

STUDY ON CONCRETE USING PLASTIC WASTE AS PARTIAL REPLACEMENT MATERIAL FOR FINE AGGREGATE

¹S.Krishnaveni, ²P.R.Kannan Rajkumar, ³P.T.Ravichandran

¹Asst. Professor, ²Associate Professor, ³Professor

¹Department of Civil Engineering, Dhaanish Ahmed College of Engineering, Chennai-601301

^{2,3}Department of Civil Engineering,

SRM Institute of Science and Technology, Kattankulathur- 603203, Tamil Nadu

¹tokannanonly@gmail.com

Abstract: In Civil engineering works, natural river sand was widely used as the fine aggregate, mainly in the concrete and cement – sand, lime – cement mortar. Due to over exploitation, the availability of river sand has become scarce and escalating environmental concerns. Limitations on Natural River sand dredging become very stern for collecting sand from river beds. In view of the long term performances and sustainability of concrete and mortar, demands a substitute material for natural river sand. In the present investigation, the plastic aggregate concrete (PAC) passing 4.75mm was made from the waste of plastic pipes by crushing into smaller pieces. The concrete is prepared by partially replacing the traditional fine aggregate with 0%, 10%, 20%, 30%, 40% and 50% of plastic aggregate with the water cement ratio of 0.39. From the results it is observed that the strength characteristics of plastic aggregate concrete shows the higher the strength in the concrete with the partial replacement of plastic aggregate by 10%. Utilization of plastic waste as fine aggregate replacement in concrete has the dual benefit of reducing the costs of disposal and lowering the cost of the concrete.

1. Introduction

Researches focusing on the use of by products to enhance the properties of concrete are going on for many decades. The recent researches indicates the use of industrial by products such as silica fume, metakaoline etc., in the concrete. Depending upon their grain size and chemical composition these industrial by products can be used in the concrete. The safe disposal of these by products is very difficult and creates environmental problems and hence these materials can be used in the concrete. [1]. Recycled plastic is one of the new materials which can be used in concrete. Due to environmental concerns the use of plastic in concrete is one of the novel solutions. One of the potential applications of this waste is in the construction industry, where it has been used in concrete, either in shredded form or combined with other materials, to

form a synthetic aggregate. Plastics can be readily used to form aggregates due to their lower density than other natural materials. Plastics can be classified into two categories thermoplastic and thermosetting plastic. The first type is thermoplastic, which can be melted for recycling in the plastic industry. The plastic types such as phenolic, melamine, unsaturated polyester etc., are grouped under thermosetting plastic which cannot be melted by heating because the molecular chains are firmly bonded together.

A significant portion of the plastic waste is generated as Municipal Solid Waste generated on India. The plastic waste generated is in the order of 10 thousand Tons per Day (TPD) in India. The low density polyethylene/ linear low density polyethylene (LDPE) constitutes about 23% of the total plastic waste whereas high density polyethylene and polypropylene constitutes about 17.3% and 18.5 % respectively. The other types of plastic wastes such as polyvinyl chloride constitute 8.5%, followed by Polyethylene Terephthalate 8.5% [3].

The objective of the investigation is to partially replacing the fine aggregate by PVC waste (0%, 10%, 20%, 30%, 40% and 50%) into the concrete. The mechanical properties such as compressive strength, split tensile test, modulus of elasticity and modulus of rupture are determined.

2. Material Investigation

2.1 Materials

To investigate upon the strength of the concrete Ordinary Portland cement OPC 53 conforming to IS: 12269:2013 [4] and ASTM Type I specifications are used. The specific gravity of the cement was 3.15 and the fineness of cement was 280 m²/kg. The chemical properties such as lime saturation factor, Insoluble residue, alumina iron ratio of 0.86, 1.08 and 1.40 was observed in the cement which was well within the limits as specified by 12269:2013 [4]. River sand collected from local sources was used throughout the

investigation as fine aggregates conforming to grading zone II as per IS: 383 (1970) [5]. The specific gravity and fineness modulus of the fine aggregate are 2.65 and 2.64 respectively, were determined. The used and broken PVC pipes are collected from local sources and it is crushed into smaller pieces such that it can pass through 4.75mm sieve with a fineness modulus of 6.50 and a apparent specific gravity of 1.45 used in the study

is shown in figure1. Superplasticizers were used at various dosages to improve the workability. The optimum dosages were varied between 1 – 1.2% to achieve a workability of 125 mm. SP based on sulphonated naphthalene admixture (SNF) with 40% mass content and relative density 1.25 was used for the investigation.



