Influence of Treated and Untreated Bamboo Fiberson Properties of Concrete

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ABSTRACT
This research paper studies the effects of bamboo fiber, treated with sodium carbonate and hydrogen peroxide combined with glacial acetic acid, on the characteristics of concrete. The study examined mechanical propertiessuch as compressive strength, split tensile strength, flexural strength, and durability of concrete incorporating bamboo fibers. Bamboo fibers, both treated and untreated, were used, measuring 24 mm in length, 5 mm in width, and 3 mm in thickness. The research investigated the impact of adding 1% and 1.5% bamboo fiber to concrete's mechanical properties and durability, using M40 grade concrete as the baseline. Evaluations were carried out at 7 and 28 days. The study compared standard concrete with bamboo fiber-reinforced concrete. Results showed that the compressive strength of concrete increased with the use of treated bamboo fibers. Adding 1% bamboo fiber improved both split tensile and flexural strength. However, increasing the bamboo fiber content beyond 1% generally led to a reduction in these properties. The highest compressive strengths recorded were 47.2 N/mm^2 for 1.5% bamboo fiber treated with sodium carbonate and 48.1 N/mm^2 for 1% bamboo fiber treated with hydrogen peroxide and glacial acetic acid. Overall, concrete with 1% bamboo fiber exhibited the best performance.

Keywords: Normal strength concrete, Bamboo fiber, Compressive strength, Split tensile strength, Flexural strength

1. INTRODUCTION

Concrete is highly versatile and frequently used in construction, but it's known for its low tensile strength. This inherent weakness, combined with concrete’s brittle nature, can lead to sudden and unexpected failures. To mitigate these issues and improve the material’s performance, steel reinforcement is added. This reinforcement enhances concrete’s tensile strength and ductility, making it a more dependable material for construction.Steel reinforcement, typically in the form of rebar or wire of steel wire, is used in concrete structures to resist tensile forces applied to loads or volume changes. However, exposure to harsh environmental conditions could cause steel to corrode, resulting in high repair and maintenance costs, and potentially causing structural failure before the design life span is reached.

Additionally, the production of steel reinforcement emits carbon dioxide, which has detrimental environmental effects. Corrosion causes the steel to expand, leading to concrete cracks and spalling. To address these issues and reduce cracking, steel fibers are now being used alongside traditional steel reinforcement. While this approach helps mitigate cracking, the high cost and risk of corrosion remain significant challenges. To further combat corrosion, various types of fibers are being explored. Other types of fibers, like carbon fiber, and glass fiber, are also utilized in concrete. However, their production is costly and harms the environment. The manufacturing processes for carbon, glass, and other fibers contribute to environmental harm, making them less economical and sustainable options. To overcome the drawbacks of other fibers previously mentioned, Bamboo fiber is used as an alternative in concrete. Bamboo fiber offers several advantages, including its sustainability and environmental friendliness. Chemical treatments are applied to the bamboo fiber to increase its strength and affordability.

Bamboo, which is abundant in many regions worldwide and is the fastest-growing plant, is increasing in demand due to the rising need for concrete. Its natural composition closely resembles that of other lignocellulosic materials, containing cellulose, hemicellulose, and lignin. It is among the most traditional and extensively utilized building materials.Bamboo is a renewable and lightweight material with similar properties to wood. Bamboo is the fastest-growing plant, bamboo comes in various species. In India, two notable species are Indian Throny bamboo and India-Calcutta bamboo. Bamboo is known for its high

tensile strength, a strong and flexible material.Bamboofibers are processed using chemicals including sodium carbonate, hydrogen peroxide, glacial acetic acid, and sodium hydrogen to remove lignin and hemicellulose.This research focused on characterizing both the chemical and mechanical changes in the fibers resulting from the application of hydrogen peroxide (H_2O_2), acetic acid (CH_3COOH), acidified sodium chlorite ($NaClO_2$), and sodium hydroxide (NaOH).
[1] Siew Choo Chin et al. (2020) investigated the thermal and mechanical properties of bamboo fiber-reinforced composites. They prepared bamboo fibers through a chemical treatment with 10% sodium hydroxide (NaOH) for 48 hours, followed by a physical milling process. This treatment produced bamboo fibers with optimal ultimate tensile and modulus strength.[2] Marcus Maier et al. (2020) developed a sustainable mortar mixture using renewable by-products to enhance its mechanical properties and fracture behavior. Bamboo fibers were incorporated into the mixture to improve its fracture toughness. Various mixes with different fiber contents were tested for mechanical performance and fracture toughness through bending tests. The addition of bamboo fibers resulted in minimal strength loss, with the mortar achieving compressive strengths of 55 MPa or higher. Their findings suggest that the bamboo fiber-reinforced mortar mixture is a promising, sustainable, and cost-effective construction material.[3] Hong Chen et al. (2019) examined the wettability and thermal properties of individual bamboo fibers following alkali treatment. The fibers were treated with sodium hydroxide (NaOH) at concentrations of 6%, 8%, 10%, 15%, and 25%, and then freeze-dried. Thermogravimetric analysis revealed that alkali treatment increased the surface roughness of the fibers. Lower NaOH concentrations improved wettability, while higher concentrations (25%) reduced it. The thermal analysis indicated that lower NaOH concentrations enhanced the thermal stability of the fibers, as evidenced by a shift in the onset and peak decomposition temperatures to higher values. Conversely, higher NaOH concentrations (15% and 25%) compromised the fibersthermal stability.

