Production of Light Weight Concrete by Bio-Materials

H.M.A.Mahzuz[1], Mushtaq Ahmed[2]

***Abstract*— The study compares the use of bio-aggregates from rattan, wood and bamboo as coarse aggregate in concrete. Also reinforced concrete short columns were made where the above mentioned coarse aggregates were used having bamboo and rattan as reinforcement. Full study was conducted by OPC, ASTM Type-1, sand of a constant fineness modulus (FM) of 2.79 and water–cement ratio of 0.485. Curing of samples was done for 28 days and crushing was performed after 56 days. The highest and lowest compressive stress was found in the concrete where coarse aggregate was rattan and bamboo respectively. The compressive strength of the specimens was seen to be increased as the amounts of bamboo and rattan as the reinforcement were increased. Moreover, as the weights of the concrete of bio-aggregates were found much less than that of normal weight concrete, therefore as light weight concrete these materials may reduce dead load of structure considerably.**

***Index Term*— Compression, Reinforcement Ratio, Specific heat, Water Absorption and release, Elasticity.**

I. INTRODUCTION

Concrete is a stone like material made mainly of Cement, sand, stone and water. Cement and sand are used as binding and filling materials respectively. Stone is used as volumetric material. Water is used for the hydration of cement. In Reinforced Concrete Steel is used to aid concrete in taking more tension and compression. This is the very common feature of conventional concrete and reinforced concrete. From the ancient time naturally available bio-products (e.g. Bamboo, Rattan, Wood etc) are used to solve the housing problem. Some of them are very cheap and locally available. Though not like steel or concrete, yet they offer considerable amount of strength. That's why they took part in various researches. For example Mark and Russell (2011), Ghavami K (1995) have successfully used bamboo as reinforcement in concrete beams. Research is also conducted by Ghavami K (2005), Mahzuz et al (2011) and Leelatanon et al (2010) using bamboo as Reinforcement in concrete column.

H.M.A.Mahzuz, PhD Student, Department of Civil and Environmental Engineering, Shahjalal University of Science & Technology, Sylhet, Bangladesh, mahzuz_211@yahoo.com
Mushtaq Ahmed, Professor, Department of Civil and Environmental Engineering, Shahjalal University of Science & Technology, Sylhet, Bangladesh mushtaq_cee@yahoo.com

Despite them research were also done to evaluate the various characteristics of bamboo by Ghavami K (2007), Sabbir et al (2011), Okhio et al (2011) and Amada et al. (1997). Rattan, which is another fast growing grass, can also show significant physical strength. Chowdhury (2004), Peki et al (1991) and Kabir et al (1993) have made a detailed study on the physical and mechanical properties of different types of rattan. But the main problem is that they are bio-degradable therefore have less serviceability. If these locally available natural materials are processed in such a way that they will be less affected by bacterial attack, fire or any other natural impurities then certainly better performance can be shown by them which may result in better durability, strength and sustainability. In this research such an attempt is taken. Here Rattan, Wood and Bamboo are used in concrete as coarse aggregate. Nevertheless, Rattan and Bamboo were used as reinforcement in concrete of bio-aggregates. Finally comparison is tried to with respect to specific heat, weight, waster absorption and strength.

Nomenclature:

Nomenclature	Description
CR	Concrete where rattan is used as coarse aggregate
CW	Concrete where wood is used as coarse aggregate
CB	Concrete where bamboo is used as coarse aggregate
CRB	Concrete where rattan is used as coarse aggregate and Bamboo is used as reinforcement
CRR	Concrete where rattan is used as coarse aggregate and Rattan is used as reinforcement
CWB	Concrete where wood is used as coarse aggregate and Bamboo is used as reinforcement
CWR	Concrete where wood is used as coarse aggregate and Rattan is used as reinforcement
CBB	Concrete where Bamboo is used as coarse aggregate and Bamboo is used as reinforcement
CBR	Concrete where Bamboo is used as coarse aggregate and Rattan is used as reinforcement

II. MATERIAL AND TESTING PROCEDURE:

The research was performed by Ordinary Portland Cement (ASTM Type-1 OPC). Two mixing ratios 1:2:2 and 1:2:3 were used in this study having the same water-cement (w/c) ratio (0.485). The fineness modulus (FM) of sand was kept constant at 2.79. Bamboo (*Bambusa balcooa*), rattan (*Daemonorops jenkinsiana*), wood (*Acacia auriculiformis*) were used as coarse aggregate in concrete.

