

# Application of Waste Ceramic Tile Aggregates in Concrete

Md Daniyal<sup>1</sup>, Shakeel Ahmad<sup>2</sup>

Research Scholar, Department of Civil Engineering, Aligarh Muslim University, Aligarh, India<sup>1</sup>

Professor, Department of Civil Engineering, Aligarh Muslim University, Aligarh, India<sup>2</sup>

**ABSTRACT:** In recent constructions, the consumption of ceramic materials is increasing day by day in the form of tiles, sanitary fittings, electrical insulators etc. But a large quantity of ceramic materials changes into wastage during processing, transporting and fixing due to its brittle nature. Therefore, using these wastes in concrete production could be an effective measure in maintaining the environment and improving the properties of concrete. Hence, the crushed waste ceramic tiles were used in concrete as a replacement for natural coarse aggregates with 10%, 20%, 30%, 40% and 50% of substitution. After analyzing results, the optimum value of waste ceramic tile to be used within the concrete mix with a water/cement ratio of 0.5 was determined as about 30%. The compressive and flexural strength of optimal concrete was found 5.43% and 32.2% higher than reference concrete respectively. The findings revealed that using waste ceramic tile lead to enhancing the properties of concrete.

**KEYWORDS:** Waste ceramic tile, Aggregate, Concrete, Compressive strength, Flexural strength

## I. INTRODUCTION

Aggregate and Cement, which are the most important constituents used in concrete production, are the essential materials needed for the construction industry. This certainly 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 discarded as a waste. Therefore, one of the most serious problems of the world has been related to remove the wastage and reusing of it. A large quantity of wastage is produced annually in all countries. In particular, Construction and Demolition (C&D) wastes contribute the highest percentage of wastes worldwide about 75%. Furthermore, ceramic materials contribute the highest percentage of wastes within the C&D wastes about 54%. The global production of ceramic tiles during 2011-12 in the world is about 11,166 million square meters. China is the largest ceramic tiles producer (5,200 million square meters) which is 46.6% of world production as well as consumer (4,250 million square meters) which is 38.9% of world consumption. Compared to China, India ranks third; accounting for just 691 million square meters tiles production which is 6.2% of world production and also ranks third in terms of consumption accounting for just 681 million square meters which is 6.2% of world consumption. This huge amount of productions has caused them to be among the most commonly-consumed materials in the world. Usually, the wastage related to tile, ceramic and sanitary ware are created in different forms some of which are produced in companies during and after production process due to errors in either construction, human activities, and also inappropriate raw materials. Some others are produced in transportation and distribution procedures and finally, the most bulk of them are created as a result of destroying constructions. It is predicted that about 30% of daily production of ceramic materials in India change into wastage and this amount reaches to millions ton per year. This waste is not recycled in any form at present. Therefore, they are useless in practiced and cause environmental and disposal problems. However, the ceramic waste is durable, hard and highly resistant to biological, chemical and physical degradation forces. The properties of these materials make them a good and suitable choice to be used in concrete. The use of waste ceramic tiles in concrete effects the properties of fresh and hardened concrete, and makes it economical and also solves some of the disposal problems.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

Some of previously studies have investigated the use of ceramic wastage in concrete as a partial replacement of cement or natural aggregates (fine/coarse). Khaloo (1995), observed that the concrete made with 100% crushed tile as the coarse aggregate had a lower density and higher compressive (+2%), tensile (+70%) and flexural (+29%) strengths. Lopez et al.(2007) concluded that this substitution process would increase slightly the compressive strength. Besides, Torgall and jalali (2010) also concluded that using ceramic wastage as sand and coarse aggregate can slightly enhance compressive strength and also durability of concrete. Medina et al.(2012) also deal with the substitution of ceramic as a coarse aggregate and finally reported a positive effect for the process. Tavakoli D. et al.(2013) estimated that the optimal case of using tile wastage as sand are amounts of 25 % to 50 %, besides, the best case of their use as coarse aggregate are as amounts of 10% to 20%. Information regarding studies on concrete made with ceramic wastes is available in different forms in a scattered manner, and has also not adequately reached the large volume of stakeholders engaged in the construction activities across the length and breadth of our country. Due to this, the effective utilization of ceramic wastes in concrete has not attained the expected level in India even today. Hence, there is a compulsion on the part of civil engineering community, to take appropriate strategies so that the consumption of such potential waste by the construction industries will be on rise day-by-day leading to a green environment which is of course the need of the hour for our nation. This paper deals with the experimental studies made on compressive strength, unit weight and flexural strength of concrete made with ceramic tiles.