2. EXPERIMENTAL WORK

The experimental work was conducted in two phases. In the first phase, the necessary materials were acquired, and a series of tests were carried out to assess their physical and chemical properties. The second phase involved proportioning the concrete mix, casting specimens, and conducting tests on both the fresh properties of the concrete and the properties of the hardened specimens. The aim was to evaluate the mechanical properties, including compressive strength, split tensile strength, flexural strength, and durability.

2.1 Phase 1

In Phase One, all necessary materials were sourced from local suppliers, and a series of tests were conducted on these materials to determine their physical and chemical properties.

Cement

OPC 53 grade cement was used as binder material (conforming to IS: 12269- 1987). The physical properties were determined as per IS: 4031 (Part II)- 1988. The particulars of test results are shown below.

Fine aggregate and Coarse aggregate

Fine aggregate conforming to IS:383- 1970 was procured from locally available sellers. Crushed granite was used as a coarse aggregate. 20 mm is the maximum size of coarse aggregate. As per IS:2386 code guidelines, the physical properties of coarse aggregate and fine aggregate were determined. The particulars of test results are shown below.

Table 1. Physical properties of Cement (OPC 53 Grade), Fine aggregate, and Coarse aggregate

Property	**Cement**	**Fine aggregate**	**Coarse aggregate**
Normal Consistency	31%	-	-
Specific gravity	3.192	2.416	2.75
Initial setting time	29 minutes	-	-
Final setting time	390 minutes	-	-
Fineness	6%	-	-
Bulk modulus Loose	-	1485.26 kg/m^3	1530 kg/m^3
Compact	-	1569.160 kg/m^3	1647 kg/m^3
Fineness modulus	-	2.8	7.5

Water
Portable water without oils, sugar, salts, acids, alkalies and organic materials conforming to IS: 456- 2000 was used for mixing of concrete ingredients and curing of concrete specimens.

Bamboo Fibers
Bamboo Fibers supplied by nearby area, Hyderabad, Telangana, India was used in this present study. The physical and chemical properties provided by the supplier are depicted.

2.2 Phase II
Under phase two, mix design, Proportioning, Casting, curing of specimens and testing of hardened specimens was undertaken to know the mechanical properties of conventional concrete and untreated and treated bamboo fiber concrete at 7 days and 28 days period.

3. Design and Proportioning of Concrete Mix
Using the various properties of materials as discussed in phase 1, M40 grade of concrete designed according to IS:10262- 2019. Water- cement binder ratio of 0.42 was maintained for all the mixes. Total 7 mixes were considered in the research work, out of which, one conventional concrete mix (MC), six bamboo fiber concrete mixes which of two mixes are untreated bamboo fiber, two mixes of treated with sodium carbonate bamboo fiber and two mixes of hydrogen peroxide with glacial acetic acid bamboo fiber with 12 mm length of Bamboo Fibers. Table 2 represents the designation of various mixes and proportions of concrete. The name of mix indicates treated bamboo fiber and percentage of use of bamboo fiber. The mix designation MC, UT1BF, UT1.5BF letter UT represents untreated, letter BF indicates bamboo fiber, 1 and 1.5 is the percentage of the bamboo fiber untreated and treated bamboo fiber. Mix designation MC represents the conventional concrete without any Fibers in it. SC1BF, SC1.5BF, HPT1BF, HPT1.5BFletter SC represents sodium carbonate, HP represents hydrogen peroxide, letter T indicates treated. The Compressive strength, split tensile strengths and Flexure strength of bamboo fiber concrete and conventional concrete were compared.

