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Enhancing Durability and Mechanical Properties of Geo Polymer Concrete Pavers using Fiber Reinforcement

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ABSTRACT

This study investigates the mechanical and durability properties of Geo Polymer Concrete (GPC) pavers reinforced with different fibers: polypropylene, coir, and hybrid fibers. GPC mixes were prepared using quarry rock dust as a replacement for fine aggregate and various fiber fractions. The performance of these GPC mixes was compared to Conventional Concrete Pavers (CCP) in terms of workability, density, compressive strength, flexural strength, split tensile strength, impact resistance, water absorption, permeability, and resistance to acid and sulfate attacks. The results demonstrated that GPC pavers exhibited superior performance compared to CCP, with the optimal mix being GPC2 reinforced with 1% polypropylene fibers. This mix achieved the highest compressive strength of 43.12 MPa and significant improvements in flexural and split tensile strengths. Polypropylene fibers, in particular, enhanced the impact resistance and durability of the GPC pavers by reducing permeability and weight loss during acid and sulfate immersion tests. The study concluded that the addition of fibers, especially polypropylene fibers, improves the mechanical properties and durability of GPC pavers, making them a viable alternative to conventional concrete pavers in aggressive environmental conditions. This research provides valuable insights into the use of fiber-reinforced GPC for sustainable and resilient infrastructure development.

Keywords: Geo Polymer Concrete (GPC), Fiber Reinforcement, Polypropylene Fibers, Durability, Compressive Strength, Acid and Sulfate Resistance

INTRODUCTION

Concrete is a fundamental construction material, widely used globally for its versatility and strength. However, conventional concrete, primarily made with Ordinary Portland Cement (OPC), poses significant environmental challenges due to its high carbon footprint and intensive energy consumption during production. Geo Polymer Concrete (GPC) emerges as an eco-friendly alternative, utilizing industrial by- products like fly ash and quarry rock dust, which significantly reduce CO_2 emissions and promote sustainability. In recent years, the integration of fibers into concrete mixes has gained attention for enhancing mechanical properties and durability. This study explores the performance of GPC pavers reinforced with different fibers: polypropylene, coir, and hybrid fibers. The incorporation of fibers aims to address common durability issues in concrete structures, such as resistance to acid and sulfate attacks, whichare prevalent in aggressive environmental conditions.

The research focuses on evaluating various properties of GPC pavers, including workability, density, compressive strength, flexural strength, split tensile strength, impact resistance, water absorption, and permeability. The performance of fiber-reinforced GPC pavers is compared to that of Conventional Concrete Pavers (CCP), highlighting the potential benefits of using fiber- reinforced GPC in sustainable construction. This paper provides comprehensive insights into the optimal mix design and fiber content for GPC pavers, presenting a viable solution for enhancing the durability and strength of concrete structures while contributing to environmental sustainability.

