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Performance Evaluation of Environmentally Sustainable Precast Cement Concrete Paver Blocks Using Fly Ash and Polypropylene Fibre

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Abstract: In this investigation, fly ash was used as a partial replacement of cement in varying proportions, while polypropylene fibre was incorporated in different dosages to improve the engineering properties and durability characteristics of concrete paver blocks. Different concrete mixes were prepared and paver block specimens were cast under controlled laboratory conditions. The specimens were cured for 7 days, 14 days, and 28 days, and various experimental investigations such as compressive strength test, water absorption test, abrasion resistance test, and durability evaluation were conducted in accordance with relevant Indian Standard specifications. The experimental results revealed that the incorporation of fly ash and polypropylene fibre significantly improved the performance characteristics of concrete paver blocks. The mix containing 20% fly ash replacement and 1.0% polypropylene fibre exhibited the best overall performance in terms of compressive strength, water absorption, abrasion resistance, and durability. The maximum compressive strength achieved at 28 days curing was 44.2 MPa, which was higher than the conventional concrete mix. Water absorption values decreased with the addition of fly ash and polypropylene fibre, indicating improved density and reduced permeability of concrete. The abrasion resistance and crack resistance of paver blocks were also enhanced due to fibre reinforcement. The study concluded that fly ash can effectively be utilized as a sustainable supplementary cementitious material in concrete paver blocks, while polypropylene fibre improves toughness, crack resistance, and durability performance. The combined use of fly ash and polypropylene fibre not only enhances engineering properties but also contributes toward environmental protection, waste utilization, reduction in cement consumption, and sustainable infrastructure development.

Keywords: Concrete Paver Blocks, Sustainable Construction, Fly Ash, Plastic Waste, Coconut Fibre, Polypropylene Fibre, Recycled Aggregates, CDW, Permeable Pavers.

I. INTRODUCTION

Infrastructure development is one of the most important indicators of economic growth and urbanization in modern society. Rapid industrialization, urban population growth, and increasing transportation demands have significantly increased the requirement for durable, economical, and sustainable construction materials. Among the various infrastructure components, pavements play a vital role in transportation systems by providing safe and smooth movement for vehicles and pedestrians. Precast cement concrete paver blocks are widely used in the construction of pavements, footpaths, parking areas, industrial floors, bus terminals, petrol pumps, container yards, and low-volume roads. The popularity of paver blocks has increased due to their high durability, attractive appearance, easy maintenance, flexibility in installation, and ability to withstand varying traffic loads. Unlike conventional rigid pavements, paver blocks can easily be removed and reinstalled during underground utility maintenance without causing significant damage. However, the production of conventional concrete paver blocks consumes large quantities of cement and natural resources.

The manufacturing of cement releases a substantial amount of carbon dioxide into the atmosphere, contributing to global warming and environmental degradation. Simultaneously, disposal of industrial waste materials such as fly ash has become a serious environmental challenge. The construction industry is continuously searching for environmentally sustainable materials that can reduce environmental pollution and conserve natural resources while maintaining the required engineering properties. Fly ash, a by-product obtained from thermal power plants, has emerged as an important supplementary cementitious material in concrete technology. Fly ash possesses pozzolanic properties and can partially replace cement in concrete mixtures. Similarly, polypropylene fibres are increasingly used in concrete to improve crack resistance, tensile strength, toughness, and durability characteristics. The incorporation of polypropylene fibre helps in reducing shrinkage cracks and improves the overall performance of concrete products. The present research focuses on the development and performance evaluation of environmentally sustainable precast cement concrete paver blocks using fly ash and polypropylene fibre. The study aims to investigate the effect of varying percentages of fly ash replacement and polypropylene fibre addition on strength and durability characteristics of paver blocks.

II. RESEARCH METHODOLOGY

MATERIALS USED:

The selection of suitable materials is one of the most important factors affecting the strength, durability, and performance of concrete paver blocks. In the present study, all materials were selected carefully according to Indian Standard specifications to ensure proper quality and consistency.

The following materials were used in the experimental investigation:

1. Cement
2. Fine Aggregate
3. Coarse Aggregate
4. Fly Ash
5. Polypropylene Fibre
6. Water

MIX DESIGN:

Concrete mix design is the process of selecting suitable ingredients and determining their relative proportions to achieve the desired strength, workability, and durability. The mix design for paver blocks was prepared according to IS 10262:2019 guidelines. Fly ash was used as partial replacement of cement in varying percentages while polypropylene fibre was added in different dosages.

