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EXPERIMENTAL INVESTIGATION ON WORKABILITY, MECHANICAL PROPERTIES & THERMAL EFFECT OF POLYMER FIBER REINFORCED CONCRETE (STYRENE BUTADIENE RUBBER (SBR), POLYPROPYLENE ROPE) USING BRICK AND NATURAL AGGREGATE

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Abstract
This study investigates the workability, mechanical properties, and thermal effects of polymer fiber-reinforced M20-grade concrete with varying aggregate compositions The experimental program evaluates four concrete mixes: (1) Control mix with 100% natural aggregate (without polymer and fiber), (2) 100% natural aggregate (with polymer and fiber), (3) 50% natural + 50% brick aggregate with polymer and fiber, (4) 100% brick aggregate with polymer and fiber, and assessment of thermal conductivity effect for each mix. A fixed 10% polymer ratio was maintained, while the polypropylene rope fiber content varied from 0% to 1%. The fresh concrete was evaluated for workability using the slump test, while hardened properties were assessed through compressive strength, split tensile strength, and flexural strength tests at 7 and 28 days also analyzing thermal conductivity and insulation performance. Results indicated that increasing fiber content reduced workability but improved mechanical properties up to an optimum fiber dosage. Incorporating brick aggregates enhanced thermal insulation properties but led to a minor reduction in mechanical strength. This study highlights the feasibility of polymer fiber-reinforced concrete with hybrid aggregates for sustainable and durable construction applications.

INTRODUCTION

Concrete remains the backbone of modern construction due to its high compressive strength, durability, and adaptability [1]. However, the increasing demand for sustainable and efficient construction materials has led researchers to explore alternative aggregates, polymers, and fiber reinforcements [2]. Conventional concrete primarily relies on natural aggregates, but their extraction poses environmental concerns, such as resource depletion and habitat destruction [3]. To address these challenges, the utilization of recycled materials, such as brick aggregates, has emerged as a viable solution. Brick aggregates, derived from demolished structures, offer an eco-friendly substitute with acceptable structural properties [4]. Furthermore, fiber reinforcement, particularly polypropylene rope fibers, has been incorporated into concrete to enhance its tensile and flexural strength [5].

Polypropylene fibers prevent crack propagation, improving structural integrity and impact resistance [6]. This study aims to comprehensively analyze the effects of SBR polymer and polypropylene rope fibers in M20- grade concrete with varying aggregate compositions. By evaluating workability, mechanical performance, and thermal conductivity, this research contributes to the development of enhanced concrete materials suitable for sustainable construction practices. The findings will provide insights into optimizing polymer-fiber reinforced concrete for improved structural performance and energy efficiency.

Statement of the Problem

Concrete is the most widely used construction material due to its high strength and durability. However, conventional concrete primarily depends on natural aggregates, whose excessive extraction leads to environmental degradation, resource depletion, and increased carbon footprint. To promote sustainable construction, the integration of recycled materials, such as brick aggregates, is being explored as an alternative to natural aggregates. However, brick aggregate concrete exhibits higher water absorption and lower strength compared to conventional concrete, necessitating modifications to enhance its performance.

Additionally, concrete is inherently brittle and susceptible to cracking under tensile stresses. To overcome this limitation, fiber reinforcement has been introduced to improve its mechanical properties. Among the available fibers, polypropylene rope fibers offer significant advantages in enhancing tensile and flexural strength while preventing crack propagation. Furthermore, the incorporation of polymers, such as Styrene Butadiene Rubber (SBR), has been found to improve the workability, durability, and adhesion of concrete. Despite the growing interest in polymer-fiber reinforced concrete, limited studies have systematically analyzed the combined effects of SBR polymer and polypropylene rope fibers on the workability, mechanical properties, and thermal behavior of concrete using different aggregate compositions. The influence of these additives on the strength, durability, and thermal conductivity of concrete needs further investigation to optimize its structural performance for sustainable applications. This study aims to bridge this knowledge gap by conducting an experimental investigation on the workability, mechanical performance, and thermal effects of SBR and polypropylene rope fiber-reinforced concrete using natural and brick aggregates. The research will provide insights into the feasibility of incorporating polymer-fiber reinforcement in concrete, particularly for applications where improved mechanical strength and thermal insulation properties are required.

Objectives of the Study

The primary objective of this study is to evaluate the effects of Styrene Butadiene Rubber (SBR) polymer and polypropylene rope fibers on the workability, mechanical properties, and thermal performance of concrete using different aggregate compositions. The specific objectives of this research are:

To assess the workability of polymer- fiber reinforced concrete incorporating SBR and polypropylene rope fibers with varying proportions of natural and brick aggregates.

To evaluate the mechanical properties of the modified concrete, including compressive strength, tensile strength, and flexural strength, to determine the impact of fiber and polymer additions.

To investigate the thermal performance of different concrete mix designs by analyzing thermal conductivity and insulation properties, particularly when incorporating brick aggregates.

To compare the performance of natural aggregate concrete and brick aggregate concrete in combination with SBR polymer and polypropylene rope fibers, identifying the most suitable mix for improved strength and durability.

To analyze the influence of fiber content variation (0% to 1%) on the overall behavior of concrete and determine the optimal fiber dosage for structural applications.

To contribute to sustainable construction practices by promoting the use of recycled aggregates and polymer-fiber reinforcement as a means of enhancing concrete performance while reducing environmental impact.

This study aims to provide a comprehensive understanding of the effects of polymer and fiber modifications on concrete and offer practical recommendations for optimizing its use in construction application Materials and Methods

Previous Studies

Several researchers have investigated the use of alternative aggregates, polymers, and fiber reinforcements to enhance the properties of concrete. The integration of recycled aggregates, such as brick aggregates, has gained attention as a sustainable alternative to natural aggregates. However, studies indicate that brick aggregates exhibit higher water absorption and lower strength compared to natural aggregates, necessitating modifications to improve their performance.

Use of Brick Aggregates in Concrete

Researchers have explored the feasibility of brick aggregates as a replacement for natural aggregates in concrete. Studies have shown that while brick aggregates can be effectively used in structural applications, they tend to reduce the compressive strength of concrete due to their porous nature. However, appropriate mix design adjustments, such as optimizing the water-cement ratio and incorporating polymer additives, can improve the overall strength and durability of brick aggregate concrete.

Effect of SBR Polymer in Concrete

The incorporation of Styrene Butadiene Rubber (SBR) polymer has been widely studied for its ability to enhance workability, adhesion, and durability in concrete. Research indicates that SBR improves the bonding properties between cement paste and aggregates, leading to better cohesion and reduced permeability. Additionally, SBR-modified concrete demonstrates improved flexural strength and crack resistance, making it suitable for structural applications requiring enhanced durability.

Influence of Polypropylene Fibers in ConcreteStudies have shown that polypropylene fibers significantly improve the tensile and flexural strength of concrete by preventing crack propagation. The addition of fibers enhances the ductility and impact resistance of concrete, reducing its brittleness under tensile stresses. Furthermore, research suggests that the performance of fiber-reinforced concrete depends on factors such as fiber content, aspect ratio, and dispersion within the matrix.

Combined Effects of Polymer and Fiber Reinforcement

Limited studies have examined the combined effects of SBR polymer and polypropylene fibers in concrete. However, existing research suggests that using both polymer and fiber reinforcements enhances mechanical performance and durability. The polymer improves bonding and cohesion, while the fibers contribute to crack control and tensile strength.

Thermal Performance of Concrete with Alternative Aggregates and Fibers

The thermal properties of concrete are influenced by its composition and porosity. Research indicates that brick aggregates have better thermal insulation compared to natural aggregates due to their porous structure. The addition of fibers and polymers may further modify the thermal conductivity of concrete, making it suitable for applications requiring better heat resistance and energy efficiency.

Research Gap

Despite significant studies on brick aggregate concrete, SBR-modified concrete, and fiber-reinforced concrete, very few studies have comprehensively analyzed the combined effects of SBR polymer and polypropylene rope fibers on the workability, mechanical performance, and thermal properties of concrete. This study aims to bridge this gap by conducting an experimental investigation on the performance of polymer-fiber reinforced concrete using both natural and brick aggregates.

This research will contribute to the development of sustainable and high- performance concrete for construction applications, particularly where improved strength, durability, and thermal insulation are required.

The materials utilized in this study include Ordinary Portland Cement (OPC) 43 grade, fine aggregate, coarse aggregate, coarse brick aggregate, Styrene-Butadiene Rubber (SBR), and Polypropylene Rope Fiber, all conforming to ASTM standards. The physical and mechanical properties of these materials were assessed to ensure their suitability for concrete production.

