STM JOURNALS

Journal of
Polymer & Composites

ISSN: 2321-2810 (Online)
ISSN: 2321-8525 (Print)
Volume 13, Special Issue 4, 2025
DOI (Journal): 10.37591/JoPC

https://journals.stmjournals.com/jopc

Research JoPC

Enhancing Concrete Durability and Mechanical Properties for Pavement Quality Concrete (PQC) Roads Using Basalt Fiber Reinforcement

Anuj Shukla[1] , Ravindra Budania[2] , Vikas Pandey[3] , Shahnawaz Ahmed Mir[4] ,Ankush Kumar Jain[5], Saurabh Singh[6,*]

Abstract

Concrete, by nature, is brittle and has a very low tensile capacity, which is a double whammy in transportation infrastructure, such as pavement quality concrete (PQC), for roadways, where we need durability and strength. One such method is the use of basalt fibre, as it is a much better way of enhancing the road runway way performance of concrete. This research studies the impact of the addition of basalt fibres on compressive strength, tensile strength, flexural strength, water absorption, chloride penetration resistance, and freeze-thaw resistance of Pervious concrete. Concrete samples were prepared with various amounts of basalt fibre (0%, 5%, 10%, 15%, and 20%) and tested according to the available standards to determine their properties. The findings showed that when concrete was reinforced with basalt fibres, it exhibited a highlighted improvement in terms of performance. 15% fibre content revealed compressive strength improvement of 23% and tensile and flexural strengths by 35% and 33%, respectively. At a fibre content of 20%, the water absorption, chloride penetration, and freeze-thaw resistance were, respectively, reduced by 23%, improved by 48%, and the mass loss during freeze-thaw was reduced by 56%. The results highlight the potential application of basalt fibre-reinforced concrete (BFRC) in improving the structural performance and durability of PQC pavement under extreme environmental conditions. Abstract: This research aims to determine the effect of basalt fibre (BF) on the mechanical and physical characteristics of the mortar and the optimum amount of BF to be used. With the addition of BF to the mortar, the size of 1. 40 g and 2. 28 g and with the addition of BF to the mortar, the size of the physical mechanisms Before starting to study the effect of BF on the physical properties of mortar, the mortar that will be studied in the work should be homogeneous and the humidity should be produced in a moist and dry environment for 24 hours or more.

Keywords: Concrete, basalt fiber reinforcement, compressive strength, tensile strength, flexural strength, durability

***Author for Correspondence**
Saurabh Singh

[1]M.Tech Scholar, Department of Civil Engineering, Suresh Gyan Vihar University, Rajasthan, India.
[2]Associate Professor, Department of Civil Engineering, Suresh Gyan Vihar University, Rajasthan, India.
[3,4]Assistant Professor, Department of Civil Engineering, Suresh Gyan Vihar University, Rajasthan, India.
[5]Assistant Professor, Department of Civil Engineering, Poornima University, Sitapura, Rajasthan, India.
[6]Associate Professor, Department of Civil Engineering, Poornima University, Sitapura, Rajasthan, India.

Received Date: January 17, 2025
Accepted Date: February 18, 2025
Published Date: June 01, 2025

Citation: Anuj Shukla, Ravindra Budania, Vikas Pandey, Shahnawaz Ahmed Mir, Ankush Kumar Jain, Saurabh Singh. Enhancing Concrete Durability and Mechanical Properties for Pavement Quality Concrete (PQC) Roads Using Basalt Fiber Reinforcement. Journal of Polymer & Composites. 2025; 13(Special Issue 4): S266–S280p.

INTRODUCTION

Pavement Quality Concrete (PQC) is one of the primary constituents of modern transportation infrastructure, serving as the foundation for roads, highways, and bridges[1], [2]. Its strength and durability are essential for long-term performance, especially in regions of heavy traffic loading, extreme climate, and environmental disabilities like freeze-thaw cycles and chloride ingestion. Despite its pervasive use, conventional concrete has intrinsic brittleness and low tensile strength —

shortcomings that can lead to cracking, decreased durability and costly maintenance[3][4]. Basalt fiber is an excellent reinforcement material for Pavement Quality Concrete (PQC) roads due to its superior tensile strength, corrosion resistance, and thermal stability[5]. These properties make basalt fibers particularly effective in enhancing the durability and lifespan of concrete pavements by improving their resistance to environmental stresses such as freeze-thaw cycles and thermal fluctuations. This reinforcement leads to concrete roads that are not only more resilient to cracking and environmental damage but also require less frequent maintenance, thus extending the service life of the pavement and reducing overall lifecycle costs. By mitigating the common degradation factors of traditional concrete, basalt fiber-reinforced concrete ensures that PQC roads can withstand harsh conditions and heavy traffic loads, making it a cost-effective and sustainable solution for modern road infrastructure. Methods such as fibreglass reinforcement have been proposed as a means of increasing concrete performance[6][7][8]. One of these innovations is basalt fibres, which are made from natural volcanic rock basalt and are financially robust due to their high tensile strength, corrosion resistance, and mastery over peak temperatures compared to other thermoplastic fibres [9][10][11]. Basalt Fiber Reinforced Concrete (BFRC) is a composite of basalt fibres and concrete that offers advantages in terms of mechanical properties and durability[8][12]. Research on the impact of basalt fibres on the compressive and flexural strengths of concrete has revealed that optimal performance is achieved when the fiber content is within the range of $0.5\% - 1\%$ by volume [13][14][15][16]. Studies show that basalt fibres improve freeze-thaw and chloride penetration resistance, resulting in longer service life of concrete[17]. BFRC is shown to retain its performance characteristics in long-term studies[18]. Basalt fibres have better performance than steel, polypropylene, and glass fibres [19]. Steel fibers have a high tensile strength but are corrosive, meanwhile, polypropylene fibers promote chemical resistance but do not improve tensile strength significantly[20]. Glass fibers, though strong, are susceptible to alkali attack, a problem addressed by AR glass fibers but still inferior to basalt fibers in thermal stability and durability[21]. Basalt fibre has mostly been used in the construction of buildings[16], with little research conducted on PQC for road pavements, making this relevant for the already established field of concrete research. The study addresses this gap by investigating the application of basalt fibre-reinforced concrete (BFRC) in road construction where distinct conditions prevail, including elevated dynamic loads and considerable abrasion. In addition to needing to reassess mix proportions to make it viable given the strains of road traffic, the use of BFRC on roads will also require meeting regulatory standards of roads and the inherent differences between road and non-road use. In addition, the economic and scalability aspects of such steps need to be carefully studied to understand if BFRC is viable at the infrastructure scale of roadway construction.

The essence of this research rests on its undertaking to tailor and improve BFRC formulations for road pavement applications, precisely and at large; this is an entirely unrepresented aspect in the literature. Thus, utilizing the superior durability and environmental resistance of basalt fibres, the study aims to use it as an alternative to conventional road construction materials, which would cover a long span of service life of road surfaces with minimized maintenance.

Other than providing improved properties of the material, there is more to the significance of the use of BFRC in road pavements. The implementation of basalt fibres not only has the potential to reduce the overall cost of roads through improved durability but also supports global environmental objectives and sustainability initiatives by reducing the carbon footprint associated with road construction.

There are multiple objectives of this research. First, the study aims to evaluate the mechanical characteristics and longevity of BFRC when used for road pavements. In addition, it seeks to develop optimized BFRC mix designs for the particularities of road construction. In addition, a full lifecycle cost and environmental impact study will be undertaken on the usage of BFRC road pavements. Finally, large-scale field experiments will be conducted to validate BFRC performance on actual roads and ensure results can be practically applied. Overall, this research will make a significant advancement in manufacturing more rugged, cheap, and sustainable road infrastructure.

Journal of Polymer & Composites
Volume 13, Special Issue 4
ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

RESEARCH DESIGN

This study is designed in an experimental manner quarter to assess the influence of basalt fibre on the mechanical and durability behaviour of concrete. IS codes, which are standardized processes, are followed to obtain accurate, viable, and reproducible outcomes. We design concrete specimens with the inclusion of basalt fibre contents of 0%, 5%, 10%, 15%, and 20% in order to evaluate their effect on the structural performance of concrete.