## II. MATERIALS AND METHODS

In this experimental study, first the grinded waste ceramic tile and then its grading were done in a way that the tile grading curve of the natural aggregates used in control concrete was completely in compatible with the ceramic tile aggregates as per IS 383-1970. After that, a range of experiments were done on natural aggregates and ceramic tile aggregates as per IS 2386 (Part I-VIII) -1960. Having been ready, in the first stage of the study, the ceramic tiles with percents of 0, 10, 20, 30, 40 and 50 were substituted for natural coarse aggregates with w/c ratio of 0.4, 0.5 and 0.6. After that, a comparison was made between the slump, unit weight and comprehensive strength, of new concrete and the reference samples. After that optimum percent of ceramic tile aggregate and w/c ratio were determined. Finally, flexural strength of optimal concrete and reference concrete were determined.

### 2.1 Material Properties

#### 2.1.1 Cement

Ordinary Portland Cement 43 Grade conforming to IS: 8112-1989 is used. Consistency, Setting time and Compressive strength tests were conducted on cement as per IS: 4031-1988.

Table-1: Properties of Cement

Property	Value
Normal consistency	30%
Initial setting time	42 minute
7 days compressive strength	22.1 MPa
28 days compressive strength	43.4 MPa

#### 2.1.2 Aggregates

The locally available river sand was used as fine aggregate and crushed quartzite aggregate of maximum nominal size of 20mm, was used as coarse aggregate as shown in Figure-1(a). The waste ceramic tiles used throughout this experimental study were gathered from the Welcome Trading Company, Aligarh (manufactured by Kajaria Ceramics Ltd., Mobi-Gujarat) as shown in Figure-1(b). The gradations of natural coarse aggregate and waste ceramic tile aggregates are shown in Figure-2(a) and Figure-2(b) respectively Physical properties of the aggregates are shown in Table-2.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015



Figure-1: (a) Natural coarse aggregates (b) Crushed waste ceramic tile aggregates

## 2.2 Mix proportions

Quantities of the concrete materials used for the all concrete mixtures are shown in the Table-3. Eighteen types of concrete mixes were prepared in order to carry out the research. All the concrete mixes were produced by keeping proportion of 1:1.5:3 (cement: fine aggregate: coarse aggregate), cement content ( $300 \text{ kg/m}^3$ ), and quantity of fine aggregate constant and changing the proportions of coarse aggregate with waste ceramic tile aggregate with the w/c ratios of 0.4, 0.5 and 0.6.

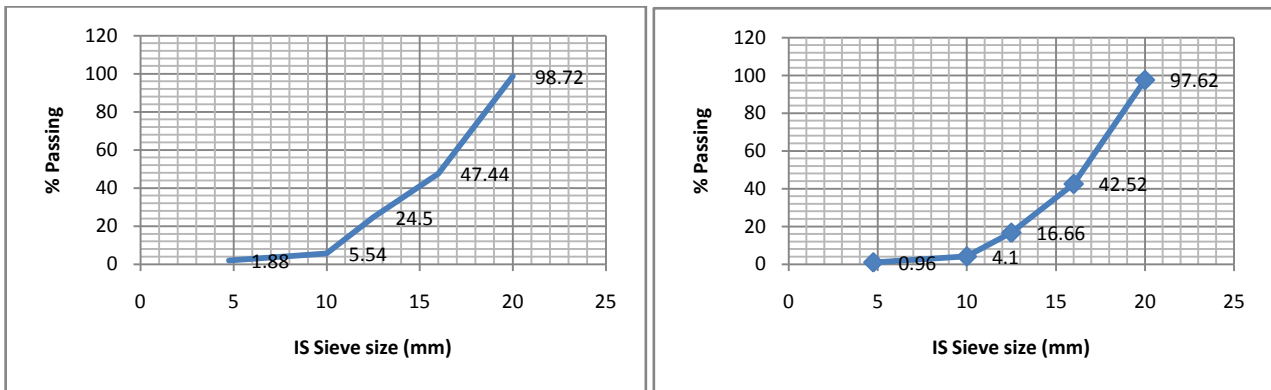


Figure-2: (a) Grain size distribution curve of Natural coarse aggregate (b) Grain size distribution of coarse waste ceramic tile aggregate

