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NATURALLY TREATED PHILIPPINE BAMBOO SPECIES AS POSSIBLE CONCRETE REINFORCEMENT MATERIALS SUBSTITUTE FOR STEEL BARS

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Abstract

In some areas of the world, bamboo is one of the most widely exploited materials for construction due to the unavailability of limited steel supplies. Replacement of RC and steel by increased usage of bamboo as a building material alternative. This research aims to determine the mechanical strength of concrete reinforced with treated and untreated bamboo sticks as a substitute for steel bars. The materials used were different bamboo species such as Dendrocalamus As per Schultes, Dendrocalamus Merrillianos Elmer, Bambusa Vulgaris Schrader, and Bambusa Blumeana Schultes cut into 60 mm length, and 10 mm diameter bamboo sticks were prepared as primary reinforcements treated with seawater and seawater with mango polyphenol extract treated for 7, days, 14 days, 28days and 56 days based on ASTM standards. The most suitable substitute for steel reinforcement for concrete was the Dendrocalamus Merrillianos Elmer and Dendrocalamus Asper Schultes, which have higher tensile strength when compared to other species. The Reinforced concrete flexural and compressive strength depended on the curing age, the species of bamboo sticks used as reinforcement, and the treatment of bamboo sticks used. Treated bamboo with seawater and mango polyphenol is a suitable replacement for steel bars for concrete reinforcement.

Index Terms: Treated Bamboo, Alternative Reinforcement Materials, and Substitute for Steel Bars, Reinforced Concrete Beam, Bamboo materials, and Concrete reinforcement.

I. INTRODUCTION

Developing robust green building technologies that bamboo is a ‘cool’ constructional material and constructing a bamboo technology for rural and urban islands wherein [1] bamboo is a source of reinforcement materials for concrete reinforced with a bamboo stick as substitute steel reinforcement. Bamboo as a modern engineering construction material [2] and structural analysis demonstrated how modern engineered structures could be a real possibility using bamboo [3], With the increasing population, there is tremendous exploitation of natural resources to produce conventional building materials and [4] to reduce the cost of construction so that houses may be made affordable to the common man society, [5] in the present research work, bamboo sticks had been provided as reinforcement in concrete beams in place of steel bars [6].

As an alternative to steel, bamboo has been tried as reinforcement in different countries on a very small scale, adopting bamboo-reinforced concrete slabs [7]. Bamboo has excellent mechanical properties, which are used as reinforcing material in concrete with small thin strips tied together in two directions to form a bamboo-strip mat. Bamboo strips were prepared from old-age bamboo. Different shapes of the cross-sections of bamboo sticks, such as circular, square, and triangular, were used as reinforcement [8]. Bamboo

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as a functional gradient material of bamboos composite behavior through the rule of mix, such as bamboo reinforced concrete beams, permanent shutter concrete slabs and columns [9].

The structural strength of concrete column reinforced with bamboo strips wherein the load carrying capacity of the column increased with increase in percentage of bamboo strip reinforcement. Still, the increase is not proportional to the support rate [10]. The structural strength of concrete columns reinforced with bamboo strips includes load capacity tests, deflection, and failure patterns on concrete columns. Wherein the load-carrying capacity of the column increased with the percentage of bamboo strip reinforcement, but the increase is not proportional to the support percentage bonds.

The tensile strength of bamboo is relatively high, making bamboo an attractive alternative to steel in tensile-loading applications [12]. The bamboo concrete composite elements can be used as a substitute for concrete, steel and wood used in housing and other products required in day-to-day applications [13]. Bamboo as reinforcement in concrete by determining the various physical and mechanical properties of bamboo moso type bamboo tensile stress, compressive stress, Modulus of Elasticity, Water absorption capacity, Shear stress, and bonding stress. In general, the strength of bamboo is as high as mild steel while, their density is as low as carbon fiber [14].