Table 2. Details of various M40 grade concrete mixtures and their corresponding mix designations

Mix designations	Constituent materials, Kg/m^3					W/C	Bamboo fiber in concrete	
	Cement	Fine aggregate	Coarse aggregate	Water	Super plasticizer		Weight, Grams	Length, mm
MC	367.61	611.52	1224.3	154.4	3.676	0.42		
UT1BF	367.61	611.52	1224.3	154.4	3.676	0.42	0.015	12
UT1.5BF	367.61	611.52	1224.3	154.4	3.676	0.42	0.015	12
SCT1BF	367.61	611.52	1224.3	154.4	3.676	0.42	0.015	12
SCT1.5BF	367.61	611.52	1224.3	154.4	3.676	0.42	0.015	12
HPT1BF	367.61	611.52	1224.3	154.4	3.676	0.42	0.015	12
HPT1.5BF	367.61	611.52	1224.3	154.4	3.676	0.42	0.015	12

Mixing and Casting of Concrete
The weight of concrete ingredients cement, Fine aggregates and coarse aggregate and water was taken according to mix design. A pan mixer was used to mix all the materials. In the first stage, Cement and Fine aggregate were mixed thoroughly in the dry state for 2 to 3 minutes. Secondly, some quantities of Bamboo Fibers were added were added to the cement-sand mix uniformly and mixed for 2 minutes, after that while in mixing the remaining amount of Bamboo Fibers were added slowly and dispersed uniformly. It was mixed for nearly 2 minutes in a dry state. In the third stage, coarse aggregate was added to the cement-sand-fiber mix and mixed for 2 to 3 minutes. After getting a uniform mix of all the ingredients in the dry state, then water was added. Mixing was done until a workable mixture of uniform colour was obtained. Also, uniform dispersion of Fibers in mix was ensured and maintained. Finally, the mixed concrete was placed in mould specimens and put on the table vibrator for better compaction and to remove air voids. Trowel and straight edge tool were used to level and smooth finish the top surface. All the specimens were then put in a water tank till the specified curing period of 28 days. After the desired curing period, the specimens are then removed from the water tank and tested to find the mechanical properties and durability.

Sample Size

After 7 days and 28 days hydration period, the mechanical properties of bamboo fiber concrete and plain concrete were determined. A total of 7 mixes considered in the present study. In each mix and for one particular age total 12 cubes, 6 cylinder and 6 prisms samples were casted. To determine the strengths, an average of six specimens has been considered.

Testing of Specimens

Compressive strength test was carried out on 150 mm x 150 mm x 150 mm cubes, split tensile strength on cylinder having 150 mm diameter and 300 mm length and flexure strength on 100 x 100 mm cross section and 500 mm length. Compressive strength and flexure strength were determined according to Indian Standard Code IS: 516 and split tensile strength in agreement with Indian Standard Code IS:5816.

RESULTS AND DISCUSSIONS

Fresh state of concrete and workability

Workabilityof concrete is the property of freshly mixed concrete which determines the ease and homogeneity with which it can be mixed, placed, consolidated and finished as defined. To access the workability of concrete mix in fresh state, the slump cone test was carried out in accordance with Indian Standard code specifications IS 1199:1959. Workability is directly proportional to water cement ratio. Increase in water cement ratio increases the workability of concrete. The slump values of all 7 mixes are presented in Table 3. Among all the 7 mixes, the MC mix has shown more workability than other mixes with bamboo fiber. Decrease in the slump indicates that the higher amount of bamboo fibers added.

Table 3. Slump values of M40 Grade

MIX ID'S	Slump in mm	% Variation
MC	80	100
UT1BF	75	93.75
UT1.5BF	66	82.5
SCT1BF	70	87.5
SCT1.5BF	71	88.75
HPT1BF	75	93.75
HPT1.5BF	70	87.5

Compressive Strength

The Compressive strength of plain concrete and bamboo fiber-reinforced concrete at various curing periods is in Table4. The compressive strength of concrete over seven and twenty-eight days is shown in the above table, which indicates a decline in strength as the proportion of untreated bamboo fiber rises. The compressive strength of HPT1BF, which contains 1% bamboo fiber treated with glacial acetic acid and hydrogen peroxide, increased from 31.33 N/mm^2 at 7 days to 48.1 N/mm^2 at 28 days, indicating a 4.4% improvement. On the other hand, within the same time span, UT1BF's compressive strength decreased by 18.8%.

