Utilization Of Waste Ceramic Tiles As Coarse Aggregate In Concrete

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***Abstract*—The utilization of waste materials in concrete production is very much helpful to reach the goal of the sustainable construction. Therefore, this study intends to use ceramic tile aggregate in concrete production. The paper reports on the performance of 3 different concrete mixes containing different ratios of crushed tiles having 20 mm maximum size as coarse aggregate. Ordinary Portland Cement 53 grade and coarse sand were used to produce standard concrete cubes. Compressive strength tests were carried out on concrete specimens at various ages. Test results indicates that except M 30 mix there is no significant effect on compressive strength of concrete in M 20 and M 25 mixes up to 20 percent replacement of normal 20 mm coarse aggregates with tile aggregates. But beyond that, strength started decreasing gradually with increase the proportion of tile aggregates in concrete.**

Keywords— Sustainable Construction; Ceramic Tile Aggregate (CTA)

I. INTRODUCTION

Huge amount of natural aggregates, sand and water are being consumed in concrete production. Consequently, to minimize these, researches have concentrated on the use of waste materials as potential alternatives in the construction industry, especially in concrete construction. In fact, utilization of waste materials (i.e., slag, fly ash, plastics, etc.) in concrete construction is one of the prime research interests to reach the goal of achieving sustainable construction. Aggregates impart about 70% to 75% of volume to concrete. In this aspect, consumption of waste tiles or broken tiles as coarse aggregates in concrete manufacturing can be a new scientific sobriety in the field of sustainable concrete. A large amount of tiles get broken or wasted in tile industries and on mega construction projects. The residual and unused wastes are disposed into environment as burden without any commercial return.

Consequently, huge money is being spent for their disposal reasons as well as environmental pollution occurs. It is well known that addition of these wastes in concrete as a supplement generally reduces the construction cost and more or less maintains the properties of concrete. In addition, waste materials, when properly processed, have shown to be effective as construction materials and readily meet the design specifications.

Ceramic tile aggregates are hard having considerable value of specific gravity, rough surface on one side and smooth on other side, are lighter in weight than normal stone aggregates. Using ceramic tile aggregate in concrete not only will be cost effective, but also will be good from environment point of view.

This study focuses on producing concrete of acceptable strength with crushed waste ceramic tiles as coarse aggregate and determining the optimum coarse aggregate mix ratio to achieve this strength.

A. literature review

1) Medina (2012)

Medina studied on effective utilization of ceramic waste as recycled coarse aggregate. It was produced by crushing of sanitary ware and its shape curve of recycled ceramic aggregate was similar to the natural coarse aggregate. Irregular shape of aggregate was presented in the ceramic waste, resulted that superior surface area and better bonding was observed in experimentation.

2) Mashitah (2008)

Mashitah concluded on recycling of homogeneous ceramic tiles used in the preparation of concrete block. The surface of ceramic tile aggregate was found as smooth, angular shaped and sharpen edges as compared with natural coarse aggregate. Flatter particles consumed more quantity of cement paste to generate better inter facial transition zone.

3) Senthamarai (2005)

Senthamarai concluded that ceramic tile waste can be effectively used as aggregates in concrete making, based on the strength of ceramic waste aggregate. The crushing value, impact value, abrasion values for ceramic scrap were 27, 21 and 28% correspondingly and for natural coarse aggregate 24, 17 and 20% respectively. Ceramic scrap does not have much variation with respect to the natural aggregates.

4) Marcio (2004)

Marcio experimented on compressed stress, water absorption and modulus of elasticity of concrete made with ceramic aggregate. Crushed ceramic blocks were used as coarse aggregate in concrete fabrication. Specific density of aggregate was 2630 to 2310 kg/m3 for 0 to 100% replacement. Up to the replacement of 20%, Compression resistance and modulus of elasticity was equivalent with conventional concrete.

5) Pacheco-Torgal and Said Jalali (2011)

Pacheco-Torgal and Said Jalali studied the behavior of strength and durability of ceramic waste based concrete. Water absorption of ceramic coarse aggregate was higher than the natural aggregate. It can be assumed that the extra water content leads to better internal curing than the controlled concrete.

