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Replacement of Coarse and Fine Aggregate by waste Ceramic Tiles and Ceramic Powder in Concrete

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Abstract – Concrete is an advanced material in civil engineering. It is binding material made with cement, fine aggregate, course aggregate and admixtures in some cases. Nowadays developments of construction field, the worldwide consumption of natural materials is very high and at the same time production of solid waste from the destructions and production units are also very high. Extensive use of concrete leads to the lack of natural materials. Because of this reasons the recycle of destructions wastes and solid waste from the production of came in to the picture to decrease the solid wastes from destructions and production units and as well as to decrease the lack of natural basic materials. The current option of dumping for this type of unused is landfill. Unavailability of standards, avoidance of risk, lack of knowledge and experience led to there being no active usage of ceramic wastes in construction. Ceramic wastes are classified as non-recyclable wastes in South Africa, except for the normal use as filling material. Based on research regarding ecological Construction and Destructions (C&D) wastes, ceramic wastes have the potential to be used in concrete production. There are no guiding principle and criteria to the usage of waste in solid. In addition, the local industry does not have knowledge and experience to utilize the material.

1. INTRODUCTION

1.1. GENERAL

Commonly in design of concrete mix, cement, fine aggregates and coarse aggregates are using in long back, which plays a crucial part in planning of a specific grade of concrete. But nowadays there is dearness in materials. So, a few new materials which are locally vacant for low cost have to introduce for replacing the fine aggregates, coarse aggregates and as well as cement to get the same strength as that these basic materials can give.

Natural sources required for various constructions are clamping depleted at a quick rate, due to which there is ever a rise in their price. This guide the engineers and researchers in finding another substitutes for the production of construction materials keeping in mind of maintaining the quality, strength and also stability. One of the uttermost main constituents of concrete being coarse aggregate the fact being that it lives in 70-80% of the volume of concrete thus creation a big effect on the physical appearance and properties of the concrete. However, with the urbanization and rapid rise in the population especially in a country like India the demands for this particular construction material cannot be met simply. Hence, to overcome this problematic is by using waste products such as waste ceramics.

In India the Ceramic Tile Manufacturing approximate price is Rs.21,000 Core and was reported, the Indian Ceramic Tiles industry grew per around 11% in 2013-14 and expected to reach a size of Rs.301 billion by 2016. As in a current report of Worldwide Ceramic Tiles Material on the Market of February 2016, the universal ceramic waste materials in market will grow at a Compound Annual Growth Amount of 9.57% for the duration of period of 2016 to 2020.

Worldwide India is placed 3rd and accounted for above 6% of total global production. Even with a amazing increase in the ceramic manufacture there is an inappropriate consumption. Thus resultant to a huge waste which is announce to be around 15%-30% annually, created from the total production.

Ceramic products are artificial at very high temperatures between 1000°C-1250°C which results in extremely very hard, extremely unaffected by to chemical, freezing and thermal shock. Seeing the properties of ceramics waste such as wrecked tiles should be involved in concrete as a substitute to conventional construction material. This help to solution the problems like cost, lack as well as other environmental problems that may arise due to improper dumping of such waste.

2. LITERATURE REVIEW

2.1. GENERAL

R.M. Senthamarai et al. (2005) substituted conventional crushed stone aggregate with ceramic electrical insulator. Different water cement ratio of 0.35, 0.40, 0.45, 0.50, 0.55 and 0.60 were adopted. Compressive strength, split tensile strength, flexural strength and Modulus of elasticity were found out. It is found that the compressive, split tensile and flexure strength of ceramic coarse aggregate are lower by 3.8%, 18.2% and 6% respectively when compared to conventional concrete.

A.Mohd Mustafa et al. (2008) studied on various types of ceramic waste like flower pots, tiles and clay bricks. Different water cement ratios were adopted such as 0.4, 0.5 and 0.7 with concrete of characteristics strength of 20 MPa. Flower pots gave the best results for compressive strength of about 2.50% lesser than that of conventional concrete.

R.M.Senthamarai et al. (2011) studied the durability properties of ceramic industry waste as coarse aggregate in concrete. Water cement ratios from 0.35- 0.60 were used and properties such as volume of voids, water absorption, chloride penetration and sorption were studied. Water absorption ranges from 3.74-7.21% whereas that of conventional concrete from 3.1 – 6.52%. Concrete with Ceramic shows higher results in all tests.