Materials

Cement

The cement used is Ordinary Portland Cement (OPC) of 43 Grade, with a fineness of 300 m²/kg and a specific gravity of 3.15. The consistency is standardized to ensure proper hydration and setting time. This cement conforms to IS: 8112-1989 specifications, ensuring adherence to quality standards for concrete use.

Fine aggregates

Natural river sand is used as fine aggregates, with a specific gravity of 2.65 and a grading zone of II, as per IS: 383-1970. The fineness modulus is 2.7. The sand is sourced from riverbeds and is thoroughly washed and sieved to remove impurities and oversized particles to ensure proper workability and strength in the concrete mix.

Coarse aggregates

The coarse aggregates consist of crushed granite stone with a specific gravity of 2.70 and the maximum size of the aggregate was 20 mm. These aggregates are the main constituents of the concrete mix and are screened in accordance with IS: 383-1970 standard, and they play a significant role in the strength, durability and workability of concrete.

Basalt fibers

We use continuous basalt fibers with diameters ranging from 13-20 micrometers and lengths between 12-50 mm. The fibers possess a 2.65 specific gravity, a 2000-3000 MPa tensile strength and a Young's Modulus in the 85-90 GPa range. These are chosen because of their excellent mechanical properties and environmental resistance.

Water

Potable water, free from impurities and contaminants, is used. The pH value of the water ranges from 6.5 to 8.5 and conforms to IS: 456-2000 specifications. The water facilitates cement hydration and affects the workability and strength of the concrete.

Chemical admixtures

A polycarboxylate ether (PCE)-based superplasticizer is used, with a dosage of 0.8% by weight of cement[22]. It has a specific gravity of 1.10 and provides a water reduction of 20-25%. This admixture enhances the workability, durability, and strength of the concrete.

Preparation of Specimens

Batching

Batching involves accurately measuring and combining the concrete mix ingredients: OPC, fine and coarse aggregates, basalt fibers, water, and chemical admixtures. Cement, fine aggregates, coarse aggregates, and water are measured as per the mix design. Basalt fibers are added in varying concentrations (0%, 5%, 10%, 15%, and 20%), and superplasticizer is added at 0.8% by weight of cement as shown in Table 1.

Mixing

The mixing process involves blending all ingredients to achieve a homogeneous mix. The procedure includes dry mixing of cement, fine, and coarse aggregates for 2 minutes, followed by the gradual addition of basalt fibers. Water mixed with superplasticizer is added while mixing for an additional 3 minutes, and the mixture is blended for 2 more minutes to ensure uniform consistency.

Table 1. Material composition of concrete mixes with varying percentages of basalt fibers (0% to 20%).

Material	Weight (kg/m³)	M0 (0%)	M1 (5%)	M2 (10%)	M3 (15%)	M4 (20%)
Cement	350	350	350	350	350	350
Fine Aggregate	780	780	780	780	780	780
Coarse Aggregate	1050	1050	1050	1050	1050	1050
Water	157.5	157.5	157.5	157.5	157.5	157.5
Basalt Fibers	0	17.5	35	52.5	70	
Superplasticizer	2.8	2.8	2.8	2.8	2.8	2.8

Casting

Concrete is poured into molds to form specimens for testing. Molds used include cube molds (150 mm x 150 mm x 150 mm) for compressive strength, cylindrical molds (150 mm diameter x 300 mm height) for tensile strength, and beam molds (100 mm x 100 mm x 500 mm) for flexural strength. The procedure includes cleaning and oiling the molds, pouring the concrete in three layers, compacting each layer, and leveling the surface before initial curing.

Experimental Procedures and Testing Methods

To determine the workability of fresh concrete, a slump cone is filled with concrete in three layers, each tamped 25 times. The cone is then lifted, and the slump is measured immediately to assess consistency. The degree of compaction is measured using a compaction factor apparatus. Concrete is allowed to fall through hoppers into a cylindrical mold, and the weights of the partially and fully compacted concrete are recorded. Workability is measured using the Vee-Bee consistometer, where concrete is placed in a slump cone and vibrated. The time required for the concrete to change shape from a cone to a cylindrical shape is recorded. The flowability of fresh concrete is evaluated using a flow table and mold. Concrete is placed in the mold, lifted, and allowed to spread. The diameter of the spread concrete is measured to determine flowability. The L-Box apparatus assesses the passing ability and flow of self-compacting concrete. The height of concrete at the beginning and end of the horizontal section is measured to calculate the L-Box ratio. The J-Ring test evaluates the passing ability and flowability of self-compacting concrete. Concrete is spread using a J-Ring, and the height difference between the inner and outer rings is measured. Flowability is assessed using the V-Funnel. The time taken for concrete to flow out of the funnel completely is recorded. The maximum compressive load that concrete can withstand is measured using a compression testing machine with cube specimens. The load at failure is recorded and used to calculate compressive strength. Tensile strength is measured by applying a diametral compressive load to cylindrical specimens. The maximum load at failure is recorded to calculate tensile strength. Concrete's resistance to bending is measured using a flexural testing machine with beam specimens. The load at failure is recorded and used to calculate flexural strength. Stiffness and deformation of concrete under load are assessed using a universal testing machine with cylindrical specimens. The modulus of elasticity is calculated from the stress-strain curve obtained from the test. Porosity and permeability are evaluated by measuring the dry and saturated weights of specimens. The water absorption percentage is calculated from these measurements.

Resistance to chloride ion ingress is assessed using the Rapid Chloride Permeability Test (RCPT). The total charge passed through the specimen is measured to determine resistance. Durability under freeze-thaw cycles is tested by subjecting specimens to 300 freeze-thaw cycles. Reductions in mass and compressive strength are measured to evaluate resistance. Surface hardness and compressive strength are estimated using a rebound hammer. The rebound number is recorded at multiple points and averaged. Concrete quality and uniformity are evaluated by measuring the time taken for an ultrasonic pulse to travel through the specimen. The pulse velocity is calculated from this measurement. Data from all tests on concrete specimens are recorded and analyzed using statistical methods such as regression analysis and ANOVA. This analysis determines the effects of varying basalt fiber content on the mechanical and durability properties of the concrete.

RESULTS AND DISCUSSION

Fresh Concrete Properties

The slump test evaluates the workability of fresh concrete by measuring its vertical settlement after removing a conical mold. Figure 1 shows the slump values for concrete mixes with varying basalt fiber contents (0%, 5%, 10%, 15%, and 20%). The control mix (M0) shows the highest slump of 75 mm, indicating good workability. As basalt fiber content increases, slump values decrease: 70 mm for 5% (M1), 65 mm for 10% (M2), 60 mm for 15% (M3), and 55 mm for 20% (M4) Figure 1. This decrease reflects reduced workability due to the basalt fibers increasing internal friction and stiffness, making the mix less flowable and more challenging to handle. The reduced workability with higher fiber content necessitates more effort for placement and compaction, potentially affecting construction practices. Despite this, basalt fibers improve other properties like tensile strength and durability, which are beneficial for structural applications.

The compaction factor test measures how well fresh concrete compacts. Figure 2 shows a decrease in compaction factor as basalt fiber content increases, indicating reduced workability. The control mix (M0) had the highest compaction factor, while higher fiber contents resulted in progressively lower values due to increased internal friction and stiffness.

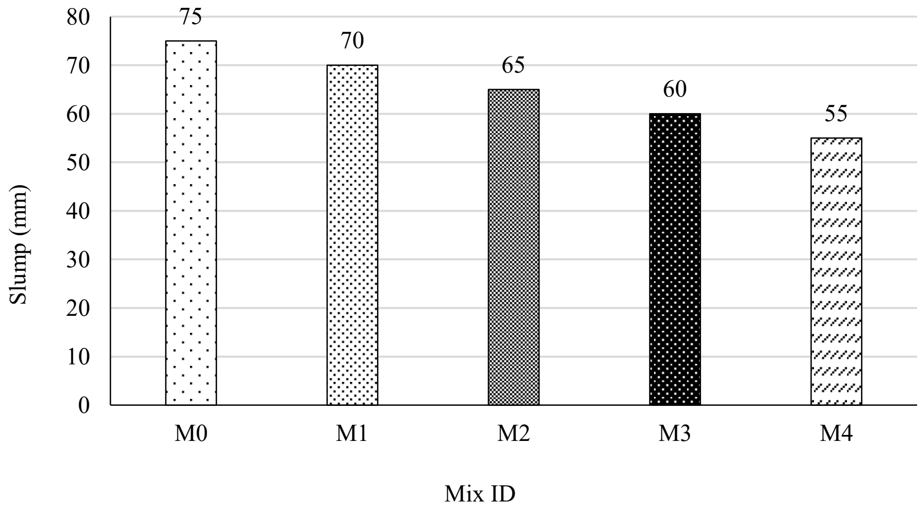

Figure 1. Slump values for different concrete mixes (M0 to M4), highlighting the effect of increasing basalt fiber content on the workability of fresh concrete.

