Table 6: Energy absorption capacity

Types of beams	NWCB	CSCB	BCSC	BCSCB
Energy absorption (kNmm)	155	132	255	205

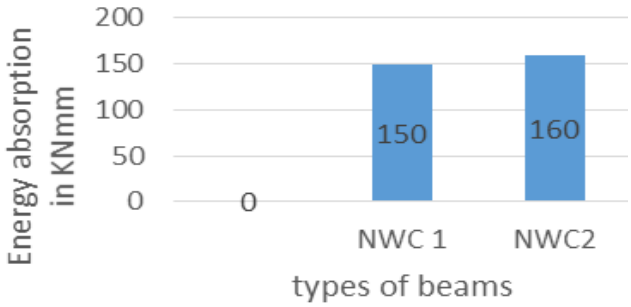

Figure 6a: Energy absorption values for NWC

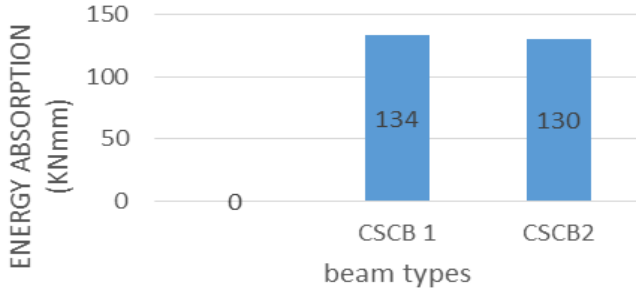

Figure 6b: Energy absorption values for CSCB beams

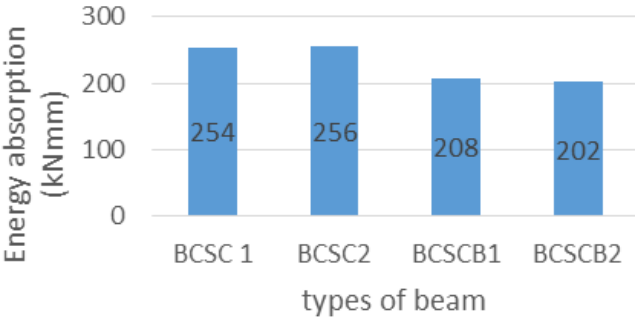

Figure 6c: Energy absorption values for BCSC and BCSCB beams**5.7.4**

4.9 Stiffness (α)

The stiffness of any beam is defined as load per unit deflection using load Vs deflection curves stiffness at various load ratios were calculated and tabulated in Table 5 and Figure. 7. The stiffness behaviour of CSCB beams showed similar trend as that of NWCB beams up to failure. Similarly, the stiffness of BCSCB beams are 37.5% higher than that of BCSC beams at a load ratio of 0.2 and 17.9% lower than NCWB beams. At maximum load ratio the stiffness of BCSCB beams remains constant from 0.8 to 1.0 load ratio, while for BCSC beams the stiffness remains constant from 0.6 to 0.8 load ratio, this is attributed due to the low stiffness of BCSC beams.

Table 7. Stiffness Vs Load ratio

P/P_u	Average Stiffness (kN/mm)			
	NWCB	CSCB	BCSC	BCSCB
0.2	33.5	27.5	12.5	20
0.4	16	25	9.17	11
0.6	12.5	12.5	5.63	10
0.8	9.5	10.5	5.63	8
1.0	9.5	9.5	3.17	8

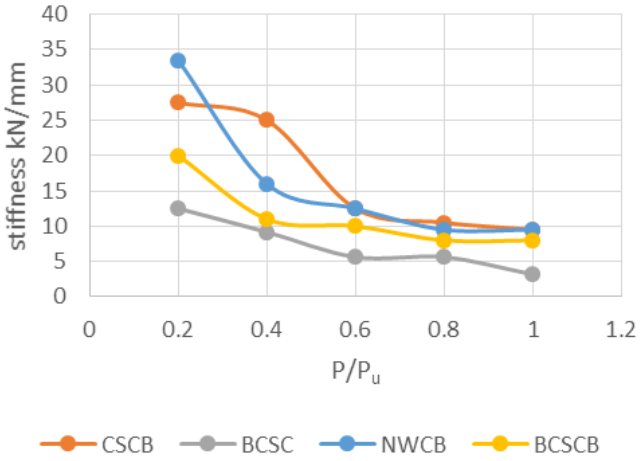

Figure 7: Stiffness Vs Load for all the types of beams.

