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Research Article

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Experimental Investigation on the Compressive Strength of 6% Novel Polypropylene Monofilament Fiber as Additive in Concrete with Conventional Concrete

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Abstract

Aim: This study's goal is to contrast the compressive strength of newly developed polypropylene monofilament fiber-reinforced concrete to that of conventional concrete with a 6% replacement rate.

Methodology: to increase the concrete's compressive strength, 6% polypropylene monofilament was used in place of a certain amount of cement. The specimens were divided into two groups. Each group includes 18 different specimens. Pre-test power is calculated at 80%. 6% of polypropylene monofilament was replaced in concrete by the weight of cement. A compressive strength test was carried out as per ASTM standards using a cube specimen on dimensions 150 x 150 x 150 mm.

Results: Using a compression testing machine with a 2000 kN capacity, the compressive strength of the specimens were determined after 28 days of curing at room temperature. Novel polypropylene monofilament fiber-reinforced concrete exhibited a compressive strength of 37.8728 N/mm^2 compared to conventional concrete of 34.3311 N/mm^2. A t-test with an independent sample was used to examine the outcomes. The novel polypropylene monofilament fiber-reinforced concrete standard deviation for 6% replacement with concrete was 2.30693. With a significance value of $p = 0.000$, there is a statistically significant difference between the two study groups (two-tailed, $p < 0.05$).

Conclusion: With the partial replacement of novel polypropylene monofilament fiber-reinforced concrete in cement, the characteristic compressive strength of concretes specimen is greatly enhanced as compared to conventional concrete.

Keywords

Novel polypropylene monofilament fiber reinforced concrete, M30 grade, Coarse aggregate, Compressive strength, Conventional concrete, Fine aggregate, Water

Introduction

The evolution of concrete from normal grade to high-strength concrete (HSC) has been a significant development in construction materials [1, 2]. Normal grade concrete, ranging from grade 5 to 45, was widely used in the 1900s for various construction applications due to its adequate strength for general purposes [3]. This type of concrete typically consisted of cement content less than 380 kg/m^3, normal aggregates such as granite, medium water requirements, and minimal use of superplasticizers [4].

However, starting from around the 1960s, with the emergence of unique structural designs and the need for higher load-bearing capacities, there arose a demand for stronger concrete [5]. This led to the development of HSC, capable of withstanding load capacities ranging from 50 MPa to 90 MPa [6]. HSC requires a different mix proportion compared to normal grade concrete, typically involving higher cement content, increased aggregates, reduced water content, and the incorporation of superplasticizers [7].

To achieve the desired properties of HSC, various additives and supplementary materials have been introduced into concrete mixes [8-10]. These include silica fume, fly ash, metakaolin, and other pozzolanic materials. Silica fume, in particular, became popular in HSC mixes due to its ability to enhance strength when used as a partial replacement for cement [11-15]. Fly ash, on the other hand, improves flowability and acts as a natural admixture in HSC mixes [16-18]. Additionally, fly ash can serve as a cost-effective alternative to superplasticizers, as it can be used in higher dosages [19, 20].

Since sustainability became an integral part of the concrete industry, researchers have been trying to replace Portland cement, which emits almost 7% of carbon dioxide into the atmosphere, by using micro-sized mineral admixtures like silica fume, fly ash, rice husk ash, slag, etc. Scientists have recently been able to study nanoscale admixtures and their effects on concrete's structure thanks to technological advances. A great deal of impact can also be brought to the construction materials field by the development of nanoscience. Cement-based materials and their fracture mechanisms have been the focus of recent nano-research in construction. By understanding the structure at nanoscale, we can influence processes related to construction materials - such as their strength development, fracture, corrosion - and even tailor their characteristics. Many construction applications require materials with new properties, such as self-cleaning, discoloration resistance, anti-graffiti protection, and high scratch- and wear-resistance.

The addition of silicon dioxide nanoparticles to polymers improved their strength, flexibility, and durability. In high-performance and self-compacting concrete, silicon dioxide nanoparticles can improve workability and strength. In addition to carbon nanotubes, conventional polymer fibers and films must be combined with carbon nanotubes. In cement production, nano-layers are formed on cement particles' surfaces by mechano-chemical activation. Metakaolin, which is a byproduct of kaolin after undergoing heat treatment, has been utilized as a cement replacement material since the early 1990s. It contributes to improved strength and durability properties in HSC mixes [21, 22].

