MANTECH Publications

Journal of Ceramics and Concrete Technology
Volume 7 Issue 2
ISSN: 2457-0826 (Online)

Experimentation on Partial Replacement of Coarse Aggregates with Ceramic Tile Pieces in Concrete

Syed Afzal Basha[1], Prof. B. Jayarami Reddy[2]

Associate Professor[1], Director[2]

Department of Civil Engineering

G Pullaiah College of Engineering and Technology, Nandikotkur Road Kurnool, A.P. India

Corresponding Author's Email: - *syedafzal74@gmail.com[1]*

Abstract

The utility of recycled ceramic waste as partial replacement for coarse aggregates in concrete has been investigated. Ceramic tile waste pieces left over after fixing the tiles have been used for the investigation. Concrete mixes with a 28 days characteristic strength of 25 MPa were prepared using water / cement ratio of 0.4. The strength development of the concrete mixes containing ceramic tile pieces was compared to that of conventional concrete. The results show that the concrete mixes containing ceramic tile aggregates achieve strength levels between 80 to 95 % compared to conventional concrete. This indicates that the recycled ceramic waste has a potential to be used as coarse aggregates in concrete. The results of experiments indicated an optimum of 10% replacement of ceramic tile pieces as coarse aggregate content in concrete.

Keywords: *Ceramic tile pieces, concrete, compression, split tension*.

INTRODUCTION

Sustainable development of the cement and concrete industry requires the utilization of industrial waste components. At present, for a variety of reasons, the concrete construction industry is not sustainable. Firstly, it consumes huge quantities of virgin materials which cannot remain for next generations. Secondly, the principal binder in concrete is Portland cement, the production of which is a major contributor to greenhouse gas emissions that are implicated in global warming and climate change. Thirdly, many concrete

Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved

structures suffer from lack of durability which may waste the natural resources. The solution is substituting the recycled product. Ceramic waste can be used safely in the production of concrete due to some of its favorable properties. It is durable, hard and highly resistant to biological, chemical and physical degradation. About 30 % of the daily manufacturing volume in the ceramic industry goes to waste. Clay, which is the most abundant material in the making of most ceramics, is naturally not a pozzolanic material. This is because it does not have silicate properties, which can react with water to form calcium hydroxide in the production of concrete. During the making of ceramics, clay is heated at relatively high temperatures, the exact temperature depending on the type of ceramic being produced. For instance, the study at hand focuses on ceramic wall tile wastes, which are reject tiles, which went through the full firing process. The ceramic wall tiles are fired at around 1150ºC. To increase the durability of the concrete made with recycled ceramic tiles admixture can be used, the admixtures increase the workability of the concrete at same water cement ratio, whereas the fiber increase compressive, tensile & flexural strength of the concrete. The required durability characteristics are more difficult to define than the strength characteristics, specification often use a combination of performance & prescriptive requirements, such as workability, compressive strength, split tensile strength, flexural strength and water-cement material ratio to achieve a durable concrete.

LITERATURE REVIEW

Historically Ceramic tiles are one of the oldest forms of decorative art. The Islamic Empires were responsible for the dissemination of the ceramic tile as a wall covering. Use of cheaper material without loss of performance is very crucial to the growth of developing countries. Recycling of aggregates is being practiced from the last few decades. The Indian scenario offers the widest opportunities, but equally the greatest challenge to the engineers for the use of recycled materials in the construction industry.

Research and development work on ceramic concrete started in India in the last few years. If there is a specific code for ceramic concrete it will give positive impact on Indian infrastructure development Ceramic tile waste is durable, hard and highly resistant to Biological, Chemical and Physical degradation forces. Ceramic tile aggregate is hard having considered value of specific gravity, rough surface on one side and smooth on other

Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved

side, are lighter in weight than normal stone aggregates. Ceramic wastes can be separated in two categories in accordance with the source of raw materials. The first one is all fired wastes generated by the structural ceramic factories that use only red pastes to manufacture their products, such as brick, blocks and roof tiles. The second one is all fired waste produced in stone ware ceramic such as wall, floor tiles and sanitary ware. These producers use red and white pastes; nevertheless, the usage of white paste is more frequent and much higher in volume [8].

The ceramics industry is comprised of the following subsectors: wall and floor tiles, sanitary ware, bricks and roof tiles, refractory materials, technical ceramics and ceramic materials for domestic and ornamental use [9]. Ceramic waste can be transformed into useful coarse aggregate. The properties of ceramic waste coarse aggregate are well within the range of the values of concrete making aggregates. The properties of ceramic waste coarse aggregate concrete are not significantly different from those of conventional concrete. The use of ceramic waste coarse aggregate concrete has increased because it has various advantages over other cementations materials [3].

Ceramic tiles are important construction materials used in almost all buildings. The term ceramics is a general term used to refer to ceramic products. Common manufactured ceramics include wall tiles, floor tiles, sanitary ware, household ceramics and technical ceramics.

