# COMPARATIVE STUDY OF POLYPROPYLENE, STEEL AND HYBRID FIBER IN CONCRETE PAVING BLOCKS

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## ABSTRACT

Most of the studies on fiber reinforced concrete contain use of only single type of fiber with different percentage and combination of materials. The use of two or more type of fibers in their suitable combinations may potentially not only improve the quality of concrete but may also improve performance. This process of mixing more than one fiber is called hybridization and mixture of fiber is known as hybrid fiber.

Now days, paving block has remarkable demand because of their wide application in parking area, footpath, and petrol stations and also for their aesthetics etc. Paving block should have sufficient strength to bear heavy compressive load and offer good resistance to impact load In this study, the comparison of polypropylene, steel and combination of both the hybrid fiber with percentage varying from 0 to 1 percent in paving block. The comparison is based on compression test and flexural test.

**Keywords:** Polypropylene, Hybrid fiber, fiber reinforced Concrete, paving block, Compressive Strength.

## INTRODUCTION

Lot of facelift is being given to roads, footpaths along with roadside. Concrete paving blocks are ideal materials on the footpaths for easy laying, better look and finish. Cement concrete paving blocks are precast solid products made out of cement concrete. The product is made in various sizes and shapes viz. rectangular, square, and round blocks of different dimensions with designs for interlocking of adjacent paving blocks. As countries continue to develop and urbanize at an exponential rate, the need for cement paving blocks has become an essential part of town and city development and expansion. This coupled with the development of technique that can improve quantity and performance of cement paving bricks than ever before.

After World War II, most of Europe was in ruin and reconstruction began. The roads where rebuilt using paving stones as they have historically proved to be able to withstand certain demands that concrete and asphalt could not meet. German engineer, Fritz Von Langsdorff developed a choice of shapes and introduced the use of colors in concrete pavers.

Concrete interlocking pavers where now an efficient and economical choice as mass production started in the 1960s in Germany. In the 1970s production technology spread through Europe and other parts of the world including the United States. Since then America has seen a significant growth of concrete interlocking pavers and has been growing steadily.

Fibers are usually used in concrete to control cracking due to both plastic shrinkage and drying shrinkage. They also reduce the permeability of concrete and thus reduce bleeding of water. Some types of fibers produce greater impact, abrasion and shatter resistance in concrete. Generally fibers do not increase the flexural strength of concrete, and so cannot replace moment resisting or structural steel reinforcement. Indeed, some fibers actually reduce the strength of concrete.

In last decade, an innovative type of fiber reinforced concrete block is developed titled as "The Hybrid Fiber reinforced concrete (HFRC)." Hybridizations refer to combination of different type of fiber. The purpose of combining the fibers is to improving the multiple properties of concrete mixture. Most of the studies on fiber reinforced concrete contain use of only single type of fiber with different percentage and combination of materials. The use of two or more type of fibers in their suitable combinations may potentially not only improve the quality of concrete but may also improve performance.

## LITERATURE REVIEW

**G.Selina Ruby et al. (2014)** The behaviour of a Hybrid Fiber Reinforced Concrete Beam under cyclic loading was explored. According to IS10262-2009, a concrete mix of M40 grade has a water cement ratio of 0.4. Six 1700mmx200mmx100mm beams were cast and tested using a fibre combination of steel and polypropylene with a volume percentage of 0.5 percent. The effect of utilising hybrid fibres in flexural members was investigated using cyclic load in both forward and backward cycles. The first crack load and ultimate load are observed in all beams. LVDT is used to measure the deflection at the centre. The fibres' robustness is increased by a substantial failure strain when used in a hybrid form, according to experimental results. The most suited combination for improving flexural strength and ductility is an HFRC specimen with a combination of S0.75P0.25.

**Geethanjali C. et al. (2014)** This research investigates the combination of fibres, also known as hybridization, for an M40 grade concrete with a volume proportion of 0.5 percent. Steel and polypropylene fibre proportions were varied in the control and three hybrid fibre composites. The results of the compressive strength, split tensile strength, and flexural strength tests were evaluated to determine which fibre combinations were associated with the above fibre combinations. The paper identifies fibre combinations that demonstrate maximum compressive, split tensile, and flexural strength of concrete based on experimental tests. It is discovered that compressive strength and split tensile strength, as well as compressive strength and flexural strength, have a relationship.

