

Recycled Plastics as Coarse Aggregate for Structural Concrete

Praveen Mathew¹, Shibi Varghese², Thomas Paul³, Eldho Varghese⁴

Assistant Professor, Department of Civil Engineering, M. A. college of Engineering, Kothamangalam, Kerala, India¹

Associate Professor, Department of Civil Engineering, M. A. college of Engineering, Kothamangalam, Kerala, India²

Professor, Department of Civil Engineering, M. A. college of Engineering, Kothamangalam, Kerala, India³

Assistant Professor, Department of Civil Engineering, M. A. college of Engineering, Kothamangalam, Kerala, India⁴

Abstract: The use of plastic is increasing day by day, although steps were taken to reduce its consumption. This creates substantial garbage every day which is much unhealthy. A healthy and sustainable reuse of plastics offers a host of advantages. The suitability of recycled plastics as coarse aggregate in concrete and its advantages are discussed here. The initial questions arising of the bond strength and the heat of hydration regarding plastic aggregate were solved. Tests were conducted to determine the properties of plastic aggregate such as density, specific gravity and aggregate crushing value. As 100% replacement of *natural coarse aggregate* (NCA) with *plastic coarse aggregate* (PCA) is not feasible, partial replacement at various percentage were examined [8], [9]. The percentage substitution that gave higher compressive strength was used for determining the other properties such as modulus of elasticity, split tensile strength and flexural strength. Higher compressive strength was found with 20% NCA replaced concrete. Heat resisting behavior of the PCA concrete is also discussed in this study.

Keywords: Coarse aggregate, plastic aggregate, partial replacement, volumetric substitution, grade substitution.

I. INTRODUCTION

Concrete is the most widely used man made construction material in the world and its second only to water as the most utilized substance in the planet. Seeking aggregates for concrete and to dispose of the waste from various commodities is the present concern. Today sustainability has got top priority in construction industry. In the present study the recycled plastics were used to prepare the coarse aggregates thereby providing a sustainable option to deal with the plastic waste [10]. There are many recycling plants across the world, but as plastics are recycled they lose their strength with the number of recycling. So these plastics will end up as earth fill. In this circumstance instead of recycling it repeatedly, if it is utilized to prepare aggregates for concrete, it will be a boon to the construction industry.

Most of the failures in concrete structures occur due to the failure of concrete by crushing of aggregates. PCAs which have low crushing values will not be crushed as easily as the stone aggregates. These aggregates are also lighter in weight compared to stone aggregates. Since a complete substitution for NCA was not found feasible, a partial substitution with various percentage of PCA was done. Both volumetric and grade substitution was employed in this investigation.

II. PLASTIC AGGREGATE

Plastics collected from the disposal area were sorted to get the superior one. These were crushed into small fraction and washed to remove the foreign particles. Then it was heated at a particular temperature so that the necessary brittleness was obtained. After extrusion the molten plastic was cooled down and collected in boulders of 100 mm size approximately. These plastic boulders were crushed down to the size of aggregates.

A. Properties

According to the Indian standard specifications the property of aggregates such as specific gravity, aggregate crushing value and density were determined [6], [7]. From Table I comparing the properties of aggregate for both NCA and PCA it is observed that the specific gravity and density for PCA is much lower than NCA which offers a light weight concrete. A lower crushing value indicates the complexity with which a PCA concrete could be crushed under compressive stresses.

