Performance Study of Waste Plastic and Industrial Waste Based Polymer Concrete

M. B. Gaikwad[1], D.S. Badade[2], P. D. Kamble[3], S. B. Gorade[4]
[1, 2, 3] UG students, [4]Asst. Professor, Department of Civil Engineering,
Pimpri Chinchwad College of Engineering, Pune, Maharashtra, India

Abstract

The need for proper housing, better communication system gave a boom to the construction industry and then the production and utilization of cement has increased. Cement production causes environmental pollution due to CO_2 emission. Not only there is a need to address the problem of environmental pollution caused by cement manufacturing but also high usage of potable water for various activities like cement production, preparing concrete mix, curing of concrete etc. Plastic is non-biodegradable, so the disposal of plastic waste is of major concern now. Also due to the development of industries, generation of industrial waste is also increasing e.g. copper and steel slag; stone, granite and marble dust; rice husk, fly ash. Such industries are facing waste disposal problems. In this study, an attempt was made to eliminate cement, water and use plastic waste for making an industrial waste based polymer concrete. Polymer has been used as a substitute to cement and water for binding purpose. In this experimental work the aggregates used was industrial waste considering environmental issues and disposal. Granite has been used as a coarse aggregate and copper slag has been used as a fine aggregate. To control the plastic waste disposal problem, shredded plastic has been incorporated by 2% of the total volume of the mix. Three mix proportion of coarse aggregate to fine aggregate have been adopted. The study revealed that compressive and split tensile strength of manufactured polymer concrete gives very high strength after one day drying and without any use of water

Keywords: *copper slag, fly ash, granite waste, polymer concrete*

1. Introduction

Construction industry is developing rapidly. Concrete is a widely used construction material. It is the second most consumed substance on earth after water. Cement production leads to carbon dioxide emission which is very harmful to atmosphere. It is estimated that, for the production of 1 ton of cement, 1 ton of carbon dioxide is emitted which causes an increase in carbon footprint [9]. Plastic is non-biodegradable product and it harms the environment. It also causes leaching problem in dumping yards. India produces over 15000 ton of plastic waste daily. Maharashtra is the 18th state in India which has put plastic ban on 23rd March 2018 considering 'World Environment Day', but not much awareness and control is seen till date [10]. Many industries facing waste disposal problem like disposal of copper & steel slag; stone dust, granite and marble dust; rice husk, fly ash etc. Industries are currently facing waste management problem. Use of industrial waste after processing as a construction material is a cost effective and environment friendly way to dispose it.

2. Literature Review

N. K. Bui et.al. (1) Conducted an experimental study on recycling woven plastic sack waste and PET bottle waste as fiber in recycled aggregate concrete. This paper deals with experimental study of mechanical properties and durability of concrete using recycled woven plastic sack (RWS) and recycled polyethylene terapthalate (RPET) fibers. RWS and RPET fibers were immersed into three different hydrated concrete solutions which had various pH values of 12.43, 12.61 and 12.79. They used RWS and RPET fibers with silica fume in different proportion of plastic fibers i.e. 25%, 50%, 75%. Design mixes were tested for compressive strength, splitting tensile strength and shear strength. The experimental results concluded that the RPET fibers give better result than woven sack fibers (25% addition of fibers).

Rajat Saxena et.al.(2) studied the impact resistance and energy absorption capacity of concrete containing plastic waste. In this paper an experimental work was carried out with using OPC-43 grade, natural sand as fine aggregate, coarse aggregate and plastic waste (shredded PET bottles). 5%, 10%, 15% and 20% of plastic by weight of concrete was used. Each concrete mix was subjected to three temperatures i.e. 30ºC, 300ºC and 600ºC for knowing the resistance to temperature. They carried out compressive strength test, impact resistance test and energy absorption capacity of concrete which contain PET bottle waste. The results show that there was decrease in compressive strength of plastic waste concrete due to exposure to elevated temperature. It also enhances the ductile behavior of concrete and increase the energy absorption capacity.

Khalifa S. Al-Jabri et.al.(3) studied the performance of high strength concrete made with copper slag as a fine aggregate at constant workability and also studied the effect of super plasticizer addition on the properties of HSC made with copper slag. They found out that when they used copper slag up to 50%, then workability increases; compressive strength, flexural strength and tensile strength may increase. After performing all experiments, they conclude that there was almost 22% reduction in water demand at 100% copper slag replacement, superplasticizers can be used to avoid dryness and segregation of concrete and 20% compressive strength increases with 100% copper slag replacement.