TABLE I

Physical Properties of the different materials used

Name	Unit Weight, (Kg/m3)	Moisture Content (%)
Water	1000	---
Cement	1440	---
Sand	1480	---
Rattan	375	32.21
Wood	480	25.37
Bamboo	455	22.75

TABLE II

Mixing criteria of Materials for Concrete

Ratio	**FM of FA**	**W/C Ratio**	**CA**	**Reinfo-rcing material**	ρg	**Time**
1:2:2 and 1:2:3	2.79	0.485	Rattan	Bamboo	0	56 days
					2	
					4	
					6	
			Wood		0	
					2	
					4	
					6	
			Bamboo		0	
					2	
					4	
					6	
			Rattan	Rattan	0	
					2	
					4	
					6	
			Wood		0	
					2	
					4	
					6	
			Bamboo		0	
					2	
					4	
					6	

The bio-aggregates were collected form at least three year old trees. They were sliced at maximum size from 12.5 mm to 25 mm (Fig 1-3). To understand the nature of bio-aggregates in absorbing water standard samples of rattan, wood and bamboo were submerged in water for 28 days. The water absorption was measured with time. After 28 days submergence they were kept in open air to measure the water release (or evaporation) for another 28 days more. To have an idea about the compressive strength of the bio coarse aggregates a total of fifty samples of each type were tested. Bamboo and Rattan were used as reinforcement at the reinforcement ratios of 0% (i.e. no reinforcement), 2%, 4% and 6%.

Here bamboo and rattan splints are used as reinforcement steel in concrete cylinder. Each splint has the same length as the concrete sample (300mm). Each sample was provided with a casing four to six number of splints. The total area of the splints per concrete sample was measured to find out the reinforcement ratio. GI weir was used in four positions to hold the splints in position while concrete is poured in mould. For all sample a clear cover of 12.5 mm was maintained (Fig 4). The samples were cured for 28 days. Within these time weight of the samples were monitored at regular interval. To access the water release they were kept at open air for another 28 days after curing. Weights of the samples were monitored at regular interval too. After 56 days the samples were tested at compressive machine.

ASTM based standard methods of concrete mixing, vibration and curing was maintained at all stages of the tests. All the samples were cylindrical in shape having a height of 300 mm and diameter of 150 mm. The unit weight and moisture content of the different materials used are shown at Table 01. Table 02 shows the detailed presentation of the process followed in this test.

Fig. 1. Sliced Rattan used in Concrete

Fig. 2. Sliced Wood used in Concrete

Fig. 3. Sliced Bamboo used in Concrete

Fig. 4. Bamboo encasement

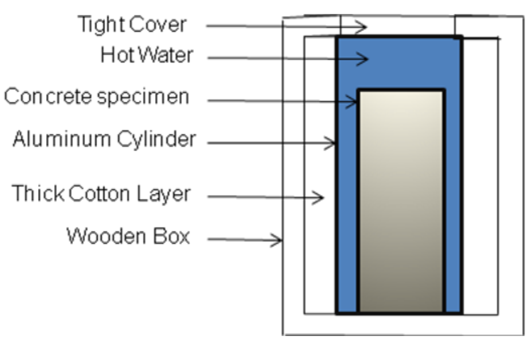

Fig. 5. Calorimeter

III. Calculation of Compressive strength of Reinforcement:

The total strength taken by a reinforced concrete is the sum of the strength taken by concrete and reinforcement respectively. From this Equation (1) was developed from which the compressive stress taken by the reinforcements (i.e. bamboo and rattan) were calculated-

