

Assessment of Concrete Properties by Replacing Ceramic Waste as Coarse Aggregate by Two-Stage Mixing Approach

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ABSTRACT: As a high priority of waste management and growing difficulty in obtaining natural coarse aggregates for the production of concrete, associated to the environmental issues and social costs that the uncontrolled extraction of natural aggregates creates, led to a search for feasible alternatives. One of the possible paths is to reuse ceramic waste as aggregates. It is one of the most active research areas since it has better mechanical behaviour and pozzolanic nature and about 30% industrial production goes as waste, which is not recycled at present.

KEYWORDS: Ceramic waste, waste materials, Two stage Mixing approach, Split tensile test, Flexural test.

I. INTRODUCTION

This study makes an attempt to check the suitability of ceramic waste in concrete as a replacement of coarse aggregate duly implementing some new methods such as Two stage Mixing approach, Previous experimental studies concluded the suitability of the ceramic industrial wastes only as a possible partial substitute for conventional crushed stone coarse aggregate. The main disadvantages of ceramic waste is its high water absorption and lower density to overcome that in this research study an attempt is made to increase the quantity of usage of ceramic industrial wastes as coarse aggregate by advocating a scientific new concrete mixing method, that is the two-stage mixing approach (TSMA). This research work is concerned with the variation of compressive strength by experimental analysis involving the modified mixing method by replacing coarse aggregates via 0%, 10%, 20%, 30% and 40% by weight of M-25 grade concrete of ceramic industrial waste and also by adding Sika Viscocrete, a super plasticizer to it. Concrete mixtures were produced, tested and compared in terms of compressive strength, Flexural strength, Split tensile strength to the conventional concrete. These tests were carried out to evaluate the mechanical properties for 7, 14 and 28 days. As a result, optimized proportion of ceramic industrial wastes in concrete corresponding to strength through two-stage mixing approach can be achieved.

II. RELATED WORK

A significant amount of research work on usage of ceramic waste as various components of concrete has been done by many investigators and till date the ceramic materials are among the major concern in the research area. Such as

Vivian W. Y. Tam¹ and C. M. Tam¹ developed the Two-Stage Mixing Approach (TSMA) for improving the strength of Recycled aggregate concrete, leading to the possibility in applying RAC for higher-grade applications.

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While the improvement in strength by TSMA has been proven in Tam's previous work in this project he verified that 68.09% on shrinkage (with 100% RA substitution after 14 days of curing);

O. Zimbili, W. Salim, M. Ndambuki [2] have conducted extensive research on ceramic waste usage. Their focus was investigating the possibility of utilizing general ceramic rubble (mostly clay bricks and tiles) as an additive of cement.

Amitkumar D. Raval, Indrajit N. Patel, Jayeshkumar Pitroda [3] analyzed the impact of the use of ceramic powder, obtained as residue from the ceramics industry, on the mechanical properties of conventional concrete. Compressive strength tests were performed on compression testing machine using cube samples. Three samples per batch were tested with the average strength values reported in this paper.

Hemanth Kumar Ch [4] in his study to understand the behavior and performance of ceramic solid waste in concrete he conducted experiments by partially replacing the waste ceramic crushed tiles as coarse aggregate by 10% and 20% say A1 and A2 respectively and the waste ceramic powder used to partially replace the fine aggregates by 10% and 20% say A3 and A4 respectively and concluded that Maximum compressive strength is obtained when 20% of tiles powder was replaced in fine aggregate.

Siddesha H [5] In his investigation, compressive, split tensile and flexural strength of the concrete specimens were tested. Mix design is done as per IS: 10262-2007. As per the Mix design, the cement content works out to be 420 kg/m³. In his study, the cement content is also varied along with the ceramic fine aggregates.

Punit Malik [6] conducted experiments by replacing ceramic materials as aggregates and following conclusions have been drawn: By using the ceramic tile aggregate, the mass of aggregate reduces about 50 % which in turn reduces the weight of concrete.

Hitesh Kumar Mandavi [7] performed experiments through a cube of dimension 100mm x 100mm x100mm was casted to find out durability. To obtain the durability of concrete containing ceramic tiles, ceramic sand replaced with natural fine aggregate at an interval of 10 up to 50 percent for 7 & 28 days.