Table 4. Compressive strength test results

MIX ID’S	Compressive strength at 7 days (MPa)	% Variation	Compressive strength at 28 days (MPa)	% Variation
MC	30.004	100	46.16	100
UT1BF	28.5	94.9	43.96	95.2
UT1.5BF	24.37	81.2	37.5	81.2
SCT1BF	25.38	84.5	39.06	84.6
SCT1.5BF	30.68	102	47.2	102
HPT1BF	31.33	104.4	48.1	104.2
HPT1.5BF	29.33	97.7	45.13	97.7

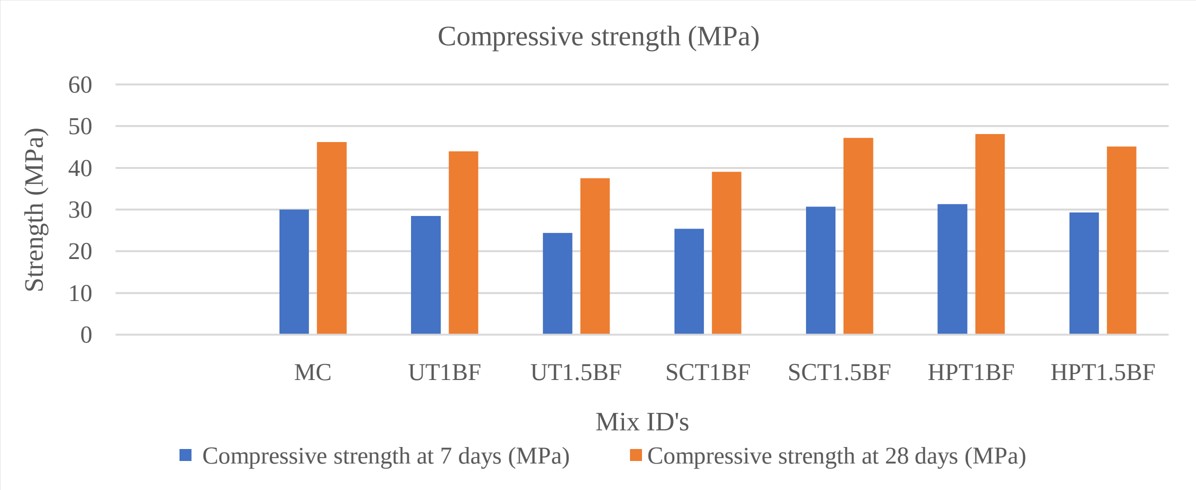

Figure 1. Compressive strength test results after 7 and 28 days

Flexure strength

The Flexure strength values of plain concrete and bamboo fiber-reinforced concrete at various curing periods are in Table5. The test results show the concrete's flexural strength for various mixes after 7 and 28 days. The flexural strength of UT1BF, which contains 1% untreated bamboo fiber, increased by 30% at 7 days and 32.95% at 28 days, from 3.85 N/mm^2 to 5.93 N/mm^2. This strength improvement was observed with both untreated and treated bamboo fibers at the 1% concentration. In contrast, SCT1.5BF experienced a significant reduction in flexural strength, with a decrease of 26.9% at 7 days and 25.4% at 28 days.

Table 5. Flexural strength test results

MIX ID'S	Flexural strength at 7 days (MPa)	% Variation	Flexural strength at 28 days (MPa)	% Variation
MC	2.96	100	4.46	100
UT1BF	3.85	130	5.93	132.95
UT1.5BF	3.029	102	4.66	104.4
SCT1BF	2.68	90.5	4.13	92.6
SCT1.5BF	2.164	73.1	3.33	74.6
HPT1BF	3.59	121.28	5.53	123.99
HPT1.5BF	3.2	108.1	4.93	110.53

