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Mechanical and Durability Effects of Fibres in Paver Block: A Review

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ABSTRACT

Concrete paving blocks, ubiquitous in our surroundings, serve as versatile construction materials utilized across private and public domains, from gardens and walkways to warehouses and vehicular traffic areas. However, their production demands a substantial amount of cement, approximately 210kg/m3, contributing to both health and environmental concerns due to carbon dioxide emissions. In response, engineers have explored methods to mitigate this impact by reducing cement usage without compromising quality standards. One such approach involves incorporating steel fibers into the blocks. This research aims to enhance the tensile strength of paving blocks by integrating steel fibers, thereby improving their overall properties. Steel fibers were added to the sample mix at different weight percentages and compared to a control mix without fibers after curing for 7 and 28 days. The results revealed a significant increase in early strength after 7 days for the block samples with fibers, although there was not a substantial strength increase observed after 28 days of curing.

Key Words: Concrete block paving, fibre reinforced concrete, Steel fibre reinforced concrete

INTRODUCTION

The popularity and utilization of pre-cast concrete paving blocks are on the rise, as they find increasing applications in various settings including street roads, parking lots, landscaping, and areas subject to heavy wheel loads such as airports, warehouse pavements, and pedestrian walkways. This widespread adoption underscores the necessity for the development of enhanced paving blocks capable of withstanding harsh environmental conditions and supporting heavier loads. In the early 1950s, the Netherlands embarked on producing hand-sized, precisely dimensioned concrete blocks to replace clay bricks on streets damaged during World War II. Given the country's low-lying geography prone to ground movement and sinking, traditional concrete pavement was deemed inadequate. Although flexible pavement could have been an option, its vulnerability to earth movement made it impractical. Consequently, concrete paving blocks emerged as the preferred solution (Marlon, 2015).

Concrete block paving has a longstanding history in Europe, with Germany witnessing its initial installations in Stuttgart during the 1960s. By the 1970s, widespread adoption of paving blocks had occurred in Britain, Canada, New Zealand, Australia, Japan, and the United States. Subsequently, the Middle East and Asia also embraced the use of paving blocks (Shackle, 1980). In recent years, steel-fibered high-strength concrete (SFHSC) has risen as a highly favored material in structural engineering. Both fiber-reinforced concrete and high-strength concrete are extensively employed as crucial construction materials due to their exceptional properties. Research into concrete performance with the addition of steel fibers has yielded promising results in various tests, including compressive strength, split tensile strength, and flexural strength.

LITERATURE REVIEW:

Song and Hwang (2004) The mechanical properties of high-strength steel fiber-reinforced concrete (HSFRC), including compressive strength, splitting tensile strength, and modulus of rupture, all demonstrate improvement with the addition of steel fibers at various volume fractions. These fibers, characterized by a needle-like discontinuous appearance, are utilized in steel fiber-reinforced concrete (SFRC) to enhance concrete elements. They are produced in various types such as hooked end, undulated, stranded, crimped, wave, twisted, or flat, tailored to specific construction projects. Employed in construction to augment the tensile strength of concrete materials (Chircu, 2009), steel fibers have been investigated extensively. Behbahani et al. (2011) provided an overview of the mechanical properties of steel fiber-reinforced concrete (SFRC), demonstrating significant improvements in flexural strength and overall toughness compared to conventional reinforced concrete.

Marlon (2015) The utilization of undulated steel fibers for reinforcement in paving blocks was investigated. The findings revealed a lack of extensive research focused on the integration of steel fibers in concrete paving blocks, prompting the need for further analysis. Therefore, a comprehensive understanding of the material properties is essential to optimize its economic utilization in concrete.

Dahlke and Charkha (2016) had addressed that the impact of steel fibers on concrete strength was investigated, revealing that their addition enhanced the mechanical properties of concrete. This improvement included heightened compressive and flexural strengths, as well as decreased porosity and absorption capacity in comparison to conventional concrete.

