J. Bangladesh Agril. Univ. 4(1): 139–149, 2006 ISSN 1810-3030

An investigation on strength and economy of cement-plastered bamboo-mat as fence of rural houses

M.Z. Abedin, M.Z. Rahman and M.S. Jalal
Department of Farm Structure, Bangladesh Agricultural University, Mymensingh-2202, Bangladesh

Abstract

This study explores the feasibility of using cement-plastered bamboo-mat as fence of rural houses. The strength properties of three common species of bamboo *Borak*, *Morol* and *Jay* were determined using its splits as test specimen. The fence slabs of size 90x30x5 cm were fabricated with coal-tar coated fence-skeletons made from splits of the three bamboo species having rectangular cross-sections of about 13x10 mm and cement mortar of ratio 1:4, 1:5 and 1:6. The load bearing capacity and the structural rigidity of the prototype fence slabs were determined against flexural and impact loadings. The load carrying capacity of the model fence slabs were evaluated in terms of the thrust resulting from devastating wind speed of 300 km/hr beyond great danger signal No.10 of weather forecast. The structural rigidity of the model fences were characterised in terms of its resistance against the dropping heights of impact loading. The unit construction costs of fence slabs were estimated. The qualitative evaluation of the bamboo-made fence in respect of construction cost, load bearing capacity, rigidity against impact load and factor of safety characterised a structurally strong and functional low cost fences suitable for flood prone and cyclone battered areas of rural Bangladesh.

Keywords: Cement-plastered, Bamboo-made fence, Low-cost, Rural houses

Introduction

It is estimated up to 2010 A.D. that about 50000 new houses will be needed each day to keep-up with the growing demand for roofs over new heads, homeless and distressed (Parkes, 1987). In most third world countries housing situation became worst since 1976 due to rapid population growth, inflation and low purchasing power of poor people. As many as seven out of ten houses in the rural areas are so unsuitable for human habitation that requires replacement or major alteration (Derek & Parkes, 1984). The self-insufficiencies of developing countries have prompted the need for the maximum utilization of indigenous materials. The quest for building materials that are easily accessible, durable, practicable and above all – available in adequate quantities, therefore, has characterised the scientist's attention and effort to provide with a cheap and economical housing in rural areas. The durability, economy and effectiveness of the materials should be taken into account in addition.

The cheaper walling materials used at farmers level in Bangladesh are clay, bamboo, jute-stick and stalk of cereals, while the costly materials are corrugated-iron sheet, fired-clay brick, metal-sheet etc. The amount of few years maintenance cost of cheaper walling materials exceeds the purchase cost of costly materials. As a matter of fact, bamboo is plentiful in tropical countries with a long history of its usefulness and making the most of it can offset the walling problem of rural houses to a great extent. Bamboo grows naturally as vegetation in the tropical, sub-tropical and mild temperate regions of the world with about 1250 identified species (Ben-George *et al.*, 1988). The scarcity and high cost of steel bars promoted much research into the practicability of using bamboo as a substitute for the steel in concrete structures. The advantages of bamboo are its relatively ample tensile strength, inexpensiveness and minimum labour needed for production. Bamboo takes about three years for its maturation but its durability and strength depend upon the maturity and quality (Janssen, 1981). Some of the species of bamboo have been found to have about 50% of the yield strength of mild steel (Singh, 1972). The bamboo-split works satisfactorily as reinforcement in roofs and floor slabs of semi-permanent low cost houses where the span does not exceed 3 m (Singh, 1972).

The load-carrying capacity of bamboo-reinforced beam is about 40 % of the reinforced concrete beam having the same reinforcement ratio (Samajpati & Abedin, 1992). The bamboo reinforced slabs could take more loads with greater deflection than the slabs reinforced with mild steel (Mattone, 1990). The bamboo-mat fence is about 33% cheaper than the wooden-framed bamboo-made fence (Abedin *et al.*, 1998). Wood being scarce and becoming expensive day by day, hence the bamboo-mat fence can be used in rural housing in developing countries like Bangladesh. The fences are suitable in areas where cyclonic wind occurs and can be used as a substitution of tin, brick or wood fences (Abedin & Rashid, 2000; Abedin *et al.*, 2000).

