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Optimizing the Strength of Paver Block Made from Plastic Waste as Partial Replacement of Sand

Sachin Kumar Yadav[1], Lilawati Chettri[2], Alisha Subba limbo[3], Lancho Lepcha[4], Neema Lhamu Lepcha[5], Prashika Tamang[6]
[1, 2, 3, 4, 5]Students, [6]Lecturer, Department of Civil Engineering, Centre for Computers and Communication Technology, Jorethang (Chisopani) South Sikkim, Sikkim, India

Abstract: The continuously increasing plastic waste quantity is a newly emerging developing global environmental issue, and thus there is a need for newly emerging and environmentally friendly ideas in waste management. Among the solutions that receive consideration is plastic waste[1] use as a replacement factor in the production of building materials with lower environmental degradation and conservation of natural resources. The present study relies on the utilization of plastic waste as a partial substitute for fine aggregate to create concrete paver blocks. The main emphasis relies on making the best use of the highest strength and toughness properties of the blocks by using plastic waste in different percentages of 0%, 2.5%, 5%, 7.5%, and 10% compared to normal paver blocks. As part of the test process, concrete paver blocks were cast and then subjected to a series of mechanical tests, such as compressive strength and water absorption. The optimal 7.5% plastic percentage has a water absorption of 3.7% and a compressive strength of 31.3 MPa after 28 days of cure. According to these results, it is possible to enhance some mechanical properties of waste plastic without appreciably reducing quality. The use of plastic in concrete is a green building practice since it reuses non-biodegradable waste. This study finds a practical and sustainable solution to reduce plastic waste and create environmentally friendly infrastructure.
Keywords: Waste plastics, paver blocks, construction sustainability, waste management, and recycling

I. INTRODUCTION

As part of the test process, concrete paver blocks were cast and also subordinated to a series of mechanical tests, similar as compressive strength and water immersion. The optimal 7.5 plastic chance has a water immersion of 3.7 and a compressive strength of 31.3 MPa after 28 days of cure. According to these results, it's possible to enhance some mechanical parcels of waste plastic without appreciably reducing quality. The use of plastic in concrete is a green structure practice since it reuses on-biodegradable waste. This study finds a practical and sustainable result to reduce plastic waste and produce environmentally friendly structure. By substituting a portion of the traditional aggregates with plastic waste, this research makes a novel and environmentally friendly effort towards minimizing plastic pollution and creating reusable construction material. The research entails the manufacturing of paver blocks using different percentages of plastic waste (0%, 2.5%, 5%, 7.5% and 10%) and corresponding compressive strength and water absorption tests after different curing ages (7, 14, and 28 days)[9]. The major aim is to determine the optimal mix ratio which ensures good structural performance and eco-friendliness. The project assists in the creation of more eco-friendly building materials and assists in recycling plastic waste on a real, large-scale basis.

II. METHODOLOGY

1) Specific gravity test of cement: Specific gravity of cement [6] is the proportion of weight of a standard volume of cement to an equal volume of water. It is a critical parameter applied in quality testing, weight, and fitness of cement for concrete mix design. The test is performed by a Le Chatelier flask using kerosene, an inert substance that does not react with cement. The first volume of kerosene is first taken. A measured quantity of cement is then added. The last volume is measured later. The result of specific gravity of cement is found to be 3.15.
2) Specific gravity of fine aggregate: Specific Gravity Test for Fine Aggregate [6] is an important device for measuring the specific gravity of fine aggregates such as sand, which is necessary for mix design calculations in concrete and other construction materials. It includes a pycnometer, balance, oven, tray, sieve, and distilled water. Bulk specific gravity (SSD) is most common for civil engineering purposes. SSD conditions, preventing air bubbles, and the use of clean, fresh, and distilled water are some of the important points. The result of fine aggregate is found to be 2.63.

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3) Impact test of coarse aggregate: Resistance to shock or tastelessness of coarse total is that which is decided by coarse aggregate impact test. IS 2386(Part IV) – 1963[14] suggests the following the patches passing through a 12.5 mm sieve but not finer than 10 mm sieve are filled in three layers in a spherical vessel and also rammed independently for 25 times. Resistance to shock or tastelessness of coarse total is that which is decided by coarse aggregate impact test. IS 2386 (Part IV) – 1963 suggests the following the patches passing through a 12.5 mm sieve but not finer than 10 mm sieve are filled in three layers in a spherical vessel and also rammed independently for 25 times.