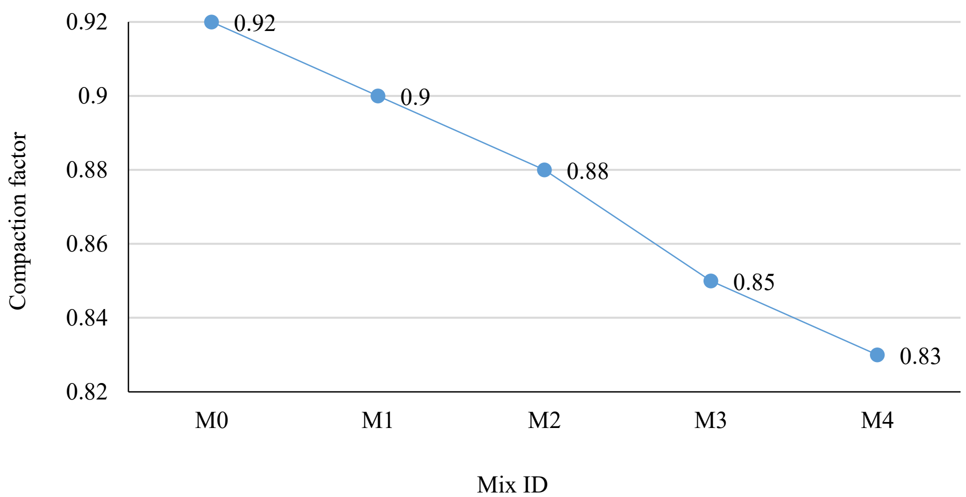

Figure 2. Compaction factor values for different concrete mixes (M0 to M4).

The Vee-Bee consistometer test assesses concrete's viscosity and plasticity by measuring the time required for concrete to settle under vibration. As shown in Figure 3, Vee-Bee time increases with higher basalt fiber content, indicating decreased workability due to increased internal resistance and cohesiveness.

The flow test evaluates the spreadability of concrete. Figure 4 shows that as basalt fiber ontent rises, flow diameter decreases, reflecting reduced followability. Basalt fibers introduce barriers and increase internal friction, making the mix stiffer and less able to spread easily.

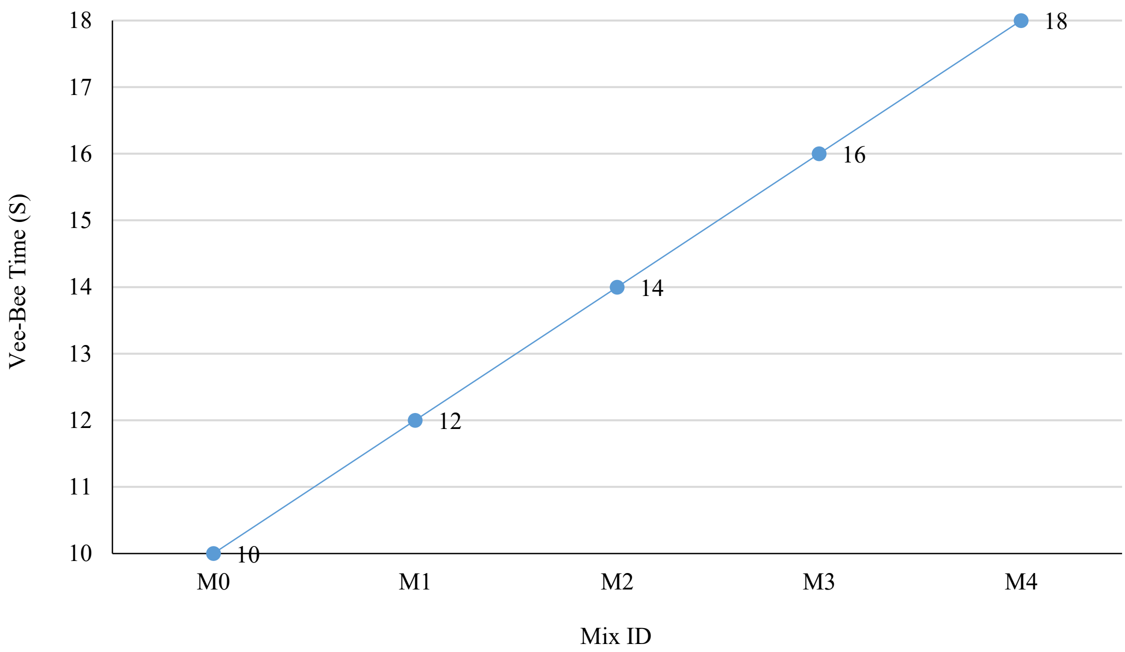

Figure 3. Vee-Bee Time values for different concrete mixes (M0 to M4).

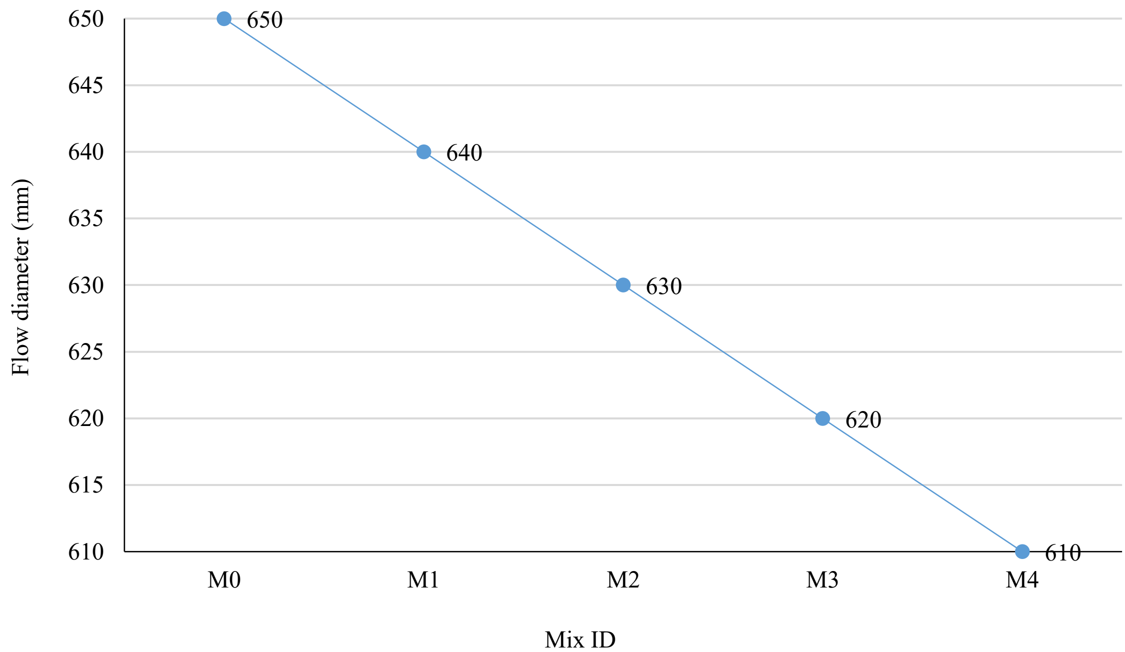

Figure 4. Flow Diameter values for different concrete mixes (M0 to M4).

ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

The L-Box test measures the passing ability of self-compacting concrete through obstacles. Figure 5 shows a reduction in the L-Box ratio with increased fiber content, indicating decreased flowability and passing ability due to increased viscosity and physical blockage.

The J-Ring test assesses the ability of concrete to flow around obstacles. Table 2 illustrates that J-Ring flow decreases and height difference increases with higher fiber content, signifying reduced flowability and increased resistance to moving around rebar.