Navdeep Singh et al. [1] discuss concrete as a major construction material and significant greenhouse gas emitter, with cement production contributing nearly 7% to global emissions. Geopolymer concrete (GPC), made from industrial waste like fly ash and coal bottom ash (CBA), offers a sustainable alternative. The review examines GPC's mechanical behavior with varying CBA amounts, influenced by factors like alkali solution content and curing type. Findings show that increased NS/NH ratio, NaOH molarity, and CBA grinding improve properties, while higher liquid/binder ratios and alkali content reduce strength. The study highlights CBA's potential in GPC and outlines future research challenges. Tianyu Xie et al. [2] highlight the environmental benefits and necessity of reusing construction and demolition (C&D) waste, particularly through recycled concrete aggregate (RCA). Recycled aggregate concrete (RAC), made by substituting natural aggregates with RCA, has garnered significant interest. This paper reviews over 200 studies on RAC's mechanical properties and influencing factors from 1978 to 2017. It also explores the less understood impacts of aggregate surface treatment, moisture state, and mixing on RAC. This comprehensive review aims to enhance researchers' understanding of RAC's behavior. Nitin Ankur et al. [3] discuss the environmental impact of cement composites like mortar and concrete, noting that 90% of concrete's carbon footprint comes from cement production. Traditional concrete ingredients deplete natural resources, while thermal power plants generate large amounts of coal ash, worsening environmental degradation. Using coal bottom ash (CBA) from power plants in mortar and concrete can mitigate these impacts. This study reviews the fresh, mechanical, and durability properties of mixes with CBA replacing fine aggregates and cement, highlighting both supportive and contradictory findings, future challenges, and research gaps, to promote sustainability in construction. P. Abhishek et al. [4] explore the use of recycled aggregates and slag in concrete as a sustainable strategy in civil engineering. Their study investigates the fresh and hardened properties of granulated blast furnace slag (GBS)-based normal vibrated concrete (NVC) and self- compacting concrete (SCC), with partial replacement of natural coarse aggregate (NCA) with recycled concrete aggregate (RCA). Testing is conducted according to Indian standards and EFNARC guidelines. The investigation focuses on compressive strength, with NCA replacement ranging from 0% to 35%. Results indicate a reduction in compressive strength for SCC specimens with NCA replaced by RCA exceeding 20%, compared to NVC specimens. SEM analysis provides insight into the topography and composition of the samples. J. Vijayaraghavan et al. [5] highlight resource concerns in global civil construction, where increased exploitation accompanies the development of globalized infrastructure. With these challenges, attention turns to construction materials, prompting studies on waste management strategies with eco-efficient parameters. Recent research focuses on alternatives for fine and coarse aggregates, yet there remains room for further exploration. This study investigates the effects of substituting copper slag (30-50%), iron slag (30-50%), and recycled concrete aggregate (20-30%) for sand and gravel, respectively, in varying mix proportions. Mechanical properties are compared with conventional concrete after 28 days of curing, with findings indicating optimal mix proportions for enhanced strength. The study employs both experimental and numerical analyses, suggesting further research opportunities to enhance construction material sustainability. Navdeep Singh M.E et al. [6] investigate the carbonation resistance of Self Compacting Concrete (SCC) made with Low Volume Fly Ash (LVFA) and High-Volume Fly Ash (HVFA), incorporating Coarse Recycled Concrete Aggregates (RCA). Accelerated carbonation tests over 4, 12, and 16 weeks assess LVFA and HVFA SCC mixes with RCA. Results show reduced carbonation resistance with increasing RCA content as a replacement for Coarse Natural Aggregates (NA). Addition of metakaolin (MK) partially offsets this decrease. Microstructural analysis via Scanning Electron Microscopy (SEM) and Thermogravimetric Analysis (TGA) validates the findings. R.K. Majhi et al. [7] aim to develop sustainable concrete by utilizing recycled coarse aggregate (RCA) and ground granulated blast furnace slag (GGBFS) as replacements for natural coarse aggregate (NCA) and ordinary Portland cement (OPC) respectively. Sixteen concrete mixes are prepared, varying the percentages of NCA replaced by RCA (0%, 25%, 50%, 100%) and cement replaced by GGBFS (0%, 20%, 40%, 60%).

The study investigates fresh and hardened concrete properties, including workability, strength, density, water absorption, and void volume. Results show increased workability with RCA or GGBFS use, while compressive strength decreases with higher RCA or GGBFS content. However, the reduction in tensile and flexural strength is less significant. Water absorption and void volume increase with RCA content, but GGBFS enhances concrete quality by improving interfacial transition zone (ITZ) and mortar-RCA bond. The mix with 50% RCA and 40% GGBFS is identified as optimal, achieving target strength while saving significant cement and NCA, thereby promoting sustainability.

Gurpreet Singh et al. [8] address the increasing presence of concrete in construction and the rise in demolition waste, highlighting the importance of Recycled Construction Aggregate (RCA) in conserving natural resources and promoting sustainable development. Their research focuses on the impact of incorporating recycled concrete aggregates and fly ash on concrete strength properties. Fine aggregates (FA) partially replace 20% of the cement by weight, while RCA substitutes 15%, 30%, 45%, and 60% of the 20mm natural aggregate by weight. Strength properties including compressive, split tensile, and flexural strength are evaluated after specified curing periods. Yasser Khodair et al. [9] explore the use of recycled concrete aggregate (RCA) and recycled asphalt pavement (RAP) in self-consolidating concrete (SCC), replacing varying percentages of natural coarse aggregate (NCA). Sixteen concrete mixtures are prepared and tested, divided into four groups with different levels of RCARAP content (0%, 25%, 50%, and 75% NCA replaced). While Portland cement is used in control mixtures, others incorporate partial cement replacement with supplementary cementitious materials (70% fly ash, 70% slag, and 25% fly ash + 25% slag). Fresh properties such as flowability, deformability, and resistance to segregation are evaluated, alongside hardened properties like compressive and split tensile strength. Durability characteristics including unrestrained shrinkage and rapid chloride permeability are also assessed. Partial cement replacement with fly ash and slag leads to slightly lower 28-day compressive strength compared to control mixtures. Meanwhile, the substitution of NCA with RCARAP decreases workability and compressive and tensile strengths of SCC mixtures.

