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Experimental Investigations on Manvel and Katang Bamboo as Reinforcement in Concrete

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ABSTRACT: Steel is widely used as a reinforcement in concrete as it has high tensile strength. The use of steel in construction is costly and also much energy is consumed in manufacturing process. Carbon emissions for manufacturing of steel is high causing adverse effect on environment. Thus a substitute of steel in concrete members with a low cost, environmental friendly but at the same time ensuring required stability and durability is a global concern. Bamboo is cheaper, easily available and have a negative carbon footprint. Bamboo is widely used from ancient times as construction material. Latest researches carried out on the possibility of using bamboo as reinforcement material shows that it is strong in compression and tension as well, making bamboo as one of the suitable replacement for steel. The present research studies the use of bamboo as reinforcement in concrete members and the experimental investigation is carried out on *Dendrocalamus strictus* bamboo locally called as Manvel and *Bambusa bambos* bamboo called as Katang. Physical properties including density and moisture content is tested on Manvel and Katang. Manvel specimen with and without node is tested for compressive strength and Katang specimens with varying thickness is tested. Manvel and Katang bamboo are tested for tensile strength and bending strength. Water absorption test is also carried on nine specimens of Manvel which includes three untreated bamboos, three bamboos treated with Black Japan bitumen paint and three specimens treated with VG-30 Bitumen. Similarly, water absorption test is carried out on nine Katang specimens. The test results were compared to select better species of bamboo as construction material.

KEYWORDS: Manvel, Katang, flexure, bond strength, bitumen.

I. INTRODUCTION

Steel and concrete are the primary materials used in construction as they have extraordinary properties, including strength, durability, etc. Production of this material requires high consumption of energy and natural resources causing high environmental contamination. With researches going worldwide to explore the cost effective and eco-friendly substitute's an insight of material already been used for decades flashed- BAMBOO. Bamboo is an ancient solution for present day problem. Bamboo is primarily a type of giant grass with woody stems located mainly in America, Asia and Africa. There are approximately 90 genera and 1100 species of bamboo. It is fast growing resource which can be harvested in a short time which is 3-5 years. A single bamboo clump can produce up to 15km of usable pole with up to 30 cm in diameter in its lifetime. The stems are called shoots when the plant is young and culms when the plant is mature. The distinctive joints along the culms of bamboo are termed as Nodes. In last century, researches have been carried out on the possibility of using bamboo as reinforcement in concrete. The results of various experiments conducted encouraged further research work. Bamboo culms have high strength in the direction parallel to the grain. The nodes present at varied distances divide bamboo into number of segments; each acting as short column which prevents buckling. Bamboo has a good tensile strength and light weight. Bamboo has low manufacturing cost compared with steel. Bamboo is able to resist more tension than compression. The fire resistance is very good because of the high content of silicate acid. Experiments conducted on bamboo over years prove that the tensile strength of bamboo is comparable to that of mild steel and compressive strength of bamboo is slightly less than that of steel. The physical and mechanical properties of bamboo have been studied and compared with steel which describes its suitability as a replacement to steel reinforcement.

Bamboo is a hygroscopic material which tends to absorb moisture from air. Bamboo absorbs moisture and swells. Later when concrete becomes dry, bamboo contracts creating voids between the contact areas, which hamper the bond strength. This is a major problem which results in failure of the member in bond. The treatment methods in research conducted over years include coating bamboo surface with epoxy paint, oil paint, oil paint with zeolite powder, bitumen and kerosene mixture, bitumen and kerosene mixture with zeolite powder, black japan paint. The treatment

methods on whole bamboo or on bamboo splints should not hamper the bond strength between bamboo and concrete surface.

The bamboo-bearing area under Maharashtra is 13,526 sq. km, distributed across 10 districts. Vidarbha produces over 90% of the total yield. The varieties grown here are *Dendrocalamus strictus* locally called as Manvel, *Bambusa bambos* locally called as Katang or thorny bamboo, *Dendrocalamus stocksii* and *Munrochloa ritchiei*. The Konkan region is home to Manga bamboo. Manga has been the preferred choice among farmers for its multipurpose uses. It is solid without thorns and grows straight, achieving a height of 15 m. It is used as stakes in horticulture, for making implements, for scaffolding and for making furniture and handicrafts. It starts yielding after five years, yielding eight to 12 sticks every year. The varieties grown in Maharashtra are *Dendrocalamus strictus*, *Bambusa bambos* or thorny bamboo, *Dendrocalamus stocksii* and *Munrochloa ritchiei*. From these four species, *Dendrocalamus strictus* which is referred as Manvel and *Bambusa bambos* which is locally termed as Katang are recommended along with 14 other species in IS 15912: 2018.

