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Research Paper

Experimental Study on High Strength Concrete by Partial Replacement of Fine Aggregate by Ceramic Tile waste

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Abstract

Growth in construction industry is linked to the growth of infrastructure sector and the building industry. Construction industry has been growing @ 8-10% per annum and is likely to maintain the same in year to come. Concrete is widely used as a construction material due to inherent advantages. Booming economic growth led to indiscriminate and unregulated mining of river sand for construction which resulted in erosion of river bank and damage to bio-diversity. The demand for river sand is only expected to grow as the demand for housing and infrastructure is ever increasing. Hence, there is a pertinent need to look for alternate materials to river sand.This study explores use of ceramic tile waste as an optionto the replacement of river Sand in terms of suitability, acceptability, and viability. In this study the ceramic tile waste is being used to replace the conventional sand i.e. fine aggregate (FA). The ceramic fine aggregate (CFA) are used in concrete by replacing FA by 10%, 20%, 24%, 28%, 30% and 40%. In order to compare the results of conventional concrete (CC) with CFA concrete a concrete design mix of M50 is produced with various proportions of CFA material. Due to the good bonding nature of ceramic materials with cement it increases the strength of the concrete with respect to the increase of CFA material. The durability properties of concrete also seems to be performed well because, the CFA materials are consist of good chemical resistance nature. From the study it is found that the percentage of replacement for FA with CFA material is 20%, within which the performance of CFA concrete is better and all the results are attained within the design limit and it help to solve the disposal problem to the environment.

Keywords: *Ceramicfine aggregate; Compressive strength; Splitensile strength;RCPT*

1. Introduction

The ceramic waste and fly ashwill helpto increase the high compressive strength of the concrete when compared to the other materials. [1, 3, 5] .Considering the environmental factors we can recycle the Construction and debris wasteused in the concrete. [2,4].Concrete is an essential construction material which is usually associated with Fine aggregate henceforth fine aggregate acts as an essential element in the construction field. In the present condition the demand of sand is going increased, and it leads to the gradual cost increment of river sand. Thus the M-sand have being implementing in present situation. But, some of the criteria regarding the manufacturing of M-sand are limited in a particular amount. So, still the demand of sand is there, so introducing the new fine aggregate from waste ceramic tiles, by crushing it to get the required size. The 30% of ceramic products are being waste daily, so there is a small cost for this waste or sometimes it has no cost because the ceramic products can't be recycled and reused[6,7].

The utilization of concrete in Indian construction industries isat the rate of about 400 million tons per year and if this continues it may reach a billion tons in less than a decade. Concrete is made of various aggregates present in the earth's crust, in this manner its assets are consistently drained causing ecological strain [4]. Environment is also been affected by various human actions which deliver solid waste in significant amounts i.e, more than 2500 million tons per year, inclusive of all the industrial, medical, agricultural and other forms of waste from the rural and urban areas. Clearance of all these solid wastes causes various issues and complication thereby affecting the ecology.

Presently large amounts of ceramic wastes are generated in ceramic industries which would have an important impact on environment and humans. But now a days the awareness regarding the use of theseceramic waste in construction field has increased. Even this type of usage produce solid waste but the disposal of them is not much complicated compared to the waste and pollution by the source industries. The non-biodegradable ceramic materials used for Floor tiles, wall tiles, and weather course tiles, sanitary ceramic products, electrical ceramic insulators and ceramic utensils etc. can be conveniently recycled into concrete elements for various service and locations[9]. This replacement has numerous advantages such as the economy, using as sustainable material and reduction solid waste disposal and minimize the environmental hazards.