Navdeep Singh et al. [10] investigate the utilization of iron slag (IS) and recycled concrete aggregates (RCA) in concrete production to address the ecological threats posed by industrial waste and construction and demolition waste. The study focuses on understanding the workability, compressive strength, and water penetration characteristics of concrete containing IS and RCA. Natural coarse aggregates (NCA) are replaced with 25% and 50% RCA, while 30% of IS substitutes natural fine aggregates (NFA). Various tests including Slump Flow, Vee-Bee Consistometer, and Compacting Factor Test assess the fresh state performance, while compressive strength tests are conducted after 7, 28, and 56 days of curing. Water penetration tests evaluate permeability characteristics. Results indicate that the inclusion of IS enhances workability, compressive strength development, and permeability characteristics of RCA-based concrete. A mix containing 30% IS and 25% RCA exhibits superior properties compared to control and RCA-only mixes, suggesting the potential for IS and RCA usage in concrete production to maintain optimal workability conditions. N Singh et al. [11] investigate sustainable blends of Self-Compacting Concrete (SCC) by replacing natural fine aggregates (NFA) and natural coarse aggregates (NCA) with recycled fine aggregates (RFA) and recycled coarse aggregates (RCA) sourced from construction and demolition (C&D) waste. Accelerated carbonation tests reveal reduced carbonation resistance with increased RFA and RCA content. Addition of Metakaolin (MK) partially compensates for this decrease. Microstructural and crystallization studies using Scanning Electron Microscopy (SEM) and X-ray Diffraction (XRD) validate the results. Compressive strength tests are also conducted for reference.

Problem Identification

The reviewed studies explore innovative applications and enhancements in concrete technology using recycled materials and industrial by-products. Investigations include the utilization of iron slag, recycled concrete aggregates (RCA), and pozzolan slurries to improve concrete properties, such as strength, durability, and workability. Various replacement ratios and treatments are examined, showcasing promising results in terms of compressive strength, microstructure enhancement, and reduced environmental impact. These findings underscore the potential of utilizing sustainable alternatives in concrete production, pavingthe way for eco-friendly construction practices and resource conservation.

Objective of the Investigation

This research focused on optimizing the replacement of fine aggregate with quarry rock dust and coarse aggregate with recycled coarse aggregate. Various combinations were considered, including Fine Aggregate + Coarse Aggregate (FA+CA), Quarry Rock Dust + Coarse Aggregate (QRD+CA), Fine Aggregate + Recycled Coarse Aggregate (FA+RCA), and Quarry Rock Dust + Recycled Coarse Aggregate (QRD+RCA). These combinations were evaluated to determine the mechanical and durability properties of geopolymer concrete.

The investigation focuses on incorporating three different types of fibers—polypropylene fibers, coir fibers, and hybrid fibers—in varying proportions (0.5%, 1%, and 1.5%) to determine the optimal fiber fraction. The study emphasizes the effects of adding higher fiber percentages, up to 1.5%, in geopolymer concrete (GPC) specimens. It aims to determine the mechanical and durable properties ofpaver blocks using the optimal GPC mix with the best fiber fraction.

METHODOLOGY

Optimal Mix Identification: The geopolymer concrete (GPC) is classified into four types—GPC-1, GPC-2, GPC-3, and GPC-4—as defined in the material investigation. Each type is cast with different ingredient combinations, cured at ambient temperature after a three-day rest period, and then tested.

Fiber Incorporation: Fibers are added to the optimal mix in varying percentages (0.5%, 1.0%, and 1.5%). The fresh and hardened properties of these mixtures are tested to determine the optimal fiber content.

Paver Block Testing: Using the optimal mix and fiber content, geopolymer hexagonal pavers (27 x 23.5 x 5 cm) and conventional concrete (CC) pavers are cast, cured in ambient conditions, and tested for mechanical properties (compressive strength, split tensile strength, flexural strength, abrasion resistance) and durability properties (water absorption, acid resistance).

MATERIAL INVESTIGATION

Flyash

Low Calcium Flyash

Mortar specimens made with high alkali content geopolymer exhibit superior performance compared to those with lower alkali content. High compressive strength is achieved when class C fly ash (CFA) is activated using a mixed alkali activator (sodium hydroxide and sodium silicate solution, or potassium hydroxide and potassium silicate solution) with an optimal modulus, specifically a SiO_2/Na_2O molar ratio of 1.5.