The main distinctive disadvantages of bamboo are its high water absorption tendency, poor bond with concrete, low modulus of elasticity, low durability and variation in mechanical properties (Geymayer & Cox, 1970). The bamboo reinforcement possesses bond-volume changes and decay (Glenn, 1980). The problems of bond-volume changes can be overcome by applying melting bitumen to bamboo strips uniformly to form a thin coat resulting in a reduced deformation and greater strength (Janssen, 1987). Durability and strength can be enhanced by seasoning and by preservative treatment with coal tar, zinc chloride, sodium fluoride etc. The expected life of bamboo-splits in controlled conditions can be as long as 35 years (IFIC, 1978).

Keeping the above discussions in view this study, therefore, aimed to determine the strength and economic feasibility of cement-plastered bamboo-mat as fence of houses suitable for rural people with low-income status. This study necessitates the following investigation.

1. To determine the ultimate tensile and compressive strength of three selected species of bamboo *Borak*, *Morol* and *Jay*.
2. To fabricate prototype fences with bamboo-splits of the selected species plastered with cement mortar of three varying ratio.
3. To ascertain the load bearing capacity and structural rigidity of the prototype fence slab against flexural and impact loadings.
4. To examine the economic feasibility of bamboo-made fences.

Materials and Methods

Preparation of bamboo splits

Locally available three varieties of bamboos - *Borak, Morol* and *Jay*, more than three years of maturation, were collected and were cut into pieces of about one metre in length discarding the slender tip of the stem. The pieces were then cleft into two equal troughs and dripped into fresh tank water for about a month. Due to the variation in properties of bamboo along the length, the three sections; Bottom (consisting of 2 meters of the lower part), Middle (consists of next 2 meters) and Top (2 meters at the upper end) were selected to prepare the test specimens and fence skeletons. The water-seasoned bamboo troughs were splited and sized down to form test specimen of desired sizes. For tension test, a uniform circular cross-section having 8 to 9 mm diameters and effective length of about 150 mm was made by using knives and emery paper to avoid stress-concentration. The ends of the split were tapered to an angle of 45° for successful performance of the tests avoiding the shear failure at the ends. Bamboo splits of about 6x6 to 10x10 mm square cross-section were used for compression tests. The length of the compression test specimen was taken in such a way that the slenderness ratio lies within the conditions encountered for short column. The specimens were kept in ambient air for few weeks for natural drying prior to the tests.

Tension and compression test of bamboo splits

In case of tension test, the Universal Testing Machine available in the Concrete and Material Testing Laboratory under the Department of Farm Structure was used (see Abedin *et al.*, 2000 for details). The load was applied gradually at a continuous rate of 1.5 mm per second until the rupture was attained. In case of compression test the specimen was placed in between the two platens of the Compression Testing Machine (see Abedin *et al.*, 2000 for details). The load was applied to the specimen by elevating the lower platen at a continuous rate of 1.0 mm per second until the failure of specimen. The ultimate tensile and compressive strengths of bamboo were calculated accordingly.

Preparation of fence skeleton

The water-seasoned troughs of *Borak*, *Morol* and *Jay* were splited longitudinally and sized down to 13x10 mm rectangular sections and air-dried for two weeks. The splits were then coated with melting coal-tar and air-dried for a week. The splits were woven to form skeleton (bamboo-mat) keeping equal alternate space in between two successive splits and thus fence skeletons of sizes 90x30 cm were prepared. A total of 36 fence skeletons were prepared with 12 for each category of bamboo. A typical fence skeleton is shown in Fig. 1. Care was also taken to alternate the basal and distal ends of the bamboo splits and this practice was ensured for a fairly uniform cross-section of the bamboo reinforcement throughout the length of member that resulted the uniform wedging effect. This would be materially increasing the bond between the mortar and the splits. A wooden frame with 5 individually equal internal sizes 90x30x5 cm was made for casting the slabs.