4) Mix design[10]

- Properties of Materials:
- Specific Gravity of Cement (for OPC Grade 43) = 3.15
- Specific Gravity of Fine Aggregate = 2.63
- Specific gravity of water = 1
- Here, F.A. adopts Zone II.

1. Target mean strength of concrete – (f'ck)

- f'ck = fck + 1.65*S
- f'ck = 30 + 1.65*5
- = 38.25 MPa

2. Water-cement ratio = 0.45
3. Water content for 20mm coarse aggregate = 186 kg/m^3 (from table 4 IS 10262-2019)
   For 75mm slump = (186 +186* 3/100)

- = 192kg

4. Calculation of cement content:

- Cement content: water used/ water cement ratio
- 192/0.45 = 426.6 kg/m^3

5. Calculation of coarse and fine aggregate

- volume of C.A. corresponding to 20mm size, Volume of F.A. zone = ii, water-cement ratio = 0.62 (from IS 10262 TABLE 5) But actually W/C is 0.45, so it is less by = 0.5 – 0.45 = 0.05.
- As the W/C ratio is reduced, it is desirable to increase the C.A. proportion to reduce the fine aggregate. C.A. increases at the rate of 0.01 for every decrease in the water-cement ratio of 0.05. (IS10262-19, cl-5.51)
- So, for every decrease of 0.05 W/C ratio, C/A increases by 0.01; for every decrease of 1 W/C ratio, C/A increases by 0.01/0.05.
- For every decrease of 0.15 W/C ratio, C/A increased by
- (0.01/0.05) * 0.05
- = 0.01
- So, the corrected proportion volume of C.A. = 0.62+ 0.01 = 0.63
- Volume of fine aggregate proportion
- 1- volume of C.A. proportion
- 1-0.62 = 0.37

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6. Mix design calculation

- the mix design calculation per unit vol. of concrete
- Volume of concrete = 1 m^3
- Volume of cement = (mass of cement / specific gravity * 1000)
- 426.6/3.15*100 = 0.135 m^3
- Volume of water = (mass of water / specific gravity * 1000)
- = 197.76 / 1 * 1000 = 0.198 m^3
- Volume of entrapped air 1% for 20mm C.A. (IS 10262-2019, Table 3)
- =1/100 = 0.01 m^3
- Volume of all aggregate = (C. A+F.A)
- volume of concrete – (volume of cement + volume of water + volume of entrapped air)
- = (1-0.135+0.198+0.01) = 0.657 m^3
- Design mix calculation as per unit volume of concrete
- Volume of concrete: 1 m^3
- Volume of all aggregate = 0.657
- Mass of coarse aggregate = volume of all aggregate vol. of *C.A.* proportion specific gravity * 1000
- Mass of coarse aggregate = 0.657*0.63*2.68*1000 =1109.27 kg/m^3
- Mass of fine aggregate = volume of all aggregate vol. of F.A. proportion specific gravity * 1000
- Mass of fine aggregate = 0.657* 0.37* 2.4* 1000 =583.4 kg/m^3
- Mass of water = volume of all aggregate. vol. of water - specific gravity * 1000
- Mass of water = 0.657* 0.192* 1* 1000 =126.1 kg/m^3
- Mix proportion = 1:1.3:2.5

Table 1: material weight

material	weight
Cement	427 kg/m^3
Fine aggregate	584 kg/m^3
Coarse aggregate	1110 kg/m^3
Water	127 lit/m^3

5) Process of making blocks: Fine aggregate is substituted with waste plastic to a certain degree in various percentages of 0%, 2.5%, 5%, 7.5%, and 10%. Paver blocks are cast and cured for 7, 14, and 28 days. Mechanical properties such as compressive strength, and water absorption are tested after each curing period[13]. This process helps in the study of the influence of plastic waste on the strength and durability of paver blocks and improves sustainable construction with non-biodegradable waste materials.

Table 2: Material weight by reducing sand at different percentages for three blocks which volume is 26225mm^3

Material	Ordinary paver block (kg)	2.5% Plastic fine Aggregate (kg)	5% Plastic fine Aggregate (kg)	7.5%Plastic fine Aggregate (kg)	10 % Plastic fine Aggregate (kg)
Cement	2.4	2.4	2.4	2.4	2.4
Fine aggregate	3	2.92	2.8	2.77	2.7
Coarse aggregate	6	6	6	6	6
Water	0.7lit	0.7lit	0.7lit	0.7lit	0.7lit
Waste plastic	0	0.75	0.150	0.225	0.300


6) Compressive strength of paver block: Compressive strength is one of the most significant parameters to ascertain the performance of concrete paver blocks, usually made up of cement, fine aggregates, and coarse aggregates, and, in the present study, different waste plastic ratios. The paver blocks, for their durability and strength to resist load, are put under a Compression Testing Machine (CTM) after curing for 28 days as per IS 15658:2019 standards [11,14]. The above requirement ensures that the blocks possess minimum specified strength to sustain their intended applications like walkways, driveways, and paths. Test results provided are essential to optimize the mix design when the plastic waste is utilized along with a sustainable yet effective method by mixing it as partial material.

