Use of Stone and Several Biomaterials as Course Aggregate in Concrete

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***Abstract*— This research is conducted to examine the performance of concrete where bio-materials like rattan, wood and bamboo are used as coarse aggregate (CA). Related comparison is made with the concrete where conventional stone is used. Three mixing ratios -1:2:2, 1:2:2 and 1:2:4, having the same water to cement ratio were considered in this research. Full study was conducted by Ordinary Portland Cement (OPC) and sand of a constant FM. The maximum size of any coarse aggregate was kept below 19 mm. Curing of all samples was done for 28 days and crushing was performed after 56 days. Within this time both the absorption and evaporation of water were measured. Finally they were crushed to identify their strength. The Stress-strain curves were also gathered from these tests. Finally it is observed that the compressive strength of the concrete samples of bamboo, wood and rattan offer much less strength that of the concrete of stone. Yet they offer the strength that may be suitable for less load bearing structures. Also as the weight of concrete was much reduced and specific heat was increased a lot by the use of these bio-aggregates.**

***Index Terms*—: Compression, Elasticity, Stress, Strain, Water absorption, Water-cement ratio.**

STONE is commonly used in concrete as coarse aggregate. Sometimes brick chips are also seen in this role in many construction sites. They are used as volumetric materials in concrete. Obviously effect of aggregate properties has serious impact over the strength of concrete. Since the starting of human age naturally available bio-products (e.g. Bamboo, Rattan, Wood etc) are used to solve the housing problem. Some of them are easily accessible. Though not like steel or concrete, yet they offer considerable amount of strength. That's why they took part in various researches. K. Gavami is a well known scientist who made a great contribution in this field. He carried out several research programs using indigenously available local materials such as bamboo, coconut fibers, sisal and other natural fibers as construction materials. His contributions in [1-5] indicate a prospective era of research in this field. Nevertheless successfully results are also found where bamboo was used as reinforcement in concrete beams [6, 8]. But very few researches, like [7], have been carried out taking bamboo, rattan, and wood as coarse aggregate in concrete. In that research comparison was made between the concrete where as coarse aggregate rattan, wood and bamboo chips were used. Also reinforced concrete short columns were made where the above mentioned coarse aggregates were used having bamboo and rattan as reinforcement. In this paper those results were improvised making a comparison with the concrete where stone used as coarse aggregate.

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I. Methodology and Characteristics of Materials Used:

Three different mixing ratios (1:2:2, 1:2:3 and 1:2:4) are used in this study having the same water-cement (w/c) ratio (0.485). The fineness modulus (FM) of fine aggregate (FA) was kept constant (2.79). Stone, bamboo, rattan, wood were used as coarse aggregate in concrete (Table: 1). Bamboo (*Bambusa balcooa*), rattan (*Daemonorops jenkinsiana*), wood (*Acacia auriculiformis*) samples were collected form at least three year old trees. Stone chips were irregular in shape having a maximum size of 12.5mm - 25mm. Bamboo, rattan and wood were cut and sliced at a size around the size of stone chip. It is done to make a similarity with the maximum size of stone.

As bio-aggregates would be involved in making concrete therefore they would absorb waste during mixing process. Therefore test is done to understand water absorption and release by all the aggregates (stone, rattan, wood, and bamboo). They 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. The unit weight and moisture content of the materials used were also measured (Table: 2). The research was performed by Ordinary Portland Cement (ASTM Type-1 OPC).

All the concrete samples were cylindrical in shape having a height of 300 mm and diameter of 150 mm. The compression test of those samples was carried out at 56th day of their preparation. Since biomaterials were used in concrete therefore weight of them were regularly taken to understand the water absorbance during the curing period (28 days). Just like CA, after 28 days submergence they were kept in open air to measure the water release (or evaporation) for another 28 days more. The Modulus of Elasticity (MoE) and specific heat of the samples were measured as well.

Table: 1 Mixing criteria of Materials for Unreinforced Concrete

W/C Ratio	Mix Ratio	FM of FA	CA	Test length (days)
0.485	1:2:2	2.79	Stone	56
			Bamboo	
			Rattan	
			Wood	
	1:2:3		Stone	
			Bamboo	
			Rattan	
			Wood	
	1:2:4		Stone	
			Bamboo	
			Rattan	
			Wood	

Table 2: Unit weight of the materials used.