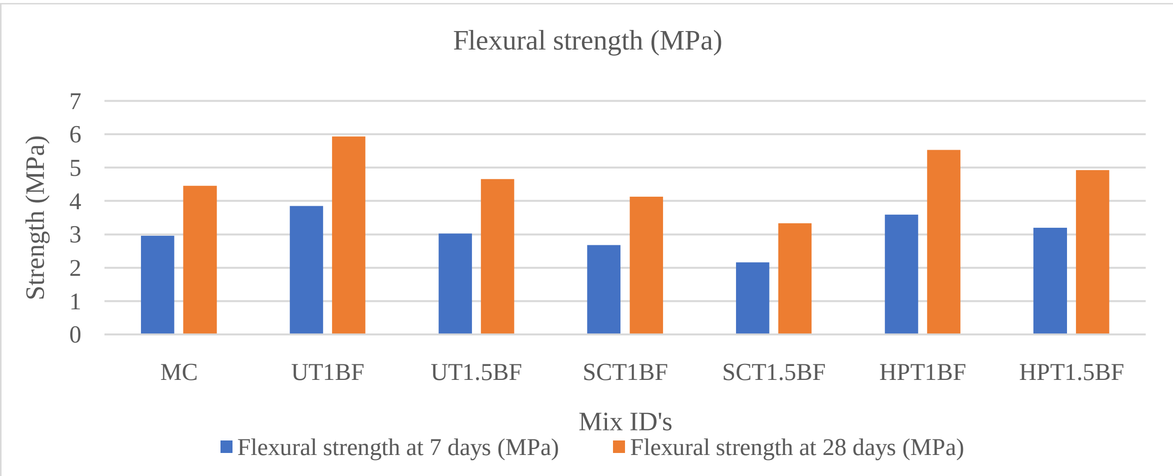

Figure 2. Flexural strength test results after 7 and 28 days

Split Tensile Strength

The Absolute split tensile strength values of plain concrete and bamboo fiber-reinforced concrete at various curing periods are in Table6.

Table 6. Split tensile strength test results

MIX ID'S	Split tensile strength at 7 days (MPa)	% Variation	Split tensile strength at 28 days (MPa)	% Variation
MC	1.989	100	3.06	100
UT1BF	1.54	77.4	2.37	77.4
UT1.5BF	1.43	71.8	2.21	72.2
SCT1BF	1.89	95	2.91	95.09
SCT1.5BF	1.91	96	2.95	96.4
HPT1BF	2.01	101	3.106	101.5
HPT1.5BF	1.7	85	2.63	85.9

The table displays the split tensile strength of concrete at seven and twenty-eight days. At 1.5%, it begins to lose strength. This is because the percentage of untreated bamboo fiber decreases. Significantly, split tensile strength increased in HPT1BF (1% bamboo fiber treated with hydrogen peroxide and glacial acetic acid) from 2.01 N/mm^2 at 7 days to 3.106 N/mm^2 at 28 days. This is a 1.5% improvement over 28 days and a 1% improvement over 7 days. On the other hand, split tensile strength of UT1.5BF, which also used bamboo fiber, significantly decreased by 28.2% within the same time period.

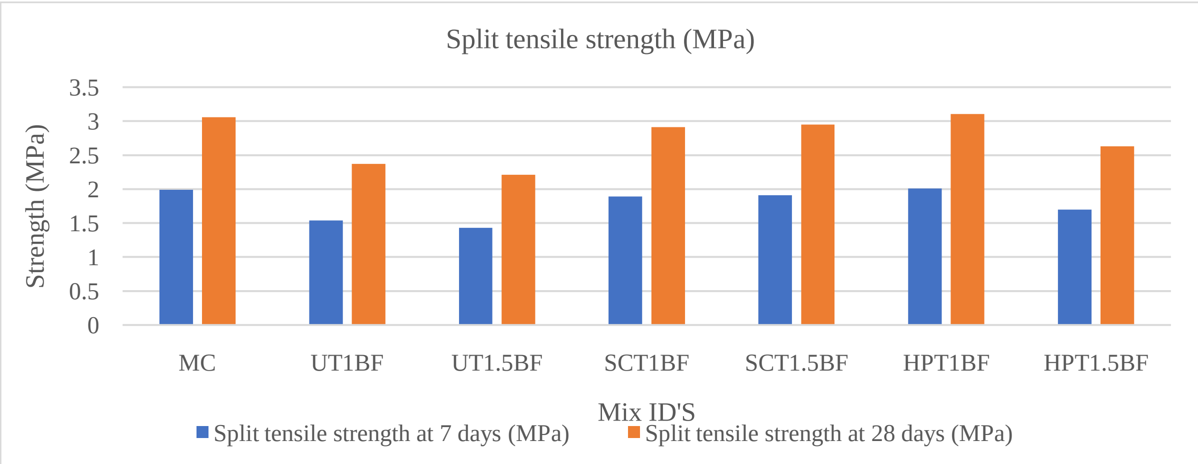

Figure 3. Split tensile strength test results after 7 and 28 days

Durability properties

Impact of Sulfuric acid on Concrete cube specimens

Table 7. Weight loss due to H_2SO_4 acid

MIX ID'S	Weight before immersion in H_2SO_4 acid (kg)	Weight after immersion in H_2SO_4 acid (kg)	% loss in weight
MC	8.15	7.5	7.98
UT1BF	8	6.5	18.75
UT1.5BF	7.99	6	24.91
SCT1BF	8.03	6.3	21.54
SCT1.5BF	8.01	6.5	18.85
HPT1BF	8.12	7.2	11.33
HPT1.5BF	8.01	7	12.61