Bamboo as a reinforcing material in reinforced-concrete members, flexural loading tests were carried out on reinforced-concrete beams in which all rebars, including the main rebar and the stirrups, were replaced with bamboo which is good load-carrying capacity, load-carrying capacity of the beams can be calculated using section analysis based on the Bernoulli–Euler assumptions; the bending moment–curvature relationships of the beams can be estimated by accounting for the bond slip of the main bamboo rebars using a reduced Young's modulus of the main rebars. [15] Bamboo reinforcement both vertically and horizontally in bond beams. Comparing different reinforcement layouts and both partially and fully grouted walls. Providing bamboo reinforcement in concrete block shear walls results in enhanced shear capacity and ductility compared to unreinforced masonry [16]. The alternate construction materials with conventional construction utilized bamboo sticks of different cross-section shapes as a substitute for steel bars in the slab. It was found that the tensile strength of bamboo is approximately one-half that of mild steel, and the modulus of elasticity is approximately one-third that of mild steel [17]. Bamboo reinforcement both vertically and horizontally in bond beams wherein the performance of the walls compared to different reinforcement layouts and both partially and fully grouted walls [18]. Bamboo is a lightweight material with good tensile strength, and bamboo is a substitute for steel reinforcement. Bamboo-reinforced concrete may be a feasible alternative to Steel Reinforced Cement Concrete Structural elements [19].

Using bamboo as reinforcement in concrete includes a tensile test of locally procured bamboo strips conducted to evaluate its ultimate strength and engineering properties. Bamboo reinforced beams and columns axial compression and transverse loading tests reveal the load carrying capacity, lateral deflection, and failure mode pattern. Properly treated bamboo can substitute steel as reinforcement in beam and column members. [20], [21]Bamboo strips were used as reinforcement in concrete that was made with

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supplementary cementitious materials and partial replacement of river sand with manufactured sand (m-sand), Cement which resulted in the micro-scale and tensile strength tests revealed that bamboo is a strong and ductile material on which makes it suitable as a substitute for steel.[22],[23] to reduce the cost of construction so that houses may be made affordable [24] to the common man of society, in the present research work, bamboo sticks had been provided as reinforcement in concrete beams instead of steel bars.

To determine the mechanical strength using bamboo as structural reinforcements for the Concrete Columns, Concrete beams, Concrete footing; and Concrete slabs, to compare the mechanical strength of concrete mixtures reinforced with steel bars and reinforced with bamboo sticks of the untreated and treated bamboo selected common bamboo species. Thus, the researcher believes that Bamboo reinforced showed remarkably similar behavior to one reinforced with steel. With this, Bamboo may be used as a substitute for steel reinforcement. However, plain concrete members are commonly used for regions of the world where the availability of steel is limited.

II. MATERIALS AND METHODS

The most used bamboo Species in the Philippines include (a) *Dendrocalamus Asper Schultes, (b) Dendrocalamus Merrillianos Elmer, (c) Bambusa Vulgaris Schrad, and (d) Bambusa Blumeana Schultes)* as sacrificial experimental materials as replacements for steel bars for concrete footing reinforcements.

(a) **(b)** **(c)** **(d)**

The selected common Philippine bamboo species was cut to 300 mm and 600 mm with one node. Each species had three treatments. Each bamboo species was prepared for untreated sample (e) kiln drying, second treatment (f) soaking with seawater, and third treatment treated with (g) seawater plus Mango polyphenol extract; all samples soaked for 7 days, 14 days, 28 days, and 56 days respectively.

(e) **(f)** **(g)**

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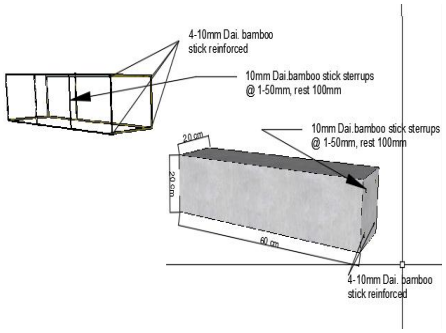
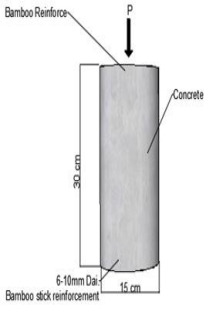
The bamboo was stripped into 10mm diameter sticks and treated naturally with (b) soaking in the seawater and (c) soaking in the seawater plus mango polyphenol extract for 7 days, 14 days, 28 days, and 56 days respectively. The bamboo reinforcements were prepared and assembled according to the reinforcement's standards, and steel reinforcements were assembled as controlled samples. The forms have been set up having dimensions of 600mm by 600 mm by 200 mm for sample (h)beam set up reinforced naturally treated bamboo reinforcements and 150 mm diameter by 300 mm length as cylindrical sample (i) experimental samples and steel reinforcements using 10mm diameter steel bars as controlled samples.