T. Sekar (2011) studied on strength characteristics of concrete utilizing waste materials viz: ceramic tiles, ceramic insulator waste and broken glass pieces. Ceramic tiles gave the best results when compared to the other two type of waste. The concrete produced by ceramic tile aggregate produced similar strength in compression, split tensile and flexure as conventional concrete.

C. Medina et al. (2012) investigated on the reuse of waste as recycled coarse aggregate in partial substitution of 15%, 20% and 25% in the manufacture of structural concrete. Compressive strength is found out t 7, 28 and 90 days. There is an increase in strength with increase of percentage replacement, the best results shown is at 25% with increase of 21.12%, 11.04% and 6.70% at 7, 28 and 90 days respectively.

Y. Tabak et al. (2012) studied on the mechanical and physical properties of concrete produced form Floor Tiles Waste Aggregate (FTWA). Two samples were made, the first one substitution by Floor Tile Waste Dust (FTDA) and the other a combination of Floor Tile Waste Dust (FTDA) and Floor Tile Waste Aggregate (FTWA).Best result is shown b FTWA substitution. Increase in compression strength is 13.53%, 16.70% and 2.91% for 2, 7 and 28 days. Similarly there is an increase of 23.21%, 0.1% and 19.47% respectively for flexure strength. There is a reduction of specific density and water absorption of 0.284Kg/m^3 and 0.158% respectively when compared to conventional concrete.

D. Tavakoli et al. (2013) investigated on the possibility of using ceramic tile in concrete. Coarse aggregate is replaced in the range of 0-40%. There is an increase in compressive strength by 5.13% whereas there is a decrease in slump, water absorption and unit weight by 10%, 0.1% and 2.29% respectively with 10% substitution.

J.Swathi et al. (2015) partially replaced fine aggregate with copper slag as 20%, 40% and 60% and coarse aggregate with waste ceramic tiles as 10%, 20% and 30%.M40 grade of concrete was used. Compressive strength increased by 7.59N/mm^2 at a combination of 40% copper slag with 10% waste ceramic tiles and also Flexure increased by 4.07%.

M.Roobini et al. (2015) determined the development strength of concrete with ceramic tiles as coarse aggregate. 20MPa characteristic strength concrete is used with water cement ratio of 0.5. The compressive strength and split tensile strength improved by 4.84% and 13.30% respectively at 20% replacement. Whereas, flexure strength is best at 10% replacement which is 4.84% more than that of conventional concrete.

R. Janarthanan et al. (2015) experimented on ceramic waste as a construction material by replacing it as coarse aggregate for 25%, 50% and 100%. M_{30} concrete mix is chosen. Best results were found out at 25% replacement with 34.63N/mm^2 Compression strength which is close to conventional concrete being 34.23 N/mm^2

3. OBJECTIVE

- To find low cost material.
- To study the strength developments hardened concrete with waste ceramic aggregate.
- To determine the effect of various fraction of ceramic waste as

Aggregates refilling towards compressive strength of concrete.

- To observe the water absorption of ceramic material in concrete containing various content of ceramic tile as aggregates replacement material.

3.1. SCOPE

There are many inquiry and study that had carried carry out to improvise the quality of concrete production and to form various types of concrete that will be used for dissimilar purposes according to its appropriateness.

Several researches had been lead to intensify the properties of the regular concrete by mixing or adding other materials in to the natural conservative concrete. For this study, ceramic waste is used as narrow coarse aggregates spare to natural coarse aggregates.

The study is essential because the proposed material to replace coarse aggregates is waste product from construction. This will reduce the waste material from building as ceramic tile waste can be reused for concrete manufacture purposes.

4. MATERIALS USED AND TEST REPORT

4.1. CEMENT

The ordinary Portland cement of 53 grade whose specific gravity of cement is 3.14, normal consistency of the cement was found as 28% and the initial and final setting times were found as 120 min and 238 min respectively was used.

FINENESS TEST

So we need to determine the fineness of cement by dry sieving as per IS: 4031 (Part 1) – 1996.The principle of this is that we determine the proportion of cement whose grain size is larger than specified mesh size. The apparatus used are 90µm IS Sieve, Balance capable of weighing 10g to the nearest 10mg, A nylon or pure bristle brush, preferably with 25 to 40mm, bristle, for cleaning the sieve.

Reporting of Results:

Report the value of R, to the nearest 0.1 percent, as the residue on the 90µm sieve.