6) Sekar (2011)

His research reported that, specific gravity of ceramic coarse aggregate varied between 2.2 to 2.56. These values were influenced the density of ceramic aggregate concrete.

7) Veera Reddy (2010)

Veera Reddy reported on impact value and crushing value of ceramic scrap as 18.2 and 24.7% respectively. These values were within the permissible limits according to IS 383-1970, hence it was safe to use as a coarse aggregate in concrete composition.

B. Scope of Investigation

The general specification for civil engineering works in India generally prohibits the use of any lower quality material to be used in concrete but tile aggregate satisfy all limits required except flakiness. These aggregates are totally flaky in shape which should be avoided as far as possible according to IS 383:1770. However natural aggregates can be replaced partially with tile aggregates in concrete.

Till now, there is no provision about the use of tile aggregates in concrete and other major civil engineering works. In the less important works, the decision is given to the engineer. In the absence of any suitable guidelines, it is quite difficult for the engineer to allow the use of these aggregates and his decision will definitely be towards the use of natural materials.

However, according to a press release Bureau of Indian Standards, the National Standards Body of the country, considering the scarcity of sand and coarse aggregates from natural sources, has evolved number of alternatives which are ultimately aimed at conservation of natural resources apart from promoting use of various waste materials without compromising in quality. These measures include permitting in the Concrete Code (IS 456:2000) as also in the National Building Code of India, the use of slag - a waste from steel industry, fly ash - a waste from thermal power plants, crushed over-burnt bricks and tiles - waste from clay brick and tile industry, in plain cement concrete as an alternative to sand/natural aggregate, subject to fulfilling the requirements of the Code.

Various experimental studies regarding tile aggregates can be helpful for this initiative of BIS to promote the suitable tile waste usage in concrete and made a provision in concrete code and national building codes of India.

To promote the use of tile aggregates in the Indian construction industry, it is necessary to make these specifications more liberal otherwise the use of tile aggregates in permanent works other than reclamation and earth filling is almost impossible.

C. METHODOLOGY

Three different concrete mix designs M 20, M 25 & M 30 has chosen to carry out the tests to find the effect of tile aggregates on strength of concrete and in each design natural aggregates will be replaced by ceramic tile aggregates with proportion of 0%, 5%, 10% & 20%.

As tile aggregates are totally flaky in shape therefore only a limited use is possible in concrete. Flaky aggregate tend to break under pressure so if used in excess will lead to poor compression strength.

Following preparations will be made to cast cubes.

- Total number of concrete mix designs will be prepared – 3
- Number of proportions in which tile aggregates will be replaced with normal aggregates in each design – 4 (i.e. 0%, 5%, 10% & 20%)
- Therefore, total concrete batches will be prepared – 12
- Number of concrete batches will be prepared in a day – 1
- Number of cubes will be filled in each batch – 6
- Number of cubes will be casted for each mix design – 24

i.e.
For M 20 – 24 cubes
For M 25 – 24 cubes
For M 30 – 24 cubes

- Total number of cubes will be casted including all 3 concrete mix designs –
  24+24+24 = 72

Table 1 - Specimen Details

Name of Test	Size of Specimen	No. of Mix.	No. of Specimens for each mixture	Total Number of Specimen
Compression Strength Test	150×150×150 mm cube	12	6	72

D. SUMMARY

This chapter establishes the need of use of tile aggregate as a partial replacement of natural aggregates in concrete in order to achieve sustainable development.

II. AGGREGATE DEMAND

The global market for construction aggregates has increased 5.2 percent per year through 2015 to 48.3 billion metric tons. This represents a slower rate of growth than during the 2005-2010 period. Nevertheless, demand for construction aggregates will still post solid gains from 2015 onwards. The Asia/Pacific region has been registered the largest increase in product sales, as construction activity raised rapidly, particularly in China and India. China alone accounted for half of all new aggregates demand worldwide during the 2010-2015 period.

Expansions in demand in developed parts of the world (the US, Canada, Japan, Western Europe, South Korea and Australia) will not be as strong as in most industrializing areas. This is primarily due to the already well-developed infrastructures found in these countries and the construction methods utilized, which tend to feature less concrete.