Table-2: Properties of Aggregates

Property	Natural fine aggregate	Natural coarse aggregate	Coarse Waste Ceramic tile aggregate
Fineness modulus	2.40	6.96	6.98
Maximum size (mm)	-	20	20
Dry compacted density ( $\text{kg/m}^3$ )	1319	1618	1325
Water absorption (%)	1.60	0.25	4.5
Specific gravity	2.60	2.62	2.35
Crushing value (%)	-	12.86	14.33
Impact value (%)	-	20.2	24.2

## 2.3 Casting and Testing of specimens

The workability of the fresh concrete was measured with a standard slump cone using the slump test. The Total 54 test specimens were cast in steel cubic moulds ( $150 \text{ mm} \times 150 \text{ mm} \times 150 \text{ mm}$ ) and compacted on a vibrating table to determine their compressive strength and unit weight after 28 days of curing. After approximately 24 hours, the

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

specimens were removed from the moulds. The concrete specimens were cured at  $27 \pm 2^\circ \text{C}$  until the test age. Then, extra series of 6 tests were conducted for determining the flexural strength for the optimal concrete mixes. All the tests were conducted as per IS 516 – 1959.

**Table-3: Concrete mixture proportions [1:1.5:3]**

Group	W/C Ratio	Cement (kg/m <sup>3</sup> )	Water (kg/m <sup>3</sup> )	Fine aggregate (kg/m <sup>3</sup> )	Natural Coarse aggregate (kg/m <sup>3</sup> )	Ceramic coarse aggregate (kg/m <sup>3</sup> )
C4-0	0.4	300	120	450	900	0
C4-10		300	120	450	810	90
C4-20		300	120	450	720	180
C4-30		300	120	450	630	270
C4-40		300	120	450	540	360
C4-50		300	120	450	450	450
C5-0	0.5	300	150	450	900	0
C5-10		300	150	450	810	90
C5-20		300	150	450	720	180
C5-30		300	150	450	630	270
C5-40		300	150	450	540	360
C5-50		300	150	450	450	450
C6-0	0.6	300	180	450	900	0
C6-10		300	180	450	810	90
C6-20		300	180	450	720	180
C6-30		300	180	450	630	270
C6-40		300	180	450	540	360
C6-50		300	180	450	450	450

### III. RESULTS AND DISCUSSIONS

#### 3.1 Effect of waste ceramic tile aggregate on concrete workability

The effect of waste ceramic tile aggregates content into the concrete mix on the workability of the fresh concrete mix expressed as the slump value for different water-cement ratios. The data interpretation was done on two different bases, the waste ceramic tile content and the mixing water cement ratio. As it can be seen, the fresh concrete workability is inversely affected by the increase of water cement ratio. Also the slump value decreases as the amount of tile as coarse aggregate increases. This decrease can be because of higher absorption of water by tiles and also being more angular shape of waste ceramic tile aggregates. On the whole, slump is changing in the samples and this change occurs between 10 to zero millimeters for w/c ratio of 0.4, between 45 to 30 millimeters for w/c of 0.5 and between 120 to 85 millimeters for w/c of 0.6 as shown in figure-4(a). The degree of workability is very low for w/c of 0.4, which is considered inappropriate for a concrete operation. The degree of workability is low for w/c of 0.5, but generally it is considered appropriate for a concrete operation. The degree of workability is high for w/c of 0.6, which is considered appropriate for a concrete operation.

#### 3.2 Effect of waste ceramic tile aggregate on concrete density

The density of concrete is a measurement of concrete's solidity. Figure-4(b), illustrates the effect of coarse waste ceramic tile content into the concrete mix on the mass density of the hardened concrete for different water cements ratios. As a general outcome, it can be easily noticed that concrete mass density was inversely affected by the increase of water cement ratio. More specifically, as we increase the substitution amount of ceramic tile aggregate, the unit weight decreases and it is due to the less unit weight of tile. That is, for 50 percent of ceramic tile substitution this decrease has been turned out to be about 3.4 percent for w/c of 0.4, 2.7 percent for w/c of 0.5 and 3.1 percent for w/c ratio of 0.6. Therefore, it can be concluded that the weight of a structure can be decreased up to 3.4 percent, 2.7 percent and 3.1percent for w/c ratio of 0.4, 0.5 and 0.6 respectively. As a whole, it can be asserted that using tile causes a decrease in unit weight and hence it helps the load bearing capacity of structures.