**H.Funkeaet al. (2013)** Combining textile reinforced concrete (TRC) with glass-fiber reinforced plastic (GFRP), a new high-performance hybrid material has been developed (GFRP). As a result, the benefits of both materials, such as high strength, durability, surface quality, and cost-effective manufacturing, can be combined in a single hybrid material. Integration of an interlayer for mechanical and thermal decoupling was required for the GFRP and TRC composite. The created interlayer, which consists of an epoxy resin and a polyester nonwoven, ensures that the detention compound between GFRP and TRC is high and long-lasting. The novel GFRP-TRC hybrid material is 165 MPa tensile strength and 1.65 g/cm3 density.

**EetharThanonDawood and MahyuddinRamli (2011)** The hybridization of various types of fibres has been examined and found to serve a vital function in preventing cracks and so achieving good concrete performance. As a result, this research looked into the employment of different percentages of steel fibre (0, 1.0, 1.25, 1.5, 1.75, and 2 percent) as a percentage of total weight. As a result, the density, compressive strength, flexural strength, and toughness indices for all the mixes were determined using the hybridization of steel fibre and palm fibre as 2% volumetric fractions on high strength concrete. The introduction of 1.0 percent steel fibres boosts compressive strength by around 13%, according to the findings. Hybrid fibres are a fascinating concept, and replacing a portion of steel fibre with palm fibre can drastically reduce density while also improving flexural strength and toughness. The findings also show that using hybrid fibre (1.5 percent steel fibre + 0.5 percent palm fibre) in specimens increases toughness indices significantly, implying that using hybrid fibre combinations in reinforced concrete would improve flexural toughness and rigidity, as well as overall performance.

**ZhiguoYouaet al. (2011)** This research presents an experimental study on the flexural behaviour of a series of fibre reinforced self-consolidating concrete beams with low reinforcement ratios, based on the workability test of fibre reinforced self-consolidating concrete. Fiber types, fibre doses, and reinforcement ratios are among the most important criteria. The load-deflection curves and flexural ductility of hybrid fibre reinforced RC beams are compared to steel fibre reinforced RC beams. The yield load and ultimate load of a hybrid reinforced RC beam rise significantly when compared to an RC beam with a minimum longitudinal reinforcement ratio or a steel fibre reinforced RC beam, suggesting that the hybrid effect is positive. The maximum load of a 40+4 kg/m3 hybrid fibre reinforced RC beam with minimal longitudinal reinforcement ratio is similar to that of a 1.5 times minimum longitudinal reinforcement ratio RC beam. The inclusion of fibres reduces the flexural ductility of an RC beam with a low longitudinal reinforcement ratio.

**Ramakrishnan, V. and Lokvik, B. J.**(**2011**) The findings of an analytical examination into the flexural fatigue strength of fibre reinforced concretes were presented (FRC). Steel fibres, straight steel corrugated steel, hooked end steel, and steel fibres were all used. The fibre content of these fibre concretes was tested at two distinct levels (0.5 percent and 1.0 percent by volume), with the same basic mix proportions employed in all of them. More than 300 beams were fatigue tested with third point loading at a rate of 20 load cycles per second for a total of one to four million cycles, and the results were analysed. Statistical and probabilistic principles are applied to estimate the flexural fatigue model and the fatigue life expectancy of the composite for higher accuracy in creating the S-N curves. The fatigue strength of fibre reinforced concrete rose with fibre volume near its endurance limit, according to this study.

## OBJECTIVES OF INVESTIGATION

1. To investigate the performance of paving blocks having various fibre percentages and to determine the best fibre percentage.
2. To compare the performance of polypropylene, steel, and a hybrid fibre made up of both steel and polypropylene fibre.

## MATERIALS

1. Fiber: The use of fibre in concrete is dependent on fibre features such as orientation, aspect ratio, and functional properties to improve concrete performance. Polypropylene, steel, and hybrid fibres are used in this project study.

2. Fine aggregate: As a fine aggregate, river sand is employed. The most important attribute of fine aggregate is its grading, which is one of many. Coarser sand may be desired since finer sand increases the water requirement of concrete, and extremely fine sand may not be required in fine aggregate because it typically contains more fine particles in the form of cement and mineral admixtures such fly ash and silica fume. The sand particles should also pack tightly in order to achieve a low void ratio. To develop a dense fine aggregate mix with the best cement content and the least amount of mixing water, properties including gradation, specific gravity, and water absorption must be evaluated. The fine aggregate was river sand, which conformed to zone 2.

3. Admixture and pigment: Chemical admixtures have the advantage of acting as accelerates, water reducers, extrusion aids, water reducing agents, and so on. The use of S 1014-compliant pigments was necessary. Pigmentation might be partial, such as on restricted to the upper surface, or it can cover the entire block. On the upper surface, dolomite powder is used.

