Experimental Investigation on Ceramic Tile Wastes as Replacement of Coarse Aggregate In Concrete Using Acrylic Polymer As An Admixture

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Abstract - *This paper presents an experimental investigation to check the suitability of using ceramic tile waste as a substitute for coarse aggregate in the construction of concrete. Concrete mixes with different percentage (0%,10%,20%,30%,40% and 50%) of ceramic tile waste were prepared and also adding 2% acrylic polymer in various mixes with different percentage of ceramic tile waste was studied. Test on fresh and hardened concrete were conducted on each mix. Compare the strength of ordinary concrete with concrete incorporating tile waste as coarse aggregate and tile waste concrete using acrylic polymer. Test on durability were conducted on maximum strength obtained in concrete mix of particular percentage of ceramic waste tile.*

Key Words*: *Ceramic tile waste, acrylic polymer, coarse aggregates, Cement, strength of concrete.

1. INTRODUCTION

Concrete, as a constructive material, has been widely used in construction industry for about two centuries. One of the most critical problems of the world has been related to remove the waste and reusing it. In most countries, large amount of wastage is produced annually. Most of these waste are not reusable or if they are their recycling leads to wasting energy and pollution which is turn increase the risk of these materials for the environment. Moreover, a good strategy to achieve the two purpose of removing the wastage material and also obtaining the positive qualities of concrete (P. K. Mehta 2001). Tile and constructive ceramics are among the most commonly used materials in structures. The global production of ceramic tiles in the world is about 8500 million square meters, this amount is about 400 million square in Iran, which make Iran the fifth ceramic tile producer in the world (D. Tavakoli et.al 2011).

Some of previous studies have investigated the use of ceramic wastage in concrete as sand or coarse aggregate (R. M. Senthamarai et.al 2005). Lopez et.al. observed that this substitution process would increase slightly the compressive strength (M. Gomes and J. De Brito 2009). Besides, (F. Torgal and S. 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 also deal with the substation of ceramic as a coarse aggregate and finally reported a positive effect for the process (C. Medina et.al 2012). In another study, the effect of ceramic electrical insulator as coarse aggregate in concrete was studied. In this study no negative effect was reported (R. M. Senthamarai et.al 2011). Furthermore, the use of these materials in non-structural concretes was performed in a study in which the only problem reported was the high water absorption of the materials (J. De Brito et.al 2005).

Acrylic Polymer is used as an internal admixture for concrete mixes. It can be used as a bonding adhesive that enhances Portland cement based mixes, giving these mixes improved flexural, tensile and bond strength. When acrylic polymer is used as a bonding agent it becomes an integral part of the interface between the cementitious material (J. A. Lavelle 1988) and the surface to be bonded. It will help bonding Portland cement mortar to brick, concrete block, clay tile, marble, ceramic tile, metal and glass block. Effects of the acrylic admixture decreases the required water/cement ratio (P. S. Mangat and D. A. Evans 1980), enhancing the resistance to deterioration in water (M. Sakuta et.al 1985), and improving the mechanical properties (A. Bentur 1982), the dispersant properties and the corrosion resistance. Acrylic has also been used as a coating on concrete to improve concrete durability (M. Ibrahim et.al 1999).

2. MATERIALS USED AND THEIR PROPERTIES

2.1 Cement

Ordinary Portland Cement (OPC) confirming to IS 12269 (43 Grade) was used for the experimental work.

Table 1-Properties Of Cement

Grade	OPC 43
Specific gravity	3.25
Initial setting time	32 min
Fineness	2%

2.2 Fine Aggregate

Locally available good quality river sand was used. Laboratory tests were conducted on fine aggregates to determine the different physical properties. Fine aggregate used conforms to IS 383:1970 specification. (Zone II)

Table 2-Properties of Fine Aggregate

Properties	Values
Specific gravity	2.645
Fineness modulus	3.2
Surface Index	1.123
Water Absorption	1.046%
Moisture Content	0.251%

2.3 Coarse Aggregate

The size of aggregate between 20mm and 4.75mm is considered as coarse aggregate. Laboratory tests were conducted on coarse aggregates to determine the different physical properties as per IS 383 (Part III)-1970.