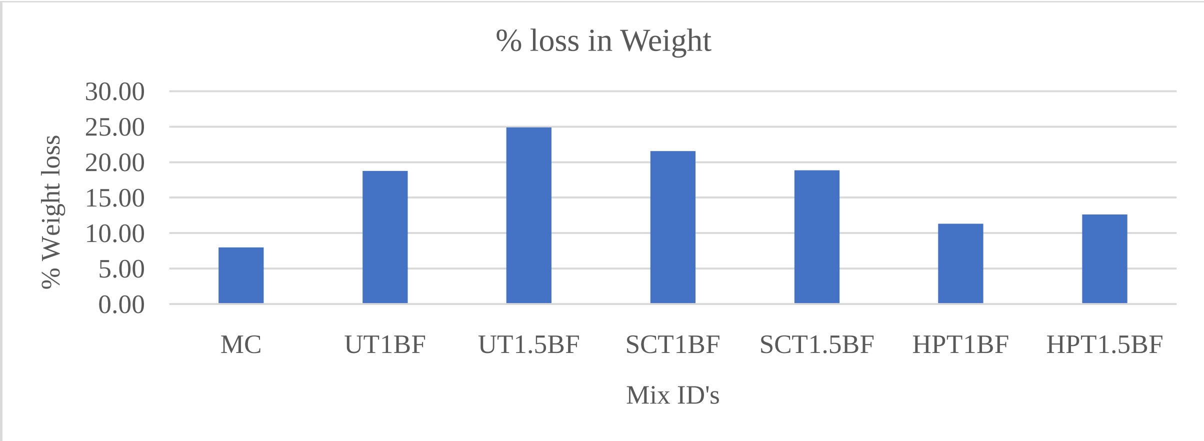

Figure 4. Weight loss due to H_2SO_4 acid

The graph illustrates the weight loss of various concrete mixes after being immersed in sulfuric acid (H_2SO_4). MC which is normal concrete, exhibits a modest weight reduction, falling from 8.15 kg to 7.5 kg. Conversely, UT1.5BF which incorporates 1.5% untreated bamboo fiber into the normal concrete, undergoes a more significant weight loss, with its weight dropping from 7.99 kg to 6 kg.

Table 8. Compressive strength loss due to H_2SO_4 acid

MIX ID'S	Before immersion in H_2S0_4 acid (MPa)	After immersion in H_2S0_4 acid (MPa)	% loss of Compressive strength	Normalisation
MC	46.16	27	41.51	1.00
UT1BF	43.96	30	31.76	0.53
UT1.5BF	37.5	26	30.67	0.48
SCT1BF	39.06	31	20.63	0.00
SCT1.5BF	47.2	34	27.97	0.35
HPT1BF	48.1	37	23.08	0.12
HPT1.5BF	45.13	35	22.45	0.09

The table shows the decrease in compressive strength following 56 days of sulfuric acid immersion(H_2SO_4). SCT1BF, which includes 1.5% bamboo fiber treated with sodium carbonate, significantly drops the compressive strength from 39.06 N/mm² to 31 N/mm² of 20.6% strength loss. In comparison, conventional concrete MC experiences a more moderate decrease, with its compressive strength falling from 46.16 N/mm² to 27 N/mm² of 41.51% strength loss.
The table above shows the normalization values after exposure to H_2SO_4 acid. SCT1BF, which contains 1% bamboo fiber treated with sodium carbonate, has a normalization value of 0.0, indicating excellent resistance to H_2SO_4 acid. HPT1.5BF with 1.5% bamboo fiber treated with hydrogen peroxide with glacial acetic acid, normalisation value of 0.09 has better resistance to the acid. HPT1BF with 1% bamboo fibers treated with hydrogen peroxide with glacial acetic acid, demonstrates better resistance with a normalization value of 0.12. In contrast, Conventional concrete MC has a higher normalization value of 1.00, indicating lower resistance to the acid.

