Development and construction of Bamboo Roofing system- An Eco-friendly system

Miss. Prajakta Deshmukh[1], Dr. A.C. Attar[2]

[1] Student of M.Tech. Civil- Construction and Management,[2] Professor Rajarambapu Institute of Technology, Rajaramnagar, Islampur.

Email: - prajaktadeshmukh68@gmail.com [1] , acattar@rediffmail.com [2]

Abstract:

According to 11th development plan, 24.71 million people are not having their own houses. Therefore there is need of development of suitable low cost housing system so that people can satisfy their shelter need. As low income group people can not bear to satisfy cost of conventional construction system, there is necessity to decrease cost of construction with the help of an eco-friendly as well as affordable construction system. Considering all these problems, bamboo is suitable solution. As bamboo is naturally available material, it can be traditionally used by mankind. Due to lack of technology and awareness about bamboo, people are not using bamboo in construction of houses. Nowadays, construction industry has many burning issues like disposal of construction waste, wastage of material which causes financial loss, labour problem etc. As bamboo is traditional and an eco-friendly material, it has zero waste and it does not require skilled labour therefore, does not arises problem of disposal of waste and requirement of skilled labours. To minimize all this problems and to achieve an economy in the construction, we have to think about the utilization of bamboo in construction. In this paper, an attempt has been made to develop and construct bamboo roofing system which is an eco-friendly system.

Keywords: low cost and affordable roofing system, bamboo, an eco-friendly system.

1. General:

Nowadays, there is a big problem arises about housing of people. Many of the people are not capable to build their own houses. According to 11th development plan, 17% people of india, living in slum area. Therefore, there is lack of housing provision and people can not satisfy their basic need. To satisfy their basic need by achieving economy is an important parameter. Considering these problems, bamboo housing is very economical as well as necessary. Therefore, while thinking about affordable housing, bamboo is an important source of raw material which can be cultivated by local farmers. Bamboo requires less energy for production as compared to material such as steel, plastics etc. Bamboo acquires maturity within four to five years. Also bamboo is useful for reduction of green house effect as well as it has highest growth rate up to 90 cm/day. Bamboo absorbs maximum percent of carbon from an environment. Bamboo roofing helps to minimize temperature effect. Bamboo roofing maintain cool environment during summer days also. It shows temperature variation in bamboo housing and outside temperature. Pollution problem does not arise due to bamboo utilization. Nowadays, bamboo is one of the advanced material which gives maximum advantages in construction.

This paper consists of bamboo roofing system with an economy as compared to conventional roofing system. Developed system is mainly consists of locally available material like bamboo. Also this work consists of simple, economical and eco-friendly roofing system.

The main function of a roof is to give a protective covering to the building so that rain, snow or wind may not damage the building. It is erected at the highest part of the building and is made up of a framework over which a covering is laid. Roofs are constructed keeping in view the climate of the place and the materials available.

The general types of roofs are as below:

a) Sloping roofs

b) Flat roofs
c) Shelled roofs
d) Domes

The various shapes which can be given to roofs of this type depend on the area covered, materials available, type of lighting and ventilation needed inside, available appliances etc.

2. Developed roofing system:

Roofing system is developed for room size (3x3)m. This roofing system consists of components such as bamboo purlins, bamboo truss, bamboo mat, polythene paper, rice and wheat straw because of their local availability. This roofing system is developed by considering local availability of material, economy of the structure, aesthetical view of the structure and life of the structure. Figure 1.1 shows an elevation of the developed roofing system.

Figure 1 Elevation of developed system with roofing details

2.1 Purlins:

These are members laid horizontally to support the common rafters. They transmit the loads to the trusses or walls. Purlins used for this developed roofing is of bamboo. As room size is (3x3) m, five purlins are required. Height of structure above G.L. is 8ft.

2.2 Truss:

Truss is a framework of triangles. The total weight of the roof is carried on to the walls vertically. The framework of a truss is built in such a way that it does not alter its shape when loaded. Triangular shape of the frame offers greater rigidity. Members of trusses are subjected to direct stresses of compression or tension, the magnitude of bending stresses is negligible. To ensure this, the central lines of the connecting members should meet at one point and the loads should be applied at the apex points of the triangles.

