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Bamboo as an Alternative to Coarse Aggregate

Bibhab Kumar Das[1], Girija.T.R[2] and Koushik Sarkar[3]

[1,2,3]Assam DonBosco University
E-mail: [1]bibhabdx@gmail.com, [2]girija.r@dbuniversity.ac.in, [3]koushik.sarkar@dbuniversity.ac.in

Abstract—*Aim of the paper is to study the effect in the compressive strength of concrete by partial and full replacement of coarse aggregates by bamboo chips made aggregates. The Bambusa tulda species of bamboo was used due to its abundance density in the North-East India. Seasoned specimens were used of nominal sizes of 25 mm. The 7, 14, 21 and 28 day compressive strength under UTM is tested. Also, the effect of shape and size of bamboo aggregates on compressive strength is tested. The hydraulic factors were maintained constant for M25 concrete. The variation in strength was in a positive direction, which attests to the fact that bamboo chips can replace the use of coarse aggregates in a concrete mix. The fibers obtained during the process of cutting the bamboo chips, helps in formation of good bond with the concrete. It also adheres to the processing of light weight concrete, and also a column for cost comparison was made as the conclusion of the paper.*

Keywords*: Partial; Bamboo Chips; Bambusa tulda; Hydraulic Factors; Fibers; Light Weight.*

1. INTRODUCTION.

Bamboo is one of the most versatile naturally occurring materials. Just like old times, in the recent years too, researches attest to the green light for the use of bamboo as a construction material. Bamboo has a strong potential for the use as a reinforcing as well as composite material with cement. The biodegradability of bamboo is a major problem rendering it less serviceable. If somehow can be processed in such a way that it is less affected by bacterial attack, fire or any other natural impurities, then certainly better performances can be obtained both for short term and long term, which may results in better durability, strength and sustainability.Various test results on mechanical, physical properties of bamboo reinforced column and beams are reviewed by **Kaware et al. (2013)[1].** Problem faced using the species namely *Dendrocalamus strictus, Bambusa vulgaris schard* are water absorption and moisture content. It was concluded that to avoid these, proper seasoning or treatment should be given to bamboo and Bamboo concrete composite structural members can provide tailored solutions to eco-housing initiatives at low cost. It was observed that bamboo is weak in shear, so it cannot be used as shear reinforcement in building.The results of the tests conducted by **Javadian et al. (2016)[5]** showed us that addition of fine sand particles to water based epoxy coating has shown little effect on enhancement on bonding between bamboo-composite reinforcement and the concrete matrix. Significant difference does not occur between coarse and fine aggregate, either can be used. **Raj and Agarwal. (2014)[6]** opined that Bamboo is easily available and eco-friendly material, which is easy and effective to work. Importantly it has enormous elasticity, which makes it very useful building material in the high risk earthquake zone. The portion of lignin inside the culm affects the compressive strength and high portion of cellulose affects the buckling and tensile strength. Bamboo is an anisotropic material. Cellulose fibers in the longitudinal direction are strong and stiff, transverse direction lignin is soft and brittle.Various properties of bamboo fiber are discussed, together with the composites made from those fibers by **Liu et al. (2014)[7]**. Various mechanical, chemical and biological approaches for the preparation and separation of macro-, micro- and nano- sized fibers from raw bamboo are summarized. The differences in the mechanical, thermal and other properties of fibers from different materials are linked to their size, aspect ratio, surface charge and groups, and their function in nature. The structure of bamboo fibers at micro level viz. chemical and crystalline structure are studied in a detailed manner in the paper. Various bamboo fiber filled composites are studied at the molecular level and their interaction at the macro-level. Bamboo fiber has a relatively high strength and low cost, and can be used effectively as reinforcement in polymer matrix composites, replacing synthetic fibers to some extent. Physical and chemical methods used to treat bamboo fiber composites improve their mechanical properties because of increased fiber matrix adhesion.**Studies done by Chen et al. (2015)[2]** revealed that the tensile strength of chemically retted samples was higher than that of mechanically retted ones, whereas the modulus and elongation are lower. In case of fiber bundles, the tensile strength, modulus and elongation of chemically retted samples are higher compared to mechanically retted ones. For bamboo strips, the tensile strength and modulus were lower than that of samples made from the outer potion of bamboo but higher than inner portion of the bamboo.Durability studies done by **Lima et al. (2008)[3]** concluded that the tensile stress v/s strain curve is linear up to failure. Average tensile strength of bamboo without node is 280 MPa and with node is 100 MPa. The results showed that even after 60 cycles of wetting and drying in solution of calcium hydroxide and tap water did not decrease the bamboo tensile strength or the Young's modulus.

