EXPERIMENTAL INVESTIGATION OF HIGH PERFORMANCE CONCRETE BY USING POLYOLEFIN MICROFILAMENT FIBER

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Abstract - *Concrete is an extensively utilised construction material in many parts of the world, and its qualities are changing as technology advances. High performance concrete is a recent advancement in concrete technology that is meant to allow for the use of materials, exposure circumstances, and cost requirements while also providing higher service life and durability. The addition of mineral admixture and chemical admixture to concrete in place of cement improves its strength and durability. Fibers are mixed into high-performance concrete to improve its strength and ductility. Polyolefin fibres are man-made synthetic fibres. Polypropylene and polyethylene fibres are the most common polyolefin fibres. Polyolefin fibres can be employed both structurally and non-structurally. A polyolefin fibre is resistant to corrosion and abrasion. M50 grade concrete will be used for testing. Fiber reinforced concrete is completed with a water cement proportion of 0.34 for different levels of polyolefin fiber addition of 0.1%, 0.3%, 0.5% of materials were blended using M50 grade of concrete. Silica fume and metakaolin are used as mineral admixture and super plasticizer are used as chemical admixture.*

Key Words: Polypropylene fibre, cement, M-sand, Coarse aggregate, Admixture, Silica fume, metakaolin.

1. INTRODUCTION

Concrete is used extensively in the construction of numerous constructions. Concrete, after water, is the most widely utilised substance on the planet. Concrete is brittle, and its tensile strength is very low. It is, however, a delicate material that breaks quickly due to a variety of factors including autogenously shrinkage, freeze-thaw reactions, and mechanical compressive and tensile stresses. Micro cracks do not influence the strength of concrete, but they do allow more fluid penetration, such as water and other chemical solutions (chlorides, sulphates, and acids), causing cement matrix deterioration and, as a result, corrosion of embedded steel reinforcing bars. The presence of cracks not only reduces the material's mechanical strength and durability, but it also compromises the structure's safety. To reduce shrinkage cracks and improve strength, fracture toughness, and ductility, it is becoming increasingly common to reinforce concrete with small and randomly distributed artificial or natural fibres in more extensive applications. To improve the performance of concrete, mineral and chemical admixtures have been used to partially replace cement in recent years. Mineral admixtures such as fly ash, GGBS, metakaolin, and silica fume density the concrete, making it stronger, safer, and more lasting. Because of the limited permeability, water and other acids will not penetrate the structure, increasing its strength and serviceability.

1.1 High Performance Concrete

According to the American Concrete Institute, high performance concrete is defined as having excellent durability, strength, and workability. Concrete with specified properties generated for a specific use and environment exposure is referred to as high performance concrete. The type of cement, partial replacement of cement with mineral admixtures (fly ash, GGBS, silica fume, metakaolin, and other industrial wastes, for example), type of super plasticizer, and mine omposition of fine and coarse aggregate have all contributed to the development of high performance concrete. High-performance concrete is stronger and easier to maintain than regular concrete. The addition of pozzolans and a low water content results in a thick microstructure with high strength and low permeability in high-performance concrete. The use of high-strength, low-water-cement-ratio concrete has resulted in improved durability. There are two methods for preventing the transit of hostile ions like chlorides: decreasing the capillary pore system and generating chemically active binding materials. When compared to regular strength concrete, HPC is typically more brittle. Applying a confining pressure to high-performance concrete can improve ductility. It can also be improved by adding fibres to the design mix to change the composition. Fibers are made from a variety of materials, including steel, glass, polyester, aramid, polyolefin, and natural fibres, and come in a variety of sizes and shapes. The majority of fibres are employed in both structural and non-structural applications. Fibers have the advantage of reducing shrinkage cracks, saving cement, and increasing concrete's tensile and compressive strength. The optimum flexural strength and toughness performance is achieved by combining high ductility with high strength fibre reinforcement. Fiber reinforced concrete is gaining popularity as a high-potential modern structural material.

1.2 Polyolefin Fibers

Polyolefin fibres are man-made synthetic fibres manufactured by polymerizing unsaturated hydrocarbons into linear saturated hydrocarbons using a synthetic linear polymer. Polypropylene (CH2 = CH – CH3) and polyethylene (CH2-CH2) are two forms of polyolefin polymers used to create synthetic fibres. Polypropylene or polyethylene is the most common polyolefin fibres. Then there are the polyolefin's that are most widely used. Melting and spinning are used to create polyolefin fibres. The granules of polymer are fed into the extruder, which melts the material. After that, the filaments are cooled in an air stream before being collected in cans.

