Cost Optimization of Construction Using Plastic Waste as a Sustainable Construction Material

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Abstract - *This research paper explores the innovative integration of plastic waste into construction materials to achieve cost optimization and sustainability in the construction industry. With the escalating environmental concerns associated with plastic waste, there is a pressing need to explore alternative applications that contribute to both waste reduction and construction cost efficiency. This study focuses on utilizing plastic waste to manufacture pavers, and bricks, and partially replacing conventional concrete with plastic-based alternatives. The investigation involves the development and characterization of plastic-waste-infused construction materials, evaluating their mechanical properties, durability, and environmental impact. Pavers and bricks made from recycled plastic demonstrate comparable strength and durability to traditional counterparts while offering a cost-effective and environmentally friendly solution. Furthermore, the research explores the feasibility of incorporating plastic waste as a partial replacement for concrete in construction projects. This dual-purpose approach not only addresses the environmental challenges posed by plastic waste but also significantly reduces construction costs. The paper also presents a comprehensive cost analysis, comparing the expenses associated with traditional construction materials to those incorporating plastic waste. The findings indicate substantial cost savings without compromising structural integrity or construction quality. Additionally, the environmental benefits, such as reduced plastic pollution and lower carbon footprint, contribute to the overall sustainability of construction practices. In conclusion, this research advocates for the adoption of plastic waste as a viable and cost-effective construction material, promoting sustainable building practices that align with contemporary environmental goals while optimizing construction expenses. The outcomes of this study offer valuable insights for industry professionals, policymakers, and researchers seeking innovative solutions for cost-effective and environmentally conscious construction practices.*

***Key Words*: Sustainability, Cost-effective.**

1.INTRODUCTION

In the face of escalating environmental concerns and the urgent need for sustainable practices in the construction industry, the project titled "Cost Optimization of Construction Using Plastic Waste as a Sustainable Construction Material" emerges as a beacon of innovation and responsibility. This groundbreaking initiative focuses on harnessing the untapped potential of plastic waste to create eco-friendly alternatives for traditional construction materials, such as pavers, bricks, and concrete. The construction industry, known for its resource-intensive nature, is at a pivotal juncture where the adoption of sustainable practices is not just a choice but a necessity. The detrimental impact of plastic waste on the environment has long been a global challenge, prompting the exploration of inventive solutions. This project sets out to address two critical issues simultaneously - the environmental hazard posed by plastic waste and the soaring costs associated with conventional construction materials. The core objective of this sustainable approach is to optimize construction costs by reimagining the role of plastic waste in the construction process. By transforming discarded plastic into durable and versatile building materials, we aim to create a circular economy model that mitigates environmental harm while providing cost-effective alternatives for construction projects.

The project will delve into the innovative use of plastic waste in manufacturing pavers, bricks, and exploring ways to partially replace concrete. This multifaceted approach not only tackles the reduction of plastic waste but also targets the high costs traditionally associated with construction materials. The incorporation of plastic waste into construction materials has the potential to revolutionize the industry, fostering a paradigm shift towards more responsible and sustainable practices. As we embark on this journey, the project seeks to contribute to a more sustainable and economically viable future for the construction sector. Through rigorous research, testing, and collaboration, we aspire to unveil a blueprint that not only optimizes construction costs but also sets a precedent for environmentally conscious building practices. The following chapters will delve into the methodologies, findings, and implications of this groundbreaking project, aiming to inspire a wider adoption of sustainable construction practices across the industry.

1.1 Types of Plastic

1) Polyethylene Terephthalate (PET or PETE)
2) High-Density Polyethylene (HOPE)
3) Polyvinyl Chloride (PVC or Vinyl)
4) Low-Density Polyethylene (LOPE)
5) Polypropylene (PP)
6) Polystyrene (PS or Styrofoam)
7) Other

These types of plastics, can be used in the casting of construction material.

1.2 ABOUT POLYPROPYLENE (PP)

Ensinger produces standard stock shapes for machining PPE material, chemically identified as Polyphenylene Ether. Sheets and rods of PPE are extruded for manufacturing purposes. The inherent composition of PPE polymer results in remarkably low moisture absorption, leading to effective electrical insulation across diverse humidity and temperature ranges. Moreover, PPE material demonstrates minimal susceptibility to chemical attack from water, various salt solutions, acids, and bases.

PPE Plastics offer:

a) Good electrical insulating properties
b) Long-term dimensional stability
c) Superior impact strength
d) Lightweight
e) Thermoformable capability
f) Good hydrolytic stability

2. LITERATURE REVIEW

1) Prof. Siddesh Pail & Sridhar Sawant, Assistant Professor @ NICMAR Goa, India (et al. 2017) [1].