Mahzuz and Ahmed (2012)[4] Conducted a there is a comparitive study on the use of bio-aggregates from rattan, wood and bamboo as coarse aggregate in concrete. Also, reinforced short concrete columns were made where the above mentioned aggregate were used having bamboo and rattan as reinforcement. The highest and lowest compressive stress was found out where bamboo and rattan was used as coarse aggregate. The compressive strength of the specimens was seen to be increased as amounts of bamboo and rattan reinforcement were increased. In this study, bamboo and rattan splints are used as reinforcement in concrete cylinder. Among the unreinforced concrete specimen, rattan reinforcement showed better strength than other two. Among the reinforced specimens, bamboo reinforced concrete showed higher compressive strength. Though rattan, wood and bamboo can take considerable amount of stress, yet their mechanical properties are not fully used when they were use in concrete. If their full strength could be used, then definitaly there would be a revolution in construction industry.For sustainable development without harming the globe, bamboo is one material which will have tremendous economical advantages, as it reaches its full growth in just a few months and reaches its maximum mechanical resistance. Bamboo shells are orthotropic materials with high strength in that direction parallel to the fibers and low strength perpendicular to the fibers respectively. Bamboo is a composite material, consisting of long and parallel cellulose fibers embedded in a ligneous matrix. The density of fibers in the cross-section of a bamboo shell varies along thickness. Drying bamboo is fundamental to its conservation for various reasons. Bamboo with low humidity is less prone to mould attacks especially when humidity content is less than 15%. Physical and mechanical properties increase with decrease in its humidity content **(Terai and Minami., 2011)[8]**.

2. MATERIALS AND METHODOLOGY.

The experiment was performed with OPC grade of 43. The fineness modulus of sand is kept constant at 2.75. Ratio of 1:1.88:2.83:0.82 *(cement: fine aggregate: coarse aggregate: bamboo aggregates)* is used with w/c ratio of 0.5. The *Bambusa tulda* species of bamboo was used due to its abundance density in the North-East India. The fibers are elongated in nature therefore they are of high compressive strength.

Table I Proportions of the mixtures used in the experiments

MATERIALS	PROPORTIONS	AMOUNT (Kg/m3)
CEMENT	1.00	394.32
FINE AGGREGATE	1.88	743.00
COARSE AGGREGATE	2.83	1114.07
BAMBOO AGGREGATE	0.82	325.28

The Bamboo species used was 5 years matured with natural seasoning of up to 1 year and more. For the cubes of coarse aggregates, the nominal size of 20mm is used. For the use of bamboo aggregates, two sets are experimented. The first set consisted of cubicle shaped bamboo aggregates with nominal size of 20mm and second set with haphazard shape with maximum dimension of 20mm. Standard moulds were used of 150 x 150 x 150mm size. Standard procedures were followed while mixing, vibration and curing at all stages of the test. The cubes were cured for 7, 14, 21 and 28 days. The weight of the sample after curing was measured and the variation is noted. The compression was carried out under Universal Testing Machine. The variation in strength is duly noted

