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Experimental Research on the Behaviour of Concrete Containing Waste Plastic Granules as a Fine Aggregate Replacement

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Abstract*— with the tremendous increase in population and changing lifestyle of people, plastic has inevitably become a part of human life. In India about 5.6 million tonnes is generated as plastic waste per annum which leads to 15,342 TPD (tonnes per day). About 70% of plastic consumed is discarded as waste. Plastics have already started showing its alarming signs such as land pollution, ocean pollution, release of poisonous gases, soil infertility, immune disorder in birds etc. A prospective appeal to this is usage of plastic granules which are produced from low density polyethylene and high density polyethylene in concrete as a replacement of fine aggregate. The aim of this research is to compare the strength characteristics of conventional concrete of grade M20 with the plastic concrete. A potential application of plastic concrete is pavement base, sub base and lightweight concrete construction.

Keywords — plastic concrete, granules, aggregate, strength.

I. INTRODUCTION

With the increase in industrialization and urbanization plastic has placed its foot print in all aspects of life. Plastic being used in electrical appliances, household materials, for packaging, as insulators, automobiles, electronic appliances, furniture and also building appliances like piping and plumbing equipments, as a result plastic has become an unavoidable thing in this world.

But only 25% of the waste plastic is recycled and the rest of 75% ends up in the landfills, oceans etc polluting the environment to adverse extent. Improper disposal of plastic leads to release of hazardous chemical gases affects human health causing impaired immunity, infertility and may cause asthma. Plastic also harms birds and animal habitat. Hence these materials must be rightly disposed off or economically recycled. Some of these waste materials may be used in construction activities. The usage of industrial leftover materials for construction reduces the consumption of natural resources, formulates an economical disposal method for the waste material as well.

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Plastics can be majorly classified into two different types based on their density namely high density polyethylene and low density polyethylene. Both HDPE and LDPE can be shredded to granular form and added to replace fine aggregate of concrete. Presence of these plastics in too much manner in gravel mining and stream sand causes the river degradation. Sand mining also affects the adjoining groundwater system and the uses that local people make of the river. In stream sand mining results in the destruction of aquatic and riparian habitat through large changes in the channel morphology. Hence plastic granules can be used as aggregate replacement to a certain extent that serves the purpose of proper disposal of plastic and also to save the nature's resources.

II. RESEARCH SIGNIFICANCE

As per the estimation of UN researchers, Single use plastics or in disposable items such as grocery bags, cutlery and straws are used by publics for about 250 billion annually. About 8 million tonnes of plastic are dumped into the oceans in each year, these equivalents to truck full garbage every minute. In India alone 5.6 million tonnes per annum is generated and also the plastic wastes from the US ends up polluting the mother land.

The existing method of disposal of plastic includes land filling, incineration, recycling and biodegradation. But due to lack of knowledge and having less concern over the environment plastic always end up being thrown into the landfills recklessly causing hazardous pollution and consuming a greater area which needs high manpower and equipment to clean the landfills.

Hence this study can help to determine whether plastic granules can be replaced in place of fine aggregates and its optimum usage. This can serve as an affordable method of reusing the plastic that cause great menace to the environment.

III. RESEARCH OBJECTIVE

This project is to formulate a procedure to use conventional concrete materials with recycled plastic granules. The main objectives of this experimental study are

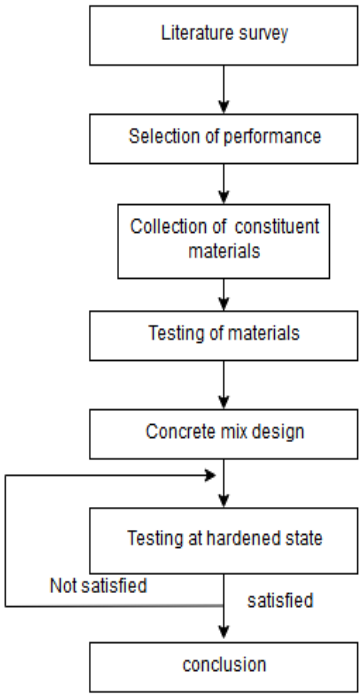
- To investigate whether recycled plastic granules can be used in concrete
- To test the hardened properties of concrete with the plastic granules

- To find which kind of plastic (low density polyethylene, high density polyethylene) is efficient.
- To test the 7,14,21,28 days of strength of 5% replaced plastic granules as fine aggregate replacement.
- If plastic can be used as a fine aggregate replacement, determining whether high density polyethylene (HDPE) or low density polyethylene (LDPE) is efficient.