OPC 43 grade cement was used, with a specific gravity of **3.12** (ASTM C188), ensuring appropriate density. The fineness was **5%** (ASTM C430), indicating adequate particle size distribution. Standard consistency was **27%** (ASTM C187), ensuring optimal water demand. Initial and final setting times were **128 minutes** and **317 minutes**, respectively, meeting ASTM C191 requirements.

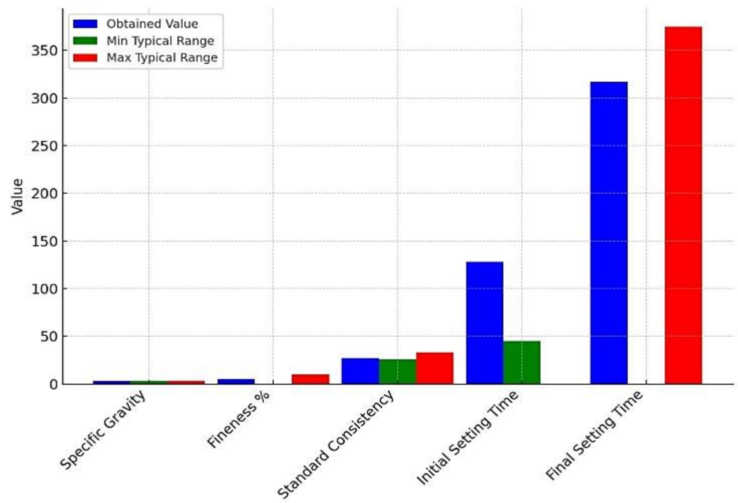


Table.1 Cement Test Results for OPC 43 Grade Standard (ASTM C150)

Test Parameter	Test Standard (ASTM)	Obtained Value	Typical Range
Specific Gravity	ASTM C188	3.12	3.10 - 3.15
Fineness %	ASTM C430	5%	≤ 10%
Standard Consistency	ASTM C187	27%	26 - 33%
Initial Setting Time	ASTM C191	128 minutes	≥ 45 minutes
Final Setting Time	ASTM C191	317 minutes	≤ 375 minutes

Figure.1 Cement Test Results (OPC 43 Grade)

FINE AGGREGATE (Sand) Fine aggregate exhibited a specific gravity of **2.66** (ASTM C128) and a fineness modulus of **2.74** (ASTM C136), confirming well-graded particle distribution. Water absorption was measured at **1.4%** (ASTM C128), ensuring minimal porosity and better durability.

Table.2 Fine Aggregate Test Results Standard (ASTM C33)

Test Parameter	Test Standard (ASTM)	Obtained Value	Typical Range
Specific Gravity	ASTM C128	2.66	2.6 - 2.9
Fineness Modulus (FM)	ASTM C136	2.74	2.0 - 3.0
Water Absorption (%)	ASTM C128	1.4%	≤ 3%

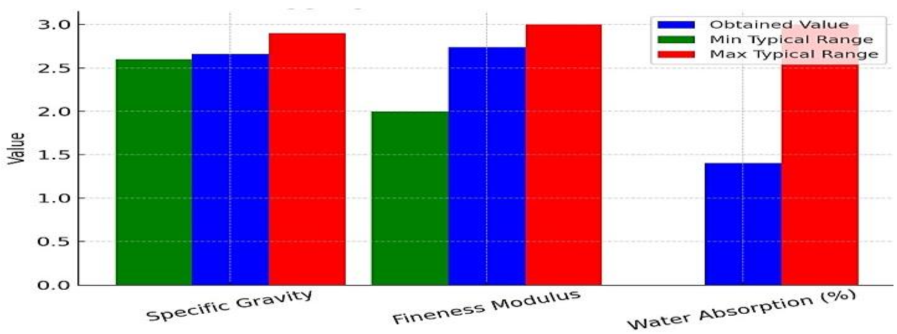


Figure.2 Fine Aggregate Test Results

OARSE AGGREGATE (Natural)

The specific gravity of coarse aggregate was 2.66 (ASTM C127), with a water absorption rate of 1.02% (ASTM C127), indicating low porosity. The flakiness and elongation indices were 16% and 26%, respectively (ASTM D4791), confirming good particle shape. The impact, crushing, and abrasion values were 9.1%, 19.50%, and 21.26% (ASTM D5874,
ASTM C131), ensuring adequate toughness and strength.

Table.3 Coarse Natural Aggregate Test Results Standard (ASTM C33)

Test Parameter	Test Standard (ASTM)	Obtained Value	Typical Range
Specific Gravity	ASTM C127	2.66	2.6 - 2.9
Water Absorption (%)	ASTM C127	1.02%	≤ 2%
Flakiness Index (%)	ASTM D4791	16%	≤ 25%
Elongation Index (%)	ASTM D4791	26%	≤ 35%
Aggregate Impact Value (%)	ASTM D5874	9.1%	≤ 20%
Aggregate Crushing Value (%)	ASTM C131	19.50%	≤ 25%
Aggregate Abrasion Value (%)	ASTM C131	21.26%	≤ 30%

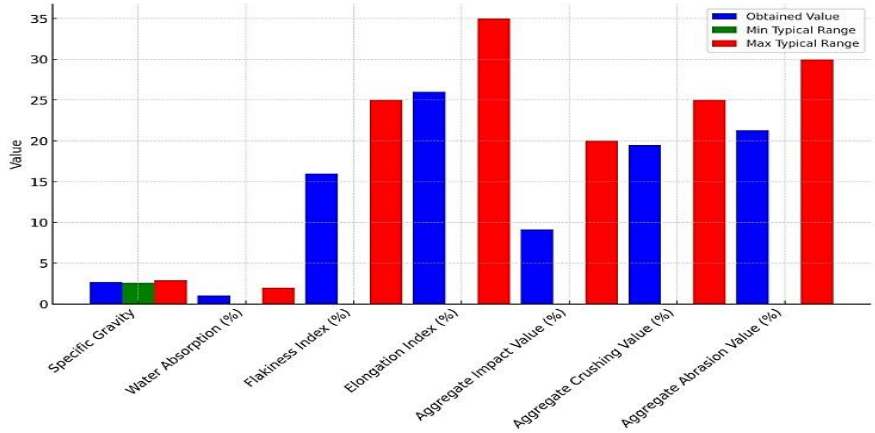


Fig.3 Coarse Natural Aggregate Test Results

COARSE AGGREGATE (Brick)
Brick aggregate had a specific gravity of **2.25** (ASTM C127) and a water absorption rate of **9.5**%, indicating higher porosity. Flakiness and elongation indices were **20**% and **18**% (ASTM D4791), while impact, crushing, and abrasion values were **6.8**%, **23.5**%, and **33.3**% (ASTMD5874, ASTM C131), demonstrating satisfactory strength characteristics.

Table.4 Coarse Brick Aggregate Test Results Standard (ASTM C33)

Test Parameter	Test Standard (ASTM)	Obtained Value	Typical Range
Specific Gravity	ASTM C127	2.25	2.2 - 2.5
Water Absorption (%)	ASTM C127	9.5%	≤ 20%
Flakiness Index (%)	ASTM D4791	20%	≤ 25%
Elongation Index (%)	ASTM D4791	18%	≤ 35%
Aggregate Impact Value (%)	ASTM D5874	6.8%	≤ 30%
Aggregate Crushing Value (%)	ASTM C131	23.5%	≤ 30%
Aggregate Abrasion Value (%)	ASTM C131	33.3%	≤ 35%

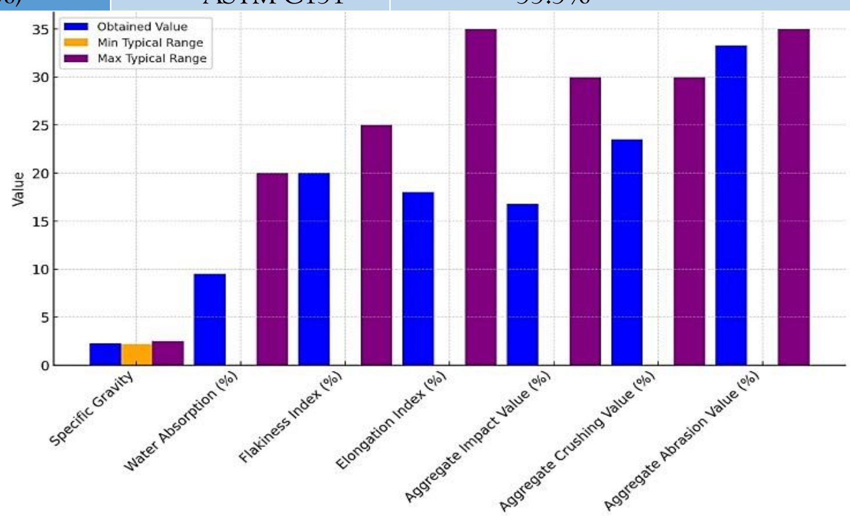


Figure.4 Coarse Brick Aggregate Test Results

(SBR)
SBR polymer was used as an additive, with a solid content of **46**% (ASTM D1417) and a level was **9.5** (ASTM E70), viscosity **250 cP** (ASTM D2196), and bond strength **3.8 MPa** (ASTM C882), indicating good adhesion properties.