Fig. 1. Cross cutter

Fig. 2. preparation of Bamboo aggregates by Cross cutter

Fig. 3. Materials used for preparation of concrete

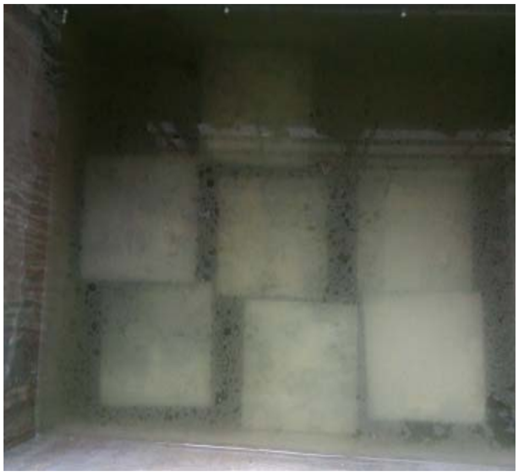

Fig. 4. Curing of cubes

Fig. 5. Natural dryed cubes

Fig. 6. Cubes placed under UTM

For the process of bamboo cutting, cross cutter and table saw were used as per the requirement. The chips were cut by the cross cutter into the desired shapes. In the second set of experiments, 25mm nominal sizes of aggregates were cut, so that gap grading of the aggregates can be obtained. The gap gradation helped in proper bonding, imparting higher strength as compared to the aggregates of uniform size. The fibers of the bamboo run in a longitudinal direction. During the process of cutting the fibers sprout out open. The process of smoothening of bamboo by removing the fibers was avoided. The fibers helped in the process of proper bonding with the concrete and the shrinkage effect was reduced. The mixing process was thoroughly done with the concrete. The quantity of water used was strictly adhered with the mix design calculation.

3. RESULTS AND DISCUSSIONS.

Table 2. Results obtained for cubes using bamboo aggregates and stone aggregates

TYPE		BAMBOO AS COARSE AGGREGATE							STONE AS COARSE AGGREGATE						
DAY OF CURING	SAMPLE	WEIGHT (KG)	AVG WEIGHT (KG)	LOAD (KN)	AVG LOAD (KN)	STRESS (MPA)	AVG STRESS (MPA)		WEIGHT (KG)	AVG WEIGHT (KG)	LOAD (KN)	AVG LOAD (KN)	STRESS (MPA)	AVG STRESS (MPA)	
3	1	6.075		88.671		3.941			8.132		198.634		8.828		
	2	6.375	6.220	78.756	84.228	3.500	3.743		8.786	8.299	201.824	195.607	8.970	8.694	
	3	6.210		85.258		3.789			7.978		186.364		8.283		
7	1	6.830		124.967		5.554			6.758		320.864		14.261		
	2	6.570	6.573	127.465	124.725	5.665	5.543		7.786	7.756	309.835	328.512	13.770	14.601	
	3	6.320		121.743		5.411			8.724		354.836		15.770		
14	1	6.145		214.346		9.526			8.296		494.375		21.972		
	2	6.085	6.103	212.867	215.559	9.461	9.580		8.574	8.872	487.735	494.293	21.677	21.969	
	3	6.080		219.465		9.754		9.943	9.745		500.768		22.256		21.142
14	1	5.980		234.524		10.423			9.473		476.835		21.193		
	2	5.900	5.985	233.264	231.887	10.367	10.306		9.385	9.502	455.644	457.111	20.251	20.316	
	3	6.075		227.873		10.128			9.648		438.854		19.505		
21	1	6.005		112.255		4.989			8.374		512.756		22.789		
	2	5.975	6.107	107.564	110.672	4.781	4.919		8.472	8.407	532.879	527.834	23.684	23.459	
	3	6.340		112.196		4.986			8.375		537.868		23.905		
28	1	6.490		89.647		3.984			9.869		550.845		24.482		
	2	6.105	6.302	89.175	87.993	3.963	3.911		9.730	9.691	547.576	550.762	24.337	24.478	
	3	6.310		85.156		3.785		4.054	9.475		553.864		24.616		23.772
28	1	6.565		94.983		4.221			8.375		543.863		24.172		
	2	6.305	6.388	94.105	94.454	4.182	4.198		8.573	8.617	512.653	518.960	22.785	23.065	
	3	6.295		94.274		4.190			8.904		500.364		22.238		

The cubes obtained after the respective day curing, were allowed to natural dry before the process of crushing. The weights were noted after drying. It was seen that bamboo-aggregates cubes were about 30% lesser weight, as compared to conventional stone based aggregates concrete cubes. In accordance to the production of light weight concrete, the use of bamboo chips serve our purpose. The variation in strength portrays the same nature as the conventional cubes, for 14 days, thereafter, a reduction in compressive strength is observed. Due to prolonged curing, the absorption of water takes place, resulting in expansion of bamboo and radial cracking of concrete bond with the bamboo. Therefore, the strength reduces after prolonged 14 day curing, i.e. for 21 and 28 days.