Table 3-Properties of Coarse Aggregate

Properties	Values
Specific gravity	2.68
Fineness modulus	7.018
Surface Index	0.228
Water Absorption	0.5%
Impact value	16.5

2.4 Ceramic Tile Waste

The tile wastes that are obtained from tile industries is used and the waste were crushed into pieces of 4.75-20mm size.

Table 4-Properties Of Ceramic Tile Waste

Properties	Values
Specific gravity	2.41
Fineness modulus	7.024
Surface Index	0.227
Water Absorption	6.56%
Impact value	23.69

2.5 Acrylic Polymer

In some of the mixes, Acrylic Polymer was used with a dosage of 2% of weight of the cement in order to improve strength of the concrete.

Fig-1: Acrylic Polymer

2.6 Water

Portable water is generally considered as being acceptable. Hence water is available in the college water supply system was used for casting as well as curing of the test specimens.

3. EXPERIMENTAL PROGRAM

3.1 Mix Proportion

The grade of concrete prepared for the experimental study was M30. The mix proportion was 1: 1.065: 2.45 with water cement ratio 0.38. The cement content in concrete was 489.5 kg/m^3. Six mixes were prepared for the test purpose. First mix was prepared by mixing calculated amount of cement, fine aggregate, coarse aggregate and water as per the mix proportion. The other mixes were prepared by replacing coarse aggregate with ceramic tile waste mix in different percentages. To enhance the strength adding 2% acrylic polymer of weight of the cement in various mixes with different percentage of ceramic tile waste by replacement of coarse aggregate. Table 5 shows the quantities of aggregates, cement and water for 1m^3 of concrete.

Table 5-Mix Proportions

Mix Id	%of Ceramic tile waste	Cement (kg/m^3)	Fine aggregate (kg/m^3)	Coarse aggregate (kg/m^3)	Ceramic tile waste (kg/m^3)	Water (kg/m^3)
MIX1	0	489.5	521.72	1198	0	186
MIX2	10	489.5	521.72	1078.2	119.8	186
MIX3	20	489.5	521.72	958.4	239.6	186
MIX4	30	489.5	521.72	838.6	359.4	186
MIX5	40	489.5	521.72	718.8	479.2	186
MIX6	50	489.5	521.72	599	599	186

3.2 Workability

The workability of various mixes were assessed by determining the Slump value as per the IS 1199:1959. Table 6 shows the values of slump value for various mixes of concrete. Table 7 shows the slump value for various concrete mixes by adding 2% acrylic polymer of weight of the cement. The replacement of coarse aggregate with ceramic tile waste does not have much effect on workability of concrete.

Table 6-Slump Value For Various Concrete Mixes

Name of Mix	Slump value
MIX 1 (Normal concrete)	97
MIX 2 (10% ceramic tile waste)	75
MIX 3 (20% ceramic tile waste)	60
MIX 4 (30% ceramic tile waste)	50
MIX 5 (40% ceramic tile waste)	45
MIX 6 (50% ceramic tile waste)	30

Table 7-The Slump Value For Various Concrete Mixes By Adding 2% Acrylic Polymer

Name of Mix	Slump value
MIX 1 (10% ceramic tile waste by adding 2% acrylic polymer)	70
MIX 2 (20% ceramic tile waste by adding 2% acrylic polymer)	50
MIX 3 (30% ceramic tile waste by adding 2% acrylic polymer)	40
MIX 4 (40% ceramic tile waste by adding 2% acrylic polymer)	35
MIX 5 (50% ceramic tile waste by adding 2% acrylic polymer)	25

3.3 Compressive strength of concrete

The cubes of size 150x150x150mm were tested for compression. 7, 14, 28 days the specimens are tested for compression strength as shown in table 8. To improving the compressive strength adding 2% acrylic polymer of weight of the cement by various percentage ceramic tile waste as replacement of coarse aggregate and the results are obtained as in table 9. These results are compared with conventional concrete.