The V-Funnel test measures the flowability of concrete through a funnel. Figure 6 shows that V-Funnel time increases with more basalt fibers, indicating reduced flowability due to increased friction and cohesiveness within the mix.

Mechanical Properties

The mechanical properties of the basalt fiber-reinforced concrete were evaluated through compressive strength, tensile strength, and flexural strength tests.

Compressive strength testing reveals that basalt fibers enhance strength up to 15% content (M3), after which strength slightly decreases at 20% (M4). Figure 7 shows this trend, where too many fibers may create clumps or affect workability, reducing overall strength.

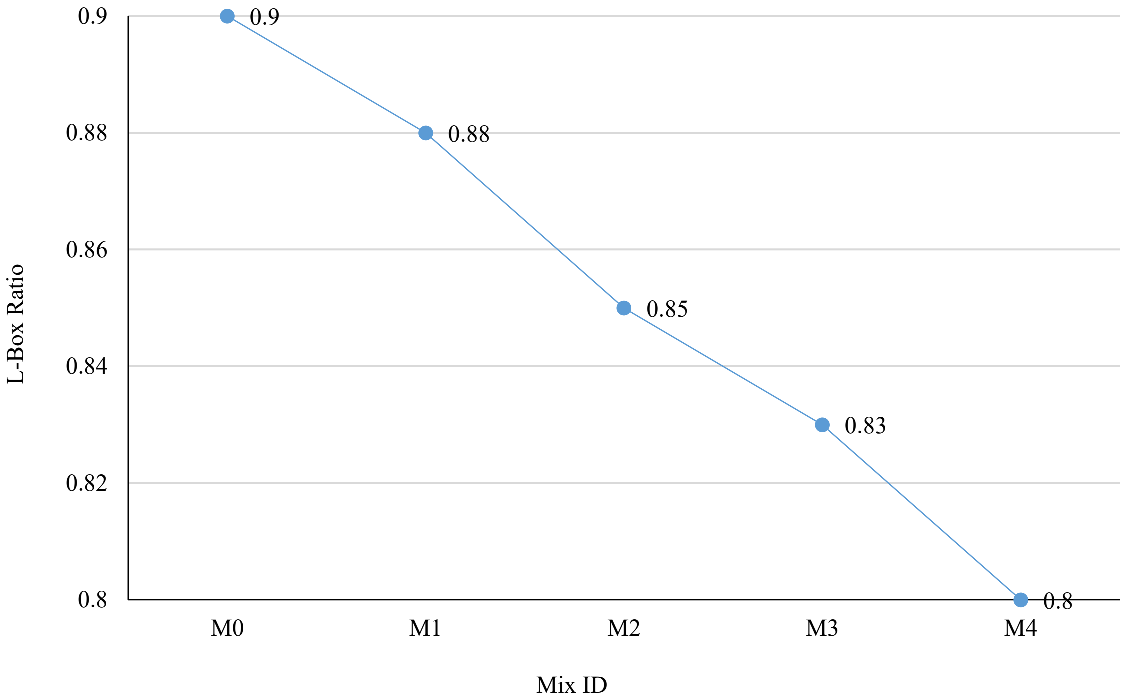

Figure 5. L-Box ratio values for different concrete mixes (M0 to M4).

Table 2. J-Ring Flow and Height Difference values for different concrete mixes (M0 to M4).

Mix ID	Basalt fiber content (%)	J-ring flow (mm)	Height difference (mm)
M0	0	650	10
M1	5	640	12
M2	10	630	14
M3	15	620	16
M4	20	610	18

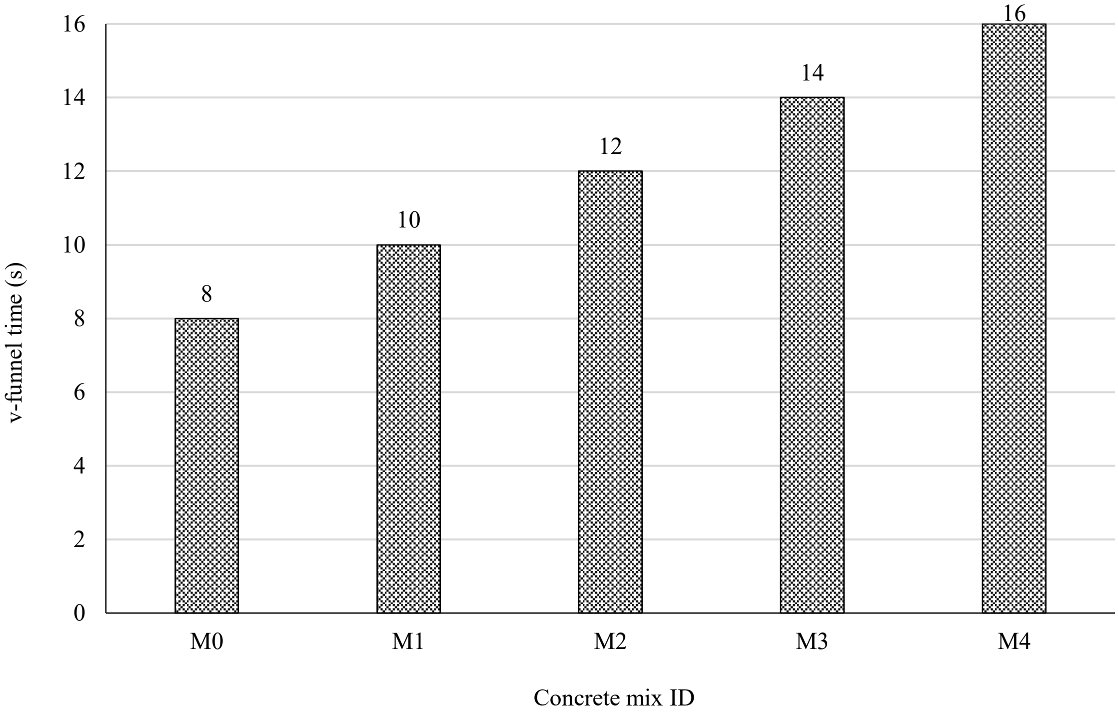

Figure 6. V-Funnel Time values for different concrete mixes (M0 to M4).

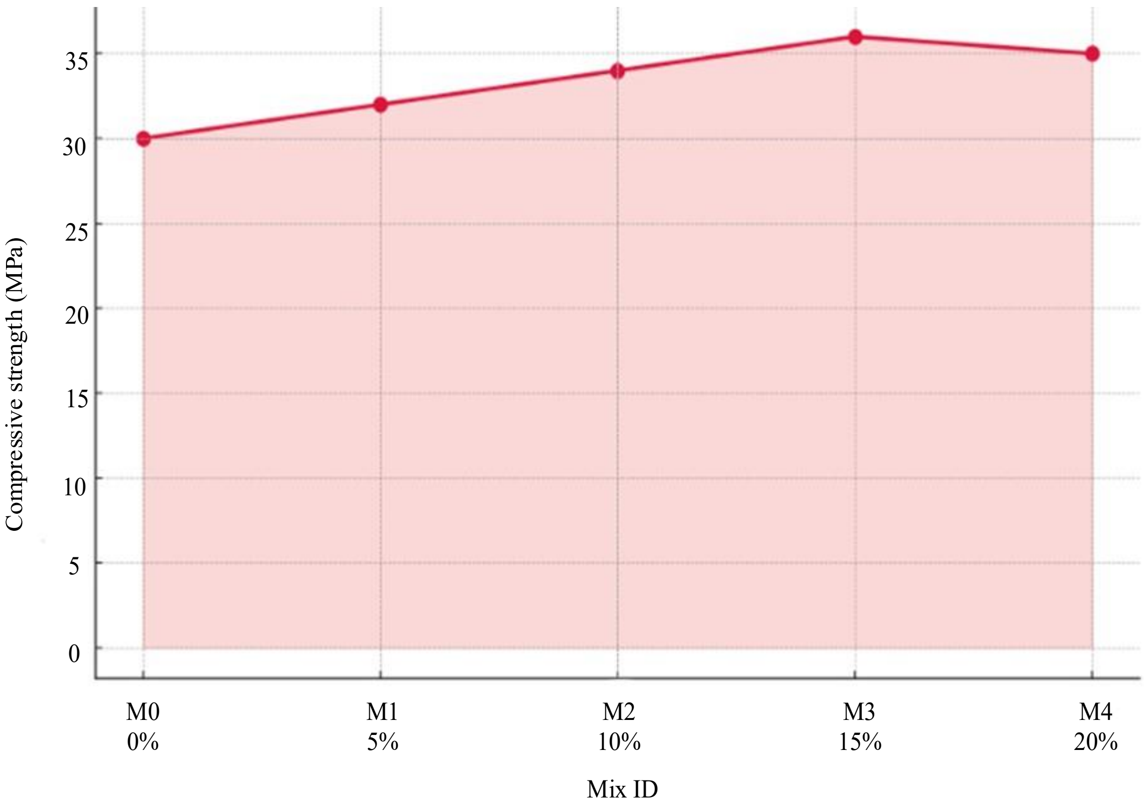

Figure 7. Compressive strength values for different concrete mixes (M0 to M4).