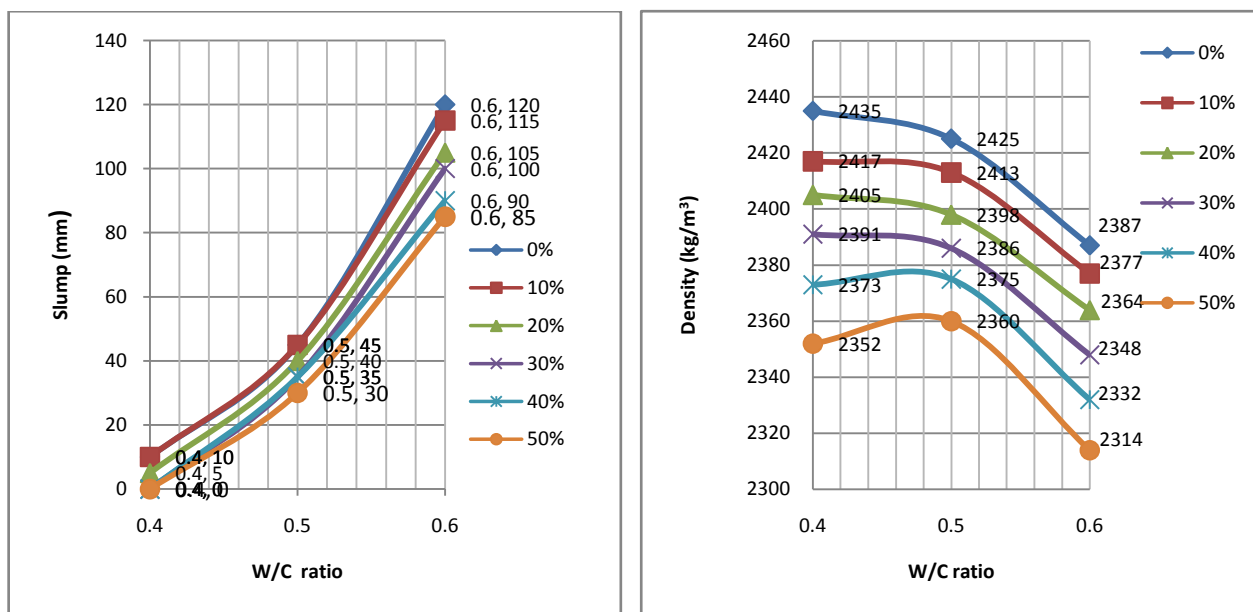


Figure- 4: (a) Slump value versus w/c ratio with different percentage of coarse waste ceramic tile aggregates (b) Concrete density versus W/C ratio with different percentage of coarse waste ceramic tile aggregates