Table 8-Compressive Strength Of Tile Waste Replacement Concrete Without Adding Admixture

Name of Mix	Compressive strength (N/mm^2)		
	7 days	14 days	28 days
MIX 1 (Normal concrete)	21.33	25.92	29.48
MIX 2 (10% ceramic tile waste)	23.5	27.32	33.32
MIX 3 (20% ceramic tile waste)	20	24.15	30.44
MIX 4 (30% ceramic tile waste)	19.19	22.89	27.85
MIX 5 (40% ceramic tile waste)	18	21.56	24.74
MIX 6 (50% ceramic tile waste)	16.15	18.59	21.55

Table 9-Compressive Strength Of Tile Waste Replacement Concrete With Adding 2% Admixture

Name of Mix	Compressive strength (N/mm^2)		
	7 days	14 days	28 days
MIX 1 (10% ceramic tile waste by adding 2% acrylic polymer)	25.04	29.71	35.40
MIX 2 (20% ceramic tile waste by adding 2% acrylic polymer)	27.7	32.52	37.37
MIX 3 (30% ceramic tile waste by adding 2% acrylic polymer)	20.89	24	28.07
MIX 4 (40% ceramic tile waste by adding 2% acrylic polymer)	18.89	23.11	25.7
MIX 5 (50% ceramic tile waste by adding 2% acrylic polymer)	17.7	20.74	22.15

3.4 Flexural strength of concrete

The beams of size 100x100x500mm were tested for Flexural strength. The specimen is tested after a curing period of 28 days for Flexural strength and the results are obtained as in table 10. To improving the flexural strength adding 2% acrylic polymer of weight of the cement by various percentage ceramic tile waste as replacement of coarse aggregate and the results are obtained as in table 11. These results are compared with conventional concrete.

Table 10-Flexural Strength Of Tile Waste Replacement Concrete Without Adding Admixture

Name of Mix	Flexural strength (N/mm^2)
	28 days
MIX 1 (Normal concrete)	6.5
MIX 2 (10% ceramic tile waste)	6.9
MIX 3 (20% ceramic tile waste)	6.1
MIX 4 (30% ceramic tile waste)	4.9
MIX 5 (40% ceramic tile waste)	3.9
MIX 6 (50% ceramic tile waste)	3.1

Table 11-Flexural Strength Of Tile Waste Replacement Concrete Adding 2% Admixture

Name of Mix	Flexural strength (N/mm^2) 28 days
MIX 1 (Normal concrete)	6.5
MIX 2 (10% ceramic tile waste by adding 2% acrylic polymer)	7.1
MIX 3 (20% ceramic tile waste by adding 2% acrylic polymer)	7.5
MIX 4 (30% ceramic tile waste by adding 2% acrylic polymer)	5.4
MIX 5 (40% ceramic tile waste by adding 2% acrylic polymer)	4.5
MIX 6 (50% ceramic tile waste by adding 2% acrylic polymer)	3.9

3.5 Spilt Tensile strength of concrete

The cylinder of size 150mm diameter x 300mm height was tested for split tensile strength. The specimen is tested after a curing period of 28 days for split tensile strength and the results are obtained as in table 12. To improving the split tensile strength adding 2% acrylic polymer by various percentage ceramic tile waste as replacement of coarse aggregate and the results are obtained as in table 13. These results are compared with conventional concrete.

Table 12-Split Tensile Strength Of Tile Waste Replacement Concrete Without Adding Admixture

Name of Mix	Split tensile strength (N/mm^2) 28 days
MIX 1 (Normal concrete)	2.26
MIX 2 (10% ceramic tile waste)	2.41
MIX 3 (20% ceramic tile waste)	2.55
MIX 4 (30% ceramic tile waste)	2.19
MIX 5 (40% ceramic tile waste)	1.98
MIX 6 (50% ceramic tile waste)	1.69

Table 13-Split Tensile Strength Of Tile Waste Replacement Concrete Adding 2% Admixture

Name of Mix	Split tensile strength (N/mm^2) 28 days
MIX 1 (Normal concrete)	2.26
MIX 2 (10% ceramic tile waste by adding 2% acrylic polymer)	2.5
MIX 3 (20% ceramic tile waste by adding 2% acrylic polymer)	2.76
MIX 4 (30% ceramic tile waste by adding 2% acrylic polymer)	2.8
MIX 5 (40% ceramic tile waste by adding 2% acrylic polymer)	2.19
MIX 6 (50% ceramic tile waste by adding 2% acrylic polymer)	1.8

4. RESULTS AND DISCUSSIONS

4.1 Fresh Concrete

The replacement of coarse aggregate with ceramic tile waste does not have much effect on workability of concrete. The workability is very low by adding 2% admixture in concrete using replacement of coarse aggregate with ceramic tile waste.

