DURABILITY PROPERTIES OF CONCRETE BY USING NATURAL FIBER (BAMBOO) AND SYNTHETIC FIBER (NYLON)

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Abstract

The study aimed to assess the durability of concrete using natural and synthetic fibers. In this study the experimental work was carried out to evaluate durability properties of concrete made of 0.5%, 1%, 1.5%, 2% bamboo fiber a natural fiber and 0.5%, 1%, 1.5%, 2% nylon fiber a synthetic fiber for M25 grade design mix concrete. Concrete cube specimens were cast by adding bamboo and nylon fibers and also manufactured sand used as a fine aggregate. All the cast concrete specimens, including nominal mix specimens after curing for 28 days in normal water, were soaked for 90 days in the chemical water solution made with 3% of H_2SO_4. Durability properties were studied by performing sulphate attack and compression test on the specimens. The test results were compared with the nominal mix. It was observed that the bamboo fiber and nylon fiber at 1% provides better durability than the nominal mix.

Keywords: Bamboo fiber, Nylon fiber, H_2SO_4 solution, Compressive strength, Sulphate attack.

1. INTRODUCTION

Usage of natural and synthetic fibers in concrete is practicing for decades. There has been promising research on the utilization of the fibers in the concrete over a long period. From the literature, it is observed that there is a significant increase in the mechanical and durability properties of concrete while using fibers. Fibers will prevent and control the formation of inherent cracking in the concrete and reduce permeability, therefore ensuring a more durable concrete structure construction. There are different varieties of natural (coconut coir, sisal, palm, jute, flax, straw, **bamboo,** and cane) and synthetic (steel. polypropylene, glass, **nylon,** and polyethylene.) fibers are readily available to use in the concrete construction. The various factors of fibers that influence the durability of concrete are its type, geometry, form, and surface.

In this study, the more commonly available fibers, natural bamboo fiber, and artificial nylon fiber are used. The experimental work was carried out to evaluate durability properties of concrete made of 0.5%, 1%, 1.5%, 2% bamboo fiber a natural fiber and 0.5%, 1%, 1.5%, 2% nylon fiber a synthetic fiber for M25 grade design mix concrete. The durability properties of the concrete specimens were evaluated after 90 days of immersing in 3% H_2SO_4 chemical solution and found optimum doses of fibers.

2. LITERATURE REVIEW

Riyadh et al. (2020) studied the acidic environment effect on concrete sewage trunks, pipelines, and manholes. It was observed that the Iraq environment is unusually corrosive due to the presence of aggressive acid attacks. Cracks in the cover of concrete sewage structures are commonly observed due to aggressive solutions in all regions of Iraq. They studied the effect of curing, cementitious content, and W/C ratio on the strength and durability characteristics of ordinary and silica fume based concrete exposed to aggressive acid. The results showed that silica fume-based concrete had higher strength compared to control mixes at 15% silica fume.

Jinliang et al. (2019) studied the effect on refining the mechanical and durability properties of concrete using glass fiber (GF) and polypropylene fiber (PF). They prepared the specimens by adding at proportions of total GF volume fraction of all mixtures was 0.5, 1, and 1.5 %, the total PF fiber volume fraction of all mixtures was 0.5, 1, and 1.5 %, the total GF and PF volume fraction of all mixtures was 0.5, 1, and 1.5 %. Testes conducted on the specimens are compressive and flexural strength, rapid chloride migration (RCM) test, rapid chloride penetration (RCPT) test, scanning electron microscopy (SEM). The results are observed and compared with plain concrete. It was found that the addition of 1.5% of GF, PF, and GF+PF gives better mechanical and durability properties.

