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Design Parameters of Bamboo Reinforcement One Way Slab

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Abstract— Investigation was undertaken to find design parameters, the potential of bamboo as a reinforcement within concrete slab to compensate the low tensile property of the concrete. Although steel reinforcement is a very appropriate material for complementing concrete's low tensile strength, considering the cost. In some parts of the world people build their houses by using solely concrete or mud-brick which is very vulnerable. To overcome these problems, bamboo may be the materials to substitute the reinforcing bar in concrete for less important structures. To evaluate these properties, tension test was conducted on bamboo specimen. From this test, the tensile strength, proof strength and modulus of elasticity were determined from stress-strain curve for bamboo reinforcement and satisfactory results are obtained in terms of tensile strength and stress-strain characteristics of bamboo for using as reinforcement in the concrete.

***Index Terms*— Tensile Strength, stress-strain characteristics, standard deviation, Stress block, Modulus of elasticity of bamboo, Modulus of elasticity of concrete**

I. INTRODUCTION

Most developing countries have many issues, and one amongst the most issues is housing. The housing problem has been related to lack of analysis in field of low price housing schemes. Scientists, engineers, and designers need training and education for finding low cost construction and efficient plans. Bamboo is one of the oldest building materials used by mankind. The bamboo culm, or stem, has been made into an extended diversity of products ranging from domestic household products to industrial applications. Their strength, straightness, lightness combined with extra ordinary hardness, range in size, abundance, simple propagation, and also the short amount within which they attain maturity, make them suitable for a variety of purposes and hundreds of different uses.

It is the single most important organic building material which is easily available in India. It's utilized over 70% of rural houses and extensively used as informal shelter for the urban poor. At present, there is an acute shortage of housing because of the scarcity of conventional materials coupled with rapid population growth. Several villagers were already adopted weavers of bamboo, thus quickly mastered the frame construction technique. Bamboo is one material, which can have an incredible economic advantage, because it reaches its full growth in just a few months and reaches its maximum mechanical resistance in just few years. Moreover, it exists in abundance in tropical and subtropical regions of the globe. The energy necessary to produce 1 m^3 per unit stress projected in practice for materials commonly used in civil construction, such as steel or concrete, has been compared with that of bamboo. It was found that for steel it is necessary to spend 50 times more energy than for bamboo. The tensile strength of bamboo is relatively high and can reach 370 MPa. This makes bamboo an attractive alternative to steel in tensile loading applications. This is due to the fact that the ratio of tensile strength to specific weight of bamboo is six times greater than that of steel.

II. CALCULATION OF DESIGN CONSTANT

Table 1 Calculation of average tensile strength and standard deviation

Sample No.	**Tensile strength (x) MPa**	**Average tensile strength $\bar{x} = \frac{\sum x}{n}$**	**Deviation $(x - \bar{x})$**	**Square of deviation $(x - \bar{x})^2$**
1	136.32	135.92	0.4	0.16
2	133.4		-2.52	6.35
3	135.6		-0.32	0.1
4	133.8		-2.12	4.49
5	135.6		-0.32	0.1
6	137.4		1.48	2.2
7	137.74		1.82	3.31
8	139.1		3.18	10.11
9	134.7		-1.22	1.49
10	135.5		-0.42	0.18
Total	1359.16			28.49

