ISSN: 2278-0181
NCRACE-2015 Conference Proceedings

Experimental Investigation on Partial Replacement of Cement and Coarse Aggregate by China Clay and Ceramic Tile

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***Abstract* - Concrete, as a constructive material, has been used in construction industry for about two centuries. Therefore, doing research about using modern technologies in production concrete is of great importance. Furthermore, one of the most critical problems of the world has been related to remove the wastage and reusing of it. If some of the waste materials are found suitable in concrete making, not only cost of construction can be cut down, but also safe disposal of waste material can be achieved. So this paper aims at utilization of waste from china clay and ceramic industry. Using ceramic tile in concrete not only it will be cost effective, but also provide considerable strength to the concrete . China clay waste is the spoil resulting from the production of china clay with charateristics similar to that of cement .This thesis work aims to study the mechanical and durability properties so as to obtain an economical mix using china clay in different percentages of 0, 5, 10, 15, 20 % and ceramic tile in a constant percentage of 30 to replace cement and coarse aggregate respectively.**

I. INRODUCTION

Concrete is the most widely consumed material in the world, after water. Nowadays, most of the construction of buildings and infrastructures are using concrete as a construction material. It is construction material composed of cement as well as other cementations materials such as slag cement, aggregate, water, and chemical admixtures. Concrete solidifies and hardens after mixing with water and placement due to a chemical process known as hydration. The water reacts with the cement, which bonds the other components together eventually creating a stone-like material. As it gives benefit to the construction field, it also give environmental problem. Cement and aggregate, which are the most important constituents used in concrete production, are the vital materials needed for the construction industry. This inevitably led to a continuous and increasing demand of natural materials used for their production. Parallel to the need for the utilization of the natural resources emerges a growing concern for protecting the environment and a need to preserve natural resources, such as aggregate, by using alternative materials that are either recycled or discarded as a waste. If some of the waste materials are found suitable in concrete making not only cost of construction can be cut down, but also safe disposal of waste material can be achieved. The cement of high strength concrete is generally high which often leads to higher shrinkage and greater evaluation of neat of hydration besides increase in cost. A partial substitution of cement by an industrial waste is not only economical but also improves the properties of fresh and hardened concrete and enhance the durability characteristics besides the safe disposal of waste material thereby protecting the environment form pollution

Waste material from china clay industry procured from the local china clay products industry was used as partial replacement for river sand.The size of the material used is 4.75 mm and down size.The ceramic wastes are obtained from a local building that has been demolished. The waste ceramics are crushed into pieces with crushing machine in laboratory. The aggregates passing through IS sieve 20mm and retained on 12.5mm are taken. The specific gravity of tile aggregates is 2.27 and fineness modulus of 5.64.

Objectives of study are:

1. To determine the workability of concrete
2. To determine the compressive strength of concrete
3. To determine the flexural strength of concrete
4. To determine the splitting tensile strength of concrete
5. To determine the durability of concrete
6. To study the flexural and shear properties of RC beams.
7. Comparison of results

1. Materials Used

- Ordinary Portland cement (53 grade)
- Waste from china clay industry
- Ceramic waste
- Fine aggregate: Locally available sand with 4.75 mm maximum size will be used as fine aggregate
- Coarse aggregate: Crushed stone with 12–20 mm size will be used as coarse aggregate
- Potable water
- Admixture

2. Methodology

- Raw materials procurement from available sources.
- Determination of material properties.
- Development of mix design.
- Workability study of developed mixes.
- Casting the specimens.
- Testing the specimens.
- Comparison of results to arrive at conclusion.

II. EXPERIMENTAL INVESTIGATION

The properties of the materials used for the preparation of concrete plays a vital role in fresh as well as a hardened properties of concrete. Tests were conducted on each material for getting their properties. Experimental investigations were carried out to determine the strength characteristics of concrete with different percentages of concrete by replacement of china clay for cement and ceramic tile for coarse aggregate and therby to arrive at the optimum replacement percentage of cement and coarse aggregate and also to study the durability of concrete

A. Test On Constituent Materials

Cement: Ordinary Portland Cement of 53 grade, conforming to IS: 12269-1987 was used. Different laboratory tests were conducted on cement to determine standard consistency, initial and final setting time and compressive strength as per IS: 4031-1988.

