STUDIES ON USAGE POTENTIAL OF BROKEN TILES AS PART REPLACEMENT TO COARSE AGGREGATES IN CONCRETES

Aruna D[1], Rajendra Prabhu[2], Subhash C Yaragal[3], Katta Venkataramana[4]

[1]*PG Student, Department of Civil Engineering, NITK-Surathkal, India*
[2]*Research Scholar, Department of Civil Engineering, NITK-Surathkal, India,*
[3]*Professor, Dept of Civil Engg, NITK-Surathkal, India*
[4]*Professor, Dept of Civil Engg, NITK-Surathkal, India*

Abstract

Concrete has several appealing characteristics that have made it as a widely used construction material. It is the material of choice where strength, performance, durability etc., are required and concrete is undoubtedly most versatile construction material. The present study aims at utilization and to ascertain the suitability of tile aggregate as partial replacement to coarse aggregate in normal pervious and blended concretes. The utility of partial replacement of tile waste as aggregates along with partially replacing OPC by fly ash is also addressed in the current work. The strength performance of these concretes (Tiled waste based, tiled waste based pervious, and tile & fly ash based blended concretes) with conventional concretes is studied and important findings are reported.

Keywords: *Clay tile aggregates, fly ash, replacement material, pervious concrete*

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1. INTRODUCTION

The use of more and more concrete in construction not only results in scarcity of materials but also turns out to be expensive. In order to cope up with the depletion of conventional resources it would be worth to make use of suitable by-products to replace some of the conventional materials. The industrial wastes like fly ash and tile aggregates, which are produced in huge quantities that cause environmental pollution need safe disposal. But these materials possess potential characteristics, which can be tapped for various uses. Thus, by using these wastes instead of conventional materials would be preserving the natural resources, but also solving the problem of disposal of waste, which has become a national problem.

There are quite a number of clay tile manufacturing industries existing in Dakshina Kannada district, located in the coastal belt of Arabian Sea. A brief survey was made regarding the availability of the broken tiles. There are nearly 74 tile factories in the whole Dakshina Kannada district producing about 6000 patented Mangalore roof tiles per factory per day, out of which about 2% results as wastage. Taking the weight of the single tile as about 2 kg it comes to about 18 tonnes of waste produced per day. Disposal of such a huge quantity is a severe problem to the tile manufacturing industries.

Fly ash is available in large quantities in the country as a waste product from a number of thermal power stations and industrial plants. Its disposal and pollution effects are posing serious problems. Almost all the fly ash produced in the country possesses good pozzolanic activity. Fly ash can be used as part replacement to OPC. In addition to saving in the cement and cost, the fly ash cement mortar and concrete possess lower permeability and better workability.

Conventional Portland cement concrete is generally used for pavement construction. The impervious nature of the concrete pavements contributes to the increased water runoff into the drainage system, over-burdening the infrastructure and causing excessive flooding in built-up areas. Pervious concrete has become significantly popular during recent decades, because of its potential contribution in solving environmental issues. Typically, pervious concrete has no fine aggregate and has just enough cementitious paste to coat the coarse aggregate particles while preserving the interconnectivity of the voids. However, usage of fine aggregates to the extent of 10% in pervious concretes is reported in literature. It has been mainly developed for draining water from the ground surface, so that storm water runoff is reduced and the groundwater is recharged.

Pervious concrete has been developed in USA in order to meet US Environmental Protection Agency (EPA) storm water regulation requirements. European countries have developed pervious concrete, not only for water permeability but also for sound absorption. In Japan, pervious concrete has been researched for the usage in not only for road surfaces but also to support vegetation along river banks.

Strength and permeability of pervious concrete are found to be affected by several factors including binder types, aggregate type, aggregate grading, mix combination, compaction and water content. The compressive strength for highly pervious concrete is half or one-third that of conventional concrete.