Figure 8. indicates that tensile strength improves with up to 15% basalt fibers but declines at 20%. Increased fiber content bridges cracks effectively but can also lead to clustering and reduced workability.

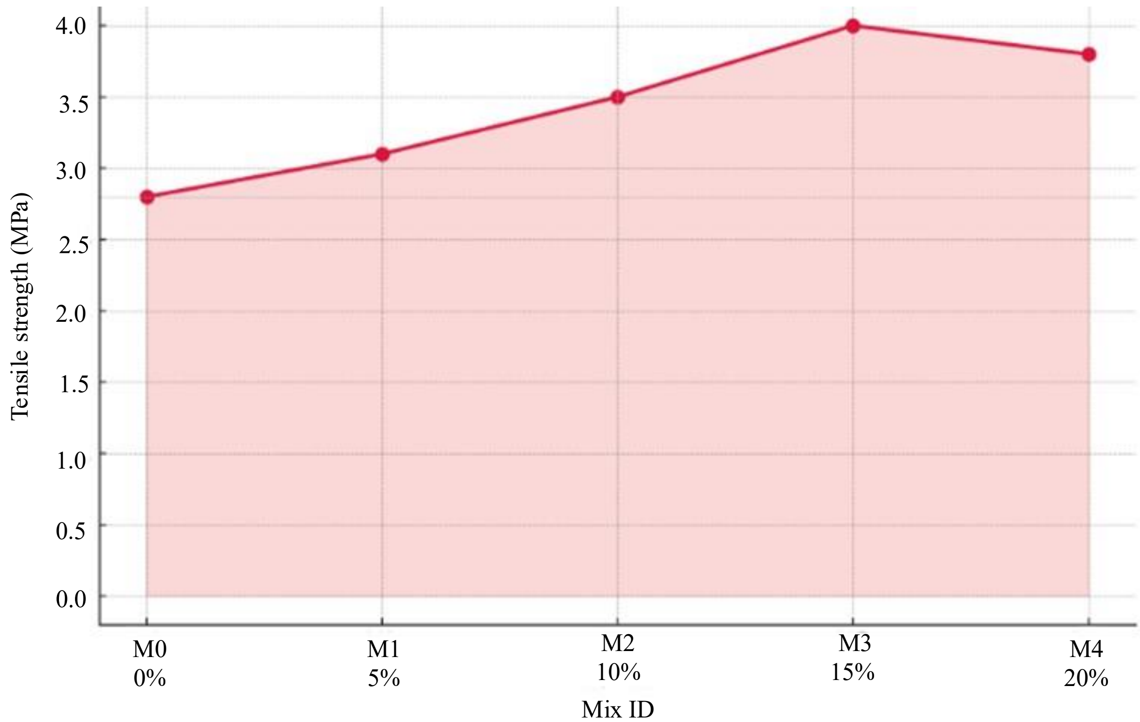

Figure 8. Tensile Strength values for different concrete mixes (M0 to M4).

Figure 9 demonstrates that flexural strength increases with basalt fibers up to 15% but slightly declines at 20%. The fibers enhance bending resistance by bridging cracks, though excessive amounts may affect distribution and workability.

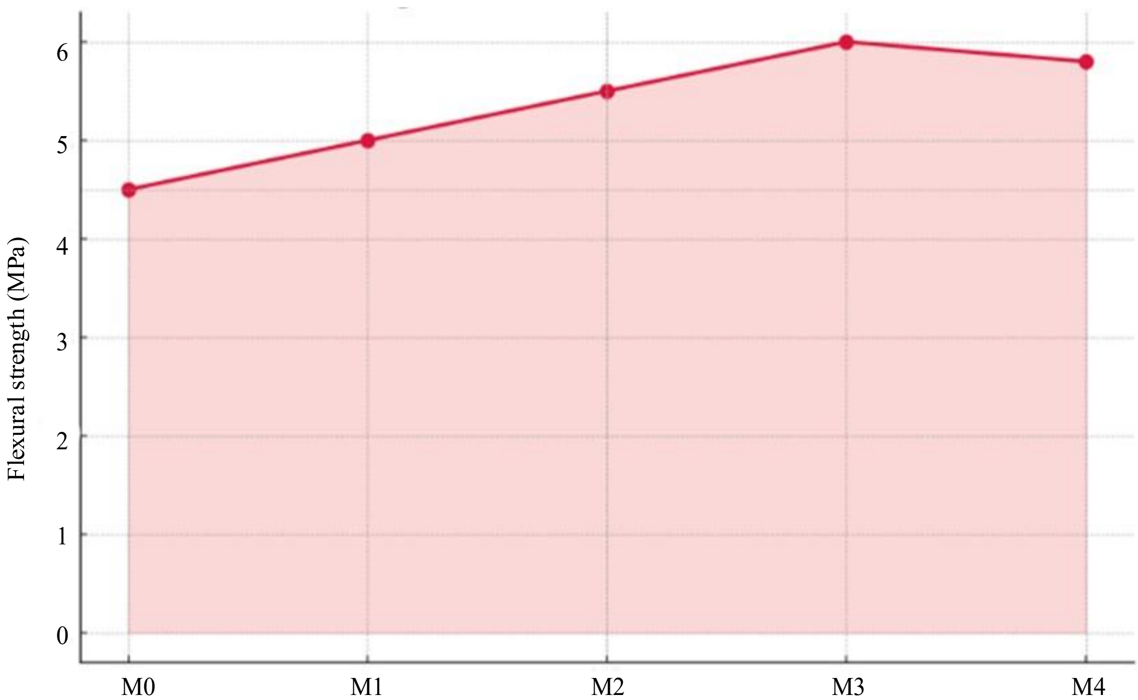

Figure 9. Flexural Strength values for different concrete mixes (M0 to M4).

Durability Tests

Figure 10 shows decreased water absorption with higher fiber content, indicating reduced porosity and improved durability. Figure 11 illustrates reduced chloride ion penetration with increased fiber content, indicating improved resistance to chloride ingress. Figure 12 shows improved freeze-thaw resistance with higher fiber content, as evidenced by reduced mass loss and strength loss.

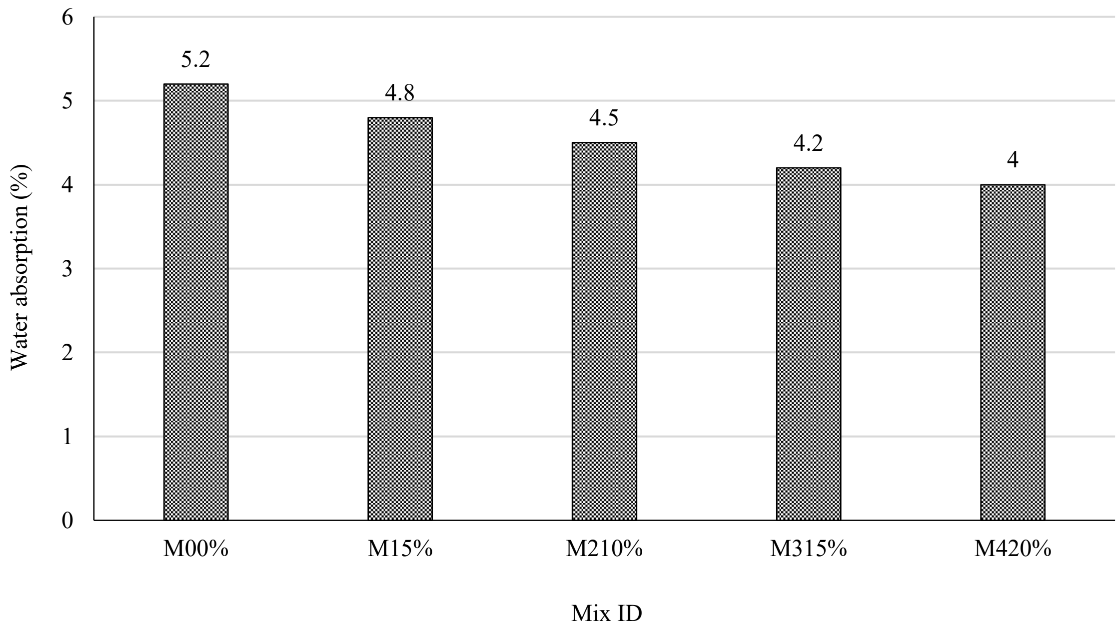

Figure 10. Water Absorption values for different concrete mixes (M0 to M4).