Polyolefin fibres are made from olefin polymers that comprise 85 percent ethylene, propylene, or other olefins and are generated via chain polymerization. At normal temperature, polyolefin fibres have a specific gravity of less than one, are unaffected by solvents, and are only swelled by aromatic and chlorinated at elevated temperatures. Abrasion resistance is high in a fibre. Polyolefin fibres have a number of advantages, including corrosion resistance and high strain capacity. It is suitable for use in a harsh environment to protect structures against corrosion due to its corrosion resistance. Polyolefin fibres enable long-term fracture control and good bonding in the cement matrix. Polymer research and engineering advancements have enhanced the use of polyolefin in everyday applications. Polypropylene and polyethylene are the fastest-growing polymeric families due to their low production costs when compared to other fibres and materials. They encouraged use because of the inexpensive cost, superior chemical resistance, high strength, and toughness. Polyolefin fibres have good tensile strength, abrasion resistance, and chemical resistance in general. Polyolefin fibres are gaining popularity as a replacement for corrosive steel solutions. Micro and macro polyolefin fibres are two varieties of polyolefin fibres available on the market, each serving a particular purpose. Polypropylene, one of the polyolefin fibres, is used in cementitious composites to improve the structure's strength, durability, and crack resistance. The addition of fibre to concrete, as well as the creation of polyolefin-based synthetic macro fibres, increased mechanical qualities and reduced shrinkage cracking. The use of macro synthetic fibres as an alternative to steel fibre in fibre reinforced concrete has grown popular. Polypropylene is reported to have a crystalline that is halfway between low density polyethylene (LDPE) and high density polyethylene (HDPE). Polypropylene, on the other hand, has a higher operating temperature and tensile strength than polyethylene.

1.3 Polypropylene Fibers

The first stereo regular polymer to attain industrial significance was polypropylene. Polypropylene fibres were first introduced to the textile industry in the 1970s, and they quickly established themselves as an important component of the fast expanding synthetic fibre family. Polypropylene is currently ranked fourth among the "big three" fibre classifications, which include polyester, nylon, and acrylic. However, in comparison to other commodity fibres, its use in garments and domestic textiles has been restricted, with the majority of the fibre produced going to industrial uses. It's a linear structure that's held together by the monomer CnH2n. It is produced using propylene gas and a catalyst such as titanium chloride. Aside from that, polypropylene could be a by product of oil refinery. In contrast to amorphous thermoplastics such as polystyrene, PVC, polyamide, and others, which have random placement of radicals, most polypropylene is crystalline and geometrically regular.

2. MATERIALS

2.1 Cement

A Binder or substance that hardens and sets and may bind other materials together in construction is cement. the fundamental justification for selecting OPC 53 grade is that it has the right strength, surface area and fineness for the hydration process. Cement has passed the primary material testing.

Table-1: Properties of Cement

Properties	Results
Specific gravity	3.13
Initial Setting Time	28 minutes
Final Setting Time	532 minutes
Consistency	33%
Fineness modulus	2.6

2.2 Fine Aggregate

Fine aggregate is that material that passes through a 4.75mm screen and is inert to chemically inactive. By bridging the gaps between the coarse particles, the fine aggregate in concrete strengthens the concrete paste and decreases its porosity. For both fine and coarse aggregate the basic materials testing have been finished.

Table-2: Properties of fine aggregate

Properties	Results
Grading of sand	Zone II
Specific gravity	2.63
Fineness modulus	2.47
Water absorption	1.5%

2.3 Coarse aggregate

Construction aggregate, a broad category of coarse particle materials used in construction, comprised sand, gravel crushed stone, slag, and recycled concrete. We utilised coarse gravel that was maintained in a 12.5mm filter after passing through a 20mm sieve. Concrete with high performance has to be strong. If coarse aggregates are utilised, shrinkage will be decreased. For fine and coarse aggregate, the basic material testing has been finished.

Table-3: Properties of coarse aggregate

Properties	Results
Specific gravity	2.70
Water absorption	2%
Fineness modulus	6.2

2.4 Polyolefin Fiber

In order to create polyolefin fibers, synthetic linear polymers are used to polymerize unsaturated hydrocarbons into saturated linear hydrocarbons. Whirling and melting used make the fibres of polyolefin fibers, which are manufactured from olefin polymers that include 85% ethylene, propylene, or other olefins. There are two different types of polyolefin on the market: macro and micro. Each has a specific use. The ultimate load is increased by a polyolefin microfilament fiber, which also has high tensile strength, abrasion resistance and chemical resistance.

