Recent Trends in Civil Engineering & Technology
ISSN: 2249-8753(online), ISSN: 2321-6476(print)
Volume 6, Issue 1
www.stmjournals.com

Feasibility Studies on Cement Mortar Replaced with Ceramic Tile Waste as Secondary Binder

Anand Kumar B.G., Ravindra R., Samanth A.
Department of Civil Engineering, RV College of Engineering, Bengaluru, Karnataka, India

Abstract
This paper presents the results of experimental works focused on replacement of ceramic waste materials with cement in the production of cement mortar. The aim of this research work is to find the optimum percentage replacement of cement by ceramic tile waste in percentage replacement (5 to 25, 50 and 100%) mortar mixes. The ceramic waste tiles are mechanically crushed down ultrafine ceramic waste (UCW) powder passing 600 µ and replaced with cement in cement mortars. The results demonstrate that recycled eco-friendly cement ceramic mortar gives higher mechanical properties than conventional cement mortar. The strength and durability parameters shows positive values higher than CM (Cement Mortar) mix at 20% replacement and density lower as the replacement level increase.

Keywords: *Ceramic waste tiles, ultrafine ceramic waste (UCW), compressive strength, density*

****Author for Correspondence*** E-mail: ravindrar@rvce.edu.in

INTRODUCTION
Nowadays construction industries are emerging enormously which in turn affecting on the depletion of natural resources. The major reason for increase in Construction and Demolition (C&D) waste is from rehabilitation and demolition of buildings. The growth in industry and economy around the world leads to considerable increase in generation of waste. The estimation shows that the construction enterprise in India generates about 10–12 million tons of waste annually. The shortage of aggregate to the extent of about 55,000 million cu.m in India. From the report of Central Pollution

Central Pollution Control Board (CPCB), New Delhi, every year 48 million tons of solid waste is produced in India. Out of 48 million tons waste, 14.5 million ton waste is generated from the construction waste sector [1]. Due to the difficulty in the availability of natural fine aggregate, led for the search of alternative aggregate for cement composite manufacturers. Many studies were done on replacement of ceramic tile waste with natural fine aggregate in mortar from construction and demolition waste [2]. The analysis shows the pozzolanic activity of ceramic powder from roof tile and electrical insulators [3]. The effective usage of manually crushed ceramic waste as an ultrafine material is the major concern in present study. The ultrafine ceramic material is replaced in place of cement as a partial replacement in cement mortar. The research work results reports about the optimum replacement levels of ceramic tile waste. It is mainly concerned with reuse of ceramic tile waste in cement mortar, in turn maintaining the acceptable performance quality of the final product and to attain sustainability [4].

EXPERIMENTAL WORK
Materials
In this study ceramic tile waste was collected from the various vendors and is crushed to a size passes 600 µ IS sieve. Tests conducted on both natural fine aggregate and crushed ceramic tiles, which include tests like specific gravity, moisture content, water absorption, sieve analysis, fineness modulus, wet sieve analysis, bulking and bulk density, conducting all the basic test conforming to IS: 383-1970 on aggregate. Cement used will be OPC of 43 Grade. Test on cement are specific gravity, fineness modulus, consistency and initial and final setting time. To overcome the various problems faced due to workability, flow test was conducted to determine the water/cement ratio for each mix and proportion separately for a flow of 100%. Table 1 and Figure 1

represent the data of C&D waste including ceramic tiles around Bangalore.

Table 1: *Shows the Data for the Various Materials Dumped on the Dump Sites around Bangalore.*

Sl No	Material	In %
1	Soil	40
2	Concrete	25
3	Brick	20
4	Ceramic/Mangalore tiles waste	6
5	Other	9

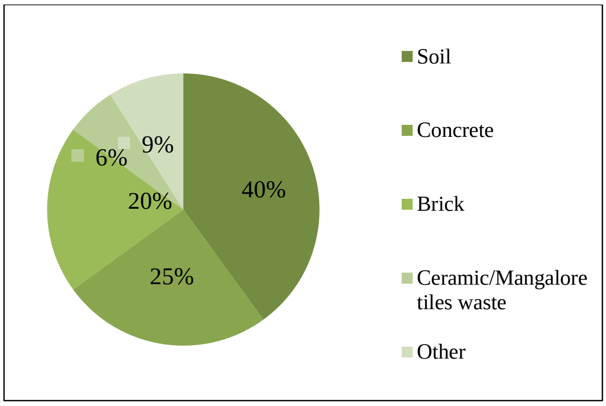

Fig. 1: *Shows Graphical Representation of Various Materials Dumped on the Dump Sites around Bangalore.*

