Mini Project Report on

"CHARACTERIZATION OF ENGINEERED BAMBOOFOR BUILDINGS"

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CERTIFICATE

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Date: April 27th 2012

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Avishek Shaw

ABSTRACT

Demand for bamboo structures have been on the rise these days. Presently, humanity is facing tough questions about the degradation of our natural environment. To this effect bamboo can be an answer to some extent, as it can be used as a building material for our structures. It has comparable strength to concrete and steel and has the added advantage of being a natural material. Its growth consumes carbon dioxide from the atmosphere, thereby making it cleaner, and its cultivation makes soil rich in nutrients.

This Project is focused on material characterization of two species of Assambamboo. Several types of test, like tension, compression, moisture and steel bamboo fixture tests were carried out on specially crafted specimens. The results have been tabulated and final value for the mean and standard deviation values of these tests have been arrived at.

For the fixture testtwo types of arrangements were made which were presumed to increase the contact between bamboospecimen and itself, and were tested on the tensile testing machine. The aim of this component was to devise joints which would be stronger than the material, and would oversee any failure of the attached bamboospecimen.

Moisture content tests were carried out to drive out any possible correlation between the bamboo moisture content and its strength properties.

The characteristic strength of bamboo in compression came out to be 63.84 Mpa for type I and 44.79 Mpa for type II. The tensile characteristic strength came out to be 76.12 Mpa and 61.89Mpa for types I and II respectively. These results seem quite encouraging since they match that of our standard construction materials like steel and concrete.

For the fixture test the load capacities were 1.6 Ton and 1.2 Ton respectively for the two tests. The results have been significantly better than the preliminary tests that were carried out in this regard.

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Chapter 1

INTRODUCTION

1.1 General

Bamboo as a construction material has largely been ignored by humans. Although throughout the past, it has been used in many rural buildings, since it is cheap and a natural material, and has comparable strength to concrete and steel, it needs to be characterized for strength and other properties before it is to be used in an economical fashion for modern day widespread urban as well as rural construction. Its material characterization is still at a nascent stage and will require a lot of efforts on the part of researchers for many years to come to develop it into a material whose behaviour can be predicted and thereby be used in the safe and economical materialization of daily use structures. Recently there have been some rapid progresses in this regard and many breath-taking simple and aesthetic structures have been made for tourist purposes. In this sense, it also offers a great opportunity to draw a lot of people to beautifully crafted bamboo buildings, which give its residents a feel of being one with nature, the joy silence and happiness.

Bamboo is a versatile, strong, renewable and environment-friendly material. It is a member of the grass family, Gramineae and the fastest growing woody plant on earth. Most bamboo species produce mature fibre in 3 years, sooner than any tree species. Some bamboos grow up to 1 metre a day, with many reaching culm lengths of 25 metres or more. Bamboo can be grown quickly and easily, and sustainably harvested in 3 to 5 years cycles. It grows on marginal and degraded land, elevated ground, along field bunds and river banks. It adapts to most climatic conditions and soil types, acting as a soil stabilizer, an effective carbon sink and helping to counter the greenhouse effect(Source : National Bank for Agriculture and Rural Development).

Bamboo seems to be a promising material for the future. It is expected that in the near future the world will be witness to more participation of bamboo in construction and creation of simple yet aesthetically pleasing buildings, encouraging healing of the environment to some extent.

1.2 Bamboo diversity in India

India is the second richest country in bamboo genetic resources after China. Sharma (1987) reported 136 species of bamboos occurring in India. Fifty-eight species of bamboo belonging to 10 genera are distributed in the north-eastern states alone.