Name	*Unit Weight, (Kg/m^3)*	*Moisture Content (%)*
Stone	1600	0.179
Rattan	375	32.21
Wood	480	25.37
Bamboo	455	22.75
Water	1000	---
Cement	1440	---
Sand	1480	---

II. EXPERIMENTAL RESULT:

Water Absorption and release by the coarse aggregates of stone, rattan, wood and bamboo with time is shown in Fig 1. And the related water absorption and evaporation rate with respect to the initial weight (After 28 days of submergence the aggregates were kept in open air) is shown in Fig 2. Water Absorption and release by the concrete Cylinder of mix ratio 1:2:2, 1:2:3 and 1:2:4 with Time are shown in Fig 3, 5 and 7. Related Water absorption and evaporation with respect to the initial weight (After 28 days of submergence the aggregates were kept in open air) are shown in Fig 4, 6 and 8.

The comparison of the compressive strength of the samples is shown in Fig: 9. The Percentage of decrease of Weight of the concrete of Bio-aggregates with respect to the concrete of stone is shown at Fig: 10. Finally the modulus of elasticity and Specific heat of the samples is presented in Table 3.

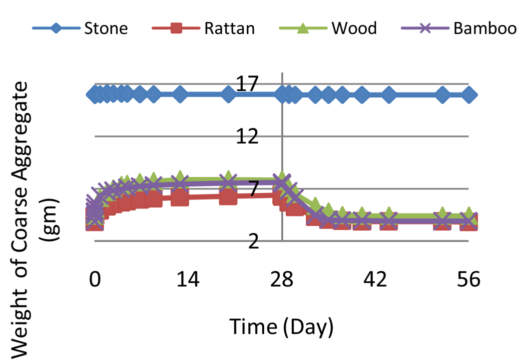

Fig 1: Weight Vs time (After 28 days of submergence the coarse aggregates were kept in open air)

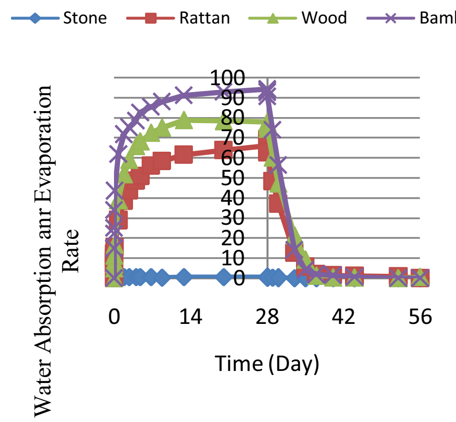

Fig 2: Water absorption and evaporation rate with respect to the initial weight (After 28 days of submergence the coarse aggregates were kept in open air)

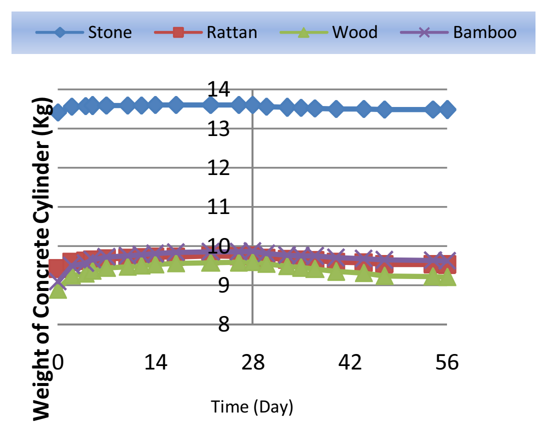

Fig 3: Weight Vs time (After 28 days of submergence the concrete cylinders of mix ratio of 1:2:2 were kept in open air).

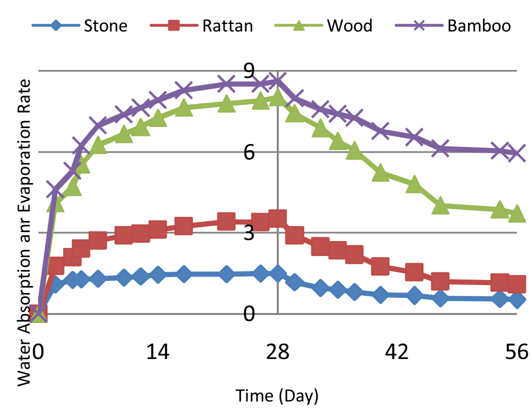

Fig 4: Water absorption and evaporation with respect to the initial weight (After 28 days of submergence the concrete cylinders of mix ratio of 1:2:2 were kept in open air)