In essence, ceramic is a term used to describe inorganic materials (with possibly some organic content), made up of non-metallic compounds and made permanent by a firing process (Reference Document by Best Available Techniques (BAT) in the Ceramic Manufacturing Industry, 2007). The global production of ceramic tile in the world is about 8500million square meters [7]. The basic raw material for ceramics tile is clay, which derives from a granite type rock, having decomposed over millions of years. Studies show that large number of ceramic tiles were broken and wasted during production, transportation and construction.

Need For Recycled Aggregate

Urbanization growth rate in India is very high due to industrialization. Growth rate of India is reaching 9% of GDP. Rapid infrastructure development requires a large quantity of construction materials, land requirements & the site. For large

Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved

construction, concrete is preferred as it has longer life, low maintenance cost & better performance.

For achieving GDP rate, smaller structures are demolished & new towers are constructed. Protection of environment is a basic factor which is directly connected with the survival of the human race. Parameters like environmental consciousness, protection of natural resources, sustainable development, play an important role in modern requirements of construction works. Due to modernization, demolished materials are dumped on land & not used for any purpose. Such situations affect the fertility of land.

As per report of Hindu online of March 2007, India generates 23.75 million tons demolition waste annually. As per report of Central Pollution Control Board (CPCB) Delhi, in India, 48million tons solid waste is produced out of which 14.5-million-ton waste is produced from the construction waste sector, out of which only 3% waste is used for embankment. Out of the total construction demolition waste, 40% is of concrete 30% ceramics, 5% plastics, 10% wood, 5%metal, & 10% other mixtures. As reported by global insight, growth in global construction sector predicts an increase in construction spending of 4800 billion US dollars in 2013. These figures indicate a tremendous growth in the construction sector, almost 1.5 times in 5 Years. For production of concrete, 70-75% aggregates are required. Out of this 60-67% is of course aggregate & 33-40% is of fine aggregate.

As per recent research by the Fredonia group, it is forecast that the global demand for construction aggregates may exceed 26 billion tons by 2012. Leading this demand is the maximum user China 25%, Europe 12% & USA 10%, India is also in top 10 users. From environmental point of view, for production of natural aggregates of 1 ton, emissions of 0.0046 million ton of carbon exist whereas for 1ton recycled aggregate produced only 0.0024-million-ton carbon is produced.

OBJECTIVES

The present work is aimed to analyze and give technical specifications on strength characteristics of Recycled Aggregate i.e., Ceramic tiles. The main objective of the experimental investigation is to assess the utility of recycled ceramic tiles in the production of concrete by performing oppressions and split tensile strength tests.

Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved

MATERIALS

Cement: Cement is the one of the binding materials. The cement used in our project is Ordinary Portland cement of 53 Grade. The cement used is fresh and without any lumps. The physical properties of cement are determined as per the code specifications.

Fine Aggregates: The sand used in this investigation is ordinary river sand. The sand passing through 4.75 mm size sieve is used in the preparation of specimens. The sand conforms to grading Zone-II as per IS: 383-1970. The properties of sand such as fineness modulus, water absorption and specific gravity were determined as per IS: 2386-1963.

Coarse Aggregates: The physical properties have been determined as per IS: 2386-1963.The course aggregates used in our project is 20mm size aggregates. The specific gravity of coarse aggregates is 2.9. Ceramic tiles aggregates: The ceramic tiles aggregates used in this project are non-vitreous tiles as it has water absorption capacity of 14.2 percent.

Water: The water used is potable water and it's free from suspended solids and organic materials, which might have affected the properties of the fresh and hardened concrete. The water used for both mixing and curing of concrete should be free from impurities, injurious amounts of acids, alkalis, oils, salts, organic matter or other substances that may be deleterious to concrete or steel. The presence of chlorides and sulphates are injurious to reinforcing bars as they may be corroded. The general required of water for mixing and curing concrete shall be as per IS 456-2000.

MIX PROPORTIONS

Cement (kg/m^3)	493
Fine Aggregate (kg/m^3)	758
Coarse Aggregate (kg/m^3)	1054.61
Water (liters)	197
Water cement ratio	0.4

CUBE COMPRESSION TEST

This test was conducted as per IS 516-1959. The cubes of standard size 150x150x150 mm were used to find the compressive strength of concrete. Specimens were placed on the bearing surface of CTM, of capacity 2000KN without eccentricity and a uniform rate of loading was applied till the failure of the cube. The maximum load was noted and the compressive strength was calculated.

Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved



Fig 1 Testing of cube specimen

Table 1 Calculation of compressive strength with 0% replacement

	7 Days Curing		**21 Days Curing**		**28 Days Curing**	
Percentage of ceramic tile pieces	Failure load KN	Compressive strength MPa	Failure load KN	Compressive strength MPa	Failure load KN	Compressive strength MPa
0%	743	33.02	1075	47.77	1139.5	50.64
0%	763.1	33.91	1168.8	51.94	1229.8	54.65
Average Compressive Strength	33.46		49.8		52.64	

Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved

Table 2 Calculation of compressive strength with 5% replacement

	7 Days Curing		21 Days Curing		28 Days Curing	
Percentage of ceramic tile pieces	Failure load KN	Compressive strength MPa	Failure load KN	Compressive strength MPa	Failure load KN	Compressive strength MPa
5%	793.23	35.25	1096.8	48.75	1200.7	53.36
5%	823.14	36.58	1153.1	51.25	1265.2	56.23
Average Compressive Strength	35.76		50.0		54.79	