Narendra Kumar Sharma et.al.(4) studied the properties of concrete containing polished granite waste as a partial substitution of coarse aggregate. The granite waste has been used with different mix proportions from 0% to 40%. These mixes were designed for 0.38, 0.40, and 0.42 water to cement ratio. There was increase in workability and bulk density with increasing amount of granite waste but reduction in water absorption and depth of water penetration. The compressive strength and flexural tensile strength of concrete gradually decreases with increase in amount of granite waste above 20%.

Gavril Sosoi et.al (5) studied the effect of waste as aggregate substitution in polymer concrete. The polymer concrete was prepared with epoxy resin and aggregate in two sorts. Fly ash was used as a filler and aggregate of 0 to 4 mm were replaced in different proportion by saw dust and pet bottles. Tests for density, workability and compressive strength were conducted after 14 days. The density of hardened polymer concrete with saw dust and PET bottles as aggregate substitution was less than conventional concrete. The workability of fresh concrete increased with increase in the PET dosage while the workability reduced with increase in the dosage of saw dust. PET bottle polymer concrete gave very good results for compressive strength. All printed material, including text, illustrations, and charts, must be kept within the parameters of the 8 15/16-inch (53.75 picas) column length and 5 15/16-inch (36 picas) column width. Please do not write or print outside of the column parameters. Margins are 3.3cm on the left side, 3.65cm on the right, 2.03cm on the top, and 3.05cm on the bottom. Paper orientation in all pages should be in portrait style.

3. Materials

3.1. Plastic

Low density polyethylene (LDPE): Low Density Poly Ethylene (LDPE) used as shredded plastic in this experimental study. LDPE is produced when ethylene is heated at high pressure (up to 3,000 bars) and temperature of 100 to 300ºC in the presence of free radial initiator. It is ductile and flexible material and it is stable in the temperature range from -50 to 85ºC. The melting point of LDPE is from 105 to 115ºC. It is light in weight because of its low density that ranges from 0.197 to 0.931 g/cm^3.

3.2. Copper Slag

Copper slag is produced during pyro metallurgical production of metal from copper ores. It is a by-product of copper extraction by smelting. Slag that is quenched in water produces angular granules which are disposed of as waste or utilized. Copper slag has been used as a fine aggregate; passing through 4.75 mm IS sieve and retained on pan.

Table no 1: Copper Slag Physical Properties

Sr. No.	Name of test	Test result
1.	Moisture content test	0.1%
2.	Water absorption test	2.44%
3.	Bulk density	2.238 kg/lit
4.	Fineness modulus	3.97
5.	Silt content	1.33%
6.	Specific gravity	3.92

3.3 Granite Tile Waste

Granite aggregates are produced from large ore crushing machinery and waste material from granite industry. They were crushed hard rock of granular structure. Granite tile waste has been used as a coarse aggregate; passing through 20mm IS sieve and retained on 4.75mm IS sieve.

Table no 2: Granite Aggregate Physical Properties

Sr. No.	Name of test	Test result
1.	Water absorption test	0.5%
2.	Bulk density	1.68 kg/lit
3.	Specific gravity	2.71
4.	Fineness modulus	4.51
5.	Silt content	Nil
6.	Aggregate crushing value	21.3%
7.	Los angels abrasion	22%
8.	Aggregate impact value	18.5%

3.4. Fly Ash as filler

Filler is used in concrete to increase its density. Fly ash has been used as filler. It is a coal combustion product. It is produced as small dark flecks by the burning of powdered coal or other materials and is carried into the air. Fly ash particles are generally spherical in shape and range in size from 0.5µm to 300 µm.

Table no 3: Fly Ash Physical Properties

Sr. No.	Name of test	Test result
1.	Color	Whitish grey
2.	Bulk density	0.994 gm/cc
3.	Moisture content	3.14%
4.	Average particle size	6.92 µm
5.	Specific gravity	2.28
6.	Fineness	272 m^2/kg
7.	Silt content	Nil

3.5. Polymer

Epoxy resin has been used as a polymer in concrete. Epoxy resin is defined as a molecule containing more than one epoxide groups. They help to improve the mechanical strength, chemical resistance and water tightness of the concrete structure.