(h)



(i)

There were 3 sets of samples; the first was concrete samples (no reinforcements), and the second was concrete samples with steel reinforcements. The last set of pieces was concrete with bamboo sticks reinforcement using untreated bamboo, bamboo naturally treated with seawater, and bamboo sticks treated with seawater plus mango polyphenol extracts. The concrete mixtures comprised type I cement, aggregate, and clean water. The concrete mixtures' proportions are 1:2:3, the water-cement ratio was also controlled, and the concrete was subjected to curing for 7 days, 14 days, 28 days, and 56 days, respectively. The concrete samples were subjected to axially loaded compression (j) and flexural loadings (k) using the universal testing machine (l).

(j)

(k)

(l)

Analysis of the results under different loadings conditions. Each experiment was repeated five times unless otherwise stated. All data were processed by using Microsoft excel and statistical analyses.

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III. RESULTS AND DISCUSSION

This paper analyzed the treated and untreated Philippine bamboo species, namely ***Dendrocalamus asper Schultes, Dendrocalamus Merrillianos Elmer, Bambusa Vulgaris Schrader, and Bambusa Blumeana Schultes*** soaked in salt water and salt water plus mango polyphenol extract in several treatment days and airdried for 1 week could affect the tensile strength and if there are significant effects for effective use for concrete reinforcements.

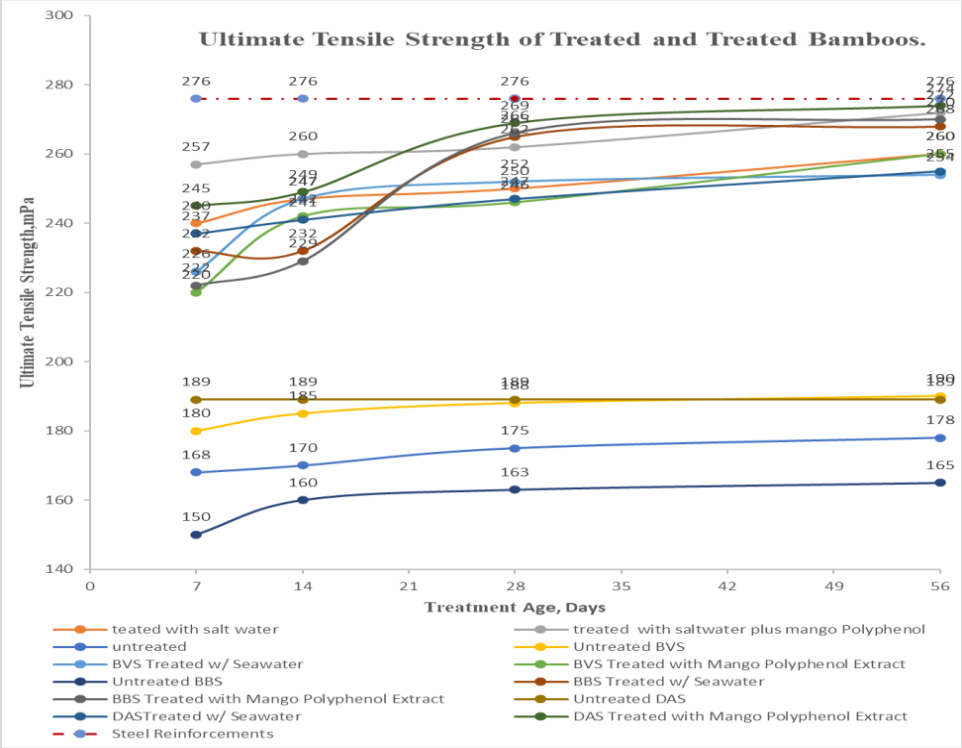

Fig 1: Ultimate Tensile Strength of Bamboo Specimen Sticks

In this graphical presentation shows in fig.4 the ultimate tensile strength of Bamboo sticks. Among the species, ***Dendrocalamus Asper Schultes*** had the highest tensile strength of 274 MPa when treated with seawater plus mango Polyphenol in 56 days. The ***Dendrocalamus Merrillianos Elmer*** had the ultimate tensile strength of 272 MPa treated in seawater plus mango polyphenol in 56 days. The lowest tensile strength among the species is the ***Bambusa Vulgaris Schrader****,* with a tensile strength of 260 MPa. This implies that *Dendrocalamus Merrillianos Elmer* and *Dendrocalamus Asper Schultes* bamboo species, when treated naturally with seawater plus mango polyphenol, is a good substitute for steel reinforcement for concrete of [25] non-structural purposes of lightweight engineering construction that is non-heavy loadbearing capacity.