Table 2: *Particle Size Analysis of Samples.*

Sieve (mm)	CFA	NFA
4.75	96	96.7
2.36	89.8	90.7
1.18	79.7	79.8
0.06	47.5	49.7
0.03	8	8.6
0.015	2.9	3.2

Preparation of Test Specimens and Method

The ceramic tile wastes are crushed mechanically and later manually and sieved passing 600 µ and incorporated with cement in mortar in incremental percentage initial 0, 5 to 25, 50 and up to 100%. Particle size distribution of samples is mentioned in Table 2 and shown in Figure 2. The mortars of 50×50×50 mm are casted and subjected to compression after 7, 28 and 45 days of curing. CF durability is tested under repetitive cycles of alternate wetting and drying is studied (Figure 3).

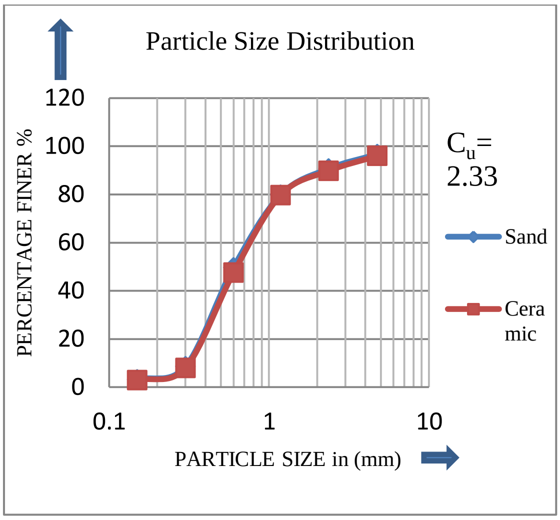

Fig. 2: *Particle Size distribution of CFA and NFA.*

Fig. 3: *Test Specimen.*

Table 3: *Physical Properties of NFA and MFA under IS: 383-1970.*

Tests	NFA	CF	Standard Values
Specific Gravity	2.6	2.44	Not less than 2.55
Moisture Content in %	20	26	----
Fineness	2.69	--	----
Gradation	Zone II	Zone II	Zone I – Zone IV

RESULTS AND DISCUSSION

Compressive Strength

The mortars cubes casted and cured were tested for compressive strength under compression testing machine which applies load at a rate of 4 kN per minute. Proving ring capacity of 100 kN with accuracy of 1 kN was used because of the small size of cube. The cubes were tested for compressive strength at 7, 28 and 45 days to find the increase in the strength.

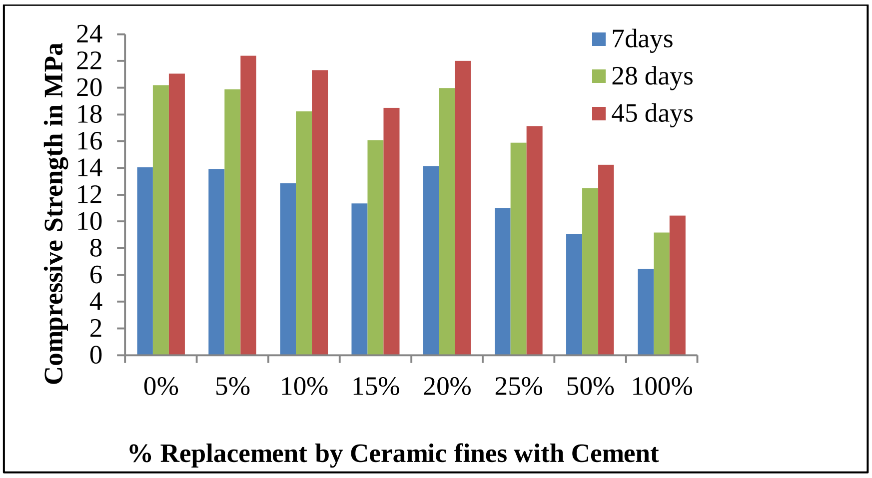

Fig. 4: *Graph showing Compressive Strength of Mortar at 7, 28 and 45 Days for 1:3 Mix Proportion.*