The forest area, over which bamboos occur in India, on a conservative estimate, is 9.57 million hectares, which constitutes about 12.8% of the total area under forests (Bahadur and Verma 1980)**.** The important genera are Arundinaria, Bambusa, Cephalostachyum, Dendrocalamus, Dinochloa, Gigantochloa, Melocanna, Ochlandra, Oxytenanhthera, Phyllostachys, and Pseudostachyum etc. Of the nearly 136 species, only about 10 are being commercially exploited today. These are Bambusaarundinacea, B.affinis, B.balcooa, B.tulda, Dendrocalamusstrictus, D.hamiltoni, D.asper, Oxytenantherastocksii and O.travancorica.

1.3 Properties of bamboo

1.3.1 Shrinkage and Swelling

Bamboo, like wood, changes its dimension when it loses or gains moisture. Bamboo is a hygroscopic material, thus the moisture content changes with the changes in the relative humidity and temperature of the surrounding environment. Dimensional stability is very crucial in structural products because the safety and comfort in a structure usually depends on them. Free water and bound water exists in bamboo, however the amount of free water is small as compared to bound water. This explains why the bamboo starts to shrink as soon as it loses moisture. The shrinkage occurs in direct proportion to the amount of water loss from the cell wall.

1.3.2 Tension parallel to grain

Tension tests parallel to the grain are seldom investigated for bamboo. Tensile strength values of Bamboo cannot be utilized as such in practical work, as bamboo will fail by shear long before its full tensile stress is developed. The tension strength value is a fundamental criterion in order to design bamboo tension members.

1.3.3 Bending

Bending is an important parameter, deciding the suitability of Bamboo as a construction material. Because of this ability Bamboo can be used as a substitute for reinforcement in construction of buildings.

1.3.4 Elasticity

The enormous elasticity of bamboo makes it to a very good building material for earthquake endangered areas. Another advantage of bamboo is its low weight. It can be transported and worked easily, thus rendering use of cranes and other big machines unnecessary.

1.3.5 Fire Resistance

The fire resistance of bamboo is very good because of its high content of silicate acid. Filled up with water, it can stand a temperature of 400° C while the water cooks inside.

Chapter 2

COMPRESSION TESTS

2.1 General

Compression tests were carried out on bamboo stubs of approximate size between 8cm to 10 cm, containing an almost equal number of both the types i.e. red and black bamboo.. The stubs were specially machined by an electronic cutter so as to ensure a smooth surface to achieve a uniform stress over the entire cross section. All the specimens used for compression test were cut out from between the nodes of bamboo. The loading rate for all the specimens was kept constant i.e. .05kN/sec.

Bamboo was seen to fail inn two modes: cracking of fibres and crushing. Most of the specimens failed as a combination of both the modes.The diameters were carefully measured so as to come up with accurate values (within limits of experimental error).

Figure 2.1Types of specimen: Type I (Right) and Type II (Left)

The picture above shows both the two types of bamboo stubs used for compression testing. To the left is the Type II or red bamboo which has a comparatively thinner cross section than Type I bamboo at the right

2.2 Observations

The table below shows the specimen dimensions and their peak stresses in compression.

Table2.1 Specimen Specifications and Peak Stresses for Compression Tests

Serial	Type	Average inner dia (mm)	Average outer dia(mm)	Area(mm^2)	Peak Load(kN)	Peak Stress(N/mm^2)
1	I	29.66	42.01	695.04	61.1	87.91
2	II	21.73	37.22	717.04	54.7	76.29
3	I	21.78	40.2	896.50	66.8	74.51
4	ii	30.81	43.47	738.44	59.7	80.85
5	II	24.64	37.46	625.15	49.2	78.70
6	II	24.19	37.73	658.35	45.9	69.72
7	II	29	40.02	597.26	42.4	70.99
8	II	20.15	34.32	606.09	35.5	58.57
9	I	15.98	40.75	1103.43	62.6	56.73
10	II	23.75	42.68	987.47	63.5	64.31
11	II	22.34	33.44	486.19	31.6	64.99
12	II	24.86	42.28	918.41	65.1	70.88
13	II	18.91	41.74	1087.29	53.3	49.02
14	II	21.4	33.75	534.84	35.9	67.12
15	II	29.06	39.64	570.76	48.8	85.50
16	II	24.98	38.88	697.03	46.3	66.42
17	II	18.31	37.97	868.85	56.7	65.26
18	II	21.59	32.32	454.23	48.6	106.99
19	II	24.66	37.72	639.73	48.9	76.44
20	II	21.37	34.03	550.75	32.3	58.65
21	II	27.93	43.05	842.74	64.7	76.77
22	II	27.61	38.79	582.93	48.6	83.37
23	II	23.76	37.95	687.62	48.9	71.12
24	I	28.87	41.5	697.91	58.8	84.25
25	I	18.03	39.68	981.11	75.7	77.16
26	I	28.33	42.15	764.86	60.5	79.10