$$P_t = P_C + P_{rf}$$

$$\Rightarrow A_g f_t = A_C f_c^{'} + A_{rf} f_{rf}$$

$$\Rightarrow A_g f_t = (A_g - A_{rf}) f_c^{'} + A_{rf} f_{rf},$$

as $\rho_g = A_{rf} / A_g$

$$\Rightarrow A_g f_t = (A_g - \rho_g A_g) f_c^{'} + \rho_g A_g f_{rf}$$

$$\Rightarrow f_t = (1-\rho_g) f_c^{'} + \rho_g f_{rf}$$

$$\Rightarrow \rho_g f_{rf} = f_t - (1-\rho_g) f_c^{'}$$

$$\Rightarrow f_{rf} = f_t / \rho_g - (1/\rho_g - 1) f_c^{'} \ldots\ldots(1)$$

Where,

P_t = Compression taken by the reinforced concrete cylinder.

P_C = Compression taken by the un- reinforced concrete cylinder.

P_{rf} = Compression taken by reinforcement.

A_g = Gross cross-sectional area of the reinforced concrete cylinder.

A_C = Cross-sectional area of the concrete cylinder.

A_{rf} = Cross-sectional area of the reinforcement.

f_t = Compression taken by the reinforced concrete cylinder.

$f_c^{'}$ = Compressive stress taken by the concrete cylinder.

f_{rf} = Compressive stress taken by the reinforcement

(f_{rf} = f_b = when reinforcement is Bamboo and

f_{rf} = f_r = when reinforcement is Rattan)

ρ_g = Reinforcement ratio.

(ρ_g = ρ_b = when reinforcement is Bamboo and

ρ_g = ρ_r = when reinforcement is Rattan)

IV. Calculation of Specific heat:

Specific heat is a basic thermal property of materials. Since different materials were used as coarse aggregate so there might be seen changes in specific heat then the conventional concrete. To identify the specific heat of the concrete specimens of different aggregates a Calorimeter was prepared. The main component of the Calorimeter is a 4.35 kg Aluminum cylinder having a diameter of 0.3m (1 ft) and a height of 0.45 m (1.5 ft). At first water was heated and its temperature was measured. Then it was poured into the calorimeter where a concrete specimen was already kept at the measured room temperature. After that the Aluminum cylinder was covered tightly and kept in a wooden box. The wooden box was already insulated by a thick layer of cotton (Fig 5). In a word the arrangement was made such that no heat would be allowed to escape. After one hour the resulting temperature of water and the weight of waster were measured. After that Using Equation (2) the specific heat of the concrete specimen was measured.

It is known that in a Calorimeter,

Rejected Heat = Received Heat

$\Rightarrow$ Heat rejected by water = Heat received by Concrete specimen + Heat received by Calorimeter.

$$\Rightarrow m_w c_w (\theta_{wi} - \theta_{wf}) = m_s c_s (\theta_{wf} - \theta_R) + m_c c_c (\theta_{wf} - \theta_R)$$

$$\Rightarrow c_s = \frac{m_w c_w (\theta_{wi} - \theta_{wf}) - m_c c_c (\theta_{wf} - \theta_R)}{m_s (\theta_{wf} - \theta_R)}$$

$$\Rightarrow c_s = \frac{m_w c_w (\theta_{wi} - \theta_{wf})}{m_s (\theta_{wf} - \theta_R)} - \frac{m_c c_c}{m_s} \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

Where,
m_w = Weight of hot water
m_s = Weight of Concrete cylinder
m_c = Weight of Calorimeter
c_w = Specific heat of waster
c_s = Specific heat of Concrete cylinder
c_c = Specific heat of Calorimeter
θ_{wi} = Initial temperature of hot water
θ_{wf} = Final temperature of hot water
θ_R = Room temperature

V. Test Result on Water Absorption and Release:

Test on Water Absorption and release was done to both coarse aggregate and concrete specimens. It is seen that the initial weights of all types of aggregates were quite similar (Fig 6) (rattan - 3.84 gm, wood - 4.41 gm and bamboo - 3.90 gm). Bio aggregates absorb more than 65% of water with respect to their initial weight at 28 days of submergence. From the 29th day they were kept in open air to see their water evaporation nature. It is seen that they come to their original weight (almost) at about 56th day. Fig 7 shows that water evaporation rate had become almost null with respect to the initial weight. But the bio-aggregates of rattan, wood and bamboo absorb 66%, 77%, and 94%water respectively in 28 days.