Plastic waste	Load applied after 7 days (N/mm^2)	Load applied after 14 days (N/mm^2)	Load applied after 28 days (N/mm^2)
0%	22.8	30.5	36.2
2.5%	21.3	28.9	35.4
5%	20.4	28	33.7
7.5%	19.6	27.1	31.3
10%	16.3	25	28.6

7) Water absorption test: Water immersion test determines the porosity and strength of paver blocks by testing the volume of water a dry block absorbs. It's a pivotal test in verification of the quality and strength of the block. The paver blocks are first counted(W1) after drying in a roaster for 24 hours. They're also submerged in water for 24 hours and counted(W2). Water immersion chance is determined by the following formula ((W2- W1)/ W1) × 100. It exhibits low rate as good quality. Paver blocks shouldn't absorb further than 7 dry weights.

Curing tank

Table 3: Water absorption value in percentages

Plastic content	Curing Days		
	7days	14days	28 days
0%	8.6%	6.9%	5.5%
2.5%	8.3%	6.6%	5.2%
5%	7.9%	6.1%	4.4%
7.5%	7.7%	5.8%	3.7%
10%	7.2%	5.4%	3.2%

III. RESULTS AND INTERPRETATION

The lab test examined the effect of plastic waste content with different percentages (0%, 2.5%, 5%, 7.5%, and 10%) on compressive strength of paver blocks and water absorption at 7, 14, and 28 days of curing.

Compressive strength of mixtures enhanced with curing age. Control mix (0% plastic) attained maximum strength at all ages: 22.8 N/mm² (7 days), 30.5 N/mm² (14 days), and 36.2 N/mm² (28 days). However, with an increase in plastic, a declining trend was noticed. Yet, the 7.5% plastic mix had a reasonable ratio, with an increase of 31.3 N/mm² at 28 days, merely 13.5% less than the control mixture. This means that although plastic decreases compressive strength by its non-cementitious nature, at 7.5%, it still provides enough strength for structural use and therefore is an ideal proportion. Above this rate, especially 10%, strength declines more significantly, indicating that excessive replacement results in weaker bonding.