China clay: A fine usually white clay formed by the weathering of aluminous minerals, $Al_2Si_2O_5(OH)_4$ (as feldspar); used in ceramics and as an absorbent and as a filler (e.g., in paper)

Fig 1 China clay

Fine Aggregate: Commercially available river sand passing through 4.75mm IS sieve and conforming to grading zone II of IS: 383-1970 was used for experiment. Sieve analysis was done to determine the fineness modulus and grain size distribution of river sand.

Crushed ceramic tile: Cracked pieces of ceramic tiles were crushed manually using hammer. The ground ceramic preparation process is shown in Figure 3.5. The gradation of aggregates affects both fresh and hardened concretes. The sieve analysis of this crushed aggregates have been performed according to IS specifications. Ceramic aggregates were sieved in such a way that their grading are exactly compatible with the natural used aggregate in concrete, this compatibility causes that the error created by the grading differences in the properties of concrete become minimized. The diagram of grading of ceramic aggregates and natural ones should be exactly compatible.

Fig 2. Crushed ceramic tile

Superplasticiser : In order to achieve the desired workability, poly carboxylate ether based new range water reducing admixture, Cera Hyperplast XR–W40 was used as the superplasticiser. Cera Hyperplast XR–W40 is available in liquid, which is dispensed into the concrete along with mixing water. It is desirable to add the admixture after adding about 50% of the mixing water into the mixture.

Coarse aggregates used for this study consists of locally supplied granite type coarse aggregate of nominal size 12.5 mm. As per IS: 2386 (part III) – 1963, laboratory tests were conducted on coarse aggregate to determine the different physical properties. As per IS: 383-1970 gradation curves were drawn.

Water: Potable water was used in concrete.Water from lakes and streams that contain marine life also. usually is suitable. Hence water available in the college water supply system was used for casting as well as curing of the test specimens.

TABLE.1. NUMBER OF SPECIMEN

Sl. No.	Property	Specimen	Size (mm)	No. of specimens
1	Compressive strength	Cube	150x150x 150	45
2	Split tensile strength	Cylinder	150 diameter &300 height	9
3	Flexural strength	Beam	500x100x 100	9
4	Durability i. Acid resistant test	Cube	100x100x 100	30
	ii. Alkali resistant test	Cube	100x100x 100	30
	iii. Sulphur resistant test	Cube	100x100x 100	30
	iv. Sea water resistant test	Cube	100x100x 100	30

B. Mix Design

M25 mix was designed as per IS10262:2009 and mix proportion was obtained as 1: 1.35 : 2.29. Water-cement ratio was 0.4. Five mixes were made namely CC0 ,CC1 ,CC2 ,CC3 CC4 to determine mechanical properties. CC0 with 0% china clay and ceramic tiles considered as control mix. Other mixes are obtained by adding china clay by 5% ,10% ,15%,and 20% . In these ceramic tile were added at a constant percentage of 30%

B.Tests On Specimens

The specimens after casting and curing were subjected to testing. Testing the specimens determines the strength and also the quality of concrete. Tests were performed on th concrete both in fresh and hardened states for getting workability , strength and durability of concrte with partial replacement of cement with china clay and coarse aggregate with ceramic tile. The tests performed were

1. Test On Fresh Concrete:

SlumpTest
Compaction Factor Test

2 Test On Hardened Concrete

Cube Compressive Strength Test
FlexuralStrengthofConcrete
Splitting Strength of Cylinders

3 Durability Tests

Acid Attack Test
Alkali Attack Test
Sulphate Attack Test
Sea Water Attack Test

III. RESULTS AND DISCUSSION

A .Properties Of Fresh Concrete

The consistency and workability of CC mix was evaluated using slump flow tests. The results as given in Table 4.1 shows that the concrete was complying with the requirements found in the literature. For all mixes with various percentage of china clay, even though the slump flow was increasing with increase in china clay, slump flow was observed to be between 50 and 100, and that of compaction factor was less than 1, thus satisfying the standard specifications .So, all mixes with different china clay content hold good for filling ability as well as compaction characteristics required for concrete to be CC mix . Fig 4.1 and 4.2 shows the test results for slump flow and compaction factor tests.