III. MATERIALS USED

- Cement (OPC): The Ordinary Portland Cement of 53 grade conforming to IS: 8112 is be use. Physical properties of cement noticed from experiments done which are Specific gravity:3.12, Fineness modulus :3.1, Consistency :35%,Initial setting time :80min
- Coarse aggregate :As per IS 383:1970 the nominal size is 20 mm is used .The shape of coarse aggregate is angular, water absorption capacity is 1.83, specific gravity is 2.33
- Fine aggregate: Uncrushed natural river sand is used as fine aggregate in this investigation .As per IS 383:1970 fine aggregate properties were tested and concluded that the fine aggregate in this investigation falls in zone-II .The water absorption capacity is 1.2, specific gravity is 2.65.
- Ceramic waste: Industrial ceramic waste and demolished ceramic materials are used in this investigation where its water absorption capacity is found to be 6.56,specific gravity is 2.11.
- Water : Tap water is used in this investigation.
- Admixture: Sika ViscoCrete is used .It is a super plasticizer based on polycarboxylic ether .This is free from chloride and low alkali .It is compatible with all types of cements .The aspect of admixture is yellow colour liquid.

IV. PROPOSED METHODOLOGY AND DISCUSSIONS

The evaluation of ceramic waste for use as a replacement of cement material begins with the concrete testing. In this study we conduct compressive strength, flexural strength, and indirect tensile strength (splitting). Concrete contains cement, water, fine aggregate, coarse aggregate and grit. With the control concrete, i.e. 10%, 20%, 30% , 40%, and 50% of the coarse aggregate is replaced with ceramic waste and 3 cube samples,3 cylinder samples , 3 beam samples are prepared ,While casting samples, we are applying Two Stage mixing Approach in concrete mixing

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the data from the ceramic waste concrete using two stage mixing approach is compared with data from replacing 10%, 20%, 30%, 40%, and 50% of the coarse aggregate standard Normal mixing approach

Following is the procedure for mix design as recommended in IS 10262 – 1982 a design mix of M25 grade is calculated as follows: The final mass ratio of cement, fine aggregate coarse aggregate, chemical admixture and water, **1: 2.31 :3.11 :0.02 :0.47**

Following the above proportioning Three cubes of size is 150*150*150 mm for compression testing, Three beams of size 150mm x 150mm x 700mm used for flexural test and three cylinders cubes of size 150mm dia x 300mm for split tensile test are prepared for 0%, 10%, 20%, 30%, 40% replacement of coarse aggregate by ceramic waste are casted respectively. A total of 45 cubes are casted while casting the mixing is done using Two stage mixing approach following the below procedure :

- First, coarse and fine aggregates are mixed for 60 seconds and then half of water for the specimen is added and mixed for another 60 seconds
- Second, cementitious material is added and mixed for 30 seconds.
- Thirdly, the rest of water is added and mixed for 120 seconds.

After about 24 h the specimens were de-moulded and water curing was continued till the respective specimens were tested after 7, 14 and 28 days for compressive strength test, split tensile test and flexural strength test are conducted duly. Compressive strength tests were performed on compression testing machine using cube samples. Flexural strength test were performed on beam specimens and split tensile test on cylindrical specimens. The comparative studies were made on their characteristics for with partial replacement of coarse aggregate with Ceramic waste as 10%, 20%, 30% and 40% And also the results obtained from TSMA and NMA method are also compared their by the feasibility of this approach can be proved.

V. EXPERIMENTAL RESULTS

The mix proportion for M25 is 1: 2.31: 3.11 and W/C ratio of 0.47 was casted. Slump and compaction factor tests were tested when the concrete in fresh state. The cubes, cylinders and beams were tested for compressive strength, split tensile strength and flexural strength. These tests were carried out at the age of 7 days, 14 days, and 28 days.

- **Tests on Fresh Concrete:**

Workability test using slump cone and compaction factor test is conducted on all mixes.