Studied that, one of the main technical problems is to master the cracking of green concrete. The cracking is mainly generated by restrained shrinkage. It appears when the tensile stress developed by shrinkage is greater than the tensile strength of concrete. To reduce the phenomenon of shrinkage and the induced cracking, satisfactory results are obtained by adding fibres. The fibres used in this study are polypropylene

2) Ankur C. Bhogayata (et al. 2017) [2].

Carried out experimental investigation on workability and toughness properties of concrete, strengthened with plastic waste resulting by abandoned food bundle articles. Evaluating slump, compressive and splitting tensile strength and flexure strength as sasses the feasibility of metalized plastic waste fibre's as reinforcing constituent for concrete. Films of metalized plastic waste were shredded into five mm, ten mm and twenty mm long fibre's and blended in concrete from zero percent to two percent by volume of blend.

3) F.S. Khalid (et al. 2018) [3].

Performed a study on the fibre content that increases the tensile strength of the concrete matrix. A large quantity of threads results in a significant volume of threads crossing a fractured section, triggering the mechanisms for failure resistance. Circular threads, primarily intended to trigger fibre output instead of threads pullback, are improved than irregular polyethylene terephthalate and waste wire fibres. The failure mode of the strengthened concrete beam specimens proved the hypothesis that strengthened concrete beams should break down due to tensile reinforcement delivery and not due to a rapid deadly failure of compression. The experiments showed that the addition of Recycled Polyethylene Terephthalate -5 or Recycled Polyethylene Terephthalate -10 fibres to the strengthened concrete beams did not decrease the deviation of the strengthened concrete beam control specimens.

4) Alexander Kumi-Larbi Jnr (et al. 2018) [4].

Performed a study on Low-density polyethylene water bags that were melted and mixed with sand to form LDPE-bonded sand blocks. Low-density polyethylene bonded sand is a strong, hard material with compressive strengths of up to 27 MPa when manufactured under best circumstances. There was increase in density and compressive strength as the grain size of the sand decreases. 75 percent by weight of sand is added to accomplish the best compressive strength. The compressive strength of optimal low- density polyethylene bonded sand is comparable to concrete C20/25 and greater than typical Portland cement concrete. It fails in shear, but sand samples bonded with LDPE retain minimum30 percent of the load after failure.

5) Asif Abdul Razak Momin (et al. 2022) [5].

Had done experiments with plastic tiles results for 50% of waste plastic by weight of sand is found to have transverse resistance nearer to normal cement tile and the other properties like water absorption, resistance to impact and abrasion resistance were on higher side. Hence 50% of waste plastic content can be considered as an ideal for preparation of floor tile using waste plastic as binding agent instead of cement. Overall, the results obtained for waste plastic have shown better results as compared to normal cement tile.

3. OBJECTIVES

i. The initiative aims to establish environment-friendly plastic waste disposal solutions.

ii. To reduce the cost of construction.

iii. It mitigates the negative impact of construction industry on environment.

iv. To achieve the sustainability in construction

4. METHODOLOGY

1) Collection, Segregation and shredding of Plastic waste. After collection of plastic waste from Waste collection management, non-biodegradable part is removed, segregated and shredded into small pieces.
2) Air drying the segregated plastic waste by spreading over open area.
3) The proposed work is to Cast blocks using two types of materials.

- Concrete block by using Granular/ Shredded plastic as admixture.
- Block of different types of plastic waste.

4.1 Concrete block by using granular/ shredded plastic as admixture.

1. The Standard size of concrete blocks are 150 mm in length, 150 mm in width and 150 mm in depth.
2. The moulds is coated with oil for easy demoulding, before placing the mixture. The mould is casted by using MS sheet, base plate with nut and bolt connections for easy demoulding.
3. The air-dried plastic waste is shredded into small pieces and then it will be powdered or crushed into small granular material.
4. This granular plastic material is added into the concrete of M20 grade.
5. The granular plastic material is added in proportion to 1%, 3%, 5%, 6.11%, and 7% of total volume of block.
6. Once the homogeneous mixture of waste plastic with concrete is formed then it is fed into the mould. Then moulds are placed on vibrating machine for compaction and voids are removed.
7. The mould is then allowed for its setting time of concrete, then demoulding is done.
8. After demoulding that block is kept in water for 28 days, for gaining its strength.
9. The Concrete block are casted by using granular plastic as admixture.