TABLE – 2 WORLD CONSTRUCTION AGGREGATE DEMAND

				% Annual Growth	
	2005	2010	2015	2005-2010	2010-2015
Construction Aggregates Demand	27300	37400	48300	6.5	5.2
North America	3280	3010	3710	-1.7	4.3
Western Europe	2920	2630	3050	-2.1	3.0
Asia/Pacific	16000	24750	32600	9.1	5.7
Other	5100	7010	8940	6.6	5.0

NOTE - All the values mentioned above are in **billion metric tons**.

COMPENSATION OF HIGH DEMAND OF NATURAL AGGREGATE WITH TILE AGGREGATES

TILE PRODUCTION
TABLE 3- STATISTICS

1.	World production:	11913 Million sq.m
2.	India's Share:	750 Million sq.m
3.	World ranking (in production):	3
4.	Per capita consumption:	0.50 sq.m
5.	Global Industry Growth Rate:	11%
6.	Growth Rate (India Domestic Market):	15%

A. TILE WASTAGE

For instance, SAMCA is a Wall Tile manufacturing company under Ceramic Industries Limited. They produce a minimum of 400 tons and a maximum of about 800 tons of ceramic waste in every 2 weeks, which is disposed as landfill. Therefore a single tile industry produces about 10000 tons of ceramic tile waste per year.

B. SUMMARY

This reveals that ceramic tile production is adequate to substitute some proportion of natural aggregates in concrete and to compensate the lack of natural aggregates as per their demand all around the world.

III. EXPERIMENTATION

TABLE - 4
MATERIAL TEST RESULTS

Sr. No.	Test	Results
1	Specific Gravity Of Cement	2.74
2	Specific gravity of Coarse Aggregates	2.69
3	Specific gravity of Fine Aggregates	2.70
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%

COMPARISON OF PROPERTIES OF TILE AGGREGATES AND NORMAL AGGREGATES
TABLE – 5

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

A. CONCRETE MIX DESIGN

RATIOS AS PER DESIGN

M 20

Cement	Fine Aggregates	Coarse Aggregates	Water cement Ratio
1	2.09	3.40	0.55

M 25

Cement	Fine Aggregates	Coarse Aggregates	Water
1	1.87	3.04	0.50

M 30

Cement	Fine Aggregates	Coarse Aggregates	Water
1	1.87	3.04	0.50

COMPRESSION TEST RESULTS OF CONCRETE SPECIMENS
TABLE - 6

Concrete Grades	Tile Aggregate Proportion % replaced with normal	No. of Days	Target Mean Strength (N/mm^2)	Compression Strength Achieved (N/mm^2)
M 20	0	28	26.6	29.03
M 20	5	28	26.6	28.21
M 20	10	28	26.6	27.33
M 20	20	28	26.6	26.81
M 25	0	28	31.6	35.63
M 25	5	28	31.6	33.99
M 25	10	28	31.6	32.36
M 25	20	28	31.6	31.99
M 30	0	28	38.25	38.73
M 30	5	28	38.25	36.73
M 30	10	28	38.25	35.92
M 30	20	28	38.25	32.96

IV. FIGURES

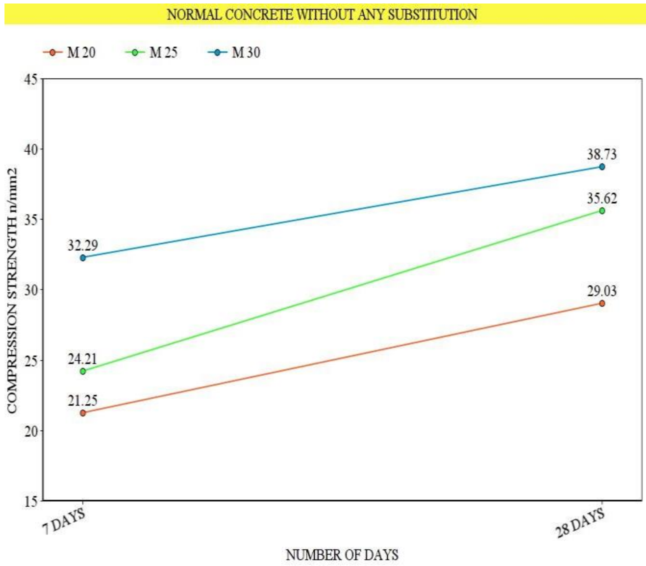

Figure 1 – Different concrete grades without any aggregate replacement and their respective compressive strength at 7 & 28 days.