SOUNDNESS TEST

Soundness of cement is determined by Le-Chatelier method as per IS: 4031 (Part 3) – 1988. Apparatus – The apparatus for conducting the Le-Chatelier test should conform to IS: 5514 – 1969. Balance, whose permissible variation at a load of 1000g should be +1.0g and Water bath.The value given in below to in table 1,

TABLE 1

CEMENT TESTING REPORT

TESTS	RESULTS
Specific gravity	3.15
consistency	33
Initial setting time	27 min
Final setting time	375 min

4.2. COARSE AGGREGATE

The coarse aggregate with 40 mm nominal size having specific gravity 2.76 was used. The impact value is 20.5%. And the water absorption of the coarse aggregate is 0.54%.The value given in below to in table 2,

TABLE 2
COARSE AGGREGATE TESTING REPORT

TESTS	RESULTS
Specific gravity	2.76
Water absorption %	0.54
Impact value	20.5%
Fineness modulus	2.596

4.3. FINE AGGREGATE

Locally available river sand is used. As per IS 383:1970, sand is confirming to Zone I to IV. Specific gravity of the sand used is 2.69. And the water absorption value is 0.45%.The value given in below to in table 3,

TABLE 3
FINE AGGREGATE TESTING REPORT

TESTS	RESULTS
Particle shape	Irregular
Appearance	Brownish yellow
Type	River sand
Specific gravity	2.64
Water absorption %	1.24
Fineness modulus	2.73

4.4. CRUSHED TILES

Broken tiles were collected from the solid waste of ceramic manufacturing unit. Crushed them into small pieces by manually (Shown in Pic.1of section VII) and by using crusher. And separated the coarse material to use them as partial replacement to the natural coarse aggregate. Specific gravity of the crushed waste tiles is 2.39. Impact value of these crushed tiles is 25.81%. Crushed tiles shown in fig.3.

Fig.4.1. Crushed Tiles

4.5. TILES POWDER

Fig.4.2. Tiles Powder

From the crushed waste tiles, powder (Shown in Pic.2 of section VII) passed through 4.75 mm IS sieve to use as partial replacement to the fine aggregate. Specific gravity of tile powder is 2.63.

TABLE 4

COMPARISON OF PROPERTIES OF TILE AGGREGATES AND NORMAL AGGREGATES

Sr. No.	Properties	Normal aggregate	Tile aggregate
1.	Shape	Angular	Flaky
2.	Texture	Rough	Rough
3.	Water absorption	0.5%	14.4%
4.	Impact value	15%	20%
5.	Specific gravity	2.69	2.24

4.6. MIX DESIGN

M25 grade of concrete was designed by following the specification given in the IS 10262: 2009. Water – Cement ratio (w/c) was selected as 0.50 based on conducting slump tests for different design trails. Mix proportion obtained for M25 mix is 1:2.29:4.12.The value given in below to in table 5,

TABLE 5

MATERIAL TEST RESULTS

Sr. No.	Test	Results
1.	Specific Gravity Of Cement	3.15
2.	Specific gravity of Coarse Aggregates	2.74
3.	Specific gravity of Fine Aggregates	2.66
4.	Fineness Modulus of Fine Aggregates	2.17
5.	Specific Gravity of Tile Aggregates	2.24
6.	Water Absorption of Tile Aggregates	14.4%
7.	Impact Value of Tile Aggregates	20%

4.7. EXPERIMENTAL PROGRAM

Total nine types of mixes were prepared by changing percentage of replacement by waste crushed tiles and tiles powder in coarse and fine aggregates respectively as shown in Table 6.

TABLE 6

PERCENTAGES OF FINE AGGREGATE AND COARSE AGGREGATE REPLACED

Mix	Fine Aggregate (%)		Coarse Aggregate (%)	
	Sand	Tiles Powder	C.A	Crushed tiles
A0	100	0	100	0
A1	80	20	80	20
A2	50	50	50	50
A3	20	80	20	80
A4	0	100	0	100

Slump cone test was performed on all mixes to assess the workability of concrete for different percentages of replacing materials. The results of workability are discussed in the section "A. Workability". Concrete cubes having size of 150 x 150 x 150 mm were prepared for all mixes to test 3 samples of a mix at 7, 28 days. Compressive strength test is also conducted on cubes after 7 and 28 days curing period, for each mix 3 samples were tested. Compressive strength of each mix is taken as average of the 3 samples and discussed in the section "C. Compressive strength".