The present study aims at utilization and to ascertain the suitability of tile aggregate as partial replacement to coarse aggregate in normal and pervious concrete. The utility of partial replacement of tile waste as aggregates along with partially replacing OPC by fly ash is also addressed in the current work. The strength performance of these concretes (Tiled waste based, tiled waste based pervious, and tile & Fly ash based blended concretes) with respective conventional concretes is studied in detail and important findings are reported.

2. MATERIALS AND METHODS

2.1 Materials used and their Properties for Normal Concrete

The materials used are Ordinary Portland Cement of 43 grade, class F fly ash as partial replacement to cement, natural sand dredged from river, and of 20 mm downsize crushed granite stone and waste clay roof tile pieces as partial replacement to coarse aggregates. Admixtures were used to modify the properties of concrete

Mix Proportion

The design of a concrete mix involves, determining the relative quantities of materials such as cement, aggregate and water for the required performance both in fresh and hardened states, with maximum overall economy.

Mix proportion for M30 (as per IS 10262- 2009) is,

W	C	FA	CA
168	400	689.8	1143.9
0.42	1	1.172	2.859

The partial replacement of coarse aggregate by clay roof tiles and partial replacement of cement by fly ash is done by volumetric method.

2.2 Materials for Porous Concretes

Ordinary Portland Cement (OPC), 4.75-10mm crushed stone and clay roof as coarse aggregate and Fine sand at 10% weight of the total aggregate. The water cement ratio was determined by a trial test was 0.41. The cement content was in the range of 150 kg/m^3 to 400 kg/m^3. Coarse aggregates were partially replaced by clay roof tiles at 10%, 20% and 30%.

Mix Proportion of Pervious Concrete

The water/cementitious materials ratio for pervious concrete is normally around 0.30 to 0.45. It is lower than for conventional concrete. The optimum aggregate/cement ratio ranges from 4:1 to 4.5:1 by mass. A high amount of aggregate led to increased permeability and dramatically decreased compressive strength. Mix proportion for various replacement levels are shown in Table 1.

Table 1: Details of pervious concrete mix design

Repla. (%)	Water content (kg/m^3)	Cement content (kg/m^3)	Fine agg. (kg/m^3)	Coarse agg. (kg/m^3)	Tile agg. (kg/m^3)
0	78	190	172	1493	0
10	78	190	172	1343	122
20	78	190	172	1194	244
30	78	190	172	1045	366

2.3 Methodology

For tile waste based concrete, coarse aggregates were replaced by 20mm down size, tile wastes by 0% , 5%, 10%, 15%, 20% and 25%. These mixes were designated as T0 (reference), T5, T10, T15, T20 and T25 respectively for the purpose of analysis. In pervious concrete, tile aggregate waste (10mm-4.75mm) in proportion of 0%, 10%, 20% and 30%, is used to partially replace coarse aggregates. These mixes were designated as P0, P10, P20, and P30 respectively for the purpose of analysis. A nominal 10% fine aggregate is also adopted in design of pervious concrete. In the third part of the study, concrete mixes were designed using tile wastes partially replacing coarse aggregates and also Fly ash partially replacing OPC. The designed mixes were designated as T0F0 (reference), T5F10, T10F20, T15F30, T20F40 and T25F50. In order to achieve the above objectives set forth, the concrete was cast, cured and tested for fresh and hardened state.

2.4 Tests

Workability test on fresh concrete was conducted by slump cone and compressive test was conducted on 150 mm cubes for hardened concrete at the age of 28 days, on a 200 ton capacity compression testing machine.

3. RESULTS AND DISCUSSIONS

3.1 Utility of Broken Tiles as part Replacement to Coarse Aggregate in Concrete

Table 2 and 3 present slump values and densities for various tile based normal concrete mixes. Workability and densities do not show significant variability.

Table 2: Slump result for tile aggregate based concrete

Sl. No.	Mix designation	Slump (mm)
1	T0	55
2	T5	50
3	T10	50
4	T15	50
5	T20	50
6	T25	75

Table 3: Densities of tile based concrete.