27	II	29.25	40.05	587.71	56.3	95.80
28	II	21.2	34.91	604.07	21	34.76
29	II	29.96	39.34	510.44	21.1	41.34
30	II	30.49	39.54	497.67	47.2	94.84
31	II	27.55	39.4	622.98	50.4	80.90
32	II	22.19	33.21	479.40	33.7	70.30
33	II	27.03	38.07	564.36	51.6	91.43
34	II	28.8	38.82	532.05	49.7	93.41
35	II	17.22	35.9	779.19	42.8	54.93
36	II	29.01	38.98	532.29	46.9	88.11
37	I	21.58	41.68	998.47	76.1	76.22
38	I	29.24	41.57	685.59	64.5	94.08
39	I	18.92	38.94	909.60	78.3	86.08

2.3 Results

The Table below shows the characteristic values of strengths of both types of bamboo in compression.

Table2.2 Characteristic strength, Mean Strength and Standard Deviation values for both types of specimens for Compression tests

Type	Characteristic Strength(Mpa)	Mean Strength(Mpa)	Standard Deviation(Mpa)
Type 1	**63.84**	**79.56**	**10.66**
Type 2	**44.79**	**72.93**	**16.28**

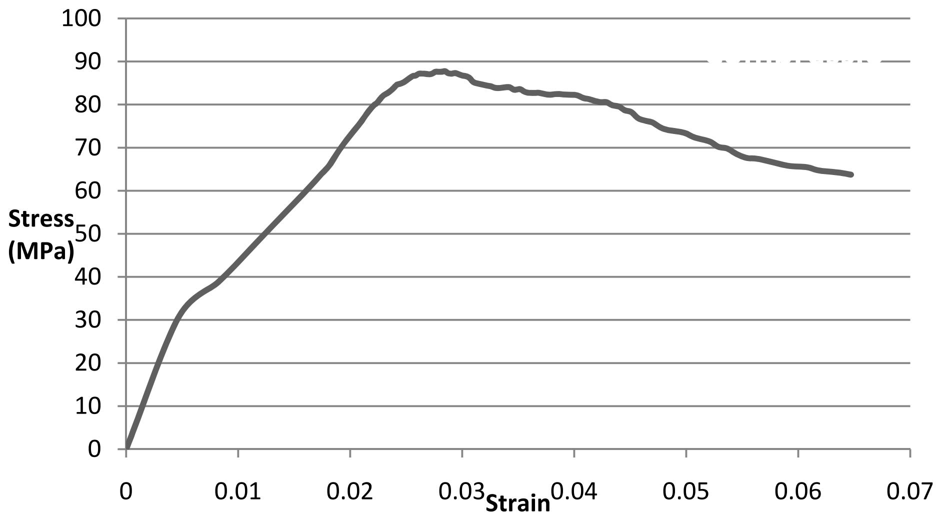

Figure2.2Stress v/s strain curve for compression specimen 1. The specimen seems to be fairly linear up to 33 MPa and then again upto 89 MPa