Table.5 Physical and Chemical Properties of SBR Polymer Standard (ASTM C1059)

Test Parameter	Test Standard (ASTM)	Obtained Value	Typical Range
Appearance	Visual Inspection	Milky white liquid	Milky white to light yellow
Solid Content (%) by Gravimetric Method	ASTM D1417	46%	45 - 55%
pH Level	ASTM E70	9.5	7 - 11
Density (g/cm3)	ASTM D1475	1.01	1.00 - 1.02
Viscosity (cP at 25°C)	ASTM D2196	250 cP	200 - 300 cP
Bond Strength (MPa)	ASTM C882	3.8 MPa	≥ 3 MPa

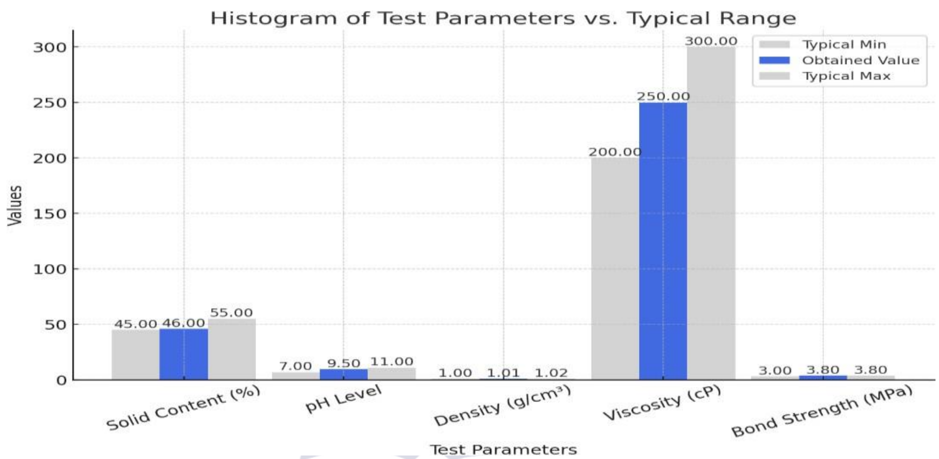


Figure.5 SBR Polymer Properties

Polypropylene rope fiber exhibited a tensile strength of **440 MPa** (ASTM D2256) and a density of **0.90 g/cm3** (ASTM D792). Water D570). The fiber length and diameter were **38.1 mm** and **0.5 mm**, respectively, ensuring effective reinforcement in concrete.

Table.6 Physical and Mechanical Properties of Polypropylene Rope Fiber Standard (ASTM C1116

Test Parameter	Test Standard (ASTM)	Obtained Value	Typical Range
Tensile Strength (MPa)	ASTM D2256	440MPa	350 – 800 MPa
Density (g/cm3)	ASTM D792	0.90 g/cm3	0.89 –0.93 g/cm3
Water Absorption (% by weight)	ASTM D570	0.01%	≤ 0.1%
Fiber Length (mm)	No Specific ASTM	38.1mm	30 – 40 mm
Fiber Diameter (mm)	No Specific ASTM	0.5mm	0.4 – 0.6 mm

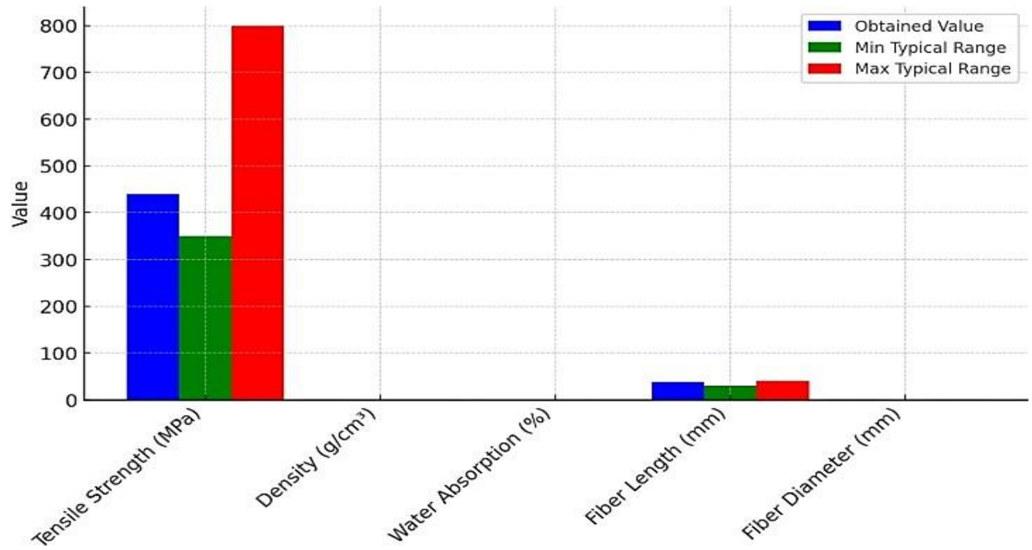


Figure.6 Physical and Mechanical Properties of Polypropylene Rope Fiber

5.7 WATER

Water quality plays a crucial role in determining the **workability, strength, and durability** of concrete. ASTM C1602 sets specific limits to ensure that mixing water does not adversely affect concrete performance. The pH level of **7.1** falls within the recommended range of **6.0 - 8.5**, allowing for proper cement hydration. The total dissolved solids (TDS) content is **1240 mg/L**, which is well below the **2000 mg/L** limit, indicating minimal impurities. Additionally, the chloride concentration of **460 mg/L** remains within the **500 mg/L** threshold for reinforced concrete, reducing the risk of corrosion. Based on these parameters, the water available in **Rahim Yar Khan meets ASTM C1602 standards**, making it **suitable for concrete mixing** while ensuring long-term structural durability.

Table.7 Water Test Results Standard (ASTM C1602)

Test Parameter	Obtained Value	Typical Range
Chloride Content mg/L	460	<500
Total Dissolved Solids (TDS) mg/L	1240	≤ 2000
pH Level	7.1	6.0- 8.5

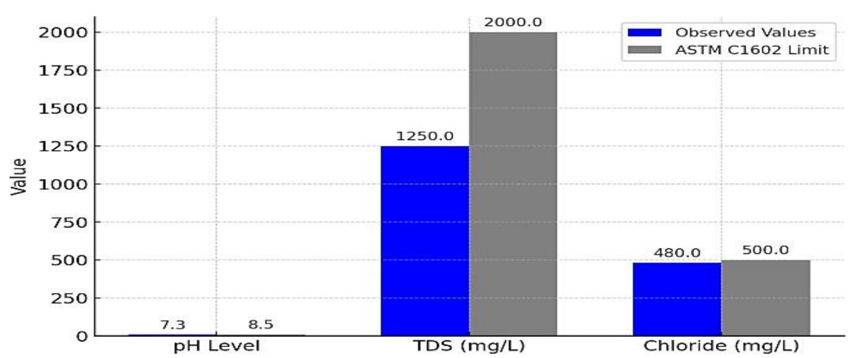


Figure.7 Water Test

Figure.8 Materials Test durability, and thermal performance. In this study, Styrene Butadiene Rubber (SBR)

5.8: Mix design proportion

Concrete mix design is a crucial process that determines the appropriate proportions of cement, fine aggregate, coarse aggregate, water, and admixtures to achieve the desired strength, polymer (10%) and Polypropylene (PP) rope fiber (0–1%) are incorporated into M20 grade concrete to enhance mechanical properties and thermal resistance. The mix variations focus on different aggregate compositions while following ASTM standard guidelines as shown in table 8.The control mix consists of 100% natural aggregates with a proportion of 1:1.65:3.08 (Cement: Fine Aggregate: Coarse Aggregate) and a water-cement ratio of 0.50. This mix provides standard strength and durability, making it suitable for conventional construction. The second variation introduces 10% SBR polymer and 0–1% PP rope fiber while maintaining the natural aggregate composition. SBR polymer enhances bond strength, durability, and resistance to chemical attack, while PP rope fiber improves tensile strength and crack resistance. To evaluate the effect of brick aggregates, the third mix replaces 50% of the natural aggregate with brick aggregate, while cement and fine aggregate proportions remain unchanged. Due to the higher absorption capacity of brick aggregate, the water-cement ratio is increased to 0.56 to ensure proper hydration and strength development. This modification results in enhanced thermal insulation and sustainable concrete production, although the compressive strength is slightly lower than the 100% natural aggregate mix. The final mix completely replaces natural aggregate with 100% brick aggregate, requiring an even higher water- cement ratio of 0.60 to maintain hydration and strength. This mix demonstrates improved thermal insulation and a lightweight structure, making it suitable for heat-resistant construction. However, the strength is reduced compared to natural aggregate-based mixes due to the lower density and weaker bonding properties of brick aggregates.