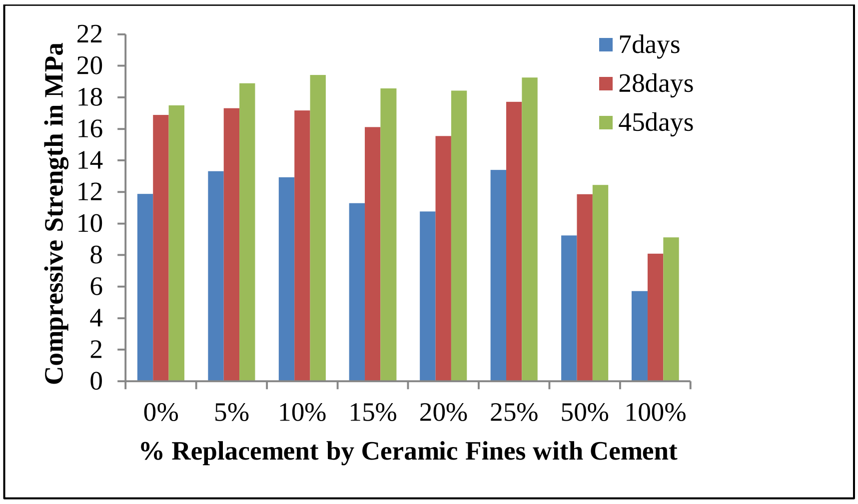

Fig. 5: *Graph showing Compressive Strength of Mortar at 7, 28 and 45 Days for 1:4 Mix Proportion.*

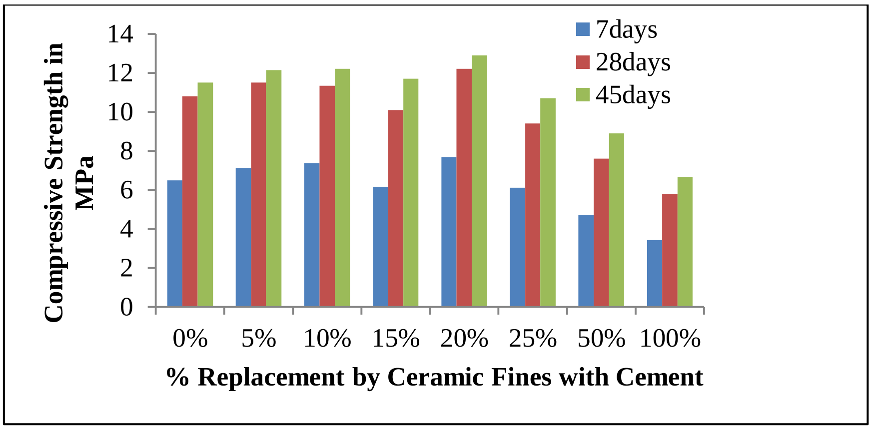

Fig. 6: *Graph showing Compressive Strength of Mortar at 7, 28 and 45 Days for 1:5 Mix Proportion.*

From the Figure 4 and 6, graph showing compressive strength at 7, 28 and 45 days plotted for the mix proportion 1:3 and 1:5, it was found that there was increase in the strength in all replacement level as the specimen age was increased. It is also observed that at a replacement level of 20% the compressive strength was maximum for 45 days strength when compared to normal mix as shown in Tables 4 and 5. The optimum replacement is about 20% replaced with cement by UCW is obtained.