Table 1 shows the properties of fly ash, while Table 2 present the initial setting time of the bindercontent.

Table 1: Property of Flyash

S. No	Property	Test Results
1	Fineness	8%
2	Initial Setting Time	130 mins
3	Specific Gravity	3.16

Table 4.2: Initial Setting Time of Flyash

S. No	Time (mins)	Penetration (mm)
1	0	0
2	15	0
3	30	0
4	45	1
5	60	1
6	75	2
7	90	10
8	105	15
9	120	21
10	135	26
11	150	35

Quarry Rock Dust

Quarry rock dust is a by-product generated during the processing of granite stones into coarse aggregates of various sizes, with the residual powder left over from the stone-breaking process.

Green concrete focuses on sustainability in all aspects, from raw materials and manufacturing to mixture design, structural design, construction, and serviceability. With infrastructure development at its peak, a significant amount of concrete is needed to meet these demands.

Concrete is essential in construction, but river sand, a key material, has become scarce and expensive. The depletion of sand due to increased construction use is a major issue. QRD, a by-product of the crushing process, is a suitable substitute for natural river sand. It consists of fine particles less than 4.75 mm and is a residue or tailing from rock extraction and processing.

Table 3: Particle Size Distribution of Quarry Rock Dust

S. No	Sieve Size	Weight Retained (g)	% Weight Retained (g)	Cumulative %of Retained	Cumulative %Finer (N)
1	2.36	85	8.5	8.5	91.5
2	1.17	128	12.8	21.3	78.7
3	0.6	392	39.2	60.5	39.5
4	0.425	365	36.5	97	3
5	0.3	30	3	100	0
6	0.15	0	0	0	0
7	Pan	0	0	0	0

Polypropylene Fibers

Polypropylene fibers serve as secondary reinforcement in the construction sector to mitigate cracks, enhance impact and abrasion resistance, and improve overall construction quality and longevity. The properties of polypropylene fibers are detailed in Table 4.

Table 4: Properties of polypropylene fiber

Properties	Value
Standard Compliance	ASTMC-1116
Shape	Monofilament
Standard Length	12mm
Specific Gravity	0.91
Melting Point	162˚C and above
Absorption	Nil
Alkali Resistance	99% Strength retained
Tensile Strength	3500-7700kg/m3
Young’s Modulus	35x103kg/cm2
Diameter	18-micron, nominal

Figure 1: Coir fibers

Coir Fiber

Coir fibers are one of the organic fibers. In this research work coir fiber of 1.4g/cc were added. Figure 1 indicate the Coir fiber. Addition of coir fibers and polypropylene fibers result in the formation of hybrid fibers.

RESULTS AND DISCUSSION

This chapter presents the results and discussions in three stages. The first stage involves determining the optimum mix for four different combinations: FA+CA, QRD+CA, FA+RCA, and QRD+RCA of Geo Polymer Concrete. The second stage focuses on the results and discussions regarding the determination of the optimum fiber volume fraction in the optimum mix of Geo Polymer Concrete using three types of fibers: polypropylene fibers, Coir fibers, and hybrid fibers, at percentages of 0.5%, 1%, and 1.5%. The third stage covers the results and discussions related to hexagonal pavers made using the optimum mix and fibers, with the required curing period at ambient temperature as per IS:15658-2006. Thus, the chapter discusses the results of Conventional Concrete Pavers (CCP), Geo Polymer Pavers with the optimum mix but without fibers (GPP), Geo Polymer Pavers cast with the optimum mix along with the optimum percentage of polypropylene fibers (GPPOPF), Coir fibers (GPPOCF), and hybrid fibers (GPPOHF).

Optimal Constituents

The GPC specimens with different combinations of FA+CA, QRD+CA, FA+RCA, and QRD+RCA were cast and subjected to various tests to evaluate their fresh and hardened properties. This chapter discusses the results and provides a detailed analysis of parameters such as workability, density, compressive strength, split tensile strength, flexural strength, water absorption, and modulus of elasticity. Through an examination of the strength and behavior observed in the test results, the optimal mix of Geo Polymer Concrete was determined.

The test results indicated that the slump values of GPC1 and GPC2 were more comparable to those of GPC3 and GPC4. Particularly, the GPC1 mix, which consisted of the combination of FA+CA, exhibited a better slump compared to all other GPC mixes. This suggested that mixes containing coarse aggregate yielded better slump values than those with recycled coarse aggregate. The water content present in the sodium silicate solution supplied the necessary amount of water for the GPC mix. However, to achieve the desired workability, an additional 5% of water was added to the GPC1 and GPC2 mixes, while 10% additional water was required for the GPC3 and GPC4 mixes. Figure 2 provides a comparison of the slump values forthe various GPC specimens.