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Table 1: Comparison of Materials with Naturally Treated Philippine Bamboo species

Materials	Ultimate Tensile Strength (MPa)	References
SS304	620	[25]
A16061	300	[25]
Rattan	85.35	[26]
Fir, Pine, and spruce	30-50	[27,28]
Dendrocalamus Asper (Treated with fresh water)	140-230	[29]
Dendrocalamus Asper (Treated with salt water)	137.97	[29]
Moso Bamboo	211.18	[27,28]
Dendrocalamus Merrillianos E. (Untreated)	168 - 178	***This study***
Dendrocalamus Merrillianos E. (Treated with salt water)	240 - 260	***This study***
Dendrocalamus Merrillianos E (Treated with saltwater + mango Polyphenol)	257 - 272	***This study***
Dendrocalamus Asper s. (Untreated)	189	***This study***
Dendrocalamus Asper s. (Treated with salt water)	237 - 255	***This study***
Dendrocalamus Asper S. (Treated with saltwater + mango Polyphenol)	245 - 274	***This study***
Bambusa Blumeana s. (Untreated)	150 – 165	***This study***
Bambusa Blumeana s. (Treated with salt water)	232 - 268	***This study***
Bambusa Blumeana s. (Treated with saltwater + mango Polyphenol)	222 - 270	***This study***
Bambusa Vulgaris s. (Untreated)	180 - 190	***This study***
Bambusa Vulgaris s. (Treated with salt water)	226 - 254	***This study***
Bambusa Vulgaris s. (Treated with saltwater + mango Polyphenol)	220 - 260	***This study***

The native Philippine bamboo species is comparable to some organic materials which stronger than [29] Dendrocalamus Asper (Treated with fresh water), Dendrocalamus Asper (Treated with salt water), and [27], [28] Moso Bamboo and against the good wood. Although bamboo is already utilized in many engineering applications in construction because of its high strength-to-weight ratio [29], data from the potential designation as reinforcement must be emphasized to accumulate the designer of respective planning for construction. The strength of bamboo is greater than the other organic and good lumber products, but it is quite lower than the tensile strength of steel [29]. Bamboo is a good substitute for steel bars as reinforcement for concrete for nonheavy load-bearing structures and low-rise structures. There would lower the construction cost and increase the strength of the building that is otherwise unreinforced [29].

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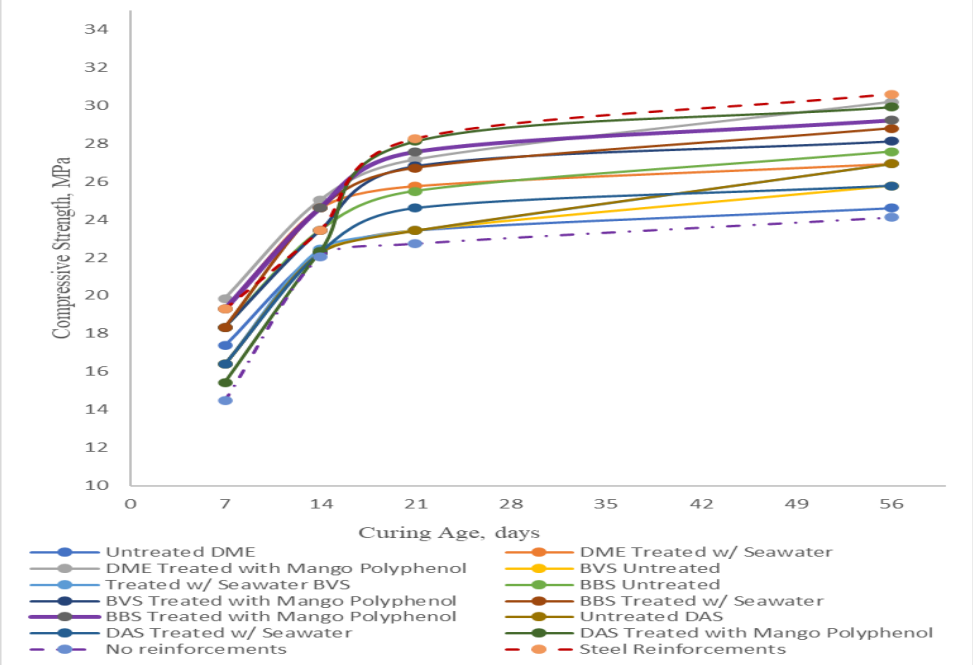

Fig 2: Compressive Strength of Concrete Reinforced with bamboo sticks as a replacement for Steel bars

Based on Graphical presentation shown in fig. 2 shows the axial compressive strength of concrete reinforced with Bamboo sticks. Among the species, ***Dendrocalamus Asper Schultes*** and ***Dendrocalamus Merrillianos Elmer*** were used as substitute reinforcements for concrete, having the highest axial compressive strength of 30 MPa when treated with seawater plus mango Polyphenol in 56 days. The lowest tensile strength among the species is the ***Bambusa Vulgaris Schrad,*** with a tensile strength of 28 MPa.