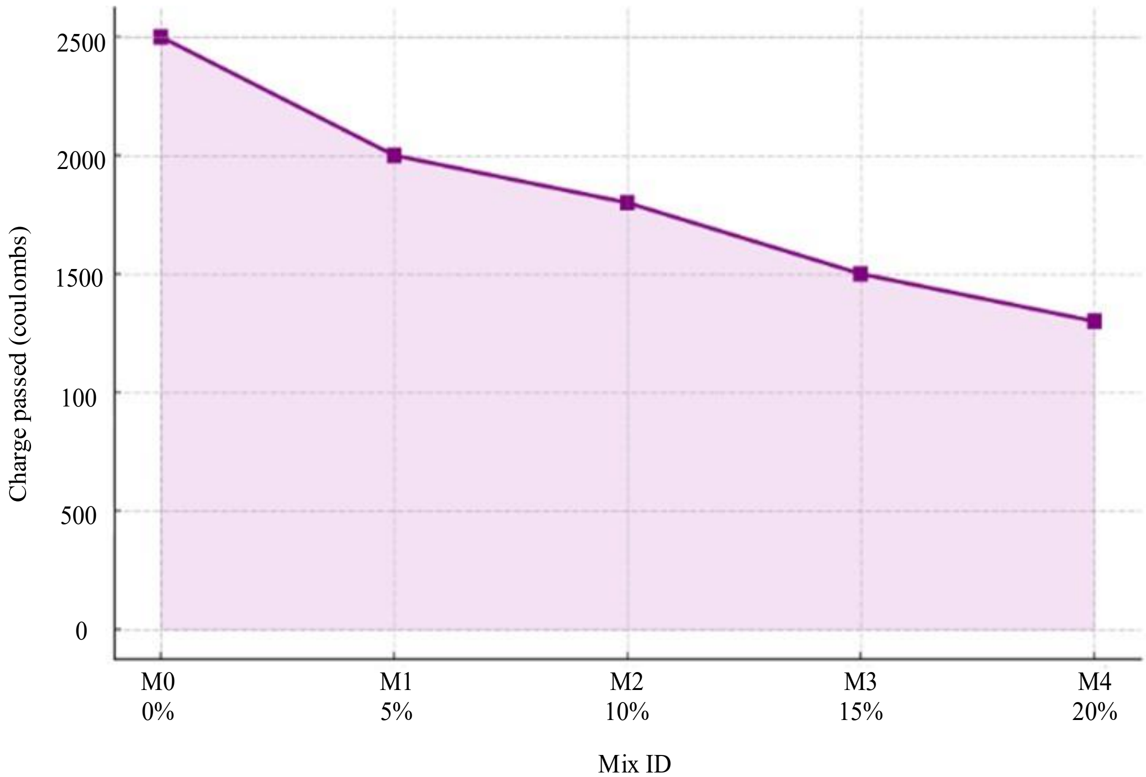

Figure 11. Chloride Penetration values for different concrete mixes (M0 to M4).

ISSN: 2321-2810 (Online), ISSN: 2321-8525 (Print)

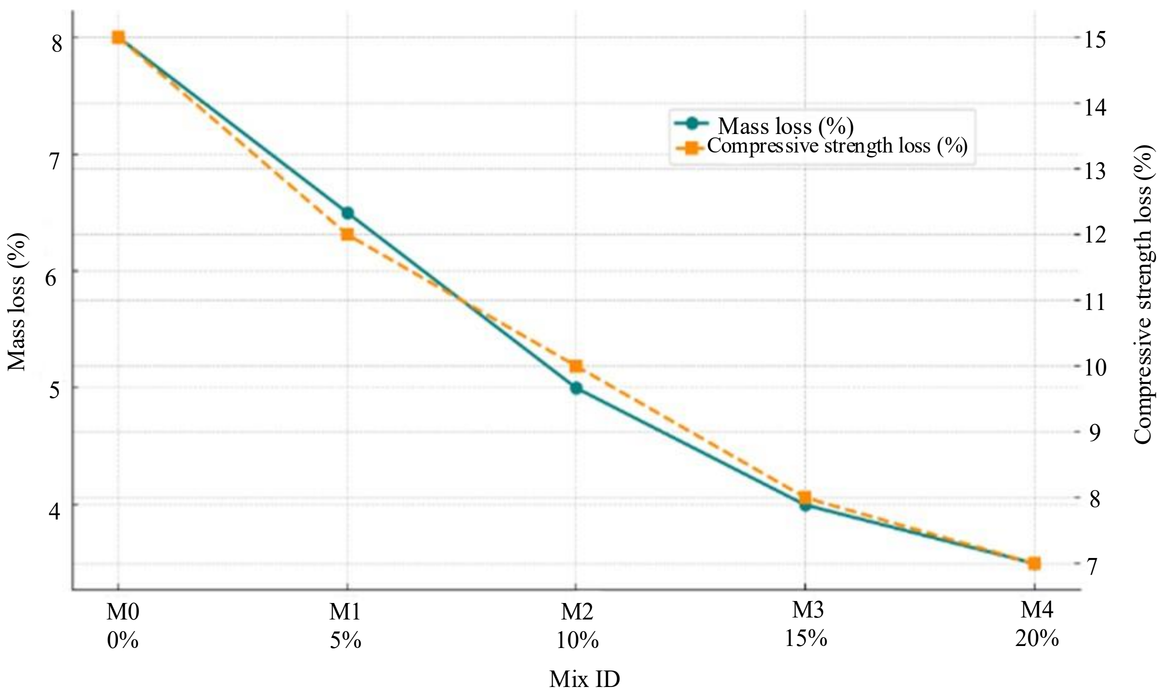

Figure 8. Freeze-Thaw resistance values for different concrete mixes (M0 to M4).