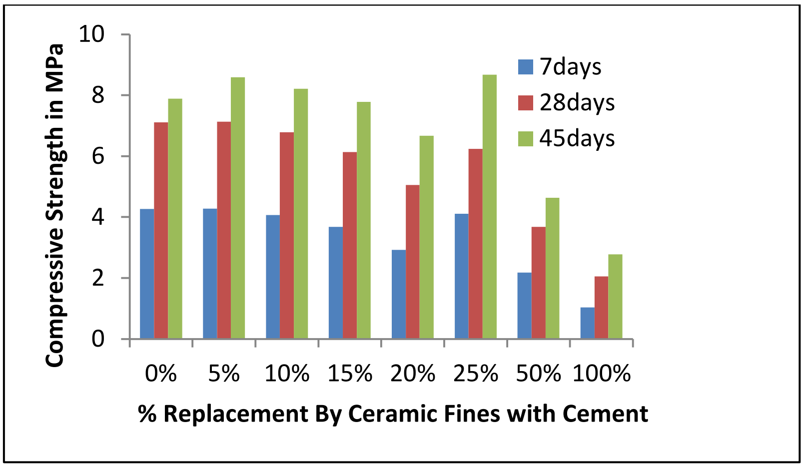

Fig. 7: *Graph showing Compressive Strength of Mortar at 7, 28 and 45 Days for 1:6 Mix Proportion.*

Table 4: *Shows Compressive Strength in MPa with UCW Replacement in %.*

Cement		Cement mortar mix proportions				
By UCW in %		1:3			1:4	
	7 days	28 days	45 days	7 days	28 days	45 days
0	14.1	20.2	21	11.9	16.89	17.5
5	13.9	19.9	22.4	13.3	17.32	18.9
10	12.9	18.2	21.3	12.9	17.17	19.4
15	11.4	16.1	18.5	11.3	16.11	18.6
20	14.2	20	22	10.8	15.54	18.4
25	11	15.9	17.1	13.4	17.71	19.3
50	9.08	12.5	14.2	9.25	11.86	12.5
100	6.45	9.16	10.5	5.72	8.08	9.12

Table 5: *Shows Compressive Strength in MPa with UCW Replacement in %.*

Cement		Cement Mortar mix Proportions				
by UCW in %		1:5			1:6	
	7 days	**28 days**	**45 days**	**7 days**	**28 days**	**45 days**
0	6.48	11	12	4.27	7.11	7.89
5	7.13	12	12	4.28	7.13	8.59
10	7.37	11	12	4.07	6.78	8.21
15	6.16	10	12	3.68	6.13	7.78
20	7.68	12	13	2.92	5.05	6.67
25	6.11	9.4	11	4.11	6.24	8.67
50	4.71	7.6	8.9	2.18	3.68	4.63
100	3.42	5.8	6.7	1.04	2.05	2.78

From the Figures 5 and 7. Graph showing compressive strength at 7, 28 and 45 days plotted for the mix proportion 1:4 and 1:6, it was found that there was increase in the strength in all replacement level as the specimen age was increased. It is also observed that at a replacement level of 25% the compressive strength was maximum for 45 days strength when compared to normal mix as shown in Tables 4 and 5. The optimum replacement is about 25% replaced with cement by UCW is obtained.

Water Absorption

UCW replaced with cement in mortar are studied under repetitive cycles of alternate wetting and drying. This test is done to find the amount of water absorbed and loss of weight in cubes. After 28 days of curing, the alternative wet density and dry density are noted with four cycles. From the Table 6 and Figure 8, it shows that the ceramic tile waste has high water absorption when compared to NFA, which may be due to fact that ceramic tiles are porous. This reduces the workability of mix and more water is required for same mix with ceramic fine when compared to NFA and w/c ratio is increased with increase in replacement level.

Table 6: *Water Absorption Result for 1:3, 1:4, 1:5, 1:6 Mortars after 28 Days of Curing.*

Cement	**Cement mortar proportions**			
by UCW	**Water absorption in %**			
in %	**1:3**	**1:4**	**1:5**	**1:6**
0	2.14	2.07	1.98	1.67
5	2.18	2.11	2.05	1.8
10	2.05	2.19	2.1	1.94
15	2.5	2.34	2.28	2.17
20	2.8	2.65	2.49	2.32
25	3.4	3.2	2.9	2.67
50	4.8	4.55	4.1	3.4
100	7.67	6.37	6.05	5.55