Ahmet and Mehmet (2019) studied the durability of the concrete specimens made with the blast furnace slag (BFS) and Elazig ferrochrome slag (EFS) based geopolymer. The specimens are submerged in 5% phosphoric acid (H_3PO_4). It was observed that as EFS's ratio in the geopolymer concrete mixture increased, the losses in the compressive strength of geopolymer concretes exposed to acid decreased. All the samples exposed to acid solutions, which showed weight loss. The H_3PO_4 solution caused less weight loss compared to other acid solutions. The HF and H_2SO_4 solutions caused the expansion of geopolymer concretes, H_3PO_4, and HCl solutions caused shrinkage of geopolymer concretes. H_2SO_4, HF, and H_3PO_4 solutions caused deterioration of the sample surfaces. The HCl solution only darkened the color of the samples. As EFS's ratio in the geopolymer concrete mixtures increased, deterioration in the samples' microstructure decreased. They concluded that the effect of acid on the geopolymer concrete was H2SO4 > HF > HCl > H_3PO_4 solutions. Then EFS is more resistant against acid than BFS.

Ashutosh et al. (2019) studies were taken up on the durability of reinforced concrete exposed to the acidic environment. They investigated the corrosion behaviour of reinforced concrete exposed to concentrated sulphuric acid. The cylindrical specimens show the formation of a brown ring. They observed that the surface near the steel resulted in the expansion of a particular spot, causing the expansion, which leads to cracking. It was found that the corrosion rate is very high when the specimens are soaked in concentrated sulphuric acid solution. It was also observed that initially decreases in the rate of corrosion without conductance condition, whereas for with conductance condition, the rate remains more or less uniform. The effect of the diameter of a bar to corrosion rate is observed to be negligible.

Ali et al. (2017) presented a review on the partial replacement of Portland Cement (PC) by Blast Furnace Slag (BFS) and Natural Pozzolan (NP), which increase or decrease the compressive strength of the concrete mix. Replacing PC up to 30% by BFS decreases capillary and water absorption after 28 days of curing. All BSF incorporated mix demonstrates lower capillary water absorption after 90 days of curing. On the other hand, NP incorporated mix had more sorptivity than the OPC mix. They observed that the use of BFS and NP as a mineral admixture improves the durability of concrete mix against sulfuric acid attack through weight and compressive loss test results. Ultra-sonic pulse velocity determination in acid corroded specimens is not an appropriate experiment for assessing the deterioration intensity of concrete specimens. They also considered capillary water absorption and durability test results and concluded that permeability is not the main property of concrete to determine the performance of concrete mixtures in sulfuric acid solution.

Maria (2017) investigated the effects of water-cooled copper slag on a wide range of fresh and hardened concrete properties and durability characteristics of concrete, where copper slag is replaced with fine aggregate. The results are observed that the copper slag percentage has more strength compared to ordinary concrete. Statistical analysis was confirmed that there was no significant effect on the compressive strengths of concrete and there is no interaction effect between water content, cement type and copper slag levels regarding the compressive strengths, so he concluded that for the further mix proportions this type of aggregate could be used as a suitable and substitute for natural sand. Therefore the waste materials are suggested for use in concrete. Using this aggregate in concrete is also economical, the availability of the material is also significant, and the cost is similar to the natural aggregates in the regions.

3. MATERIALS AND METHODS

The materials used in this paper:

3.1 Cement

A 53 grade Ordinary Portland Cement (OPC) of (UltraTech brand) pertaining as per IS 2013 was considered in the current study. Some physical properties of the cement were ensuing IS 4031, and the results were presented in Table 1.

Table 1: Physical properties of the cement

S.No.	Property	Test value	Standard value (IS 12269: 2013)	Method of the test, Ref. to
1	Specific gravity	3.13	---	IS 4031 (Part 11): 1988
2	Fineness, m^2/kg	370	Min. 225	IS 4031 (Part 2): 1999
3	Soundness, mm (By Le-Chatelier method)	6	Max. 10	IS 4031 (Part 3): 1988
4	Normal consistency	33%	---	IS 4031 (Part 4): 1988
5	Initial setting time, min	42	Min. 30	IS 4031 (Part 5): 1988
	Final setting time, min	350	Max. 600	
6	Compressive strength, MPa (After 28 days curing)	53	Min. 53	IS 4031 (Part 6): 1988

3.2 Coarse Aggregate

The locally available coarse aggregates of maximum 20 mm size, which are granite origin, free from clayey matter, silt, and organic impurities, were used. It is tested for their properties, as per IS: 2386-1963, and the results were presented in Table 2.