Mix	T0	T5	T10	T15	T20	T25
Density (kg/m^3)	2549	2548	2518	2499	2520	2432

The compressive strength results are shown in Fig.1 for tile based concretes. It is observed that the partial replacement of clay roof tiles concrete achieve the target mean strength. The compressive strengths of T5, T10, T15, T20 and T25 reduce by 3%, 7%, 8%, 10% and 13% with respect to T0. It could be seen from the graph that the compressive strength values are as low as 38.9 N/mm^2 and as high as 44.30 N/mm^2.

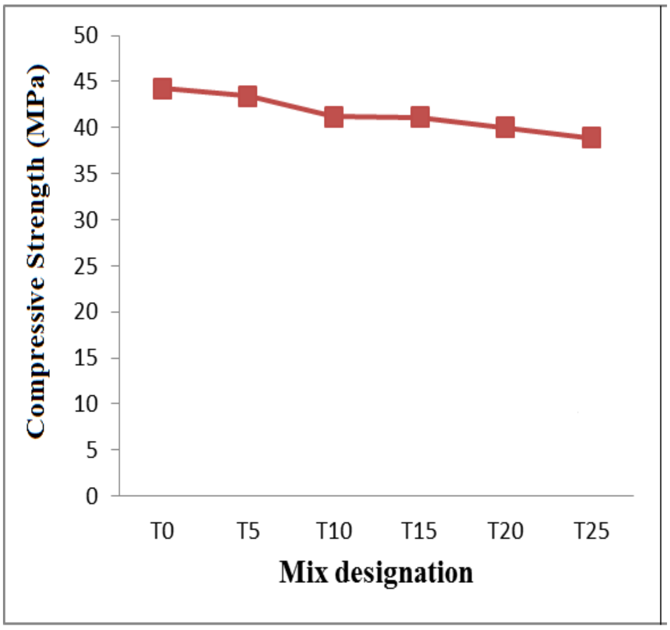

Fig.1: 28th day Compressive strength in normal concrete with broken tiles as aggregates

3.2 Scope for Waste Tiles Utilization in Porous Concretes

The porosity of pervious concretes is shown in Table 4 the porosity of each specimen mean value is reported. Pervious concrete shows considerably higher porosity than conventional concrete. With increase in percentage of partial replacement of tile to coarse aggregate the porosity of the samples gradually increased. The porosity of pervious concrete lies between 15% to 40%. The different types of pore structure are responsible for this phenomenon. However, the porosity in pervious concrete is mainly large size air voids which are bigger than the pores in cement paste. The porosity of pervious concrete is influenced by aggregate grading and compaction. Hence, the porosity of the pervious does not noticeably changed with an increase in the age of concrete. The results showed that clay roof tiles replacement does not show significant change in porosity.

The density obtained is as shown in Table 5. The density decreases with increase in percentage of tiles.

Table 4: Porosity of tile based pervious concrete.

Tiles (%)	Subm-erged wt. (kg)	Dry wt. (kg)	Vol. of solids (litres)	Vol. of voids (litres)	Poros-ity (%)	Avg. porosity (%)
0	3.882	6.360	2.647	1.235	26.6	27.4
	3.713	6.104	2.191	1.522	29.2	
	3.913	6.397	2.689	1.224	26.4	
10	3.708	6.145	2.438	1.270	27.8	27.4
	3.707	6.142	2.391	1.316	27.9	
	3.751	6.230	2.570	1.181	26.5	
20	3.660	6.020	2.509	1.151	30.1	27.7
	3.511	5.990	2.490	1.021	26.5	
	3.500	5.978	2.808	0.692	26.6	
30	3.170	5.650	2.247	0.923	26.5	27.9
	3.403	5.786	2.432	0.971	29.4	
	3.354	5.787	2.433	0.921	27.9	

Table 5: Average densities of tile based pervious concrete.