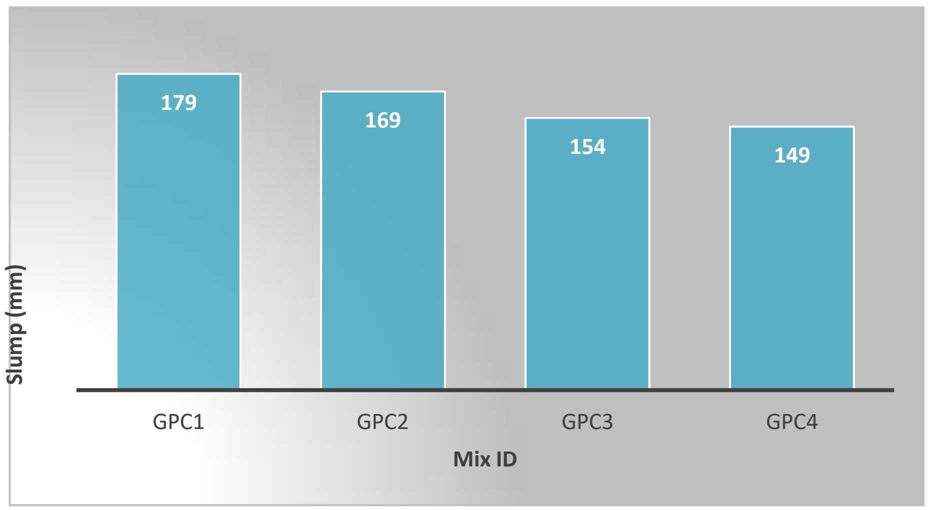

Figure 2: Comparison of slump in GPC specimens

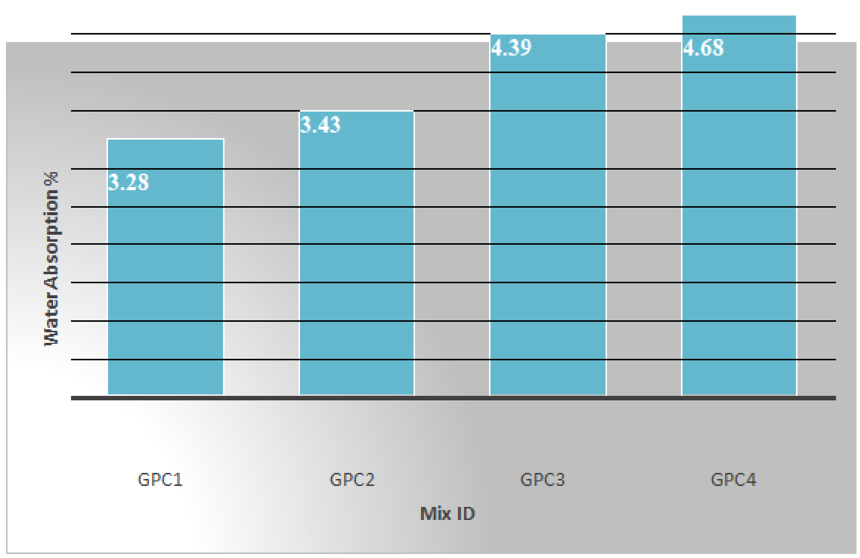

Figure 3: Water absorption in GPC specimens

Figure 3 illustrated that the percentage of water absorption was higher in GPC mixes with FA+RCA and QRD+RCA combinations compared to the other two mixes. This suggests that specimens cast with coarse aggregate exhibited lower water absorption compared to those cast with recycled coarse aggregate. Consequently, the percentage of water absorption was higher in GPC 3 and GPC 4 compared to GPC 1 and GPC 2. Notably, since GPC 4 comprised quarry rock dust and recycled coarse aggregate, its water absorption percentage was found to be higher compared to all other GPC mixes.

The compressive strength of concrete is closely linked to its density, with higher density generally leading to greater strength. Consequently, GPC mix 2, comprising QRD+CA, exhibited superior compressive strength compared to the other mixes. At 3 days, the strength of GPC 2 increased by 10.07%, 24.21%, and 36.12% compared to GPC 1, GPC 3, and GPC 4, respectively. This trend persisted at 7 days, with GPC 2 showing strength increases of 11.55%, 18.66%, and 23.04% compared to GPC 1, GPC 3, and GPC 4, respectively.