Overall, natural aggregate-based mixes provide higher strength, while brick aggregate-based mixes offer better thermal insulation and environmental sustainability. The addition of SBR polymer and PP rope fiber significantly enhances durability, crack resistance, and bond strength, making polymer fiber-reinforced concrete an effective material for applications requiring improved structural integrity and thermal efficiency.

Table.8 Mix Design Proportion for Different Compositions

Mix Type	Cement	Fine Aggregate	Coarse Aggregate	Water	Polymer (SBR)	Fiber (PP Rope)
100% Natural Aggregate	1	1.65	3.08	0.50	0%	0%
100% Natural Aggregate (With Polymer & Fiber)	1	1.65	3.08	0.50	10%	0–1%
50% Natural + 50% Brick Aggregate (With Polymer & Fiber)	1	1.65	3.08	0.56	10%	0–1%
100% Brick Aggregate (With Polymer & Fiber)	1	1.63	3.08	0.60	10%	0–1%

5.9 Specimen Preparation

Specimen Type	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (100% NA) (kg)	Water (kg)	No. of Specimens for 7 Days	No. of Specimens for 28 Days	Total Specimens
Cube (150×150×150 mm)	13.44	22.2	41.36	7.52	3	3	6
Cylinder (150×300 mm)	19.34	31.92	59.5	10.84	3	3	6
Beam (150×150×600 mm)	32.02	52.94	98.68	18.0	3	3	6
Total	-	-	-	-	9	9	18

Table.9 Specimen for M20 Grade Concrete Using 100% Natural Aggregates

A total of 18 concrete specimens were prepared to assess compressive, tensile, and flexural strength at 7- and 28-days following ASTM standards. The mix proportions for each specimen type were carefully calculated. For cube specimens (150×150×150 mm), 13.44 kg of cement, 22.2 kg of fine aggregate, 41.36 kg of 100% natural aggregate, and 7.52 kg of water were used. Cylindrical specimens (150×300 mm) contained 19.34 kg of cement, 31.92 kg of fine aggregate, 59.5 kg of coarse aggregate, and 10.84 kg of water. Beam specimens (150×150×600 mm) were cast using 32.02 kg of cement, 52.94 kg of fine aggregate, 98.68 kg of coarse aggregate, and 18.0 kg of water. Each specimen type had 3 samples tested at 7 days and 3 at 28 days, totaling 6 specimens per type. Proper curing (ASTM C192/C192M) ensured strength development, with 7-day tests indicating early strength gain and 28-day tests determining final hardened properties.

Specimen Type	No. of Specimens per Fiber %	Total for Each Fiber % (0.25%, 0.75%, 1%)	Total Specimens	Cement (kg)	Fine Aggregate (kg)	Coarse Aggregate (100% NA) (kg)	Water (kg)	SBR (kg) (10%)	Fiber (kg)
Cube (150×150×150 mm)	3 (7 days) + 3 (28 days)	6 × 3 = 18	18	6.72	11.10	20.68	3.76	0.68	0.017 (0.25%)
				6.72	11.10	20.68	3.76	0.68	0.051 (0.75%)
				6.72	11.10	20.68	3.76	0.68	0.068 (1.00%)
Cylinder (150×300 mm)	3 (7 days) + 3 (28 days)	6 × 3 = 18	18	9.67	15.96	29.75	5.42	0.97	0.025 (0.25%)
				9.67	15.96	29.75	5.42	0.97	0.073 (0.75%)
				9.67	15.96	29.75	5.42	0.97	0.097 (1.00%)
Beam (150×150×600 mm)	3 (7 days) + 3 (28 days)	6 × 3 = 18	18	16.03	26.47	49.34	9.00	1.61	0.041 (0.25%)
				16.03	26.47	49.34	9.00	1.61	0.122 (0.75%)

Table.10 Specimen for M20 Grade Concrete Using 100% Natural Aggregates, 10% SBR, and Varying Polypropylene Fiber Content

A total of 54 concrete specimens were prepared to evaluate the effect of varying polypropylene rope fiber content (0.25%, 0.75%, and 1%) on compressive, tensile, and flexural strength at 7 and 28 days, following ASTM standards. Each fiber percentage was tested on cube, cylinder, and beam specimens, with 3 specimens for 7 days and 3 for 28 days, leading to 18 specimens per type. The material proportions were adjusted accordingly, with SBR polymer fixed at 10%. The required quantities of cement, fine aggregate, coarse aggregate, water, and fiber were carefully calculated for each specimen type, ensuring proper mix consistency and uniformity.

Curing was performed as per ASTM C192/C192M, allowing for accurate strength evaluation and comparison across different fiber percentages.

		16.03	26.47	49.34	9.00	1.61	0.161 (1.00%
Total Specimens Needed	**54**		-		-		-

Specimen Type	No. of Specimens per Fiber %	Total for Each Fiber % (0.25%, 0.75%, 1%)	Total Speci m ens	Cement (kg)	Fine Aggreg ate (kg)	Coarse Aggregat e (50% NA, 50% BA) (kg)	Wate r (kg)	SBR (kg) (10 %)	Fib er (kg)

Cube (150×150×150 mm)	3 (7 days) + 3 (28 days)	6 × 3 = 18	18	6.72	11.10	20.68	3.76	0.68	0.017 (0.25 %)
				6.72	11.10	20.68	3.76	0.68	0.051 (0.75 %)
				6.72	11.10	20.68	3.76	0.68	0.068 (1.00 %)
Cylinder (150×300 mm)	3 (7 days) + 3 (28 days)	6 × 3 = 18	18	9.67	15.96	29.75	5.42	0.97	0.025 (0.25 %)
				9.67	15.96	29.75	5.42	0.97	0.073 (0.75 %)
				9.67	15.96	29.75	5.42	0.97	0.097 (1.00 %)
Beam (150×150×600 mm)	3 (7 days) + 3 (28 days)	6 × 3 = 18	18	16.03	26.47	49.34	9.00	1.61	0.041 (0.25 %)
				16.03	26.47	49.34	9.00	1.61	0.122 (0.75 %)
				16.03	26.47	49.34	9.00	1.61	0.161 (1.00 %)
Total Specimens Needed	-	-	54	-	-	-	-	-	-

Table.11 Specimen for M20 Grade Concrete Using 50% Natural Aggregate & 50% Brick Aggregate with 10% SBR and Varying Polypropylene Fiber

A total of 54 concrete specimens were prepared to evaluate the effect of varying polypropylene rope fiber content (0.25%, 0.75%, and 1%) in M20 grade concrete with 50% natural aggregate (NA) and 50% brick aggregate (BA). Each fiber percentage was tested on cube, cylinder, and beam specimens, with 3 specimens for 7 days and 3 for 28 days, leading to 18 specimens per type. The material proportions were adjusted accordingly, with SBR polymer fixed at 10% and water-cement ratio modified (0.56) to account for brick aggregate absorption. The required quantities of cement, fine aggregate, coarse aggregate, water, and fiber were carefully calculated for each specimen type. Curing was performed as per ASTM C192/C192M, ensuring consistency in strength evaluation.