WORKABILITY

Slump cone test was performed on fresh concrete, for all mixes having different percentages of replacing materials which are shown in Table 6 (A0 to A4). The slump value for different mixes are obtained as follows.

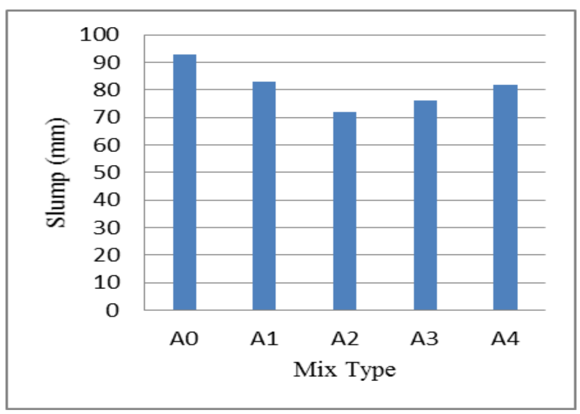

Fig.4.3. Workability

Fig. 5. Shows slump variation for different mixes. Slump values are not changing when waste crushed tiles are replaced

in place of coarse aggregate. But, increase in percentage of tile powder in place of fine aggregate leads to the increase in slump value. Maximum slump is obtained for A0 mix i.e., when 20% of fine aggregate replaced by the tiles powder. In case of combinations also slump value is increasing. From the Fig.5 clearly observe that the workability is increasing for all mixes at different percentages of replacing materials. There is a huge change in slump value when only tile powder was replaced in place of fine aggregate.

4.8. TESTS FOR CONCRETE

4.8.1 TEST FOR COMPRESSIVE STRENGTTH OF CONCRETE CUBES:

Compressive strength is the most common test conducted on hardened concrete. It is very easy and simple to perform and partly because many of the desirable properties of concrete are qualitatively related to its compressive strength. Compression test specimens are used: cubes, cylinder and prisms. Take required quantities of material and mixed it by hand or by machine mixing. Concrete should be filled in mold in three equal layers. Each layer should be compacted for 25 times with a 16mm dia. rod. After hardened the specimens are taken out and cured in clean, fresh water. Curing is done until the required days of testing. The test should be carried out immediately upon the removal of specimen from water curing and after that finding out the compressive strength by compressive machine.

Compressive strength=maximum load/area =P/A

The value given in below to in table 7,

TABLE 7

TEST FOR COMPRESSIVE STRENGTTH OF CONCRETE CUBES

Replacement Details	7 days (N/mm^2)	14 days (N/mm^2)	28days (N/mm^2)
Nominal Mix	20.7	23.34	28.43
(F.A (80%) + T.P (20%)) + (C.A (80%) + T.P (20%))	22.2	25.08	30.12
(F.A (50%) + T.P (50%)) + (C.A (50%) + T.P (50%))	23.1	27.23	31.62
(F.A (20%) + T.P (80%)) + (C.A (20%) + T.P (80%))	22.4	23.13	25.23
(F.A T.P (100%)) + (C.A T.P (100%))	20.3	22.59	23.46

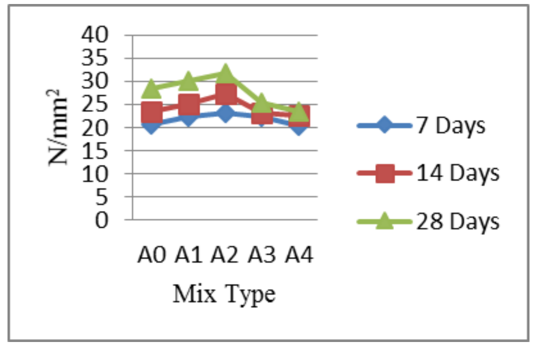

Fig.4.4. Comparisonof Compressive Strength of Mix

4.8.2. TEST FOR SPLIT TENSILE OF CONCRETE CYLINDER

Tensile stress is likely to develop in concrete due to drying, shrinkage, corrosion of steel reinforcement or due to temperature gradients. The determination of flexural tensile strength is essential to estimate the load at which the concrete members may cracks. It is of a great importance while designing liquid retaining structures and prestressed concrete structures. The cylinder is placed with its axis horizontal between the platens of a testing machine, and the load is increased until failure by splitting along the vertical diameter takes place. Narrow packing of plywood strip or rubber is used to reduce the magnitude of high compressive stress immediately below load. If such strips are not provided then the observed stress will be reduced for up to 8%.