Overall, the evolution of concrete from normal grade to HSC has been driven by the need for stronger and more durable construction materials, leading to the adoption of new technologies and the utilization of various additives and supplementary materials to achieve desired performance characteristics [23].

Materials and Method

Sample size was calculated by clinacalc. For this experiment, there were two groups. Each group includes 18 different specimens. Pretest power is calculated at 80%. With a significance value of $p = 0.000$, there is a statistically significant difference between the two study groups. (two-tailed, $p < 0.05$). Conventional and polypropylene monofilament fiber-reinforced concrete compressive strengths showed standard deviations of 1.65492 and 2.30693, respectively. Novel polypropylene monofilament fiber-reinforced concrete was used in group 1, while conventional concrete was used in the other, replacing it with 6%. The materials required for producing concrete are shown in figure 1.

Concrete cubes specimen of 150 mm was created to evaluate the strength of the samples. Cement classified as group 1 is described as having a 6% replacement of polypropylene monofilament fiber. The cement used was Ramco cement (OPC 53 grade), with the following specifications: specific gravity of 3.15, consistency of 31.5%, initial setting time 30 min, final setting time 600 min, and soundness 2.8. As a fine aggregate, 2.74 fineness modulus, 2.63 specific gravity, and 4.75 mm sieve passable M-sand from the neighborhood was employed. The coarse aggregate, which is crushed stone from a quarry that has been broken up into small pieces and has an irregular shape, is used in the project and has a size of 20 mm, with sieve passes through 80 mm, 40 mm, 20 mm, etc. Table 1 shows the parameters of cement, whereas table 2 and table 3

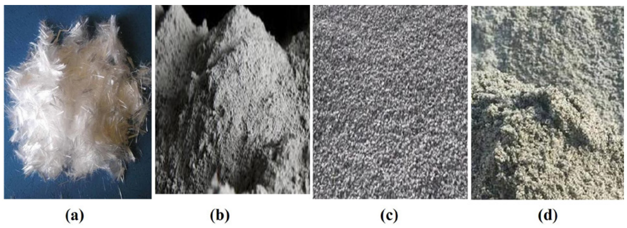

Figure 1: Materials used in concrete preparation. **(a)** Polypropylene monofilament fiber, **(b)** Cement (OPC53 Grade), **(c)** Coarse aggregate, and **(d)** Fine aggregate.

Table 1: Properties of cement.

S. No.	Properties	Result
1	Fineness	90 micron
2	Specific gravity	3.15
3	Standard consistency	31.5%
4	Initial setting	30 min
5	Final setting	600 min

Table 2: Properties of fine aggregate.

S. No.	Properties	Result
1	Size of sample	4.75
2	Sieve analysis	2.59
3	Water absorption	3%
4	Specific gravity	2.65

Table 3: Properties of coarse aggregate.

S. No.	Properties	Result
1	Size	20 mm
2	Sieve analysis	20 mm
3	Water absorption	3.14%
4	Specific gravity	2.68

show the parameters of fine and coarse aggregate, respectively.

The mix design of the M30 grade of concrete for both groups must be evaluated using the Indian Standard Method (IS 10262-2009), and the required materials must then be manually prepared in groups. For group 1, the basic requirements should be mixed as they would for conventional M30 grade concrete under wet conditions, and the compaction procedure must also be done manually using a tamping rod. In order to eliminate the air voids in the concrete specimen, vibration is also carried out during the casting process. Similar to group 1, group 2 should similarly follow the same procedure, with the exception of adding 6% polypropylene monofilament fiber and casting concrete specimens in a cubic mold.

During sample preparation and following the curing process, specimens are taken out of the mold. Figure 2 shows the casting of the cube in mold, workability test, curing process of the concrete cube, and polypropylene monofilament fiber concrete.

The performance of conventional concrete and fiber-reinforced concrete was compared using a compression testing machine after 28 days of curing. By gradually applying pressure at a rate of 140 kg/cm^2 per minute until the specimen collapses, the compressive strength is ascertained. The universal testing machine used to gather information on compressive strength is shown in figure 3. The broken specimen after testing is shown in figure 4.