Table 2: Physical properties of coarse aggregate

S.No.	Property	Test value	Standard value (IS 383: 2016)	Method of the test, Ref. to
1	Specific gravity	2.66	Max. 3.2	IS 2386 (Part III): 1963
2	Water absorption, %	0.25	Max. 5	IS 2386 (Part III): 1963
3	Unit weight, kg/m^3	1.25	---	IS 2386 (Part III): 1963

3.3 Manufactured sand (M –Sand)

M-sand is obtained by crushing of hard granite rocks, is readily available at the nearby study area. Hence transportation costs reduce than from the far-off river sand beds so that the construction cost can be reduced. The physical properties are shown in Table 3.

Table 3: Physical properties of M-Sand

S.No.	Property	Test value	Standard value (IS 383: 2016)	Method of the test, Ref. to
1	Specific gravity	2.58	Max. 3.2	IS 2386 (Part III): 1963
2	Water absorption, %	2.2	Max. 5	IS 2386 (Part III): 1963
3	Bulk density, kg/m^3	1.25	---	IS 2386 (Part III): 1963
4	Grading Zone	Zone II	Zone I to IV	IS 2386 (Part I): 1963

3.4 Water

Potable water available in the study area is used for mixing and curing. The locally available potable water, free from the concentration of acid and organic substances, is used to mix the concrete.

3.5 Bamboo fiber

Bamboo fiber is one of the natural fibers that are obtained from the bamboo tree. It has a better modulus of elasticity and low specific weight. Bamboo is fast-growing, readily, and locally available natural resources. The physical properties of bamboo fiber used in the study are shown in Table 4.

Table 4: Physical properties of bamboo fiber

Type of fiber	Bamboo
Length (L), mm	50
Diameter (D), mm	0.80
Aspect ratio (L/D)	60

3.6 Nylon fiber

For improving the mechanical bond between the fiber and matrix, the circular cross-sectional fibers are used. Fibers made from nylon wire drawn conforming to IS: 667 with the diameter of wire 0.2 mm have been used, and its physical properties are shown in Table 5.

Table 5: Physical properties of nylon fiber

Type of fiber	Nylon
Length (L), mm	25
Diameter (D), mm	0.2
Aspect ratio (L/D)	125

3.7 Sulphate Attack

Sulphate attack is one of the causes of concrete deterioration. It happens when concrete comes in contact with water containing sulphates (SO_4), which may be found in some soils, seawater, groundwater, wastewater treatment plants, and acidic environment.

The sulphate attack is the reaction between sulphate ions in the pore solution in concrete and the constituents in concrete that results in the formation of other reaction products with a relatively large molar volume. It shows the percentage loss of weight in concrete cube specimens for different propositions. The sulphate attack leads to cracking, loss of bond between cement paste and aggregates, loss of strength in concrete. So, we have to minimise the sulphate attacks. In this experimental investigation, the specimens are cured for 90 days in 3% of the H_2SO_4 chemical solution and then tested.

3.8 Methodology

Concrete design mix prepared by completely replacing of river sand (fine aggregate) with M-sand and mixing of bamboo and nylon fibers at proportions of 0.5%, 1%, 1.5%, and 2% for M25 grade. Cubes of standard size 150mm x 150mm x 150mm were used to cast specimens using the mix. All the cast concrete specimens, including nominal mix specimens after curing for 28 days in normal water, were soaked for 90 days in the chemical water solution made with 3% of H_2SO_4. The sulphate attack and compressive strength tests were conducted on the specimens to assess the concrete durability to found the optimum proportion of bamboo and nylon fibers.