Table -1: Workability and compaction factor results of mixes using NMA

s.no	Mix	Slump (mm)	Compaction factor
1	Conventional mix 0%	80	0.921
2	10% ceramic mix	65	0.924
3	20% ceramic mix	63	0.931
4	30% ceramic mix	58	0.935
5	40% ceramic mix	49	0.936

Table -2: Workability and compaction factor results of mixes using TSMA

s.no	Mix	Slump (mm)	Compaction factor
1	Conventional mix 0%	80	0.921
2	10% ceramic mix	75	0.923
3	20% ceramic mix	73	0.924
4	30% ceramic mix	68	0.925
5	40% ceramic mix	61	0.931

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- Tests on Hard concrete:
- Compression strength test results :

Table -3: Results of compression strength test by NMA method

Compression strength in N/mm ² BY NMA					
Age	0% (CC)	10%	20%	30%	40%
7 days	25.08	23.94	21.32	22.07	21.38
14 days	37.51	35.92	35.76	32.78	31.27
28 days	41.68	39.76	39.12	36.79	35.64

Table -4 Results of compression strength test by TSMA method

Compression strength in N/mm ² by TSMA				
Age	10%	20%	30%	40%
7 days	24.097	23.56	23.15	20.47
14 days	34.94	36.12	35.67	33.516
28 days	40.16	38.22	38.12	37.24

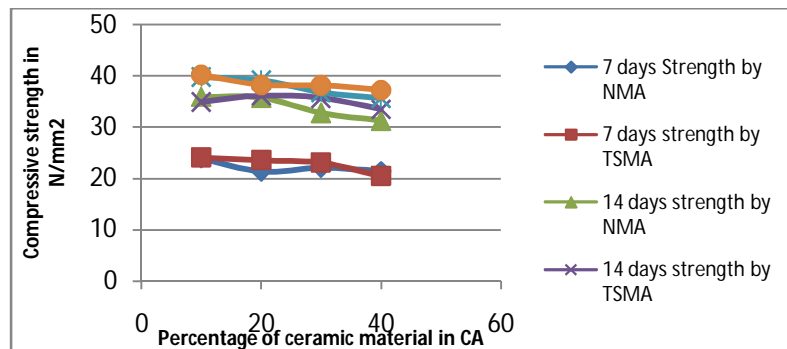


Chart No:1 Comparison of Compressive strengths of TSMA and NMA cubes for all mixes

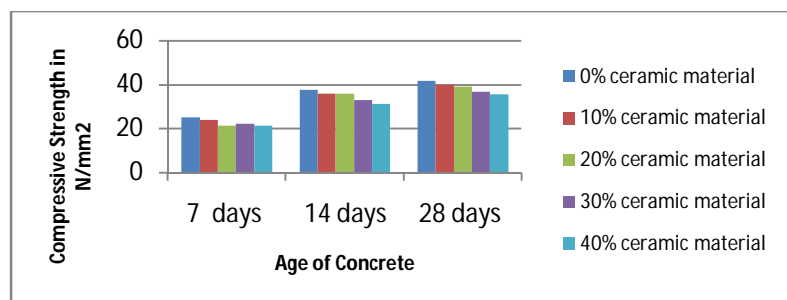


Chart No:2 Comparison of Compressive strengths of Conventional concrete and Ceramic waste concrete.

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- Flexural strength test results:

Table-5: Results of Flexural strength test by NMA method

Flexural strength (N/mm ²) by NMA					
Age	0% (CC)	10%	20%	30%	40%
7 days	7.1	6.48	5.89	5.33	5.31
14 days	7.61	6.9	6.35	5.78	5.81
28 days	8.32	7.2	6.94	6.61	6.58

Table-6: Results of Flexural strength test by TSMA method

Flexural strength (N/mm ²) by TSMA				
Age	10%	20%	30%	40%
7 days	7.01	6.92	6.05	5.96
14 days	7.52	7.03	6.23	6.12
28 days	8.21	7.31	6.96	6.78