$fck = 20\ N/mm^2$

$$\text{Average tensile strength of bamboo, fby} = \frac{1359.16}{10}$$
$$\text{fby} = 135.92\ \text{N/mm}^2$$
$$\text{Standard deviation} = \sqrt{\frac{135.92}{\text{N}-1}}$$
$$= \sqrt{\frac{135.92}{10-1}} = 3.87\ \text{N/mm}^2$$
$$\text{Coefficient of variation} = \frac{\text{Standard deviation}}{\text{Average tensile strength}} \times 100$$
$$= \frac{3.87}{135.92} \times 100 = 2.85\ \%$$
$$\gamma_m = 1.5$$
$$\text{Strain} = 0.0028$$
$$E_b = 19.7 \times 10^3\ \text{N/mm}^2$$
$$E_c = 5700\sqrt{\text{fck}}$$
$$E_c = 5700\sqrt{20}$$
$$E_c = 25.49 \times 10^3\ \text{N/mm}^2$$
$$\frac{\text{fby}}{\gamma_m} = \frac{\text{fby}}{1.5} = 0.67\text{fby}$$
$$\varepsilon_{bu} = \frac{0.67\ \text{fby}}{E_b}$$
$$x_u = \frac{\varepsilon_{cu}}{\varepsilon_{cu} + \varepsilon_{bu}} \times d$$
$$\frac{x_{u\ max}}{d} = \frac{\varepsilon_{cu} \times E_b}{(\varepsilon_{cu} \times E_b) + (0.67\ \text{fby})}$$
$$\frac{x_{u\ max}}{d} = \frac{0.0035 \times 19.7 \times 10^3}{(0.0035 \times 19.7 \times 10^3) + (0.67 \times 135.92)}$$
$$\frac{x_{u\ max}}{d} = 0.431$$
$$\%\ \mathbf{Pt} = \frac{\mathbf{100\ Asb}}{\mathbf{bd}}$$

III. For Singly Reinforced Section

The maximum stress in bamboo is limited to $\frac{\text{fby}}{\gamma_m} = \frac{\text{fby}}{1.5} \cong 0.67\ \text{fby}$

From fig. 5.2 area c_u of design stress block,

$$c_u = \text{area ABCD} = k_1 \times x_u \times \text{DC} = k_1 \times x_u \times \frac{k_3 \times \text{fck}}{\gamma_m}$$
$$k_1 = 0.8095, k_3 = 0.67 \text{ and } \gamma_m = 1.5$$
$$c_u = 0.36\ \text{fck}\ x_u$$
$$C_u = T_u$$
$$0.36\ \text{fck}\ X_u b = 0.67\ \text{fby Asb}$$
$$\frac{x_u}{d} = \frac{0.67 \times \text{fby} \times \text{Asb}}{0.36 \times \text{fck} \times b \times d}$$
$$\frac{x_u}{d} = 1.861 \frac{\text{fby}}{\text{fck}} \times \text{Pt}$$
$$\text{Pt} = 0.431 \times \frac{\text{fck}}{\text{fby}} \times \frac{1}{1.861}$$
$$\text{Pt} = 0.431 \times \frac{20}{135.92} \times \frac{1}{1.861}$$
$$\%\ \mathbf{Pt = 3.41}$$

IV. Moment Calculation

$$M_u = T_u \times Z$$
$$T_u = 0.67\ \text{fby Asb}$$
$Z = (d - 0.42\ x_u)$ ………… As per page No.64 IS 456-2000
$$M_u = 0.67 \times \text{fby} \times \text{Asb} \times (d - 0.42\ x_u)$$
$$\mathbf{M_u = 0.67 \times fby \times Asb \times d \left(1 - 0.42\ \frac{x_u}{d}\right)}$$

V. Equal to Limiting Value

$$M_{u\ lim} = 0.36 \times \text{fck} \times x_{u\ max} \times b \times (d - 0.42\ x_{u\ max})$$

$$M_{u\,lim} = \frac{0.36 \times fck \times x_{u\,max}}{d}\left(1 - \frac{0.42\ x_{u\,max}}{d}\right) bd^2$$

$$M_{u\,lim} = 0.36\ fck \times 0.431\left(1 - (0.42 \times 0.431)\right) \times bd$$

$$\mathbf{M_{u\,lim} = 0.127\ fck\ bd^2}$$

VI. DESIGN TO DETERMINE AREA OF REINFORCEMENT OF BAMBOO

Determine the limiting value moment of resistant

$$M_{u\,lim} = \frac{0.36 \times fck \times x_{u\,max}}{d}\left(1 - \frac{0.42}{d}\right) bd^2$$

