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# Performance Evaluation of Hybrid Fiber-Reinforced High-Performance Concrete Incorporating Nanosilica and Metakaolin

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**ABSTRACT:** This study investigates the synergistic effects of nanosilica and Metakaolin on the performance of high-performance concrete (HPC) reinforced with a hybrid combination of steel and polypropylene fibers. The primary objective is to evaluate the influence of key mix variables on both the fresh and hardened properties of concrete, aiming to enhance its mechanical characteristics and durability. Experimental investigations were conducted to analyze compressive, split tensile, and flexural strength of various HPC mixes containing different proportions of nanosilica and Metakaolin. Comparative analyses were performed against conventional concrete to assess the improvements achieved through fiber reinforcement and mineral admixtures. The study further examines the viability of using hybrid fiber-reinforced HPC as a cost-effective and environmentally sustainable alternative to traditional cement concrete. Results indicate a significant improvement in strength performance and material efficiency, demonstrating the potential of such composite mixes in modern structural applications where high durability and strength are critical.

**KEYWORDS:** High-performance concrete, Nanosilica, Metakaolin, Hybrid fiber reinforcement, Mechanical properties.

## I. INTRODUCTION

Concrete is the most often used construction material developed by humanity. It has replaced brick and stone masonry owing to its exceptional ability to be cast into any desired form. Notwithstanding these attributes, it has many deficiencies that would render it inappropriate as a construction material were it not for its remarkable resilience, flexibility, and ability to distribute stress. Ongoing research aims to enhance concrete, resulting in the development of fiber-reinforced concrete, ferro-cement concrete, slurry-infiltrated fibrous concrete, and several other formulations [1], [3], [6]. The characteristics of concrete have improved with the advent of High Performance Concrete (HPC), including superior compaction, refined paste characteristics, and the link between aggregate and matrix.

The condition of newly constructed concrete buildings has deteriorated, resulting in the most compelling evidence in the last two to three decades about the service life performance of our construction. This issue highlights the frightening and unsustainable pace of deterioration of our global infrastructure systems when subjected to real-world conditions. The early deterioration of buildings constructed in the past, prior to their expected lifespan, prompted a transition in concrete technology from an emphasis on pure compressive strength to durability [4], [5]. Enhancing the durability of concrete requires a holistic approach that considers the interplay between strength, cracking, and durability—a transition to an all-encompassing approach to regulation.

Since the 1800s, reinforcement has been used, and fiber-reinforced concretes have garnered significant attention in the construction sector. During the 1980s, fiber consumption increased significantly. The performance characteristics of cement concrete have been enhanced by the use of several types of fibers [3], [7]. Despite extensive research published on the subject, there is limited information concerning the utilization of hybrid fibers in high-performance concrete (HPC), particularly regarding the application of fibers like steel and polypropylene to modify the strength and workability properties of conventional concrete [2], [6], [9].

HPC varies from conventional concrete due to the use of supplementary raw ingredients, such as chemical and mineral admixtures. Therefore, it is essential to understand the efficacy of fibers in conjunction with certain minerals and

chemical admixtures. Specific attention must be directed into the impact of fiber hybridization on the strength, workability, and durability characteristics of HPC. Empirical models linking the various workability and strength characteristics of hybrid fiber-reinforced high-performance concrete must be established for enhanced applications. Moreover, workability and compressive strength are the only factors taken into account while formulating a concrete mix. Nevertheless, as HPC mostly focuses on performance metrics, the mix design should include other factors beyond compressive strength, including tensile strength, flexural strength, and permeability [6], [8]. Consequently, mix design charts for enhanced performance of hybrid fiber reinforced concrete (HFRHPC) must be developed, taking into account all pertinent features.

This paper advocates for comprehensive investigation into the durability, workability, and strength characteristics of HFRHPC. Researchers continuously strive to enhance concrete, leading to the development of fiber-reinforced concrete, ferro-cement concrete, slurry-infiltrated fibrous concrete, HPC, and several other concrete variants [1], [3], [10]. The advancement of Ultra-High-Performance Concrete (UHPC) has enhanced the properties of concrete in recent years. UHPC yields enhancements such as reduced porosity, improved aggregate-matrix adhesion and paste characteristics, and heightened compaction. Superplasticizers are used in UHPC to markedly reduce the water-to-cement ratio. Enhancements to certain properties have been realized by the use of mineral admixtures or microfillers, such as nanosilica fume and Metakaolin [4], [5], [8].

