic waste in different percentages.*

Material used in the test concrete are:
The materials used were:

1) Cement: Ordinary Portland cement.
2) Sand: The river sand having a fineness modulus of 2.74 and specific gravity of 2.7 with good gradation.
3) Gravel: The gravel with maximum size of 9.5 mm and specific gravity equal to 2.72 from was used as coarse aggregate.
4) Crushed ceramic tiles: Crushed ceramic tiles as a partial replacement of coarse aggregate. The particle size of crushed ceramic tiles was ranging between12.5 mm to 4.75mm.
5) Water: ordinary tap water.

B. *Mix proportion*

Electrical concrete mixer with capacity of 0.05 m3 was used for mixing the concrete. Aggregates were dry mixed with filler and cement inside the mixer for nearly one minute, then super-plasticizer was poured to water, and then added to mixer and mixed to attain a homogenous mixture. Figure 2, shows the mixer which was used for mixing process.

1) Type of specimen are made:

Group	Coarse
SCC1	Natural aggregate
SCC2	15% ceramic waste replacement as coarse aggregate
SCC3	25% ceramic waste replacement as coarse aggregate
SCC4	35% ceramic waste replacement as coarse aggregate

Table 3: type of specimen for SCC

IV. SLUMP FLOW TEST AND T 50 CM TEST ON SELF-COMPACTING CONCRETE

The slump flow test is used assess the horizontal free flow of self-compacting concrete in the absence of obstructions. It was first developed in Japan for use in assessment of underwater concrete.

The test method is based on the test method for determining the slump. T is the diameter of the concrete circle is a measure for the filling ability of the concrete. It is the most commonly used test, and gives a good assessment of filling ability. It gives no indication of the ability of the concrete to pass between reinforcement without booking, but may give some indication of resistance to segregation.

It can be argued that the completely free flow, unrestrained by any foundries, is not representative of what happens in concrete construction, but the test can be profitably be used to assess the consistency of supply of supply of ready-mixed concrete to a site from load to load.

A. *Equipment for Slump Flow Test*

The apparatus is show in figure;

- Mold in the shape of a truncated cone with the internal dimensions 200 mm diameter at the base, 100mm diameter at the top and a height of 300 mm.
- Base plate of a stiff non-absorbing material, at least 700mm square, marked with a circle marking the central location for the slump cone, and a further concentric circle of 500mm diameter
- Trowel
- Scoop
- Ruler
- Stopwatch(optional)

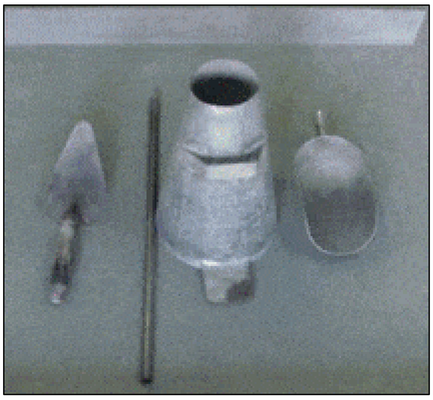

Fig. 1: Accessories for Flow cone Flow table Slump test

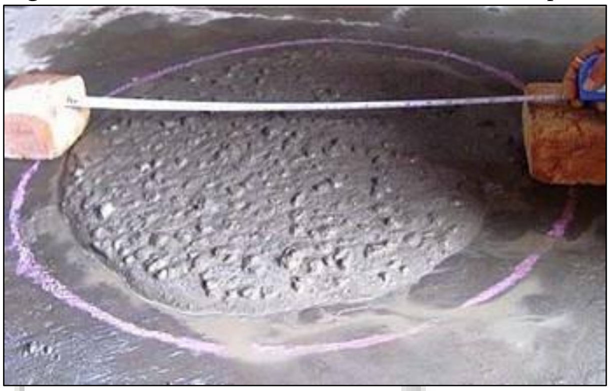

Fig. 2: Slump flow test and T 50 cm test

B. Procedure of Slump Flow Test on Self Compacting Concrete

About 6 liter of concrete is needed to perform the test, sampled normally. Moisten the base plate and inside of slump cone, place base plate on level stable ground and the slump cone centrally on the base plate and hold down firmly.