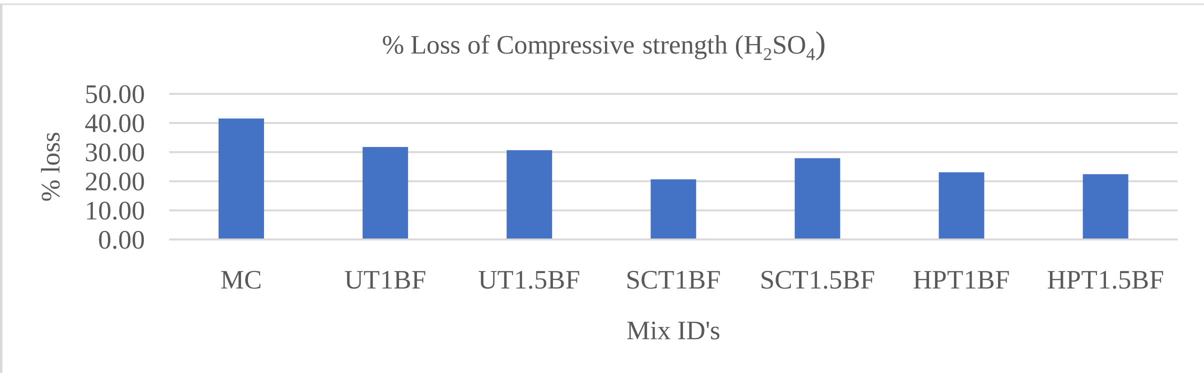

Figure 5. % loss of compressive strength

The above graph displays the best durability against sulfuric acid found in SCT1BF, which contains 1% bamboo fiber treated with sodium carbonate 39.06 N/mm^2 to 31 N/mm^2. The decrease in compressive strength after 56 days of immersion in sulfuric acid. For MC the compressive strength falls markedly from 46.16 N/mm^2 to 27 N/mm^2.

Durability

Impact of HCl acid on Concrete cube specimen.

Table 9. Weight loss due to HCl acid

MIX ID'S	Weight before immersion in HCl acid (kg)	Weight after immersion in HCl acid (kg)	% loss of Weight loss
MC	8.15	7	14.11
UT1BF	8	6.9	13.75
UT1.5BF	7.99	6.5	18.65
SCT1BF	8.03	6.7	16.56
SCT1.5BF	8.01	6.95	13.23
HPT1BF	8.12	6.8	16.26
HPT1.5BF	8.01	6.5	18.85

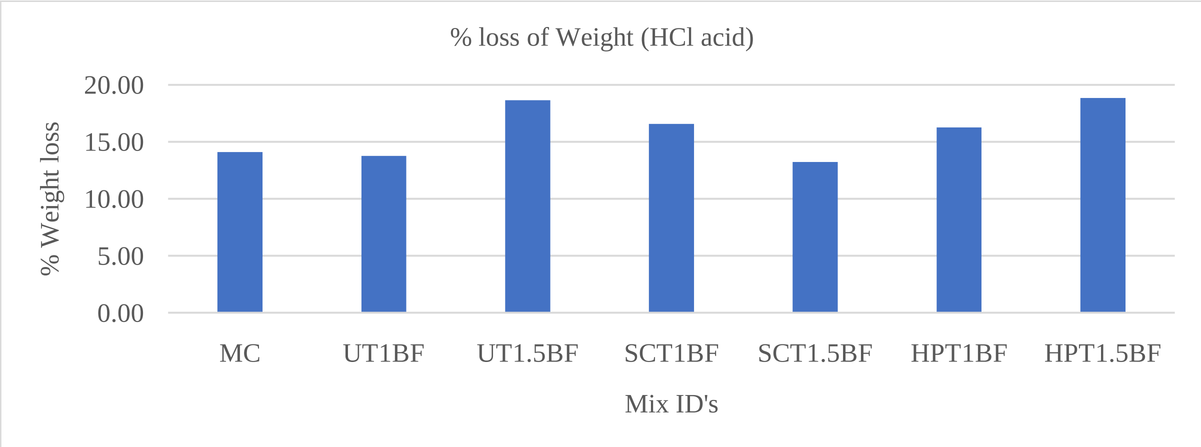

Figure 6. % loss of weight loss

The graph depicts the weight loss of different concrete mixes after being immersed in hydrochloric acid (HCl). The SCT1BF mix, which includes 1.5% bamboo fiber treated with sodium carbonate, shows a relatively minor weight loss, decreasing from 8.15 kg to 7 kg, representing a reduction of 13.23%. In contrast, the HPT1.5BF mix, containing 1.5% bamboo fiber treated with hydrogen peroxide and glacial acetic acid, experiences a more pronounced weight loss, dropping from 8.01 kg to 6.5 kg, equating to a reduction of 18.85%.