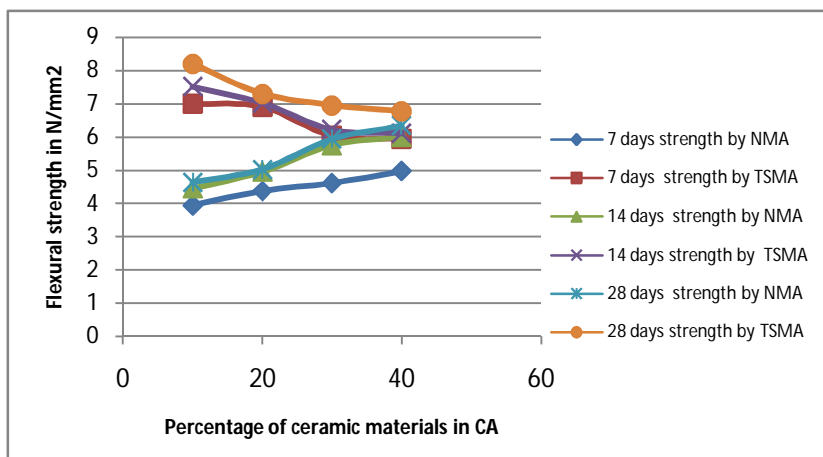


Chart No:3 Comparison of Flexural strengths of TSMA and NMA cubes for all mixes

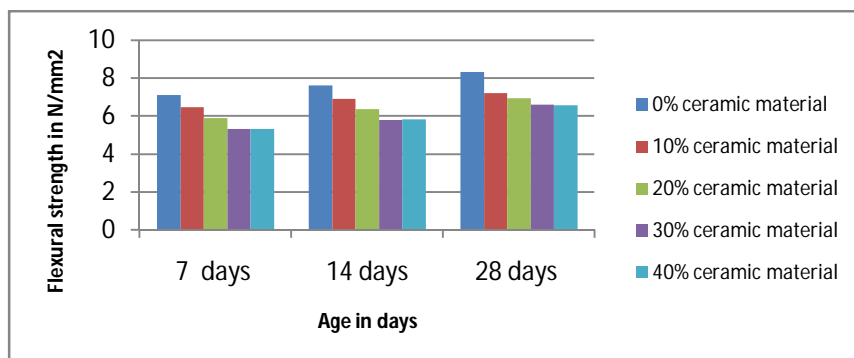


Chart No :4 Comparison of Flexural strengths of Conventional concrete and Ceramic waste concrete

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- Split tensile strength test results

Table-7: Results of Split tensile test by NMA method

Split tensile strength (N/mm ²) TEST BY NMA					
Age	0% (CC)	10%	20%	30%	40%
7 days	2.01	2.05	2.11	1.98	1.96
14 days	2.47	2.42	2.38	2.45	2.46
28 days	2.99	2.89	2.85	2.81	2.77

Table-8: Results of Split tensile test by TSMA method

Split tensile strength test (N/mm ²) in TSMA				
Age	10%	20%	30%	40%
7 days	2.11	2.05	1.98	1.89
14 days	2.52	2.38	2.31	2.55
28 days	3.05	2.97	2.89	2.75

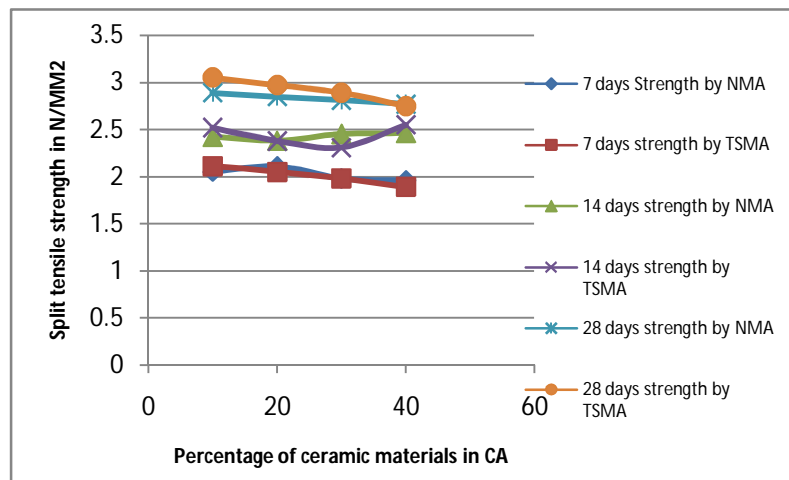


Chart No :5 Comparison of Split tensile strengths of TSMA and NMA cubes for all mixes