Fabrication of prototype fence slabs

Unlike other sophisticated engineering constructions, bamboo-reinforced fences require minimum of skilled labour and utilizes readily available materials. The cement mortar of three different ratio 1:4, 1:5 and 1:6 ratio were prepared with normal Portland cement (ASTM Type I) and well graded coarse sand having fineness modulus of 2.25 with water cement ratio of 0.4 by weight. It is utmost important that the mixing of mortar should be done to obtain a consistent and homogenous paste.

A polythene sheet was placed on the smooth floor of the Laboratory and the wooden frame was placed over it. Cement mortar was then spreaded evenly in the frame and the fence skeleton was put in-place as shown in Fig. 2. The mortar thickness was kept uniform on both sides of the skeleton. Care was also taken to ensure sufficient penetration of the mortar through the plaited pores of the skeleton. The mortar was properly rammed and trimmed with trowel so that the fence-thickness finished to 5 cm. A total of 36 slabs were cast with the splits of three different bamboo species and the stipulated three mortar ratio.

The prototype fence slabs were water-cured to promote the hydration of cement. The curing was done by covering the exposed surface of slabs with gunny bags and sprinkling water over it at intervals and kept continuously moist during the entire curing period of 4 weeks. After completion of curing, the prototype fence slabs were air-dried in room temperature for a few weeks. Photograph view of the water-cured slabs ready for flexural and impact tests are shown in Fig. 3.

Testing of prototype fence slabs

(a) **Flexural test:** The slabs were tested for flexure applying the centre-point line loading by the Beam Testing Machine. A typical centre-point loading is shown in Fig. 4. The load bearing capacity of slabs were evaluated against flexural load (see Abedin *et al.*, 1998 for derails) and converted into wind speed (Barre & Sammet, 1963). The mathematical calculations for converting the centre-point line loading to pressure unit are as follows (Abedin *et al.*, 1998):

The bending moment (M_p) for fence-slab of length L_s failing at centre-point line load P, is

$$M_p = PL_s/4 \tag{1}$$

In case of simply support, the bending moment (M_w) of a beam loaded with uniformly distributed load w, is

$$M_w = w\ L_s^2/8 \tag{2}$$

For $M_p = M_w$,

$$w = 2P/L_s \tag{3}$$

In slab action, load bearing capacity per unit length,

$$q = w + w_s \tag{4}$$

with w_s being the weight per unit length of the model fence-slab. If B be the slab width, then the ultimate load bearing capacity,

$$q_u = q/B \tag{5}$$

The wind pressure (W_p) at right angles to wind stream as proposed by Barre and Sammet (1963) is:

$$W_p = 0.00256\ V^2\ \text{lb/ft}^2 \tag{6}$$

where V = wind speed, miles/hr. or its equivalent form,

$$W_p = 0.0473\ V^2\ \text{N/m}^2 \tag{7}$$

with V in km/hr. For $q_u = W_p$, $V = 145\sqrt{q_u}$ km/hr (8)

where q_u in N/m^2. For most devastating wind speed of 300 km/hr, $W_p = 0.0473\ V^2 = 4257$ N/m^2 is taken as reference wind pressure. The factor of safety (F_s) against reference wind pressure, therefore, becomes

$$F_s = \frac{q_u}{W_p} \tag{9}$$

(b) **Impact test:** The prototype fence slabs were also tested to determine its structural rigidity against the impact load of 1.6 kg allowed falling freely through heights from 1.0 to 5.0 m. (see Manga, 1983 for derails). The working principle for impact test is shown in Fig. 5. The dropping heights were measured from the graduated scale of staff gauge erected vertically beside the dropping direction.