4.2 Hardened Concrete

4.2.1 Compressive strength of concrete

The test results are presented in chart 2 shows that using tile as coarse aggregate increases the compressive strength of it up to 10% tile waste compared to the normal concrete compressive strength. For 28 days of curing, compressive strength of conventional concrete is 29.48 N/mm^2, 20% replacement of ceramic tile waste is 30.44 N/mm^2. In 28 days, 20% replacement of ceramic tile waste is increased more than the conventional concrete compressive strength. The compressive strength gets decreases at 20%, 30%, 40% and 50% replacement of ceramic tile waste. To improving the compressive strength adding bonding agent 2% acrylic polymer by various percentage ceramic tile waste as replacement of coarse aggregate. The test result are presented in chart 2 shows that adding 2% acrylic polymer increases the compressive strength of it up to 20% compared to the normal concrete. The compressive value gets decreases at 30%, 40% and 50% replacement of tile wastes.

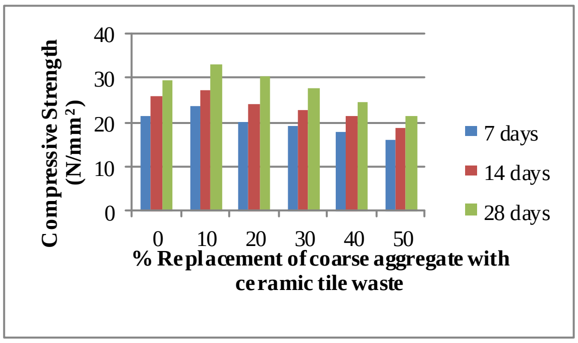

Chart-1: Compressive Strength Of Tile Waste Replacement Concrete Without Adding Admixture

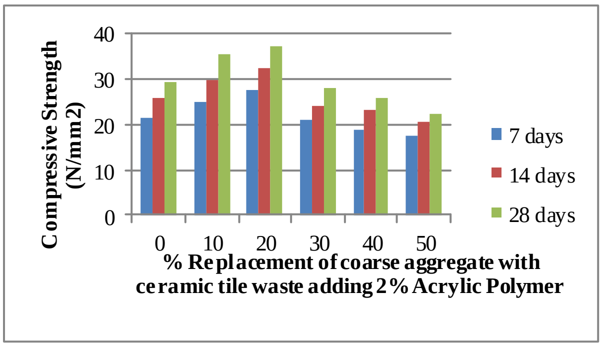

Chart-2: Compressive strength of tile waste replacement concrete with adding 2% admixture

4.2.2 Flexural strength of concrete

The rectangular specimens of ordinary concrete and tile wastes concrete were tested for flexural strength and the results are obtained as in Chart 3. Flexural strength is tested to resistance against failure in bending. From the figure it is clear that up to 10% replacement, flexural strength of concrete increases and then decreases for 20%, 30%, 40% and 50% replacement for 28 days testing.

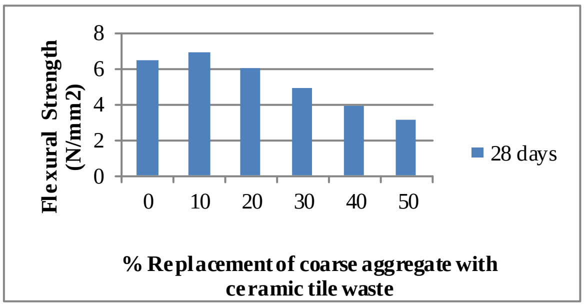

Chart-3: Variation of flexural strength for various mixes

To improving the flexural strength adding bonding agent 2% acrylic polymer of weight of the cement by various percentage ceramic tile waste as replacement of coarse aggregate. The test result are presented in chart 4 shows that adding 2% admixture increases the flexural strength of it up to 20% compared to the normal concrete. The flexural value gets decreases at 30%, 40% and 50% replacement of tile wastes.