This implies that ***Dendrocalamus Asper Schultes and Dendrocalamus Merrillianos Elmer*** species, when treated naturally with seawater pus mango polyphenol extract, is a good substitute for steel reinforcement for concrete subjected to axial load. This implies that the treatment with mango polyphenol extracts improves the tensile strength of bamboo sticks, which is nearly comparable to the steel tensile strength.

However, when it is used as reinforcement for concrete, the bamboo sticks have lower effects on the compressive stress of concrete. However, a similar study of bamboo as reinforcement in structural concrete elements shows that it can replace steel satisfactorily as reinforcement in concrete structures [30].

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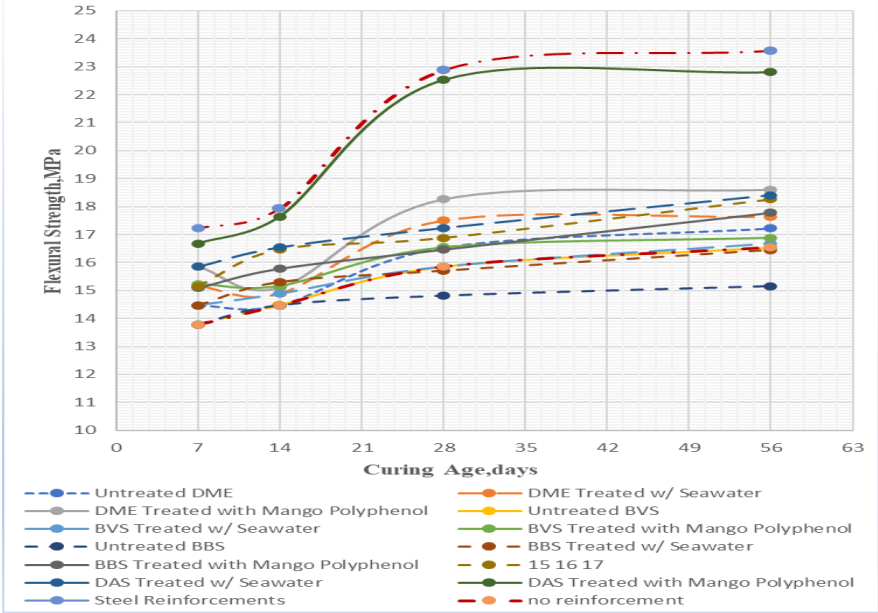

Fig 3: Flexural Strength of Concrete beam reinforced with bamboo sticks as a replacement for Steel bars.

The graphical Presentation in fig. 3 reveals the flexural strength of concrete reinforced with 10mm diameter bamboo sticks treated with saltwater plus mango polyphenol subjected to flexural loading in the midspan. The highest flexural strength obtained was 23 MPa cured for 56 days of the ***Dendrocalamus Asper Schultes*** and ***Dendrocalamus Merrillianos Elmer*** however, the flexural strength of concrete with bamboo sticks reinforced materials did not exceed the highest compressive stress of concrete reinforced with 10 mm diameter steel bars. This implies that the treatment of bamboo with mango polyphenol extracts improves the tensile strength of bamboo sticks, which is nearly comparable to the steel tensile strength, however, when it is used as reinforcement for concrete, the bamboo sticks influence the flexural stress of concrete [30]. Thus, the ***Dendrocalamus Asper Schultes and Dendrocalamus Merrillianos Elmer*** is the best substitute for concrete reinforcement, wherein almost comparable to steel [29].