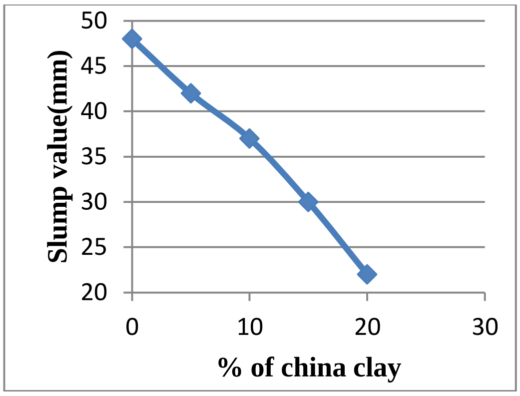

Fig 3. Slump flow results

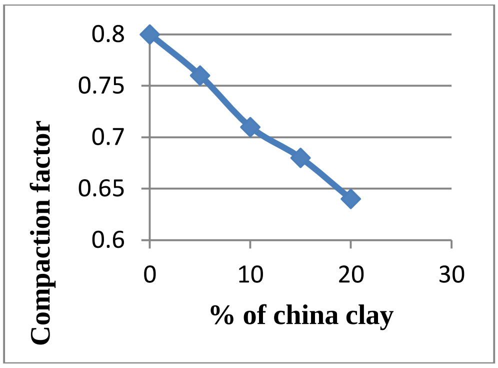

Fig 4. Compaction factor results

TABLE 2 : FRESH PROPERTIES OF CC

Mix designation	Slump value (mm)	Compaction factor
CC0	48	0.80
CC1	42	0.76
CC2	37	0.71
CC3	30	0.68
CC4	22	0.64

TABLE 3 HARDENED PROPERTIES OF CC

Property	CC0	CC1	CC2	CC3	CC4
7 days Cube Compressive Strength	18.7	21.1	20.9	19.8	10.4
14 days Cube compressive strength	20.9	22.7	21.8	20.7	12.2
28 days Cube compressive strength	24.6	30.7	25.6	21.6	15.6
Splitting tensile strength	3.54	2.97	2.54	2.12	1.91
Flexural strength	5	5.5	4.5	3.75	2.5

B. Properties Of Hardened Concrete

Compressive strength*:* Cube Compressive strength test is one of the most important properties of concrete, as it will affect many other properties of hardened concrete. According to the results, there is an increase in compressive strength by the addition of china clay at 5% and 30% ceramic tile , after which it shows a reduction in strength . Thus CC1 is considered at the optimum mix with an increase in compressive strength of 22.8% with respect to control mix (CC0).The average reduction in cube compressive strength for CC0, CC2, CC3 and CC4 with respect to optimum mix was around 19.9%, 16.6%, 29.64% and 49.2% for control mix and china clay contents of 10%, 15% and 20% (with 30 % of ceramic tile) respectively . The reason for decrease in strength after the addition of increased percentages of china clay (10 ,15 , 20 %) is due to the presence of aluminious minerals in china clay because increased percentage of aluminium particles weakens the cement property of imparting strength.

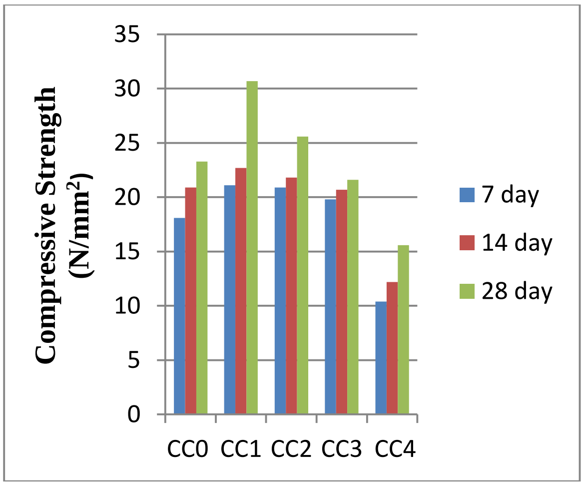

Fig.5: Cube Compressive strength of CC mix

Splitting tensile strength test was carried out on cylindrical specimens placed horizontally between the loading surfaces of the compression testing machine. On addition of china clay and ceramic tile there is a gradual decrease in splitting tensile strength of 16.1, 28.2, 40.1, 46.04% with respect to optimum mix . The variations in splitting tensile strength are shown in Fig. 4.4

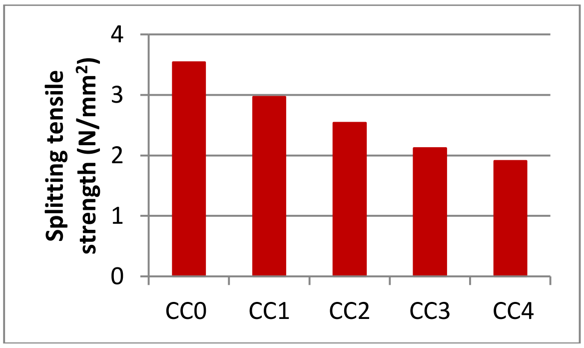

Fig. 6: Splitting tensile strength of CC mix

Flexural strength test was found out by testing prisms under two point loading. The load was applied until failure of the cylinder along the vertical diameter. The results of splitting tensile strength are also given in Table 4.2 and represented as a graph in Fig. 4.4. The variation of splitting tensile strength of CC mix is also similar to that of cube compressive strength & splitting tensile strength .The decrease in split tensile strength of CC mix could be attributed to the same factors that reduced the compressive strength.