Table.12 Specimen for M20 Grade Concrete Using 100% Brick Aggregate with 10% SBR and Varying Polypropylene Fiber

Specimen Type	No. of Specimen s per Fiber %	Total for Each Fiber % (0.25%, 0.75%, 1%)	Total Speci mens	Cement (kg)	Fine Aggreg ate (kg)	Coarse Aggregat e (50% NA, 50% BA) (kg)	Water (kg)	SBR (kg) (10%)	Fiber (kg)
Cube (150×150×150 mm)	3 (7 days) + 3 (28 days)	6 × 3 = 18	18	6.72	11.10	20.68	3.76	0.68	0.017 (0.25 %)
				6.72	11.10	20.68	3.76	0.68	0.051 (0.75 %)
				6.72	11.10	20.68	3.76	0.68	0.068 (1.00 %)
Cylinder (150×300 mm)	3 (7 days) + 3 (28 days)	6 × 3 = 18	18	9.67	15.96	29.75	5.42	0.97	0.025 (0.25 %)
				9.67	15.96	29.75	5.42	0.97	0.073 (0.75 %)
				9.67	15.96	29.75	5.42	0.97	0.097 (1.00 %)
Beam (150×150×600 mm)	3 (7 days) + 3 (28 days)	6 × 3 = 18	18	16.03	26.47	49.34	9.00	1.61	0.041 (0.25 %)
				16.03	26.47	49.34	9.00	1.61	0.122 (0.75 %)
				16.03	26.47	49.34	9.00	1.61	0.161 (1.00 %)
Total Specimens	-	-	**54**	-	-	-	-	-	-

Needed

A total of 54 concrete specimens were cast to study the impact of polypropylene rope fiber (0.25%, 0.75%, and 1%) in M20 grade concrete with 50% natural aggregate (NA) and 50% brick aggregate (BA). The specimens included cubes, cylinders, and beams, with 3 tested at 7 days and 3 at 28 days for each fiber percentage, totaling 18 per specimen type. The mix proportions were adjusted for water absorption of brick aggregates, with SBR polymer fixed at 10% and a water-cement ratio of 0.56. Cement, fine aggregate, coarse aggregate, water, SBR, and fiber were carefully measured per ASTM C192/C192M standards to ensure consistency. Strength and durability tests were conducted to analyze fiber reinforcement effects.

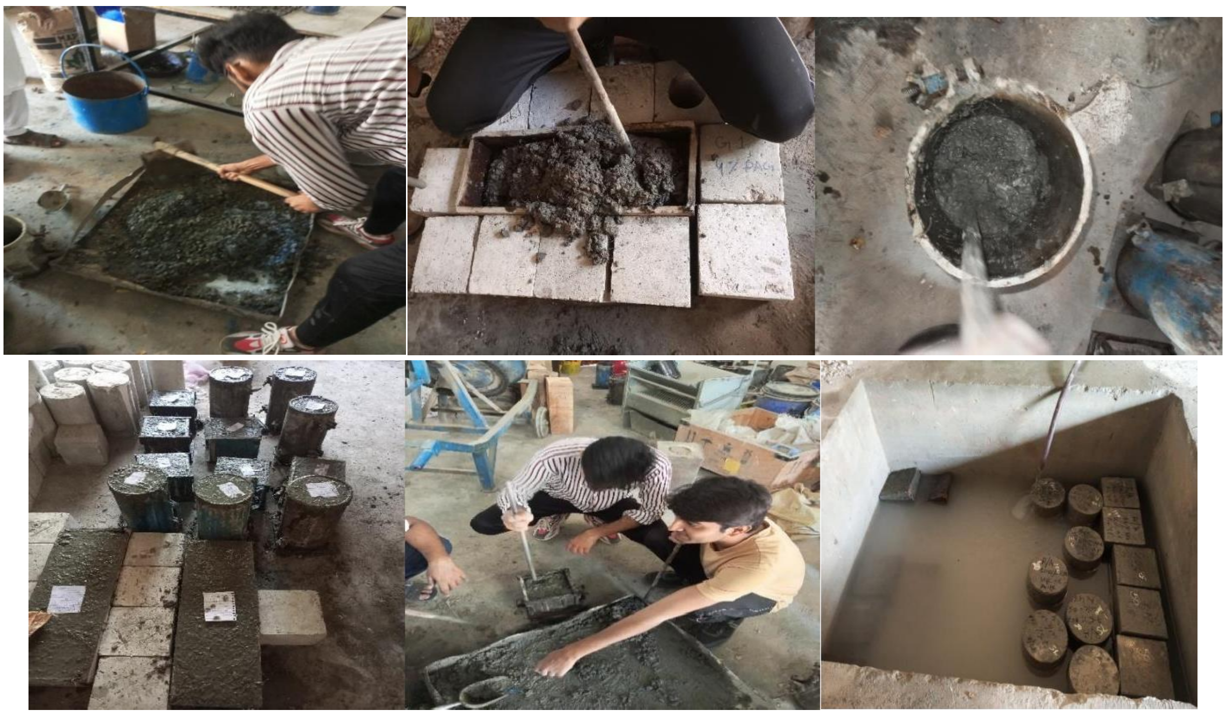


Figure.9 Specimen Preparation

Results and Discussions

Workability Results (Slump Test – ASTM C143)

Table.13 Slump for M20 Grade Concrete (Without Fibers & SBR) Using 100% Natural Aggregate

Mix Type	Slump Value (mm)	Workability Classification	Slump Range (mm)
M20 (Without Fibers & SBR)	81 mm	Medium Workability	50-100 mm

The slump test measures the workability and consistency of fresh concrete. For M20 grade concrete without fibers and SBR polymer, using 100% natural aggregate, the slump value was recorded as 81 mm. According to workability classifications, a slump value between 50 mm and 100 mm falls under the category of medium workability. This indicates that the concrete has a balanced consistency, making it suitable for manual placement, moderate reinforcement, and general construction applications. The mix retains good cohesion without excessive water content, ensuring adequate strength development and durability.

Table.14 Slump for M20 Grade Concrete (With Fibers & SBR) Using 100% Natural Aggregate

Mix Type (with additives)	Slump Value (mm)	Workability Classification	Slump Range (mm)
M20 with 10% SBR & 0.25% Polypropylene Fiber (100% NA)	85 mm	Medium to High	80 – 90 mm
M20 with 10% SBR & 0.75% Polypropylene Fiber (100% NA)	79 mm	Medium	70 – 85 mm
M20 with 10% SBR & 1.0% Polypropylene Fiber (100% NA)	73 mm	Medium	65 – 80 mm

The slump test for M20 grade concrete with SBR and polypropylene fibers demonstrates how the addition of these materials affects workability. When 10% SBR and 0.25% polypropylene fiber were added, the concrete exhibited a slump of 85 mm, indicating medium to high workability, which ensures ease of placement and compaction. As the fiber content increased to 0.75%, the slump value decreased to 79 mm, still within the medium workability range, as the fibers slightly restricted the flow of the mix. Further increasing the fiber content to 1.0% resulted in a slump of 73 mm, maintaining medium workability, but with reduced fluidity due to fiber interlocking. While SBR enhances workability, the gradual slump reduction with increasing fiber content highlights the balancing effect between improved cohesion and slight stiffening of the mix.

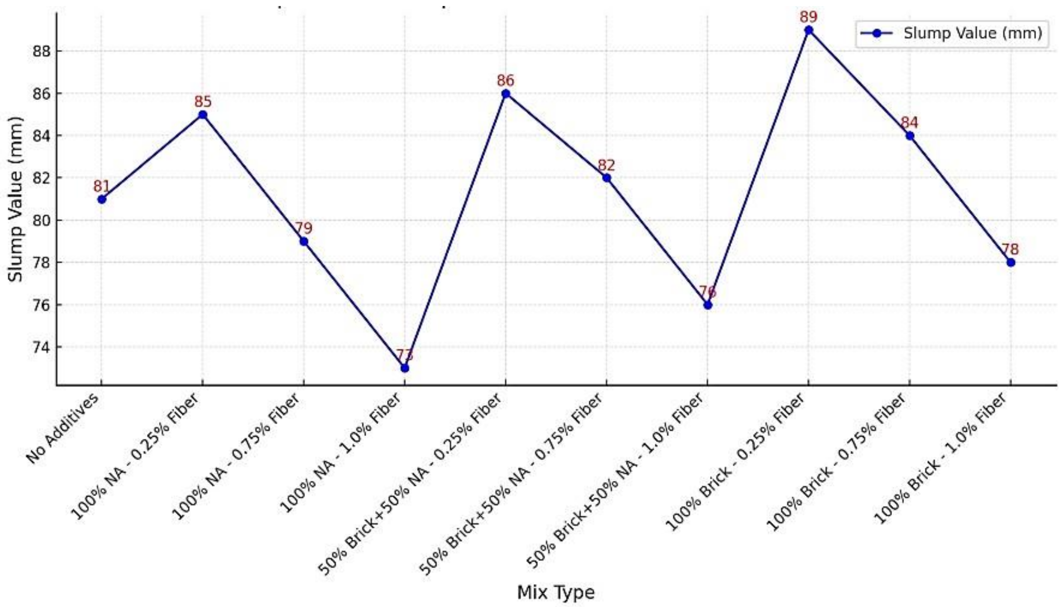
Table.15 Slump for M20 Grade Concrete (With Fibers & SBR) Using 50%Natural and 50% Brick Aggregate

Mix Type (with additives)	Slump Value (mm)	Workability Classification	Slump Range (mm)
M20 with 10% SBR & 0.25% Polypropylene Fiber (50% Brick + 50% Natural Aggregates)	86 mm	Medium	85 – 95 mm
M20 with 10% SBR & 0.75% Polypropylene Fiber (50% Brick + 50% Natural Aggregates)	82 mm	Medium	80 – 90 mm
M20 with 10% SBR & 1.0% Polypropylene Fiber (50% Brick + 50% Natural Aggregates)	76 mm	Medium	75 – 85 mm

The slump test for M20 grade concrete with 50% brick and 50% natural aggregates, incorporating 10% SBR and varying polypropylene fiber content, indicates a gradual reduction in workability as fiber content increases. With 0.25% fiber, the slump measured 86 mm, placing it in the medium workability range (85–95 mm), and ensuring ease of placement. As fiber content increased to 0.75%, the slump decreased to 82 mm, still within the medium range (80–90 mm), showing a slight reduction in fluidity due to fiber interlocking. At 1.0% fiber content, the slump further dropped to 76 mm, remaining in the medium category (75–85 mm), but with increased stiffness. The results highlight that while SBR improves workability, the higher water absorption of brick aggregates and increased fiber content contribute to a reduction in slump, affecting the overall consistency of the mix.