Table 3 Calculation of compressive strength with 10% replacement

	7 Days Curing		21 Days Curing		28 Days Curing	
Percentage of ceramic tile pieces	Failure load KN	Compressive strength MPa	Failure load KN	Compressive strength MPa	Failure load KN	Compressive strength MPa
10%	811.01	36.04	1143.2	50.80	1282.6	57.00
10%	936.6	41.62	1217.8	54.12	1285.1	57.11
Average Compressive Strength	38.81		52.46		57.05	

Table 4 Calculation of compressive strength with 20% replacement

	7 Days Curing		21 Days Curing		28 Days Curing	
Percentage of ceramic tile pieces	Failure load KN	Compressive strength MPa	Failure load KN	Compressive strength MPa	Failure load KN	Compressive strength MPa
20%	744.8	33.1	1075.0	47.77	1210.8	53.81
20%	785.9	34.92	1164.9	51.77	1275	56.66
Average Compressive Strength	34.01		49.77		55.2	

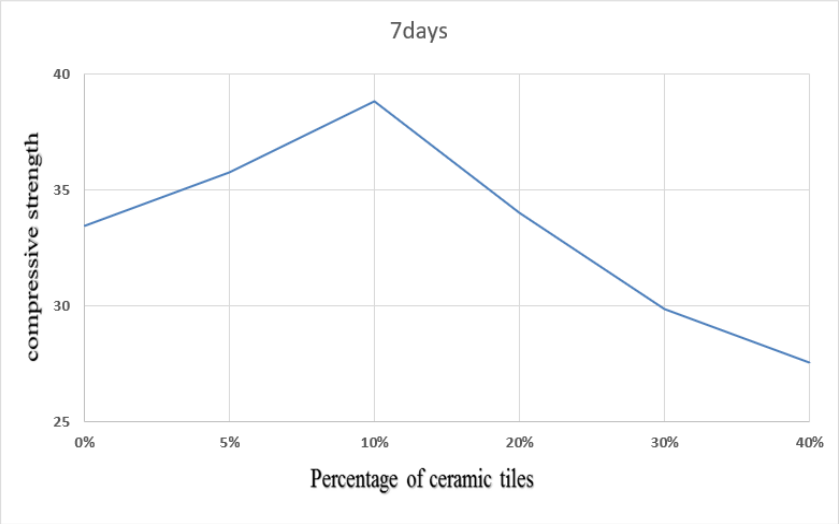
Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved

Table 5 Calculation of compressive strength with 30% replacement

	7 Days Curing		21 Days Curing		28 Days Curing	
Percentage of ceramic tile pieces	Failure load KN	Compressive strength MPa	Failure load KN	Compressive strength MPa	Failure load KN	Compressive strength MPa
30%	643.04	28.57	966.8	42.96	1139.5	50.64
30%	701.8	31.19	1094.4	48.64	1229.8	54.65
Average Compressive Strength	29.88		45.80		52.4	

Table 6 Calculation of compressive strength with 40% replacement

	7 Days Curing		21 Days Curing		28 Days Curing	
Percentage of ceramic tile pieces	Failure load KN	Compressive strength MPa	Failure load KN	Compressive strength MPa	Failure load KN	Compressive strength MPa
40%	612.9	27.24	951.0	42.26	1153.2	51.25
40%	627.9	27.90	959.4	42.64	1178.7	52.3
Average Compressive Strength	27.57		42.45		51.77	



Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved

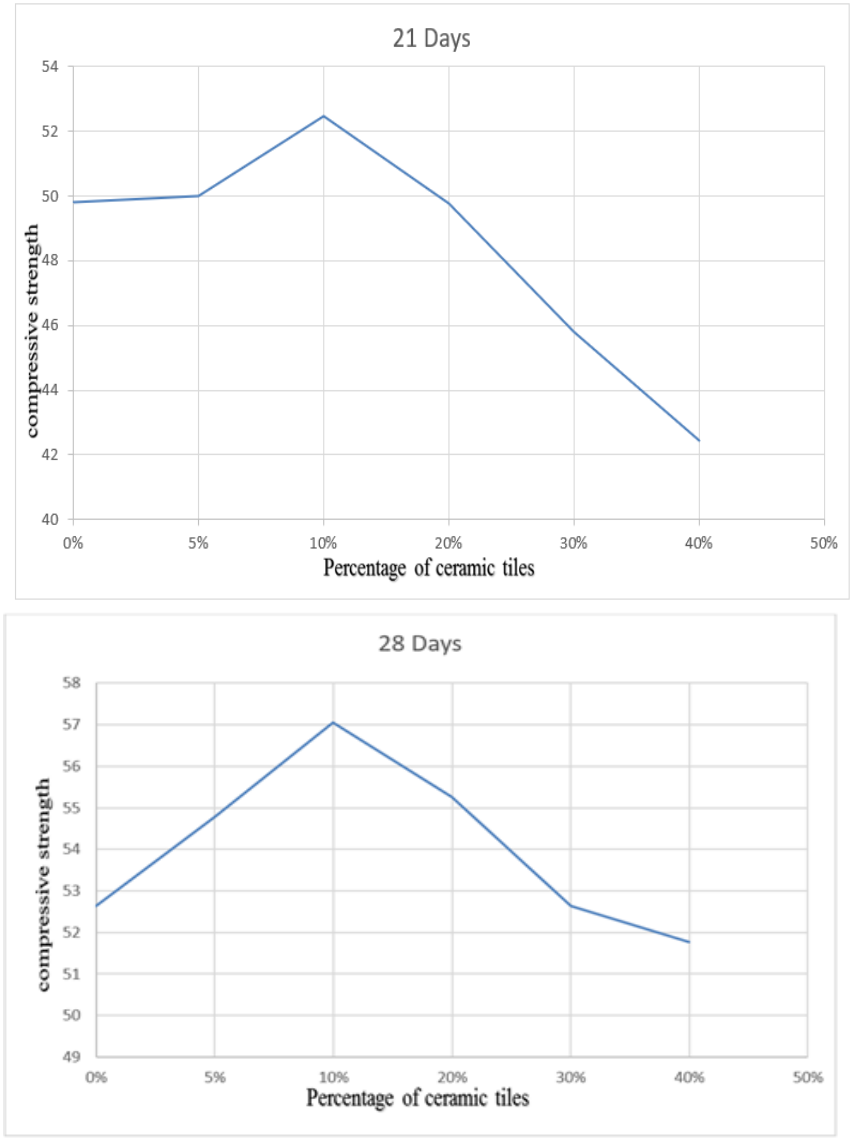
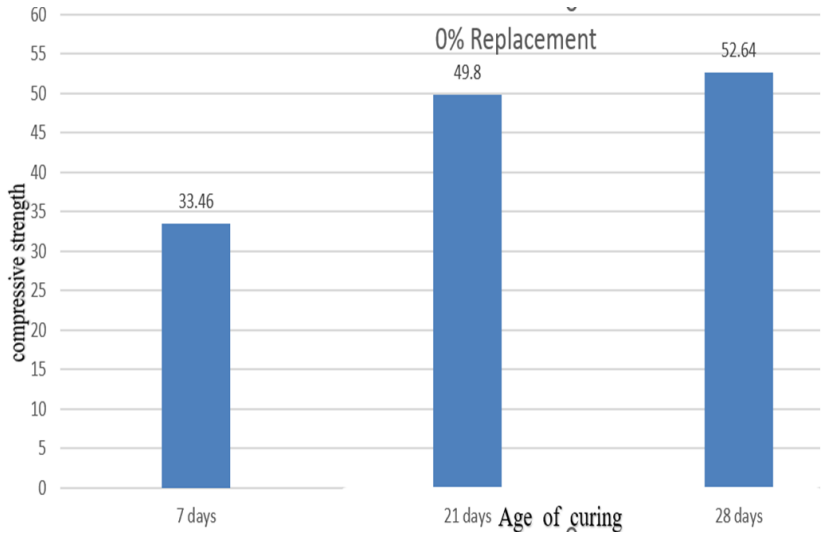
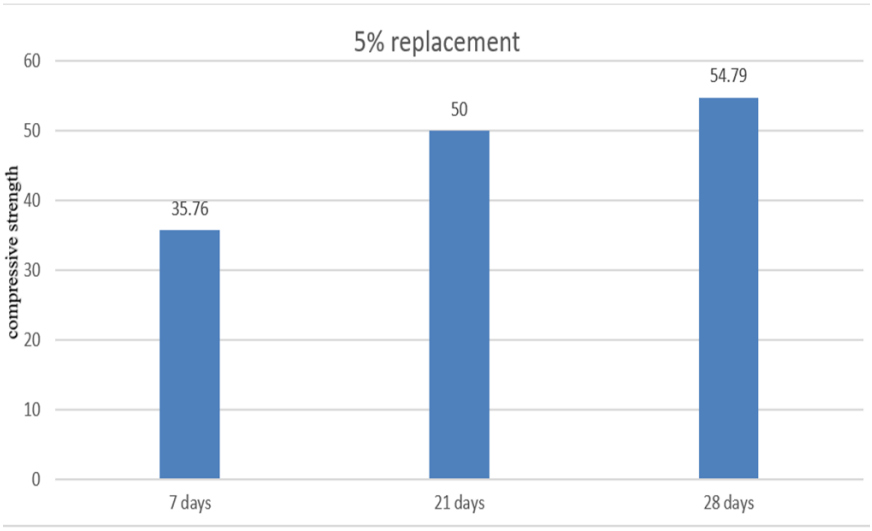
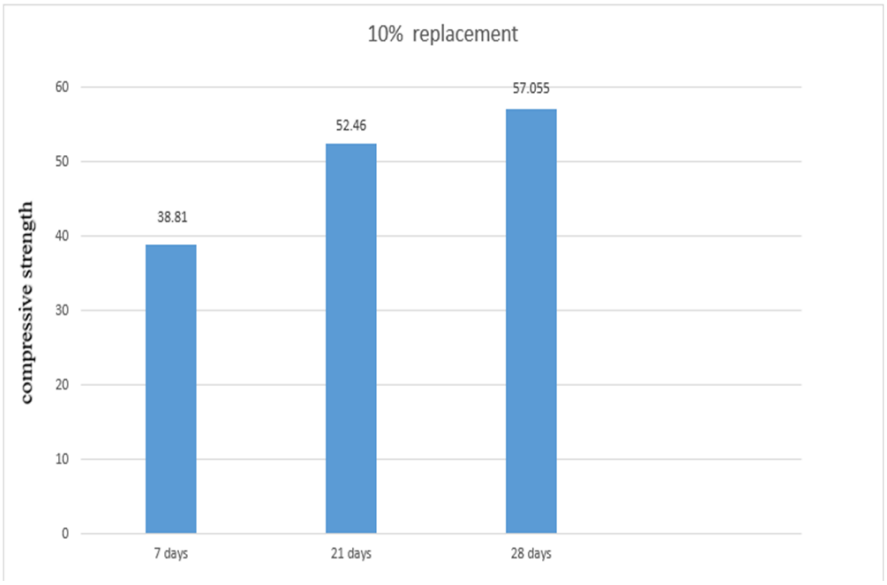