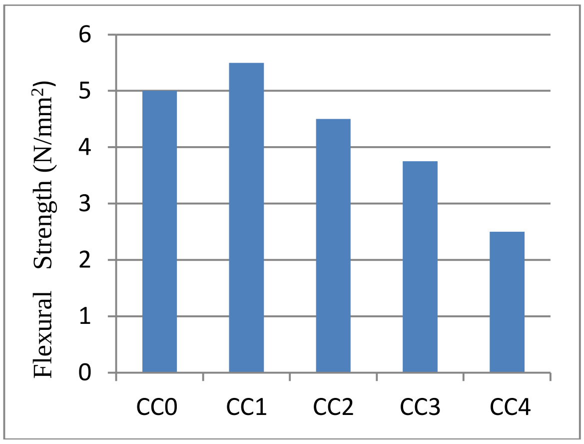

Fig. 7 . Flexural strength of CC mi

3. *Durability Test Results*

a) Acid Resistant Test

From the results it was clear that the concrete mix has moderate durability in acid. It was noted that as the amount of china clay increases the weight loss decreases and correspondingly compressive strength increases. The reaction of acids on concrete is the conversion of calcium compounds into calcium salts of the attacking acid. These replacement of cement with china clay and coarse aggregate with ceramic tile is found to have increased durability against acid attack. The amount of silica in china clay and ceramic tile is greater which combines with calcium hydroxide and reduces the amount susceptible to acid attack.