Tiles (%)	Dry wt. (kg)	Density of the material (kg/m^3)	Avg. density (kg/m^3)
0	6.360	1884.44	1862.8
	6.104	1808.59	
	6.397	1895.41	
10	6.145	1820.74	1828.8
	6.142	1819.85	
	6.23	1845.93	
20	6.02	1783.70	1776.6
	5.99	1774.81	
	5.978	1771.26	
30	5.65	1674.07	1701.0
	5.786	1714.37	
	5.787	1714.67	

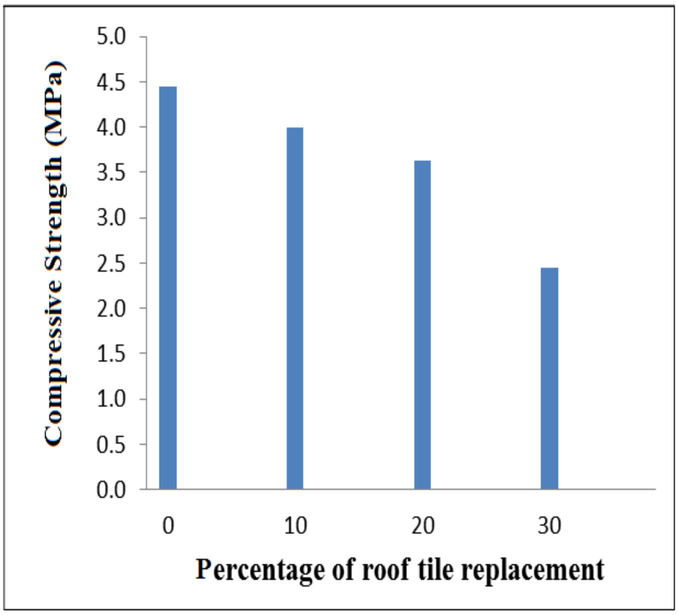

Fig.2: Compressive strength

3.3 Suitability of Broken Tiles in Blended Concrete

The slump, densities and compressive strengths obtained are as shown in Tables 6, 7 and 8 respectively. It could be seen from the tabulated results, that the compressive strength varies from 24.96 N/mm^2 to 44.30 N/mm^2. Partial replacement by fly ash- clay roof tiles concrete, it is observed that up to T20F40, target mean strength is achieved.

Table 6: Slump result for fly ash-tile aggregate based concrete

Sl. No.	Mix designation	Slump (mm)
1	T0F0	50
2	T5F10	75
3	T10F20	75
4	T15F30	75
5	T20F40	75
6	T25F50	75

Table 7: Densities of tile-fly ash based concrete.

Mix	T0F0	T5F10	T10F20	T15F30	T20F40	T25F50
Avg. density (kg/m^3)	2549	2505	2480	2434	2418	2389

Table 8: 28 day Compression test results of fly ash-tile based concrete

Mix designation	Specimen wt. (kg)	Failure load (kN)	Comp. strength (MPa)	Avg. comp. strength (MPa)
T0F0	8.692	920	40.89	44.3
	8.655	1050	46.67	
	8.460	1020	45.33	
T5F10	8.506	740	32.89	34.8
	8.402	800	35.56	
	8.422	810	36	
T10F20	8.390	770	34.22	35.6
	8.340	910	40.44	
	8.377	720	32	
T15F30	8.231	850	37.78	36.0
	8.122	780	34.67	
	8.286	800	35.56	
T20F40	8.149	735	32.67	31.9
	8.155	735	32.67	
	8.170	685	30.44	
T25F50	8.122	590	26.22	25.0
	8.015	545	24.22	
	8.048	550	24.44	