Table 2.1: Mix Proportions Adopted in Study

Mix ID	Fly Ash Replacement	Polypropylene Fibre
CM	0%	0%
FA10PF0.5	10%	0.5%
FA20PF1.0	20%	1.0%
FA30PF1.5	30%	1.5%

Figure 2.1: Concrete Mixing Process

Figure 2.2: Casting of Paver Blocks

Figure 2.3: Water Curing Tank

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III. RESULTS AND DISCUSSION

COMPRESSIVE STRENGTH RESULTS:

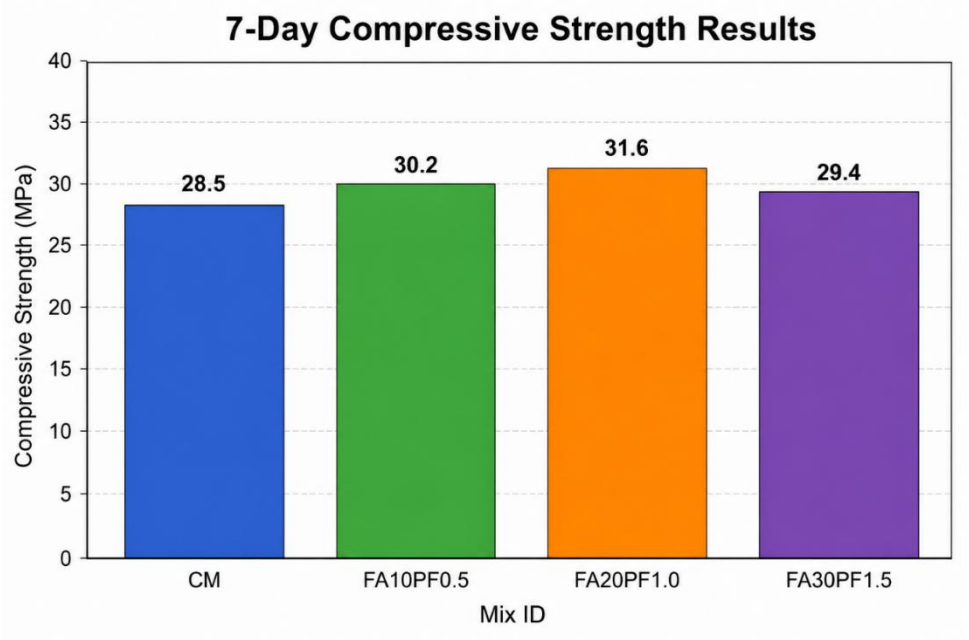
Compressive strength is one of the most important properties governing the performance of concrete paver blocks. The compressive strength test was conducted using a compression testing machine as per IS 15658:2006. The specimens were tested after curing periods of 7 days, 14 days, and 28 days. The average compressive strength values obtained from the tests are presented below.

Compressive Strength at 7 Days:

The compressive strength results at 7 days indicated that the incorporation of fly ash slightly reduced early-age strength due to slower pozzolanic reaction. However, polypropylene fibre helped in improving crack resistance and load distribution within the concrete matrix.

Table 3.1: 7-Day Compressive Strength Results

Mix ID	Compressive Strength (MPa)
CM	28.5
FA10PF0.5	30.2
FA20PF1.0	31.6
FA30PF1.5	29.4



Graph 3.1: 7-Day Compressive Strength Variation

The results showed that the mix FA20PF1.0 exhibited the highest compressive strength at 7 days. The improvement in strength was mainly due to better particle packing and fibre reinforcement action.

Compressive Strength at 14 Days:

At 14 days curing, the strength of fly ash-based paver blocks increased significantly because of the ongoing pozzolanic reaction between fly ash and calcium hydroxide released during cement hydration.