Figure 1. Shape of crushed PVC waste used as Fine Aggregate

2.2 Mix Proportioning

The mix design of the control concrete and Plastic Aggregate concrete was developed according to the IS 10262-2009. For the mixes containing plastic aggregate, the quantity of fine aggregate was calculated by using the specific gravity of the Plastic Aggregate as a replacement for the specific gravity of the fine

aggregate (river sand). The concrete mix proportions and the slump values of all the mixes are shown in Table 2. The improvement of workability was found in mixes with the higher addition of plastics in concrete with that of normal concrete. The reason may be not only due to the smooth shape but also due to absorption of plastic aggregates.

Table 2. Concrete Mix Proportions

Mixture	Cement kg/m ³	Fine Aggregate kg/m ³	Plastic aggregate kg/m ³	Coarse Aggregate kg/m ³	Water kg/m ³	w/c	Slump (mm)
PC	360	866	-	1100	142	0.39	125
PAC1	360	779	47.4	1100	142	0.39	128
PAC2	360	693	94.8	1100	142	0.39	133
PAC3	360	606	142	1100	142	0.39	140
PAC4	360	519	189.6	1100	142	0.39	142
PAC5	360	433	237	1100	142	0.39	145

2.3 Mixing and Casting

Coarse aggregate, fine aggregate and plastic aggregate were mixed for one minute in a mixer. Cement was added to the mix and the water was mixed gradually for a period of three minutes. The workability was tested using slump cone apparatus in accordance with ASTM C143 [6]. Fresh concrete was placed in steel moulds

and vibrator was used for compacting the concrete. After 24 hours the specimens were removed from the mould and placed for curing. The specimens were demoulded after 24 hours and then placed in a curing tank for 27 days. For 12 hours prior to the tests, the specimens were allowed to air dry in the laboratory. At this stage the compressive strength was measured at 7 and 28 days, whereas splitting tensile strength, flexural

strength and modulus of elasticity were measured at the age of 28 days.

3. Experimental Test Procedure

For each mixture, fifteen specimens (six 100mm cubes, six 100mm diameter and 200mm height cylinders and three 100x100x500mm beam specimens) were prepared. The compressive test was carried out on 100mm cubes, splitting tensile tests and elastic modulus were carried out on the 100mm diameter and 200mm height cylinders. The four-point loading

flexural tests were carried out on the 100x100x500mm beams.

4. Discussion of Test Results

The performances of concrete designed by incorporating PVC were evaluated in terms of strength by performing compressive strength test, split tensile test, elastic modulus and flexural tests. These test results along with the density of PAC is illustrated in Table 3.

Table 3. Results of Concrete Properties

Batches	Percentage replacement of Plastic aggregate (%)	Density (kg/m ³)	Compressive strength (MPa)		Split Tensile strength (MPa)	Modulus of Elasticity (GPa)	Modulus of Rupture (MPa)
			7 days	28 days			
PC	0	2445	32.3	46.0	5.15	25.0	7.6
PAC1	10	2377	34.0	48.0	5.73	25.2	7.8
PAC2	20	2233	33.7	47.3	5.31	24.3	7.3
PAC3	30	2211	32.0	45.7	5.09	23.8	6.9
PAC4	40	2200	29.7	43.3	4.98	22.9	6.2
PAC5	50	2156	28.0	39.7	4.78	20.3	5.7