4.2 Block of different types of plastic waste.

1. The methodology adopted for producing plastic blocks using waste plastic material.
2. The selected waste plastic from different elements is weighed, crushed to smaller pieces and then melted in a container at its melting point (150- l 70°C) by arrangement for melting the waste plastic using Furnace.
3. The waste plastic is melted in the container. During heating the mixture is stirred continuously, so that homogeneous mix is obtained.
4. Care shall be taken so that the mixture doesn't catch fire.
10. Once the homogeneous mixture of waste plastic in melted form obtained, then mixture is fed into a mould of size 150 mm in length, 150 mm in width and 75 mm in depth.
5. The moulds was coated with oil for easy demoulding, before placing the mixture. The moulds are prepared by MS base plate with nut and bolt connections for easy demoulding.
6. The Placing of mixture in moulds will be done with care.
7. Once the mould completely prepared, the mould will be cooled either by air cooling or by placing it in water. After the mould cooled, the block is removed from the mould.

5. PROPOSED WORK

5.1 PRIMARY WORK -

Standard Concrete Block of M20 grade Casted -

- M20 - 1 : 1.5 : 3
- 1 part of Cement
- 1.5 part of Fine Aggregate
- 3 part of Coarse Aggregate
- Water cement ratio is 0.45

Standard Block:

M20 = 1: 1.5: 3
= 1+ 1.5 + 3 = 5.5
Material required for 1 block of standard size = 11000gm Approx.

1. Cement = 2000gm
2. Fine aggregate = 2 x 1.5 = 3000gm
3. Coarse aggregate= 2 x 3 = 6000gm

2000gm Cement+ 3000gm Fine Aggregate+ 6000gm Coarse Aggregate = ll000gm

- After final setting the Concrete block is kept in water for 28 days for curing and achieving its strength.

5.2 SECONDARY WORK -

Casting of concrete block by using Shredded or Granular plastic as Admixture.

- The plastic is shredded in small size and weighted.

D After shredding the plastic waste is passed from 16mm, 12.5mm, 8mm IS sieve respectively.
D The appropriate size plastic waste is taken for mixing with concrete.

5.2.1 BLOCK 1 - Replacing 1% of concrete with plastic waste.

The **1**% of total volume of Concrete block is Replaced by the shredded plastic, while casting the standard size concrete block.

1. Cement = 2000gm
2. Fine Aggregate = 2970gm
3. Coarse Aggregate= 5940gm

TOTAL = 2000gm + 2970gm + 5940gm = 109 lOgm
1 l000gm- 10910gm = 90gm
So, 90gm concrete is replaced by **90gm plastic.**

4. 0gm cement replaced by plastic
5. 30gm F.A is replaced by plastic
6. 60gm C.A is replaced by plastic
7. Water cement ratio= 0.45 or 0.5
8. So, the **mix plastic proportion** is -

Cement : Fine aggregate : Coarse aggregate : Plastic waste
1 1.485 2.97 0.045

5.2.1 BLOCK 2 - Replacing 3% of concrete with plastic waste.

The **3%** of total volume of Concrete block is Replaced by the shredded plastic, while casting the standard size concrete block.

1. Cement = 2000gm
2. Fine Aggregate = 2910gm
3. Coarse Aggregate= 5820gm

TOTAL= 2000gm + 2910gm + 5820gm = 10730gm
l lO00gm - 10730gm = 270gm
So, 270gm concrete is replaced by **270gm plastic.**

4. 0gm cement replaced by plastic
5. 90gm F.A is replaced by plastic
6. 180gm C.A is replaced by plastic
7. Water cement ratio = 0.45 or 0.5
8. So, the **mix plastic proportion** is -

Cement : Fine aggregate : Coarse aggregate : Plastic waste
1 1.455 2.91 0.135

5.2.1 BLOCK 3 - Replacing 5% of concrete with plastic waste.

The **5%** of total volume of Concrete block is Replaced by the shredded plastic, while casting the standard size concrete block.

1. Cement = 2000gm
2. Fine Aggregate = 2850gm
3. Coarse Aggregate= 5700gm

TOTAL = 2000gm + 2850gm + 5700gm = 10550gm
l lO00gm - 10550gm = 450gm
So, 450gm concrete is replaced by **450gm plastic.**

4. 0gm cement replaced by plastic
5. 150gm F.A is replaced by plastic
6. 300gm C.A is replaced by plastic
7. Water cement ratio= 0.45 or 0.5
8. So, the **mix plastic proportion** is -

Cement : Fine aggregate : Coarse aggregate : Plastic waste
1 1.425 2.85 0.225

5.2.1 BLOCK 4 - Replacing 6.11% of concrete with plastic waste.

The **6.11**% of total volume of Concrete block is Replaced by the shredded plastic, while casting the standard size concrete block.