II. LITERATURE SURVEY

The physical and mechanical properties, water repellent treatment of bamboo and bond strength between bamboo and light weight concrete was studied by **K. Ghavami**[1]. The experiment was conducted on two simply supported bamboo reinforced lightweight concrete beams with overall length of 3400mm, width of 120mm and 300mm depth subjected to two point loads. *Dendrocalamus giganteus* bamboo was used as reinforcement. The concrete mix proportions was 1:3.22:0.78 and water cement ratio of 0.55. The research showed that there was lower bonding between bamboo and concrete as compared with steel. Use of locally available negolin sand wire treatment improved the bonding by 90%. Further work in treatment of bamboo and analysis of bamboo reinforced beams is required for development of a simple design code.

Nathan Schneider[4] acknowledged the work done by other researchers Yu et al. (2008), Cao and Wu (2008), Ghavami (2005), Khare (2005), Amada (1997), and Kankam and Perry (1989) in general properties of bamboo. The study aimed to confirm the mechanical properties of Moso bamboo to be used as reinforcement in concrete beams. The dimensions of beam tested were 254 wide x 508 depth and 2286 mm long. Tensile strength, modulus of elasticity and bond strength tests were worked out. Results for tensile tests indicated the average tensile strength of bamboo around 18ksi and modulus of elasticity around 1149ksi. The results confirmed the benefit of diaphragms on bond strength. Test specimen with one diaphragm had bond strength of 106psi whereas one without diaphragm had bond strength of 59psi. Bamboo cages were successfully constructed in a unique closed stirrup design.

Ayesha Siddika [7] studied the physical and mechanical properties of Borak Bash species of bamboo commonly found in Bangladesh. Bamboo reinforced concrete beam of 150x150x1000mm were casted in M20 grade of concrete to test their flexural strength. The test resulted showed that bamboo reinforced beam with 1% reinforcement got 32% more strength and 1.5% reinforcement got 80% more flexural strength as compared with plain cement concrete beam were failure occurred at 25Kn load with 1.9 mm deflection at centre of the beam. Cost analysis was done between bamboo reinforced beams and columns with moderate steel reinforcement. The study showed strength to cost ratio of different specimen in which, bamboo had nine times higher ratio than that of steel. The work concluded that deflection of plain cement concrete beam is higher than bamboo reinforced concrete beams at same loading conditions. Bamboo reinforced beam found to withstand larger deflection than PCC beams before failure.

The characteristics of four bamboo species, *Dendrocalamus pendulus*, *Dendrocalamus asper*, *Gigantochloa Levis*, *Gigantochloa scortechinii* and their top, middle and bottom parts was investigated by **Parnia Zakikhani** [10]. Moisture content, Water absorption and tensile tests were performed on bamboo. The results showed that aspect ratio which indicates the strength and efficiency of fibres decreased from bottom to the top portions. *Dendrocalamus pendulus* showed highest water absorption but lowest mechanical properties. *Dendrocalamus asper* exhibited best mechanical and physical properties. The results indicated the need to characterize bamboo species so that it can be used effectively as reinforcement.

III. METHODOLOGY

A detailed investigation was carried out through a comprehensive experimental program followed by analysis of results. Manvel and Katang bamboo were experimented for their physical properties. Test for Density and Moisture content of bamboo is carried out. Experimental investigations on Manvel and Katang bamboo was done to study its mechanical properties which included Compression test, Tensile strength tests and static bending strength tests. Water absorption test was carried out on specimens of Manvel and Katang and the results are compared. The treatment methods should be easy to adopt, cheap, involving locally available materials. The material selected should have water repellent properties, providing good impervious layer of coating. Bamboo splints were used. Water absorption test was conducted for seven days minimum until the difference in percentage of water absorption is almost zero.