4. RESULTS AND DISCUSSIONS

This part presents and discusses the results of this investigation on the effectiveness of natural fiber and artificial fiber to enhance the engineering properties of various concrete mixes made with the addition of fiber. The results obtained are used to analyse the effect of these bamboo fiber and nylon fiber on the above engineering properties. Based on the various tests that are conducted in the laboratory are to analyse the strength characteristics, and their results correlate with the study and derive positive results and improvement. The results of the present investigation are presented both in tabular and graphical forms in order to facilitate the analysis. Interpretation of the results is carried on each phase of the experimental work. This interpretation of the results obtained is based on the results obtained. The significance of the results is assessed by the relevant IS codes.

4.1 Compressive strength

The compressive strength is tested for the nominal concrete for three cubes on 90 days curing period, and 90 days soaking in the chemical water solution made with 3% of H_2SO_4, the cubes were tested using Compression Testing Machine (CTM) of capacity 2000 kN following IS 516:1959 specification. The compressive strength of M25 grade of concrete after 90 days soaking in the chemical water solution made with 3% of H_2SO_4, for various combinations of bamboo fiber (0.5, 1, 1.5, and 2%) are obtained along with the nominal mix were tabulated in Table 6 and corresponding graphical representation shown in Figure 1. Similarly, various combinations of nylon fiber (0.5, 1, 1.5, and 2%) are obtained along with a nominal mix tabulated in Table 7 and the corresponding graphical representation shown in Figure 2.

Table 6: Compressive strength of concrete specimens for various proportions of the bamboo fiber after 90 days soaking in the chemical water solution

S.No.	Type of mix	Compressive strength before soaking in the chemical water solution (N/mm^2)	Compressive strength after soaking in the chemical water solution (N/mm^2)	% of loss in compressive strength
1	Nominal mix	30.78	28.95	5.94
2	0.5% Bamboo fiber	31.46	29.76	5.40
3	1 % Bamboo fiber	34.76	33.00	**5.06**
4	1.5 % Bamboo fiber	32.24	30.38	5.77
5	2 % Bamboo fiber	29.54	27.82	5.82

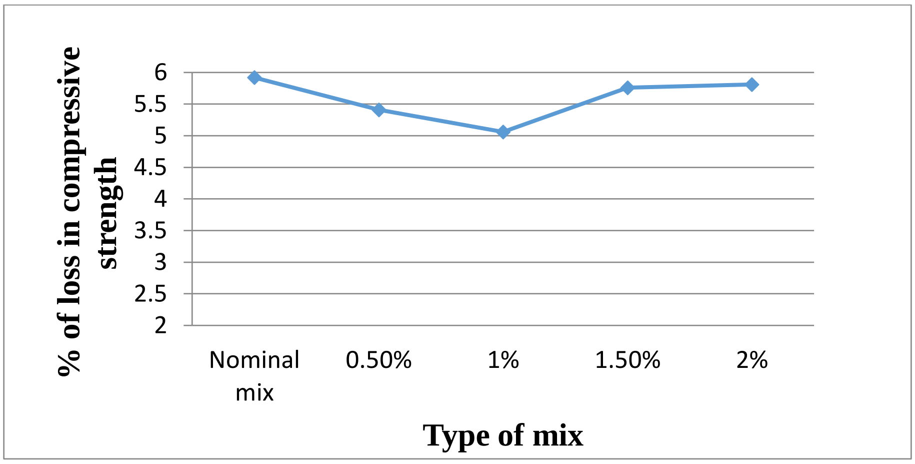

Figure 1: Compressive strength of concrete specimens for various proportions of the bamboo fiber after 90 days soaking in the chemical water solution.