2.2.1 Components of trusses are:

a) A central upright member called King post.
b) Inclined rafters called principal rafters.
c) A horizontal connecting member called tie-beam.
d) Two struts which give support to the rafters.
e) Purlins running over the principal rafters from truss to truss.
f) Ridge piece and common rafters for supporting the roof coverings.

The weight carried by the purlin is placed in the centre of the principal rafter and is carried through the struts to the foot of the king post. The principal rafters and the struts act as compression

members whereas the tie beam and the king post acts as tension members.

2.2.2 Truss Design:

Developed roofing system mainly consists of bamboo truss of span 3m. As room size is (3x3) m, one truss is required. Height of the structure above G.L. is 8ft. Truss is rests on the bamboo wall panel.

Design data for developed truss:-

Bamboo truss for 3m span @ 2mc/c:

Description	Design data	Units
Type of truss	HOWE	
Span of truss	3.000	M
Rise of truss	0.600	M
Slope of truss	18.435	Degree
Eaves height	0.100	M
Spacing of truss	2.000	M
Permeability	Normal	

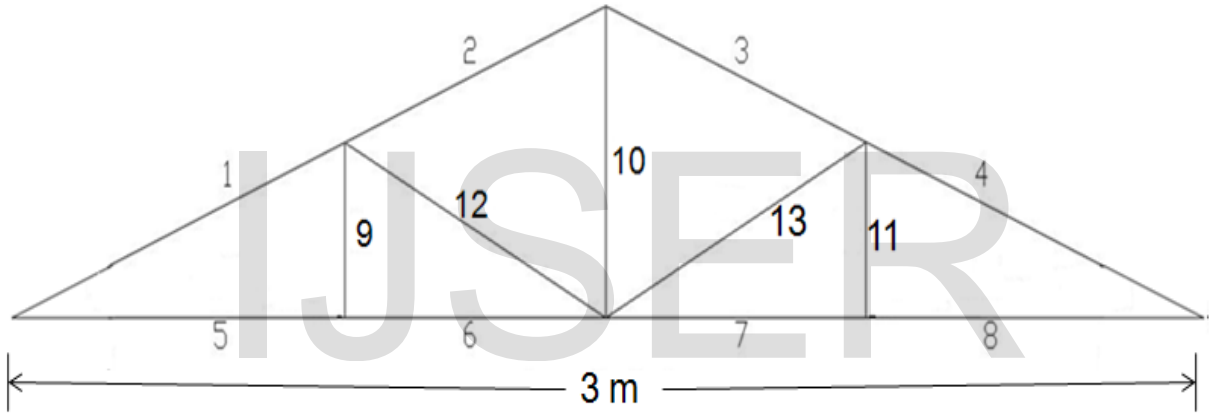

Figure 2.1 Truss for 3m span

HOWE TYPE TRUSS FOR 3m SPAN @ 2m C/C

Member No.	Length of member	Diameter of bamboo
1	0.753	2.5”
2	0.829	2.5”
3	0.829	2.5”
4	0.753	2.5”
5	0.714	2.5”
6	0.786	2.5”
7	0.786	2.5”
8	0.714	2.5”
9	0.100	2.5”
10	0.338	2.5”
11	0.600	2.5”
12	0.338	2.5”
13	0.100	2.5”
14	0.856	2.5”
15	0.856	2.5”

Total length of the 3m span truss = 9.352m

Truss is formed as per design as well as used in bamboo house which is constructed at RIT, Rajaramnagar. Joints are the very weak portion of the truss therefore care must be taken while constructing truss. Screws and nut-bolts are used while designing joints. Figure shows prepared truss at RIT, Rajaramnagar by considering all the parameters and design.

Figure 2.2 Prepared truss at RIT, Rajaramnagar

2.2.3 Testing of Truss:

Aim: To determine strength of bamboo truss which is used as a roofing component.

