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Evaluating the Impact of Using Bamboo Fibers in Pavement Design

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ABSTRACT- The primary function of a pavement, which is characterized as a structure made up of layers, is to distribute the applied load to the subgrade. Typically, rigid pavements have three layers: the subgrade, the base layer, and the top layer. For the most critical and fundamental testing, the flexural test, beams are often casted to determine the hardened properties of pavement quality concrete. Cubes are casted to determine compressive strength. Concrete pavements have a longer lifespan, are more durable, and require less maintenance than flexible pavements, but crack in concrete pavement is one of the main problems observed in concrete technology due to drying shrinkage. One method used to reduce cracks is to incorporate fibers into concrete pavement. This report covers the subject of bamboo fiber-based rigid pavement settlement. The purpose of the study is to enhance the performance of bamboo reinforced concrete at the tension crack area. This report details the precise amount of fiber used, as an addition by weight of cement with a range of 0% to 1.5% However, this report helps us to know whether bamboo fiber can stop cracks from spreading and growing. Incorporating mineral admixtures,(metakoalin and flyash) as a 15 % replacement for cement each reduces the permeability of concrete, increasing its durability, water tightness, and assistance in enhancing compressive strength, split tensile strength, and flexural strength. Compressive strength increases with the addition of bamboo fibre up to 1 percent; at 1.5 percent strength decreases; and as the percentage of fibre is raised up to1.5%, flexural strength also increases in this study.

KEYWORDS- Flyash, Metakoalin, Bamboo fiber, Cracks, Rigid pavement.

I. INTRODUCTION

A mixture of materials called concrete is made up of coarse granular material (the aggregate) that is encased in a hard matrix of material (the cement or binder) that fills the spaces between the aggregate particles and binds them together. Concrete is used twice as often as steel, wood, plastics, and aluminum combined throughout the world. Only naturally occurring water is used more frequently than concrete in the modern world. Reinforced concrete is a fantastic material for a variety of structural applications due to its affordability, effectiveness, durability, capacity to preserve shape, and rigidity [8]. Concrete is frequently used to build foundations for buildings, brick or block walls, roadways, bridges. Combining water with a cementitious material forms a cement paste by the process of hydration. The cement paste glues the aggregate together, fills voids within it, and makes it flow more freely. Compared to flexible pavements, rigid pavements have a longer lifespan, are more robust, and require less maintenance, yet cracks in concrete pavement are one of the most common issues seen in concrete technology because of drying shrinkage. The development of cracks [4] in structural concrete can result from both internal characteristics, such as poor strength, and external causes, such as the load on the structure, temperature changes, and age of the structure. Due to concrete's absorptivity, cracks become larger with time, which in turn causes the concrete to degrade. In this experiment, bamboo fiber was added to the cement weight to prevent cracks from forming [5]. Bamboo also makes stiff pavement ductile, which is otherwise brittle. Concrete's strength quality is also improved. Additionally, bamboo fibers can be utilized as a filler material in concrete for ground works like paver block construction, waist slabs, and other water retention structures while building roads or other ground works.

A. *Aim & Scope*

The primary goal of this study is to determine whether it is feasible to use bamboo fiber inpavement-grade concrete to avoid cracks. To see how the addition of minerals affects the strength of concrete. To evaluate the durability of concrete after adding bamboo fiber to properly draw a conclusion to the investigation. Make concrete more affordable. Because steel has such high tensile strength, it is simple for a building to resist bending, but because steel is expensive and heavy, construction is a little more expensive. The tensile strength of bamboo fiber, on the other hand, is around 370 mpa, which makes it easy to handle and capable of producing good results. The use of bamboo fibre to enhance the performance of bamboo reinforced concrete at the tension crack area is imperative given that cracks in concreteare a growing concern. Fibers are one method used to minimize cracks in concrete pavement. It may be risky to use bamboo fiber in pavement since moisture causes the fiber to deteriorate, which makes the pavement less likely to be able to resist bending or avoid cracking. Mineral admixtures are strongly advised to prevent this.

