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Experimental study on use of HDPE plastic aggregate in concrete

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ABSTRACT

Construction industry with its wide scope and specializations in various Civil Engineering branches became a possibility with the introduction of new construction techniques, equipment and building materials worldwide. The much anticipated and foreseen upset in development is picking up energy. Analysts and different foundations are taking innovation to the following level. Advancement in concrete and different other development materials has been forceful and serious. The overall market for development totals is extended to progress to 51.7 billion T in 2020, speaking to a yearly development pace of 5.2%. Natural resources for construction materials are depleting and disappearing at a very fast pace. Hence the need for alternative materials and methods are important. On the other hand, disposal of plastic waste in environment is considered to be a big problem due to its very low biodegradability and presence in large quantities. One of the solutions for this problem is utilization of plastic waste such as HDPE (High Density Polyethylene) plastic as aggregate in building construction, which is also a partial solution for environmental and ecological problems. Hence this work aims to investigate the effect of using waste HDPE plastic as partial replacement of coarse aggregate by volume in concrete with percentage replacement ranging from 0%, 10%, 20%, and 30% taking the strength criteria of M25 concrete. This paper also intends to examine the experimental study of flexural strength of RCC beams casted with both conventional and plastic concrete and compare the results also to utilize it for industrial purpose.

Key words: Plastic concrete, Plastic aggregate, Compressive strength, Flexural strength

INTRODUCTION

Concrete is a well-known heterogeneous mix of cement, aggregates and water. The worldwide demand for new concrete buildings is increasing at a rapid pace to keep up with urban development. On the other hand, disposal of plastic waste in environment is considered to be a big problem due to its very low biodegradability and presence in large quantities. Plastics have been used in packaging, automotive and industrial applications, medical delivery systems, artificial implants, other healthcare applications, water desalination, land/soil conservation, flood prevention, preservation and distribution of food, housing, communication materials, security systems, and other uses. With such enormous and fluctuating applications, plastics add to a regularly expanding volume in the strong waste stream. Plastics present issues in earthly and sea-going conditions. Few biodegrade, and filter unsafe synthetic compounds into water and soil upon throwing away. Land-filling of plastic is additionally perilous because of its moderate corruption rate and cumbersome nature and harmfulness.

Recycling plastics is a possible option but burning plastic releases toxic substances for solving the disposal of large amount of plastic materials. It can be used to produce new plastic waste products after processing. The Utilization of waste HDPE (High Density Polyethylene) plastic in concrete is a partial solution for environmental and ecological problems.

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HDPE plastic

High-density polyethylene, as the name suggests, has a higher specific density than low-density polyethylene, though this difference is only marginal. What really makes the difference in the physical properties of HDPE is the lack of branching, meaning it is light with a high tensile strength. Because there is no branching the structure is more closely packed, make HDPE a linear polymer. The branching can be controlled and reduced by using specific catalysts during production. HDPE has many advantageous properties that make it important in the manufacturing of different products. HDPE has a comparatively high density compared to other polymers, with a specific gravity of 0.95. HDPE is relatively hard and resistant to impact and can be subjected to temperatures of up to 120^{o}C without being affected. HDPE is primarily used for milk containers, as well as Tupperware, shampoo bottles, bleach bottles and motor oil bottles.

Plastic Recycling and Re-using

Reusing strategies and development applications incorporates Chemical alteration, Mechanical reusing, and Thermal handling and utilized as Fillers. Plastics can be reused by concoction alteration or depolymerization. The two different ways to accomplish depolymerization for example hydrolysis (concoction disintegration) and pyrolysis (warm deterioration). Mechanical reusing of plastics alludes to measures which include liquefying, destroying or granulation of waste plastics. Warm handling comprises of warming a thermoplastic at exceptionally high temperatures, consequently making the plastic stream. The plastic is then changed over into new item as it cools. Plastic waste can likewise be utilized as fillers with virgin pitches or different materials like cement or as fill materials in street development.