2. Materials

a) *Cement* **:**The cement is a one of the binding material which used widely among these modern days, it can create bond between fine and coarse aggregate in concrete. In thisresearch Ordinary Portland Cement of 53 Grade was used for the entire work and care has been taken to store it based on the reference of standard codes. The cement was tested for physical requirement in accordance withstandards [14] and the values are given in Table 1.

b) *Ceramic Fine aggregate (CFA)* **:** The waste disposed as a waste from the ceramic industry is the broken ceramic pieces not uniform in shape and sizes, most of them are in the crushed and in fine texture only. It is obtained mainly during the processing of polishing, dressing and laying, which is around 25% of total raw material used. The waste ceramic tiles and crushed ceramic waste as fine aggregate is shown in Figure. 1.

c) *Fine aggregate (FA)* **:**The River sand is used in this experiment is clean and it is free from clay, silt and other impurities. Medium and fine sand shall be used for the mortars. Coarse sand shall be sieved through 2.36mm sieve and used to make the concrete.

d) *Coarseaggregate (CA)* **:**Coarse aggregate used in this study is dry and clean.It is free from moisture content, dust, dirt and other foreign matter like clay, graphite etc. The size of the stone varies from 20mm, 12.5mm size and it should retain in a 5mm square mesh and well graded such that voids do not exceed 42%.

e) *Water***:** Potable water is used in mixing of concrete and the suspended solid matter is less than 200mg/l. The quality of water used in mixing and curing of concrete is clean and clear which free from physical and chemical impurities.

Table 1: Properties of Cement

Property	**Value**	**Range as per IS**
Standard consistency	29.5%	27 - 33%
Initial Setting Time	38 Minutes	30 Minutes (min.)
Final Setting Time	430 Minutes	600 Minute (max.)
Specific Gravity	3.15	3.1 – 3.25

3.Design Mix

The design mix for concrete plays a vital role in determining the required quantity of materials to be introduced in the trail mix such that the results of mechanical properties shall fall as per the target strength [15,16].The mix proportions for M50 grade concrete are arrived by trial mix method. In this the fine aggregates are partially replaced with CFA of various percentages (10, 20, 24, 28, 30 and 40%). The details of ratio and the symbols used are given in Table 2.

Fig. 3.a) Broken waste ceramic floor tiles and (b) Crushed Fine Aggregate

Table 2: mix Proportion and Symbols Used

Sym.	**Repl. (%)**	**Mix Proportion**					
		Cement	***Fly Ash***	***CFA***	***FA***	***CA (12.5mm)***	***CA (20mm)***
S0	0	1	0.34	1.86	1.25	1.52	0.33
S10	10	1	0.34	0.17	1.67	1.25	1.52
S20	20	1	0.34	0.34	1.49	1.25	1.52
S24	24	1	0.34	0.41	1.41	1.25	1.52
S28	28	1	0.34	0.48	1.34	1.25	1.52
S30	30	1	0.34	0.51	1.30	1.25	1.52
S40	40	1	0.34	0.68	1.12	1.25	1.52

4. Experimental Investigations

The slump test for concrete is an important test; to measures the workability of fresh concrete and it measures the consistency of the concrete. It is mention the state of fresh concrete and it visibly shows the ease with which the concrete flows.The slump values to measure the workability on various mixes are determined and the values with the inferences are given in Table 4.

4.1Compressive strength of CC and CFA concrete

In this study the compressive strength of concrete cubes as per IS code procedure [17] are determined at the age of 7, 14, 28 days curing. The results obtained for the various mixes are shown in Table 5. From the results it is observed that the strength of concrete for all the mix proportions used are increased with increase in curing period, but with the addition of CFA of beyond 24%, the compressive strength of concrete is started to decline.

Table 3: slump Value Of Various Mixes

Symbol	**Value of Slump (mm)**	**Nature of Collapse**
S0	130	True Slump
S10	133	True Slump
S20	147	True Slump
S30	163	Shear
S40	170	Shear

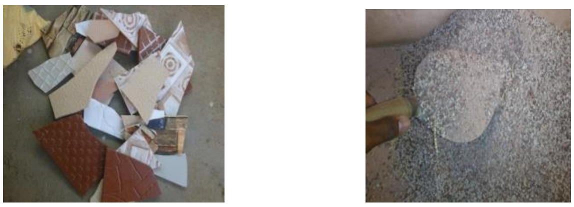
Table 4: Compressive Strength Of Cc And Cfa Concrete

Symbol	**Average Compressive Strength(N/mm^2)**		
	7 Days	***14 Days***	***28 Days***
S0	44.8	52.4	59.2
S10	52.2	57.2	64.9
S20	53.8	56.2	59.9
S24	45.7	51.1	58.6
S28	39.1	45.6	46.4
S30	35.8	39.3	44
S40	31.7	37.4	44

4.2 Split tensile strength of CC and CFA concrete

The split tensile strength of concrete cylinder is determined on the mix proportion used in this study as perIS code procedurefor the curing period of 7, 14, 28 days are shown in Table 6.Similar to compressive strength the split tensile of strength of concrete for all the mix proportions are also increased with increase in curing period, but with the addition of CFA of beyond 20%, here also it is started to decreases.