### 3.3 Effect of waste ceramic tile aggregate on compressive strength of concrete

Figure -6(a) shows a typical hardened concrete sample after failure under the compressive loading test, which indicate that the failure mode is similar to normal concrete failure. Figure-6(b) illustrates the effect of coarse waste ceramic tile content into the concrete mix on the 28-days compressive strength of the hardened concrete for different water-cement ratios. It was observed that 28-days compressive strength is improved for w/c ratio of 0.4 up to 20% coarse waste ceramic tile aggregate as compared to reference concrete. Beyond 20% coarse waste ceramic tile aggregate the compressive strength is decreased as compared to reference concrete. Further, the highest reported strength belonged to the sample which included 10 percent tile whose compressive strength has increased about 3.5 percent. Also the 28-days compressive strength is fairly improved at 0.5 w/c ratio with a portion of 30% coarse waste tile aggregate content as compared to reference concrete. After 30% coarse waste ceramic tile aggregate the compressive strength is decreased as compared to reference concrete. Further, the highest reported strength belonged to the sample which included 10 percent tile whose compressive strength has increased about 8.9 percent. However for w/c ratio of 0.6, compressive strength is improved somewhat up to a portion of 40% coarse waste tile aggregate content, but the increment is found to be less and is comparable to reference concrete. The highest reported strength belonged to the sample which included 20 percent tile whose compressive strength has increased about 3.2 percent. It shows that using tile as a coarse aggregate not only cause no reduction in the strength of concrete, but also increase the compressive strength of it up to 20 percent for w/c ratio of 0.4, 30 percent for w/c ratio of 0.5 and 40 percent for w/c ratio of 0.6. Also bear no negative impact on compressive strength. The strength of the samples which include tile has been reported to be very similar to each other. On the contrary, the compressive strength decreased considerably as the amount of tile aggregate increased beyond 20%, 30% and 40% for w/c ratio of 0.4, 0.5, and 0.6 respectively. One reason for decreasing the strength of samples as a result of enhancing the amount of tile may be the increase in the flaky aggregate. The tile aggregates especially in bigger sizes have flaky shapes, as the use of this aggregate increase in concrete the percent of flaky aggregate in it and in turn lead to the decrease of strength. Further, another reason could be due to lack of engagement of aggregates with concrete, as a result of the smooth surface of aggregates.

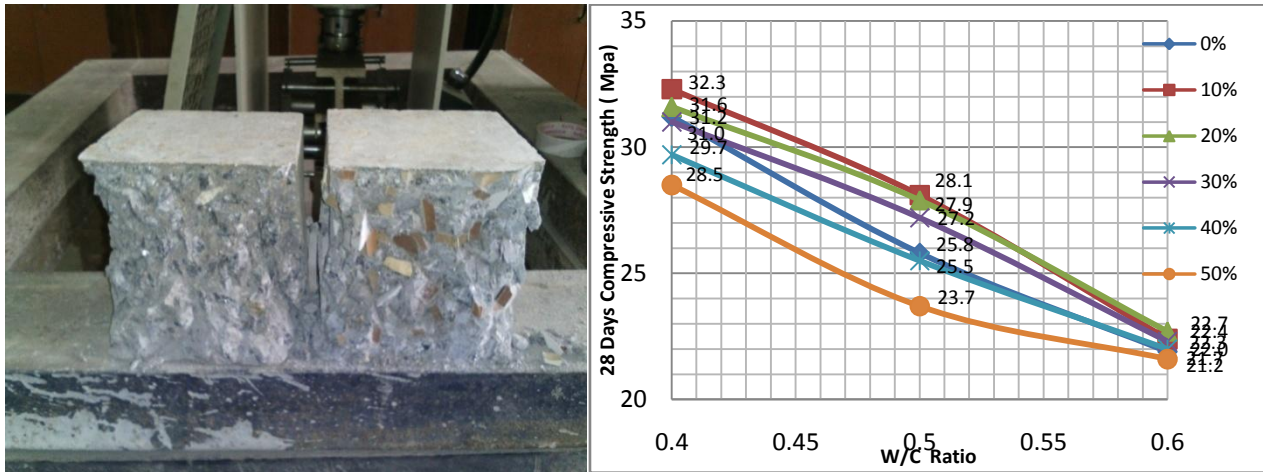


Figure-6: (a) Typical testing reference cube (left) and waste ceramic tile cube (right) after failure for determining concrete compressive strength (b) 28-Days concrete compressive strength versus w/c ratio for different percentage of coarse waste ceramic tile in the mix

### 3.4 Optimal waste ceramic tile contents in concrete mixes

The main goal of this research is to introduce the waste ceramic tiles into the concrete mix for economical and environmental benefits, but with the improvement of the concrete compressive strength, or at least without losing the expected level of standard concrete mixes. The second objective of this research program is to find out the optimal waste ceramic tile contents in concrete mixes. The optimal case is obtained by analyzing the above mentioned output results and the corresponding illustrative figures. The optimal case is one, which will give workable concrete mix and improved compressive strength.