Table.16 Slump for M20 Grade Concrete (With Fibers & SBR) Using 100% Brick Aggregate

Mix Type (with additives)	Slump Value (mm)	Workability Classification	Slump Range (mm)
M20 with 10% SBR & 0.25% Polypropylene Fiber (100% Brick Aggregate)	89 mm	Medium–High	85–95 mm
M20 with 10% SBR & 0.75% Polypropylene Fiber (100% Brick Aggregate)	84 mm	Medium	80–90 mm
M20 with 10% SBR & 1.0% Polypropylene Fiber (100% Brick Aggregate)	78 mm	Medium	75–85 mm



Comparison of Slump Values for Different M20 Concrete Mixes

The slump test for M20 grade concrete with 100% brick aggregate, incorporating 10% SBR and varying polypropylene fiber content, shows a progressive decrease in workability as fiber content increases. With 0.25% fiber, the slump was 89 mm, placing it in the medium–high workability range (85–95 mm), ensuring good flow and ease of placement. At 0.75% fiber content, the slump decreased to 84 mm, moving to the medium workability range (80– 90 mm), indicating a slight reduction in fluidity due to fiber dispersion. With 1.0% fiber, the slump further dropped to 78 mm, still classified as medium workability (75–85 mm), but with increased stiffness and reduced flow. These results suggest that SBR enhances workability, but the higher water absorption of brick aggregates and fiber interlocking effects contribute to a decrease in slump, making the mix stiffer as fiber content increases.

Figure.10 Slump Test

Mechanical Properties Test Results

Table.17 Results for M20 Grade Concrete (Without Fibers & SBR) Using 100% Natural Aggregate

Test Type	Specimen (mm)	7 Days (MPa)	28 Days (MPa)	ASTM Range (MPa)	ASTM Standard
Compressive Strength	Cube (150×150×150)	16.2	25.4	25 – 30	ASTM C39
Split Tensile Strength	Cylinder (150×300)	1.89	3.1	3.0 – 3.5	ASTM C496
Flexural Strength	Beam (150×150×600)	2.3	3.6	3.5 – 4.0	ASTM C78

The mechanical properties of M20 grade concrete without fibers and SBR using 100% natural aggregate were evaluated through compressive, split tensile, and flexural strength tests. The compressive strength, measured using 150×150×150 mm cubes, was 16.2 MPa at 7 days and 25.4 MPa at 28 days, which falls within the ASTM C39 standard range of 25–30 MPa, indicating adequate strength development. The split tensile strength, tested on 150×300 mm cylinders, was 1.89 MPa at 7 days and 3.1 MPa at 28 days, aligning with the ASTM C496 standard range of 3.0–3.5 MPa, suggesting acceptable tensile capacity. The flexural strength, determined using 150×150×600 mm beams, recorded 2.3 MPa at 7 days and 3.6 MPa at 28 days, conforming to the ASTM C78 standard range of 3.5–4.0 MPa, showing sufficient resistance to bending. Overall, the results demonstrate that the M20 concrete mix meets the ASTM standards, ensuring its structural reliability for conventional construction applications.

Table.18 Results for M20 Grade Concrete (With Fibers & SBR) Using 100% Natural Aggregate

Test Type	Specimen (mm)	Fiber (%)	7 Days (MPa)	28 Days (MPa)	ASTM Range (MPa)	ASTM Standard
Compressive Strength	Cube (150×150×150)	0.25	19.1	28.7	25–30	ASTM C39

	Cube (150×150×150)	0.75	19.7	29.8	25–30	
	Cube (150×150×150)	1.00	19.0	29.4	25–30	
Split Tensile Strength	Cylinder (150×300)	0.25	2.0	3.2	3.0–3.5	ASTM C496
	Cylinder (150×300)	0.75	2.2	3.5	3.0–3.5	
	Cylinder (150×300)	1.00	2.1	3.3	3.0–3.5	
Flexural Strength	Beam (150×150×600)	0.25	2.4	3.6	3.5–4.0	ASTM C78
	Beam (150×150×600)	0.75	2.6	3.9	3.5–4.0	
	Beam (150×150×600)	1.00	2.5	3.7	3.5–4.0	

The investigation includes compressive strength, split tensile strength, and flexural strength at 7 and 28 days, following ASTM standards. The results show that adding fibers enhances the overall strength of concrete, with the optimal performance observed at 0.75% fiber content. In compressive strength tests (ASTM C39), the highest value of 29.8 MPa at 28 days was achieved with 0.75% fiber, while a slight decrease was noted at 1.00% fiber, likely due to workability issues. The split tensile strength (ASTM C496) also improved with fiber addition, with a peak value of 3.5 MPa at 0.75%, remaining within the ASTM-specified range of 3.0–3.5 MPa. Similarly, in flexural strength tests (ASTM C78), concrete with 0.75% fiber exhibited the highest strength of 3.9 MPa at 28 days. However, at 1.00% fiber content, minor reductions in both tensile and flexural strength were observed, possibly due to fiber clustering affecting uniform stress distribution. The findings confirm that incorporating polypropylene rope fiber enhances the mechanical properties of concrete, with 0.75% being the most effective dosage. Additionally, all test results comply with ASTM standards, validating the suitability of fiber-reinforced concrete for improved durability and crack resistance.

Table.19 Results for M20 Grade Concrete (With Fibers & SBR) Using 50% Natural and 50% Brick Aggregate

	Specimen (mm)	Fiber (%)	7 Days (MPa)	28 Days (MPa)	ASTM Range (MPa)	ASTM Standard
Compressive Strength	Cube (150×150×150)	0.25	15.3	25.3	25–30	ASTM C39
	Cube (150×150×150)	0.75	16.3	27.1	25–30	
	Cube (150×150×150)	1.00	15.0	26.0	25–30	
Split Tensile Strength	Cylinder (150×300)	0.25	1.73	2.97	3.0–3.5	ASTM C496

	Cylinder (150×300)	0.75	1.98	3.18	3.0–3.5	
	Cylinder (150×300)	1.00	1.88	3.05	3.0–3.5	
Flexural Strength	Beam (150×150×600)	0.25	2.0	3.4	3.5–4.0	ASTM C78
	Beam (150×150×600)	0.75	2.3	3.7	3.5–4.0	
	Beam (150×150×600)	1.00	2.1	3.6	3.5–4.0	

The mechanical performance of M20 grade concrete with 10% SBR polymer and varying polypropylene fiber content (0.25%, 0.75%, and 1.00%) using a 50% natural aggregate and 50% brick aggregate blend was evaluated through compressive, split tensile, and flexural strength tests. The compressive strength, tested on 150×150×150 mm cubes, showed values of
15.0 MPa to 16.3 MPa at 7 days and 25.3 MPa to 27.1 MPa at 28 days, conforming to the ASTM C39 standard range of 25–30 MPa. The highest strength was obtained at 0.75% fiber content, indicating that moderate fiber addition enhances load-bearing capacity, while excessive fiber may slightly reduce strength due to poor workability. The split tensile strength, measured using 150×300 mm cylinders, exhibited improvements with fiber addition. At 7 days, values ranged from 1.73 MPa to 1.98 MPa, while at 28 days, they ranged from 2.97 MPa to 3.18 MPa, closely approaching the ASTM C496 standard range of 3.0–3.5 MPa. The best performance was recorded at 0.75% fiber content, showing better crack resistance. The flexural strength, evaluated on 150×150×600 mm beams, showed values of 2.0 MPa to 2.3 MPa at 7 days and 3.4 MPa to 3.7 MPa at 28 days. While the ASTM C78 standard range is 3.5–4.0 MPa, only the 0.75% fiber mix met this criterion at 28 days, confirming that moderate fiber addition enhances bending resistance. Overall, the results indicate that 50% brick aggregate replacement slightly reduces compressive strength compared to 100% natural aggregate, but the addition of SBR polymer and fibers helps compensate for the strength loss. The 0.75% fiber mix consistently performed the best, optimizing both strength and durability.