Statistical analysis

Version 2.3 (2022) of IBM-SPSS software was used to conduct the statistical analysis to compare group 1 and group 2 of comparison of compressive strength of polypropylene monofilament fiber concrete with conventional concrete. By comparing the means of two sets of cases, the independent samples t-test technique automates the calculation of the t-test effect size. The experiment's data was analyzed using the SPSS 22 software, as shown in figure 5.

An independent t-test was used to ascertain the statistical significance between the study and control groups. sample was used. The variables that affect concrete's compressive strength—grade, water/cement ratio, cement quality, and curing days—were all independent in this study; there were no dependent variables. With a significance value of $p = 0.000$, there is a statistically significant difference between the two study groups. (two-tailed, $p < 0.05$). Conventional and novel polypropylene monofilament fiber-reinforced concrete compressive strengths showed standard deviations of 1.65492 and 2.30693, respectively.

Results

According to table 4, the typical concrete's mean compressive strength was 34.3311 N/mm^2. As shown in table 5, the new polypropylene monofilament fiber-reinforced concrete had a compressive strength of 37.8728 N/mm^2.

Standard deviations for both traditional concrete and the innovative polypropylene monofilament fiber-reinforced con-

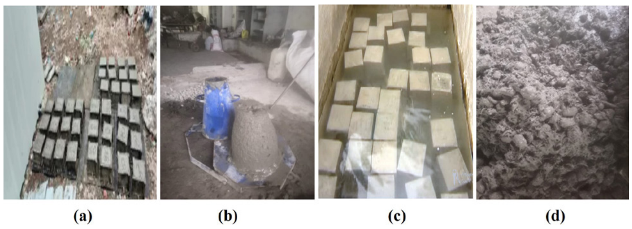

Figure 2: (a) Casting of the cube in mold, **(b)** Workability test, **(c)** Curing process of concrete cube, and **(d)** Polypropylene monofilament fiber concrete.

Figure 3: Using a universal testing machine, the compressive strength results were obtained.

Figure 4: Broken specimen after testing.

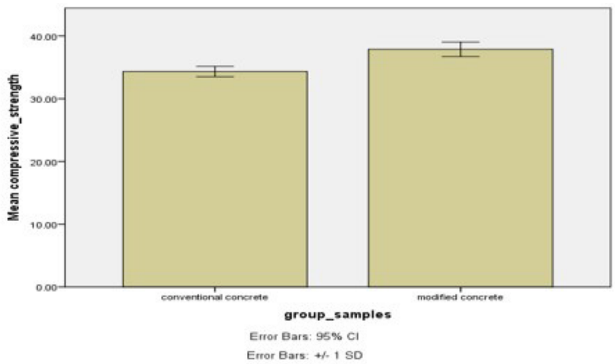

Figure 5: A bar chart comparing the mean compressive strength of conventional concrete and concrete with 6% fiber reinforcement is shown. When 6% more polypropylene is included in concrete than conventional concrete, the high accuracy is increased. The X-axis shows the group sample, the Y-axis shows the mean compressive strength, and the mean highest standard of quality is ± 1 standard deviation.

crete were 1.65492 and 2.30693, respectively. Table 4 displays the compressive strength values of 18 samples made with ordinary concrete. Table 5 displays the figures of 18 samples' compressive strength that were created without using regular concrete. Table 6 presents group statistics for both sample groups. Table 7 displays the independent samples t-test findings. Table 7 displays the compressive strength values for 18 samples together with the importance of compressive strength as shown by the equality of variance Levene's test, which was determined to be 0.120.

Table 4: Compressive strength of conventional concrete.

S. No.	Weight (kg)	Strength (kN)	Compressive strength (N/mm²)
1	8.132	590	30.67
2	8.543	672	34.31
3	8.231	659	33.73
4	8.987	680	34.67
5	9.011	674	34.40
6	8.654	685	34.89
7	8.256	725	32.22
8	8.987	689	35.07
9	9.231	617	31.87
10	8.765	693	35.24
11	9.043	662	33.87
12	8.798	653	33.47
13	8.675	696	35.38
14	8.793	699	35.38
15	9.045	720	36.44
16	8.894	650	33.33
17	9.406	597	35.42
18	9.654	746	37.60

Table 5: Compressive strength of 6% novel polypropylene monofilament fiber reinforced concrete.