Table 5 Split Tensilestrength Of Cc And Cfa Concrete



(a) (b)

Sym-bol	**Average Split tensile Strength(N/mm^2)**		
	7 Days	***14 Days***	***28 Days***
S0	3	3.4	4.4
S10	3	3.5	4.6
S20	3.3	3.9	4.81
S24	3.2	3.75	4.50
S28	3.08	3.27	3.85
S30	2.73	2.92	3.61
S40	2.44	2.66	3.32

4.3 Water Permeability Test

Water permeability test are conducted on the plain cement concrete and the concrete prepared with partial replacement of fine aggregate by ceramic fine aggregates are conducted on 28th day cured specimens. The test results are given in Table 6. The increase in percentage of partial replacement of ceramic fine aggregate with fine aggregate shows the increase in value of penetration while compared with the plain cement concrete, but it is less than the prescribed value of 25mm as per DIN-1048.

4.4 Rapid Chloride Permeability Test

The Rapid Chloride Permeability Test (RCPT) is one of the durability test generally conducted on the concrete specimen. In this study the RCPT is conducted on the concrete and concrete with ceramic fine aggregate as per ASTM – C-1202. The test results of concrete and CFA concrete with various replacement proportions for the period of 28 days curing are given in Table 7. As per the code the RCPT value should not be more than 1500 Columbs for M45 and higher grades. RCPT Results of CFA concrete shows the higher value than the PCC, however the values are less than the prescribed value and the permeability characteristics are low.

Table 6: WPT Value of CC and CFA Concrete At 28 - Days Test

Symbol	Pressure (bars) – time(Hrs)	Depth of penetration (mm)	Average depth of penetration (mm)	As per DIN-1048
S0	1bar – 48hr.	02	2.67	< 25 mm
	3bar – 24hr.	04		
	7bar – 24hr.	02		
S10	1bar – 48hr.	02	4.33	
	3bar – 24hr.	05		
	7bar – 24hr.	06		
S20	1bar – 48hr.	03	5.00	
	3bar – 24hr.	06		
	7bar – 24hr.	06		
S30	1bar – 48hr.	06	5.00	
	3bar – 24hr.	04		
	7bar – 24hr.	05		
S40	1bar – 48hr.	03	5.67	
	3bar – 24hr.	08		
	7bar – 24hr.	06		

Table 7 Rcpt Value of Cc and CFA Concrete At 28 - Days

Symbol	Time in minutes	Applied voltage	Average charge passed (columbs)	RCPT Value	Concrete permeability category
S0	0 - 360	60	263.19	100 - 1000	Very low
S10	0 - 360	60	479.54	100 - 1000	Very low
S20	0 - 360	60	485.56	100 - 1000	Very low
S30	0 - 360	60	499.27	100 - 1000	Very low
S40	0 - 360	60	573.26	100 - 1000	Very low

5. Conclusion

From the experimental study on plain cement concrete and the ceramic fine aggregate concrete, the following conclusions are drawn :

- The compressive strength of concrete with the addition of CFA increases with the increase in percentage up to 24% and it gives 58.9 N/mm2 beyond which strength started to decrease with further addition of CFA.
- The split tensile strength of concrete has increased upto 20% replacement of FA with CFA material. Further addition of CFA in concrete shows the reduction in split tensile strength value. Hence the replacement of 20% of CFA can be used to achieve strength both in tensile and compression.
- The durability tests on concrete like water permeability and rapid chloride penetration results shows the increase in value on CFA concrete while compared PCC, but these experimental results shows all the values are within the prescribed limits as per DIN 1048 and ASTM –C-1202.
- From the study it is observed that, in civil construction works the replacement of 20% ceramic waste as fine aggregate in M50 grade concrete can be adopted and it help to solve the disposal problem and reduce the dwelling of natural sand save the environment.

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