$M_u = M_{u\,lim}$ Balanced section

$M_u > M_{u\,lim}$ Doubly reinforced section

$M_u < M_{u\,lim}$ Under reinforced section

Take $M_u < M_{u\,lim}$

$$M_u = 0.67 \times fby \times Asb \times (d - 0.42\ x_u)$$

$$\frac{x_u}{d} = \frac{0.67 \times fby \times Asb}{0.36 \times fck \times b \times d}$$

$$M_u = 0.67 \times fby \times Asb \times d\left(1 - 0.42\ \frac{x_u}{d}\right)$$

$$M_u = 0.67 \times fby \times Asb \times d\left(1 - 0.42\ \frac{0.67 \times fby \times Asb}{0.36 \times fck \times b \times d}\right)$$

$$M_u = 0.67 \times fby \times Asb \times d\left(1 - \frac{0.774 \times fby \times Asb}{fck \times b \times d}\right)$$

$$M_u = 0.67 \times fby \times Asb \times d\left(1 - \frac{0.519 \times fby^2 \times Asb^2}{fck \times b}\right)$$

$$M_u \times fck \times b = 0.67 \times fby \times Asb \times fck \times b \times d - 0.519\ fby^2 Asb^2$$

$$0.519\ fby^2 Asb^2 - 0.67 \times fby \times Asb \times fck \times b \times d + M_u \times fck \times b = 0$$

This is a quadratic equation in the form of,

$$ax^2 + bx + c = 0$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$x = Asb$

$a = 0.519\ fby^2$

$b = -0.67 fby \times fck\ bd$

$c = Mu \times fck \times d$

$$Asb = \frac{-(-0.67 fby \times fck \times bd) - \sqrt{[(-0.67 \times fby \times fck \times bd)^2 - (4 \times 0.519 \times fby^2 \times Mu \times fck \times b)]}}{2 \times 0.519 \times fby^2}$$

$$Asb = \frac{(0.67 fby \times fck \times bd) - \sqrt{[(0.67 \times fby \times fck \times bd)^2 - (2.076 \times fby^2 \times Mu \times fck \times b)]}}{1.038 \times fby^2}$$

$$Asb = \frac{(0.67 fby \times fck \times bd) - \sqrt{\left[(0.67 \times fby \times fck \times bd)^2\left(1 - \frac{4.624 Mu}{fck \times bd^2}\right)\right]}}{1.038 \times fby^2}$$

$$Asb = \frac{(0.67 fby \times fck \times bd) - (0.67 \times fby \times fck \times bd)\sqrt{\left(1 - \frac{4.624 Mu}{fck \times bd^2}\right)}}{1.038 \times fby^2}$$

$$Asb = \frac{0.67 fby \times fck \times bd\left[1 - \sqrt{1 - \frac{4.624 Mu}{fck \times bd^2}}\right]}{1.038 \times fby^2}$$

$$\mathbf{Asb = \frac{0.645 fck}{fby}\left[1 - \sqrt{1 - \frac{4.624 Mu}{fck \times bd^2}}\right]}$$

Table 2 List of Abbreviations

F_{ult}	Maximum load	f_{by}	Tensile strength of bamboo
σ_{ult}	Maximum tensile strength	E_b	Modulus of elasticity of bamboo
F_{ck}	Characteristic compressive strength	E_c	Modulus of elasticity of concrete
M_u	Factored moment	γ_m	Partial safety factor for material
pt %	Percentage tensile steel	A_{sb}	Tensile area for bamboo
τ_c	Shear taken by concrete	asb	Tensile area for one bamboo
f_y	Tensile strength of steel		

VII. CONCLUSION

The bamboo Culm, in general, is a cylindrical shell, which is spilt by transversal diaphragms at the nodes. Bamboo shells are orthotropic materials with high strength in the direction parallel to the fibers and low strength perpendicular to the fibers. The thickness and strength of bamboo, however, decreases from the bottom to the top of the bamboo shell. In this paper work attempt is made to find out design parameters of Chandrapur bamboo over steel. Tensile strength of bamboo with node is

135.92 N/mm^2 and bamboo without node is $349.21 N/mm^2$. $\% \, Pt = \frac{100\, Asb}{bd}$, $\% \, Pt = 3.41$, $M_u = 0.67 \times fby \times Asb \times d\left(1 - 0.42\,\frac{x_u}{d}\right)$, $M_{u\,lim} = 0.127\, fck\, bd^2$,

$$Asb = \frac{0.645fck}{fby}\left[1 - \sqrt{1 - \frac{4.624Mu}{fck \times bd^2}}\right]$$

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