Materials for treatment on Bamboo Surface:

i. Black Japan Paint:

It is a fast-drying modified solution designed to seal and prepare surfaces for the application of roofing and waterproofing systems and is ready to use. Black Japan paint is available in Indian market at around Rs. 50 per L. This paint can be easily applied on bamboo splints in a single coat.

ii. Bitumen (VG 30 Bitumen):

VG 30 is used for bitumen pavements, in road construction, insulation and building construction industries. It is a popular grade of bitumen in India. Because of having good thermal susceptibility, VG-30 can be used in areas that have higher temperature. It is also suitable for use in hot and rainy weather conditions instead of bitumen penetration grades.

IV. RESULTS

Table I: Results of Density test on Manvel

Manvel		
Sr. No.	Specifications	Properties
1	Initial Mass	34.64 gm
2	Oven Dry	32.53 gm
3	Height	50 mm
4	Outer Diameter	36 mm
5	Inner Diameter	20 mm
6	Volume	35.18 cm ³
7	Density	924.52 kg/m ³

Table II: Results of Density test on Katang

Katang		
Sr. No.	Specifications	Properties
1	Initial Mass	24.98 gm
2	Oven Dry	23.36 gm
3	Height	45 mm
4	Outer Diameter	37 mm
5	Inner Diameter	18 mm
6	Volume	36.93 cm ³
7	Density	632.49 kg/m ³

Table III: Results of Moisture Content test

Moisture Content				
Sr. No.	Specimen	Initial Mass(gm)	Oven Dry(gm)	Moisture Content (%)
1	Manvel	34.64	32.53	6.48
2	Katang	24.98	23.36	6.93



a)



b)

Figure 1: Compression test results a) Manvel Specimen b) Katang Specimen

Table IV: Results of Compressive Strength Test on Manvel

Manvel		
Sr. No.	Specifications	Properties
1	Outer Diameter	39.94 mm
2	Length	44.1 mm
3	Thickness	8.07 mm
4	Inner Diameter	23.8 mm
5	Load	64.86 kN
6	Area	807.99 mm ²
7	Compressive Strength	80.27 N/mm ²

Table V: Results of Compressive Strength Test on Katang

Katang		
Sr. No.	Specifications	Properties
1	Outer Diameter	36.98 mm
2	Length	41.71 mm
3	Thickness	10.32 mm
4	Inner Diameter	16.34 mm
5	Load	50.59 kN
6	Area	864.35 mm ²
7	Compressive Strength	58.53 N/mm ²



a)



b)

Figure 2: Tensile test results a) Manvel Specimen b) Katang Specimen

Table VI: Results of Tensile Strength Test on Manvel

Manvel		
Sr. No.	Specifications	Size
1	Outer Diameter	41 mm
2	Length	750 mm
3	Thickness	8 mm
4	Inner Diameter	25 mm
5	Load	76.21 kN
6	Area	829.38 mm ²
7	Tensile Strength	91.88 N/mm ²

Table VII: Results of Tensile Strength Test on Katang

Katang		
Sr. No.	Specifications	Properties
1	Outer Diameter	38.26 mm
2	Length	595 mm
3	Thickness	10 mm
4	Inner Diameter	18.26 mm
5	Load	45 kN
6	Area	887.81 mm ²
7	Tensile Strength	50.68 N/mm ²

Table VIII: Results of Static Bending Strength Test on Manvel

Manvel		
Sr. No.	Specifications	Properties
1	Outer Diameter	41 mm
2	Length	1000 mm
3	Thickness	8 mm
4	Inner Diameter	25 mm
5	Moment of Inertia	119473.86 mm ⁴
6	Load	4.8 kN
7	M.O.R	137.27 N/mm ²
8	Modulus of Elasticity	15596.93 N/mm ²

Table IX: Results of Static Bending Strength Test on Katang

Katang		
Sr. No.	Specifications	Properties
1	Outer Diameter	38 mm
2	Length	1000 mm
3	Thickness	7 mm
4	Inner Diameter	24 mm
5	Moment Of Inertia	86024.225 mm ⁴
6	Load	2.7 kN
7	M.O.R	99.39 N/mm ²
8	Modulus of Elasticity	9077.26 N/mm ²



Figure 3: Test Specimens for Water Absorption Test - Bamboo surface treated with Black Japan paint