TABLE I
 Properties of Aggregate

Property	NCA	PCA
Specific gravity	2.74	0.9
Crushing value	28	2
Density	3.14	0.81

III. EXPERIMENTAL INVESTIGATION

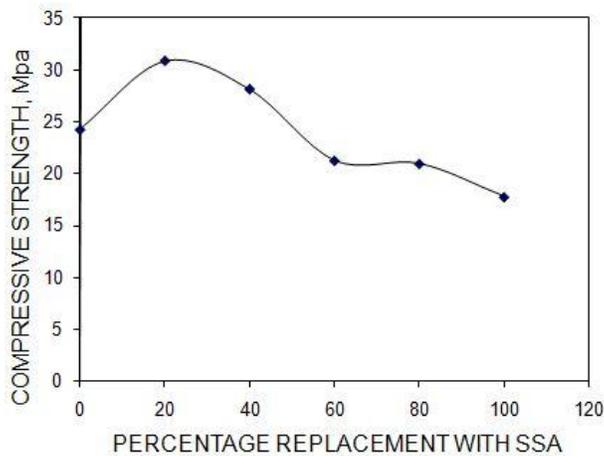
Tests were conducted to determine the fresh and hardened properties of both NCA and PCA concrete [1]. Slump and compaction factor was determined as per the Indian standards and the values are tabulated in Table II [2], [3]. It shows that the workability of 20% PCA concrete is superior to NCA concrete which is due to the lower water absorption rate of plastic aggregates.

TABLE II
 Fresh Properties of Concrete

Particulars	Slump in mm	Compaction factor
NCA	33	0.93
20% replaced with PCA	36	0.95

A. Volumetric Substitution

In this method the volume occupied by NCA was substituted with PCA for various percentage substitutions, knowing their densities [5]. The cube compressive strength (size: 15 x 15 x 15 cm) obtained for various percentages are shown in Fig. 1. It can be seen that 20% substitution has shown a better strength even more than NCA concrete at the end of 28 day curing period. All the tests on concrete specimens for M20 mix to determine their hardened properties were conducted at the end of 28 days [4].



From the graph shown in Fig. 1 the optimum percentage substitution was taken at 22% and the other structural properties were determined with this optimum value.

B. Grade Substitution

Volumetric substitution and grade substitution was employed with a view to decide the best method for substituting plastic aggregates. In grade substitution method a particular grade of NCA was entirely replaced with PCA of same size which was 20 mm. From the results of compressive strength tabulated in Table III, it can be seen that, the grade substitution is only

inferior to both NCA concrete and 20% replaced PCA concrete. Hence volumetric substitution was selected as the best among the two substitution methods.

TABLE III
 Compressive Strength for Grade Substitution

Particulars	Compressive strength in Mpa
NCA concrete	24.2
20% PCA concrete	30.83
20 mm size NCA replaced with PCA	18.74

C. Structural Behaviour

Tests were conducted to determine the cylinder compressive strength, split tensile strength and modulus of elasticity on specimen of size 150 mm x 300mm, and are tabulated in Table IV [4].

TABLE IV
 Structural Properties of Concrete

Particulars	Cylinder compressive strength in Mpa	Splitting tensile strength in Mpa	Modulus of elasticity in Mpa
NCA	11.8	2.45	16290
22% PCA	16.27	1.91	12686

Eventhough the PCA concrete has shown a better compressive strength as compared to conventional with an increment of 28%, its lower in split tensile strength and modulus of elasticity. It can be assessed that deficient bonding between PCA and the matrix must be a reason to have the lower values. This concern could be minimised with the use of suitable admixtures to improve bond strength. The stress strain curve for both NCA and PCA concrete is shown in Fig. 2.

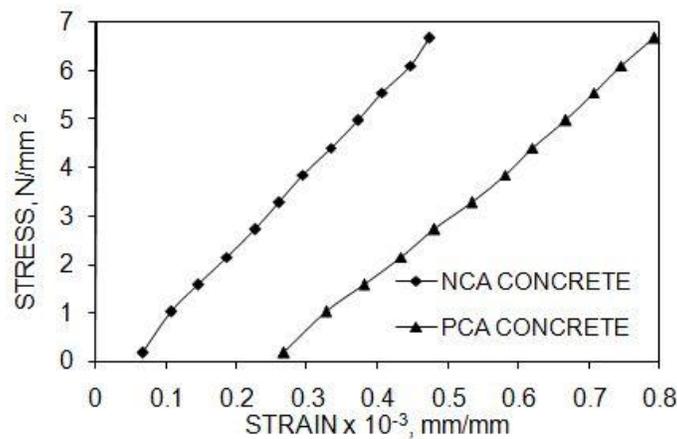


Fig. 2 Stress-Strain Curve

Further to evaluate the tensile strength, flexural strength test was conducted on specimen of size 100 x 100 x 500 mm. A strength of 4.4 Mpa for NCA concrete and 4.24 Mpa for PCA concrete was observed. Eventhough a slight reduction in strength was noted for PCA as compared with NCA concrete, the values are well within the permissible limits.