UHPC is generally more brittle, especially when the main objective of performance is high strength. It is well acknowledged that increasing the confining pressure on UHPC may improve its ductility. Alongside confinement, compositional modifications, like the use of polypropylene and glass/steel/basalt fibers in the design mix, may enhance the ductility of UHPC [2], [7]. Composite Fibers Reinforced in Ultra High Performance Concrete (CFUHPC) is an ultra-high performance concrete containing polypropylene fibers inside and glass, steel, or basalt fibers outside. The primary impediment to the widespread adoption of CFUHPC is the lack of adequate stipulations under various national codes of practice [9]. The development of innovative, cost-effective methods for the creation, evaluation, and design using CFUHPC will assure users that the performance standards established for each work will be achieved.

Enhanced understanding of CFUHPC produced using locally sourced materials, indigenous mineral admixtures, glass, steel, basalt fibers, and polypropylene fibers is essential for broadening the applications of CFUHPC in India. This project will use locally sourced aggregates and mineral admixtures, including Metakaolin and nanosilica, to generate CFUHPC [4], [5], [8]. The use of mineral admixtures as a substitute for cement in the following proportions: 0%, 5%, 10%, and 0%, 1.5%, and 3%. Volume percentages of 0% and 0.75% are used for the incorporation of steel fibers, while 0% and 0.25% are designated for the inclusion of polypropylene fibers. To evaluate the workability of fresh CFUHPC mixes, tests including the Vee-bee time test, compaction factor, and slump test are conducted. Cubes, cylinders, and beams are cast and cured for both the seven-day and twenty-eight-day tests [10].

## II. LITERATURE SURVEY

The literature review of past studies that served as background information, support and references for this investigation is covered in this part.

Continuous research efforts to enhance the qualities of concrete have led to the development of fiber-reinforced concrete, ferro-cement concrete, slurry-infiltrated fibrous concrete, and other variations. Ultra High-Performance Concrete (UHPC) has been developed recently, improving the qualities of concrete. Additional improvements to some properties of UHPC have been achieved by including additives made of minerals, such as fly ash, nano silica, and Metakaolin. The creation of innovative, cost-effective processes for creating, testing, and designing using UHPC using composite fibers would give users confidence that each product will function at the level stipulated by the user can be consistently met in practice.

V.V. Praveen Kumar , Subhashish Dey in 2023 [1] concluded that Using fly ash in place of cement, ground-granulated blast furnace ash, and nano silica at 20%, 20%, and 2%, respectively, the strength qualities of blended concrete mix were significantly improved. When concrete is mixed with mineral admixtures mixes, their workability rises when compared to control mixes across all concrete grades.



Fadi Althoey , Osama Zaid , Rebeca Martínez-García , Fahad Alsharari , Mohd Ahmed , Mohamed M. Arbili in 2023[2] concluded that vast surface area included To maintain the slump value of concrete, adding nanomaterials to cement and concrete mixes needs a substantial amount of water or admixtures. • The amount, water-to-cement ratio, surface area, and particle size of the nanosilica all affect how it affects concrete. Additionally, the review stated that adding up to 4% of Nano-silica could improve the mechanical properties and durability. This may be because of the behavior of nano-silica pozzolan, filling influence, and refined pore structure.

- As the dosage of NS is increased, compression strength increases as well. NS also functions as an activator to support the hydration process. However, if nano-silica is increased from 4%, strength may drop
- Because of its pozzolan reactivity and influence on nucleation, adding nano-silica to concrete can speed up the hydration reaction rate, particularly during the initial phases of hydration
- By strengthening calcium silicate hydrate and reducing detrimental holes and permeability, nano-silica can help maximize its mechanical and long-term qualities.
- The combined use of Nano-silica with leftover pozzolanic ingredients can positively affect the hydration, pore structure, and mechanical characteristics of paste, mortar, and concrete.
- The packed interfacial transition zone microstructure amid the paste of binder and aggregates is the result of nano-silica's filling impact, pozzolan behavior, and reaction with calcium-hydrate crystals to reduce their size and proportion. This microstructure helps concrete form longer-term mechanical strength and durability.
- By incorporating nano-silica particles and dispersing them uniformly, concrete's microstructure is enhanced.