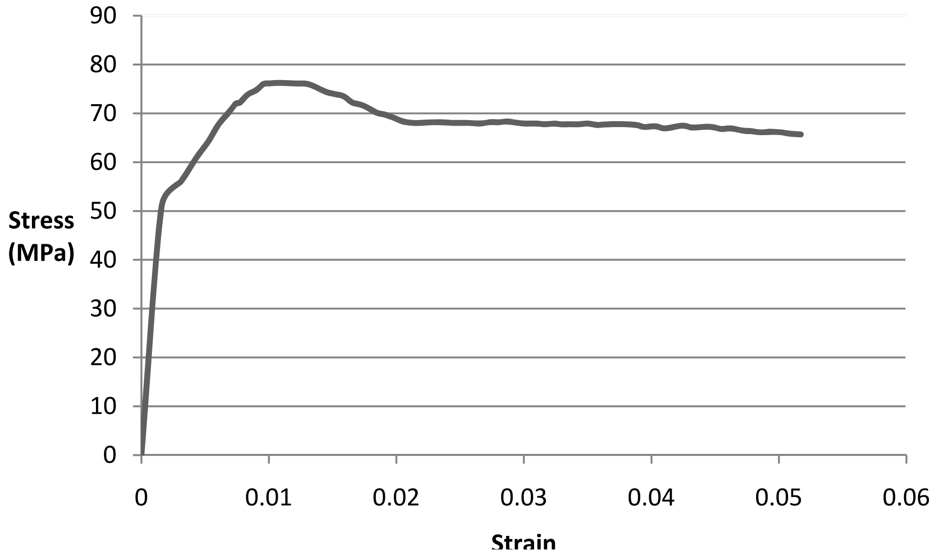

Figure2.3Stress v/s strain curve for compression specimen 2. The specimen seems to be fairly linear up to 53 MPa

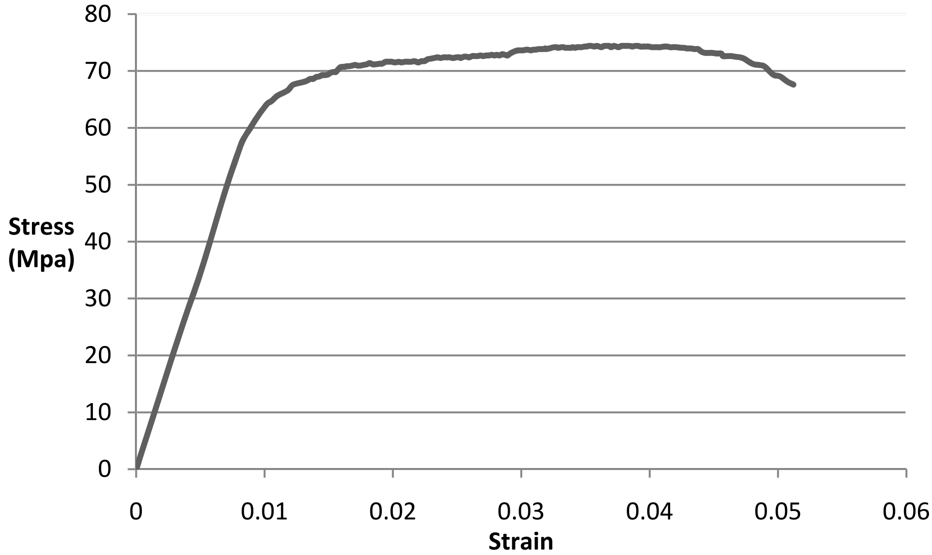

Figure2.4 Stress v/s strain curve for compression specimen 3. The specimen seems to be fairly linear up to 65 MPa