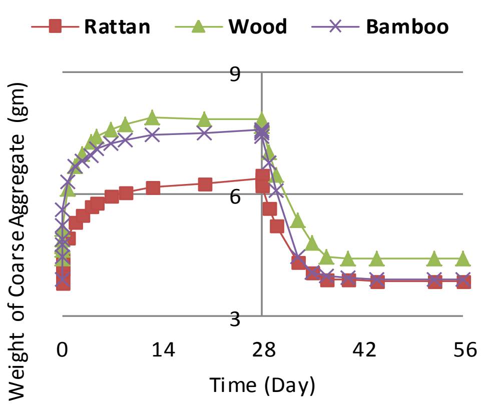

Fig. 6. Weight Vs time (After 28 days of submergence the aggregates were kept in open air)

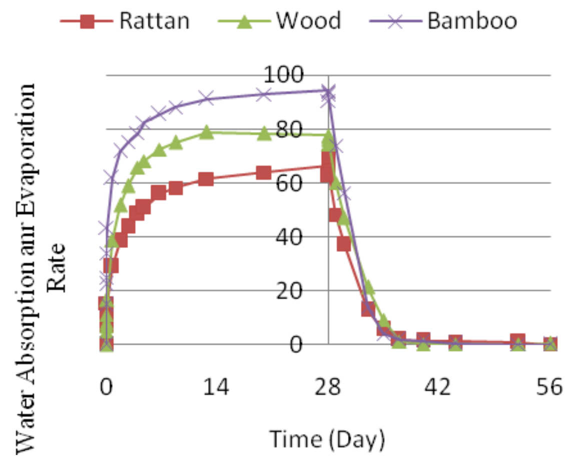

Fig. 7. Water absorption and evaporation with respect to the initial weight (After 28 days of submergence the aggregates were kept in open air)

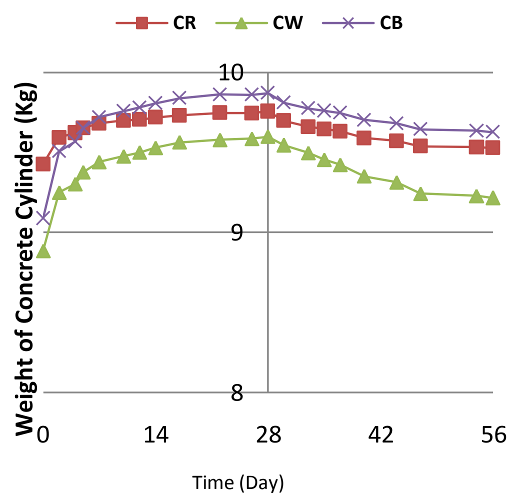

Fig. 8. Weight Vs time (1:2:2, after 28 days of submergence the cylinders were kept in open air)

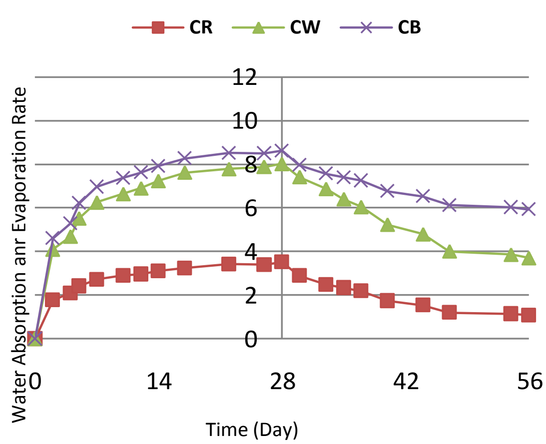

Fig. 9. Water absorption and evaporation with respect to the initial weight (1:2:2, after 28 days of submergence the cylinders were kept in open air)