B. Properties of Bamboo

- The dimensions of bamboo alter as a result of moisture gain or loss. Because bamboo quickly absorbs moisture from its surroundings, the dampness changes when the relative humidity and temperature of the encircling environment change.
- Because of bamboo's ability to bend, it is seen to be the ideal alternative to steel in constructing structures. Bending is the factor that determines the viability of using bamboo as a building material [1].
- Bamboo is a special building material for earthquake-prone areas because of its exceptional elasticity. Another benefit of bamboo is its light weight, which makes it easy to handle and use, negating the need for cranes and other heavy machinery.

II. EXPERIMENTAL DETAILS

A. Materials

When designing a concrete grade, the choice of materials is crucial, and it all depends on the desired slump and the corresponding grades. Fly ash, metakaolin, bamboo fiber, coarse and fine aggregates, Ordinary Portland cement of grade 43, and the chemical additive masterpel 777 were the materials employed in this study as shown in figure 1. According to IS 10262: 2009 and IS 456-2000[9], the water/binder ratio for concrete of the M25 grade is 0.4

1) Cement

Cement plays a significant part in the creation of strength. Therefore, cement should be used appropriately, and the amount should be determined according to the concrete's grade. The cement utilized in this study is Ordinary Portland Cement of grade 43, namely Khyber cement. Basic test were performed on cement as shown in table 1.

Table 1: Basic Tests on Cement

Weight of pycnometer (W1)	648.5 grams.
Weight of sample cement	277.5 grams.
Weigh tof sample + pycnometer (W2)	926 grams.
Weight of sample + pycnometer + kerosene (W3)	1583.5 grams.
Weight of pycnometer + kerosene (W4)	1344.5 grams.
Specific gravity	3.12 (According to IS 4031-11:1988).
Initial setting time	30 minutes.
Final setting time	240 minutes.
Consistency	32%.

2) Fine Aggregates

The choice of the fine aggregates depends on the zone in which they will be used, much as the cement and other materials, The zone II (crushing sand) fine aggregates utilized in this project were purchased from Regoo dealers in Ganderbal.Below are the fundamental tests that were run on the fine aggregates as shown in table 2 to determine their characteristics in accordance with IS regulations:

Sieve analysis:

Weight of fine aggregate = 1 kilogram = 1000gms

Table 2: Sieve Analysis of fine aggregates. IS 383:1970

Sieve size (mm)	Weight Retained (gm)	Cumulative weight Retained(gm)	Cumulative percentage weight retained	Cumulative percentage passing
10	0	0	0	100-0
4.75	0	0	0	100-0
2.36	90	90	9	100-9
1.18	208.5	298.5	29.85	100-29.85
0.6	149	447.5	44.75	100-44.75
0.3	287.5	735	73.5	100-73.5
0.15	212	947	94.7	100-94.7
Pan	33	980	98	100-98

Fineness modulus =Σ cumulative percentage weight retained up to 150 micron/100.

Fineness modulus = 2.518

From the above test the results showed that the sand is of zone II and is fit for the use in pavement construction.

3) Coarse Aggregates

Given the continued high traffic volume, pavements typically require aggregates that are 20 mm in size, which enhances their need for strength (maximum).. The coarse aggregates used here were having the 20mm nominal size, the specific gravity was 2.7 as shown in table 3 and water absorption 0.89%

Table 3: Specific gravity test

Weight of sample	1000gm
Weight of container + sample + water (A_1)	1912 gm
Weight of container + water (B_1)	1257 gm
Weight of soaked dry sample (C_1)	1010gm
Weight of oven dry sample (D_1)	1001 gm
Specific gravity = D_1/C_1-(A_1-B_1)	2.7
Water absorption = (C_1-D_1/D_1)*100	0.89% (MAX.= 1% IS 2386 part III)

4) Fly Ash

The mineral admixture utilized in this project is fly ash, which was purchased from Haryana. Prior to usage in the project, all of fly ash's parameters were examined [7], and its specific gravity was discovered to be 2.77.