Plastic Concrete

- HDPE Plastic can be used in concrete with percentage replacement for coarse aggregate.
- The basic materials for mixing Concrete are
- Cement,
- Sand, Water
- Aggregate and
- HDPE re-cycled Plastic

AIMS AND OBJECTIVES

- To study the effect of plastic aggregate as a partial replacement of coarse aggregate by volume in concrete.
- To perform laboratory tests those are related to compressive and flexural strength by using HDPE plastic aggregate in concrete.
- To analyze the flexural behavior of plastic beams.
- To compare the flexural strength, crack behaviours and failure modes of plastic beams with ordinary concrete beams.

METHODOLOGY

The flowchart given explains the detailed methodology of this study.

LITERATURE REVIEW

This chapter includes a brief account of the published literature related to the present investigation. Several experiments have been done in the past to study the behaviours and mechanical properties of plastic modified concrete. The following papers are the studies based on the specimens like cubes, prisms and cylinders (including fresh concrete properties and hardened concrete properties)

Ashwini Manjunath B T (2016**)** discussed about the utilization of E-waste particles as fine and coarse aggregates in concrete with a percentage replacement ranging from 0 %, 10% to 30% i.e. (0%, 10%, 20% and 30%) on the strength criteria of M20 Concrete. Compressive strength, Tensile strength and Flexural Strength Concrete with and without E- waste plastic as aggregates was observed which exhibits a good strength. The attainability of using E-squander plastic particles as incomplete substitution of coarse total has been introduced. In the current examination, compressive quality was researched for Optimum Cement Content and 10% E-plastic substance in blend yielded soundness and awesome in compressive quality of 53 evaluation concrete [1].

Rafiq Ahmad Pirzada (2018) discussed about the replacement of natural coarse aggregate by plastic aggregate and replacement ranging 0%, 5%, 10%, 15% and 20% by the weight of the coarse aggregate. Strength of concrete was increased by using super plasticizer polycarboxylate ether in design mix M25 grade concrete. In this investigation it was found that concrete properties got improved rather than previous work done on the use of waste plastic as coarse aggregate in addition with plastic coarse aggregate. The workability of concrete was insisted by slump cone showed increment. The compressive strength increases up to 15%, tensile and flexural shows increment up to 10%. The most important change brought about using plastics is that the thermal conductivity of concrete is reduced using waste plastic concrete. Therefore, it can be said use of plastic waste in concrete can reduce environmental concern and can save our land from becoming barren [2].

Ahmad K. Jassim (2017) examined the chance of plastic concrete. i.e., high thickness polyethylene squander is blended in with Portland concrete, and contemplated the impact of supplanting sand by fine polyethylene squander with various rate on the properties of item. The investigations were finished by utilizing the misuse of polyethylene bundles incorporate jug and food cartons in the scope of 10% to 80% by volume as a short support structure. The outcomes show that there is alikelihood to deliver plastic concrete from polyethylene waste and Portland concrete by utilizing 60% and 40%, separately. Also, their thickness was diminished, flexibility expanded, and the functionality improved, which lead to deliver lightweight materials [3].

Feng Liu, Yong Yan (2015) investigated about recycled plastic concrete (RPC) that uses recycled acrylonitrile-butadiene-styrene/polycarbonate copolymer (ABS/PC) plastic particles to replace 5, 10, 15, and 20% (in volume) of fine aggregate sand.. The static and dynamic mechanical properties of specimens made of 5, 10, 15, and 20% plastic aggregate in volume were measured on a mechanical testing machine. The cube strength, axial compressive strength, and static stress-strain relationship of the RPC specimens with different plastic content were obtained. The ultimate compressive strength, ultimate strain, and dynamic stress-strain relationship of these specimens were measured with a split Hopkinson pressure bar device under four different strain rates. The stress-strain curves and energy absorption of the RPC specimens with different plastic content were obtained under the four different strain rate levels. The influences of plastic content and strain rates on the mechanical properties of RPC were analyzed. The results showed that the energy absorption capability of RPC was higher than that of normal concrete and increased with the plastic content [4].