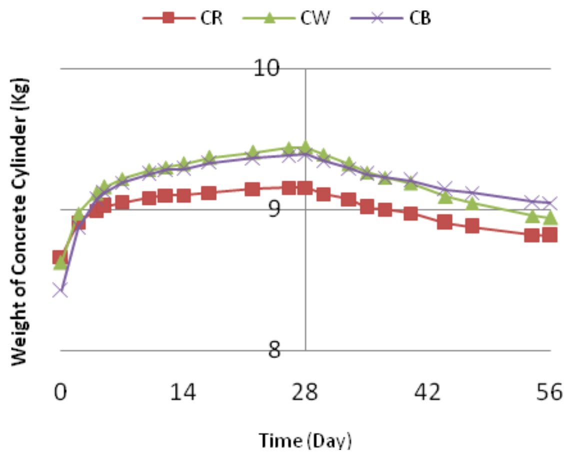

Fig. 10. Weight Vs time (1:2:3, after 28 days of submergence the cylinders were kept in open air)

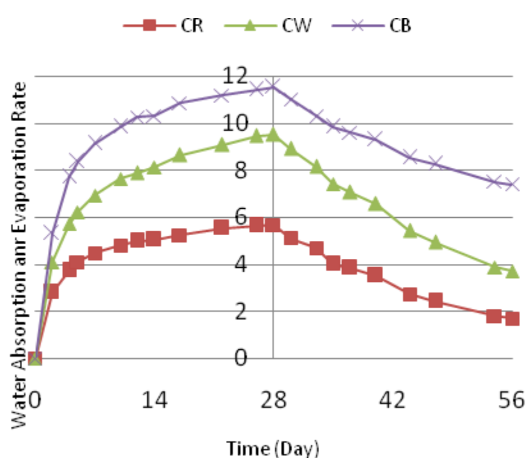

Fig. 11. Water absorption and evaporation with respect to the initial weight (1:2:3, after 28 days of submergence the cylinders were kept in open air)

The above result has a significant impact on the water absorption of concrete. Since at higher mixing ratios more coarse aggregate having less unit weight compared to cement and sand was mixed therefore the corresponding weight of CR, CW, and CB was reduced (Fig 8 and Fig 10). Water absorption is found the highest for CB (8% and 11% in Fig 9 and Fig 11 respectively) and the lowest for CR at both the mixing ratios (3% and 5% in Fig 9 and Fig 11 respectively). At the 56th day no significant change in water evaporation rate was observed.

VI. Test Result on Compressive Strength:

Among the unreinforced concrete specimens CR shows better strength then the rest two. CW and CB exhibit almost similar strength. Two types of reinforcement – Bamboo and Rattan were used in this test. Among them at the same mixing ratio and the same coarse aggregate Bamboo reinforced concrete show higher compressive stress than that of Rattan reinforced

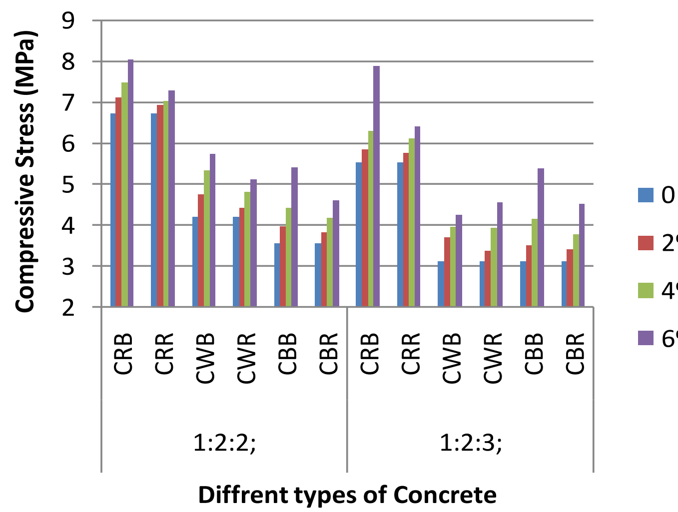

Fig. 12. Compressive stress of different types of Concrete specimens.