Fig-1: Polyolefin Fibres

Table-4: Properties of micro polyolefin fiber

Fiber	Micro polyolefin
Length (mm)	12
Appearance	White
Specific gravity	0.91
Melting Point (°c)	160
Acid and alkali proof	High

2.5 Silica Fume

By definition, silica fume is very fine non-crystalling silica generated in electric arc furnace as a by product of the manufacture of elemental silicon or silicon alloys, according to the American Concrete Institute (ACI). Silica fume is also known is micro silica, condensed silica fume, volatized silica, and silica dust. Typically it is a grey powder that resembles fly ashes or Portland cement. It possesses pozzolanic and cementitious properties. Concretes durability is increased by adding silica fume, which also shields the embedded steel form corrosion. The pastes finely dispersed pozzolana particles produce a lot of nucleation sites where the hydration products can precipitate. This process causes the paste to thicken and become more homogeneous in terms of fine pore distribution. This is brought on by an interaction between the amorphous silica found in pozzolanic materials and the calcium hydroxide created during cement hydration processes. Several by products of silica fume include concrete uses due of its chemical and physical characteristics; it is a pozzalana that is extremely reactive. Silica fume may make concrete incredibly durable androbust.

Table-5: Properties of silica fume

Properties	Results
Physical form	Powder
Color	White
Specific gravity	2.20
Size of particles	0.1 μ
Chloride Content	Nill

Fig-2: Silica Fume

2.6 Metakaolin

Numerous studies have been conducted on natural pozzolans, particularly kaolintic clay and thermally activated common caly. These impure substances are reffered to as metakolin. Despite having some pozzolanic characteristics, they are not extremely reactive. Purely reactive pozzolan is produced when water processing eliminates non-reactive. Purely reactive pozzolan is produced when water processing eliminating nan-reactive contaminants form highly reactive metakolin. High reactivated metakolin that is white or cream in colour (HRM). High reactive metakolin displays significant pozzolanic reactivity and a decrease in $Ca(OH)^2$ as early as one day. Silica fume can be competed with by the highly reactive metakolin. Instead than being a by product like other pozzolanic compounds, metakolin is an intentionally created substance with specified properties.

Table-6: Properties of Metakolin

Properties	**Results**
Physical form	Powder
Color	White
Specific gravity	2.50
Fineness modulus	800 m^2/kg
Specific surface	11 m^2/g

Fig-3: Metakolin

2.7 SIKACIM PINK

Waterproofing compound for concrete, mortar, and plaster in liquid form. For use in concrete, mortar and plaster, a specifically formulated unique, pink colour liquid integrated water proofing compound has been created using Sika's technology of particular selective polymers, surface active agents and additives.

Table-7: Properties of sikacim pink

Appearance	Pink colour hazy liquid
Density	1.21 at 25°C
pH value	$\geq$6

3. TESTS AND RESULTS

3.1 Slump cone test

The measuring of specimens 0.3m in height, 0.2m in base diameter and 0.1m in top diameter. The damping rod has a 0.0016m diameter and 0.6m length.

Table-8: Slump Cone Test Result

Replacement of polyolefin fiber (%)	Trial No	Slump Value (mm)	Average Slump value (mm)	Type of slump
0	1	105	100	True or High Slump
	2	95		
0.1	1	110	108	
	2	105		
0.3	1	105	110	
	2	115		
0.5	1	110	115	
	2	120		

3.2 Compressive strength test

On a compressive testing machine with a capacity of 2000kN, a cube with standard dimensions of 0.15m X 0.15m X 0.15m is subjected to compressive strength test while being loaded at a rate of 4 kN/s. At the age of 7 and 28 days, the test was conducted. Concretes compressive strength with and without fibers, with and without substitutes for metakaolin (10%) and flyash (15%). Below table is displays the concretes compressive strength values.

Table-9: Compressive Strength Test Result

Replacement of polyolefin fiber (%)	Average Compressive Strength of concrete at 7 Days (N/mm^2)	Average Compressive Strength of concrete at 28 Days (N/mm^2)
0	34.44	51.33
0.1	34.75	53.51
0.3	**36.43**	**56.21**
0.5	35.69	55.67

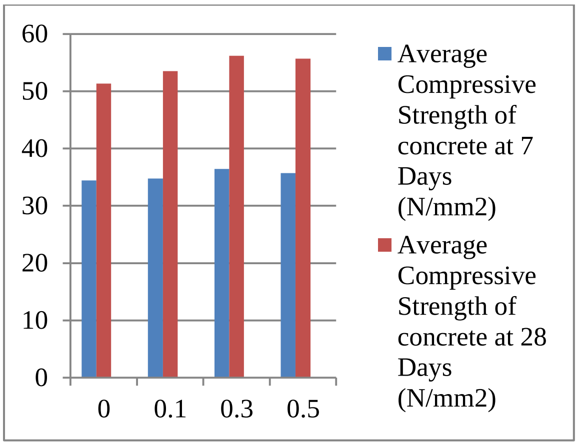

Chart-1: Compressive Strength Test Result

- Compressive strength at 28 days in HPC (56.21 N/mm²) at **0.3%** of polyolefin fibers is more than that of ordinary concrete.