After the analyzing the outputs results, concrete mix with a water/cement ratio of 0.5 with 30% of waste ceramic tile aggregate was chosen to be optimal case. It was because of the fact that the concrete mix with a water/cement ratio of 0.5 has given workable concrete mix and improved compressive strength as compared to reference concrete. The obtained optimum waste ceramic tile proportions were used to implement the second phase of the testing program comprises testing waste ceramic tile concrete mix for flexural strength. The next sections focus only on the mixes with the optimum value of waste ceramic tile to be used to determine flexural strength. The flexural strength of the optimal concrete mixes is to be compared with reference concrete mixes. The optimal concrete mixes were made with coarse waste ceramic tile content of 30% and reference concrete were made with natural coarse aggregate only. The cement content  $300\text{kg/m}^3$  and w/c ratio of 0.5 were chosen to be constant for both the mixes.

### 3.5 Effect of waste ceramic tile aggregate on flexural strength of concrete

The flexural test measures the force required to bend a beam under two point loading conditions. Flexural modulus is used as an indication of a material's stiffness when flexed. This test method follows the IS: 516-1959 procedure where the  $10 \times 10 \times 50$  cm hardened concrete specimen lies on two 40 cm apart supporting spans and the load is applied to the centre by the loading nose at a specified rate till failure, as illustrated in Figure-8(a).

The test was conducted on Reference Concrete (C5-0) and Ceramic Waste Concretes (C5-30) containing optimum percentage of waste ceramic tile aggregate i.e. 30% as shown in Figure-8(b). The final output results are listed in Table-4. From the testing results, it can be noted that the flexural strength of the ceramic waste concrete increased with the increase of quantity of ceramic waste in the concrete as partial replacement of natural coarse aggregate. Taking the strength of reference concrete ( $2067 \text{ kN/m}^2$ ) as base value, it is analyzed that the flexural strength of Optimal Ceramic Waste Concrete 32.2% higher than flexural strength of Reference Concrete. This increase again may be due to the pozzolanic property of ceramic tiles and its water absorption capacity which ultimately reduces the w/c ratio.

## International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

Table -4: Flexural strength test results

Group	28 days Flexural Strength (kN/m <sup>2</sup> )
C5-0	2067
C5-30	2733



Figure -8: (a) Flexural strength testing apparatus with specimen (b) specimen after failure

### IV. CONCLUSIONS

The process of substituting 0 to 50 percent waste ceramic tile as coarse aggregate was studied and then parameters of Slump, compressive strength, unit weight and flexural strength were measured. Finally, the following conclusions can be highlighted from the output of this research and can be summarized as follows:

- 1) The output results revealed that using coarse waste ceramic tile within the concrete mix lead to a considerable reduction in the workability for all the mixtures. Also, it was noticed that the workability of concrete gradually decreased with the increase of quantity of waste ceramic tile content.
- 2) As a general outcome, it was noticed that the concrete mass density was decreased by the increase of water cement ratio. Also, it was noticed that the density of concrete gradually decreased with the increase of quantity of waste ceramic tile content.
- 3) Compressive strength of concrete gradually increased with the increase of quantity of coarse waste ceramic tile aggregate up to certain limits i.e 20% for w/c ratio of 0.4, 30% for w/c ratio of 0.5 and 40% for w/c ratio of 0.6. The greatest compressive strength was observed for C5-10 concrete.
- 4) It was noticed that the flexural strength of Optimal Waste Ceramic Concrete was 32.2% higher than flexural strength of Reference Concrete. Therefore, it can be concluded that the use of coarse waste ceramic tile content in the concrete enhanced the flexural strength considerably.
- 5) Also, it can be seen that using waste ceramic tiles in concrete production causes no remarkable negative effect in the properties of concrete. The optimal case of using waste ceramic tiles as coarse aggregates is found to be 10 to 30 percent. In these measures, not only an increase happens in compressive strength, but also a decrease in unit weight is reported.
- 6) Finally, using waste ceramic tiles in concrete is an effective measure with regard to reducing the costs of concrete and keeping the environment clean along with wastage management and decreasing the use of natural raw materials.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