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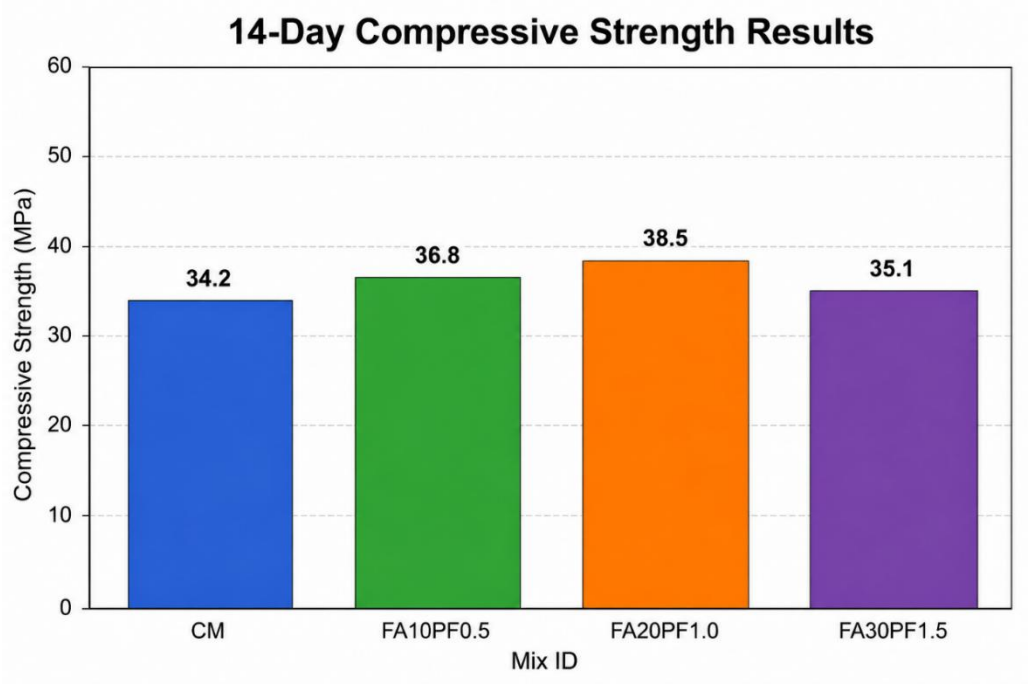
Table 3.2: 14-Day Compressive Strength Results

Mix ID	Compressive Strength (MPa)
CM	34.2
FA10PF0.5	36.8
FA20PF1.0	38.5
FA30PF1.5	35.1



Graph 3.2: 14-Day Compressive Strength Results

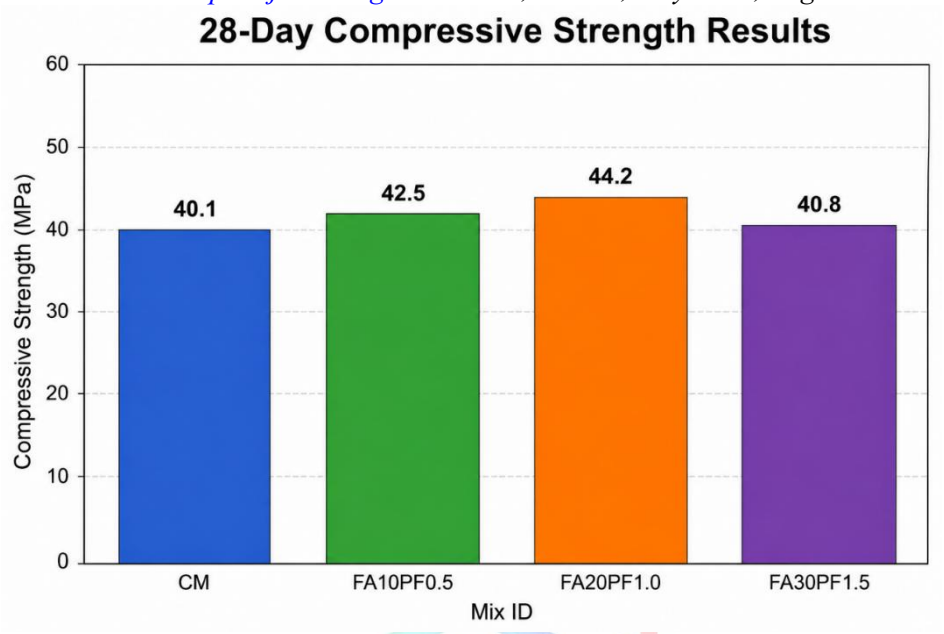
The results indicated that fly ash replacement up to 20% improved compressive strength considerably. Beyond optimum replacement level, strength started decreasing due to reduction in cementitious material content.

Compressive Strength at 28 Days:

The 28-day compressive strength results demonstrated that the sustainable paver blocks containing fly ash and polypropylene fibre performed better than conventional paver blocks.

Table 3.3: 28-Day Compressive Strength Results

Mix ID	Compressive Strength (MPa)
CM	40.1
FA10PF0.5	42.5
FA20PF1.0	44.2
FA30PF1.5	40.8