TABLE III

Modulus of Elasticity

Ratio	1:2:2			1:2:3		
Type	CR	CW	CB	CR	CW	CB
E (Mpa)	4000	3000	2917	3333	2778	2500

TABLE IV

Compressive Stress on Reinforcement:

Ratio	CA	ρ_b	Stress (MPa) f_b	Stress (MPa) f_r
1:2:2	Rattan	2	26.10	17.36
		4	25.54	14.59
		6	28.68	16.19
	Wood	2	31.64	15.18
		4	32.49	19.30
		6	29.81	19.48
	Bamboo	2	24.87	17.50
		4	25.40	19.16
		6	34.64	21.32
1:2:3	Rattan	2	22.15	17.99
		4	25.00	20.52
		6	44.85	20.50
	Wood	2	32.74	16.17
		4	24.51	23.72
		6	22.31	27.24
	Bamboo	2	23.06	18.43
		4	29.50	19.84
		6	41.15	26.80
Average			**29.14**	**19.52**
Standard Deviation			**6.32**	**3.54**

concrete. The bamboo and rattan splints are cut to maintain reinforcement ratios of 2%, 4% and 6%. The test results are shown in Fig 12. It is seen from the figure that strength of concrete samples are increased as the reinforcement ratio is increased. Using Equation- (1) the compressive stress of Bamboo and Rattan is calculated. The result is presented as a tabular form in Table 4. It is seen that the average compressive stress (29 MPa) of bamboo is higher than that of rattan (19 MPa). For Bamboo (as reinforcement) the largest amount of compressive stress estimated was 44 MPa, while the lowest value recorded was 22 MPa. The Standard deviation of the values was 6.32. For Rattan (as reinforcement) the largest amount of compressive stress estimated was 27 MPa, while the lowest value recorded was 14 MPa. The Standard deviation of the values was 3.54. Table 3 shows the Modulus of Elasticity of the different types of Concrete at different Mixing Ratio.

VII. FAILURE ANALYSIS:

After crushing of the concrete samples no bio-aggregate was seen to be failed or crushed. In all cases only the mortar was failed (Fig 13 to Fig 15).

Fig. 13. Crushed CR

Fig. 14. Crushed CW

Fig. 15. Crushed CB

This means that the strains of mortar and bio-aggregate were not similar. Also the bond between the bio-aggregate and mortar was not good enough to take high load. This case is applicable for both reinforced and non-reinforced concrete. To see the actual strength \of the rattan, wood and bamboo, randomly fifty samples each were tested in compression machine. Before failure the average compressive strength of rattan, wood and bamboo aggregates were 33, 11 and 41 MPa respectively (Table 5). This means that the strength of bio-aggregates was not fully utilized in concrete.

TABLE V

Compressive strength of the bio-coarse aggregates used:

Item Name	Rattan	Wood	Bamboo
Sample Tested	50	50	50
Avg Strength (Mpa)	33.55	11.15	41.67
STD Deviation	4.754	3.36	12.99
Upper Strength (Mpa)	40.26	16.72	66.67
Lower Strength (Mpa)	25.16	5.57	16.67

VIII. TEST RESULT ON SPECIFIC HEAT:

Specific heat represents the heat capacity of concrete. It is considerably increased by an increase in the moisture content of concrete. Specific heat increases with an increase in temperature and with a decrease in the density of concrete. The common range of values for ordinary concrete is between 840-1170 J/Kg/^{o}C (Neville 2006). After the specific heat test the variation of specific heat of the Concrete Specimen at different coarse aggregate and mixing ratios is shown at Fig 16. It is seen that almost all the values of CR, CW and CB are higher than the above mentioned range. As the content of coarse aggregate is increased the specific heat is also increased. Since higher the specific heat of a material the higher the heat absorption capacity therefore concrete of bio-aggregate can offer cooler temperature in the surrounding environment than that of the concrete of stone.