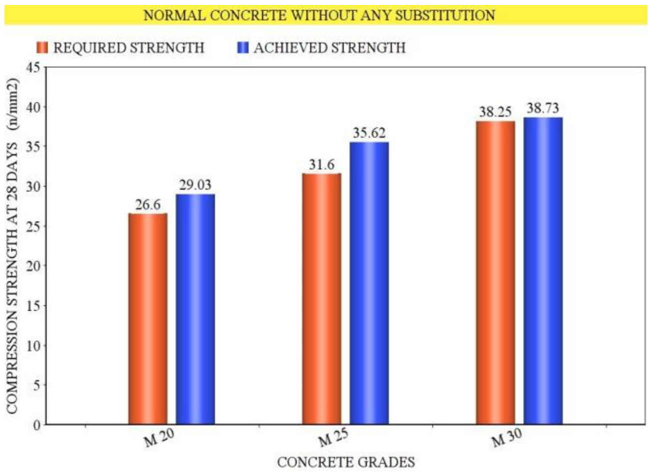

Figure 2 – Different Concrete Grade represents their obtained compressive strength against their required Target Mean Strength.

- All three grades shows higher strength than required target mean strength, hence all concrete grades are accepted.

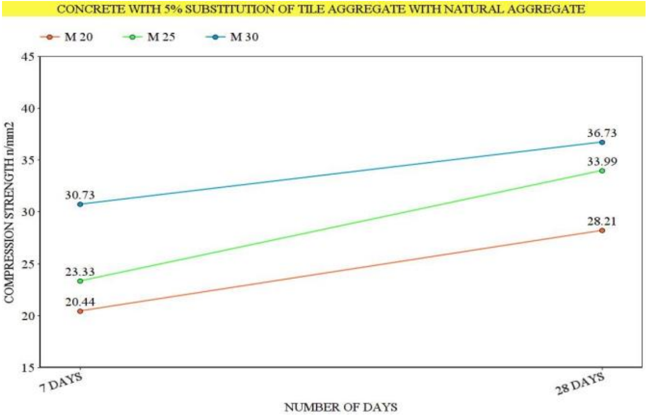

Figure 3 - Different concrete grades with 5% replacement of natural aggregate with tile aggregate and their respective compressive strength at 7 & 28 days.

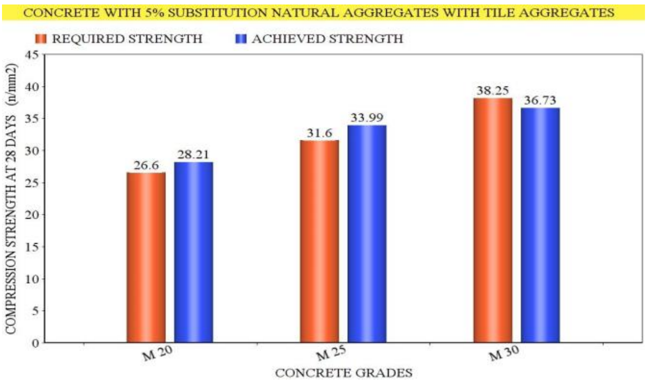

FIGURE 4 – Different Concrete Grade with 5% replacement of natural aggregates with tile aggregates represents their obtained compressive strength against their Required Target Mean Strength

- ➢ In this case also all concrete grades except M-30 show higher strength than required. M-20 and M-25 are accepted.