Anbuhezian Ashokan , Silambarasan Rajendran & Ratchagaraja Dhairiyasamy in 2023 [3]concluded concrete, which is tougher, stronger, and more durable can be generated by the strategic use of steel microfibers and nanosilica integration, opening up new possibilities in the structural and building industries.

Haneen AlTawaiha , Fadi Alhomaidat and Tamer Eljufou in 2023 [4] concluded that the treated Concrete with nano silica can significantly increase in durability when the right dosage is used. This is because the pozzolanic process produces stable hydration products that prevent the entry of dangerous substances that degrade.

Vikram Singh Kashyap , Gaurav Sancheti , Jitendra Singh Yadav and Utkarsh Agrawal in 2023[5] concluded that This study looked into the mechanical strength, durability, and microstructure of concrete that had been nanomodified with different NS replacement ratios.

With regard to the reference mix, It was discovered that the inclusion of NS significantly boosted the mechanical potency of the concrete. This early-day strength increase's quick rise indicates the value of NS-modified concrete for building projects requiring quick strength growth. The modified concrete with NS after ninety days had reduced carbonation depth, indicating a stronger resistance to carbonation. Additionally, the concrete samples containing NS demonstrated remarkable withstandance of sulfuric acid, demonstrating the material's potential for application in challenging chemical environments. Compact aggregate packing, a denser overall microstructure, and fewer voids were all present in the NS-modified concrete. The NS-modified concrete had reduced hydroxide (CH) consumption rates, which would have led to the longevity and strength of the concrete.

Kumarraju B , Manu Vijay H , Chandre Gowda , Sanjay Shekar N and Vijay Kumar Y M in 2023 [6]concluded that In the future, steel fiber and metakaolin may be utilized as site-pecific cement substitutes to boost strength. Unlike cement, metakaolin has cementitious properties that allow it to bind and offer superior strength. The addition of steel fiber to concrete blocks gives them good mechanical strength qualities The rate of hydration is accelerated by the metakaolin at higher curing temperatures. The pair gives the concrete more durability

A. Swetha , Suguna K, Raghunath P. N. in 2022[7] concluded that Concrete performed far better overall when micro filler, nano filler, and micro-reinforcement were added.

Pandiaraj Karthigai Priya and Sankararajan Vanitha in 2021[8] concluded that When utilized in place of cement-based materials:particularly cement, NS able to successfully enhance the material's microstructural, robustness and longevity qualities. All things considered, it is recognized that using nano silica as a building material will be more advantageous and improve the material's qualities.

A.O. Adetukasi , O.G. Fadugba , I.H. Adebakin , O. Omokungbe in 2020 [9] concluded that the inclusion of polypropylene fibers adding concrete improved its tensile strength. As the amount of PP contained in the blend increased, so did the splitting tensile strength. Similar to polypropylene, using nano-silica also helped increase the Tensile strength of splitting concrete, but not considerably. Tensile strength improved by as much as 34% when nano-silica and polypropylene were incorporated into regular concrete.

B. Yugandhar<sup>1</sup>, B. Bala Krishna Bharath<sup>2</sup>, K. Jaya Chandra<sup>3</sup>, N. Mohan Reddy in 2017[10] determined that adding glass fibers to control cracks. Little fissures have been noted as having progressively spread to the final failure. This phenomenon is valid for all glass fiber percentages. Additionally, glass fiber aids in preventing shrinkage cracks

### III. METHODOLOGY

This experimental study aims to investigate the influence of Metakaolin, Nanosilica, and hybrid fibers (steel and polypropylene) on the mechanical and workability properties of High-Performance Concrete (HPC). The methodology encompasses three primary stages: mix design, specimen preparation and curing, and testing of fresh and hardened concrete.

#### 3.1 Mix Design

A total of 18 concrete mixes were designed for M60 grade HPC. The mixes varied in:

- **Metakaolin (MK)** replacement levels: 0%, 5%, and 10%
- **Nanosilica (NS)** content: 0%, 1.5%, and 3%
- **Composite fiber reinforcement:** 0.75% steel fibers + 0.25% polypropylene fibers (by volume of concrete)

The control mix (Mix A) contained only Ordinary Portland Cement (OPC) without any fibers or mineral admixtures. Other mixes (Mixes B–R) were proportioned by varying the percentage of MK, NS, and hybrid fibers, as detailed in **Table 3.1**. All mix proportions followed guidelines of IS:10262–2019.