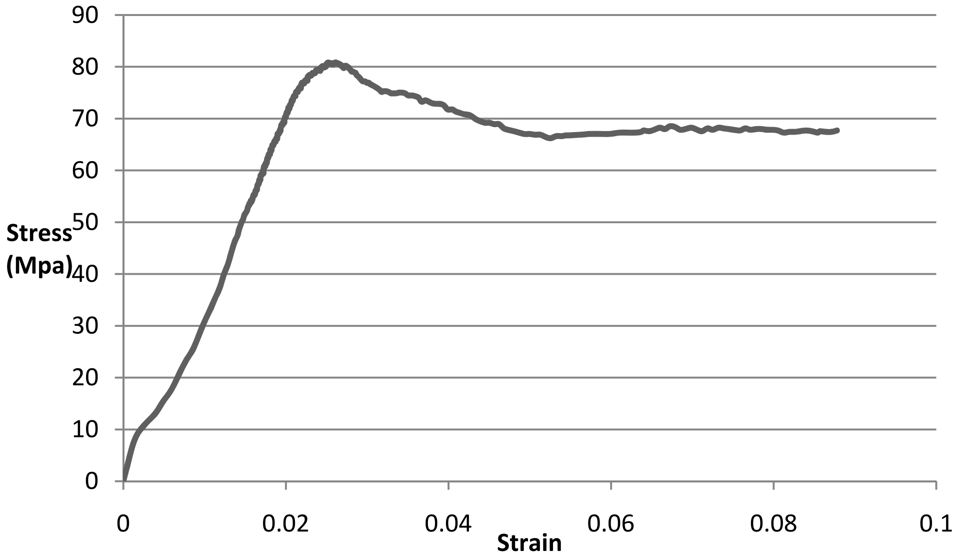

Figure2.5 Stress v/s strain curve for compression specimen 4. The specimen seems to be fairly linear up to 80 MPa

2.4 Photographs

Figure2.6Specimen before Compression test (Left) and after Compression test (Right). The specimen on the right shows the crushing of the left most end.

Figure2.7Compression Machine used for testing.

Figure2.8Some Photographs showing modes of failure of the compression specimens. The specimen at the bottom left failed in pure cracking whereas the one at the top right failed in crushing predominantly, very similar to the one at the bottom right. The specimen at the top left seems to fail in both cracking and crushing.

2.5Conclusion

Both the types of bamboospecimens show fairly good strength. Type I (Black) showed more characteristic strength than the Type II bamboo. The same was estimated because the first type had a thicker cross section and seemed denser, thereby providing it extra strength. Some of the specimens showed an ideal failure by cracking longitudinally but most of them showed a mixed mode of failure wherein the specimen cracked as well as got crushed. If bamboo is to be used for economical and safe construction the crushing mode of failure will have to be investigated more and be provided against so that there is no untoward failure even before it reaches its cracking load limit. A check of global buckling proved that the specimens were safe from buckling, whereas local buckling need not be checked for such small specimens.

Chapter 3

TENSION TESTS

3.1 General

About 20 specimens were tested in tension, containing an equal number of both types of bamboo. For the purpose 60 cm long bamboospecimens were cut with skilled labour. Instead of testing the complete bamboo, it was circumferentially cut into 4 parts (Figure9), so that it would fit properly into our tensile testing machine. This was done due to two reasons, the first one being the fact that that the whole bamboo tested as a single piece would exceed the tensile capacity of the machine being referred to, and the other being the fact that the circumference of bamboo is quite smooth and leads to slippage at the machine collars, where it is held to apply tension. Some of the specimens were seen to be failing in pure tension, i.e. cracking along the middle of the test specimen. But a majority of the specimen failed due to crushing of the part of the specimen which was clamped into the machine collar. This happened because bamboo has a natural surface curvature whereas the machine jaw is flat. Thereby, the jaw being stronger than the specimen ripped through it most of the times and lead to a premature failure, which needs to be corrected for correct characterization of bamboo.

Figure3.1Specimens used for tensile testing. The specimens were cut from a whole bamboo piece circumferentially into four equal parts

3.2 Observations

The tabulation below shows the loads and strengths of specimens in tension.