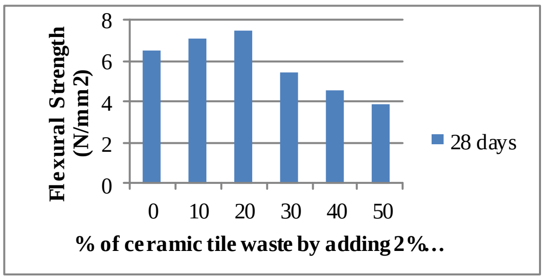

Chart-4: Flexural strength of tile waste replacement concrete with adding 2% admixture

4.2.3 Spilt Tensile strength of concrete

The cylindrical specimens of ordinary concrete, and ceramic waste concrete were tested and the results obtained are shown in chart 5. It is seen that up to 20% replacement with ceramic waste, split tensile strength of concrete specimen increases and from MIX 4 onwards split tensile strength goes on decreasing. However for MIX 3 split tensile strength is greater than that of conventional concrete mix. Maximum split tensile strength is obtained for MIX 3.

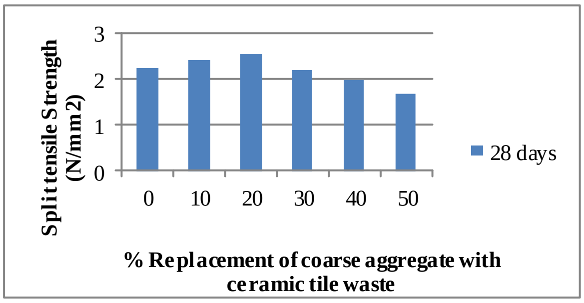

Chart-5: Variation of split tensile strength for various mixes

To improving the split tensile strength adding bonding agent 2% acrylic polymer of weight of the cement by various percentage ceramic tile waste as replacement of coarse aggregate. The test result are presented in chart 6 shows that adding 2% admixture increases the flexural strength of it up to 30% compared to the normal concrete. The flexural value gets decreases at 40% and 50% replacement of tile wastes.

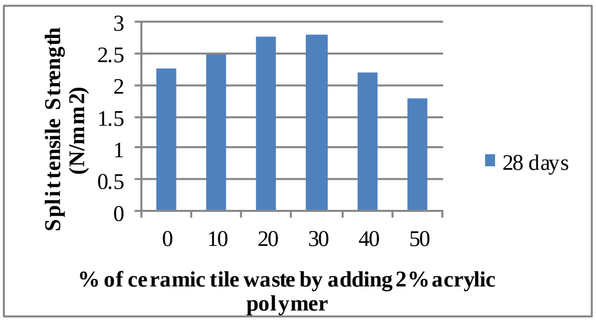

Chart-6: Split tensile strength of tile waste replacement concrete with adding 2% admixture

4.2.4 Comparing the strength of concrete using tile waste with 2% of acrylic polymer

Comparing the hardened strength of concrete using tile waste with 2% of acrylic polymer of weight of the cement shows in chart 7 and chart 8. Hardened strength of tile waste replacement concrete is higher than the concrete without adding acrylic polymer.

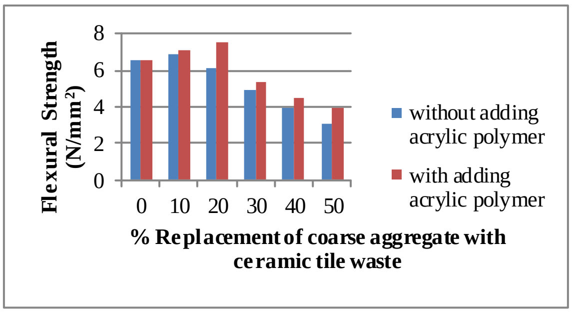

Chart-7: Comparing Flexural strength of tile waste replacement concrete with adding admixture and without adding admixture