5) Metakaolin

Metakaolin is a little, white mineral that aids in quickening the time it takes for concrete to set up initially. The metakoalin that was utilized [6] here was imported from Haryana, and its specific gravity was determined to be 2.3 before usage

6) Masterpel 777

Masterpel 777, a super plasticizer with a specific gravity of 1.145 and a dark brown tint, was employed in this project.

7) Water

Pure water was utilized to make the blended concrete. Ph of water used was 7

8) *Bamboo Fiber*

Go Green Products provided the fiber from Jaipur that was used in this project [2]. The characteristics of bamboo fiber are shown in table 4.

Table 4: Properties of bamboo.

Strength (gm/tex)	28.3
Elongation (%)	14
Fiber length (cm)	1.5 to 2
Force at which it breaks (N)	6.1
Tensile strength (Mpa)	180
Diameter (cm)	0.2 to 0.4

Figure 1: Materials

B. Mix Design

A chart and empirical relationship created by researchers based on in-depth laboratory experiments are often the foundation of the mix design approaches employed in various locations. Using IS 10262:2019[10] as a guide, the concrete mix has been created for M25 grade as shown in table 5. Ordinary Portland cement was used to make the control concrete along with both fine and coarse aggregates, but no other materials were used. Cement was then replaced with 15 percent each of metakoalin and flyash, and bamboo fiber was employed as an addition of 0 to 1.5 percent by weight to the cement. With the exception of the control concrete, the super plasticizer was utilized in all the mix.

Table 5: Mix design calculations

Quantity of concrete in m	1
Quantity of cement in m^3	(252/3.07)*1000 = 0.082
Volume of water in m^3	(173/1000) = 0.173
Volume of super plasticizer @ 0.6% by weight of cement.	(2.16/1.145)*1000 = 0.00221
quantity of all aggregates	0.99-(0.082+0.0194+0.0234+0.018)=0.69016
Mass of coarse aggregates	0.69016*0.6204*2.74*1000 = 1173.2 kg/m^3
Mass of fine aggregates	0.69016*0.3790*2.65*1000 = 693 kg/m^3
Mix ratio	1:1:2
Percentage of bamboo fiber used by weight of cement.	0%,0.5%, 1%, 1.5%

III. CASTING

Fresh concrete characteristics and fundamental material properties were tested. The cube specimens were made at a size of 150mm x 150mm x 150mm to evaluate the compressive strength of mixed concrete. Concrete cylinder specimens in the dimensions of 150mmx 150mmx300mm were constructed to examine split tensile strength. The flexural behavior of cast beams of 100 x 100 x 500 mm was investigated. All of the specimens were cast in steel moulds, demoulded 24 hours later, and then maintained in curing until they were tested at 28 days and 56 days, respectively.

A. Testing

1) *Compressive Strength Test*

The machines, their capacity, the type of loading, their size, etc., must be known before testing any specimen. Cubes measuring 150 mm* 150 mm* 150 mm were cast and tested on a compression testing equipment as shown in figure 2 to determine the specimens' compressive strength. The laboratory-used CTM can withstand loads of up to 3000 KN at a rate of 140 kg/sq.cm/min. 24 samples in all were cast for testing across periods of 28 and 56 days. 30% of a mineral admixture (fly ash, metakaolin) was used as a replacement of cement to cast the cubes; the amount of fiber utilized was 0%, 0.5%, 1% and 1.5% respectively. According to the test results, the strength increases as the amount of fibre increases up to 1% percent before starting to decline after that point because a greater quantity of fibre prevents the aggregates from forming a solid link.