5. Conclusions

From the research work and experimental result obtained the following conclusions can be made:

1) Tension test performed on bamboo strip revealed elastic behaviour and its ultimate strength was 112.05N/mm^2.
2) The modulus of elasticity of coconut shell concrete was found to be 12075.2N/mm^2 which represents 54%, 57%, 43.88% and 60.36% that of modulus of elasticity of conventional concrete for IS 456, ACI-318, EU and BS 8110 codes respectively.
3) The load carrying capacity of the NWC beams were slightly higher than CSCS, BCSC, and BCSCB beams
4) The stiffness behaviour of CSC beam showed similar trend as that of NWC up to failure
5) Energy absorption was more for BCSC than NWC, BCSC and BCSCB beams. This is attributed due to the high deflections due to applied loads
6) Deflections are higher in BCSC and BCSCB beams when compared to NWC and CSCS beams and by wrapping the split bamboo with binding wire the deflections were slightly reduced in BCSCB beams compared to BCSC beams.
7) The ductility of BCSC and BCSCB beams were higher than that of NWCB and CSCB beams, this is due to the larger deformations by the bamboo reinforcements before failure.

References

[1] Ajinkya. (2013) ″Analysis of bamboo reinforce concrete column″ International journal of innovative Research in Science and Technology, Vol.2, pp. 2461-2464.
[2] Adom-Asamoah (2011), ″A comparative study of bamboo reinforced concrete beams using different stirrup material for rural construction ″ International journal of civil and structural engineering volume 2, No 1, 2011.
[3] Amutha. S (2014), ″ Study of behaviour of coconut shell aggregate concrete with bamboo reinforcement in compression member ″M. Tech thesis SRM University Kattankulathur Chennai, India.
[4] FIP Manual, 1983. "FIP Manual of Lightweight Aggregate Concrete, 2ed. London: Surrey University Press.

[5] Gunasekaran. K., Kumar. P.S, Lakshmipathy. M (2011) ″Mechanical and bond properties of coconut shell concrete ″, Construction and building material journal. Vol. 25(1):92-98.
[6] Gunasekaran. K., Kumar. P.S (2008) ″ Lightweight concrete using coconut shell aggregate. In: proceedings of the ICACC-2008. International conference on advances in concrete and construction, Hyderabad, India, 7-9 pp. 4-9
[7] Ghavami, K. (2005), ″Bamboo as reinforcement in structural concrete elements, ″ cement & concrete composites journal. Vol.17, pp281-288.
[8] Johnson Alengaram (2008), "Ductility Behaviour of Reinforced Palm Kernel Shell Concrete Beams" European Journal of Scientific Research ISSN 1450-216X Vol.23 No.3 (2008), pp.406-420.
[9]] Maninder Kaur. (2012), A Review on utilization of coconut shell as coarse aggregates in mass concrete. International journal of Applied Engineering Research, Issue, Vol.7 No.11, pp.73-4562.
[10]] Jigar K. Sevalia (2013) "Bamboo as Reinforcement in Cement Concrete" International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622 Vol. 3, March -April 2013, pp.1181-1190.
[11] Kent. A (2006) "Structural use of full Culm bamboo in the path of standardization "international journal of Architecture, Engineering and construction. Vol.1, No.2 pp. 66-75.
[12] Satjapan Leelatanon., Suthon Srivaro., and Nirundorn Matan. (2010)., "Compressive strength and ductility of short columns reinforced by bamboo ″ wood science and engineering Research unit, school of engineering and management, Walailak University , Thasala Nakhon si Thammarat, 80160 Thailand.
[13] Sitti Aminah Bt Tukiman and Sabarudin Bn Mohd (2009) "Coconut shell and grained palm kernel to replace aggregate in concrete: a technical review″ National conference on postgraduate research (NCON-PGR) UMP Malaysia.
[14] Vishwas.P (2013) "Comparative study on coconut shell aggregate with conventional concrete", International Journal of Engineering and Innovative Technology, (IJEIT) Vol.2 No.12.
[15]] Wu Yao, Zongjin Li (2003) "Flexural behaviour of bamboo-fiber reinforced mortar laminates " cement and concrete research, Vol.33(1):pg. 15-19.

Author Profile

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