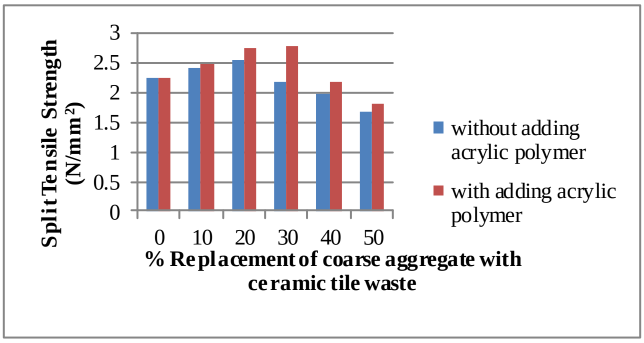

Chart-8: Comparing Split Tensile strength of tile waste replacement concrete with adding admixture and without adding admixture

5. CONCLUSIONS

Waste tiles are the main problem of tile industries. The aim of this investigation was the utilization of tiles collected from industries in concrete as coarse aggregate and the strength characteristics of tile waste as replacement of coarse aggregate in concrete by adding 2% acrylic Polymer of weight of the cement. The bonding agent acrylic polymer is added to improve the bonding between cement and tiles in concrete to get increase in concrete strength. The following are the conclusions obtained

1. Replacement of coarse aggregate with ceramic tile waste has not much effect on the workability of concrete.
2. Compressive strength of concrete mixes up to 10% replacement of ceramic tile waste is greater than conventional concrete mix.
3. For 28 days of curing, compressive strength of 20% replacement of ceramic tile waste is greater than conventional concrete.
4. Adding 2% acrylic polymer of weight of the cement by various percentage ceramic tile wastes as replacement of coarse aggregate increases the compressive strength of it up to 20% compared to the normal concrete.
5. Flexural strength of concrete mixes, up to 10% replacement with tile waste, is greater than conventional concrete mix.
6. Adding 2% acrylic polymer of weight of the cement by various percentage ceramic tile wastes as replacement of coarse aggregate increases the Flexural strength of it up to 20% compared to the normal concrete
7. Split tensile strength of concrete mixes, up to 20% replacement with sanitary ceramic waste, is greater than conventional concrete mix.
8. Adding 2% acrylic polymer of weight of the cement by various percentage ceramic tile wastes as replacement of coarse aggregate increases the split tensile strength of it up to 30% compared to the normal concrete
9. The comparing flexural strength and split tensile strength of tile waste replacement concrete with admixture added concrete is increased than the without adding acrylic polymer to the concrete.

REFERENCES

[1] P. K. Mehta, "Reducing the environment impact of concrete. Concrete can be durable and environmentally friendly," Concrete International, vol. 10, pp. 6-61,2001.

[2] D. Tavakoli, A. Heidari, M. Etemadi, "Using tile as a pozzolan in concrete" The Third National Conference on Concrete, Tehran, Iran, 2011.

[3] C. Meyer, "The greening of the concrete industry", Cement and Concrete Composition, vol.31, pp. 601-5, 2009.

[4] A. R. Khaloo, "Crushed tile coarse aggregate concrete", Cement and Concrete Aggregate, No. 2, vol.17, pp.119-25, 1995.

[5] R. M. Senthamarai, P. Devadas Manhoharan, "Concrete with ceramic waste aggregate", Cement and Concrete Composites, No.(9-10), vol.27, pp. 910-3, 2005.

[6] M. Gomes, J. De Brito, "Structural concrete with incorporation of coarse recycled concrete and ceramic aggregates: durability performance", Materials and Structures, No.5, vol. 42, pp.663-75, 2009.

[7] F. Torgal, S. Jalali, "Compressive strength and durability properties of ceramic wastes based concrete", Construction and Building Materials, vol. 24, pp.832-8, 2010.

[8] C. Medina, M. I. Sánchez de Rojas, M. Frías, "Reuse of sanitary ceramic wastes as coarse aggregate in eco-efficient concretes", Cement and Concrete Composites, vol.34, pp. 48-54, 2012.