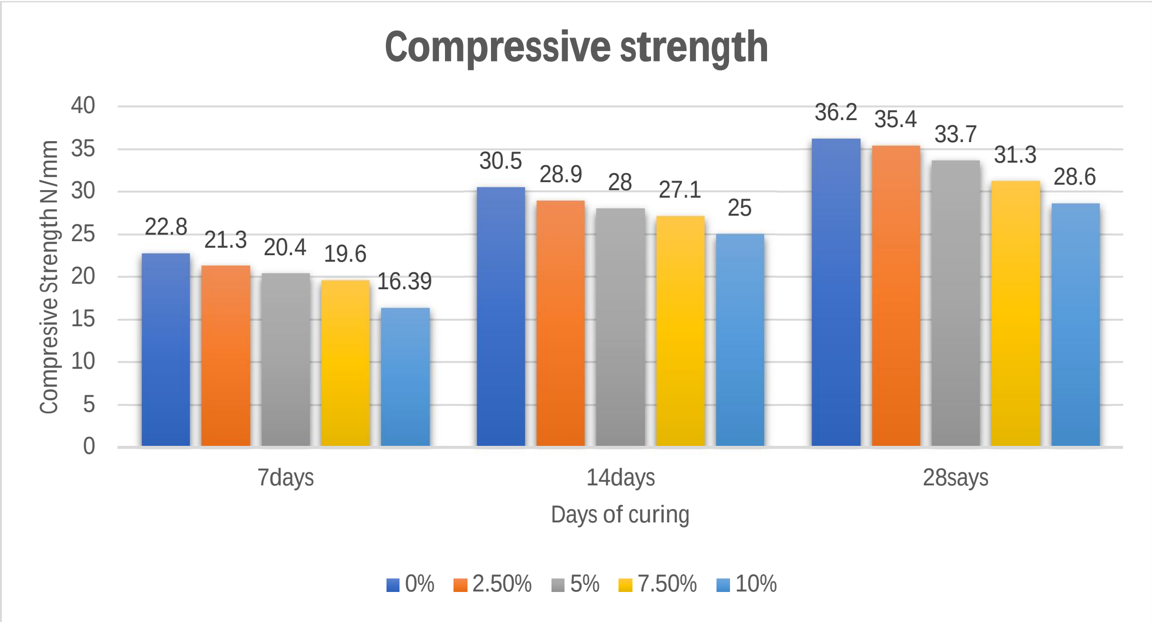

Figure 1: bar graph showing compression strength value of paver block

Water absorption decreased with greater plastic content and curing time. The control mix took up the most (8.6% after 7 days and 5.5% after 28 days), and the least was with the 10% plastic mix (7.2% after 7 days and 3.2% after 28 days). This is because plastic is impermeable, thus the total pore volume of the mix decreases. The 7.5% plastic mixture had a good 28-day uptake of 3.7%, which is within acceptable standards (usually <7%). This implies greater durability and lower permeability, resisting weather and moisture more firmly by the paver blocks.

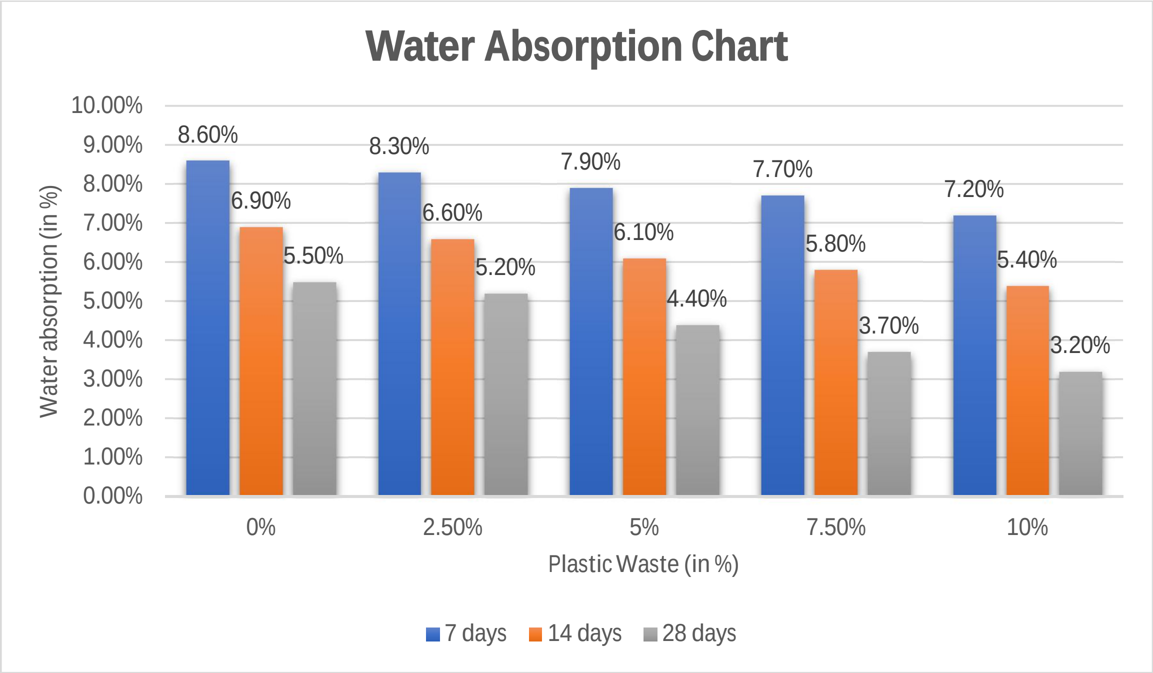

Figure 2: bar graph showing water absorption value

IV. CONCLUSION

The current research has established that plastic waste addition in paver block production has a genuine impact on compressive strength and water absorption properties. Different mixes were taken into account, and plastic waste percentages were changed from 0% to 10%. The outcome of the compressive strength tests has established that more plastic content gets weaker because the plastic is non-cementitious and non-bonding in nature that resists cement-aggregate bonding. The blend with 7.5% plastic waste proved to be the most balanced combination in terms of both strength and sustainability. It had moderate compressive strength, which meant that a minimum of plastic could be used without affecting structure adversely.