No. of Day	Average Water Absorption (%)		
1(6hours)	24.01	17.91	14.12
1(12hours)	38.50	28.95	18.22
2	43.56	33.45	20.63
3	57.73	47.00	27.75
4	59.01	47.35	28.98
5	60.22	47.62	30.52
6	61.14	47.89	31.72
7	61.86	52.36	35.73

Table X: Results of Water Absorption Test on Manvel

Katang Water Absorption			
Specimen	Untreated Bamboo	Black Japan Painted	Bitumen Coated
No. of Day	Average Water Absorption (%)		
1(6hours)	47.67	22.65	30.58
1(12hours)	79.63	52.93	40.64
2	86.95	60.67	44.14
3	110.65	73.05	57.49
4	111.01	74.98	58.29
5	110.86	75.73	58.88
6	111.68	76.37	59.29
7	112.82	82.81	64.05

Table XI: Results of Water Absorption Test on Katang

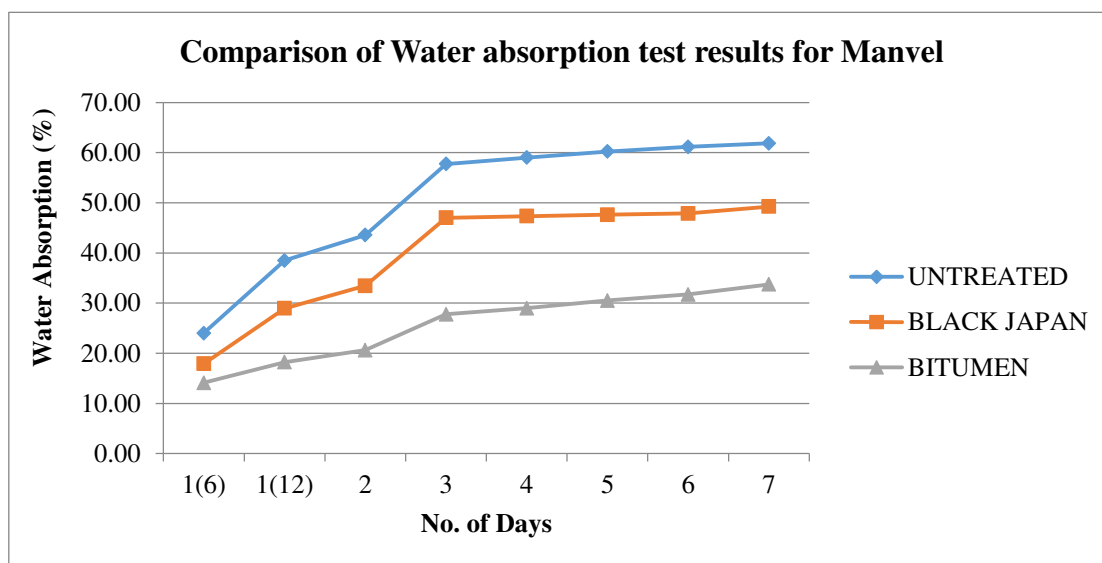


Figure 4: Comparison of Water Absorption test results for Manvel

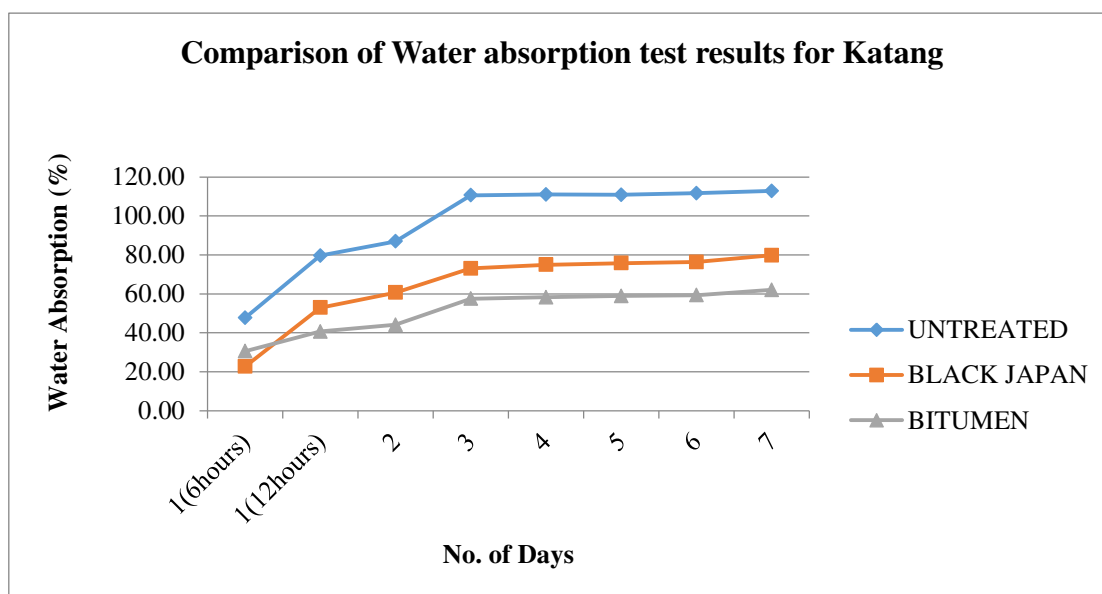


Figure 5: Comparison of Water Absorption test results for Katang

V. DISCUSSION

The density of Manvel is 924.52 kg/m^3 and for Katang is 632.49 kg/m^3 . As per IS 15912:2018, Density for Manvel and Katang is specified as 728 and 663 kg/m^3 and moisture content of Manvel is 6.48% whereas for Katang it is 6.93%. The compressive strength of Manvel is 80.27 N/mm^2 . IS 15912:2018 states compressive strength of Manvel as 69.1 N/mm^2 . For Katang, compressive strength is 58.52 N/mm^2 . IS 15915:2018 states compressive strength of Katang as 53.4 N/mm^2 . Manvel sample during tensile test took a maximum load of 76.21 kN. Katang bamboo during test took a maximum load of 45 kN. During tensile strength test, failure occurred at node for both Manvel and Katang bamboo. The test results calculated for ultimate strength in static bending, also called as modulus of rupture is 137.27 N/mm^2 for Manvel and 97.18 N/mm^2 for Katang.