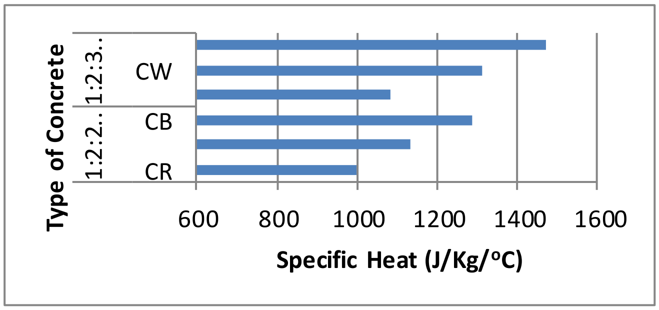

Fig. 16. Specific heat of the Concrete Specimen at different coarse aggregate and mixing ratios

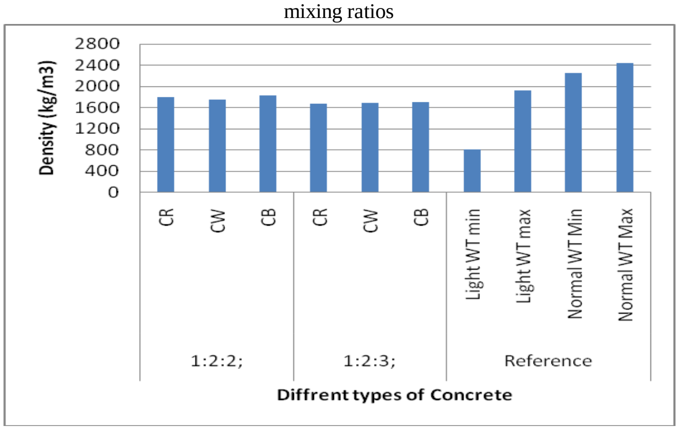

Fig. 17. Density of different types of concrete.

IX. TEST RESULT ON DENSITY

The density of normal weight concrete varies from 2246-2438 Kg/m^3 (140-152 pcf). The density of light weight concrete varies from 802-1925 Kg/m^3 (50-120 pcf) (Nilson 1997)). It is revealed form the study that the density of CR, CW and CB are within the range of light weight concrete (Fig 17). Maximum density is found at CB at the mixing ratio of 1:2:2 (1817 Kg/m^3).

X. DISCUSSION

In all cases mixing ratio 1:2:2 gives higher strength then 1:2:3. Since CR, CW, and CB have comparatively less weight then the normal weight concrete, so they can be used to reduce the dead load of the structure as light weight concrete. Since CR, CW, and CB have comparatively higher Specific heat, so they can be used to provide cooler environment at the interior portion of structure. As the strength offered by them is not so much high to take the high stress so they can be used for light weight structures. Since the unreinforced CR, CW, and CB have less strength so they can be suggested for non-load bearing members. Since the reinforced CR, CW, and CB have better strength then the unreinforced cases so they can be suggested for load bearing members of light weight structures. Exposure to environmental elements like fire, water may harm the quality of the CR, CW and CB. So it is suggested not to use them in exterior elements of structure.

XI. CONCLUSION

Though rattan, wood and bamboo can take considerable amount of stress yet their mechanical property is not fully used when they were used in concrete. If their full strength could be used than definitely the resulting strength of concrete cylinder could be upgraded. Wood and Rattan are widely used as decorative purpose. They are hugely used in making furniture. In Bangladesh Wood has some Government initiative for production. But Rattan and Bamboo has no private or Governmental initiative for production. That's why the price of them is relatively higher compared to that of stone. If initiative is taken to use them in construction purpose then their production will be increased. It will reduce cost and serve to increase the total forest area of our country. The target of the research is to see the effects of used of Bio-materials in concrete in its natural state. No research is conducted using them as coarse aggregate in concrete. This is just a preliminary work without any physical or chemical treatment.