4. Methodology

The following trial mixes have been designed by referring the thesis "A study on the mix design of polymer concrete made with polyester and epoxy resins" [6]. It is seen that the optimum content of filler for making a polymer concrete was 40% while the percentage of polymer upto 30%.

Table no 4: Trial Mix for 15% Polymer

Mixes	Mix 1	Mix 2	Mix 3
CA:FA	3:2	2:1	1:1
Coarse Aggregate	25.8%	28.66%	21.5%
Fine Aggregate	17.2%	14.33%	21.5%
Shredded Plastic	2%	2%	2%
Polymer	15%	15%	15%
Filler	40%	40%	40%

Table no 5: Trial Mix for 30% Polymer

Mixes	Mix 1	Mix 2	Mix 3
CA:FA	3:2	2:1	1:1
Coarse Aggregate	16.8%	18.66%	14%
Fine Aggregate	11.2%	9.33%	14%
Shredded Plastic	2%	2%	2%
Polymer	30%	30%	30%
Filler	40%	40%	40%

PVC pipe of 15 cm diameter and 30 cm height has been used as mould for casting the samples. The cylinder dimensions have been finalized referring ACI committee 211. The samples have been casted for 3 mix proportions of coarse aggregate (CA) to fine aggregate (FA), 3:2, 2:1 and 1:1. First, the dry mix of aggregates and plastic was made and later epoxy resin and hardener was added. The percentage of polymer and filler has been kept constant. Compressive strength test and split tensile test has been performed on the samples casted. Total 18 samples have been casted and tested.

Figure no.1. a) Demoulded Test Samples B) Failure under Compression Testing C) Failure under Split Tensile Testing

5. Result

The cylinder specimens (150mm dia. and 300mm length) were casted and tested for compressive strength of concrete for various mixes given in table 4 and 5. The compressive strength results are presented in table 6 and figure 2. It was observed that the average compressive strength for mix 3:2, 2:1, 1:1 are 46.78 MPa, 36.31 MPa and 28.67 MPa respectively. The maximum compressive strength of 46.78 MPa is observed for mix 3:2.

Table no. 6 Compression Test Results

Mix	Sample no.	Load (KN)	Compressive strength (Mpa)	Average compressive strength (Mpa)
3:2	1	820	46.402	46.78
	2	840	47.534	
	3	820	46.402	
2:1	1	650	36.782	36.31
	2	645	36.499	
	3	630	35.650	
1:1	1	510	28.860	28.67
	2	490	27.728	
	3	520	29.426	

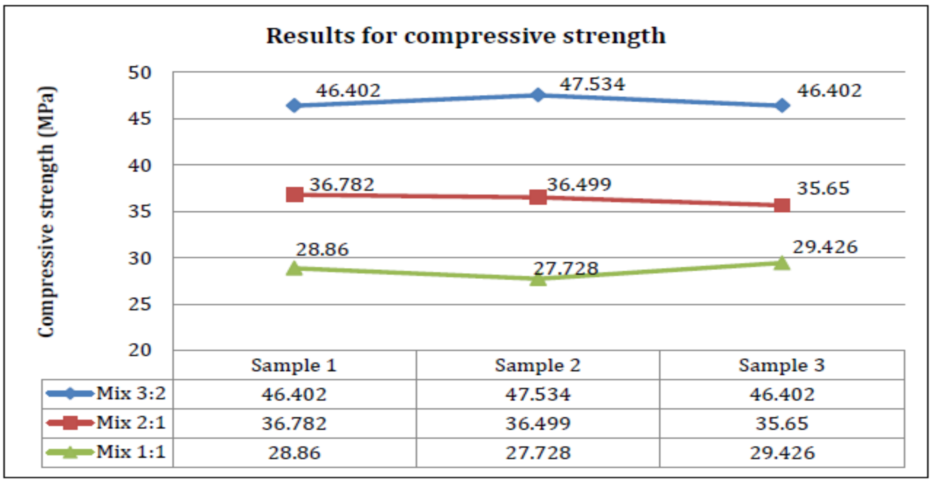

Figure no 2. Compressive Strength Test Results

Split tensile test on cylinder specimens have been performed on compression testing machine, confirming to IS 5816-1970. The specimen was kept horizontal and load was applied gradually. The split tensile strength results are presented in table 7 and figure 3. It was observed that the average split tensile strength for mix 3:2, 2:1, 1:1 are 6.55 MPa, 5.05 MPa and 4.19 MPa respectively. The maximum split tensile strength of 6.55MPa is observed for mix 3:2. As per IS the average split tensile strength of concrete mix should not be less than 10% of its compressive strength.