Water Absorption test on Manvel Bamboo- Water absorption is 24 % during the initial 6 hours of the test. The water absorption test is carried out for seven days and at the end of the test water absorption for untreated sample is 61.86%. The results of water absorption test on bamboo coated with black japan paint shows 17.91% during the initial 6 hours of the test. The water absorption increases steadily during four days of the test. On the seventh day of the test, 52.36% of water absorption is calculated. The results of water absorption test on bamboo coated with bitumen during initial 6 hours is 14.12% which increases up to 35.73% at the end of 7 days. The calculations shows that untreated bamboo absorbs 61% of water in 7 days, which decreases to 52% for bamboo treated with Black Japan paint and 35% for Bamboo treated with VG-30 Bitumen coat. Water absorption during the first 24 hours is 24% for untreated bamboo which reduces to 15% for treated samples. Water absorption is least for specimen treated with bitumen and highest for untreated bamboo.

Water Absorption test on Katang Bamboo- The results of water absorption test on untreated Katang shows 47.67 % absorption during initial 6 hours which increases to 112.82% at 7 days. The test results shows that Katang bamboo coated with black japan paint absorbs 82.81% water at the end of 7 days and bamboo surface treated with bitumen absorbs 64.05 % water at the end of 7 days. The untreated bamboo absorbs 112% of water in 7 days, which decreases to 82% for bamboo treated with Black Japan paint and 64% for Bamboo treated with VG-30 Bitumen coat. Water absorption during the first 24 hours is 47% for untreated bamboo which reduces to 25% for treated samples. Water absorption is least for specimen treated with bitumen and highest for untreated bamboo. Water absorption of Katang is more than Manvel.

Comparison of Manvel and Katang

A comparison of physical and mechanical properties of Manvel and Katang obtained from test results is done. Water absorption of Manvel and Katang for untreated bamboo specimens are also compared.