Fill the cone with the scoop. Do not tamp, simply strike off the concrete level with the top of the cone with the trowel.

Remove any surplus concrete from around the base of the cone. Raise the cone vertically and allow the concrete to flow out freely.

Simultaneously, start the stopwatch and record the time taken for the concrete to reach the 00mm spread circle (This is the T50 time).floatable test, might be appropriate.

The T50 time is secondary indication of flow. A lower time indicates greater flow ability.

In case of severe segregation most coarse aggregate will remain in the center of the pool of concrete and mortar and cement paste at the concrete periphery. In case of minor segregation a border of mortar without coarse aggregate can occur at the edge of the pool of concrete. If none of these phenomena appear it is no assurance that segregation will not occur since this is a time related aspect that can occur after a longer period.

C. Result

Group No.	% of waste ceramic in the mix	SLUMP TEST	
		T-50 (SEC)	D_{max}(mm)
SCC1	0%	5	695
SCC2	15%	6	685
SCC3	25%	6.5	679
SCC4	35%	7	664

Table 4: slump flow test result

V. HARDEN PROPERTY TEST

The experimental program consists of casting and testing sixty (100 mm x 100 mm x 100 mm) cubes for determining compressive strength (fcu), sixty cylinders (100 mm x 200 mm) for determining indirect tensile strength (fct).

Moulds were cleaned and oiled before casting. Then put on a level area. Filling moulds by SCC. Concrete surface was leveled by trowel, and then marked. After casting, the molds were put on the level ground without vibration or compaction, and they were put in the laboratory for 24 hours. After 24 hours molds were removed, and SCC specimens were put into the curing tank for 28 days.
Tests for hardened SCC:

A. Compressive strength test

This test is the most common of all tests on hardened concrete and it is the most important parameter in structural design.

For cube test two types of specimens either cubes of 15cm X 15cm X 15cm or 10cm X 10cm x 10cm depending upon the size of aggregate are used. For most of the works cubical moulds of size 15cm x 15cm x 15cm are commonly used.

This concrete is poured in the mould and tempered properly so as not to have any voids. After 24 hours these moulds are removed and test specimens are put in water for curing. The top surface of these specimen should be made even and smooth. This is done by putting cement paste and spreading smoothly on whole area of specimen.

These specimens are tested by compression testing machine after 7 days curing or 28 days curing. Load should be applied gradually at the rate of 140 kg/cm2 per minute till the Specimens fails. Load at the failure divided by area of specimen gives the compressive strength of concrete.

Fig. 3: compressive strength test

1) Result:

Type of specimen	% of waste ceramic in the mix	Compressive Strength fcu (MPa)
SCC1	0%	48.51
SCC2	15%	44.43

SCC3	25%	38.62
SCC4	35%	36.58

Table 5: result of compressive strength test

B. Indirect Tensile Test

The tensile strength of concrete is one of the basic and important properties. Splitting tensile strength test on concrete cylinder is a method to determine the tensile strength of concrete.

The concrete is very weak in tension due to its brittle nature and is not expected to resist the direct tension. The concrete develops cracks when subjected to tensile forces. Thus, it is necessary to determine the tensile strength of concrete to determine the load at which the concrete members may crack.

The specimen is the conventional 100mm x 200 mm, cylinder. The cylinder is loaded in compression along two axial lines which are diametrically opposite through bearing strips of plywood.

Fig. 4: Indirect Tensile Test

1) Result:

Type of specimen	% of waste ceramic in the mix	tensile Strength fct (MPa)
SCC1	0%	3.91
SCC2	15%	3.84
SCC3	25%	3.48
SCC4	35%	3.28

Table 5: result of Indirect Tensile Test

VI. CONCLUSION

From this research we can conclude that:

1) Solid waste ceramic tiles can be reduced in the landfill by using them in the production of self-compacting concrete.
2) Reusing waste ceramic tiles to produce sustainable concrete has a positive impacted on the environment.
3) Workability of concrete decrease with increase in percentage of replacement of coarse aggregate by ceramic waste.
4) Compressive strength of concrete decrease with increase in percentage of replacement of coarse aggregate by ceramic waste.
5) Tensile strength of concrete decrease with increase in percentage of replacement of coarse aggregate by ceramic waste.

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