4. Polypropylene fiber: Tactility is a key term in understanding the relationship between polypropylene structure and characteristics. The capacity of the polymer to form crystals is strongly influenced by the relative orientation of each methyl group (CH3 in the figure) compared to the methyl groups in nearby monomer units.

Figure 1: Polypropylene fiber

**Physical property of Polypropylene fiber**

Fiber type –Monofilament

Diameter –0.03$\pm$0 mm.

Melting point -170 degree Celsius

Density -0.91 $\pm$ 0.01e (g/cm3)

Aspect ratio - 40

Tensile strength-450 MPa.

Used length – 12 mm

5. Steel Fiber: Steel fibre can be found in plenty on the market. It also has great tensile strength and melting point, as well as resistance to most chemicals, making it an excellent reinforcing material. Steel fibre is one of the most commonly used materials in many building projects due to its high ductility.

Figure 2: Steel fiber

**Physical property of steel fiber**

Fiber type – Crimped Metallic

Diameter – 0.$\pm$6mm.

Aspect ratio– 60

Tensile strength- 800mpa.

Used length – 35mm.

6. Hybrid fiber**:** Hybrid fiber is combination of both steel and polypropylene fiber.

7**.** Hybridization of fibers**:** In the recent decade, a novel type of fibre reinforced concrete called "The Hybrid Fiber Reinforced Concrete (HFRC)" was developed, which improves both tensile strength and ductility [9-14]. The term "hybridization" refers to the blending of different fibre kinds. The goal of mixing the fibres is to improve the concrete mixture's numerous qualities. This composite material outperforms plain and mono fibre reinforced concrete in terms of behavioural efficacy.

8. Hybrids Based on Fiber Constitutive Response: The first form of fibre is stronger and stiffer, resulting in reasonable first crack strength and ultimate strength, while the second type is more flexible, resulting in better toughness and strain capacity in the post-crack zone.

9.Hybrids Based on Fiber Dimensions: One form of fibre is smaller, allowing it to bridge micro-cracks, slowing their growth and preventing coalescence. As a result, the composite's tensile strength is increased. The second fibre is larger and is designed to stop macro-cracks from propagating, resulting in a significant increase in the composite's fracture toughness. The specific surface area (SSA) of the fibre used is frequently used to differentiate hybrids based on fibre parameters. The surface area for a unit mass [5] can be defined as the SSA and mathematically,

SSA m – [2(2/+ d) / ldDf]

When using fibers based on their size (micro or macro) alone, SSA can also be defined as the surface area for a unit volume, and can be written mathematically as,

SSA v – [2 (2/+d) /d]

Where l is the length of a circular fibre, d is its diameter, and Df is the density of the fibre material. Micro fibres are defined as fibres with an SSA more than 500cm2/gm while macro fibres are defined as fibres with an SSA of around 10 cm:/gm. The micro-fibers support cement paste and mortar phases, as their high SSA and tiny size imply, delaying crack coalescence and enhancing the apparent tensile strength of these phases.

## TESTING PROGRAM

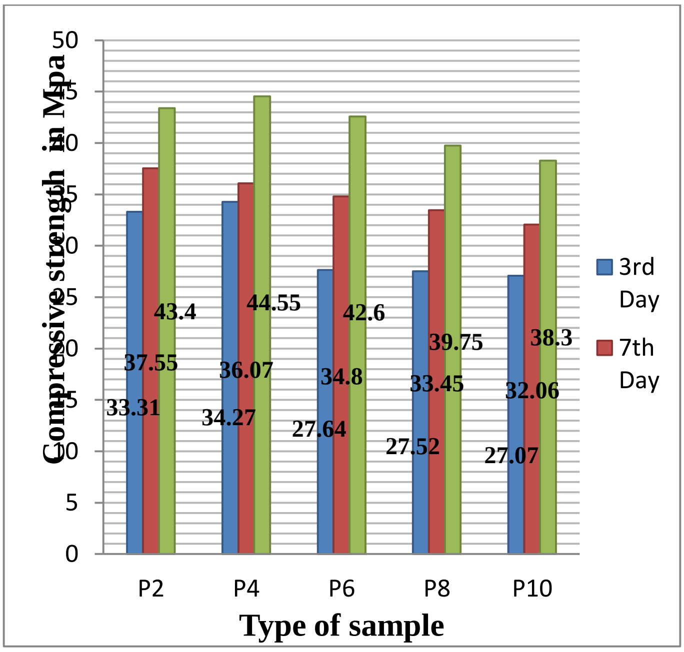
**Compression test**: When blocks are removed from the water and are still wet, they must be tested right away. Surface water and grit must be removed from the specimens, as well as any protruding fins.