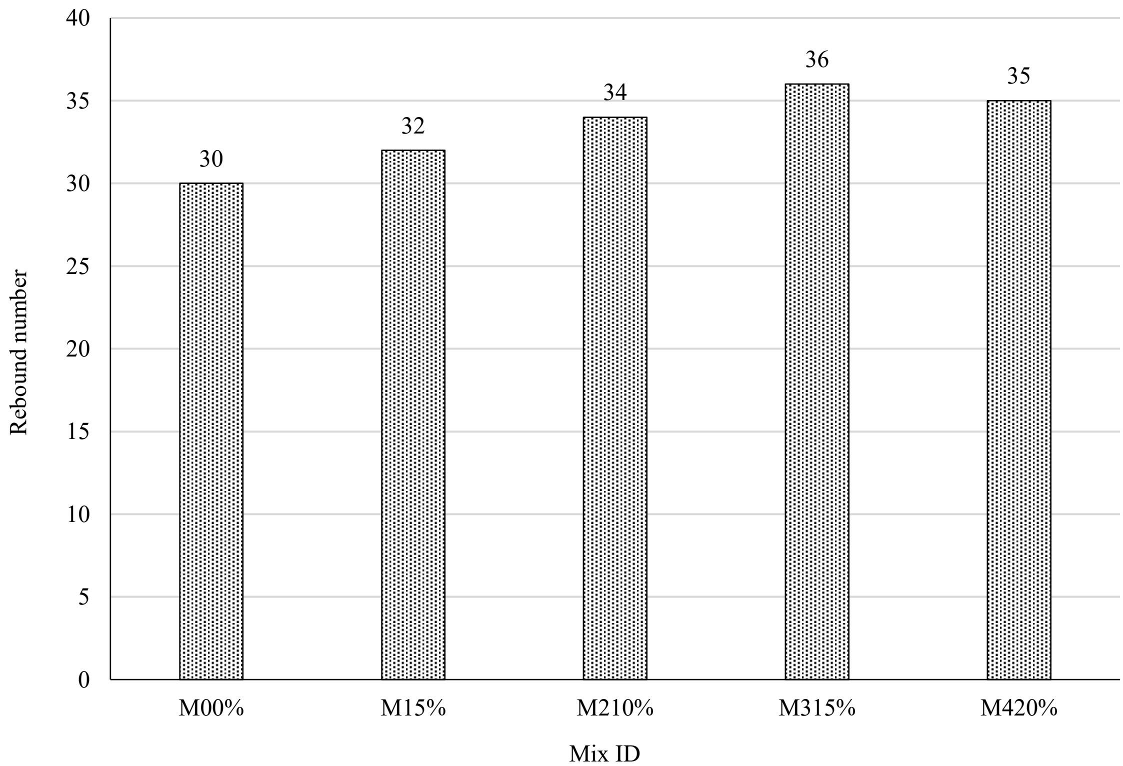

Figure 9. Rebound Hammer values for different concrete mixes (M0 to M4).

Non-Destructive Tests

Figure 13 shows that rebound hammer values increase with higher fiber content, indicating improved surface hardness. Figure 14 indicates higher ultrasonic pulse velocity with increased fiber content, reflecting improved concrete quality and uniformity.

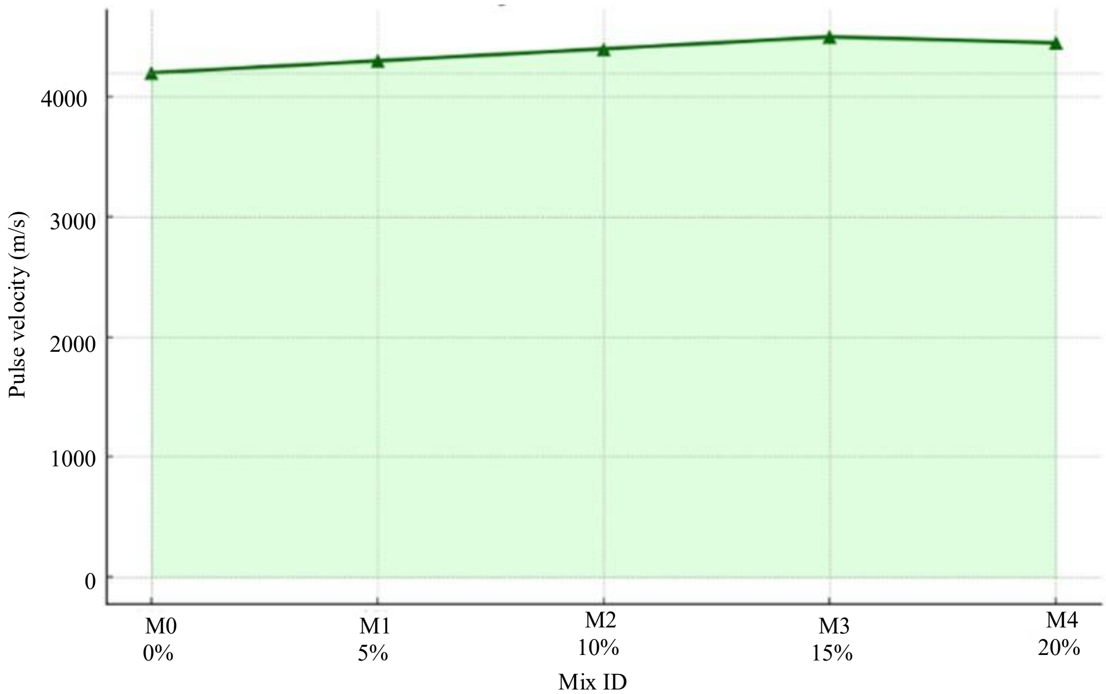

Figure 10. Indicates higher ultrasonic pulse velocity.

This deep understanding of how basalt fibers transform the properties of concrete is revealed in the results of thorough testing of basalt fiber-reinforced concrete. The fibers have played a consistent role to improve the quality and performance of concrete, from workability, mechanical strength, and durability. With respect to workability, the addition of basalt fibers reduced the slump value from 75 mm in the control mix to 55 mm in the mix utilizing 20% fiber content; therefore, it exhibited a lower workability. This is due to internal friction increase in the mix, and the way fibers absorb water. With rising fiber content comes the demand for more water and energy to reach a workable consistency, indicated by rising Vee-Bee times and lowering compaction factors. The fibers notably enhance the mechanical properties of the concrete, improving its strength characteristics. Compressive strength was observed to increase from 30 MPA during the fiber-free mix to a maximum of 45 MPa in the solution with 15% fiber, with a marginal decrease at the 20% fiber concentration. The peaks correspond to a range of fibers contents in which the compressive strength increases. Likewise, tensile and flexural strengths are significantly enhanced at the optimal fiber content, indicating that the fibers are able to better distribute the stress and inhibit the propagation of cracks. Testing proved that basalt fibers will make the concrete more durable in the face of environmental challenges. There was reduced water absorption according to the data which decreased from a control mix of 6% to 3% for the20% fiber mix, which means that a denser and less permeable material has been obtained. Additionally, results from chloride penetration tests and freeze-thaw resistance indicated improved durability of fiber-reinforced mixes, implying that this type of concrete could endure aggressiveness of environmental exposure superior. These trends were corroborated by non-destructive evaluations using rebound hammer tests and ultrasonic pulse velocity tests, the results of which indicated development of surface hardness and internal uniformity vis-à-vis increased rebound numbers and pulse velocities respectively, thereby confirming the availability of voids for the concrete. These results are important as it indicates that basalt fiber-reinforced concrete are not only better-suited against mechanical stresses but have better durability characteristics as well. A very significant development on the concrete manufacture - is the addition of a basalt fiber in the mix, aiming for increased mechanical strengths and durability features. This makes basalt fiber reinforced concrete a potent prognosis for modern construction applications, in an age when demand for durability and strength are ever-increasing. Overall, the progressive enhancement in multiple tests presents affirmative merits for employing basalt fibers in concrete, ushering us toward a more sustainable and durable approach in construction.

CONCLUSION

This is a study to Enhance the durability and mechanical properties of Pavement Quality Concrete (PQC) roads using basalt fiber reinforcement. The research achieved several key findings in terms of workability, mechanical strength, and durability based on varying amounts of basalt fiber added to the concrete mix design (from 0% to 20%).

The main finding was the decrease in workability with increasing basalt fiber content. In the slump test results, workability decreased from 75 mm in the control mix (0% fiber) to 55 mm at 20% fiber content. This decline was also validated by the compact test factors Vee-Bee consistometer tests, confirming that the increased fibers content makes the concrete mix stiffer and therefore increasingly difficult to pose. Although this poses practical issues when it comes to placement and compaction, these are manageable through appropriate construction techniques and adjustments of the mix. Basalt fiber-augmented concrete showed substantial itself an improvement in compressive, tensile and flexural strength. It was also discovered that 15% volume fraction of fibers was optimal since there were the most significant improvements in strength seen at that volume fraction. Further improvement had been observed in this percentage and thereafter the benefits started to plateau or decrease marginally which proved that 15% was the optimum fiber content to be used for enhancement of the structural capacity of PQC without compromising either workability or performance. Moreover, the durability tests confirmed the benefits of using basalt fiber reinforcements in PQC, especially for road applications. Basalt fibers replaced the water absorption, improved resistance to penetrating chloride, and significantly increased durability to frost and thaw. These engineering improvements are crucial in the durability of pavements exposed to heavy traffic load, moisture, de-icing salts and temperature cycles leading to more impermeable and durable pavement structures. Due to increased durability of BFRC, the service life of PQC road gets extended and reduced frequency of repairs / overall maintenance cost. Surface hardness of the PQC was measured using rebound hammer tests while an assessment of internal uniformity was conducted using ultrasonic pulse velocity tests which confirmed that PQC with basalt fiber had superior hardness and internal uniformity which contributes to long-term performance of road applications. The results confirm the economic potential of basalt fibers for enhancing the performance and sustainability of road pavements. Overall, this stale gives a better understanding of the use of basalt fiber reinforced concrete in the engineering field especially in PQC roads which helps in extending life of the pavements. The enhanced mechanical properties and durability characteristics make it especially relevant for applications in roadways that experience high loading and aggressive conditions[23]. These findings corroborate the polymeric features of basalt fibers for the potential development of low-cost, durable, and sustainable road infrastructure, thus helping to pave the way for the realization of long-lasting and resilient transportation systems.