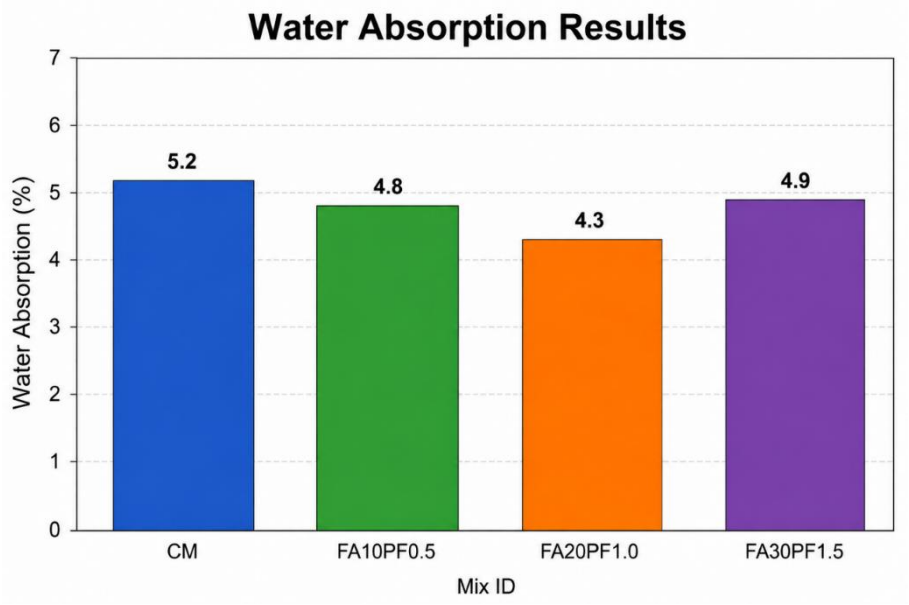
Graph 3.3: 28-Day Compressive Strength Results

The highest compressive strength of 44.2 MPa was observed for mix FA20PF1.0, indicating that 20% fly ash replacement with 1.0% polypropylene fibre provided optimum performance.

WATER ABSORPTION RESULTS:

Table 3.4: Water Absorption Results

Mix ID	Water Absorption (%)
CM	5.2
FA10PF0.5	4.8
FA20PF1.0	4.3
FA30PF1.5	4.9

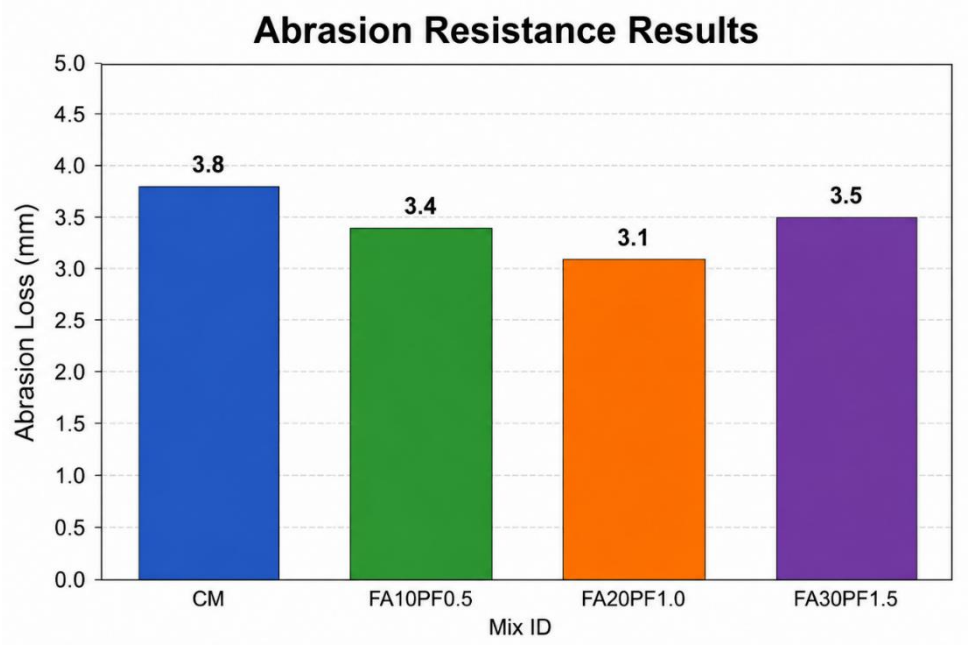


Graph 3.4: Water Absorption Results

ABRASION RESISTANCE RESULTS:

Table 3.5: Abrasion Resistance Results

Mix ID	Abrasion Loss (mm)
CM	3.8
FA10PF0.5	3.4
FA20PF1.0	3.1
FA30PF1.5	3.5

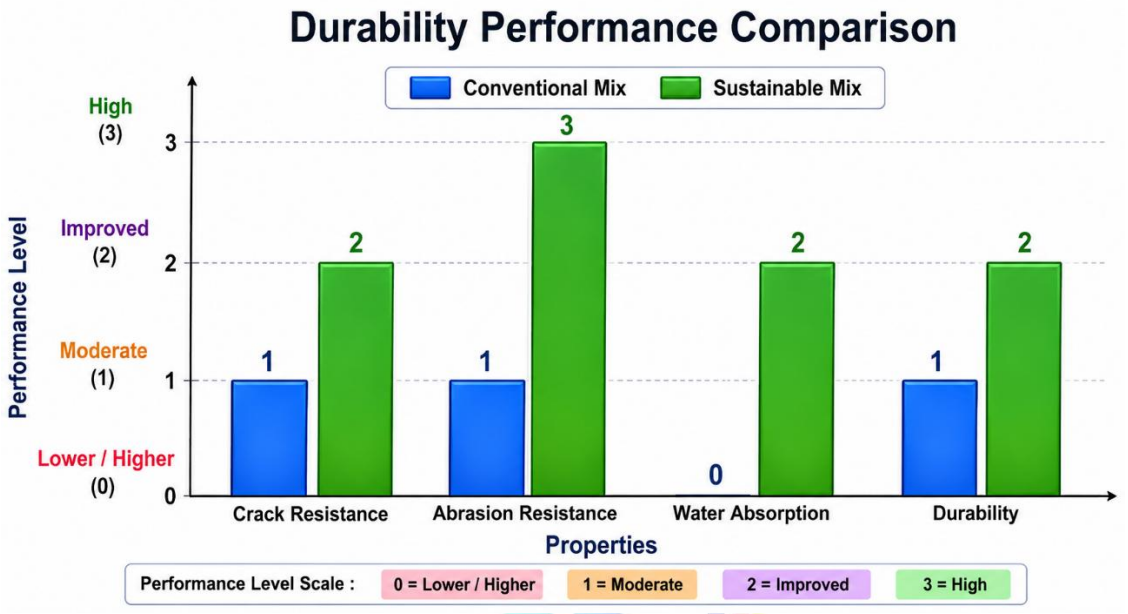


Graph 3.5: Abrasion Resistance Results

DURABILITY PERFORMANCE:

Table 3.6: Durability Performance Comparison

Property	Conventional Mix	Sustainable Mix
Crack Resistance	Moderate	Improved
Abrasion Resistance	Moderate	High
Water Absorption	Higher	Lower
Durability	Moderate	Improved



Graph 3.6: Durability Improvement in Sustainable Paver Blocks

CONCLUSION

Based on the detailed experimental investigation carried out on environmentally sustainable precast cement concrete paver blocks using fly ash and polypropylene fibre, the following conclusions are drawn:

1. The present study successfully demonstrated the feasibility of manufacturing environmentally sustainable concrete paver blocks using fly ash and polypropylene fibre.
2. Fly ash can effectively be used as a partial replacement of cement in concrete paver blocks without adversely affecting the engineering properties when used within optimum limits.
3. The incorporation of fly ash reduced cement consumption and promoted sustainable utilization of industrial waste materials.
4. Polypropylene fibre significantly improved crack resistance, toughness, and durability characteristics of concrete paver blocks.
5. The addition of polypropylene fibre minimized shrinkage cracks and improved the overall structural integrity of paver blocks.
6. The compressive strength of concrete paver blocks increased with fly ash replacement up to an optimum level.
7. The mix containing 20% fly ash replacement and 1.0% polypropylene fibre addition exhibited the highest compressive strength among all mixes.
8. The maximum compressive strength achieved at 28 days curing was found to be 44.2 MPa for the optimum mix proportion.
9. Water absorption values decreased due to incorporation of fly ash and polypropylene fibre, indicating improved density and reduced permeability.
10. The minimum water absorption value was observed for the mix containing 20% fly ash and 1.0% polypropylene fibre.
11. Abrasion resistance of paver blocks improved significantly due to fibre reinforcement, making the blocks more suitable for pavement applications subjected to traffic movement and friction.
12. Fly ash improved the workability and cohesiveness of concrete mixes because of its fine particle size and pozzolanic characteristics.
13. The pozzolanic reaction between fly ash and calcium hydroxide contributed to long-term strength gain and improved durability performance.
14. Sustainable paver blocks exhibited better resistance against cracking and surface deterioration compared to conventional paver blocks.

15. The use of fly ash and polypropylene fibre contributed toward reduction in environmental pollution and greenhouse gas emissions associated with cement production.
16. The developed sustainable paver blocks can effectively be used for footpaths, parking areas, pedestrian pathways, industrial floors, and low-volume roads.
17. The study supports the concept of sustainable construction and green infrastructure development through effective utilization of industrial waste materials.
18. The optimum mix proportion identified from the present investigation was:
    - 20% Fly Ash Replacement of Cement
    - 1.0% Polypropylene Fibre Addition

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