Table XII: Results of Water Absorption Test on Katang

Comparison of Manvel and Katang			
Sr. No.	Properties	Manvel	Katang
1	Moisture Content (%)	6.48	6.93
2	Density (Kg/m ³)	924.52	632.49
3	Compressive strength (N/mm ²)	80.27	58.53
4	Tensile strength (N/mm ²)	91.88	50.68
5	Static Bending Strength (N/mm ²)	137.27	99.39
6	Modulus of Elasticity(N/mm ²)	15596.93	9077.26
7	Water Absorption after 7 days (%)	61.86	112.82

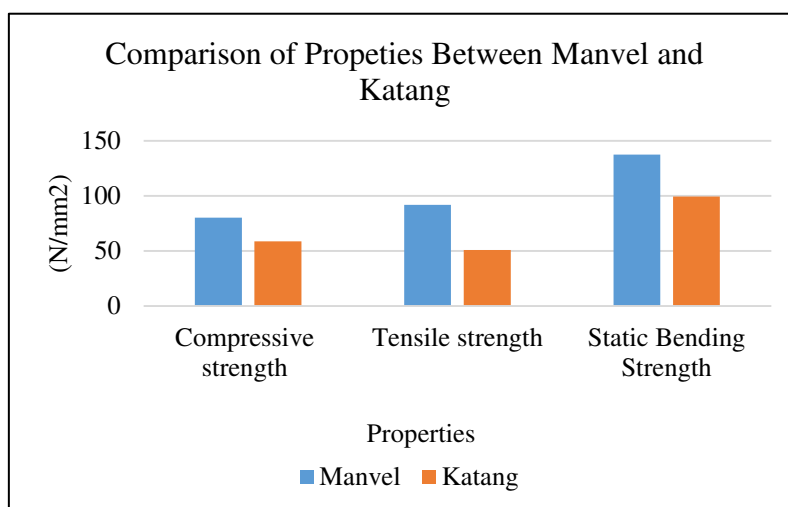


Figure 5 Comparison of properties between Manvel and Katang

Moisture Content for Manvel is less than Katang by 7 %. The density of Manvel is found to be 32% more than that of Katang. The compressive strength, Tensile strength and static bending strength (modulus of rupture) of Manvel bamboo are more than that of Katang. For untreated bamboos, Katang has a very high water absorption.

Comparison chart of mechanical properties of Manvel and Katang is shown in Figure 5. The physical and mechanical properties proves that Manvel is better material to be used as a reinforcement in concrete structure. The results show that Manvel and Katang bamboo can be used as a construction material. Manvel can be used under higher loading conditions as compared to Katang.

VI. CONCLUSION

- 1) Density of Manvel and Katang are 925 and 632.5 kg/m³ respectively. Density of Manvel is 45% more than Katang since the mass of Manvel is more than Katang.
- 2) The moisture content of Manvel is 6.5% and that of Katang is 6.9%. Moisture content of Katang is 7% more than that of Manvel. Moisture content depends on period of seasoning and age of bamboo.
- 3) The compressive strength of Manvel is 38% more than that of Katang. The compressive strength of Manvel was found out to be 80.27 N/mm² and 58.53 N/mm² for Katang. The diameter to thickness ratio of Manvel is 38% more than that of Katang.
- 4) During tensile strength, failure occurred at nodes for both Manvel and Katang specimens as bamboo is weaker at nodes. The tensile strength of Manvel was found out to be 92 N/mm² and for Katang it was 50.68 N/mm².
- 5) Modulus of rupture for Manvel was calculated as 137.27 N/mm² at maximum load of 4.8 kN with a 5 mm deflection. For Katang, at a maximum load of 2.7 kN, the Modulus of rupture was 99.4 N/mm² for 1000 mm specimens.
- 6) Water Absorption for untreated Manvel bamboo was up to 60% and for Katang it was 112%. The fibre distribution of Manvel is more compact than Katang.
- 7) Water absorption for treated bamboo specimens decreased for both Manvel and Katang. For Manvel, when surface was treated with black japan paint water absorption decreased to 52% and 35% for Bamboo treated with VG-30 bitumen. When surface of Katang bamboo was painted with Black Japan, the water absorption decreased to 82% and for Bitumen it decreased to 64%.
- 8) Bitumen treatment on bamboo surface is effective in reducing water absorption.
- 9) The comparison between results of all physical and mechanical properties proves that Manvel is better material than Katang to be used as reinforcement in concrete structure.

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