Cost estimation of fence slabs

The item-wise construction costs of slabs were estimated based on existing market price of the material and the cost per unit area was estimated. The unit cost of fence slabs was compared to the traditional wall made of 5 inch thick brick to examine the economic feasibility.

Results and Discussion

The strength properties of bamboo splits, both for tension and compression tests, are shown in Table 1 and 2 respectively. The average tensile strength of splits for *Borak*, *Morol* and *Jay* species were found to be 192.8, 209.1 and 219.5 N/mm^2 respectively and these are about 50% of the ultimate tensile strength of mild steel rod. The average compressive stresses of those were 69.7, 100.3 and 83.2 N/mm^2 respectively. It was observed from Table 1 and 2 that the variation in strength among the sections of a particular species is greater than the variations within individual species. Rahman, *et al.* (1991) also found this sort of variations in strength. The strength varies with species, age, growth conditions, moisture content, disposition of nodes and position along the culms and hence such variations were obvious.

Table 1. Tension test results for the experimental bamboo species

Bamboo species	Test sections	Ultimate load, P (N)	Average area, A_{av} (mm^2)	Average ultimate load, P_{av} (N)	Average tensile strength, $\sigma_t = P_{av}/A_{av}$ (N/mm^2)
Borak	Top	7415	58.70	11319	192.8
	Middle	11418			
	Bottom	15123			
Morol	Top	10084	65.00	13591	209.1
	Middle	15345			
	Bottom	15345			
Jay	Top	7785	50.00	10972	219.5
	Middle	9564			
	Bottom	15568			

Table 2. Compression test results for the experimental bamboo species

Bamboo species	Test sections	Cross-sectional area, A (mm^2)	Average ultimate load, P (N)	Compressive strength, $\sigma_c = P/A$ (N/mm^2)	Average compressive strength, σ_c (N/mm^2)
Borak	Upper	6x6	2646	73.50	69.7
	Middle	10x10	6005	60.05	
	Bottom	10x10	7562	75.62	
Morol	Upper	6x6	3558	98.80	100.3
	Middle	7x7	4893	99.86	
	Bottom	10x10	10230	102.30	
Jay	Upper	6x6	2891	80.31	83.2
	Middle	8x8	5560	86.88	
	Bottom	9x9	6672	82.37	

The ultimate load bearing capacity of slabs made from the splits of *Borak*, *Morol* and *Jay* species at different mortar ratio is given in Table 3. A typical example of load bearing capacity calculation is given as follows.

The common values for calculations are: the effective length of fence-slab placed over two rollers of the beam testing machine, L_s = 82 cm and the slab width, B = 30 cm and the reference wind pressure, W_p = 4257 N/m^2.

Say, the model fence is made from splits of *Borak* species with cement mortar ratio = 1:4.

Average line loads at crushing (from Table. 3) P = 3600 N

The equivalent uniformly distributed load, $w = \frac{2P}{L_s} = \frac{2x3600}{0.82}$ = 8780.5 N/m

The average weight of model fence, w_s = 231 N/m length

The load bearing capacity of the slab, $q_u = \frac{w + w_s}{B} = \frac{8780.5 + 231}{0.3}$ = 30038.3 N/m^2

The crushing wind speed, V = $145\sqrt{q_u} = 145\sqrt{30.0383}$ = 794.7 km/hr

Factor of safety against reference wind pressure, $F_s = \frac{q_u}{W_p} = \frac{30038.3}{4257}$ = 7.0

Table 3. Load bearing capacity of slabs made from splits of different bamboo species