Md. Mostafizur Rahman (2012) reused squander polymeric materials as a substitute for totals in concrete has been explored in the investigation. Two unique kinds of waste polymer, specifically polyurethane formaldehyde (PUF) based bundling waste and high thickness polyethylene (HDPE) were reused and utilized in the test. Cement and workmanship poly block examples were readied utilizing reused polymer materials, and test examples were portrayed. The impacts of waste polymer a material on the mechanical, physical and morphological properties of cement and poly obstructs have been examined. The outcome shows that the consideration of waste polymer materials diminishes thickness, porosity and water retention of cement and poly impedes fundamentally. Polyurethane formaldehyde (PUF) based square showed lower thickness than that of HDPE-based cement. Because of uncommonly low thickness, reused polymer adjusted squares and cement can be utilized in non-load bearing structures, coasting structures and where lightweight materials suggested [5].

Anju Ramesan (2015) examined the solidness and holding attributes of reused plastic total in concrete. The current examination zeroed in on the impacts of sulphuric corrosive, hydrochloric corrosive and sodium sulfate on the resultant cement. From the test, sulfate assault, corrosive assault and chloride assault on concrete were estimated. The got outcomes upheld the utilization of high thickness polyethylene total for halfway substitution of characteristic total. Holding of plastic total in concrete is likewise a significant boundary to be estimated. Holding of plastic total cement was tried and concentrated with the

assistance of pull-out contraption. From the outcomes, holding worry of solid blend was discovered to be 0.4 N/mm2 and that of 30 rate substitution was 0.44 N/mm2. This demonstrates the holding of plastic total is nearly the equivalent to that of regular total [6].

Noridah Mohamad1 (2017) explored the basic conduct of strengthened solid pillar inserted with high thickness polyethylene balls (HDPE) exposed to flexural load. The HDPE balls with 180 mm breadth were inserted to make the circular voids in the bar which lead to decrease in its self-weight. Two pillar examples with HDPE balls (RC-HDPE) and one strong shaft (RC-S) with measurement 250 mm x 300 mm x 1100 mm were projected and tried until disappointment. The outcomes were examined with regards to its definitive burden, load-diversion profile, and break example and disappointment mode. It was discovered that a definitive heap of RC-HDPE was diminished by 32% contrasted with RC-S pillar while the greatest avoidance at its mid-range was expanded by 4%. Notwithstanding, RC-HDPE is seen to be more flexible contrasted with RC-S pillar. The two kinds of shafts experienced flexure splits and inclining pressure breaks before disappointment [7].

PROPERTIES OF MATERIALS USED

Cement

Cement is a fine powder, produced by heating limestone and clay minerals in a kiln to form clinker, grinding the clinker, and adding 2 to 3 percent of gypsum. Pozzolona Portland cement has adhesive and cohesive properties. So that it forms a good bond with other materials. It solidifies when mixed with water. Cement imparts strength to concrete. In this project Ambuja Cement is used. The properties of concrete utilized were given in table beneath.

SL.NO	PROPERTIES	VALUES OBTAINED
1	Specific gravity	2.95
2	Initial setting time	30 minutes
3	Consistency	31%

Coarse aggregates

The materials whose particles are of size are retained on IS sieve NO.480 (4.75mm)is termed as coarse aggregates.

SL.NO	PROPERTIES	VALUES OBTAINED
1.	Specific gravity	2.8
2	Water Absorption	1%

Fine aggregates

River sand passing through 4.75mm is used

SL.NO	PROPERTIES	VALUES OBTAINED
1	Specific gravity	2.95
2	Fineness modulus	2.6 -2.9
3	Water Absorption	3%

Water

Water is an important ingredient in concrete as it actively participates in chemical reaction with cement. The water which was used for making concrete was clean and free from harmful impurities such as oil, alkali, acid etc. By and large, the water which is good for drinking ought to be utilized for making concrete.

HDPE plastic aggregate

High-thickness polyethylene, as the name recommends, has a higher explicit thickness than low-thickness polyethylene. HDPE is basically utilized for milk holders, just as Tupperware, cleanser bottles, fade jugs and engine oil bottles.

SL.NO	PROPERTIES	VALUES OBTAINED
1.	Specific gravity	0.95
2	Water Absorption	0%

Mix design

Concrete mix design is defined as the appropriate selection and proportioning of constituents to produce a concrete with predefined characteristics in the fresh and harden states. As a rule, concrete blends are planned so as to accomplish a characterized usefulness, quality and toughness.