Figure 2: Sample on Compression Testing Machine

2) *Flexural Strength Test*

A test for flexural strength is typically conducted to determine a beam or slab's capacity for bending as shown in figure 3. Flexural testing indirectly aids in assessing the tensile strength of a slab or beam. Flexural testing also allows us to forecast how long concrete will last. It is used to pinpoint the loading or onset cracking point at which structural cracks first appear. Universal test machine are the tools used to determine a specimen's flexural strength. 24 beam samples measuring 100 mm x 100 mm x 500 mm each were cast in total. The flexural strength of 12 beams was evaluated at 28 days of curing and 12 beams at 56 days of curing. The idea of the center-point loading method was used to conduct the flexural test. The beams were positioned in accordance with usual procedure so that the reference loading direction was parallel to the casting direction. At the center of the beams, deformation was measured. The maximum tensile stress in the beam at the peak load is represented by the equation: $\boldsymbol{\sigma} = \boldsymbol{PL} / \boldsymbol{BH2}$ where P is the peak load in newtons, L is the beam span length in millimeters, B is the beam width in millimeters, and H is the beam height in mm. The specimens were tested, and the results revealed that as the proportion of fibers increased, the flexural strength continued to rise. Contrary to fiber reinforced concrete, which still experiences deflection before entirely collapsing, the plain concrete beam collapses virtually as soon as the maximum load is met. All of the beam failures took place in the middle third of the span, which is where the bending moment is greatest. This indicates that no horizontal shear failure occurred at the level of loading.

Figure 3: Determination of Beam strength

3) *Split Tensile Test*

Concrete's tensile strength is assessed using the split tensile test as shown in figure 4. We can determine the uniform stress distribution with the use of the split tensile test. In order to learn more about the behavior of concrete, this test is highly beneficial. A universal testing machine is used to determine the tensile strength of specimens. The testing device has a 700KN capacity. A total of 24 cylinders were cast, 12 of which underwent Testing after 28 days of cure and the remaining 12 after 56 days. The following equation is used to get the splitting tensile strength: $\boldsymbol{fct} = \boldsymbol{2F}/ \boldsymbol{\pi LD}$ where fct equals the tensile splitting strength, measured in megapascals F is the maximum load in Newtons. The test findings for the specimens showed that the tensile strength rose up to 1% with an increase in fiber percentage before it began to decline. As a material contains more than 1% bamboo, it tends to extend under strain tests, and when a material elongates, the binding between bamboo fibers and other materials weakens, which causes the bamboo fibers to become loose and causes the material to fracture.

Figure 4: Sample on Universal Testing Machine

4) *Durability test*

The goal of a durability test is often to examine how long-term exposure to acids or bases will affect concrete. The effects of sodium hydroxide solution on the specimens' strength, weight, and dimensions have been noted by this study. Sodium hydroxide solution was employed as 5 percent by weight of the water and had a pH value of 12. A total of 8 specimens were created, of which 2 normal cubes were treated for 28 days with sodium hydroxide solution and 2 normal cubes were treated for 28 days with regular water. For comparison, 2 fiber-reinforced cubes were treated for 56 days in hydroxide solution A and 2 fiber-reinforced cubes were treated for 56 days in plain water. After being removed from the solution after 28 and 56 days, it was discovered that the specimens' strength and weight had decreased in comparison to those that had been left in regular water for curing concrete.

IV. METHODOLOGY

This chapter outlines the fundamental methods for the study. This chapter mainly aids in giving us a clear understanding of the research and aids in the completion of our assignment. The steps I took to ensure the success of this research are listed below:

- Researching concrete for paving and its design.
- Researching concrete pavement fractures.
- Examining research and review papers to learn the fundamentals
- Before beginning the project, gather all the materials to learn about their properties.
- To prepare the design mix and determine the precise material quantity.
- Making full use of both chemical and mineral admixtures.
- Creating a concrete mix that is nominal in order to achieve the desired mean strength.
- Casting the samples.
- Tests on hardened concrete.
- Analysis and a summary of the project's work.

IV. RESULT AND DISCUSSION

A. Compressive Strength Test

To evaluate the required strength for M25 grade concrete,150mm*150mm*150mm concrete cubes were cast and aged in curing tanks for 28 and 56 days, respectively. Three different fiber percentages were used to compare the results to the controlled concrete as shown in figure 5. A total of 24 specimens were cast, 12 of which were intended for 28-day curing and the other 12 for 56-day curing. The specimens were put through testing, and the results as shown in table 6 and 7 showed that strength grew as the percentage of fiber climbed up to 1%, but strength declined as the percentage of fiber increased above 1%.