The higher silica content in quarry rock dust promotes polymerization with fly ash, resulting in increased strength percentages due to the formation of more SiO-Al bonds. By 28 days, the strength of GPC 2 increased by 5.71%, 11.98%, and 17.51% compared to GPC 1, GPC 3, and GPC 4, respectively. However, the compressive strengths of GPC 3 and GPC 4, utilizing FA+RCA and QRD+RCA combinations, were found to be lower than other combinations.

This decrease in strength can be attributed to water absorption by recycled coarse aggregate, which hinders the polymerization process by reducing water availability in the concrete matrix. The initial stages of polymerization require sufficient water to dissolve alumino-silicate atoms from the source material under the influence of hydroxide ions in a strong alkali solution. Therefore, the combination of quarry rock dust with recycled coarse aggregate results in reduced concrete strength due to water deficiency. Figure 4 illustrates the comparison of compressive strength among various mixes.

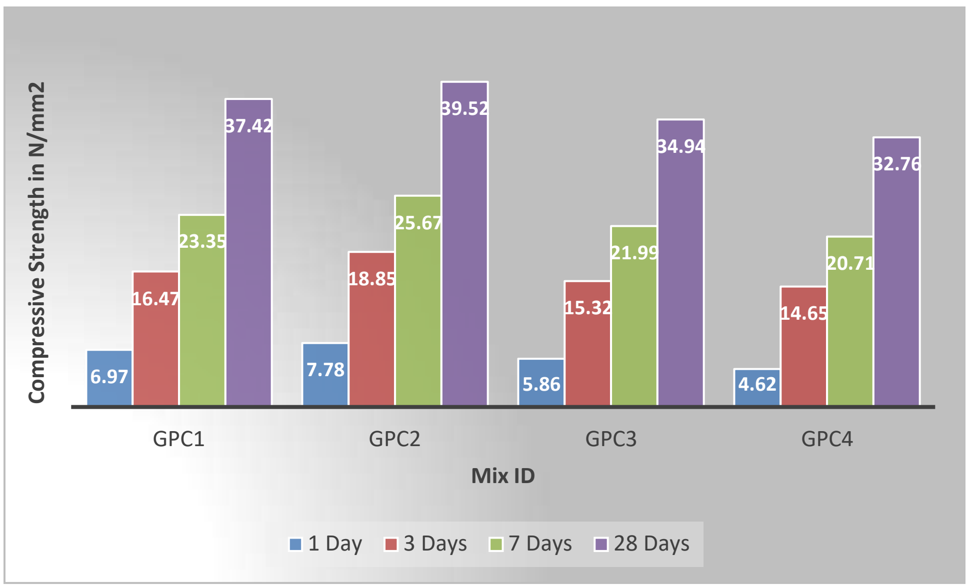

Figure 4: Compressive strength at 1, 3, 7 and 28 days

Figure 5 illustrates the flexural strength behavior of GPC mixes. At 3 days, the strength of GPC 2 increased by 13.46%, 18.36%, and 31.83% compared to GPC 1, GPC 3, and GPC 4, respectively. Similarly, at 7 days,
GPC 2 exhibited strength increases of 9.77%, 13.79%, and 29.02% compared to GPC 1, GPC 3, and GPC

This superior performance is attributed to the formation of a greater number of three-dimensional links compared to other GPC mix combinations. The high concentration of 16M sodium hydroxide reacts vigorously with the silica and alumina present in quarry rock dust, resulting in the formation of aluminates and silicates, which in turn leads to the development of more ring structures and higher strength gains.

However, the mix with recycled coarse aggregate demonstrated lower strength due to its reduced strength-carrying capacity. At 28 days, the flexural strength of GPC 2 increased by 6.14%, 14.10%, and 28.75% compared to GPC 1, GPC 3, and GPC 4, respectively. Thus, the combination of QRD+RCA in the optimal mix exhibited lower strength, while the mix with QRD+CA showed superior results compared to other combinations.