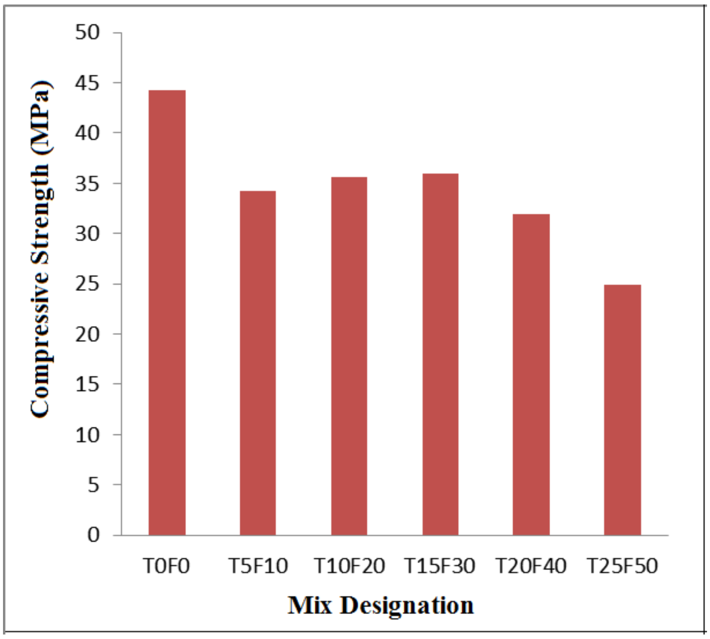

Fig. 3: Compressive strength variation with increase in tile and fly ash replacement

Figure 3 has been drawn to indicate the 28 days average compressive strength. It is observed that in Table 8, the partial replacement by clay roof tiles in concrete satisfies the target mean strength. It is observed that partial replacement by fly ash and clay roof tiles concrete designated by T5F10, T10F20 and T15F30, the compressive strength gradually increased and T20F40 and T25F50 gradually decreased. The conventional concrete strength is higher than that with the inclusion of clay tile aggregate as partial replacement to crushed stone aggregate.

4. CONCLUSION

The test results obtained were analysed and discussed in the previous section. Based upon the detailed analysis following conclusions have been drawn.

1) T25 design mix could be recommended for tile based concrete, as about 10-15% decrease in strength is observed, however waste tiles are used as fillers and there is a substantial benefit in waste handling and management also.
2) Compressive strength of the porous concrete containing partial replacement by clay roof tile to coarse aggregates decreases with increase in percentage of clay roof tile as aggregate. The reduction in strength is of the order of 10%, 17% and 46% corresponding to P10, P20 and P30 mixes. One can recommend using 20% tile wastes in place of stone aggregates in porous concretes.

3) T20F40 concrete mix is recommended for use which is economical in using tile wastes in place of coarse aggregates as well as fly ash in place of OPC.

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BIOGRAPHIES

Aruna D, P.G Student, graduated in Civil Engineering from Malnad College of Engineering, Hassan, Karnataka, in the year 2011.

K. Rajendra Prabhu obtained his B.E (Civil) and M. Tech (Structural Engg.) from MIT, Manipal. He worked in the areas of consultancy, teaching and ready mix concrete industry. Currently he is pursuing his doctoral degree in the area of concrete technology in NITK, Surathkal.

Dr. Subhash C. Yaragal graduated from NITK Surathkal and obtained his post-graduation and doctoral degree from the Indian Institute of Science, Bangalore. He completed his post-doctoral studies in Japan, Tokyo, in the area of Wind Hazard Mitigation”. Currently he is working as Professor in the department of Civil Engineering at NITK, Surathkal, India. His areas of research include Concrete Technology, Pervious Concrete and Performance of Concrete at Elevated Temperature. He has 18 years of Teaching, Research and Industrial consultancy experience.

Prof. Katta Venkataramana graduated from NIE Mysore, did his Master’s degree from Kagoshima University, Japan. He obtained his doctoral degree from University of Kyoto, Japan. He is serving as Professor in the Dept. of Civil Engineering, NITK, Surathkal from 2002. Currently he is also discharging his duties as Head of the Department. His areas of research interests include Earthquake engg. and Earthquake resistant design, concrete technology, etc