Test Type	Specimen (mm)	Fiber (%)	7 Days (MPa)	28 Days (MPa)	ASTM Range (MPa)	ASTM Standard
Compressive Strength	Cube (150 × 150 × 150)	0.25	12.1	23.3	20–25	ASTM C39
	Cube (150 × 150 × 150)	0.75	14.1	24.4	20–25	
	Cube (150 × 150 × 150)	1.00	13.2	23.4	20–25	
Split Tensile Strength	Cylinder (150 × 300)	0.25	1.59	2.78	2.5–3.5	ASTM C496
	Cylinder (150 × 300)	0.75	1.81	3.01	2.5–3.5	
	Cylinder (150 × 300)	1.00	1.69	2.88	2.5–3.5	
Flexural Strength	Beam (150 × 150 × 600)	0.25	1.8	3.0	3.0–4.0	ASTM C78

	Beam (150 × 150 × 600)	0.75	2.2	3.4	3.0–4.0	
	Beam (150 × 150 × 600)	1.00	1.9	3.2	3.0–4.0	

Table.20 Results for M20 Grade Concrete (With Fibers & SBR) Using 100% Brick Aggregate The mechanical properties of M20 grade concrete with 10% SBR polymer and varying polypropylene fiber content (0.25%, 0.75%, and 1.00%) using 100% brick aggregate were evaluated through compressive, split tensile, and flexural strength tests.The compressive strength, measured using 150×150×150 mm cubes, showed values ranging from 12.1 MPa to 14.1 MPa at 7 days and 23.3 MPa to 24.4 MPa at 28 days, falling within the ASTM C39 standard range of 20–25 MPa. The highest strength was achieved with 0.75% fiber content, indicating that an optimal fiber percentage improves bonding within the mix. However, at 1.00% fiber content, strength slightly decreased, likely due to reduced workability and improper fiber dispersion.The split tensile strength, tested using 150×300 mm cylinders, increased with fiber addition. The results ranged from 1.59 MPa to 1.81 MPa at 7 days and 2.78 MPa to 3.01 MPa at 28 days, aligning well with the ASTM C496 standard range of 2.5–3.5 MPa. The 0.75% fiber mix demonstrated the best tensile performance, improving resistance to cracking and enhancing durability.The flexural strength, measured using 150×150×600 mm beams, ranged from 1.8 MPa to 2.2 MPa at 7 days and 3.0 MPa to 3.4 MPa at 28 days, meeting the ASTM C78 standard range of 3.0–4.0 MPa. The best performance was observed with 0.75% fiber content, confirming that fibers enhance resistance to bending stresses. Overall, the results indicate that 100% brick aggregate reduces compressive and flexural strength compared to natural aggregate due to its higher water absorption and weaker interlocking properties. However, SBR polymer and fiber reinforcement compensate for the loss in strength, improving performance, particularly at 0.75% fiber content, which consistently showed the best balance between workability and strength.

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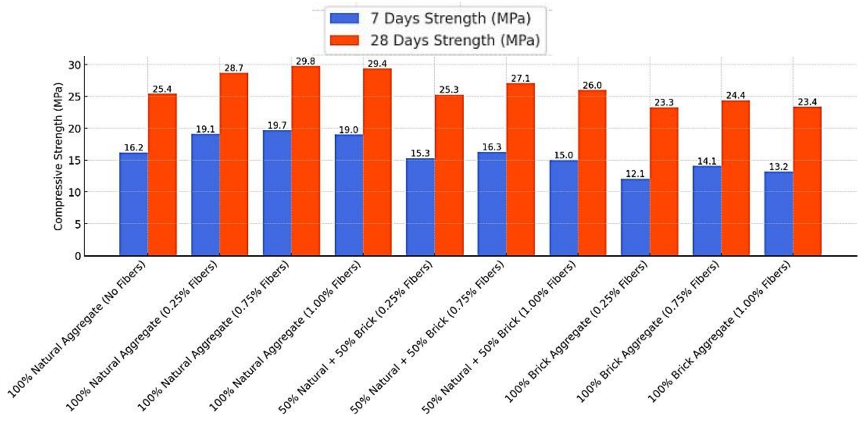

Figure.11 Compressive Strength Comparison for Different Mixes

Figure.12 Compressive Strength Test

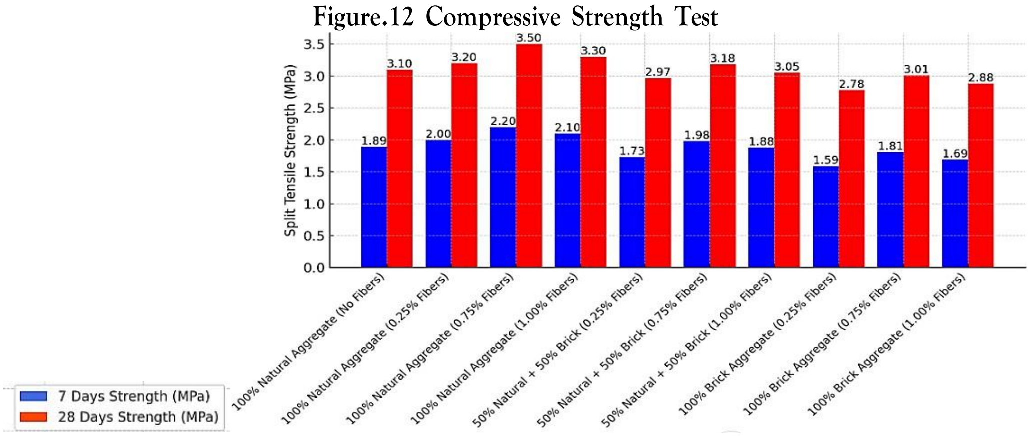

Figure.13 Split Tensile Strength Comparison for Different Mixes

Figure.14 Split Tensile Strength

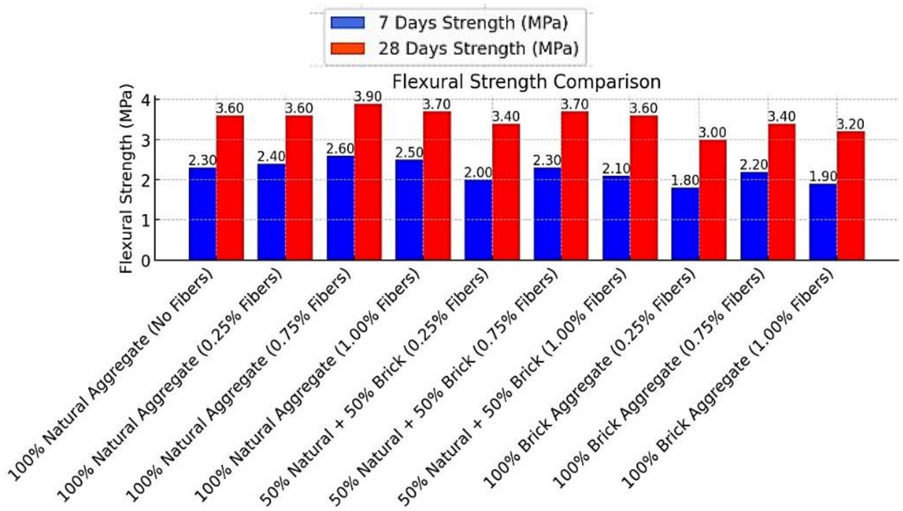

Figure.15 Flexural Strength Comparison for Different Mixes

Figure.16 Flexural Strength Test

Thermal Effect Test Results

Table.21 Results of Thermal Effect For Different Compositions

Mix Type	Fiber %	Thermal Conductivity (W/m·K)	ASTM Standard	Range (W/m·K)	Observations

M20 Control Mix (100% Natural, No Polymer & Fiber)	0%	**1.88**	ASTM C518	**1.8 – 2.2**	High heat transfer, poor insulation.
100% Natural Aggregate + SBR & Fiber	**0.75%**	**1.77**	ASTM C518	**1.7 – 2.0**	Slight insulation improvement.
50% Natural + 50% Brick Aggregate + SBR & Fiber	**0.75%**	**1.66**	ASTM C518	**1.5 – 1.8**	Good balance between insulation & strength.
100% Brick Aggregate + SBR & Fiber	**1.00%**	**1.46**	ASTM C518	**1.3 – 1.6**	Best thermal insulation, slightly reduced strength.