Table 10. Compressive strength loss due to HCl acid

MIX ID'S	Before immersion in HCl acid (MPa)	After immersion in HCl acid (MPa)	% loss of Compressive strength	Normalisation
MC	46.16	34	26.34	1.00
UT1BF	43.96	35	20.38	0.23
UT1.5BF	37.5	33	12.00	0.39
SCT1BF	39.06	38	2.71	0.00
SCT1.5BF	47.2	44	6.78	0.17
HPT1BF	48.1	44	8.52	0.25
HPT1.5BF	45.13	36	20.23	0.74

The table shows the reduction in compressive strength after 56 days of immersion in HCl acid. The SCT1BF mix, which includes 1% bamboo fiber treated with sodium carbonate, exhibits a smaller decrease in compressive strength, falling from 39.06 N/mm^2 to 38 N/mm^2 of 2.71%. In comparison, the

MC mix experiences a more significant reduction in compressive strength, decreasing from 46.16 N/mm^2 to 34 N/mm^2 of 26.34%.
The table above shows the normalization values after exposure to HCl acid. SCT1BF, containing 1% untreated bamboo fiber, has a normalization value of 0.0, indicating the highest resistance to the acid. SCT1.5BF, which includes 1.5% bamboo fibers treated with sodium carbonate, has a normalization value of 0.17, reflecting better resistance. In contrast, MC shows the lowest resistance, with a normalization value of 1.00, indicating a greater effect of the acid.

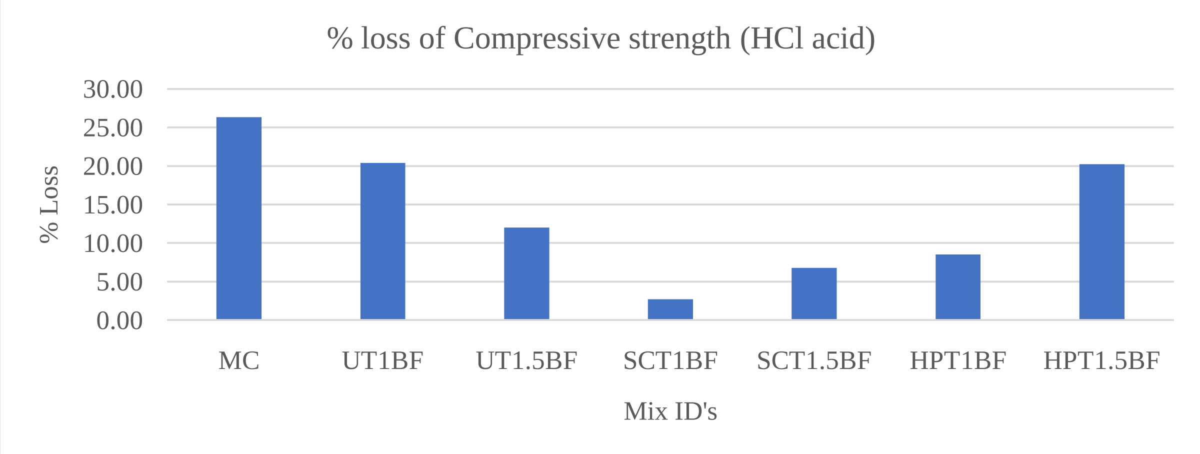

Figure 7. % loss of Compressive strength

The graph displays the decrease in compressive strength after 56 days of immersion in HCl acid. SCT1BF which incorporates 1% bamboo fiber treated with sodium carbonate, experiences a significant drop in compressive strength, falling from 39.06 N/mm^2 to 38 N/mm^2. On the other hand, MC shows a decrease in compressive strength from 46.16 N/mm^2 to 34 N/mm^2.

4. CONCLUSIONS

The Conclusions given below are from experimental research work done. The properties of concrete materials and types of bamboo fibers are identified, the results achieved in the work are based on the work done by specimens.

1. The Physical properties of concrete was obtained based on the tests to be performed.
2. The fresh property of concrete is workability to be performed by slump test and the results of workability reduced as the percentage of bamboo fiber increased in the concrete.
3. There is slight increase in the compressive strength values when bamboo fibers are added in plain concrete.
4. The 1% of bamboo fiber is added in the concrete showed the increase in compressive strength.
5. As same as compressive strength, the split tensile strength and flexure strength increase with 1% of bamboo fiber added in concrete.

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