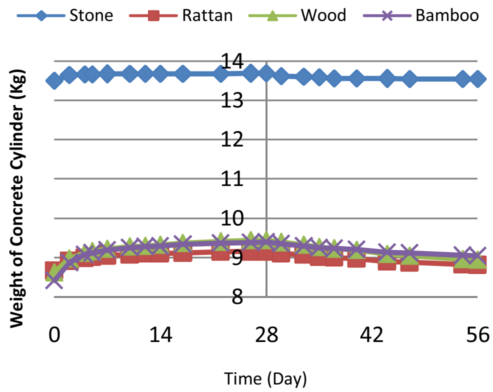

Fig 5: Weight Vs time (After 28 days of submergence concrete cylinders of mix ratio of 1:2:3 were kept in open air)

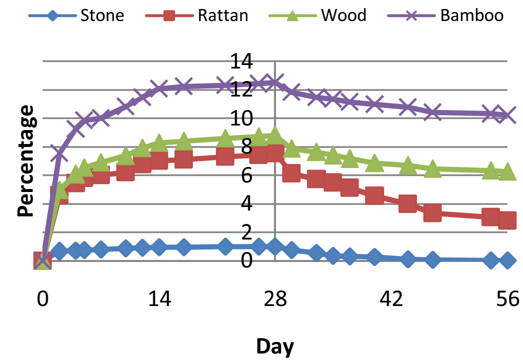

Fig 8: Water absorption and evaporation with respect to the initial weight (After 28 days of submergence the concrete cylinders of mix ratio of 1:2:4 were kept in open air)

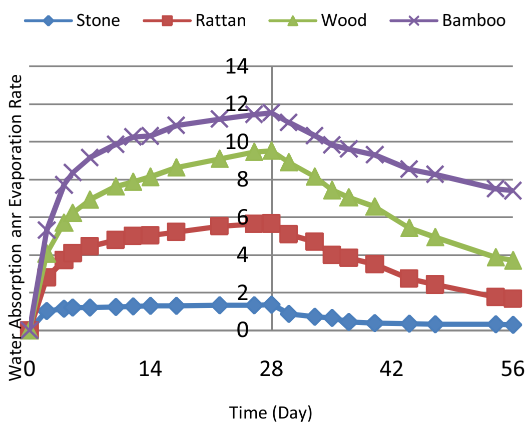

Fig 6: Water absorption and evaporation with respect to the initial weight (After 28 days of submergence the concrete cylinders of mix ratio of 1:2:3 were kept in open air).

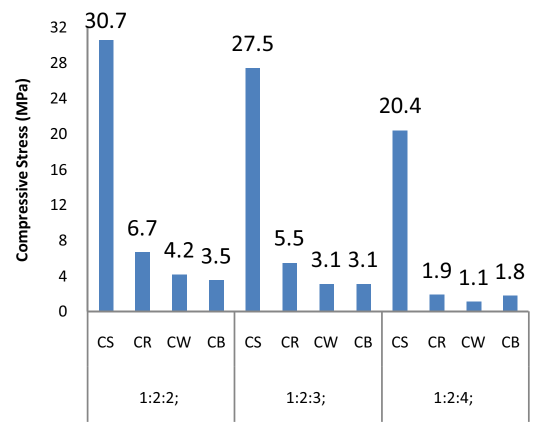

Fig 9: Compressive stress of the Concrete Cylinders at different coarse aggregate and mixing ratios.

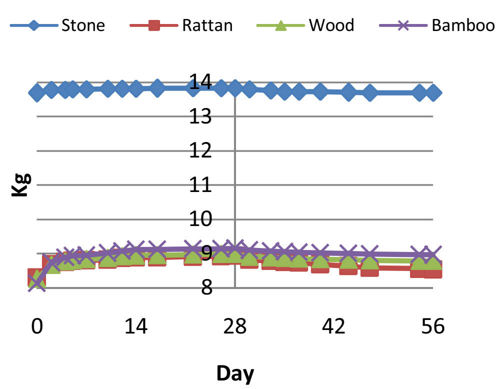

Fig 7: Weight Vs time (After 28 days of submergence concrete cylinders of mix ratio of 1:2:4 were kept in open air)

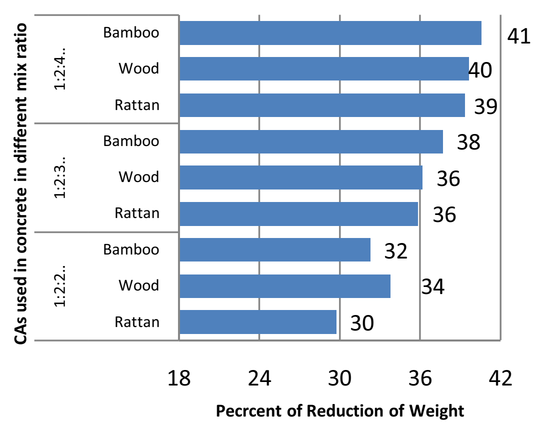

Fig 10: Percentage of decrease of Weight of the concrete of Bio-aggregates with respect to the concrete of stone