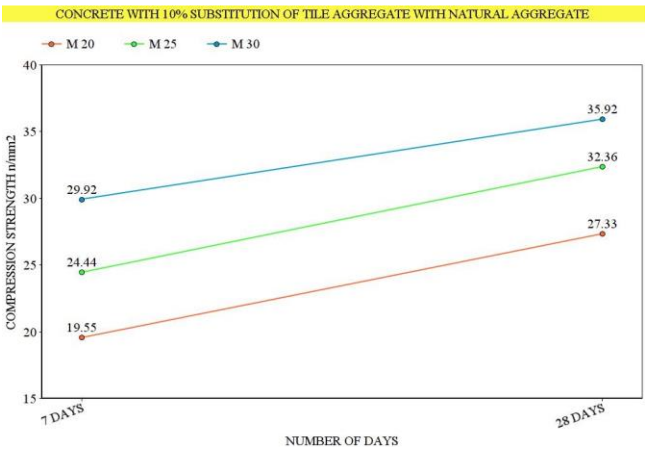

Figure 5 - Different concrete grades with 10% replacement of natural aggregate with tile aggregate and their respective compressive strength at 7 & 28 days.

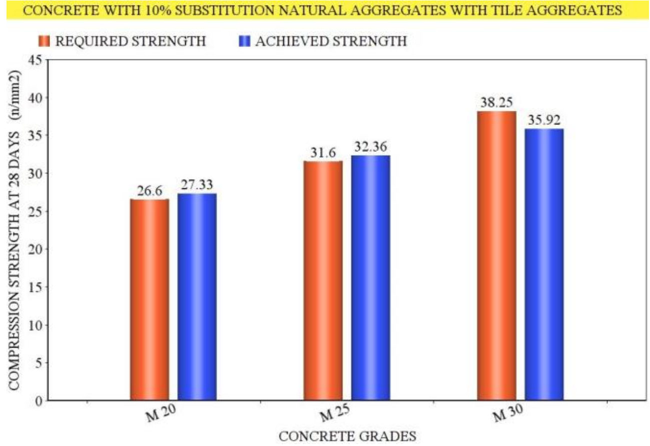

FIGURE 6 - Different Concrete Grade with 10% replacement of natural aggregates with tile aggregates represents their obtained compressive strength against their Required Target Mean Strength

- ➢ Similarly, in this case all grade concrete possess higher strength than required except M-30 and are accepted.

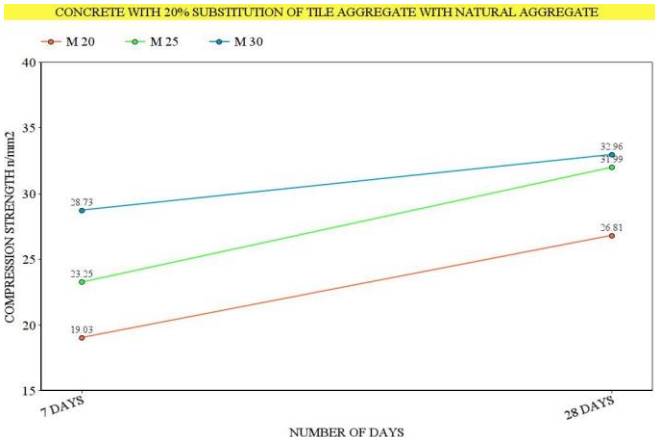

Figure 7 - Different concrete grades with 20% replacement of natural aggregate with tile aggregate and their respective compressive strength at 7 & 28 days.

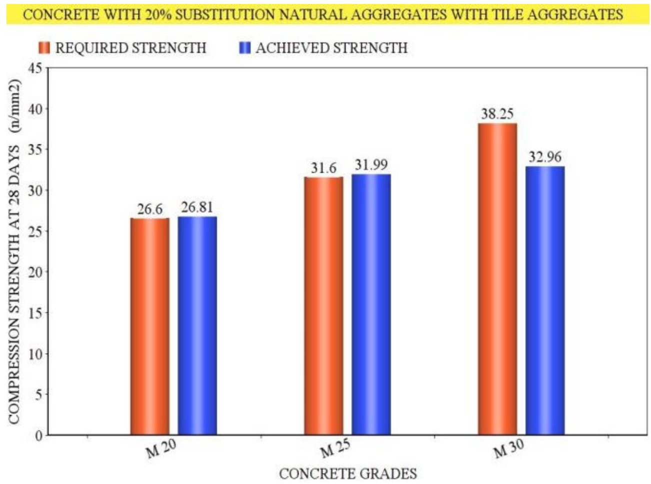

FIGURE 8 – Different Concrete Grade with 20% replacement of natural aggregates with tile aggregates

represents their obtained compressive strength against their Required Target Mean Strength

- Here, M 20 & M 25 show acceptable strength but M 30 has lower strength than required. So, M 30 is rejected.