Procedure:

Bamboo used for preparing truss is solid in nature. Four bamboo trusses are prepared for testing. Out of these four trusses, two trusses have 3m span and remaining two has 5m span. A loading frame shall be used for the testing of the truss. Load shall be applied gradually and deflection to the nearest 1mm shall be used. The test shall be carried out in college testing lab on loading frame. The test specimen shall be mounted on loading frame in such a way that the horizontal members are parallel to the horizontal plane. It shall be adjusted by level tube. The loading of the test specimen shall be carried out uniformly at constant speed. Deflection at the middle span and at the nodal portion shall be noted by means of a dial gauge at load increments of every 500 N. Three dial gauges are used to measure deflection and truss shall be placed on the support at both the end. Direct load through loading frame is not applied. Loading frame transfers load on the hydraulic jack having weight of 56 Kg. This jack transfers load on the channel and then channel distributes load over the truss span. Weight of channel and hydraulic jack is also considered. The load shall be recorded at the points of sudden changes in deflection, at the time of failure and at maximum level, if different from the load at failure. Crack development and the form of failure shall be noted.

Test Set-up:

Figure 4.4.A Test set-up for truss testing

Observation table:

Table 3.6: For truss sample

Span in 'm'	Sample	Load in Kg	Load in N	Deflection in mm		
				At 'A'	At 'B'	At 'C'
3 m	A	3500	35000	6	11	5
3m	B	5000	50000	10	12	10
5m	A	1800	18000	9	18	9
5m	B	2100	21000	10	20	11

Figure 4.4.B Failure of truss observed during testing

Conclusion of the test :

By Testing:

- Different modes of failure are observed at joints.
- 5m span truss shows maximum deflection at the central portion of the truss as compared to 3m span truss.
- Central portion of the truss shows slight bending during testing.

2.3 Coverings:

The function of the covering is only to prevent ingress or egress of heat and moisture into the building. It does not withstand structural loads which are directly taken by the roofing elements. It is only to take loads to an extent over which it is supported on the roof members. There are various types of coverings depending on the character of the building, the type of roofing structure, local conditions, cost etc. Mainly in India, wood, tiles, slates, asphalt, asbestos cement sheets and corrugated iron sheets are used as a covering materials.

A] Selection of a suitable roof covering:

The various factors which have to be kept in view while selecting a particular type of roof covering for a given building are as follows:

a) **Initial cost**: The initial cost of roofing material varies from time to time and also with a given place. While considering the initial cost of covering material, the additional cost on account of the weight of the supporting members must be considered. Materials which are heavier need stronger superstructure which adds to the cost.

b) **Maintenance**: The cost of maintenance forms one of the main items while deciding the types particular roofing material.

c) **Slope of the roof**: It is mainly considered to prevent water penetration.

d) **Durability**: The life of the roofing material is important to determine its economical value. It depends on many factors and varies from place to place.

e) **Weight of the roof covering**: Heavier the weight of the particular roof covering, the stronger supporting structure is needed which adds to the cost.

f) **Type of construction**: Special type of construction is needed for certain types of roof coverings. Extra care has to be taken at joints.

g) **Appearance**: It is an important factor from architectural point of view.

h) **Heat insulation**: In tropical countries, insulation against heat is very important, as transmission of heat through the roof makes the rooms very hot and unsuitable for living.

By keeping all these points in mind, suitable roof covering should be selected. A covering of developed roofing system consists of bamboo mat, polythene paper, rice and wheat straw considering their local availability and economy. Two pieces of (15 X 7.5) ft. size mat is required for this roofing and one piece of (15 X 15) ft. size fabric paper is required.

3. Construction details:

A] An errection of wall panel is done by fixing a eucalyptus wood in ground up to 1m depth. A eucalyptus wood and wall panel is connected by 4" nails. Whole assembly is rests on the ground. After resting wall panel on the ground, construction of roofing is started.