With limited test on bond strength of PCA concrete an admixture was added to the mixing water @ 0.4% by weight of cement to improve bonding between plastic aggregate and the matrix. The limited test result shows that the compressive strength increased @ 14% when compared with PCA concrete without admixture. Some tests were also conducted to study the heat resistivity of PCA concrete. Concrete specimens were subjected to various temperatures and its compressive strength was noted. At a temperature of 400°C, the NCA concrete has shown a 33% reduction of strength while PCA concrete show about 75% reduction. Hence special fire proof coatings are required when PCA concrete risks fire.

IV. CONCLUSION

A pilot study was conducted to determine the suitability of PCA for structural concrete. A percentage replacement of 22% NCA with PCA was found to be of superior concrete compressive strength. With regard to its tensile behavior the bonding strength of PCA with matrix needs more attention, since PCA concrete has shown a substantial reduction in split tensile strength and elastic modulus.

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REFERENCES

- [1] Neville, A. M., *Properties of concrete*, 4th edition, Addison Wesley Longman, London, 1997
- [2] Shetty, M. S., *Concrete Technology*, S. Chand and company, New Delhi, 2005
- [3] Gambir, M. L., *Concrete Technology*, 3rd edition, Tata McGraw-Hill, New Delhi, 2007
- [4] IS: 516-1959, *Methods of test for strength of concrete*, Bureau of Indian Standards, New Delhi, 1959
- [5] IS: 1199-1959, *Methods of sampling and analysis of concrete*, Bureau of Indian Standards, New Delhi, 1959
- [6] IS: 2386-1963, *Methods of test for aggregates of concrete*, part I, III & IV, Bureau of Indian Standards, New Delhi, 1963
- [7] IS: 383-1970, *Specification for coarse and fine aggregate*, Bureau of Indian Standards, New Delhi, 1970
- [8] Zoorob, S., E., Suparna, L., B., *Laboratry design and investigation of the properties of continuously graded Asphaltic concrete containing recycled plastics aggregate replacement (Plastiphalt)*, Cement and Concrete Composites, Vol 22, Issue 4, pp. 233-242, 2000
- [9] Zainab, Z. I., Enas A. AL-Hasmi, *Use of waste plastic in concrete mixture as aggregate replacement*, Waste Management, Vol 28, Issue 11, pp. 2041-2047, 2008
- [10] Nabajyothi, S., Jorge, B., *Use of plastic waste as aggregate in cement mortar and concrete preparation: A review*, Construction and Building Materials, Vol 34, pp. 385-401, 2012

BIOGRAPHY



Praveen Mathew, is working as an Assistant Professor in Mar Athanasius college of engineering, Kothamangalam, Kerala, India. He obtained M.Tech in Building Science and Technology from IIT, Roorkee, India. His area of research interest is in Recycled Aggregate Concrete. He has published papers in National journal and presented a paper on strut-and-tie model in an international conference.



Shibi Varghese, is working as an Associate Professor in Mar Athanasius college of engineering, Kothamangalam, Kerala, India. He obtained M.Tech in Building Technology and Construction Management from IIT, Madras, India.



Thomas Paul, is working as a Professor in Mar Athanasius college of engineering, Kothamangalam, Kerala, India. He obtained M.Tech in Building Technology and Construction Management from IIT, Madras, India.

Eldho Varghese, is working as an Assistant Professor in Mar Athanasius college of engineering, Kothamangalam, Kerala, India. His area of interest is in sustainable constructions.