[9] R. M. Senthamarai, P. Devadas Manhoharan, D. Gobinath, "Concrete made from ceramic industry waste: Durability properties", Construction and Building Materials, vol. 25, pp. 2413-9, 2011.

[10] J. De Brito, A. S. Pereira, J. R. Correia, "Mechanical behaviour of non-structural concrete made with recycled ceramic aggregates", Cement and Concrete Composites, No. 4, vol. 27, pp.429-33, 2005.

[11] N. Ay, M. Ünal, "The use of waste ground ceramic in cement production", Cement and Concrete Research, No. 3, vol.30, pp.497-9, 2000.

[12] J.A. Lavelle, "Acrylic latex-modified portland cement", ACI Mater. J. vol 85 (1), pp. 41– 48, 1988.

[13] P.S. Mangat, D.A. Evans, "Influence of polymer admixtures on the strength, deformation and fracture of high strength concretes", ASTM Spec. Tech. Publ., pp. 67–87, 1980.

[14] M.Sakuta, Y. Yoshioka, T. Kaya, "Use of acryl-type polymer as admixture for underwater concrete", Publ. SP-Am. Concr. Inst. '89, Polym. Concr.: Uses, Mater., Prop., American Concrete Institute, Detroit, MI, pp. 261–278, 1985.

[15] A. Bentur, "Properties of polymer latex –cement composites", Int. J. Cem. Compos. Lightweight Concr, vol 4 (1), pp. 57– 65, 1982.

[16] M. Ibrahim, A.S. Al-Gahtani, M. Maslehuddin, F.H. Dakhil, "Use of surface treatment materials to improve concrete durability", J. Mater.Civ. Eng, vol.11[-6u(1), pp. 36– 40, (1999).

[17] Dr. T. Sekar, N. Ganesan, Dr. NVN. Nampoothiri "Studies on strength characteristics on utilization of waste materials as coarse aggregate in concrete", International Journal of Engineering Science and Technology (IJEST), Vol. 3 No. 7, 2011.

[18] D. Tavakoli, A. Heidari and M. Karimian, "Properties Of Concretes Produced With Waste Ceramic Tile Aggregate", Asian journal of civil engineering (bhrc) vol. 14, no. 3, pages 369-382, 2013.

[19] G.Murali, R.Saravanakumar, C.Balaji, R.Muthuraman, V.SreeKavitha, S.Archana "Experimental Investigation on Concrete with Different Waste Stone as a Aggregate", International Journal of Engineering Research and Applications (IJERA), Vol. 2, Issue 3, pp. 253-256, May-Jun 2012.

[20] M. Veera Reddy, "Investigations on stone dust and ceramic scrap as aggregate replacement in concrete", International Journal Of Civil And Structural Engineering, Volume 1, No 3, 2010.

[21] B. Topcu & M. Canbaz, "Utilization Of Crushed Tile As Aggregate In Concrete", Iranian Journal of Science & Technology, Transaction B, Engineering, Vol. 31, No. B5, pp 561-565, 2007.

[22] C. Medina, M. Frías, M.I. Sánchez de Rojas, "Microstructure and properties of recycled concretes using ceramic sanitary ware industry waste as coarse aggregate", Construction and Building Materials, vol 31, pp.112–118, 2012.

[23] U. Umapathy, C.Mala, K.Siva, "Assessment of Concrete Strength Using Partial Replacement of Coarse Aggregate for Waste Tiles and Cement for Rice Husk Ash in Concrete", Int. Journal of Engineering Research and Applications, Vol. 4, Issue 5(Version 1), pp.72-76 May 2014.

[24] Jingyao Cao and D.D.L. Chung, "Carbon fiber reinforced cement mortar improved by using acrylic dispersion as an admixture", Cement and Concrete Research, vol 31, pp.1633–1637, 2001.

[25] R. Kamala and B. Krishna Rao, "Reuse of Solid Waste from Building Demolition for the Replacement of Natural Aggregates", International Journal of Engineering and Advanced Technology(IJEAT) ISSN:2249-8958,volume-2,Issue-1, 2012.