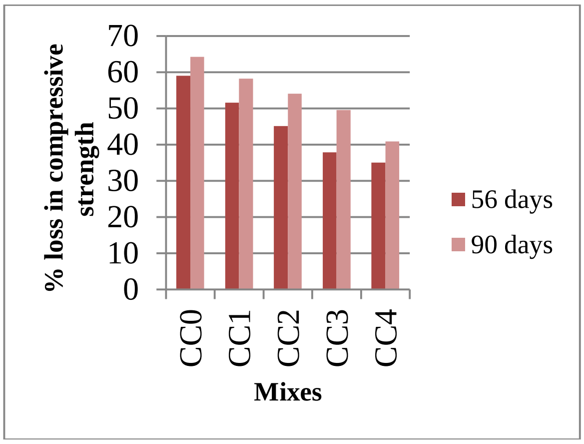

Fig 8: Percentage loss in compressive strength in acid solution

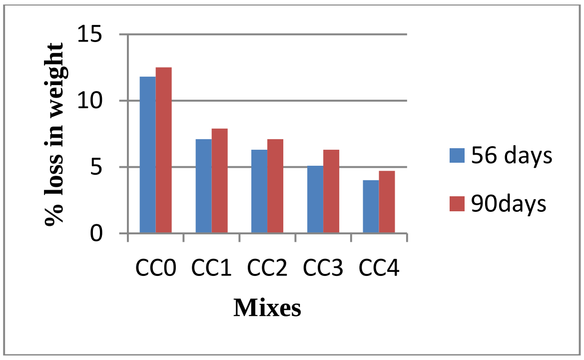

Fig 9: Percentage loss in weight in acid solution

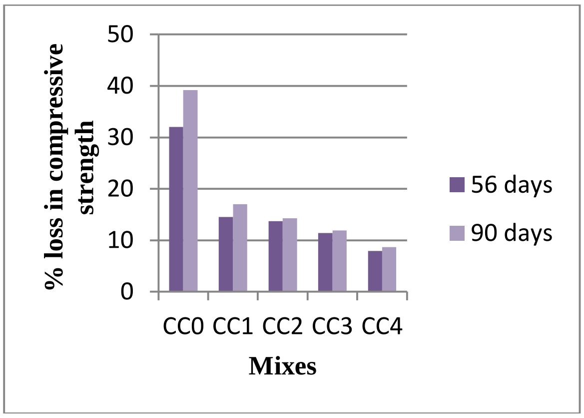

Fig 10: Percentage loss in in compressive strength alkali solution

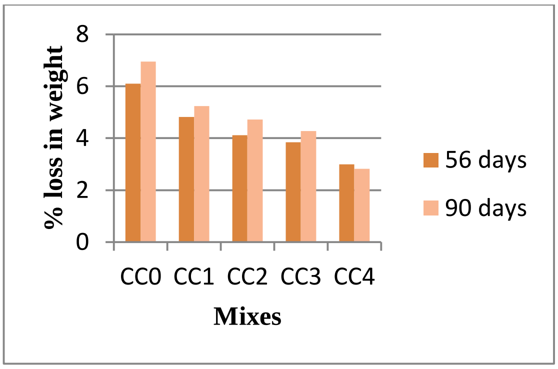

Fig 11: Percentage loss in weight in sea water

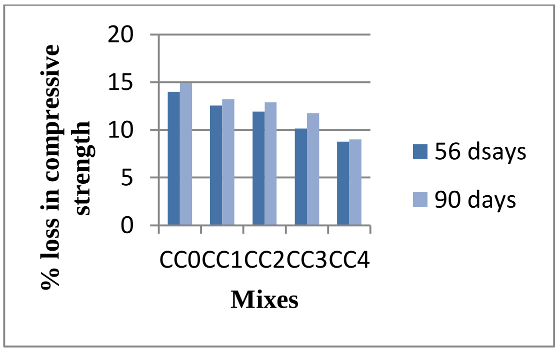

Fig 12: Percentage loss in compressive strength in sea water

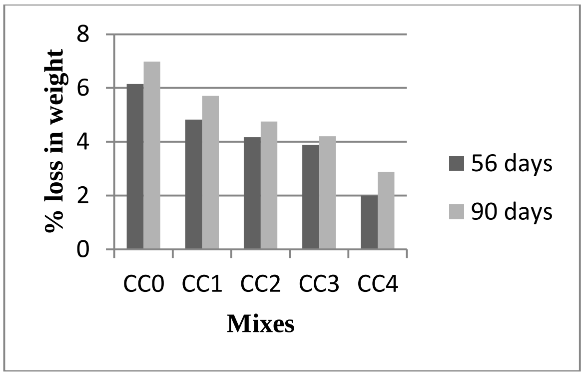

Fig 13: Percentage loss in weight in Sulphate solution

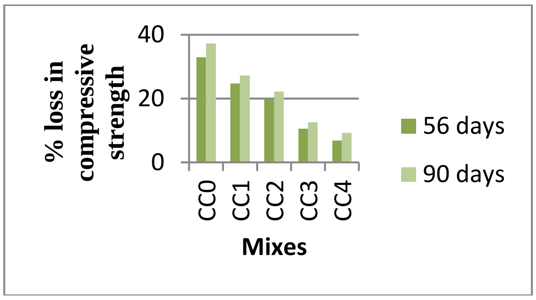

Fig 14: Percentage loss in compressive strength in Sulphate solution

IV. CONCLUSION

The major conclusions of my thesis work are the following:

- Replacement of cement with china clay and ceramic tile with coarse aggregate has an effect on the workability of concrete to a certain limit. There is a decrease in the workability of the mix as the percentage of china clay increases. Thus the workability of the mix is increased to the required consistency by the addition of Superplasticizer Cera hyperplast.
- Compresssive strength of concrete mix upto 5 % replacement of cement by china clay and 30% coarse aggregate by ceramic tile is greater than conventional concrete mix. Maximum compressive strength was obtained was 30.7 N/mm^2. This results are by considering water cured specimens.
- Optimum mix got higher flexural strength than control mix. But final mix got less flexural strength than control mix and optimum mix. This means replacement of cement beyond a limit decreases the flexural strength.
- Optimum mix got higher splitting tensile strength than control mix. But final mix got less splitting tensile strength than control mix and optimum mix. This means replacement of cement beyond a limit decreases the flexural strength
- The Chloride permeability of concrete mixes decrease with percentage increase of china clay. So Chloride permeability of all concrete mixes with china clay is lower than that of conventional concrete.
- Durability of china clay mix increases with increase in china clay percentage. This result is obtained by

considering acid attack , alkali attack, Sulphate attack and sea water attack.

- From the above observations, it was understood that concrete mix with 5 % china clay replacement of cement is suitable with respect to strength and that of final mix is durable than other mixes.

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