Gherman et al. (2016) investigated the impact of fiber additions to high-strength concrete, highlighting improvements in various engineering properties. These included enhanced post-crack behavior, where fibers bridged across cracks, providing increased ductility. Significantly, the compressive strength of high-strength concrete reinforced with fibers reached its zenith at a volume fraction of 0.8% of fibers, showcasing a notable 21% enhancement compared to high-strength concrete devoid of fibers. Furthermore, fiber-reinforced concrete displayed a substantial surge in energy absorption, attaining a volumetric increase of 97.8%.

Kandekar et al. (2015) had addressed the results of the compressive test demonstrate that strength rises from 68.70 MPa to 86.80 MPa as the proportion of steel fibers increases from 0.50% to 2.50% (figure 1). Therefore, it is feasible to experiment with various percentages of steel fibers. However, considering economic factors, a mass fraction of 0.50% for steel fibers is deemed preferable

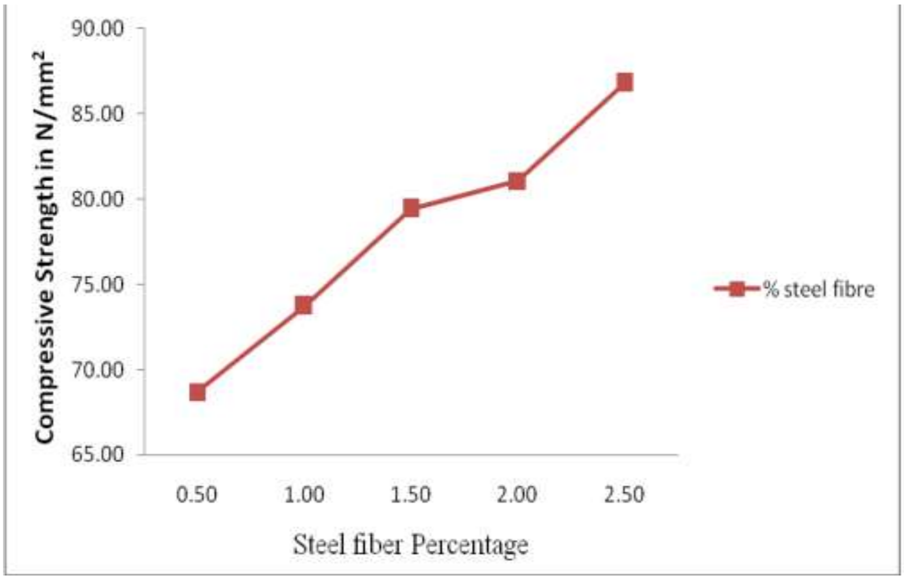

Figure 1 Compressive strength of steel fiber paver block

The results from the flexural strength test indicate that the flexural strength increases from 15.69 MPa to 25.49 MPa with the increment in steel fiber content from 0.50% to 2.50% (Figure 2). This suggests that different percentages of steel fibers can be investigated. However, considering economic factors, a mass fraction of 0.50% for steel fibers is recommended.

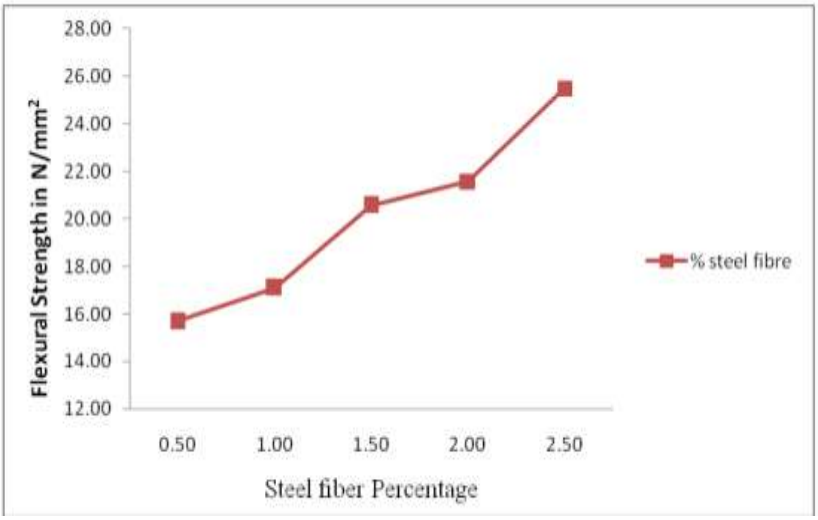

Figure 2 Flexural strength of steel fiber paver block

The split tensile test illustrates that tensile strength increases from 1.69 MPa to 1.88 MPa with the rise in steel fiber content from 0.50% to 2.50% (Figure 3). Hence, different proportions of steel fibers can be evaluated. However, from an economic standpoint, a mass fraction of 0.50% for steel fibers is favored.