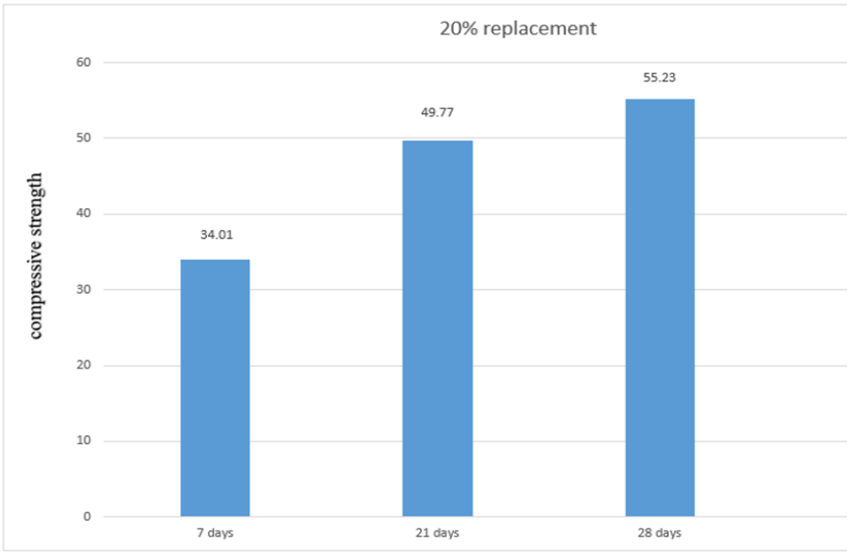
Fig 2 Variation of Compressive strength with various percentages of ceramic tile pieces



Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved







Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved

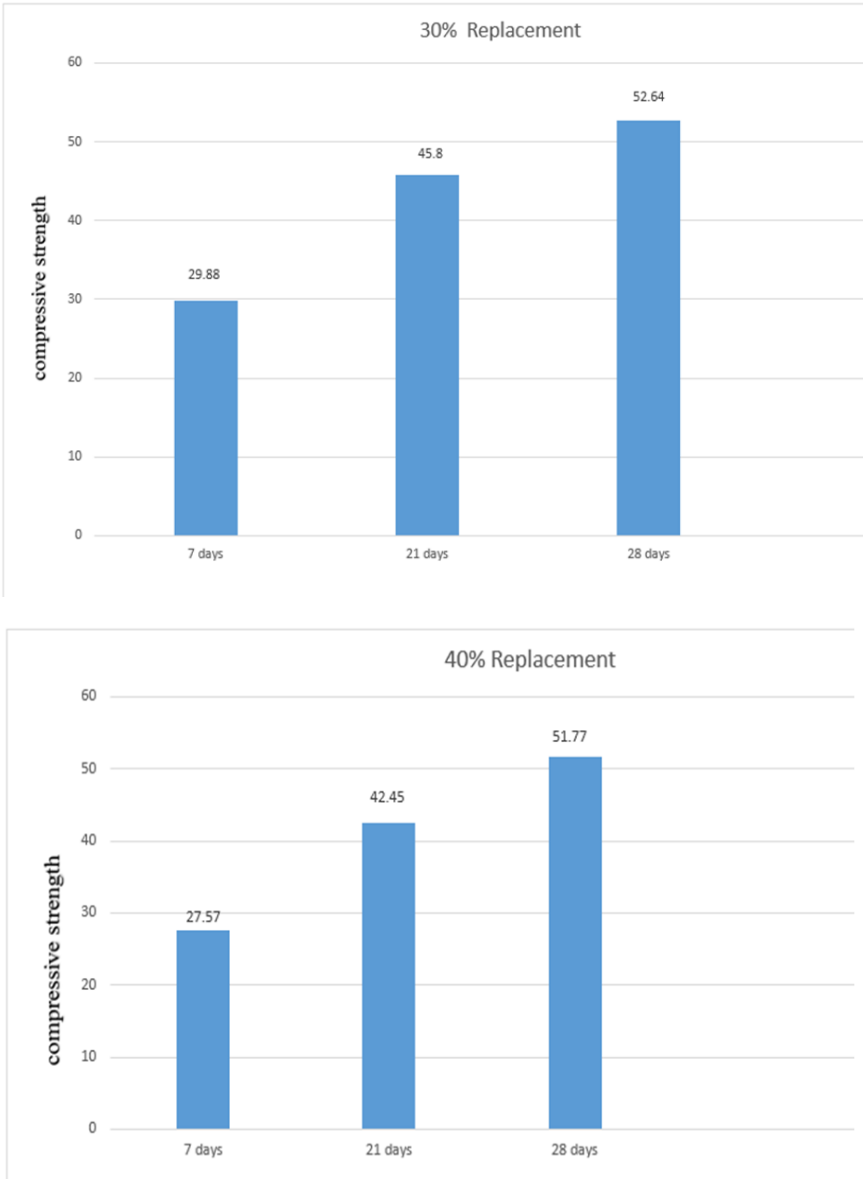


Fig 3 Variation of Compressive strength at different curing periods for various percentages of ceramic tile pieces

Split Tensile Strength

Cylindrical specimens of diameter 150mm and length 300mm were prepared. Split tension test was carried out on 2000 kN capacity compression testing machine as per IS 5816-1999. The tensile strength is calculated using the equation,

$F = 2P / (3.14DL)$

Where, F = Tensile strength of concrete (in MPa).

P = Load at failure (in N).

L = Length of the cylindrical specimen (in mm).

D = Diameter of the specimen (in mm).

Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved

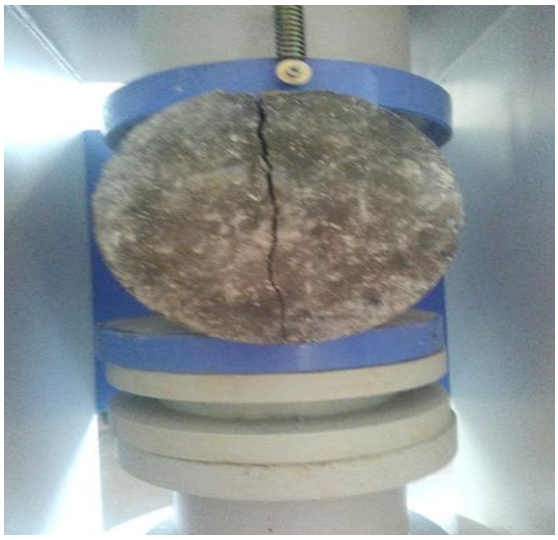




Fig 4 Cylindrical specimen tested for split tension

Table 7 Calculation of split tensile strength with 0% replacement

	7 Days Curing		**21 Days Curing**		**28 Days Curing**	
Percentage of ceramic tile pieces	Failure load KN	Split tensile strength MPa	Failure load KN	Split tensile strength MPa	Failure load KN	Split tensile strength MPa
0%	232.55	3.29	347.77	4.92	317.37	4.99
0%	233.26	3.30	354.13	5.01	369.68	5.23
Average split tensile strength	3.29		4.96		5.11	

Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved

Table 8 Calculation of split tensile strength with 5% replacement

	7 Days Curing		**21 Days Curing**		**28 Days Curing**	
Percentage of ceramic tiles	Failure load KN	Split tensile strength MPa	Failure load KN	Split tensile strength MPa	Failure load KN	Split tensile strength MPa
5%	233.9	3.31	362.61	5.13	397.96	5.63
5%	242.45	3.43	371.80	5.26	400.08	5.66
Average split tensile strength	3.37		5.19		5.65	

Table 9 Calculation of split tensile strength with 10% replacement

	7 Days Curing		**21 Days Curing**		**28 Days Curing**	
Percentage of ceramic tiles	Failure load KN	Split tensile strength MPa	Failure load KN	Split tensile strength MPa	Failure load KN	Split tensile strength MPa
10%	247.4	3.50	385.94	5.46	447.44	6.33
10%	277.79	3.93	418.46	5.92	475.71	6.73
Average split tensile strength	3.72		5.69		6.53	

Table 10 Calculation of split tensile strength with 20% replacement

	7 Days Curing		**21 Days Curing**		**28 Days Curing**	
Percentage of ceramic tiles	Failure load KN	Split tensile strength	Failure load KN	Split tensile strength MPa	Failure load KN	Split tensile strength MPa
20%	246.69	3.49	375.34	5.31	417.75	5.91
20%	241.74	3.42	392.30	5.55	412.09	5.83
Average split tensile strength	3.45		5.43		5.87	