Table 3.1 Specifications and peak stresses of tension tests

Serial	Type	Peak Load(kg)	Peak Load(N)	Area(mm^2)	Tensile Strength(Mpa)
1	I	3000	29430	313.5	93.88
2	I	2680	26290.8	204.3	128.69
3	I	2320	22759.2	182	125.05
4	I	2620	25702.2	336	76.49
5	I	2220	21778.2	216	100.83
6	I	1700	16677	220	75.80
7	I	2780	27271.8	210	129.87
8	I	3020	29626.2	300	98.75
9	I	2620	25702.2	252	101.99
10	I	3040	29822.4	273	109.24
11	II	2100	20601	135	152.6
12	II	1620	15892.2	168	94.60
13	II	1340	13145.4	138	95.26
14	II	1700	16677	135	123.53
15	II	1700	16677	157	106.22
16	II	1700	16677	195	85.52
17	II	1780	17461.8	192	90.95
18	II	1100	10791	234	46.12
19	II	1820	17854.2	165	108.21

3.3 Results

The table below shows the results in terms of characteristic strengths of the two types of sample in tension.

Table3.2 Results of tension test

	Characteristic Strength(Mpa)	Mean Strength(Mpa)	Standard Deviation(Mpa)
Type 1	**76.12**	**104.06**	**19.56**
Type 2	**61.89**	**100.33**	**28.88**

3.4 Photographs

The photographs below show the compression test specimens and their failure pattern. The machine used for testing has also been shown.

Figure 3.2Tensile Test Specimen before testing (Left) and after testing (Right). The specimen has been ripped off from its joint.

Figure3.3The tensile machine used for testing

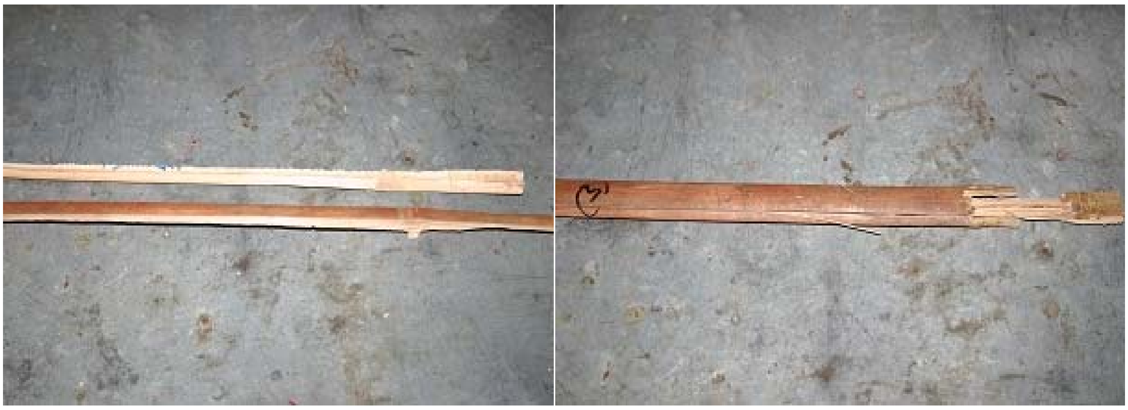

Figure 3.4 **The failure patterns of specimens. The specimen on the left failed ideally by cracking, whereas the one at the right failed by the joint.**

3.5 Conclusions and Suggestions

The tension test proved out again that specimens of Type I (Black type) have more strength than the ones belonging to Type II (Red type). Since most of the specimens failed by their joints, we can be sure that the strength values present here are safe because the specimen still had tensile strength when cracks propagated through them due to the failure of joints. For future tests a few improvements can be made : A machine claw could be made suiting the specific curvature of bamboos or a soft filler material could be used which would protect the specimen from the jaws of the machine.

Chapter 4

MOISTURE CONTENT

4.1 General

Moisture content is an important parameter since bamboo contains moisture when it is growing and hence may affect its behaviour during the time of immediate construction and thereafter, when the water content is lost. Thereby, it becomes necessary to investigate the strength dependencies of bamboo on moisture content. For this purpose around 10 specimens were tested for moisture content. They were kept in the oven at 100 degree Celsius for about 24 hours and their dry weight measured.

