Study On Partial Replacement of Powdered Waste Plastic with Fine Aggregates in Concrete

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Abstract: Using powdered waste plastic as a partial replacement for fine aggregates in concrete is a concept that has gained attention in recent years as a sustainable and environmentally friendly approach to waste management. Incorporating waste plastic into concrete can have several potential benefits, but it also comes with certain challenges. The objective is to develop a suitable composition for a concrete mixture by replacing fine particles with pulverised and granular plastic. To attain the desired strength, the design incorporates a combination of pulverised and granular plastic in concrete, taking into account specific properties such as density, workability, flexural strength, compressive strength, and tensile strength. The restricted movement of aggregates caused by the plastic's resistance could explain the impact of the plastic on the concrete's workability. Moreover, the dried density is reduced, resulting in the formation of a lightweight concrete. The inclusion of waste plastic material in concrete results in a reduction of compressive strength compared to traditional concrete.

Key Words*: Waste Plastic, Concrete*

1. INTRODUCTION:

The issue of plastic pollution has become increasingly significant in modern society as a result of the significant increase in the production and use of plastic items. India has a daily plastic pollution output of approximately 15,000 tons, out of which only 9,200 tons undergo recycling while the remaining quantity is disposed of on land. The current global challenge that the international community is facing is the implementation of sustainable development practices with a focus on environmental conservation. The global consumption of plastic is experiencing a significant and rapid increase due to a wide range of factors. The utilization of chemical additives in plastic production can lead to potentially harmful outcomes. Hence, it is imperative to engage in recycling practices or implement rigorous surveillance measures to effectively manage the disposal of this plastic waste. Groundwater contamination occurs as a result of the persistent and non-biodegradable decomposition process of plastic bags, which can endure for over a thousand years. Due to their non-biodegradable properties, plastics have a significant impact on the environment by causing contamination in the air, water, and soil. To mitigate adverse environmental effects, these minerals have the potential to be utilized in alternative industries.

Sand mining, the reason behind sand mining is the enormous use of concrete in the construction sector. All raw materials in concrete mixture are essential but sand and gravel is far the most important constituent. The reason behind the sand mining is most widely used of sand and gravel in construction. Theses raw materials of concrete are rapidly growing in demand in areas around the world. It will mostly harm the environment. It leads to erosion of the riverbed and banks, increase in channel bed slope, changes in channel morphology, physical habitats and food webs. It plays an important role in barriers against like floods, heavy storms and earthquakes. The persistent problem of environment in the developing world has now become so serious that existence of river ecosystem and earth surface has been disturbed with excessive amount of sand mining.

2. LITERATURE REVIEW

A study was conducted by **Prahllada (2009)** to evaluate the durability and efficacy of waste plastic fibre reinforced concrete (WPFRC) produced using recycled aggregates. The aspect ratio of the residual plastic fiber-reinforced concrete is 50:1. The volumetric proportions of the concrete vary from 0% to 3%. The results suggest that incorporating 1% fibers into concrete has the potential to produce waste plastic fiber reinforced concrete. This particular form of concrete exhibits enhanced mechanical properties and ease of handling, particularly when incorporating both recycled and traditional aggregates.

Ramesh .et .al (2009) The primary aim of the study conducted was to evaluate the potential of incorporating low density polyethylene plastic waste as a reinforcement material in concrete by partially replacing the coarse particles. Various concrete mixtures were created by adding recycled plastic aggregate, which is produced by subjecting waste plastic to thermal treatment in a plastic reprocessing device, in proportions of 40%, 0%, 20%, and 30% by weight. The concrete mixture formulation consists of a ratio of three parts aggregate, one part grit, and one-half part cement, with a water-to-cement ratio of 0.5. It is feasible to achieve an 80% enhancement in strength by replacing a maximum of 30% of plastic debris. After observing a notable decline in the compressive strength, the proportion of plastic aggregate is subsequently augmented. Additional research is necessary to assess the long-term strength and resilience of plastic aggregate when used in construction elements such as columns and beams. The current study highlights the utilization of recycled plastic aggregate as a substitute for lightweight aggregate.

Mariaenrica frigione (2010) conducted an investigation on the effects of Polyethylene Terephthalate (PET) plastic remnants present in concrete. Plastic particles were introduced into the concrete mixture at weight percentages varying from 5% to 5%. The results indicated that PET concrete exhibited similar workability characteristics, with slightly reduced fracture and compressive tensile strengths compared to the reference concrete. However, the ductility of PET concrete was significantly improved.