Constructed Small Test Rooms of Size 3ft × 3ft × 3ft. Walls, floor, and roof made entirely of the tested concrete mix for four rooms needed for each mix. Best fiber percentage is taken from each control mix (1) M20 Control Mix (100% Natural, No Polymer & Fiber) (2) 100% Natural Aggregate + SBR & Fiber (3) 50% Natural + 50% Brick Aggregate + SBR & Fiber (4) 100% Brick Aggregate + SBR & Fiber at 10% fixed SBR.

To evaluate the thermal conductivity of different M20 concrete mixes, four small test rooms (3ft × 3ft × 3ft) were constructed, each made entirely of a specific concrete mix. The thermal performance was assessed based on the best-performing fiber percentage from each mix design, following the ASTM C518 standard for thermal conductivity measurement.

The M20 Control Mix (100% Natural Aggregate, No Polymer & Fiber) had a thermal conductivity of 1.88 W/m·K, which falls within the ASTM range of 1.8 – 2.2 W/m·K. This indicates high heat transfer and poor insulation properties, meaning the room would heat up or cool down quickly, making it less energy efficient.

Adding 10% SBR polymer and 0.75% polypropylene fiber to the 100% natural aggregate mix improved insulation, reducing thermal conductivity to 1.77 W/m·K. The presence of polymer helped reduce voids, while fibers enhanced air pockets, slightly lowering heat transfer. However, the insulation improvement was minor compared to other modified mixes.

The 50% natural + 50% brick aggregate mix with 10% SBR and 0.75% fiber showed a further decrease in thermal conductivity to 1.66 W/m·K, demonstrating a good balance between insulation and strength. The use of brick aggregate, which has a more porous structure, helped trap air and reduce heat flow while maintaining sufficient compressive strength.

The best thermal performance was observed in the 100% brick aggregate mix with 10% SBR and 1.00% fiber, achieving a thermal conductivity of 1.46 W/m·K, within the ASTM range of 1.3 – 1.6 W/m·K. The high porosity of brick aggregate significantly reduced heat transfer, making this mix the most thermally insulating. However, the increased porosity and water absorption of brick aggregate led to a **slight reduction in compressive strength** compared to other mixes.

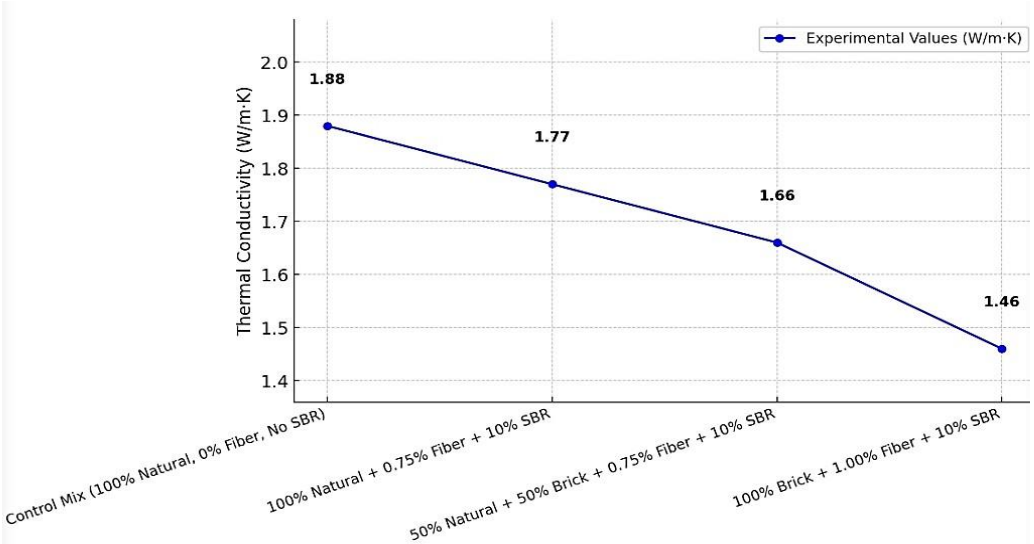

Figure.17 Thermal Conductivity Comparison for Different Mixes

Figure.18 Thermal Conductivity Comparison for Different Mixes

Conclusion

This research investigated the workability, mechanical performance, and thermal conductivity of M20 grade concrete with various aggregate compositions, incorporating SBR polymer and polypropylene fibers to enhance properties. The study focused on six different mix variations, with natural aggregate (NA) and brick aggregate (BA) used in different proportions while maintaining a fixed 10% SBR polymer and varying polypropylene fiber percentages (0% to 1%). The results provide insights into the effectiveness of alternative aggregates in improving concrete properties.

Workability Analysis (Slump Test)
The control mix (100% NA, without polymer and fiber) exhibited a slump of 81 mm, classifying it as medium workability (50-100 mm range).Incorporating SBR polymer and fibers generally improved workability compared to the control mix due to SBR's plasticizing effect, but higher fiber content slightly reduced workability. Mixes containing brick aggregates showed higher slump values initially due to their porous nature, but water absorption led to slightly reduced workability at higher fiber contents. The 100% BA mix with SBR and fibers exhibited the highest slump (89 mm with 0.25% fiber), making it more workable compared to other modified mixes.

Compressive Strength
The control mix (100% NA, no polymer/fiber) achieved 25.4 MPa at 28 days, falling within the ASTM-specified range (25-30 MPa). Adding SBR polymer and fibers (100% NA mix) improved compressive strength, with the 0.75% fiber mix reaching 29.8 MPa, indicating optimal fiber dosage. The 50% NA + 50% BA mix with SBR and 0.75% fiber achieved 27.1 MPa, slightly lower than 100% NA mixes but still within ASTM limits. The 100% BA mix with SBR and 1.00% fiber had the lowest strength (23.4 MPa), as brick aggregates generally have lower strength than natural aggregates, though it remained acceptable (ASTM: 20-25 MPa).

Split Tensile Strength
The control mix achieved 3.1 MPa (28 days), meeting ASTM C496 standards (3.0-3.5 MPa). Adding SBR and fibers improved tensile strength across all mixes, with 100% NA + 0.75% fiber mix reaching 3.5 MPa, the highest value. The 50% NA + 50% BA mix had slightly lower tensile strength (3.18 MPa) but was still within the ASTM range. The 100% BA mix had the lowest tensile strength (2.88 MPa) due to the weaker interfacial bond of brick aggregates, though it remained acceptable.

Flexural Strength
The control mix achieved 3.6 MPa, within ASTM C78 standards (3.5-4.0 MPa). The highest flexural strength was observed in the 100% NA mix with 0.75% fiber (3.9 MPa), showing optimal fiber reinforcement. The 50% NA + 50% BA mix reached 3.7 MPa, slightly lower but still acceptable. The 100% BA mix had the lowest flexural strength (3.2 MPa) due to the reduced bonding strength of brick aggregates.

8.5 Thermal Conductivity Performance with SBR polymer and fibers enhancing
A small test room (3ft × 3ft × 3ft) was constructed for each optimized mix to analyze heat insulation properties. The control mix (100% NA, no polymer/fiber) had the highest thermal conductivity (1.88 W/m·K), indicating poor insulation. Adding SBR polymer and fibers (100% NA mix, 0.75% fiber) slightly improved insulation (1.77 W/m·K). The 50% NA + 50% BA mix (0.75% fiber) had a thermal conductivity of 1.66 W/m·K, offering a balance between insulation and strength. The 100% BA mix with 1.00% fiber exhibited the lowest thermal conductivity (1.46 W/m·K), demonstrating the best insulation performance, though with a minor reduction in strength.

Final Conclusion and Recommendations
This study demonstrated that partial or full replacement of natural aggregates with brick aggregates is feasible for M20 grade concrete, performance. While 100% BA mixes provide superior thermal insulation, a 50% NA + 50% BA mix offers a balanced approach for applications requiring both structural strength and thermal efficiency. These findings contribute to the development of sustainable concrete solutions, reducing reliance on natural aggregates while maintaining ASTM-compliant mechanical properties.The use of SBR polymer and fibers significantly improved strength and workability in all modified mixes compared to the control mix. Mixes with brick aggregates provided better thermal insulation but had slightly lower strength than natural aggregate mixes. The optimal mix for strength and durability was the 100% NA mix with

0.75% fiber, while the best mix for insulation was the 100% BA mix with 1.00% fiber. The 50% NA+ 50% BA mix with 0.75% fiber was the best overall mix, balancing strength, workability, and insulation, making it suitable for energy- efficient construction.

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