Sr No	Mix No.	Mix ID	Cement	Metakaolin	Nano silica	Steel Fibers	Polypropylene Fibers
1	A	M0N0C0 (PC)	100%	0%	0%	0%	0%
2	B	M0N0C1	100%	0%	0%	0.75%	0.25%
3	C	M0N1.5C0	100%	0%	1.5%	0%	0%
4	D	M0N1.5C1	100%	0%	1.5%	0.75%	0.25%
5	E	M0N3C0	100%	0%	3%	0%	0%
6	F	M0N3C1	100%	0%	3%	0.75%	0.25%
7	G	M5N0C0	95%	5%	0%	0%	0%
8	H	M5N0C1	95%	5%	0%	0.75%	0.25%
9	I	M5N1.5C0	95%	5%	1.5%	0%	0%
10	J	M5N1.5C1	95%	5%	1.5%	0.75%	0.25%
11	K	M5N3C0	95%	5%	3%	0%	0%
12	L	M5N3C1	95%	5%	3%	0.75%	0.25%
13	M	M10N0C0	90%	10%	0%	0%	0%
14	N	M10N0C1	90%	10%	0%	0.75%	0.25%
15	O	M10N1.5C0	90%	10%	1.5%	0%	0%
16	P	M10N1.5C1	90%	10%	1.5%	0.75%	0.25%
17	Q	M10N3C0	90%	10%	3%	0%	0%
18	R	M10N3C1	90%	10%	3%	0.75%	0.25%

Table 3.1 Methodology of mix proportion

### 3.2 Materials and Mix Proportions

The concrete mix consisted of:

- **Binders:** Cement, Metakaolin, Nanosilica
- **Aggregates:** Coarse aggregates (20–12.5 mm and 12.5–4.75 mm) and fine aggregates
- **Superplasticizer:** Dosage varied from 1% to 3.5% by weight of binder
- **Water:** Adjusted for target workability
- **Fibers:** Steel and polypropylene fibers, used in specific combinations

Detailed quantities of each constituent per cubic meter are provided in **Table 3.2**.

Mix Prop.	Cement (kg)	CA		FA (kg)	MK (kg)	NS (kg)	SF (kg)	PF (kg)	Water (%)	SP (%)
		20-12.5	12.5-4.75							
1	30.3	40.9	27.3	33.9	0	0	0	0	0.3%	1%
	30.3	40.9	27.3	33.9	0	0	0.99	0.33	0.3%	1%
2	29.85	40.9	27.3	33.9	0	0.45	0	0	0.3%	1%
	29.85	40.9	27.3	33.9	0	0.45	0.99	0.33	0.3%	1%
3	29.4	40.9	27.3	33.9	0	0.91	0	0	0.3%	1%
	29.4	40.9	27.3	33.9	0	0.91	0.99	0.33	0.3%	1%
4	28.8	40.9	27.3	33.9	1.51	0	0	0	0.3%	2.5%
	28.8	40.9	27.3	33.9	1.51	0	0.99	0.33	0.3%	3%
5	28.35	40.9	27.3	33.9	1.51	0.45	0	0	0.3%	3.5%
	28.35	40.9	27.3	33.9	1.51	0.45	0.99	0.33	0.3%	2.5%
6	27.85	40.9	27.3	33.9	1.51	0.91	0	0	0.3%	2.5%
	27.85	40.9	27.3	33.9	1.51	0.91	0.99	0.33	0.3%	2.5%
7	27.3	40.9	27.3	33.9	3.03	0	0	0	0.3%	2.5%
	27.3	40.9	27.3	33.9	3.03	0	0.99	0.33	0.3%	2.5%
8	26.8	40.9	27.3	33.9	3.03	0.45	0	0	0.3%	2.5%
	26.8	40.9	27.3	33.9	3.03	0.45	0.99	0.33	0.3%	2.5%
9	26.4	40.9	27.3	33.9	3.03	0.91	0	0	0.3%	1.5%
	26.4	40.9	27.3	33.9	3.03	0.91	0.99	0.33	0.3%	2.5%

Table 3.2 Mix Proportion

### 3.3 Specimen Casting and Curing

Standard specimen sizes were adopted for testing:

- **Cubes:** 100 mm × 100 mm × 100 mm for compressive strength
- **Cylinders:** 150 mm diameter × 300 mm height for split tensile strength
- **Beams:** 100 mm × 100 mm × 500 mm for flexural strength

#### Procedure:

1. Moulds were cleaned, oiled, and prepared for casting.
2. Coarse aggregates, fine aggregates, and binders were dry mixed.
3. MK, NS, SF, and PF were added and mixed thoroughly.
4. Water and superplasticizer were added to achieve a uniform wet mix.
5. Concrete was cast in moulds and compacted using a table vibrator.
6. After 24 hours, specimens were demoulded, labelled, and weighed.
7. Curing was done by water immersion for **7 and 28 days**.

### 3.4 Tests on Fresh Concrete

Workability characteristics were evaluated using:

- **Slump Test:** To determine consistency
- **Compaction Factor Test:** To assess relative workability
- **Vee-Bee Consistometer Test:** To evaluate remoulding time under vibration

Each test was conducted immediately after mixing, and results were recorded for all 18 mixes.

### 3.5 Tests on Hardened Concrete

The major purpose of measuring compressive strength is to learn more about the nature of concrete as well as its attributes and qualities. Concrete's compressive strength is determined by a number of variables, including the cement's strength, water-to-cement ratio, type of material used, and quality control during the concrete-making process. The materials' compressive strength high-performance concrete in this project is dependent on the binder ratio, water addition, cement proportion of Nano silica and Metakaolin, and appropriate merging of the high-performance concrete.

The Eighteen type of mix of versatile high-performance concrete percentage of Cement, Metakaolin and Nano silica within one cubic volume of concrete is considered and for each type of mix different percentage of mix proportion is made with Metakaolin and Nano silica by partial replacement of cement. Hence eighteen type of different mixing is prepared.

Each mix is casted of six Cube, three Cylinders and three Beams therefore, for 7 days - 54 cubes are tested, for 28 days - 54 cubes are tested, Totally 108 cubes are casted. 28 days – 54 cylinders are tested. 28 days – 54 Beams are tested.

Procedure:

- For a compression test, the cube dimension adopted is 100 mm X 100 mm X 100mm.
- The cube mould is cleaned and oil is applied totally on the interior surface of the cube mould.
- The mould's volume is calculated and the required ingredients for the mixing of concrete is calculated.
- The High performance concrete mix is prepared by mixing Cement, Metakaolin, Nano silica in different proportions, water, superplasticizer and with or without addition of steel fibers and Polypropylene fibers, These components are well combined and the mix attains uniformity.
- After preparation of HPC mixture the concrete is filled into cube mould and positioned on the vibrator to remove the air in the mix and to obtain a uniform compaction.
- 24 hours later of casting the samples are taken outside of the cube mould and weight of sample is noted down and immediately the samples are stored in water similar to conventional concrete curing.
- After 7 and 28 days the cube specimen is tested for compression strength.
- Now the cubes from the mould are kept in Compression testing machine and the load is applied till the cube fail to sustain the maximum load and load is noted down
- The values are tabulated and calculations are done for compressive strength.

Compressive strength = Load/ Area of the specimen (P/A)

$F_c = P/A$  in MPa Where,  $F_c$  = Compressive strength - cube in MPa,  $P$  = Maximum load at failure in N,  $A$  = Cross sectional area of prepared cube in  $mm^2$

in N,  $A$  = Cross sectional area of prepared cube in  $mm^2$



Compression Test

Compression Test





Compression Test

Compression Test

#### IV. EXPERIMENTAL RESULTS

This section presents the experimental results and analysis of the mechanical performance of High-Performance Concrete (HPC) incorporating varying percentages of Metakaolin (MK), Nanosilica (NS), and hybrid composite fibers (0.75% Steel + 0.25% Polypropylene). A total of 18 mixes were evaluated for compressive, split tensile, and flexural strength at different curing periods.

##### 4.1 Compressive Strength (7 Days)

- A consistent increase in 7-day compressive strength was observed with the inclusion of MK and NS.
- Strength improved by **14%** from 0% to 10% MK (at 0% NS) and by **8%** from 0% to 1.5% NS.
- The benefit of adding NS beyond 1.5% was marginal (~4%), indicating saturation in strength contribution.
- **Maximum 7-day compressive strength** was recorded at **52.27 MPa** for mix **MK10NS3CF1**, i.e., 10% MK, 3% NS, and 1% fibers.