Table 3: Modulus of Elasticity and Sp. Heat

Concrete of		MoE (Mpa)	Sp. Heat (J/Kg/K)
Mix ratio	CA		
1:2:2	Stone	30000	732
	Rattan	4000	992
	Wood	3000	1113
	Bamboo	2917	1273
1:2:3	Stone	20834	850
	Rattan	3334	1067
	Wood	2778	1282
	Bamboo	2500	1445
1:2:4	Stone	14286	955
	Rattan	1800	1193
	Wood	400	1454
	Bamboo	1889	1677

III. DISCUSSIONS:

Water Absorption of Aggregate:

From Figure 1 it is seen that no water is absorbed by the Stone aggregates. Other three sample wood, rattan, bamboo's water absorption were raising until up to the 28th day, after that it falls down. Bamboo absorbs the highest water (above 90%). Water absorption of the rattan & wood were almost 65% and 75% respectively (Figure 02).

Water Absorption of Concrete Sample

The water absorption of aggregates has a serious effect on the water absorption of concrete as well. For the ratio 1:2:2 from Figure 03 it is seen that very less amount of water was absorbed by the concrete of stone. The amount is only 1.5% of the initial weight (Figure 4). For the other three concrete samples of wood, rattan, bamboo aggregate, water absorption were raising until up to the 28th day, after they were fall down. Concrete of bamboo absorbs the highest water (above 8.5%). Water absorption concrete of wood and rattan were almost 8% and 3.5% respectively (Figure 9). Similar result is seen for the ratio of 1:2:3 and 1:2:4. But the respective water absorption is seen to be increased at higher mix ratios (Figure 5-8). But in all cases water absorption by the concrete of stone was marginally varied.

Compressive Strength:

From Figure 9 it is obvious that the compressive strength of concrete of stone is much higher than the others. Among the bio-aggregates, concrete of rattan shows better strength then the rest two. Concrete of Wood and bamboo exhibited almost similar strength. It was observed that both stone and mortar failed at the moment of failure of the concrete cylinder of stone. That is the strain of both mortar and stone was quite similar. But no bio-aggregate was seen to be failed or crushed when the mortar failed. That means that the strain of mortar and bio-aggregate are not similar. Also the bond between the bio-aggregate and mortar was not good enough to take high load. The variation of compressive stress of different concrete with respect to the conventional one is shown at Table 4. The result of the mix ratio 1:2:4 show much is much less comparing to the other two mix ratios.

Table 4: Percentage variation of compressive stress with respect to the concrete of stone

Ratio	CA type in concrete	Stress (Mpa)	Variation (%)
1:2:2	Stone	30.7	
	Rattan	6.7	22
	Wood	4.2	14
	Bamboo	3.5	12
1:2:3	Stone	27.5	
	Rattan	5.5	20
	Wood	3.1	11
	Bamboo	3.1	11
1:2:4	Stone	20.4	
	Rattan	1.9	9
	Wood	1.1	6
	Bamboo	1.8	9

Weight Reduction:

It is revealed from the study that concrete of stone is much higher in weight than the concrete of bio-aggregates (Fig: 10). As the coarse aggregate is increased the difference becomes higher. This happens because the unit weight of stone is much higher that those of sand and cement. At higher mix ratio the difference is higher. The overall weight reduction varies from 30% to 41%.

IV. CONCLUSION

This study focuses the relative performance of concrete where coarse aggregate were stone, rattan, wood and bamboo. From laboratory study, it is found that strength of Rattan, Bamboo and Wood concrete was less then concrete of stone. Rattan concrete strength was about 22%-20% of stone concrete, Wood concrete was 14% -11% of stone concrete and . Bamboo concrete was 12% -11% of stone concrete for 1:2:2 and 1:2:3 mix ratios. Therefore such mix ratio can be used for low load bearing members or zero load bearing members like partition wall. Since the mix ratio 1:2:4 offer much less strength therefore this can be neglected from any kind of structures. Weight of specimen was reduced more than 30% for bamboo, rattan, wood concrete than stone concrete. Water absorption of stone concrete was less than other three samples. Water absorption continuously increased to 28day then decreased, after 54 day water reduction was remaining constant. Overall load of structure may be decreased by using bamboo, rattan and wood aggregate. Bamboo, rattan & wood are biodegradable materials so special precaution should be taken to prevent biodegradation, which may decrease strength of concrete. Taking these things in count such concrete can be suggested for light weight structures which must be kept away from water contact.

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