IV. RESEARCH METHODOLOGY

In this experimental work, the concrete mix having characteristic compressive strength of 50Mpa has been tested with varying percentage of HDPE and LDPE ranging from 0% to 20%. The tensile and compressive strength of plastic concrete were investigated. The methodology followed in the current research is given as flow chart in figure1.

Fig1.Research Methodology



4.1 Materials

4.1.1Cement

Ordinary Portland cement of grade 53 along with the following basic properties like Specific Gravity 3.09, Fineness (wt of residue) 7%, Final setting time 235 min, Initial setting time 35 min, Soundness 3.6 mm, Compressive Strength of 31.5 MPa on 3rd day, 46 MPa on 7th day, 58 MPa on 28th day.

4.1.2 Fine Aggregate

Manufactured sand, Fineness Modulus 2.65,Specific Gravity 2.78, , Density 2.3 gm/cm^3,water absorption 1.05%, , Dry rodded Bulk Density 1610 kg/m3, Loose Bulk Density 1430 kg/m3, free from clay / organic matter.

4.1.3 Coarse Aggregate

Coarse Aggregate of size 12.5mm size are manufactured from Crushed blue granite in angular shape with Specific Gravity 2.61, , Dry rodded bulk density 1480 kg/m3, Fineness modulus 5.9, Loose bulk density 1290 kg/m3

4.1.4 Plastic granules

Recycled HDPE and LDPE. Specific gravity 0.76, 4.75mm sieve, angular shape, density of LDPE 903 kg/m3.density of HDPE 970 kg/m3.

Fig. 2. Recycled plastic granules

4.1.5 Water

As per ASTM C1602 / C1602M – 12[39] specifications potable water is used .

4.2 Mix design

The concrete has been designed for characteristic strength of 20Mpa. The concrete has been designed by replacing fine aggregate by (5% low density polyethylene and high density polyethylene. The mix design has been prepared according to IS 10262 (2009). The maximum cement content does not exceed more than 450kg/m3. The water content does not exceed 200lit/m3.

Table I. Mix design of plastic concrete

Plastic concrete mix design					
Cement	***Fine Aggregate***	***Coarse Aggregate***	***Water***	***HDPE***	***LDPE***
Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3	Kg/m^3
438.18	916.59	1220.14	197.16	5% FA	5%FA

Fig3. Mix of conventional and 5% (HDPE and LDPE)

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4.3 Preparation of test specimen

Concrete mix is prepared by mixing all the essential materials at room temperature. All the constituents were mixed in dry state and water is gradually added to produce a uniform mix manually using trowel.

4.4 Curing

Steel trowel is used to provide smooth finish over the casted specimens. The casted specimens were stored for 24 hours at room temperature which is approximately 26ºC. Once it get hardened, cubes were demoulded and immersed into the portable water for curing purpose. At the end of curing period, specimens were taken out from the curing tank, allowed to dry and tested.

Table II. Tests conducted on hardened concrete

Test details	Specimen details	Reference
Compressive strength (7^{th}, 14^{th} 21^{st} , 28^{th})	Cube – 150 x 150 x 150 mm	Tests carried out as per BS 1881: Part 116 [41], IS:516-1959 (Reaffirmed 2004)
Split tensile strength (7^{th}, 14^{th}, 21^{st} , 28^{th})	Cylinder – 150 mm diameter and 300 mm long	Tests carried out as per BS 1881: Part 116 [41], IS:516-1959 (Reaffirmed 2004)

V. TEST RESULT AND DISCUSSION

5.1 Compressive strength:

Three cubes (150 X 150 150mm) with 0%, 5% HDPE and 5% LDPE as fine aggregate of each mix were casted to check the compressive strength on 7^{th}, 14^{th}, 21^{st}, and 28^{th} day. The compressive strength on 28^{th} day for conventional mix (0% plastic and 100% sand was 20N/mm$^{2)}$. For 5% replacement of HDPE the compressive strength was 19.5N/mm^{2}. And for 5% LDPE the compressive strength was 19.69N/mm^{2}. Compressive strength of 5% replaced HDPE and LDPE concrete showed a decrease in strength. When comparing LDPE and HDPE, the LDPE contributed to more strength. The reduction in the compressive strength may be due to the improper bonding of plastic granules. This is due to the lack of adhesion between plastic and cement.