Truss is rests on the front two wall panels. After fixing of the truss, five bamboo purlins are fixed along the wall panel. Spacing between purlins are properly adjusted. Roof covering consists of three layers such as bamboo mat, polythene paper, rice and wheat straw. Bamboo mats are fixed to the purlins with the help of nails and binding wire. Mat and purlins are connected to each other at a certain specified spacing using binding wire. Thus, mat is fixed to the purlins. Bamboo mats are manufactured by cutting uppermost surface of bamboo in strips. It does not require skilled labour and special assembly for connection.

B] After fixing bamboo mat on the purlins, polythene paper of size (15 X 15) ft. is laid on bamboo mat. Polythene paper is mainly used to prevent an entry of water in inner side of room. Therefore, there is no any problem arises during rainy season. Polythene paper is connected to the bamboo mat with the help of binding wire at a certain specified interval.

C] After laying polythene paper, an outermost layer is fixed on the polythene paper i.e. rice and wheat straw. As many people of islampur and nearby areas of islampur are mainly farmers, rice and wheat straw are easily available in maximum amount. Polythene paper is sandwiched in between bamboo mat and rice-wheat straw layer. For laying of rice and wheat straw on polythene paper, first of all two separate bamboo grids are formed. Grids are formed by using bamboo strips. In between these two separate bamboo grids rice and wheat straw are filled. These two grids and straw are binding together with the help of binding wire. Thus, rice and wheat straw layer is formed and laid on polythene paper.

D] After making rice and wheat straw layer, it is fixed to the bamboo mat with the help of binding wire very tightly. It has very attractive appearance. Thus, construction and fixing of roofing is completed very easily and quickly.

Thus, construction of roofing system is completed for (3X3) m size room in RIT, Rajaramnagar. Figure 4.12 shows developed roofing system in RIT, Rajaramnagar campus.

E] It is one of the simple roofing method. It does not require maximum no. of labours as well as skilled labour.

Figure 2.3 Developed roofing system in RIT, Rajaramnagar

4. Cost comparison between conventional and developed system:

For the determination of an economy of the structure, cost analysis of the structure can be done. Therefore, to know the actual cost and economy of the structure, cost analysis is very important

parameter. Aim of this work is to achieve positive results from work done such as development of low cost as well as economical roofing system. To analyze the economy of the developed roofing system, not only cost analysis but also cost comparison with conventional system is also important.

4.1 Cost Analysis for conventional roofing system:

While doing cost analysis of conventional system, room size is considered as (3x3) m. As roofing system is developed for low income group people, it is very simple. This conventional system consists of steel truss for 3m span and above this truss, purlins are laid. After the fixing of purlins on the truss, G.I. sheets are laid. G.I. sheets are used as a roof covering.

Rate analysis of conventional roofing system for room size (3x3) m:-

Span of steel truss = 3 m;
No. of trusses reqd. = 1;
No. of purlins reqd. = 4;
Approx. cost of 1 truss = Rs.2140/-
Approx. cost of 4 purlins = Rs. 1600/-
Approx. cost of roof truss = Rs. 3740/-

Cleat angle:-
Selected angle section = ISA (40x40x5)
Length of each angle = 1 ft.
Total length of angle = 10 ft. = 3 m
Total length of angle at corner = 4x (1.582+0.3) = 9m
Total length = (6+6) m = 12 m
Approx. cost = 45x36 = Rs.1620/-
Cost of roofing sheet:-
Use G.I. sheet of size (14x3) ft.
No. of sheets reqd. = 4
Approx. cost = Rs. 7200/-

And,
Labour charges = Rs. 15/- per sq. ft.
Total labour charges = Rs. 2000/-
Other charges welding, screw etc. = Rs.500/-
Considering all these charges,
Total cost of conventional roofing system =3740+1620+7200+2000+500
= Rs.15060/-

Therefore,
Approx. total cost = Rs.15060/-

Approx. cost of conventional roofing system per sq. ft. = Rs.123/-

4.2 Cost Analysis for developed bamboo roofing system:

Bamboo roofing system is developed for room size (3x3) m. This roofing system consists of bamboo truss, bamboo mat, polythene paper as well as rice and wheat straw.