1) Discussion

Contrary to controlled concrete, the strength of the concrete increases as the fraction of fibre rises up to 1%; nevertheless, the strength of the concrete falls when more fiber is added. This is due to the specimens' constrained dimensions, which prohibit the extra fiber from spreading evenly and preventing the aggregates from creating a solid link with one another.

Table 6: 28 day's compressive strength test results

Percentage of fibre (%)	Average load in KN	Avg. Compressive strength N/mm^2
0	634	28.2
0.5	659	29.3
1.0	690	30.7
1.5	657	29.2

Table 7: 56 day's compressive strength test results

Percentage of fiber (%)	Average load in KN	Avg. Compressive strength N/mm^2
0	679	30.2
0.5	738	32.8
1.0	762	33.9
1.5	726	32.3

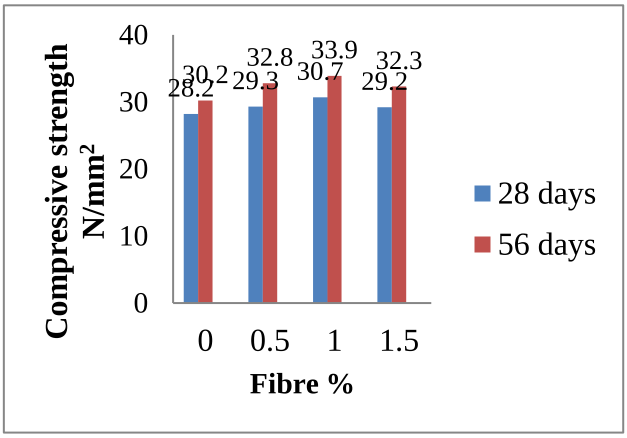

Figure 5: Comparison between 28- & 56-days compressive strength of cubes

B. Flexural Strength Test

A universal test machine is used to evaluate a beam's ability to bend. 100mm*100mm*500mm was the beam's dimension, and 24 beams were cast in total for 28 and 56 days. The results demonstrated that as the proportion of fibers increased as shown in table 8, so did the flexural strength.

1) Discussion

While the compressive strength reduces as the percentage of fiber increases due to the smaller specimen sizes preventing the additional fiber from fully combining with the other materials in the mix, the flexural strength of beams increases as the percentage of fiber increases. The larger beam's dimensions make it easier for the fiber to spread evenly and give it a chance to properly bind with the aggregates, which improves the specimens' capacity to bend. The plain concrete beam basically collapses as soon as the maximum load is reached, in contrast to fiber reinforced concrete, which still experiences deflection before completely collapsing. The center third of the span, which is where the bending moment is greatest, is where all of the beam failures occurred. This shows that there was no horizontal shear failure at the loading level.

Table 8: Flexural Strength test results

Bamboo Cutting Percentage (%)	Flexural Strength Test	
M25		
	28 days	56 days
0	2.4	3.8
0.5	3.8	4.9
1	4.5	5.7
1.5	5.2	6.1

C. Durability Test

Durability test is usually carried out for the purpose of long term effects on concrete either by acids or bases. This research has noticed the effects of sodium hydroxide solution on the strength, weight and dimensions of the specimens. The ph value of sodium hydroxide solution was 12 and it was used as 5% by weight of the water. A total of 8 specimens were made out of which 2 normal cubes were kept for 28 days in ordinary water and 2 normal cubes in sodium hydroxide solution for 28 days of treatment. Further 2 fiber reinforced cubes were kept for 56 days in hydroxide solution and 2 fiber reinforced cubes were placed in ordinary water for 56 days of treatment for comparison.

1) Discussion

When compared to specimens that were kept in regular water for curing, it was observed that after 28 and 56 days, both the strength and weight of the specimens had decreased as shown in table 9 and 10. This is due to the extracts being removed, which individualize the fibers.