Table 2: Comparison of compressive strength of concrete mixtures reinforced with steel bars and reinforced with untreated and treated bamboo

Source of Variation	*SS*	*df*	*MS*	*F*	*P-Value*	*F crit*	
Curing age	259574.8	3	86524.94	3.198824	0.035	2.866266	Significant
Reinforcements	6546975	12	545581.2	20.17012	0.000	2.032703	Significant
Error	973763.4	36	27048.98				
Total	7780313	51					

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Table 2 reveals a significant difference between the compressive strength of concrete subjected to several curing periods. This means that concrete curing affects its compressive strength and the treatment age of bamboo reinforcements. The table also reveals a significant difference between the compressive strength of concrete reinforced with bamboo sticks when no treatment at all, treated with seawater, and treated with seawater plus 10 percent mango polyphenol and steel bars. The results also revealed that the compressive strength of concrete reinforced with different bamboo species did differ significantly. This implies that the concrete compressive strength depended on the curing age of the concrete, the treatment age of bamboo sticks, the species of bamboo sticks used as reinforcement, and the treatment of bamboo sticks used. Bamboo provides good support, holding high tension and compressive strength [34]. The performance of bamboo as an alternative material in reinforced concrete shows that bamboo has a similar characteristic to steel and can be used as an alternative material for reinforcing concrete. Thus, with proper treatment, ***Dendrocalamus Asper Schultes and Dendrocalamus Merrillianos Elmer*** bamboo species are significantly significant as a possible replacement for steel bars in concrete structures.

Table 3: Comparison of compressive strength of concrete mixtures reinforced with steel bars, untreated and treated bamboo

Sources of variation	**SS**	**df**	**MS**	**F- values**	P-value	F-critical @ 0.05	Remarks
Concrete curing	2309231	3	769743.6	37.6623	0.00	2.8663	Significant difference
Reinforcements	925769.2	12	77147.44	3.7747	0.001	2.0327	Significant difference
Error	735769.2	36	20438.03				
Total	3979769	51					

Table 3 reveals a significant difference between the flexural strength of concrete subjected to several curing periods, the treatment age of bamboo reinforcements, and bamboo species used as replacements for steel bars. The table also reveals a significant difference between the flexural strength of concrete reinforced with bamboo sticks when no treatment at all, treated with seawater, and treated with seawater plus 10 percent mango polyphenol and steel bars. The results also revealed that the flexural strength of concrete reinforced with different bamboo species did differ significantly. This implies that the concrete flexural strength depended on the curing age of the concrete, the treatment age of bamboo sticks, the species of bamboo sticks used as reinforcement, and the treatment of bamboo sticks used. Bamboo provides good support, holding high tension and flexural strength [34]. A flexural strength test of the bamboo singly reinforced beam has been undertaken to determine the performance of bamboo as reinforcement. It has resulted that bamboo has good potential as an alternative material in concrete support for the low-cost housing industry [36]. The performance of bamboo as an alternative material in reinforced concrete shows that bamboo has a similar characteristic to steel

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and can be used as an alternative material for reinforcing concrete. Thus, with proper treatment, ***Dendrocalamus Asper Schultes and Dendrocalamus Merrillianos Elmer*** bamboo species are significantly significant as a possible replacement for steel bars in concrete structures.

IV. CONCLUSION AND RECOMMENDATION

The tensile strength of bamboo was improved and increased when treated in seawater and with 10 percent mango polyphenol. The ***Dendrocalamus Meridians Elmer*** and **Dendrocalamus Asper Schultes** are a good possible substitute for steel-reinforced concrete subjected to axial compression and flexural test, [33] thus being used for long-span, heavy-load bamboo structural engineering.. The obtained compressive strength of concrete reinforced with treated bamboo sticks achieved good quality, wherein concrete compressive strength depended on the curing age, the specie of bamboo sticks used as reinforcement, and the treatment of bamboo sticks used. Therefore, treated bamboo can replace steel bars, specifically ***Dendrocalamus Merrillianos Elmer and Dendrocalamus Asper Sc*****hultes**. The bamboo sticks naturally treated were the best possible concrete reinforcements as replacements for steel bars, hereby recommended for no heavy load-bearing structures for low-rise residential structures only. ***Dendrocalamus Asper Schultes and Dendrocalamus Merrillianos Elmer*** are significant potential for constructing low-cost and low-rise housing units [31] as concrete beams, columns, and other structural concrete. Bamboo provides good reinforcement as it holds excellent tension and compressive strength. The flexural strength of the concrete beam having bamboo reinforcement shows greater strength which helps to improve the usage of bamboo [32]. Hence, bamboo can act as a good potential reinforcement for low-cost housing and conveniently replace steel, thereby saving natural resources considerably [35]. It is recommended to further study bamboo molecular interlinks and interactions between the concrete.

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