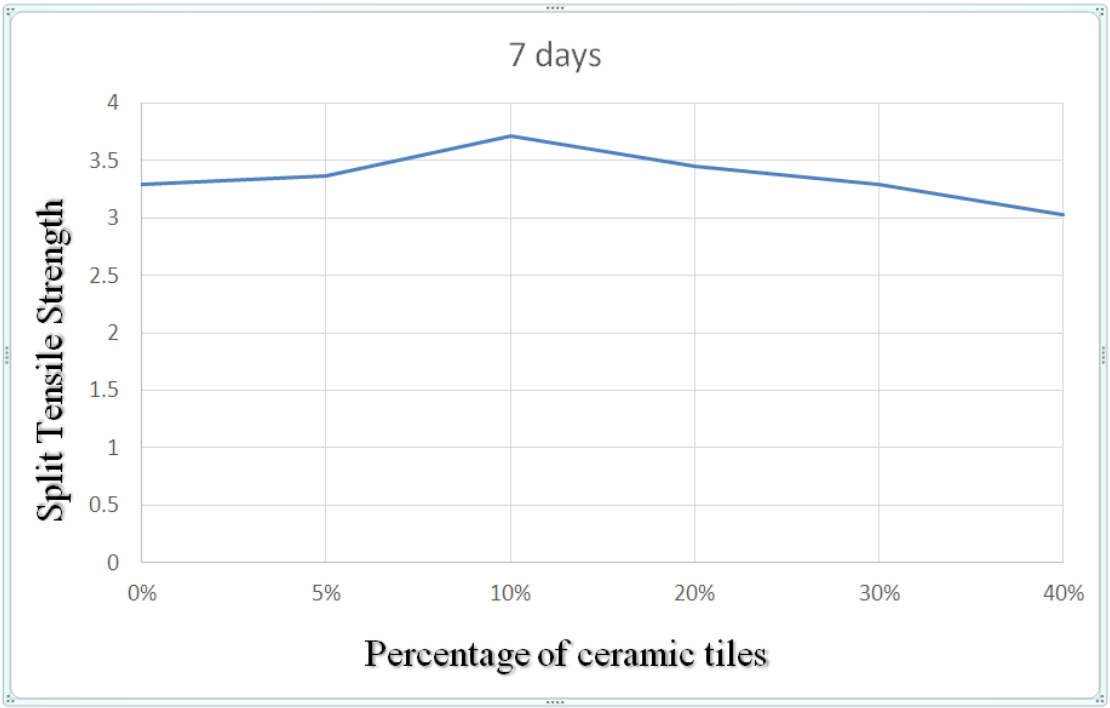
Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved

Table 11 Calculation of split tensile strength with 30% replacement

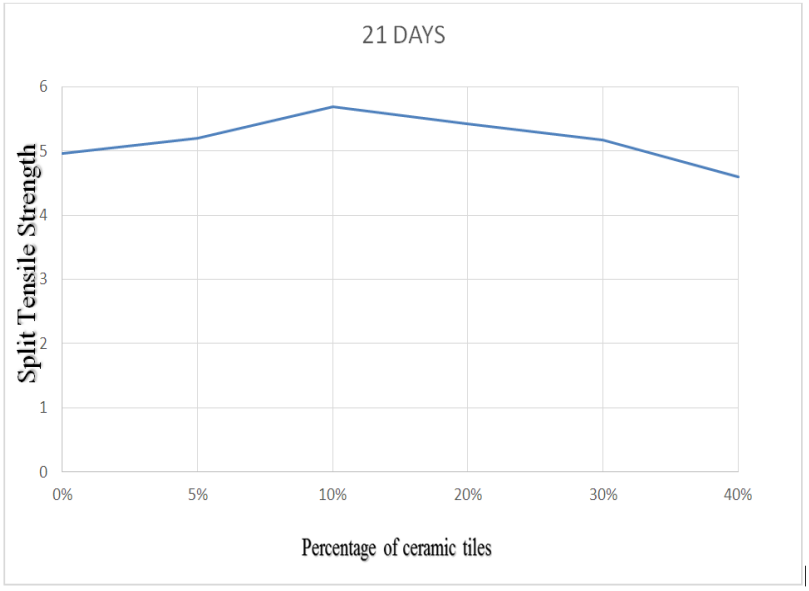
	7 Days Curing		21 Days Curing		28 Days Curing	
Percentage of ceramic tiles	Failure load KN	Split tensile strength MPa	Failure load KN	Split tensile strength MPa	Failure load KN	Split tensile strength MPa
30%	228.31	3.23	361.20	5.11	382.41	5.41
30%	237.50	3.36	370.39	5.24	379.58	5.37
Average split tensile strength	3.29		5.18		5.39	