The compressive strength was determined at the end of 7 and 28 days whereas split tensile test, elastic modulus and flexural tests were conducted at the end of 28 days. The 28 days compressive strength varies between 48 to 39.7 MPa. A marginal increase in compressive strength (4.34%) was found by replacing fine aggregate with plastic waste and thereby increase in replacement shows a sign of reduction in strength. This reduction in compressive strength of concrete by the increase of addition of plastic waste may be due to the reduction in bond strength between plastics and cement paste. Similar trend of results were also obtained by Choi et al 2005 [7]. The variation in the split tensile strength test was in the range between 4.78 - 5.73 MPa. The reduction in the strength results by adding plastic fibres more than 20% is also due to the bond strength only. The failure pattern of the cylinder it was visible the crack does not occur in the plastic, but goes around the plastic aggregate. In the case of control concrete, the failure took place right through the aggregates in control concrete indicates the higher bond strength between the aggregates and cement pastes. Similar results were also obtained during elastic modulus test and flexural strength results. The elastic modulus obtained was in the range between 20.3 to 25.2 GPa. During the testing it was found that using plastic aggregates in concrete more than 30% there was

a sudden drop in the strain after achieving the peak load. The modulus of rupture was determined using four point loading test with a span of 400mm. The results were also in similar trend to those of compressive and split tensile results. Due to the weak bond strength between the cement and plastic aggregates the results varied between 5.7 to 7.8 MPa. The density of PAC varies from 2156 to 2445 kg/m³, indicating a saving in the self-weight between 2.7 % and 11.8 % compared to the density of normal-weight concrete.

5. Conclusion

The present study investigated the effectiveness of using waste PVC for the partial replacement of sand in concrete. Various tests such as compressive strength test, split tensile strength test, elastic modulus and flexural strength were performed.

- In the case of replacing fine aggregate with partially with PVC, compressive strength increases by 4.34% and 2.80% and split tensile strength increases by 11.2% and 3.10% at 10% and 20% of replacement of plastic wastes. After which the compressive strength as well as split tensile strength starts declining due to weak bond strength between the plastics and cement mortar.

- The unit weight of PVC batches decreases with increases in percentage of replacement of plastic waste.
- Since the unit weight of the specimen decreases drastically, when taken into practical considerations the total dead load of the structure will decline.
- Utilization of PVC as fine aggregate replacement in concrete has the dual benefit of reducing the costs of disposal and lowering the cost of the concrete.
- The utilization of waste PVC in concrete provides additional environmental as well as technical benefits for all related industries.
- Applications may also include those where low strengths are desirable, such as utility trench backfill. Other applications may include low rise housing.

Thus we can conclude that PVC can be used as a replacement of fine aggregate in concrete. This would lead to the reduction in construction cost and proves to be eco-friendly. These types of alternative would lead to reduction in land filling issues and aids in sustainable development also.

References

- [1] Boutemur, R., Taibi, M., Ouhib, N., Bali, A., 2004. "Investigation of the use of waste plastic as aggregate for concrete" In: International Conference, Sustainable Waste Management and Recycling: Challenges and Opportunities, 14–15. Thomas Telford Publishing, Thomas Telford Ltd., London, ISBN 0727732854.
- [2] Panyakapo.P., Panyakapo.M., 2007. "Reuse of thermosetting plastic waste for lightweight concrete."Waste Management, 28, 1581-1588, (2008).
- [3] www.cpcb.nic.in&www.urbanindia.nic.in (Government of India).
- [4] IS: 12269 (1987, Reaffirmed: 2004), "Code of Practice: Specification for 53 Grade OPC," Bureau of Indian Standards, New Delhi.
- [5] IS: 383 (1970, Reaffirmed: 2002), "Code of Practice: Specification for Coarse and Fine Aggregates from Natural Sources for Concrete," Bureau of Indian Standards, New Delhi.
- [6] ASTM C143., (2010), "Standard Test Method for Slump of Hydraulic Cement Concrete" American Society of Testing and Materials, pp. 1–4.
- [7] Choi, Y.W., Moon, D.J., Chung, J.S., Cho, S.K., 2005. "Effects of waste PET bottles aggregate on properties of concrete". Cement and Concrete Research 35, 776–781.
- [8] T. Padmapriya and V. Saminadan, "Priority based fair resource allocation and Admission Control Technique for Multi-user Multi-class downlink Traffic in LTE-Advanced Networks", International Journal of Advanced Research, vol.5, no.1, pp.1633-1641, January 2017.
- [9] S.V.Manikanthan & T.Padmapriya "Recent Trends In M2m Communications In 4g Networks And Evolution Towards 5g", International Journal of Pure and Applied Mathematics, ISSN NO:1314-3395, Vol-115, Issue -8, Sep 2017.