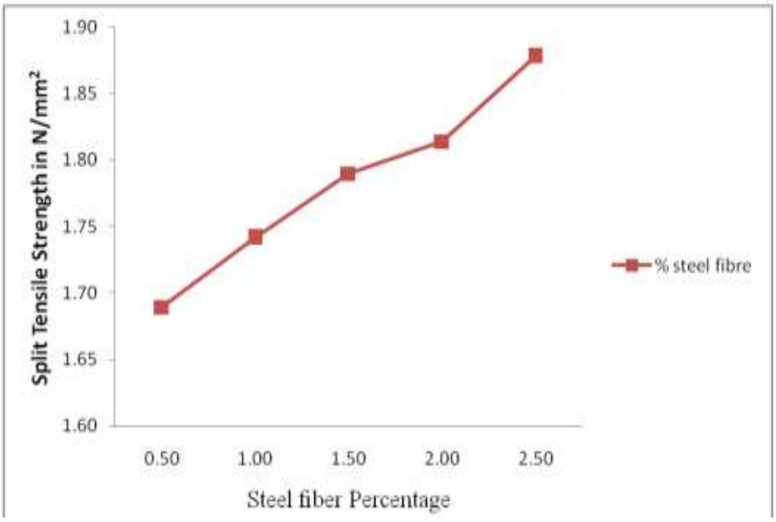

Figure 3 Split tensile strength of steel fiber paver block

Arube et al. (2021) had addressed the test results from the experiments did not meet the required structural performance of 3.6 MPa, as recommended by the British Standard Institute. However, the samples successfully achieved the primary objective of the research, which was to enhance the tensile strength of CPB by incorporating steel fibers into the mix.

Consistent improvements in tensile strength were observed for samples that underwent the study. Among these, the sample CAR13CDM-006, with a steel fiber dosage of 5% and a curing age of 7 days, exhibited the most promising performance. It recorded a split tensile value of 3.40 MPa, indicating a notable increase compared to the control mix at the same age, with a percentage difference of 78.01% (Figure 4).

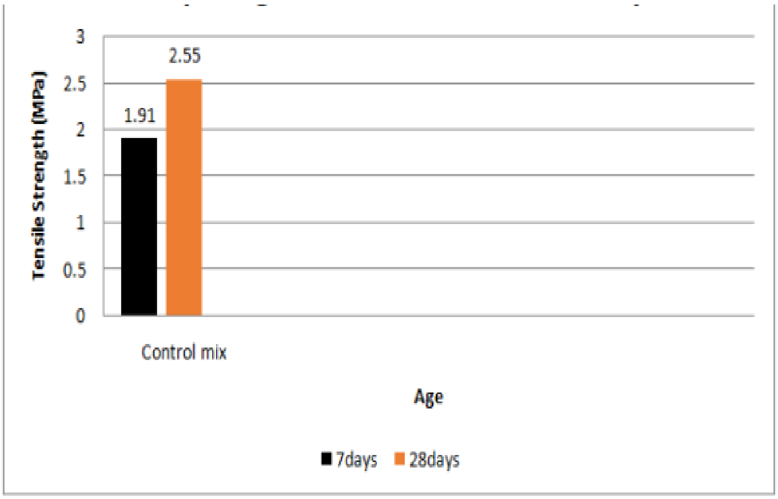

Figure 4 Comparison of tensile strength of conventional concrete in curing days

Augustino et al. (2021) Experimental findings have shown that concrete's compressive strength, with a fiber length of 50 mm and a content of 0.5%, surpasses the control mix by 15.2%. Unlike some literature findings, synthetic/industrial fibers enhance compressive strength until the fiber content reaches 1.5% (Figure 5). This study highlights the potential for utilizing waste tire steel fibers in concrete production instead of discarding them in developing countries' capitals.