In a study conducted by **Raghatate, Atul M. (2012)**, the compressive and split tensile strengths of a concrete mixture that included plastic bag fragments were determined through the analysis of experimental data. The “concrete mixture consists of Ordinary Portland cement, natural river sediment used as coarse and fine aggregate, and varying proportions (0.2%, 0.4%, 0.8%, and 1%) of refuse plastic bags.The inclusion of supplementary plastic bag fragments in concrete leads to a decrease in its compressive strength. The inclusion of 1% plastic bag fragments in the concrete mixture leads to a significant decrease of 20% in the compressive strength of the mixture. In contrast, the tensile strength of the concrete mixture is enhanced by 0.8% through the inclusion of plastic bag fragments”. Nevertheless, the inclusion of plastic bag fragments exceeding 0.8% in the concrete mixture leads to a deterioration of its structural integrity. Based on the research findings, the incorporation of plastic bag fragments into the concrete mixture has the potential to enhance its split tensile strength. Additional investigations will evaluate the implications of altering the configuration and dimensions of the plastic bags.

Suganthy et al. (2013) conducted a “study to assess the practicality of utilizing coarsely pulverized plastic high density polyethylene as a partial replacement for fine aggregate. To fabricate concrete specimens, pulverized plastic sand was substituted for natural sand in varying ratios: 0%, 25%, 50%, 75%, and 100%. To achieve the desired 90mm concrete sag, it is necessary to increase the water-cement ratio, resulting in a greater replacement of sand. The compressive strength of the concrete experienced a gradual reduction of 25% following the replacement of plastic fine aggregate, as evidenced by the collected data. The concrete exhibited a significant decline in strength as a result of the heightened utilization of plastic fine aggregate”.

3. OBJECTIVES

The objective is to develop a suitable composition for a concrete mixture by replacing fine particles with pulverised and granular plastic. To attain the desired strength, the design incorporates a combination of pulverised and granular plastic in concrete, taking into account specific properties such as density, workability, flexural strength, compressive strength, and tensile strength.

4. METHODOLOGY

The selection of the components in the concrete mixture was done in compliance with the relevant standards and guidelines. The materials that are linked with concrete are classified based on their relevant physical properties. A fine aggregate consisting of pulverized and powdered waste plastic was added to the concrete mixture. Waste plastic has been crushed by grinding machine in dump yard. After that shredded

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plastic can be converted in powder form by milling machine. The size of crushed plastic was 3 mm to 1 mm.

Figure 1: Shredded waste plastic

The M20 grade concrete was produced following the guidelines specified in IS: 10262-2009, which served as the reference mix design. A proportionate quantity of plastic debris, pulverized to four percent, was utilized as a substitute for the tiny particles. Pulverized plastic waste was partially substituted at concentrations of 2%, 4%, 8%, and 12%. The process of casting concrete was infeasible without the need for replenishing the fine aggregate. A total of five samples, comprising of both cubes and cylinders, were fabricated for each unique percentage. These samples were then subjected to evaluation at three different time intervals: 7, 14, and 28 days. Upon the conclusion of the casting and curing procedures, a total of 75 spherical objects and 75 cylindrical objects were successfully fabricated.

5. RESULTS AND DISCUSSION

The compressive strength of concrete is determined by various factors, such as the strength of the cement used, the ratio of water to cement, the quality of the materials used in the concrete, and the implementation of quality control procedures during the production process. To perform compressive strength tests, specialized equipment such as cubes or cylinders is employed. Multiple established protocols recommend the use of concrete cubes and cylinders as the designated specimens for analysis.

- Apply lubricant and disinfectant to the cube form in a comprehensive manner. Following that, exercise prudence while depositing three layers of concrete into the mould, with each layer measuring approximately five centimetres in thickness.
- Utilising a standard 16mm steel rod equipped with a rounded tip, each layer was pulverised using a consistent application of 25 strokes.
- Utilise a trowel tool to achieve a flat and smooth surface on the topmost layer, followed by a complete 24-hour period for the material to fully harden.

Table 1: Compressive strength of different grades of concrete at 7 and 28 days

Grade of Concrete	Minimum compressive strength N/mm2 at 7 days	Specified characteristic compressive strength (N/mm2) at 28 days
M15	10	15
M20	13.5	20
M25	17	25
M30	20	30
M35	23.5	35
M40	27	40
M45	30	45

SPLIT TENSILE STRENGTH TEST ON CONCRETE CYLENDERS

Compression testing machine, "two packing strips of plywood 30 cm long and 12mm wide, cylindrical mould (3mm thickness, 100mm internal diameter and 200mm height), a metal base plate mould, the tamping rod etc.

Procedure:

- Clean the cylindrical moulds and apply grease it properly. Fill the concrete in the moulds in 3 layers
- Each layer was tempted 25 times with a standard temping rod.
- Level the top surface and smoothen it with a trowel, put cylindrical mould for 24 hours of setting.
- After de-molding put moulds in water for 7, 14 and 28 days of curing.