The specimen's measured compressive strength is computed by dividing the greatest force applied to it during the test by the cross-sectional area, estimated from the section's mean dimensions, and expressed to the closest N per sq mm. As a representative of the batch, the average of three values will be used. The compression test will be performed on the specimens on the 3rd, 14th, and 28th days edged. Multiply the apparent compressive strength by the appropriate correction factor from Table 5 of IS 15658: 2006, Annex D to get the corrected compressive strength.

Figure 3 - Compressive strength testing on CTM

Table 1. Compression test result for PP fiber

| Nomenclature Of sample | Percentage Fiber content (%) | | 3rd day compressive strength In MPa.. | 14th day compressive strength In MPa.. | 28th day compressive strength In MPa.. |
|---|---|---|---|---|---|
| | **Steel** | **Polypropylene** | | | |
| **P2** | -- | 0.2 | 33.31 | 37.55 | 43.40 |
| **P4** | -- | 0.4 | 34.27 | 36.07 | 44.55 |
| **P6** | -- | 0.6 | 27.64 | 34.80 | 42.60 |
| **P8** | -- | 0.8 | 27.52 | 33.45 | 39.75 |
| **P10** | -- | 1 | 27.07 | 32.06 | 38.30 |

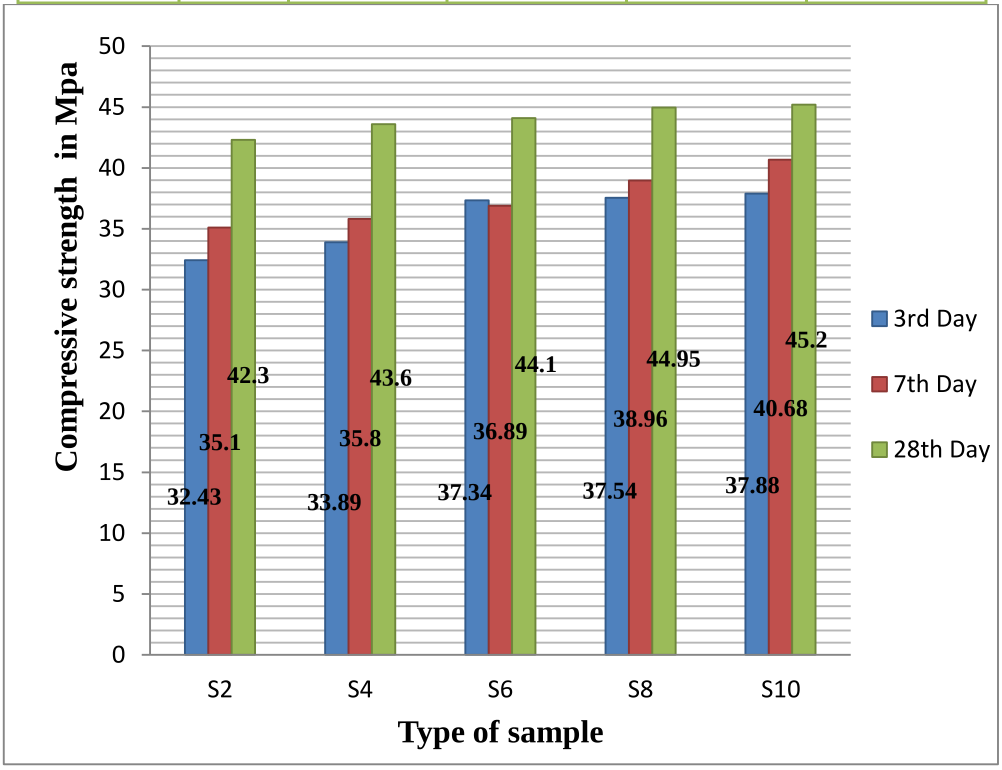



Graph 1. Compression test result for PP fiber

- As the amount of polypropylene fibre is increased, the compressive strength of polypropylene fibre reinforced concrete increases. However, as the compression strength reaches a certain limit, it begins
- For the third day test, compressive strength improved by 0.2 percent (P2) to 0.4 percent (P4), which is over 10%.
- Concrete paving block compressive strength was shown to be reduced above 0.4 percent polypropylene.
- As a result, the optimal fibre content is 0.4 percent (P4), which has a better compressive strength than conventional concrete.