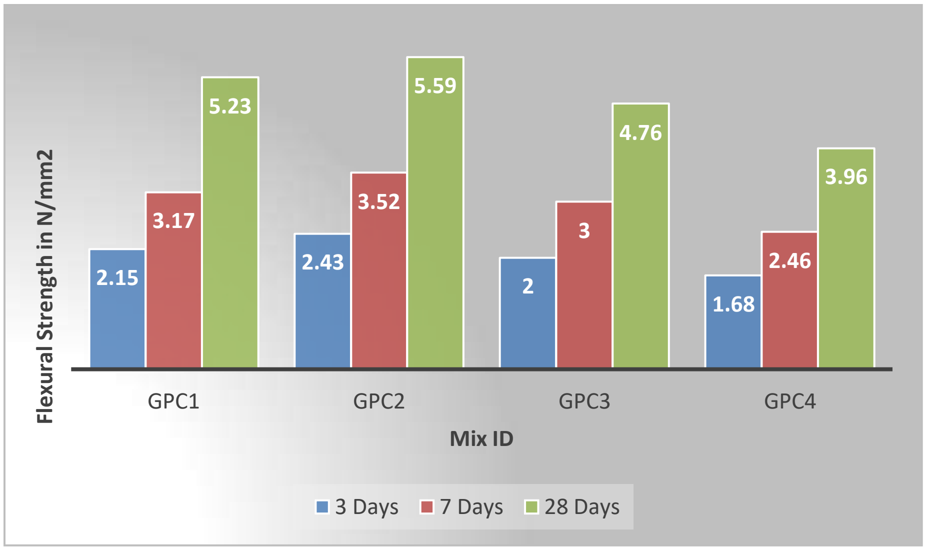

Figure 5: Flexural strength at 7 and 28 days

Paver Block Test

Using the optimal mix fraction of GPC2, which combines quarry rock dust and coarse aggregate, and the optimal percentages of polypropylene fibers, coir fibers, and hybrid fibers, hexagonal pavers of size 27.5 cm x 26.5 cm x 5 cm were cast and tested according to IS specification for pavers (IS:15658-2006). The fresh and hardened properties, including workability, density, compressive strength, split tensile strength, flexural strength, abrasion resistance, impact resistance, and durability properties such as acid attack, sulphate attack, water absorption and permeability, were evaluated. The test results of GPP, GPP with optimum polypropylene fiber, coir fiber, and hybrid fibers were compared with those of normal Conventional Concrete Pavers. Figure 6 shows that the slump of Geo Polymer Concrete Paver (GPP) is 155mm, compared to Conventional Concrete Paver (CCP). The slump of CCP is 8.82% higher than that of GPP. Adding fibers to GPP reduces the slump value, with the optimum percentage of polypropylene fibers showing a greater slump compared to GPP with optimum coir and hybrid fibers. GPP without fibers shows a reduction in slump by 19.35%, 32.25%, and 29.03% for GPPOPF, GPPOCF, and GPPOHF, respectively. Coir fibers, being natural, absorb more water, thereby reducing the slump more than other mixes. Test results indicated that the workability of GPPOCF and GPPOHF was almost the same.

GPP without fibers exhibited a better slump than CCP. The addition of fibers reduced workability depending on the type of fiber; artificial fibers (polypropylene) showed more workability, while natural fibers (coir) reduced the slump. The combination of natural and artificial fibers resulted in a moderate slump value, higher than natural fibers alone but lower than artificial fibers alone. These variations are due to differences in fiber density and water absorption capacity. Thus, GPPOPF demonstrated the highest workability amongall GPC composites.

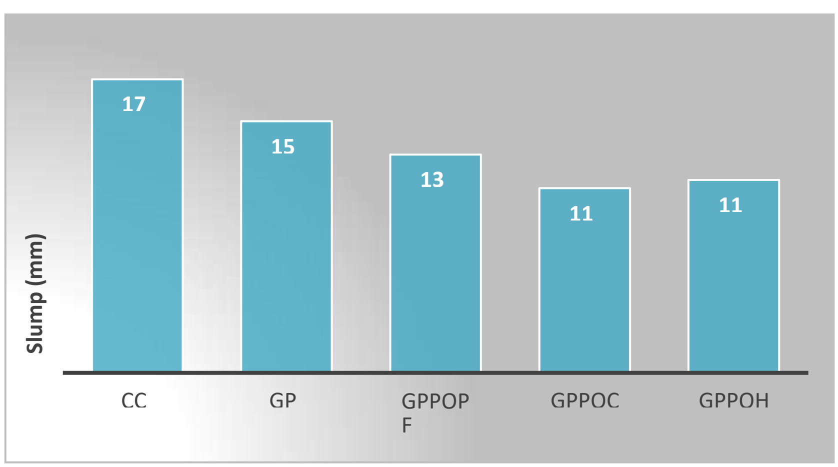

Figure 6: Workability of pavers

After determining the optimal mix and fiber, hexagonal paver specimens were cast and cured at an ambient temperature of 27°C for 28 days. The pavers were tested according to the Annexure of IS: 15658-2006. At 3 days, the compressive strength of GPPoPF (Polypropylene fiber) pavers showed an improvement, reaching 18.47 MPa, which was higher than all other fiber pavers. Geo Polymer Pavers cast with polypropylene fibers provided better results compared to CC Pavers, as the polypropylene fibers acted as reinforcement, enhancing the paver's strength and stiffness. GPP also demonstrated superior strength compared to CCP.