Bamboo species	Cement Mortar ratio	Parameters					
		Av. line loads at crushing, P (N)	Equivalent uniformly distributed load, *w* (N/m)	Av. weight of fence slabs, w_s (N/m)	Load bearing capacity, q_u (kN/m^2)	Wind speed, V (km/hr)	Factor of safety, F_s
Borak	1:4	3600	8780.5	231	30.0383	794.7	7.0
	1:5	2500	6097.5	241	21.1285	666.5	4.9
	1:6	1900	4634.1	235	16.2304	584.1	3.8
Morol	1:4	3100	7560.9	236	25.9899	739.2	6.1
	1:5	2300	5609.7	256	19.5525	641.1	4.5
	1:6	1900	4634.1	240	16.2471	584.4	3.8
Jay	1:4	4000	9756.1	259	33.3836	837.7	7.8
	1:5	3600	8780.4	254	30.1149	795.7	7.1
	1:6	2700	6585.3	249	22.7812	692.1	5.3

It was found that the test slabs made of *Jay* species with 1:4, 1:5 and 1:6 cement mortar ratio can bear the wind speed of about 838, 796 and 692 km/hr respectively. In comparison to *Jay*, the load bearing capacity of slabs made from splits of *Borak* and *Morol* species were in the lower order.

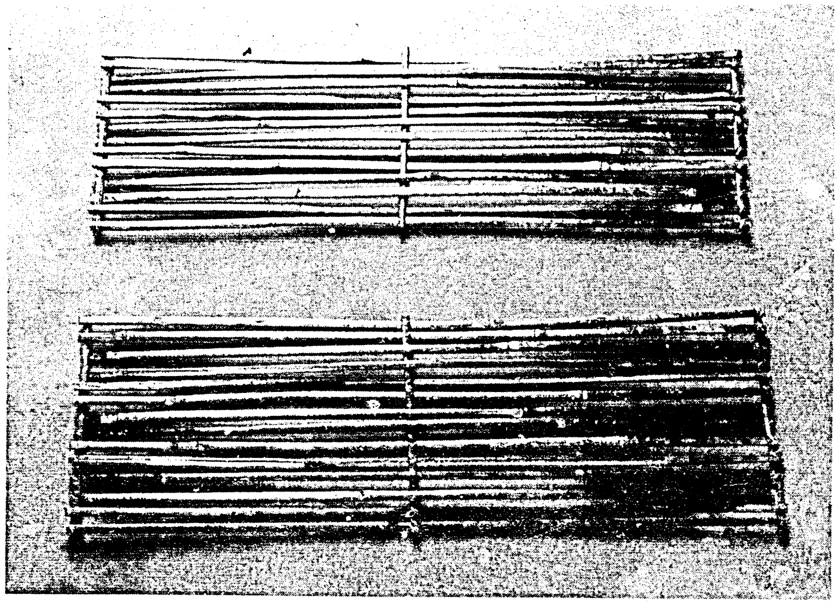

Fig.1 Fence skeleton with bamboo splits

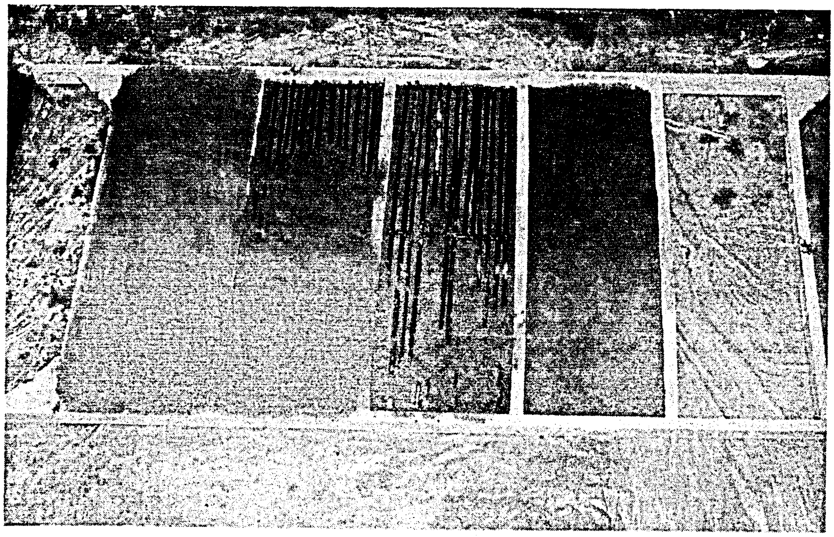

Fig.2 Model fence slab under construction

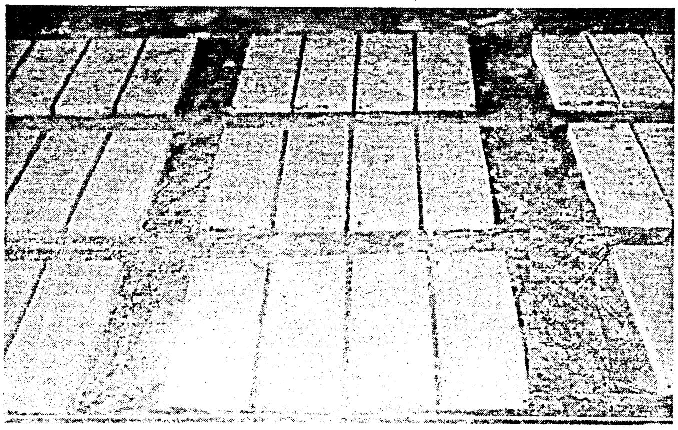

Fig.3 Water-cured and air-dried fence slabs ready for testing

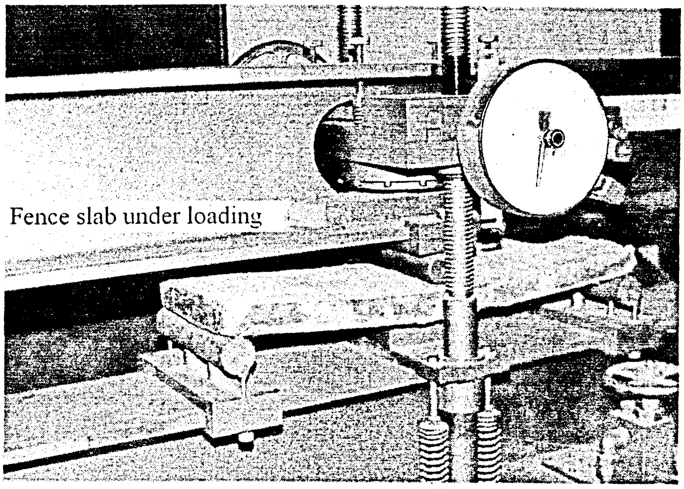

Fig.4 Fence slab under flexural test

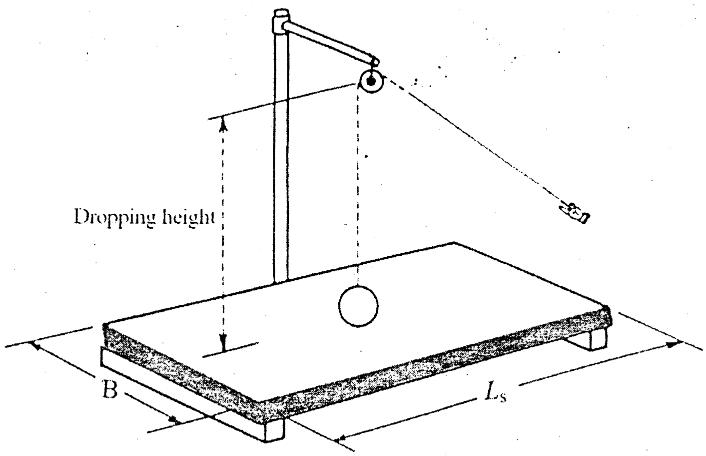