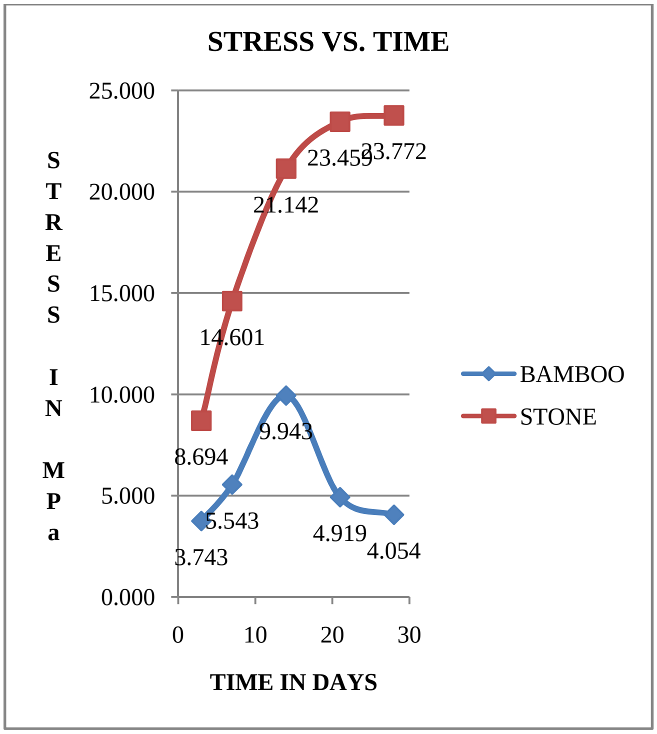

Fig. 7.Comparision of strengths of the cubes on subsequent days

4. FAILURE ANALYSIS

After crushing of the concrete samples, it was observed that for all the cubes, only the mortar has failed rather than the bamboo aggregates. It attests to the fact that there lies a difference in strain in mortar and the bamboo aggregates. Though the bamboo fibers supplemented to the bond formation, it was not good enough to take high load. Smooth bamboo aggregates imparted lesser strength than aggregates with bamboo fibers. For the 3rd and 7th day, the load tends to increase subsequently, till the 14th day. Subsequent day results decreases in the parabolic way, giving us a parabolic graph for the load v/s time. The actual strength of the whole bamboo is tested under the compression testing machine and failure load was observed to be 30 MPa. It clearly shows that the actual strength of the bamboo aggregates was not fully utilized in the concrete, thereby reducing the strength of the cubes.

Fig. 7. Failed specimen

Fig. 8. Fibers helps in bonding with concrete

Fig. 9. Failure of mortar without any effect on bamboo aggregates.

In our study the ratio of the aggregates were confined with the design mix. Ratio of 1:1.88:2.83:0.82 *(cement: fine aggregate: coarse aggregate: bamboo aggregates)* is used with w/c ratio of 0.5. The stone aggregates were completely replaced with the bamboo aggregates. Since the concrete with bamboo aggregates have comparatively less weight than the normal concrete, they can be used to reduce the dead load of the structure, as light weight concrete. The questions come into play is the strength of the bamboo based concrete. As the strength offered is not so high enough, they can be used for light weight structures, and non load bearing members. Exposure to environmental conditions may harm the quality of the concrete with the bamboo aggregates; therefore it is suggested not to use it in exterior elements of the structure.

5. CONCLUSION.

Though bamboo can take considerable amount of stress, though their strength rivals steel, yet their mechanical property and strength is not fully utilized when they were used with composite concrete. If, by some means, the mechanical and full strength could be used, then definitely the resulting strength of the concrete cubes could be upgraded. Though there are some governmental organizations, for the development of bamboo technology, yet initiative for engineered production is very meagre. Therefore the price of the bamboo is relatively higher as compared to that of stone. If initiative is taken to use them in construction industry, then definitely their production will be increased in a more engineered manner. It will reduce the cost and supplement in a low cost construction technology.

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