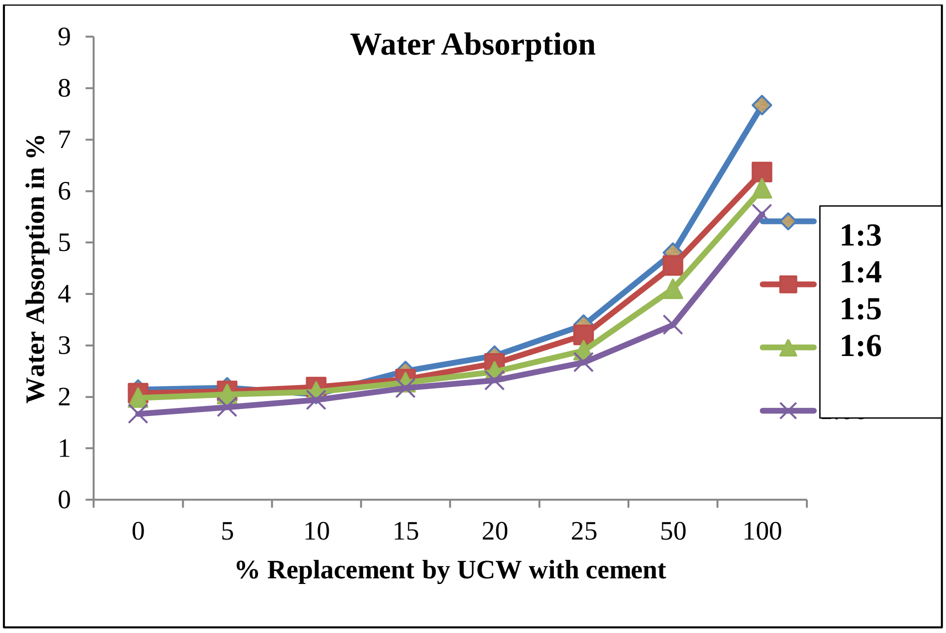

Fig. 8: *Curve Showing Water Absorption for 1:3, 1:4, 1:5 and 1:6 after 28 Days of Curing.*

Density

Density of nominal cement mortar cubes is compared with the mortar cubes replaced by UCW. Wet density and dry density are compared as shown in Tables 7 and 8 for all the mix proportions after 28 days of curing. Figure 9 shows the variation of different proportions with the replacement level.

The dry density of mix proportion is shown in Table 8 and variations are shown in Figure 10. It is observed that there is increase in the wet density as the percentage of ceramic tile fine increases due to its higher water absorption capacity. The dry density of the mortar decreases as the percentage of UCW increases.

Table 7: *Showing Wet Density of All Mix Proportion.*

Cement	Cement mortar			
by UCW	1:3	1:4	1:5	1:6
in %	Wet Density in kN/m^3			
0	23.15	22.65	21.7	21.14
5	23.4	23.04	22.7	22.25
10	23.15	22.56	22.28	22.13
15	22.45	21.43	21.1	20.67
20	21.78	20.89	20.43	19.78
25	21.15	20.45	19.58	19.1
50	19.43	18.7	18.12	17.89
100	16.15	15.65	15.24	14.98