S. No.	Weight (kg)	Strength (kN)	Compressive strength (N/mm²)
1	8.132	845	37.56
2	8.543	897	39.87
3	8.231	825	36.67
4	8.987	852	37.87
5	9.011	805	35.78
6	8.654	807	35.87
7	8.256	785	34.89
8	8.987	762	33.87
9	9.231	765	34.00
10	8.765	857	38.09
11	9.043	845	37.56
12	8.798	912	40.53
13	8.675	925	41.11
14	8.793	867	38.53
15	9.045	905	40.22
16	8.894	922	40.98
17	9.406	885	39.33
18	9.654	877	38.98

Figure 5 shows the mean accuracy values for two groups of conventional concrete and concrete reinforced with polypropylene monofilament fibers using a 95% error bar and a 0.05 p-value. error charts with a +/-1 standard deviation mean accuracy detection error.

Discussion

It was discovered that the innovative polypropylene monofilament fiber-reinforced concrete with added superplasticizer had a 10.3% higher compressive strength than regular concrete. By adding fiber, concrete's permeability is decreased, and its compressive strength is increased. It was discovered that super-plasticized novel polypropylene monofilament fiber-reinforced concrete had a lower standard deviation for compressive strength than conventional concrete. It shows that the characteristic compressive strength of concrete reinforced with novel polypropylene monofilament fiber-reinforced concrete and a superplasticizer deviates more from the mean value. The two study groups differ statistically, with a significance value of $p = 0.000$ (two-tailed, $p < 0.05$) indicating that there is a difference.

It is a recent M30-grade concrete variant that was created as a result of study. A 28-day characteristic compressive strength test was used to produce and evaluate it. Superplasticizer and polypropylene monofilament fiber were mixed with fresh M30 grade concrete to produce the concrete. The proportion of cement to water was 0.5. Compressive tests on the two group's data were compared. In this research, the author discusses using mineral additions like polypropylene monofilament fiber and accelerator, superplasticizer, and air-entraining agent. After 28 days was spent doing the testing. In this

Table 6: Represents group statistics for both sample groups. Mean (34.3311, 37.8728), standard deviation (1.65492, 2.30693), standard error mean (0.39007, 0.54375).

	Group	N	Mean	Std. deviation	Std. error mean
Compressive strength (N/Mm²)	Without fiber	18	34.3311	1.65492	0.39007
	With fiber	18	37.8728	2.30693	0.54375

Table 7: Independent samples t-test results: Statistical significance difference observed for compressive strength is a statistically significant difference between the two study groups, with a significance value of $p = 0.000$ (two-tailed, $p < 0.05$).

Compressive strength	Levene's test for equality of variances		T-test for equality of means						
	F	Sig.	t	df	Sig. (2-tailed)	Mean difference	Std. error difference	95% CI of the difference: Lower	95% CI of the difference: Upper
Equal variance assumed	2.545	0.120	-5.292	34	0.000	-3.54167	0.66919	-4.90163	-2.18171
Equal variance not assumed	-	-	-5.292	30.833	0.000	-3.54167	0.66919	-4.90679	-2.17654

study, it was examined various fiber-reinforcement affected the characteristics of conventional concrete with great strength and durability This study looked at the effects of different fiber reinforcements on the concrete's mechanical characteristics with normal strength and high strength. The design thickness of jointed plain concrete pavement was then estimated using the mechanical characteristics of concrete under the same traffic-loading conditions [2].

The average compressive strength of novel polypropylene monofilament fiber-reinforced concrete is 37.8728 N/mm^2. The average characteristics compressive strength of conventional concrete was 34.3311 N/mm^2. The drawbacks of polypropylene monofilament fiber include their sensitivity to fire, sunlight, and oxygen as well as their low elastic modulus and poor bonding properties with concrete. Concrete that has been reinforced with fibrous material has a higher structural stability. Future construction projects will need high strength concrete.

Conclusion

The average compressive strength of novel polypropylene monofilament fiber-reinforced concrete is 37.8728 N/mm^2. The average compressive strength of conventional concrete was 34.3311 N/mm^2. Compared to conventional concrete, novel polypropylene monofilament fiber-reinforced concrete was 10.3% increase. Comparing the compressive strength of conventional concrete to novel polypropylene monofilament fiber-reinforced concrete with a superplasticizer added shows that modified concrete performs better than unmodified concrete in this regard.

Acknowledgements

None.

Conflict of Interest

None.

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