Fig-4: Compressive Strength Test

3.3 Split tensile strength test

A cylindrical structure with standard diameter of 0.15m and a height of 0.3m was used for the split tensile strength test. In line with IS 5816:1998, the load was gradually raised to produce split tensile stress. Test specimens were gathered when the animals were 28 and 7 days old. The spilt tensile strength of concrete with and without fibers, with a replacement of 10% metakaolin and 15% fly ash the concretes split tensile strength findings are displayed in the table.

Table-10: Split Tensile Strength Test Result

Replacement of polyolefin fiber (%)	Average Split Tensile Strength of concrete at 7 Days (N/mm²)	Average Split Tensile Strength of concrete at 28 Days (N/mm²)
0	3.28	5.50
0.1	3.32	5.28
0.3	**3.74**	**5.90**
0.5	3.43	5.47

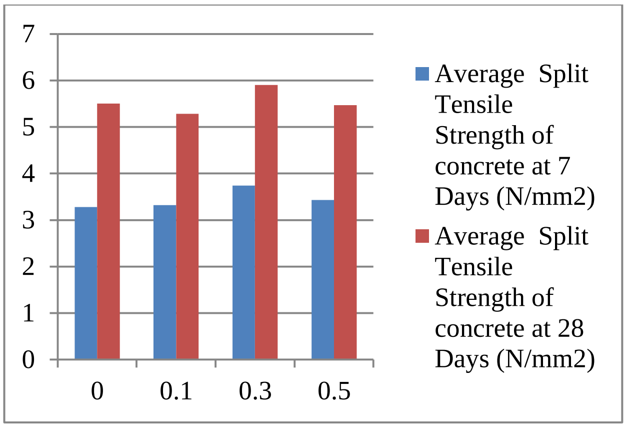

Chart-2: Split Tensile Strength Test Result

- The Split tensile strength at 28 days in HPC (5.90 N/mm²) at **0.3%** of polyolefin fibers is more than that of ordinary concrete.

Fig-5: Split Tensile Strength Test

3.4 Flexural strength test

The specimens beam length is 0.75m. Either three point load test may be used to guide the flexural test on concrete. the concretes flexural strength data are displayed in a table,

Table-11: Flexural Strength Test Result

Replacement of polyolefin fiber (%)	Flexural Strength of concrete at 7 Days (N/mm^2)	Flexural Strength of concrete at 28 Days (N/mm^2)
0	4.40	6.23
0.3	**4.98**	**7.35**

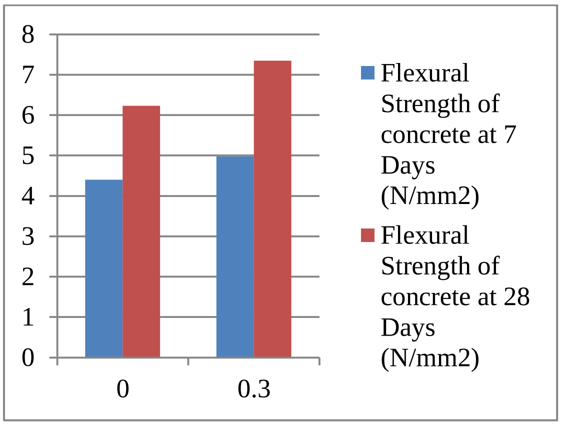

Chart-3: Flexural Strength Test Result

- The flexural strength at 28 days in HPC (7.35 N/mm^2) at **0.3%** of polyolefin fibers is more than that of ordinary concrete

Fig-6: Flexural Strength Test

4. CONCLUSION

The best results were achieved in high performance concrete at 0.3% polyolefin fiber with 10% silica fume and 10% metakaolin as fractional trade for the fine aggregate.

When compared to ordinary concrete, HPCs strength is relatively high replacement for silica fume and metakaolin as fine aggregate.

The highest compressive strength measured in HPC at 28 days (56.21 N/mm^2) at 0.3% polyolefin fibers is higher than that of regular concrete.

The highest split tensile strength measured in HPC at 28 days (5.90 N/mm^2) at 0.3% polyolefin fibers is higher than that of regular concrete.

The highest flexural strength measured in HPC at 28 days (7.35 N/mm^2) at 0.3% polyolefin fibers is higher than that of regular concrete.

When fiber content is added to traditional concrete, the compressive strength, split tensile strength, and flexural strength all raise.

The addition of polyolefin fibers to concrete can solve the issue of the low tensile strength of concrete.

Their research makes it clear that reinforced concrete beams built using silica fume and metakolin as a cement substitute material may perform more structurally well.

Beams have shown an increase in deflection value as a result of the admixtures ductile behaviour.

Due to their capacity to stop macro fractures form growing out of micro fissures, fibers can aid to decrease water permeability.

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