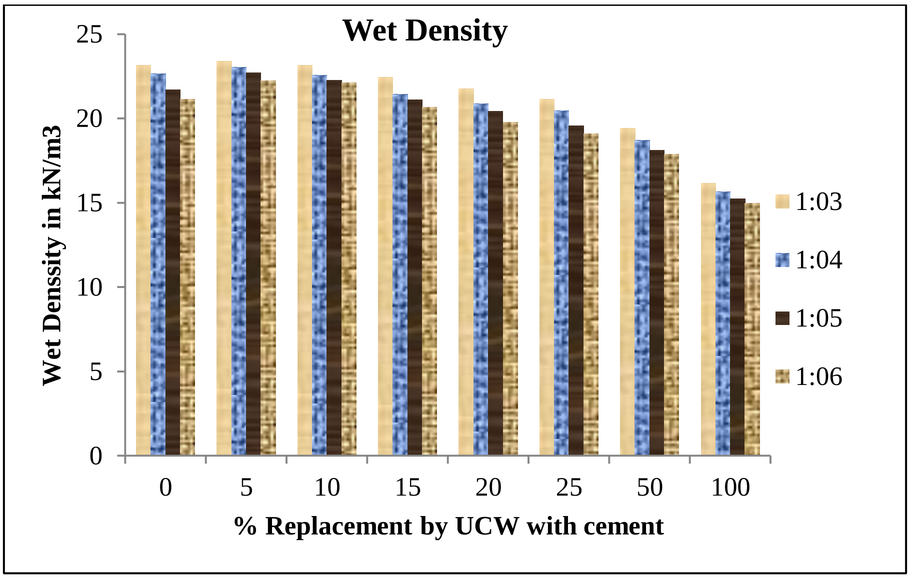

Fig 9: *Graph Showing Wet Density after 28 Days of Curing.*

Table 8: *Showing Dry Density of All Mix Proportion.*

Cement	Cement mortar			
by UCW	1:3	1:4	1:5	1:6
in %	Dry Density in kN/m^3			
0	22.45	22.15	21.87	21.09
5	23.1	22.78	22.43	21.67
10	22.56	21.9	21.62	20.95
15	21.24	20.88	20.45	20.15
20	20.5	19.66	19.1	18.77
25	19.43	18.4	18.13	17.11
50	17.14	16.55	15.57	15.3
100	15.09	14.78	14.1	13.8

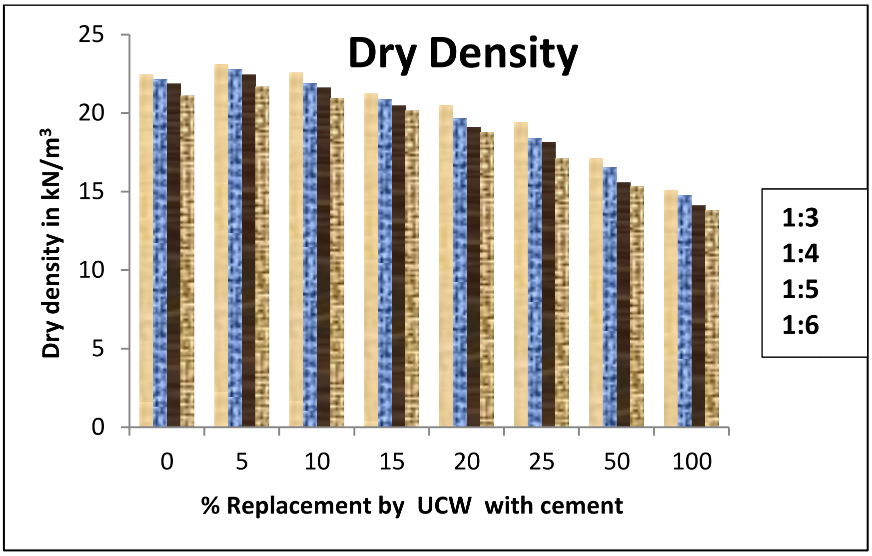

Fig 10: *Graph Showing Dry Density after 28 Days of Curing.*

Specific Gravity

Table 3 shows that the specific gravity of CF is lower when compared to NFA. Due to the low in specific gravity, the dry density of mortar replaced with ceramic fines decreases with increase in percentage of ceramic fines in mortar.

CONCLUSION

The following conclusions can be drawn from the study reported in this paper:

1. The compressive strength of cement mortar with partial replacement of ultrafine ceramic tile waste up to 20% with cement shows increment in strength compared to conventional mortar at 45 days.
2. The compressive strength increased to 5 and 12% more than the mean compressive strength of conventional mortar for 20% replacement level in 1:3 and 1:5 mix proportions, respectively. Similarly 5 and 10% more than mean compressive strength for 25% optimum replacement in 1:4 and 1:6 mix proportions, respectively.
3. Specific gravity of ceramic tile fines is less compared to NFA, due to which density of mortar decreases.
4. Ceramic tile fine has higher water absorption.
5. Reduction in dead weight of structure as dry density of mortar is less when compared to conventional mortar.

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Cite this Article
Anand Kumar B.G., Ravindra R., Samanth A. Feasibility Studies on Cement Mortar Replaced with Ceramic Tile Waste as Secondary Binder. *Recent Trends in Civil Engineering & Technology*. 2016; 6(1): 68–75p.