Acknowledgments

We extend our deepest gratitude to all those who contributed to the successful completion of this research. Special thanks to the faculty and technical staff of the Department of Civil Engineering at Suresh Gyan Vihar University and Poornima University for their invaluable support and access to the laboratory facilities, which were crucial for our experiments.

REFERENCES

1. S. Singh, S. K. Singh, R. Kumar, A. Shrama, and S. Kanga, ‘Finding Alternative to River Sand in Building Construction’, 2022, Accessed: May 24, 2024. [Online]. Available: https://catalog.lib.kyushu-u.ac.jp/ja/recordID/6625713/?repository=yes
2. R. K. Dhir, J. de Brito, R. Mangabhai, and C. Q. Lye, ‘7 - Use of Copper Slag in Road Pavement Applications’, in Sustainable Construction Materials: Copper Slag, R. K. Dhir, J. de Brito, R. Mangabhai, and C. Q. Lye, Eds., Woodhead Publishing, 2017, pp. 247–277. doi: 10.1016/B978-0-08-100986-4.00007-9.
3. K. Ashwini and P. Srinivasa Rao, ‘Behavior of concrete using alccofine and nano-silica under elevated temperature’, IJATEE, vol. 8, no. 78, pp. 600–618, May 2021, doi: 10.19101/IJATEE.2021.874077.

4. S. Luo, T. Bai, M. Guo, Y. Wei, and W. Ma, ‘Impact of Freeze–Thaw Cycles on the Long-Term Performance of Concrete Pavement and Related Improvement Measures: A Review’, Materials, vol. 15, no. 13, Art. no. 13, Jan. 2022, doi: 10.3390/ma15134568.
5. S. Gandhi, S. S. S. Roji, M. Motta, R. R. D. Nalawade, M. Allah Khan, and S. Palanisamy, ‘Analysis of potential incorporation of waste into asphalt pavements’, Materials Today: Proceedings, May 2024, doi: 10.1016/j.matpr.2024.05.097.
6. B. V. Bahoria, A. Ranjith, G. Laxmaiah, S. Solomon Raj, M. Ranjan Padhi, and S. Palanisamy, ‘Verification of the mechanical behavior of concrete with partial replacement of the fiber resulting from tire retreading’, Materials Today: Proceedings, Apr. 2024, doi: 10.1016/j.matpr.2024.04.067.
7. Effect of Additional Fiberglass Fiber on Concrete Performance | IIETA’. Accessed: Jan. 06, 2025. [Online]. Available: https://www.iieta.org/journals/acsm/paper/10.18280/acsm.430502
8. N. Kumar, Brijbhushan. S, Maneeth. P.D, Shreenivas. Reddy. S, and Siddharth. B, ‘Experimental study on strength properties of concrete replacing cement by marble dust and sand by iron ore tailings’, IJATEE, vol. 5, no. 45, pp. 255–261, Aug. 2018, doi: 10.19101/IJATEE.2018.545009.
9. S. Palanisamy, K. Vijayananth, T. M. Murugesan, M. Palaniappan, and C. Santulli, ‘The prospects of natural fiber composites: A brief review’, International Journal of Lightweight Materials and Manufacture, vol. 7, no. 4, pp. 496–506, Jul. 2024, doi: 10.1016/j.ijlmm.2024.01.003.
10. H. Liu et al., ‘A Review on Basalt Fiber Composites and Their Applications in Clean Energy Sector and Power Grids’, Polymers, vol. 14, no. 12, Art. no. 12, Jan. 2022, doi: 10.3390/polym14122376.
11. R. Kattoli, S. Brijbhushan, P. D. Maneeth, S. S. Reddy, and B. Siddharth, ‘Effect of partial replacement of cement by ground granulated blast furnace slag and sand by iron ore tailings on properties of concrete’, International Journal of Advanced Technology and Engineering Exploration, vol. 5, no. 45, pp. 269–275, 2018.
12. Y. Zheng, Y. Zhang, J. Zhuo, Y. Zhang, and C. Wan, ‘A review of the mechanical properties and durability of basalt fiber-reinforced concrete’, Construction and Building Materials, vol. 359, p. 129360, Dec. 2022, doi: 10.1016/j.conbuildmat.2022.129360.
13. S. Singh et al., ‘Evaluating Recycled Concrete Aggregate and Sand for Sustainable Construction Performance and Environmental Benefits’, CivilEng, vol. 5, no. 2, Art. no. 2, Jun. 2024, doi: 10.3390/civileng5020023.
14. M. B. Khan, M. Houda, N. S. Zada, M. Imran, and O. Benjeddou, ‘Hybrid effect of basalt fibers and carbon fibers on concrete mechanical and environmental properties’, Results in Engineering, vol. 25, p. 103780, Mar. 2025, doi: 10.1016/j.rineng.2024.103780.
15. A. M. Jabbar, M. J. Hamood, and D. H. Mohammed, ‘The effect of using basalt fibers compared to steel fibers on the shear behavior of ultra-high performance concrete T-beam’, Case Studies in Construction Materials, vol. 15, p. e00702, Dec. 2021, doi: 10.1016/j.cscm.2021.e00702.
16. N. I. Vatin, M. Hematibahar, and T. H. Gebre, ‘Impact of basalt fiber reinforced concrete in protected buildings: a review’, Front. Built Environ., vol. 10, May 2024, doi: 10.3389/fbuil.2024.1407327.
17. J. Wei, Z. Wang, W. Sun, and R. Yang, ‘Durability Performance and Corrosion Mechanism of New Basalt Fiber Concrete under Organic Water Environment’, Materials, vol. 16, no. 1, Art. no. 1, Jan. 2023, doi: 10.3390/ma16010452.
18. E. T. Al-Rousan, H. R. Khalid, and M. K. Rahman, ‘Fresh, mechanical, and durability properties of basalt fiber-reinforced concrete (BFRC): A review’, Developments in the Built Environment, vol. 14, p. 100155, Apr. 2023, doi: 10.1016/j.dibe.2023.100155.
19. S. Gupta, P. Sihag, M. S. Thakur, and U. Kose, Eds., Applications of Computational Intelligence in Concrete Technology. Boca Raton: CRC Press, 2022. doi: 10.1201/9781003184331.
20. Y. I. A. Aisheh, D. S. Atrushi, M. H. Akeed, S. Qaidi, and B. A. Tayeh, ‘Influence of polypropylene and steel fibers on the mechanical properties of ultra-high-performance fiber-reinforced geopolymer concrete’, Case Studies in Construction Materials, vol. 17, p. e01234, Dec. 2022, doi: 10.1016/j.cscm.2022.e01234.
21. Ya. V. Lipatov, S. I. Gutnikov, M. S. Manylov, E. S. Zhukovskaya, and B. I. Lazoryak, ‘High alkali-resistant basalt fiber for reinforcing concrete’, Materials & Design, vol. 73, pp. 60–66, May 2015, doi: 10.1016/j.matdes.2015.02.022.

22. M. Schmid and J. Plank, 'Dispersing performance of different kinds of polycarboxylate (PCE) superplasticizers in cement blended with a calcined clay', Construction and Building Materials, vol. 258, p. 119576, Oct. 2020, doi: 10.1016/j.conbuildmat.2020.119576.
23. N. M. Azmee and N. Shafiq, 'Ultra-high performance concrete: From fundamental to applications', Case Studies in Construction Materials, vol. 9, p. e00197, Dec. 2018, doi: 10.1016/j.cscm.2018.e00197.