Table 9: Durability test results for compressive strength

Percentage of fiber	28 days compressive strength of normal water curing (N/mm^2)	28 days compressive strength of sodium hydroxide solution based water (N/mm^2).	56 days compressive strength of normal water curing (N/mm^2)	56 days compressive strength of sodium hydroxide solution based water (N/mm^2).
0%	28.2	26.1		
0.5 %			32.8	29.3

Table 10: Durability test results for weight check

Percentage of fibre	Weight of specimens after 28 days of normal curing.	Weight of specimens after 28 days of sodium hydroxide solution curing.	Weight of specimens after 56 days of normal curing	Weight of specimens after 56 of sodium hydroxide solution curing.
0.5 %	8.51	7.98	8.56	7.8

D. Split Tensile Test

Concrete's tensile strength is assessed using the split tensile test. We can determine the uniform stress distribution with the use of the split tensile test. This test is highly beneficial when learning about concrete behavior. Universal Test machines are the tools used to determine a specimen's tensile strength. . A total of 24 cylinders were cast, 12 of which underwent testing after 28 days of cure and the remaining 12 after 56 days. According to the test results for the specimens as shown in table 11, the tensile strength increased up to 1% with an increase in fiber percentage before it started to deteriorate

1) Discussion

According to the test results for the specimens, the tensile strength increased up to 1% with an increase in fiber percentage before it started to deteriorate. When a material elongates during strain tests, the bonding of bamboo fibers to other materials weakens, causing the bamboo fibers to fall loose and causing the material to fracture. This happens when a material contains more than 1% bamboo and tends to elongate under strain tests. In the case of composites, this fall in tensile strength beyond 1% may also be caused by weak interfacial bonding

Table 11: Split tensile strength test results

Fiber Content (%)	28 Days		56 Days	
	Load kN	Average flexural strength N/mm^2	Load kN	Average flexural strength N/mm^2
0	89.1	1.98	121.5	2.7
0.5	99.45	2.21	130.5	2.9
1	114.3	2.54	157.5	3.5
1.5	111.6	2.48	139.5	3.1

V. CONCLUSION

- In most cases, it takes too many attempts to achieve the feat of obtaining the necessary 28-day strength for M25 grade of concrete. Although the goal was to obtain the strength of fiber reinforced concrete, the strength of controlled concrete was initially attained after approximately six attempts. It is recommended to implement a mineral admixture since fiber absorbs moisture, making concrete more porous and reducing strength. Compressive strength requirements for both controlled and fibre reinforced concrete are reached by using 0.6 percent of masterpel 777 and 30 percent fly ash and metakaolin in replacement of cement.
- The strength reduces after increasing the proportion of fiber because the smaller cubes' size prevents the extra fiber from fully mixing. As a result, with the increase in fiber percentage up to 1%, strengths were achieved earlier.
- After 1% of fiber, the strength began to decline because the additional fiber could not form the correct link between the aggregates.
- Flexural strength and the likelihood of resisting bending both rise as we continue to increase the percentage of fiber. This is because beams have bigger dimensions, which aid in the fiber spreading uniformly and give the fiber a chance to properly bind with the aggregates, increasing the specimens' capacity for bending.
- The fiber reinforced concrete exhibits deflection before fully collapsing, whereas the plain concrete beam collapses essentially as soon as the maximum load is attained.
- Sodium hydroxide-based solutions have a much lower compressive strength than standard based cubes. Bases have a negative impact on both the strength and weight of the specimens. This is as a result of the extracts being eliminated since they individualize the fibers.
- However, the results show that the fiber is effective for strengthening concrete that has been subjected to tensile loading since it plays a significant role in preventing cracks from spreading and postponing the concrete's eventual failure.
- Concrete cracking patterns show that fiber reinforced concrete has fewer cracks than unreinforced concrete

because an impact test reveals that bamboo fiber plugs pores in the concrete.
- In addition to being cost-effective, using flyash and metakoalin as a 30 percent alternative for cement increases required strength without significantly compromising permeability qualities.
- With the optimum amount of utilization in a concrete application, it demonstrates that bamboo has the ability to improve the qualities of concrete

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