Table no. 7 Split Tensile Strength Test Results

Mix	Sample no.	Load (KN)	Split Tensile strength (Mpa)	Average Split Tensile strength (Mpa)
3:2	1	480	6.790	6.55
	2	470	6.649	
	3	440	6.224	
2:1	1	340	4.810	5.05
	2	370	5.234	
	3	360	5.093	
1:1	1	300	4.244	4.19
	2	290	4.103	
	3	300	4.244	

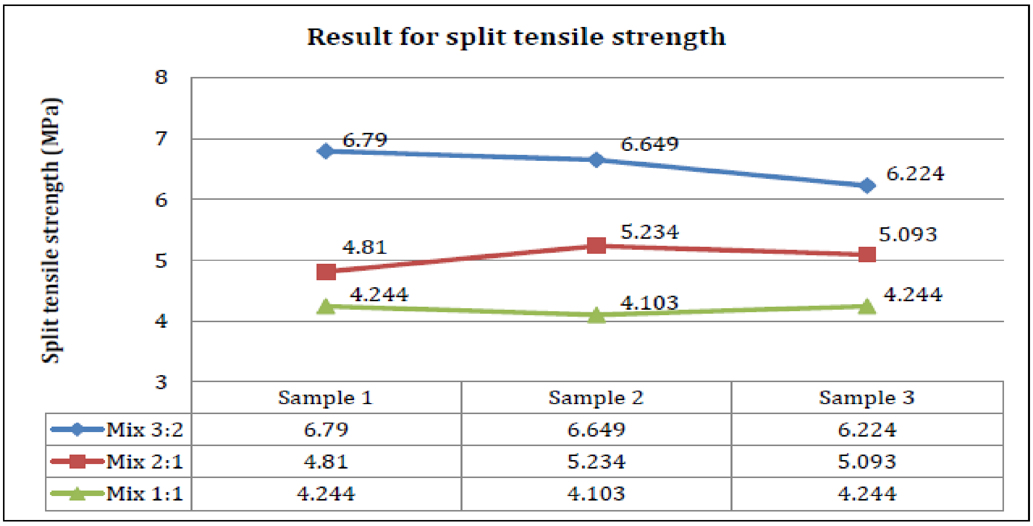

Figure no 3. Split Tensile Strength Test Results

6. Discussion

The designed polymer concrete mix gives high strength as compared to conventional concrete mix. Mix 3:1 gives maximum compression strength (46.78 MPa) and maximum tensile strength (6.55MPa).The designed polymer concrete attains its maximum strength within 1 day, whereas conventional concrete gives maximum strength after 28 days. Densities of the designed polymer concrete mixes 3:2, 2:1 and 1:1 are 2588.44 kg/m^3, 2553.53 kg/m^3 and 2658.01 kg/m^3 respectively. It is more than the conventional concrete (2400 kg/m^3). No use of cement for binding and no use of water for mixing and curing the design mix hence waterless concrete possible. Industrial waste like granite and copper slag have been successfully used as a replacement to coarse aggregate and fine aggregate respectively. A successful attempt to incorporate plastic waste in the designed polymer concrete mix has been made so as to reduce the problem of plastic waste management. Fly ash is a thermal power plant waste and it has been used to reduce the binder content as well as increase the density of mix. Design concrete mix hardens within 2 hours and gives maximum strength in one day. So, there is reduction in construction time.

7. Conclusion

From the finalized mix proportions, best results of compressive and split tensile strength were obtained for 3:2 mix. While deciding the trial mixes we observed that as fly ash increases, the density of concrete mix also increases upto 40% use of fly ash. Granite and copper slag have good density thereby improving the mechanical properties of the mix. It was observed that the designed concrete mixes have high strength, high density and early strength gaining property as compared to conventional concrete mix. Taking into consideration the recent scarcity of water, huge amount of water can be saved annually by using designed polymer concrete mix. It also reduces time required for construction work

8. References

8.1. Journal Article

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