The 3-day compressive strength results for GPPOCF and GPPOHF were lower than those for GPP and GPPOPF. Figure 7 shows that the high early strength of Geo Polymer Pavers was slightly higher compared to Conventional Concrete Pavers. At 3 days, the strength of GPP, GPPOPF, GPPOCF, and GPPOHF increased by 11.78%, 17.70%, 15.18%, and 16.78%, respectively, compared to CCP.

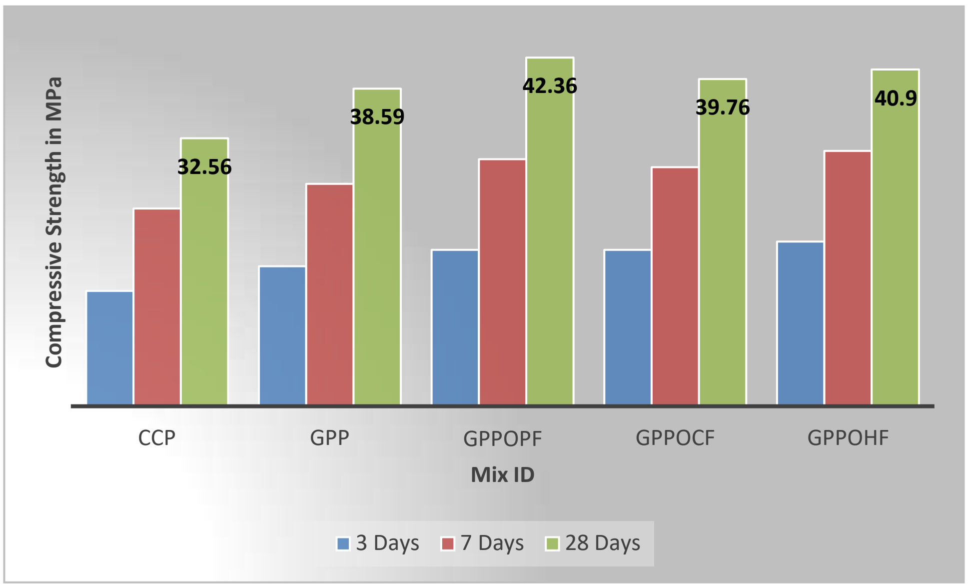

Figure 7: Comparison on compressive strength of pavers

CONCLUSION

This study comprehensively evaluated the mechanical and durability properties of Geo Polymer Concrete (GPC) pavers reinforced with polypropylene, coir, and hybrid fibers. By replacing fine aggregate with quarry rock dust and incorporating various fiber fractions, GPC mixes were compared to Conventional Concrete Pavers (CCP) to determine their performance under various conditions.

Optimal Mix and Fiber Selection:
The GPC2 mix, composed of quarry rock dust and coarse aggregate, was identified as the optimal mix.

The addition of 1% polypropylene fibers (GPPOPF) to GPC2 yielded the best results in terms of compressive strength, flexural strength, and split tensile strength.

Mechanical Properties:
GPPOPF achieved the highest compressive strength of 43.12 MPa, significantly outperforming CCP.

Flexural strength and split tensile strength were also significantly enhanced in GPPOPF compared to other fiber reinforced GPC mixes and CCP.

Workability and Density:
The addition of fibers generally reduced the workability of the GPC mixes, with polypropylene fibers showing better workability compared to coir and hybrid fibers.

GPC pavers, particularly GPPOPF, exhibited higher density than CCP, contributing to improvedmechanical properties.

Durability:
GPC pavers demonstrated superior resistance to water absorption, acid attack, and sulfate attackcompared to CCP.

GPPOPF showed the lowest water absorption and the highest resistance to acid and sulfate attacks, enhancing the overall durability of the pavers.

The inclusion of fibers acted as a preventive layer against the ingress of harmful substances, further improving the durability of the pavers.

Impact Resistance:
The addition of polypropylene fibers significantly improved the impact resistance of GPC pavers.

GPPOPF exhibited the highest impact resistance among all tested pavers, further underscoring the benefits of fiber reinforcement in enhancing the structural integrity of GPC pavers.

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