ACKNOWLEDGMENT

The authors are deeply grateful to the Seven Circle (Bangladesh) Ltd. for providing all the OPC, ASTM Type-1 needed for the research. The authors also express their gratitude to the Department of Civil and Environmental Engineering, Shahjalal University of Science & Technology, Sylhet, Bangladesh for providing all the necessary laboratory supports.

REFERENCES

[1] S. Amada, Y. Lchikawa, T. Munekata, Y. Nagase, and H. Shimizu, "Fiber Texture and Mechanical Graded Structure of Bamboo", *Composites Part B*, vol.288, 1997, pp. 13-20.
[2] M. Q. Chowdhury), "Assessment of Physical and Mechanical Properties of Golla Bet (Daemonorops jenkinsiana) from North-eastern Region of Bangladesh", *Journal of Bamboo and Rattan*, vol. 3 No. 3, 2004 pp. 195-201.
[3] K. Ghavami, "Low cost and Energy saving construction materials", in *Proc. International on Modern Bamboo Structures*, Changsha, China, 2007, pp. 5-21.
[4] K. Ghavami, "Bamboo as Reinforcement in Structural Concrete elements", *Cement & Concrete Composites*, vol. 27(6): 2005, pp. 637-649.
[5] K. Ghavami, "Ultimate load behavior of Bamboo-reinforced lightweight concrete beams", *Cement & Concrete Composites*, vol. 17(4), 1995, pp. 281-288.
[6] M. F. Kabir., D. K. Bhattacharjee. and M. A. Sattar, "Influence of height on physical and mechanical properties of Golla Cane (Daemonorops jenkinsiana)", *Bangladesh Journal of Forest Science*, vol. 22 (1-2), 1993, pp. 52–56.
[7] S. Leelatanon, S. Srivaro and N. Matan, "Compressive strength and ductility of short concrete columns reinforced by bamboo", *Songklanakarin J. Sci. Technology*, vol. 32 (4), 2010, pp. 419-424.
[8] A.A. Mark, A. O. Russell, "A Comparative Study of Bamboo Reinforced Concrete Beams Using Different Stirrup Materials for Rural Construction" *International Journal of Civil and Structural Engineering*, vol. 2, No 1, 2011, pp. 407-427.
[9] H. M. A. Mahzuz., M. Ahmed, M. Ashrafuzzaman, R. Karim and R. Ahmed, "Performance Evaluation of Bamboo with Mortar and Concrete" *Journal of Engineering and Technology Research*, vol. 3(12), 2011, pp. 342 – 350.
[10] A.H. Nilson., "*Design of Concrete Structures*", McGraw-Hill International Edition, 1997, pp. 32.
[11] A.M. Neville, "*Properties of Concrete"*, Dorling Kindersley (India) Pvt Ltd, licensees of Peasrson Education in South Asia, 2006, pp. 377.
[12] C. Okhio, J. Waning, Y. T. Mekonnen, "An Experimental Investigation of the Mechanical Properties of Bamboo and Cane", *Journal of Selected Areas in Bioengineering (JSAB)*, September Edition, , 2011, pp. 8-15.

[13] M. Peki and C. Konabe, "Evaluation of moisture content and specific gravity of Rattan", in *Proc. of the National Rattan Workshop*, Forest Research Institute, Lae, Papua New Guinea, 1991, pp. 23–25.
[14] M.A. Sabbir., S.M.A. Hoq, and S. F. Fancy, "Determination of Tensile Property of Bamboo for Using as Potential Reinforcement in the Concrete", *International Journal of Civil & Environmental Engineering IJCEE-IJENS*, 2011, vol. 11, no. 05, pp. 47-51.