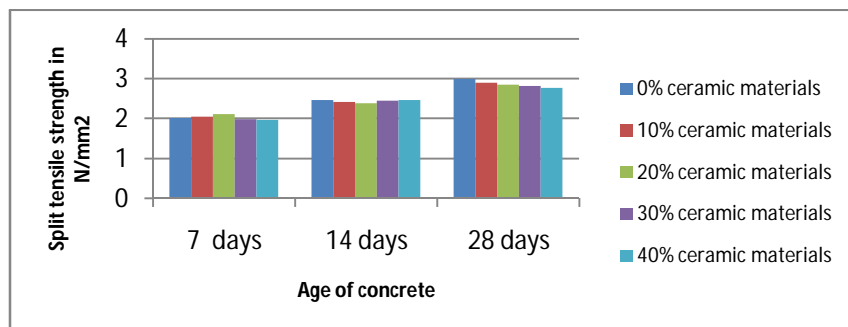


Chart No:6 Comparison of Split tensile strengths of TSMA and NMA cubes for all mixes

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VI. CONCLUSIONS

Based on the results obtained for the different tests conducted and of physical observations, the following conclusions are drawn:

1. The slump of the ceramic concrete is less than Conventional concrete and when compared with NMA ,slump value increased by applying TSMA.
2. There are no considerable deviations in the compaction factor with increase in percentage of ceramic waste in NMA and TSMA with the conventional concrete.
3. The compressive strength of the concrete reduced with increasing percentage of the ceramic waste replacement in NMA method when compared with conventional concrete but by applying TSMA method there is not much remarkable decrease in compressive strength of concrete up to 30% replacement .
4. Further replacement of coarse aggregate with ceramic waste decreases the compressive strength.
5. Up to 30% replacement of concrete coarse aggregate with ceramic waste in M25 grade is technically and economically feasible and viable
6. The TSMA developed by Tam et al can improve the strength .The current paper has studied another alternate mixing methods by modifying the pre-mix procedure and altering the ingredients of concrete. TSMA offers a way for the cement slurry to gel up the Ceramic Waste aggregate, providing a stronger bonding provides a layer of cement slurry with a lower w/c ratio around Ceramic Waste. From the laboratory tests, the compressive strengths of both methods can be improved, and TSMA can achieve a higher improvement when compared with NMA.
7. The flexural strength of concrete slightly decreased with increase in percentage of ceramic coarse aggregate in NMA method and by applying TSMA method it is slightly increased than NMA.
8. Hence, we can say ceramic material concrete presents better mechanical behavior in terms of flexural strength than conventional concrete.
9. The split tensile strength of concrete slightly decreases with increase in percentage of ceramic Coarse aggregate in concrete but there is no much variation in split tensile strength of concrete with the variation of ceramic coarse aggregate in both methods.
10. It is the possible alternative solution of safe disposal of ceramic waste. By adopting such methods we can overcome problems such as waste disposal crisis

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BIOGRAPHY



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Dr. S. SREENATHA REDDY Professor & Principal, Guru Nanak Institute of Technology under JNTUH, Hyderabad. Dr. S. SREENATHA REDDY obtained B.Tech, Mechanical Engineering from JNTU, Hyderabad, M.Tech.- Heat power, Refrigeration & Air conditioning from JNTU, Hyderabad and Ph.D. Faculty of Mechanical Engineering from JNTUA. Dr. S. SREENATHA REDDY held various administrative posts and developed the Institution with his projects and developmental activities. Notable among his award i.e National award for best research publication i.e Jawaharlal Nehru memorial prize issued Institution of Engineers on the occasion of Inauguration 27 th Indian Engineering Congress at New Delhi. He is a young & dynamic Technical Person worked 14 years in Teaching in Mechanical & Aeronautical field and 3 years in Industry from Thermal Power plants. Dr. S. Sreenatha Reddy is having rich experience in administrative area. Earlier he worked as Principal, Head of both the Aeronautical & Mechanical department, coordinating R&D cell for Aeronautical Research and Development Board (ARDB) projects, TPO & developing courseware and implementing ISO 2001 and NBA Accreditation