## REFERENCES

- [1] Khaloo, A. R., "Crushed tile coarse aggregate concrete", Cement and Concrete Aggregate, Vol.17, pp.119-125, 1995.
- [2] Lopez, V., Llamas, B., Juan, A., Moran, J.M. and Guerra, I., "Eco-efficient concretes: Impact of the use of white ceramic powder on the mechanical properties of concrete", Biosystems Engineering, Vol.96, pp.559-564, 2007.
- [3] Torgal, F.P. and Jalali, S., "Reusing ceramic wastes in concrete", Construction and Building Materials, Vol.24, pp.832-838, 2010.
- [4] Medina, C., Sanchez, M.I. and Frias, M., "Reuse of sanitary ceramic wastes as coarse aggregate in eco-efficient concretes", Cement and Concrete Composites, Vol.34, pp.48-54, 2012.
- [5] Tavakolia, D., Heidari, A. and Karimian, M., "Properties of concretes produced with waste ceramic tile aggregate", Asian Journal of Civil Engineering, Vol.14, pp.369-382, 2013.
- [6] Binici, H., "Effect of crushed ceramic and basaltic pumice as fine aggregates on concrete mortars properties", Construction and Building Materials, Vol.21, pp.1191-1197, 2007.
- [7] Correia, J.R., de Brito, J. and Pereira, A.S., "Effects on concrete durability of using recycled ceramic aggregates", Material and Structure, Vol.39(2), pp.169-177, 2006.
- [8] Fatima, E., Jhamb, A., and Kumar, R., "Ceramic dust as construction material in rigid pavement", American Journal of Civil Engineering and Architecture, Vol.1(5), pp.112-116, 2013.
- [9] Higashiyama H., Yamauchi k., Sappakittipakorn, M., Sano, M. and Takahashi, O., "A visual investigation on chloride ingress into ceramic waste aggregate mortars having different water to cement ratios", Construction and Building Materials, Vol.40, pp.1021-1028, 2013.
- [10] Ay, N. and Unal, M., "The use of waste ceramic tile in cement production", Cement and Concrete Research, Vol.30, pp.497-499, 2000.
- [11] Lavat, A.E., Trezza, M.A. and Poggi, M., "Characterization of ceramic roof tile wastes as pozzolanic admixture", Waste Management, Vol.29, pp.1666-1674, 2009.
- [12] Senthamarai, RM. and Manoharan, P.D., "Concrete with ceramic waste aggregate", Cement and Concrete Composites, Vol.27, pp.910-913, 2005.
- [13] Torkittikul, P. and Chaipanich, A., "Utilization of ceramic waste as fine aggregate within portland cement and fly ash concretes", cement and concrete composites, Vol.32, pp.440-449, 2010.
- [14] Senthamarai, RM., Manoharan, P.D. and Gobinath, D., "Concrete made from ceramic industry waste: durability properties" construction and building materials, Vol.25, pp.2413-2419, 2011.
- [15] IS: 8112-1989, "Specification for 43grade Ordinary Portland Cement", Bureau of Indian Standards, New Delhi, 1989.
- [16] IS: 383-1970, "Specification for coarse and fine aggregates from natural sources for concrete", Bureau of Indian Standards, New Delhi, 1970.
- [17] IS: 2386 (Part I-VIII) -1963, "Indian standards method of testing for concrete", Bureau of Indian Standards, New Delhi, 1963.
- [18] IS: 10262-2009, "Indian standard concrete mix proportioning", Bureau of Indian Standards, New Delhi, 2009.
- [19] IS: 516-1959, "Method of tests for strength of concrete", Bureau of Indian Standards, New Delhi, 1959.

## BIOGRAPHY



**Prof. Shakeel Ahmad** did B. Tech (Civil) in 1983 from AMU with I(Hons), M.Tech (Civil) in 1986 with I(Gold Medal) from IIT, Roorkee and Ph.D (Str.) in 2001 from IIT, Roorkee. Presently he is working as Professor in the Department of Civil Engineering, AMU, Aligarh. He has published more than 70 papers in reputed journals. He has presented many papers in India and Abroad. Prof. Ahmad has been awarded the **Best Paper Award** from **Indian Society for Wind Engineering**(2004) and **John C Gammon Prize** by **Institution of Engineers** (2011).



**Md Daniyal** is presently working as a Junior Research Fellow and pursuing Ph.D (structural engineering) from Department of Civil Engineering, Aligarh Muslim University (AMU), Aligarh. He did his B.Tech (Civil Engineering) and M.Tech (structural engineering) from AMU, Aligarh in 2012 and 2014 respectively. He has successfully awarded the **GATE-2012** and **CSIR-UGC NET(JRF)-2013** fellowship.