V. COST ANALYSIS

A. Total cost of 20 mm tile aggregates to prepare 1 m^3 M 20 grade concrete

- Cost of 20 mm natural aggregate for preparation of 1 m^3 M 20 concrete = Rs. 200
- After 20% replacement of 20 mm natural aggregate with tile aggregate cost reduces to = Rs. 162
- Therefore, the saving is = 200-162 = Rs.32 i.e. 16%
- If Labor Cost, Machine operation cost and transportation cost (within 10 km) is included (i.e. Rs. 2.275) for tile aggregate then this saving becomes Rs. 29.725

Hence, net saving by using 20% tile aggregate with substitution of normal 20 mm for preparing 1 m^3 M 20 concrete aggregate is Rs. 29.725 or **14.86%**

B. Tile Crushing Machine

Tile crushing machine comes in various shapes and sizes. It crushes the broken pieces of tiles into aggregate form to be used in concrete

Machine Model Φ400×400 specification –

a) Manufacturer = ALPU
b) Price = Rs. 50000 approx.
c) Rotor speed = 1500 rpm
d) Input opening size = 145 × 450 mm
e) Discharge size = 0 – 30 mm
f) Capacity = 5 – 8 tons/hour
g) Power = 7.5 kw
h) Weight = 0.9 ton
i) Overall dimensions = 844×942×878 mm (L×W×H)

FIGURE 9 Tile Crushing Machine

VI. CONCLUSIONS

Research on the usage of waste construction materials is very important due to the material waste is gradually increasing with the increase in population and increasing of urban development. The reasons that many investigations and analysis had been made on ceramic tile aggregate are because tile aggregates are easy to obtain and their cost is cheaper than the natural aggregates. For natural aggregates mining is needed but tile aggregate can ignore this process.

1. Ceramic tile aggregate is an appreciated and appropriate concrete material for substitution into concrete composition based on its properties.

2. Mechanical properties of ceramic aggregate are similar to the natural aggregate and its behavior is similar but not same. Water absorption, crushing value and impact value, are higher than natural coarse aggregate and lower by specific gravity i.e. 2.24 g/cm^3.

3. It is possible in M 20 grade concrete to substitute 20% of normal 20 mm aggregates with ceramic tile aggregates without compromising its required compressive strength.

4. For all concrete mixes (M 20, M25, M30) compression strength of concrete decreases with increase in the proportion of replacement of natural aggregates with tile aggregates which is due to low specific gravity higher porosity of tile aggregates as compare to natural aggregates.

5. In M 30 grade concrete with 5% substitution of tile aggregates its strength decreases from 38.73 to 36.73 n/mm^2, which is less than target mean strength. So, as per results substitution should be avoided for this grade of concrete. M 20 and M 25 concretes are suitable for the replacement of aggregates.

6. Tile aggregate concrete is little bit more economical as compare to conventional concrete. As an estimate for making 1 m^3 of concrete by substituting 20% normal 20 mm aggregates with tile aggregates about 16% money can be saved on total amount of 20 mm aggregates.

7. By addition of ceramic tile waste into concrete, proper effective utilization of ceramic tile waste can be achieved.

A. SCOPE FOR FURTHER STUDY

1. In this experimental study only compression strength has been checked, effect on tensile strength and flexural strength of concrete with inclusion of tile aggregates can be investigated.

2. Although by decreasing the water/cement ratio, high strength concrete can be obtained. But the workability will be very low. As in this study the required workability is achieved by using maximum water cement ratio. Therefore, it is recommended that adding admixtures such as super plasticizer and silica fume into the mixing so that the workability will be improved.

3. More trials with different particle sizes of tile aggregate and percentage of replacement of natural aggregate are recommended to get different outcomes and higher strength characteristics in concrete.

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