Horizontal Tensile Stress = $2P/\pi LD$. The value given in below to in table 8,

TABLE 8

TEST FOR SPLIT TENSILE OF CONCRETE CYLINDER

Replacement Details	7 days (N/mm^2)	14 days (N/mm^2)	28days (N/mm^2)
Nominal Mix	2.45	3.02	3.99
(F.A (80%) + T.P (20%)) + (C.A (80%) + T.P (20%))	2.3	2.89	3.51
(F.A (50%) + T.P (50%)) + (C.A (50%) + T.P (50%))	2.53	3.64	4.02
(F.A (20%) + T.P (80%)) + (C.A (20%) + T.P (80%))	2.42	2.98	3.06
(F.A T.P (100%)) + (C.A T.P (100%))	2.13	2.47	2.78

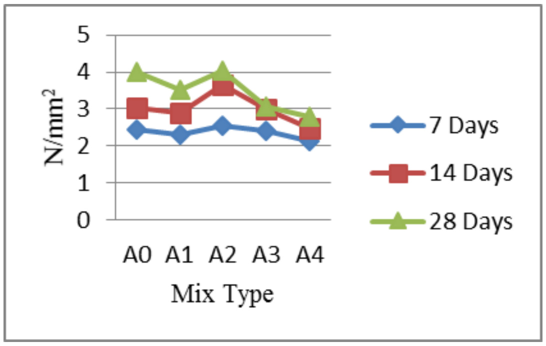

Fig.4.5. Comparison of Split Tensile Strength of Mix

4.8.3. TEST FOR FLEXURAL STRENGTH OFCONCRETE BEAMS

The normal tensile stress in concrete, when cracking occurs in a flexure test is known as modulus of ruptures, i.e. flexural strength. The standard test specimen is a beam of size 150mm × 150 mm × 700mm size. The specimen should be 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. The flexural strength can be finding out by universal testing machine. The flexural strength can be found out by central loading as well as the load is applied through two similar rollers mounted at the third point of the supporting span. The flexural strength can be found out by formula as follows, Fcr = $(P.L)/bd^2$. The value given in below to in table 9,

TABLE 9

TEST FOR FLEXURAL STRENGTH OF CONCRETE BEAMS

Replacement Details	7 days (N/mm^2)	14 days (N/mm^2)	28days (N/mm^2)
Nominal Mix	3.99	4.12	4.81
(F.A (80%) + T.P (20%)) + (C.A (80%) + T.P (20%))	4.04	4.23	4.38
(F.A (50%) + T.P (50%)) + (C.A (50%) + T.P (50%))	4.12	4.36	4.65
(F.A (20%) + T.P (80%)) + (C.A (20%) + T.P (80%))	4.08	4.20	4.34
(F.A T.P (100%)) + (C.A T.P (100%))	4.01	4.10	4.22

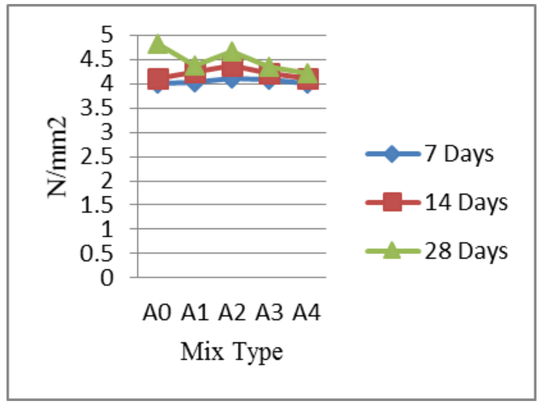

Fig.4.6. Comparison of Flexural Strength of Mix

5. CONCLUSION

From the experimental study we concluded that, the crushed tiles can be used in the form of fine and coarse aggregate.

Based on workability observations were made. Replacing tiles powder in the concrete got increased the workability of concrete.

When compared to normal concrete 50% replacement of coarse and fine aggregate the compressive strength increased in huge level but split tensile and flexural strength got slight increase only when compared to nominal concrete.

Mechanical properties of ceramic aggregate are similar to the natural aggregate and its character is similar but it enhance the workability, water absorption, crushing value and impact value, are comparability higher then natural coarse aggregate and lowered by specific gravity ($2.24g/cm^3$). Crushed tile aggregate concrete is economical as compared to conventional concrete.

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