Table III. Compressive strength test result

Compressive strength of concrete (N/mm$^{2)}$				
% Replacement	7^{th}	14^{th}	21^{st}	28^{th}
0%	15.66	17.32	19.7	20
5%HDPE	13.21	15.22	18.5	19.5
5%LDPE	13.27	15.35	18.9	19.69

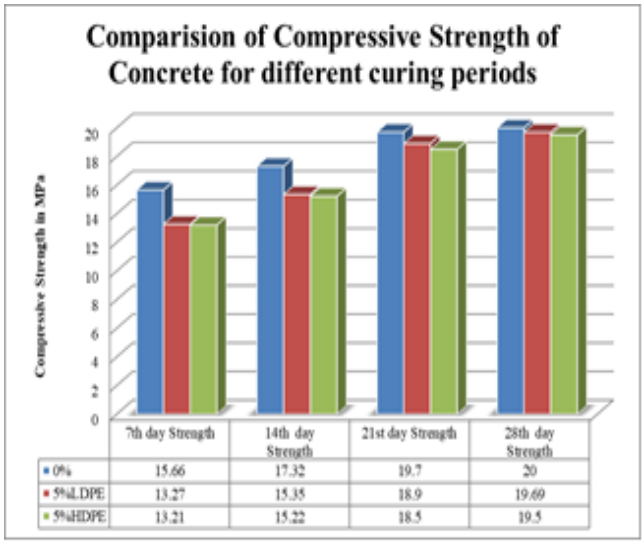

Fig 3. Variation of compressive strength

5.2 Tensile strength

Three cylinders each measuring (150mm diameter and 300mm long) were checked for 0%, 5% HDPE and 5% LDPE fine aggregate replacement. The tensile strength showed opposite result as that of the compressive strength.

The tensile strength of conventional mix was 3.15MPa. The tensile strength of 5% HDPE was 3.30MPa and 5% LDPE was 3.2MPa . HDPE showed same behavior as fiber reinforced concrete increasing the tensile strength. The fibrous nature of plastic due to shredding provided internal shear and tension reinforcement preventing the spread of cracks.

Table IV. Split tensile strength test result

% Replacement	Tensile strength (28^{th} day) Mpa
0%	3.15
5% HDPE	3.30
5% LDPE	3.18

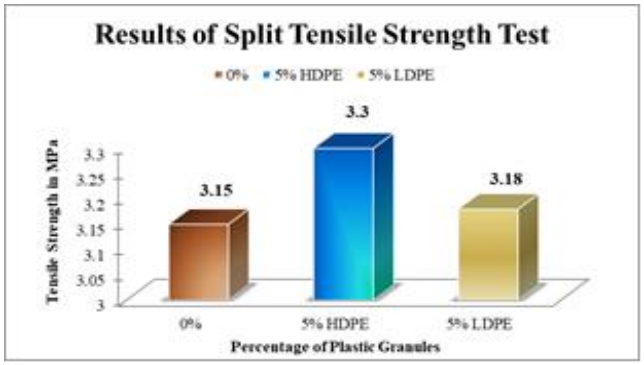

Fig4. Variation of Tensile strength

VI. CONCLUSION AND RECOMMENDATIONS

i) During the research, it is observed that, workability of concrete decreased with addition of plastic due to their angular shape and irregularity.

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ii) It is determined that there is reduction in the compressive strength of plastic concrete. But LDPE showed higher results than HDPE which is almost equal to the conventional concrete

iii) The overall cost of the mix is reduced and also serves as a purpose to utilize the waste plastic that decreases the land pollution

iv) The tensile strength of the concrete increases with addition of plastic granules. HDPE is preferred over LDPE to increase the tensile strength of concrete.

v) This research attributes to the commercialization of waste plastic granules that can reduce the total cost

vi) Finally the research reveals that, the plastic concrete does not increase the compressive strength, hence it cannot be used for load bearing structures , it can be for pavements, lightweight concrete structures, partition walls etc,.

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