Table 7: Compressive strength of concrete specimens for various proportions of the nylon fiber after 90 days soaking in the chemical water solution

S.No.	Type of mix	Compressive strength before soaking in the chemical water solution (N/mm^2)	Compressive strength after soaking in the chemical water solution (N/mm^2)	% of loss in compressive strength
1	Nominal mix	30.78	28.95	5.94
2	0.5% Nylon fiber	33.53	31.83	5.07
3	1 % Nylon fiber	37.65	35.77	**4.99**
4	1.5% Nylon fiber	34.21	32.42	5.23
5	2% Nylon fiber	30.35	28.73	5.34

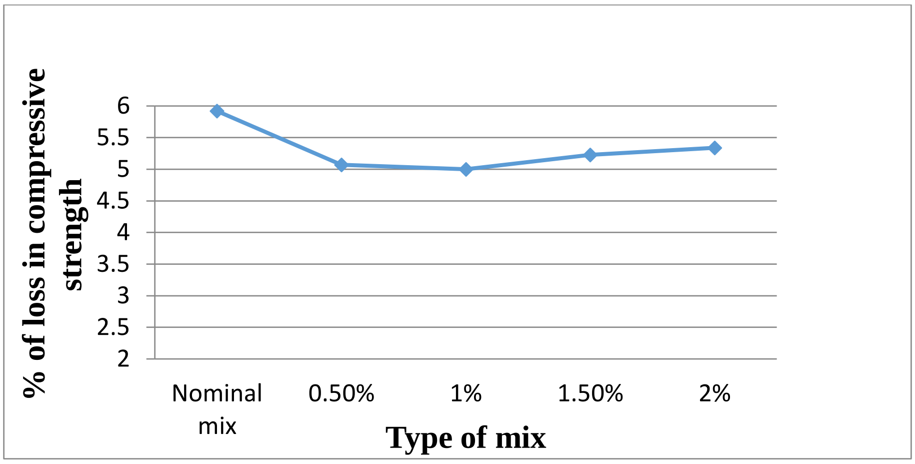

Figure 2: Compressive strength of concrete specimens for various proportions of the nylon fiber after 90 days soaking in the chemical water solution.

4.2 Loss of weight

The sulphate attack test results on the specimens after 90 days soaking in the chemical water solution made with 3% of H_2SO_4 were obtained. Various combinations of bamboo fiber (0.5, 1, 1.5, and 2%) are obtained along with a nominal mix tabulated in Table 8 and the corresponding graphical representation shown in Figure 3. Similarly, various combinations of nylon fiber (0.5, 1, 1.5, and 2%) are obtained along with a nominal mix tabulated in table 9 and the corresponding graphical representation shown in Figure 4.

Table 8: Results of sulphate attack test on concrete specimens for various proportions of the bamboo after 90 days soaking in the chemical water solution.

S.No.	Type of mix	Weight of the specimens before soaking in the chemical water solution (W_1) (kg)	Weight of the specimens after soaking in the chemical water solution (W_2) (kg)	% of loss in weight of the specimens
1	Nominal mix	8.312	8.159	1.84
2	0.5 % Bamboo fiber	8.335	8.165	2.03
3	1 % Bamboo fiber	8.359	8.220	**1.66**
4	1.5 % Bamboo fiber	8.372	8.200	2.05
5	2 % Bamboo fiber	8.407	8.231	2.09

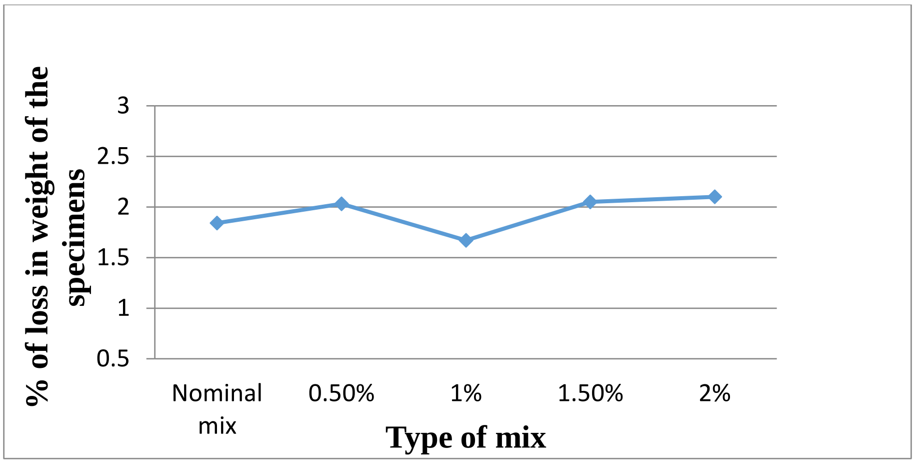

Figure 3: Results of sulphate attack on concrete specimens for various proportions of the bamboo fiber after 90 days soaking in the chemical water solution.