Table 2. Compression test result for Steel fiber

| Nomenclature Of sample | Percentage Fiber content (%) | | 3rd day compressive strength | 14th day compressive strength | 28th day compressive strength |
|---|---|---|---|---|---|
| | **Steel** | **Polypropylene** | | | |
| **S2** | 0.2 | -- | 32.43 | 35.10 | 42.3 |
| **S4** | 0.4 | -- | 33.89 | 35.80 | 43.6 |
| **S6** | 0.6 | -- | 37.34 | 36.89 | 44.10 |
| **S8** | 0.8 | -- | 37.54 | 38.96 | 44.95 |
| **S10** | 1 | -- | 37.88 | 40.68 | 45.20 |

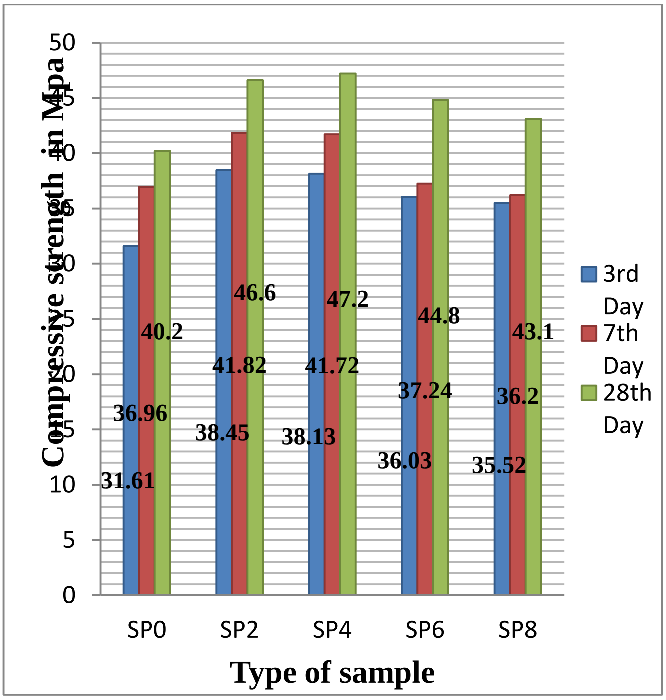



Graph 2. Compression test result for Steel fiber

- As the proportion of fibre increases, the compressive strength of steel fibre reinforced concrete increases.
- Steel fibre reinforced concrete blocks have a compressive strength of 42.3 MPa for 0.2 percent fibres in concrete paving blocks and 45.2 MPa for 1 percent steel fibre in concrete paving blocks.
- The results reveal that utilising steel fibre increased the compressive strength of conventional concrete paving blocks by 10%.

Table 3. Compression test result for hybrid fiber

| Nomenclature Of sample | Percentage Fiber content (%) | | 3rd day compressive strength | 14th day compressive strength | 28th day compressive strength |
|---|---|---|---|---|---|
| | **Steel** | **Polypropylene** | | | |
| **SP0** | -- | -- | 31.61 | 36.96 | 40.2 |
| **SP2** | 0.8 | 0.2 | 38.45 | 41.82 | 46.6 |
| **SP4** | 0.6 | 0.4 | 38.13 | 41.72 | 47.2 |
| **SP6** | 0.4 | 0.6 | 36.03 | 37.24 | 44.8 |
| **SP8** | 0.2 | 0.8 | 35.52 | 36.20 | 43.1 |




Graph 1. Compression test result for hybrid fiber

- As the proportion of fibre increases, the compressive strength of hybrid fibre reinforced concrete increases. For samples SP6 and SP8, however, compression strength diminishes as the amount of polypropylene fibre increases.
- The maximum compressive strength of a steel fibre reinforced concrete block is 47.2 MPa when it contains 0.4 percent polypropylene and 0.6 percent steel fibre.
- The compressive strength of the SP4 sample is 47.2 MPa. This is over 18% more than a standard concrete paving block.

## CONCLUSIONS

1. It has been discovered that the workability of concrete decreases with the inclusion of fibre, particularly with the addition of polypropylene fibre. Steel fibre has a slight effect on workability, although not as much as polypropylene fibre.

2. Paving block compressive strength rises with increasing fibre percentages up to 0.4 percent polypropylene, but steel fibre compression capacity increases with rising fibre percentages. The best combination for hybrid fibre is 0.4 percent polypropylene and 0.6 percent steel fibre, since the compressive strength for the same combination is 47.2 MPa. Ordinary concrete paving block is 18% more expensive.

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