Testing of Concrete Mix Design (M20)

Design Stipulations

- Characteristic compressive strength required in the field at 28 days 20 MPa
- Maximum size of aggregates-20 mm
- Degree of quality control- good
- Type of exposure- Mild
- Specific gravity of cement-3.16

Design of grade M20 concrete:

Target mean strength of concrete (Ft) = f_{ck} + 1.65 S (f_{ck} = 20)

Assume standard deviation = 4

F_t = 20+1.65(4) = 26.6 MPa

- Water Cement Ratio required Target mean strength of concrete of 26.6 MPa is 0.50
- Water Cement Ratio from durability considerations 0.55
- Adopt the lower value for water cement ratio 0.50

Table 16: Adjustments of water and sand contents:-

Change in condition	Percentage adjustment required	
	Water content	Sand in total aggregates
For decrease in water cement ratio by 0.60-0.50=0.10 $\frac{0.1}{0.05} \times 1 = 2$	0	-2.0
For increase in compacting factor0.9-0.8 = 0.10 $\frac{0.1}{0.1} \times 3 = 3$	+3	0
For sand confirming to zone III of table 4 in IS383 : 1970	0	-1.5
Total	3	3.5

From Table 2 clause-4.2, A-5 and B-5(BIS 10262- 2009) for 20 mm nominal maximum size aggregates and sand confirming to grading zone II water content m^3 of concrete 186 kg/m^3 and sand content as percentage of total aggregates is 35%

Required water content = 186+ $(\frac{186 \times 3}{100})$ (note 3% adjustment of water)

= 186+5.58 = 191.6 lit/m^3

Required sand content as % of total aggregates = 35 – 3.5 = 31.5%

Required air content = 2%

- **Determination of cement content: -**

Water cement ratio = 0.5

Water = 191.6 lit/m^3

Cement = $\frac{\text{water}}{\text{water cement ratio}}$ $\frac{191.6}{0.5}$ = 383.2 $kg/m3$

- **Determination of fine and coarse aggregates: -**

Size of coarse aggregates = 20mm

Air content = 2%

Water = 191.6 lit/m^3

Cement = 383.2 $kg/m3$

Absolute volume of total aggregates (V_a) =

$1.0 - (W + \frac{c}{Sc}) \frac{1}{1000} - v$

Where, V = the air content (m^3) of concrete. 2%

Sc = specific gravity of cement. 3.15

W = Mass of water per cubic meter of concrete 191.6 lit/m^3

C = mass of cement per cubic meter of concrete 383.2 $kg/m3$

$V_a = 1.0 - (191.6 + \frac{383.2}{3.15}) \frac{1}{1000} - \frac{2}{100} = 0.666$ m^3

For the absolute volume of coarse and fine aggregates per unit volume of concrete may be calculated for the given relation:

Volume of fine aggregates (V_{fa}) = pV_a (note required sand content as % p of total aggregates 31.5%)

$= \frac{31.5 \times 0.666}{100} = 0.209$

Volume of coarse aggregates (V_{ca}) = (1-p) V_a

$= (1 - \frac{31.5}{100}) \times 0.666 = 0.456$

The mix proportion by mass (kg) is given by:

Water: cement: fine aggregate: coarse aggregate

W: C : $V_{fa}S_{fa}$ (1000): V_{ca} S_{ca} (1000)

191.6 : 383.2 : 0.209×2.65 (1000) : 0.456 × 2.60 (1000)

191.6 lit/m^3 : 383.2kg/m^3 : 553.85kg/m^3 : 1185.6kg/m^3

S_{fa},S_{ca} = specific gravities of saturated surface dry fine and coarse aggregates in kg/l

6. CONCLUSION

In order to promote environmental conservation, contemporary environmentalists endorse the principles of "reduce, recycle, and reuse." Conversely, the concept of "Replace" has gained significant recognition as a national slogan. Other refuse materials, including glass, are interchangeable. Over the course of time, the advancement of innovative recyclable primary materials by enterprises could potentially lead to a decrease in waste generation. Alongside significant economic growth, the twenty-first century observed an unparalleled surge in environmental apprehensions. Without a doubt, the scale and intricacy of global environmental problems, such as pollution, deforestation, resource depletion, and sand mining, may make our individual efforts appear insignificant. Environmental preservation refers to the systematic efforts undertaken by individuals, groups, or governmental entities to safeguard the natural world, with the aim of promoting the well-being of both the environment and humanity. The main reason of global warming is increasing amount of carbon dioxide in environment as we know that while manufacturing of construction such as buildings, roads and bridges etc. are increasing day by day to create big problem for this. Plastic waste is a viable partial replacement for fine aggregates in structural concrete. It have similar properties as fine aggregates and also safe for environment because while the production of powdered plastic waste amount of carbon dioxide emission is too small which leads to healthy environment. So, powdered plastic wastes are also known as green pozzolanas. Second and most important factor for construction is cost, as both are available at very reasonable cost; powdered plastic waste has lower cost. Powdered plastic waste is also used as admixture which replaces the additional use of admixture. As, in the production of both the product, there is negligible emission of carbon dioxide which directly leads to Global Warming

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