4.2 Observations

The table below shows the specimen weights and corresponding strengths.

Table4.1Table showing the strength along with moisture content of specimens

Specimen number	Type	Initial weight(gm)	Dry Weight(gm)	Moisture Content	Strength(Mpa)
29	II	34.97	32.49	0.071	41.34
33	II	38.15	35.47	0.070	91.43
31	II	39.23	36.49	0.070	80.9
35	II	37.31	34.59	0.073	54.93
39	I	66.96	62.07	0.073	86.08
32	II	25.97	24.11	0.072	70.3
30	II	36.8	34.23	0.070	94.84
34	II	35.5	33.04	0.069	93.41
28	I	31.02	28.77	0.073	34.76
36	II	36.01	33.5	0.070	88.11
37	I	61.43	57.07	0.071	76.22

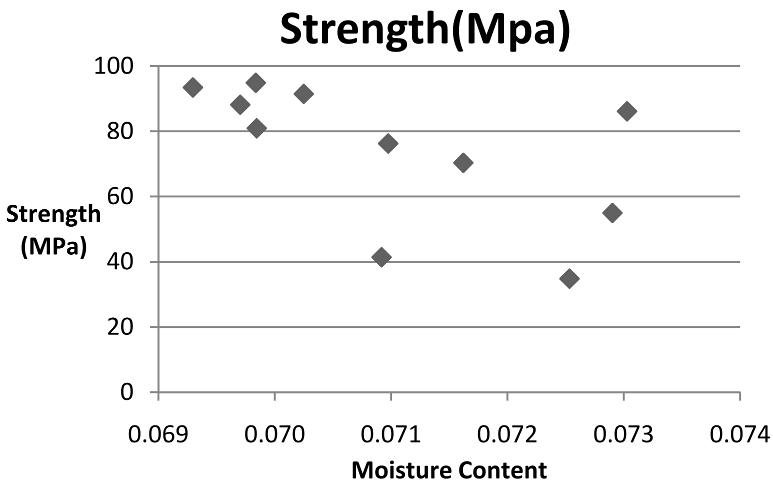

Figure4.1 Graph showing a correlation between moisture content and Strength

4.3 Conclusion

The graph comes out to be a haphazard curve and therefore no possible correlation can be drawn out of this plot. To investigate further more careful tests need to be carried out before completely rooting out the possibility of independence of specimen strength from its moisture content.

Chapter 5

STEEL BAMBOO FIXTURE TEST

5.1 General

Fixtures are also very important inspection criteria since any successful deployment of bamboo into modern structures would require the fabrication of standard joints which maximize joint friction is strong enough to oversee the failure of bamboo members, i.e. if such a situation arises. The philosophy has to create joints with serrations which could maximize the friction capacity. To this respect 2 tests were carried out on two 6ocm specimens. In the first specimen a rubber tube coating was fixed to the bamboo ends with the help of araldite and on that the collar assembly was fixed. But it resulted in rubber facilitating slippage and thereby the joint failed before the specimen, which was not what was intended. In the second attempt instead of making only 2 serrations along the collar, a continuous threading was made in an attempt to increase the joint capacity, but it too was met with the same fate :bamboo slipped out before it could fail, leading to joint failure again.

5.2 Photographs

Figure5.1 The joint collar assembly showing various components

Figure5.2 Close up photograph showing serrations in the collars made with the intention of increasing the friction capacity

Figure5.3 Photograph showing the failure of joint test. Upon looking carefully it can be observed that the rubber started to tear out and slip

5.3 Observations and Results

The table below highlights the results of the fixture test.

Table5.1Table showing the loads of joint test

Test Number	Load (Kg)
1	1600
2	1200

5.4 Conclusion

The joint test performed here can be improved in future and therefore more investigations are needed into this matter

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