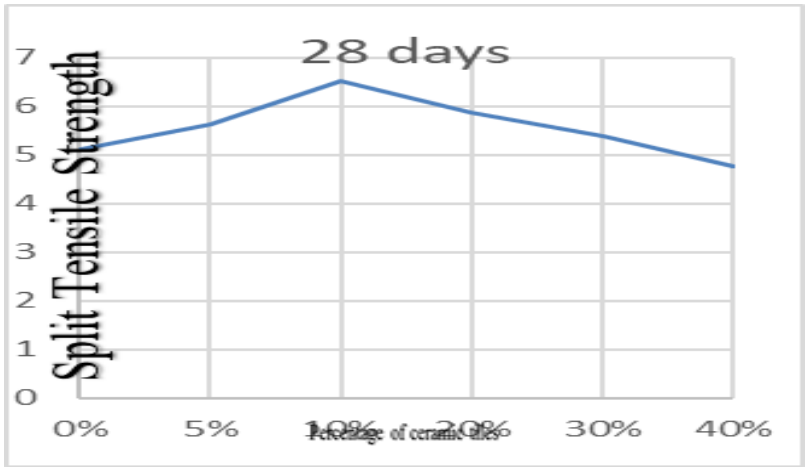
Table 12 Calculation of split tensile strength with 40% replacement

	7 days curing		21 days curing		28 days curing	
Percentage of ceramic tiles	Failure load KN	Split tensile strength MPa	Failure load KN	Split tensile strength MPa	Failure load KN	Split tensile strength MPa
40%	207.10	2.93	337.87	4.78	345.65	4.89
40%	220.53	3.12	313.13	4.43	327.27	4.63
Average split tensile strength	3.02		4.60		4.76	



Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved





CONCLUSIONS

1. The concrete prepared with the recycled ceramic tiles can be used as an alternative to conventional concrete.

2. Strength achieved from the recycled ceramic tiles concrete is more for 10% replacement. At 30% replacement the strength will be lesser than the conventional concrete.

3. It gives a high value of split tensile strength for 10% replacement.

4. The workability of concrete goes on decreases with increase in the ceramic tiles.

5. Using of ceramic tiles in concrete is an effective measure with regards to reduction in costs of concrete.

Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved

REFERENCES

1. P. Kumar Mehta, "Reducing the Environmental Impact of Concrete", Concrete International, vol.23, no.10 pp.61-66, October, 2001.

2. M. J. Stokoe, P. Y. Kwong and M. M. Lau, "Waste reduction: a tool for sustainable waste management for Hong Kong", In Barrage, A., Edelman Y., (Eds.), Proceedings of R'99 World Congress, vol 5. Geneva, Switzerland, pp.165-170.

3. J. Ferguson, N. Kermode, C. L. Nash, W. A. J. Sketch and R. P. Huxford, "Managing and Minimizing Construction Waste: A Practical Guide". Institute of Civil Engineers, London, 1995.

4. D. J. Craven, H. M. Okraglik, I. M. Eilenberg, "Construction waste and a new design methodology" Kibert, C. J. (Ed.), Proceedings of First Conference of CIB TG 16 on Sustainable Construction. Tampa, FL, pp.89-98, 1994.

5. United States Environmental Protection Agency, "Estimating 2003 Building-Related Construction and Demolition material amounts" march 2009.

6. T. H. Christensen & L. Anderson, "Construction and Demolition Waste", In Thomas H. Christensen (ed) Solid Waste Technology and Management. Blackwell Publishing Ltd. Vol 1. Pg.104. 2011.

7. Paulo B. Cachim, "Mechanical properties of brick aggregate concrete", Construction and Building Material, vol.23, pp.1292-1297, 2009.

8. Application of waste ceramic tiles aggregates in concrete", vol 4, issue 12, December 2015

9. Pincha Torkittikul, Arnon Chaipanich, "Utilization of ceramic waste as fine aggregate within Portland cement and fly ash concrete", Cement and Concrete Composites, vol. 32, pp. 440-449, 2010.

10. Hiroshi Higashiyama, Fumio Yagishita, Masanori Sano, and Osamu Takahashi, "Compressive strength and resistance to chloride penetration of mortars using

Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved

ceramic waste as fine aggregate", Construction and Building Materials, vol. 26, pp. 96-101, 2012.

11. BS 12:1996, Specification for Portland Cements, British Standard Institute.

12. BS 5328 Part 2:1990, Methods for specifying concrete mixes.

13. BS EN 12350 Part 2:2009, Testing fresh concrete: slump test. London.

14. BS 882:1992, Specification for aggregate from natural resources for concrete, London. British Standard Institution.

15. A. A. Umoh, I. E. Ekop, "The use of Erosion Sand and Palm kernel Shell as Aggregate in the production of Structural Lightweight Concrete", Nigerian Journal of Agriculture, Food and Environment, vol.9(1), 2013.

16. A. M. Neville, "Properties of Concrete", 5th edition, Pitman, New York, 2000.

17. R. Senthamari, M. Devadas, "Concrete with ceramic waste aggregate", Cement and Concrete Composites, vol 27, pp. 910-913, 2005.

Text books

1. Neville, A.M. Properties of concrete, Pitman Publishing Ltd., London, (1995).

2. Hewlett, P. C. (editor), Lea´s chemistry of cement and concrete, 4th Edition (Elsevier, Oxford, 2005).

3. M.S.Shetty, ―Concrete Technology‖ S.Chand Publishers (2011).

4. S.H. Kosmatka, and B. Kerkhoff, "Design and Control of Concrete Mixtures", Seventh Edition; (2002).

Page 56-72 © MANTECH PUBLICATIONS 2022. All Rights Reserved