Table 8: Results of sulphate attack test on concrete specimens for various proportions of the nylon after 90 days soaking in the chemical water solution.

S.No.	Type of mix	Weight of the specimens before soaking in the chemical water solution (W_1) (kg)	Weight of the specimens after soaking in the chemical water solution (W_2) (kg)	% of loss in weight of the specimens
1	Nominal mix	8.312	8.159	1.84
2	0.5 % Nylon fiber	8.341	8.180	1.93
3	1 % Nylon fiber	8.362	8.225	**1.64**
4	1.5 % Nylon fiber	8.390	8.225	1.97
5	2 % Nylon fiber	8.401	8.231	2.02

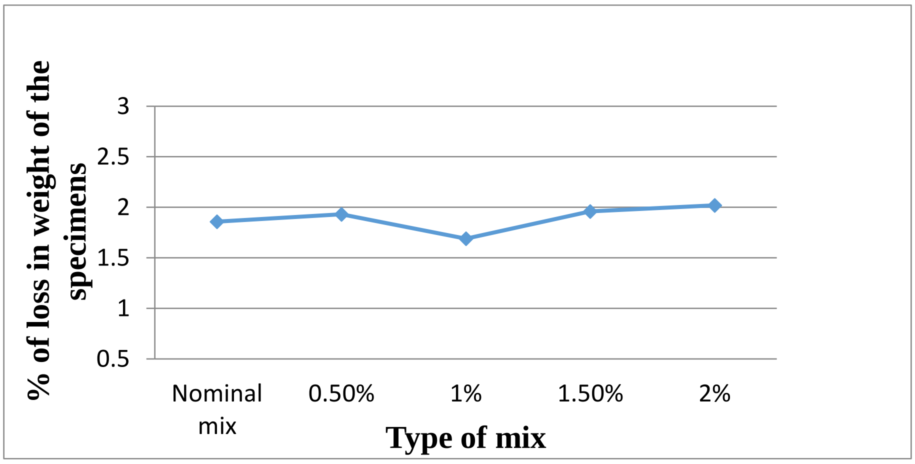

Figure 4: Results of sulphate attack on concrete specimens for various proportions of the nylon fiber after 90 days soaking in the chemical water solution.

5. CONCLUSIONS

Based on the test data and analysis of the results, the following conclusions were drawn.

- The % loss in compressive strength for the M25 design mix concrete without adding natural and artificial fiber (nominal mix) after 90 days immersing in the chemical water solution made with 3% of H_2SO_4 is observed as 5.94%. Whereas the lower % loss of weight observed at 1% adding bamboo fiber and nylon fiber to the nominal mix as 5.06% and 4.99%, respectively. That means the loss in compressive strength due to the addition of bamboo fiber and nylon fiber, which is 14.81% and 15.99% less than the nominal mix.
- The % loss of weight for the M25 design mix concrete without adding waterproofing admixture (nominal mix) after 90 days soaking in the chemical water solution made with 3% of H_2SO_4 is observed as 1.84%. Whereas the lower % loss of weight observed at 1% adding bamboo fiber and nylon fiber to the nominal mix as 1.66% and 1.64%, respectively. That means loss of weight due to the addition of bamboo fiber and nylon fiber, which is 9.78% and 10.87 % less than the nominal mix.
- Finally, it can be concluded that by 1% adding, bamboo fiber and nylon fiber gives better durability than the nominal mix.

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