However, the spiral deformation of fibers with higher content may create weaker spots and reduce bonding strength at the fiber-concrete interface, resulting in minimal improvements in final tensile strength. Concrete beams without fibers (control mix) and all SFRC30 samples experience abrupt flexural failure, while increasing length and content delay crack formation, with SFRC50-1.0 exhibiting a crack width 82.4% smaller than SFRC50-0.3 (Figure 6).

Incorporating waste tire fibers increases Young's modulus of elasticity, with the optimal content for modulus of elasticity being 0.3% for a fiber length of 50 mm. These fibers also provide superior residual strength of 5.68 MPa and flexural toughness of 142 Joules for beam SFRC60-1.0; however, achieving workability requires a specialized mix design.

Furthermore, high-strength concrete with waste tire steel fibers exhibits lower water absorption rates, making it suitable for coastal areas with 75% less absorption than the control mix. This suggests improved corrosion resistance for main rebars, although proper treatment is necessary for fibers protruding on the concrete surface.

While this study demonstrates enhanced compressive strength at a fiber content of 0.5% and a fiber length of 50 mm, investigations for fiber content between 0 and 0.3%, 0.3–0.5%, 0.5–0.75%, and 0.75–1.0% remain unexplored (Figure 7). Additionally, durability tests beyond 56 days are lacking. Future research should focus on evaluating mechanical properties and fiber-concrete interface behavior at high temperatures.

Figure 5 Failure of fiber reinforced concrete

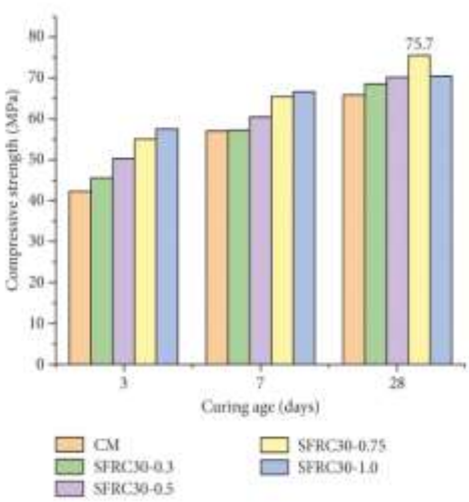

Figure 6 Compressive strength of fiber reinforced concrete

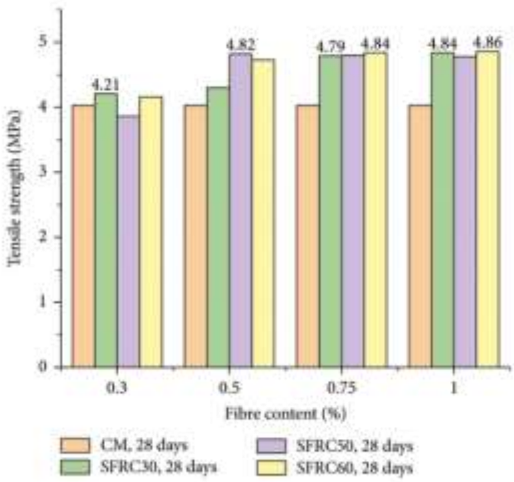

Figure 7 Tensile strength of fiber reinforced concrete

CONCLUSION

Fiber-reinforced concrete provides a level of safeguard against concrete failure by partially reducing crack formation. Moreover, it bolsters a range of mechanical attributes such as flexural strength, resilience to dynamic forces, tensile strength, and ductility. Fibers can be either natural or synthetic, with both types having the potential to enhance concrete strength based on their characteristics. Integrating fibers into pavement blocks has been demonstrated to enhance their mechanical characteristics. Additionally, it has been observed that, given the zero-slump requirement for pavement blocks, vibration plays a critical role in achieving their strength. The quality of pavement blocks is affected by various factors including compaction capacity, machine vibration, and the grade of cement utilized.

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