Conversely, water absorption decreased with increased plastic content. This is due to the hydrophobic property of plastic, which decreases porosity and water retention ability of the blocks. Decreasing water absorption increases the durability of the paver blocks, which are less water sensitive and resist deterioration by water. Such a property is favourable for outdoor use like pavements and parking lots. The results establish that 7.5% plastic waste replacement is optimal as it provides a satisfactory replacement that is environmentally friendly with minimal environmental pollution and satisfactory mechanical performance. Long-term performance under diversified environmental conditions must also be studied. High-density plastic form performance, thermal insulation effect, and commercial feasibility are issues that future studies need to investigate. Overall, the study encourages green construction practice through the enablement of efficient recycling of non-recyclable plastic waste.

V. ACKNOLEDGEMENT

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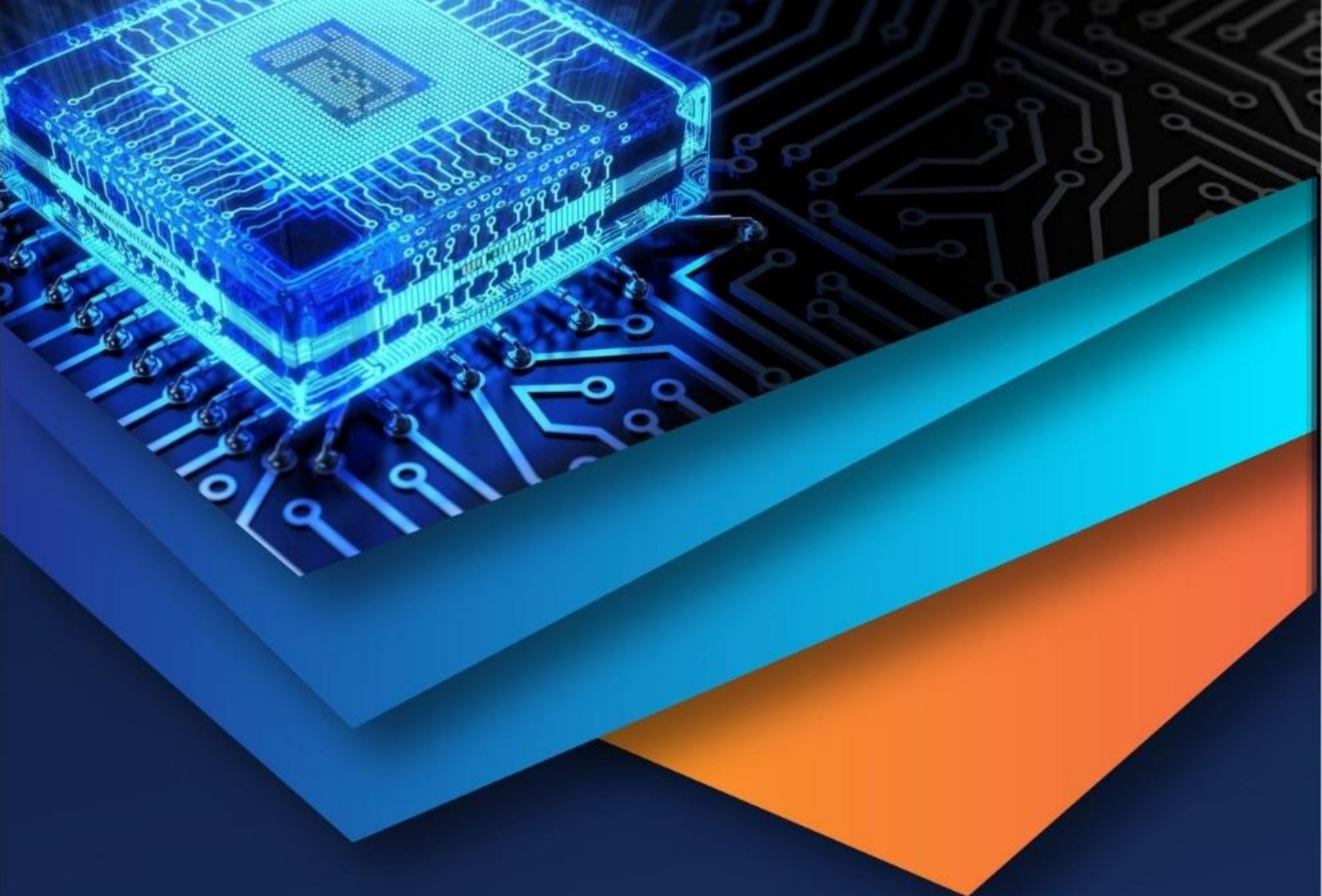

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