Mix design proportions

- Cement = 455.56 kg/m3
- Water =205 kg/m3
- Fine aggregate =865.64 kg/m3
- Coarse aggregate =915.1 kg/m3
- Water cement ratio =0.45

Then, Mix proportion (by wt.) =455.56: 865.64: 915.1
= 1: 1.9: 2
Minimum cement content as per IS code 456 is 280 kg/m^3

ANALYSIS AND RESULTS

Specimen study

Compressive strength results of cubes

Sl.No	Percentage replacement of plastic aggregate in concrete (%)	Avg. compressive strength (7 days, N/mm^2)	Avg. compressive strength (28 days, N/mm^2)
1	0	20.79	33.12
2	10	22.33	32
3	20	17.50	30.1
4	30	16.44	27.25

Beam study

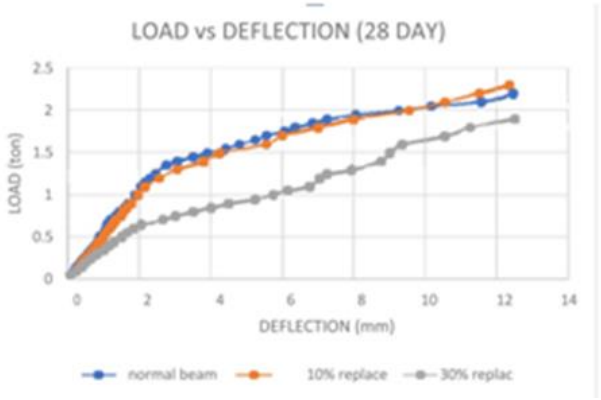
The experimental study consists of designing, casting and testing of beams to find out the flexural behavior of specified mixes. The beams were casted with the normal mix and the mix with 10 % and 30 % of plastic aggregate replacing coarse aggregate. Structural beams were designed as per IS 456:2000 with mixed design 1:1.9:2 and they are designed as under reinforced sections with minimum reinforcement. Fe500 steel and M25 concrete are used for this study.

Dimensions of the beam l x b x d = 3200 x 150 x 200 mm

Flexural strength results

Sl.No	Item	Load at failure (T)	Flexural strength(N/mm^2)
1	Conventional beam	2.2	11.5
2	10% replacement	2.3	12.02
3	30% replacement	1.9	9.92

Comparison and results of beams based on load deflection curve



DISCUSSION

After conducting specimen study and beam study in M25 mix design of concrete, the results were compared. Both the compressive and flexural strengths with cube test and beam study shows that compressive strength in cube test and flexural strength in beam study displayed an inferior performance in specimens with plastic aggregate. From the graph, it is clear that plastic beam with 10% replacement of coarse aggregate with plastic aggregate shows almost the same performance compared to the conventional beam but plastic beam with 30% replacement shows bad performance compared to the conventional beam. Water cement ratio used is 0.45. With water cement ratio less than 0.45, better results can be acquired. However weight of the concrete will be reduced which may have an effect on the structural load. Taking into consideration, the disposal of plastic waste and reduced use of non-renewable resources like natural aggregates, plastic concrete will be an option in the construction industry.

CONCLUSIONS AND RECOMMENDATIONS

Utilizing the waste HDPE plastic as partial substitute for coarse aggregate in concrete reduces the issues of disposing the waste.

Findings of this project can be concluded as follows:

From the specimen study

- Compressive strength slightly decreased with increasing plastic ratio
- Weight of the modified concrete reduced with increasing plastic ratio.
- From the results, 10% replacement of plastic aggregate in concrete with W/C ratio 0.45 can be considered for industrial purpose

From the beam study

- In terms of crack morphology, crack propagation, the behavior of the plastic beam and conventional beams were virtually identical.

- Plastic beam shows more ductile behavior than conventional beam.
- The plastic beam shows more load carrying capacity and large mid span deflection.
- Plastic beam shows more ductile behavior than conventional beam.

Recommendations from this project are

- Plastic concrete can be considered as a light weight concrete
- Plastic beam can be used in concrete with a replacement of 10% coarse aggregate.
- Best solution for the disposal of HDPE plastic waste.
- Reduce the use of non-renewable resources like natural aggregates.

In this project M25 mix is used to compare the properties. Further study can be done including higher grade mix. Further study can be done including higher grade mix. Lower water cement ratio may be used to improve the properties of concrete.

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