##### 4.2 Compressive Strength (28 Days)

- 28-day strength improved significantly with both MK and NS. Strength increased by:
  - **17%** with the addition of 1% composite fibers,
  - **4.66%** from 7 to 28 days for MK10NS3 mixes.
- **MK10NS3CF1** exhibited the highest 28-day compressive strength of **76.86 MPa**, compared to **74.52 MPa** for the same mix without fibers.
- Fiber-reinforced cubes showed **ductile failure**, unlike non-fibered cubes which failed in a brittle manner.

##### 4.3 Flexural Strength (28 Days)

- Flexural strength increased with higher MK and NS content:
  - Up to **56.45%** increase with 10% MK and 3% NS,
  - **37.29%** increase with the addition of 1% composite fibers to MK10NS mixes.
- The highest flexural strength was **9.72 MPa** for **MK10NS3CF1**, with notable improvement from fiber inclusion.
- Beams with fibers exhibited **controlled cracking and ductile behavior**, whereas beams without fibers failed **brittly and suddenly**.

##### 4.4 Split Tensile Strength (28 Days)

- Split tensile strength increased by:
  - **43.49%** with 10% MK and 3% NS,
  - **39.96%** further with 1% fiber addition.
- The highest split tensile strength was **6.83 MPa** for **MK10NS3CF1**, showing a clear benefit of hybrid fiber reinforcement.



- Cylinders with fibers exhibited **ductile splitting patterns**, whereas non-fiber specimens showed **sudden brittle failure**.
- **Overall Observations:**
- **Metakaolin** significantly improved early and long-term strength due to its pozzolanic reactivity.
- **Nanosilica** enhanced microstructure densification, contributing to strength gain, especially up to 1.5%.
- **Hybrid fibers** effectively improved post-cracking behavior and contributed to ductility across all tests.
- Optimal performance was achieved with **10% MK, 3% NS, and 1% composite fibers (MK10NS3CF1)** in terms of compressive, flexural, and tensile strength.

## V. CONCLUSION AND FUTURE WORK

The experimental analysis shows that adding composite fibers improved the tensile and flexural strengths while partially replacing cement with concrete based on metakaolin and nanosilica produced the greatest results for compressive strength. The following is the list of most noteworthy results from the conducted experimental inquiry:-

1. 7 days compressive strength of concrete mix MK10NS3CF0 increases by 10.21% when compared to plain cement concrete.
2. 28 day compressive strength of concrete mix MK10NS3CF0 increases by 14.13% when compared to plain cement concrete.
3. The 28 days Flexural strength of concrete mix MK10NS3CF0 increases by 2.93% when compared to plain cement concrete and 28 days Flexural strength of concrete mix MK10NS3CF1 increases by 4.23% compared to plain cement concrete.
4. The 28 days Split Tensile of concrete mix MK10NS3CF0 increases by 1.27% when compared to plain cement concrete and 28 days Split Tensile of concrete mix MK10NS3CF1 increases by 2.07% compared to plain cement concrete.
5. Maximum 7 day Compressive strength of cube is 52.27 MPa is achieved with MK10NS3CF1.
6. Maximum 28 day Compressive strength of cube is 76.86 MPa and is achieved with MK10NS3CF1.
7. Maximum 28 day Flexural strength is 9.72 MPa and is achieved with MK10NS3CF1.
8. Maximum 28 day Split Tensile strength is 6.83 MPa and is achieved with MK10NS3CF1.
9. Maximum Compressive, Tensile and Flexural strengths are attained at 10% replacement of cement with Metakaolin and with 3% Nano silica employed in this investigation. As a result, 10% replacement of cement by Metakaolin (mineral additive), 3% replacement with NanoSilica (filler) and 1% addition of Steel fiber and Polypropylene fiber (composite fibers) has shown best strength.

### Scope for future research

- Further investigational studies can be tried out combining natural occurring fibers such as Jute, Hemp, Sisal, Agave, Banana fiber, Coconut Coir and manmade fibers like Steel, Glass, Polypropylene fibers.
- Investigational studies can be carried out using same mix to find the durability properties of high performance concrete.

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