Rate analysis of developed bamboo roofing system for room size (3x3) m:-

Span of truss = 3 m
No. of bamboo trusses reqd. = 1
No. of purlins reqd. = 5
Cost of 1 truss = Rs. 500/-
Cost of 5 purlins = Rs. 500/-
Cost of roof truss + purlins = Rs. 1000/-
Size of bamboo mat used = (15 X 7.5) ft.
No. of bamboo mat used = 2
cost of 2 bamboo mat used = 70x 2 = Rs.140/-
Size of polythene paper used = (15 X 15) ft.
Cost of polythene paper used = Rs. 550/-

For fixing of roof :-
No. of bamboo used for bamboo grid= 2
Cost of bamboo = Rs. 200/-
Cost of rice or wheat straw = Rs. 400/-
Cost of nails = Rs. 100/-
Cost of binding wire= 1Kg. = Rs. 60/-
Transportation cost = Rs. 1000/-
Fixing Charges= Rs. 1000/-

Considering all these charges,
Total cost of developed roofing system = Rs. 5000/-
Therefore,
Cost of bamboo roofing per sq. ft. = Rs. 41/-

Cost of developed Bamboo roofing system per sq. ft.= Rs.41/-

From this cost analysis, it can be concluded that, bamboo roofing system is economical than conventional roofing system. Bamboo roofing system minimizes 65% cost than conventional roofing.

5. Conclusion

This paper highlights and summarizes simple as well as economical bamboo roofing system which is affordable for low income group people to satisfy their basic need. Applicability of bamboo achieves greater economy in the construction. Bamboo products are biodegradable

therefore they do not pollute the nature. From this paper, it is concluded that bamboo roofing system minimizes 65% cost than conventional roofing. It does not require any type of curing like R.C.C. slab. One of the greater advantages of this type of roofing is that in summer season, it maintain cool environment in innermost part of room. It shows 5-6 ºC variation of temperature in inner and outside of the room during summer season. Bamboo has greater advantage is that it does not create any waste as well as does not pollute an environment. Therefore, does not arise problem of its disposal. It is not only light weight structure but also time saving roofing system. This roofing system does not take much time for its fixing. Bamboo is highly used as a construction material in future due to its unique properties. Bamboo can gives better results in composite material such as bamcrete, bamboo reinforcement etc. There is necessity of more awareness of the bamboo material's advantages so that further research can be carried out on bamboo and its extensive use in future.

6. References

1] Wahab Razak, Sulaiman Othman, Mohamad Aminuddin, Hashim W. Samsi and Khalid Izyan (2008). "Bamboo as an Eco-friendly Material for Use in Aquaculture Industry in Malaysia", Journal of Sustainable Development, Vol 2.

2] Rath Bikash "Bamboo in Orissa: Trade and livelihood Perspective" June 2005.

3] Paudel Shyam K. (INBAR)- International Network for Bamboo and Rattan "Bamboo as a Building Material for the 21st century", 1st Asia-Pacific Housing Forum 2004.

4] Solomon-Ayeh K.A.(2004), "Use of bamboo for buildings- A sustainable, strong, versatile and economic option for the preservation of timber in Ghana", INBAR publication.

5] Nwoke O.A, Ugwuishiwu B.O. (Dec. 2011). "LOCAL BAMBOO AND EARTH CONSTRUCTION POTENTIALS FOR PROVISION OF AFFORDABLE STRUCTURES IN NIGERIA", International Journal of Sustainable Construction Engineering & Technology (ISSN: 2180-3242) Vol 2.

6] G. Leake, K. Toole, P. Divis, C. Torres-Sanchez UK National Research Conference 2010 "Bamboo as a solution for low-cost housing and storage in Pabal (India)" 19th February 2010.

7] CBTC, INBAR, Govt. Of Mizoram An international workshop on"Affordable Bamboo Housing in Earthquake Prone Areas", 29th October-11th Nov., 2001 Mizoram, India.