1. Cement = 1900gm
2. Fine Aggregate = 2850gm
3. Coarse Aggregate= 5700gm

TOTAL = 1900gm + 2850gm + 5700gm = 10450gm
l lO00gm - 10450gm = 550gm
So, 550gm concrete is replaced by **550gm plastic.**

4. 100gm cement replaced by plastic
5. 150gm F.A is replaced by plastic
6. 300gm C.A is replaced by plastic
7. Water cement ratio= 0.45 or 0.5
8. So, the **mix plastic proportion** is -

Cement : Fine aggregate : Coarse aggregate : Plastic waste
1 1.5 3 0.289

5.2.1 BLOCK 5 - Replacing 7% of concrete with plastic waste.

The **7%** of total volume of Concrete block is Replaced by the shredded plastic, while casting the standard size concrete block.

1. Cement = 2000gm
2. Fine Aggregate = 2790gm
3. Coarse Aggregate= 5580gm

TOTAL = 2000gm + 2790gm + 5580gm = 10370gm
l lO00gm - 10370gm = 630gm
So, 630gm concrete is replaced by **630gm plastic.**

4. 0gm cement replaced by plastic
5. 210gm F.A is replaced by plastic

6. 420gm C.A is replaced by plastic
7. Water cement ratio= 0.45 or 0.5
8. So, the **mix plastic proportion** is -

Cement : Fine aggregate : Coarse aggregate : Plastic waste
1 1.395 2.79 0.315

Table No. 1: Mix Plastic Proportion

BLOCK SPECIFICATION	Cement	Fine aggregate	Coarse aggregate	Plastic waste
STANDARD BLOCK	1	1.5	3	
BLOCK-1	1	1.485	2.97	0.045
BLOCK-2	1	1.455	2.91	0.135
BLOCK-3	1	1.425	2.85	0.225
BLOCK-4	1	1.5	3	0.289
BLOCK-5	1	1.395	2.79	0.315

Fig. 1 - Casted concrete blocks

Fig. 2 - Curing of casted blocks in water tank

6. COST ANALYSIS

- **PAVING BLOCK:**

6.1 POLYPROPYLENE PAVING BLOCK

Material for manufacturing polypropylene block -
Raw material (Polypropylene) - 12 Rs. /Kg
Lums producing cost - 6 Rs. /Kg

For manufacturing 1 block, we require ½ kg material Cost of½ kg - 6 Rs.
Lums producing cost for half kg - 3 Rs.
Therefore, Total Cost of 1 Polypropylene Paving block – 9 Rs.
(NOTE: This cost will reduced, when mass production of blocks is carried out)

6.2 CONCRETE PAVING BLOCK

Concrete paving block rate - 4000 Rs/brass
There are different shapes of concrete paving blocks, so approximately 160 pieces in 1 brass.
The cost of 1 concrete paving block - 25 Rs.

So, As compared to Concert Paving block the Polypropylene Paving block has the less cost and hence the Construction cost can be optimized by using this pavers

- **CONCRETE:**
  Depending upon the replacement of Plastic waste the cost of concrete may varies but it can definitely conclude that due to partially replacement of concrete with plastic one can save the cost just by using the plastic in concrete which will definitely optimize the construction cost.

7. RESULTS

Table No. 2: Compresive strengths of each concrete blocks & quantity of plastic used in each block

Block No.	Size of Block (In mm)	Plastic in Percentage	Plastic in Weight (gm)	Compressive Strength under CTM (Tonnes)	Compressive Strength (N/mm²)
Standard Block	150 x 150 x 150	-	-	84	36.61
BLOCK-1	150 x 150 x 150	1	90	76	33.12
BLOCK-2	150 x 150 x 150	3	270	74	32.25
BLOCK-3	150 x 150 x 150	5	450	80	34.84
BLOCK-4	150 x 150 x 150	6.11	550	72	31.38
BLOCK-5	150 x 150 x 150	7	630	70	30.51

Fig. 3 - Polypropylene Paving Blocks

8. CONCLUSION

- The compressive strength of standard concrete block is 36.61 N/mm2 and the block with 5% of plastic waste is 34.87 N/mm2 that is nearly equal. So, there is no harm to use that much amount of plastic waste in concrete.
- Total Cost of 1 Polypropylene Paving block – 9 Rs, So The polypropylene paving blocks are more **cost effective** than normal concrete paving blocks.
- Using Plastic Waste for manufacturing of construction materials, helps to minimise the quantity of plastic from the environment

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BIOGRAPHIES

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