Fig. 5 Schematic arrangement of fence slab under impact test

As the wall is considered to be a non-load bearing type, therefore, the lateral pressure exerted mainly due to wind is responsible for its crushing. Conventionally, wind speed of 300 km/hr is considered as the most devastating value for walls and was taken as reference wind speed for calculation. The slabs made from splits of *Jay* species with 1:4, 1:5 and 1:6 cement mortar ratio was found strong enough with corresponding safety factors of 7.8, 7.1 and 5.3 respectively against the reference wind speed. A lower order trends in factor of safety were found in case of the slabs made from splits of *Borak* and *Morol* species respectively. The slabs made from splits of *Jay* species was found to resist the wind speed of 692 km/hr with 1:6 mortar ratio having the safety factor of 5.3 against the reference wind speed. In fact, the selection of cement mortar ratio depends on cost per unit area of slab and its bearing strength. For the present context, *Jay* species of bamboo may be considered to be the most suitable for wall construction. The comparison for load bearing capacity of slabs consisting of the splits of different bamboo species is shown in Fig. 6. It is worth to be mentioned here that the machine used for this test was too heavy with no digital recording systems.

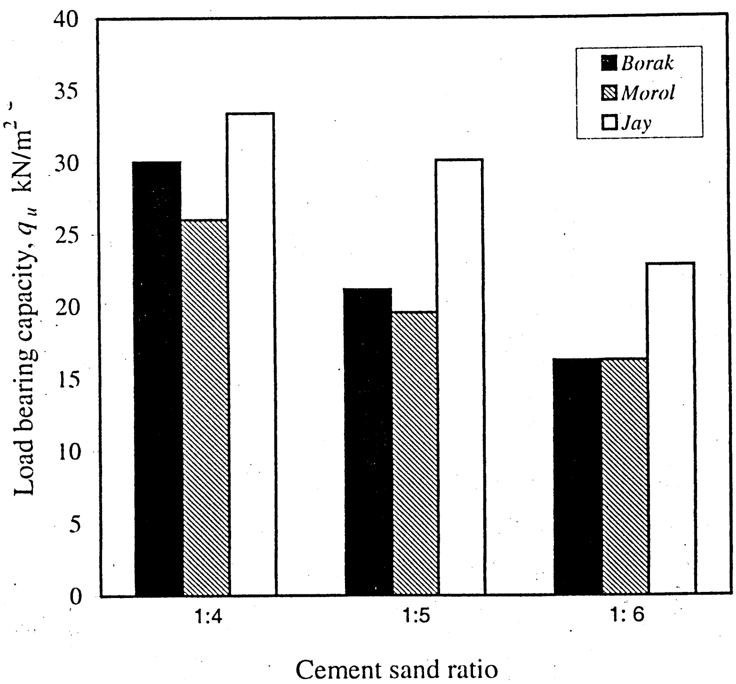

Fig.6 Load bearing capacity of fence slab at different mortar ratio

The structural rigidity against the impact load on test slabs, characterized into four categories of observation in terms of dropping height, was measured for different bamboo species with varying cement mortar ratio and is given in Table 4. It was observed that the slabs made splits of *Jay* species with 1:4 registered no imprint at a drop height of 1.8 m. Small defects began to appear at 3.1 m. A rather deep defect was observed when the weight was allowed to drop from 3.6 m and fracture was occurred at 4.5 m dropping height. The bamboo-made slabs registered no imprints below dropping heights of 1.4 m in all 1:6 mortar ratio. The slabs made from *Jay* species registered the relatively higher dropping height at fracture indicating the higher structural rigidity against impact loading. In comparison to *Jay*, the structural rigidity of slabs made from splits of *Morol* and *Borak* species were in the lower order.

Table 4. Structural rigidity of bamboo-made fence slabs against impact loads

Bamboo species	Cement mortar ratio	Dropping heights, m			
		Registered no imprint	Small defects began to appear	Deep defect observed	Fracture occurred
Borak	1:4	2.00	2.40	3.00	3.50
	1:5	1.70	2.50	3.00	3.40
	1:6	1.50	2.00	2.50	3.00
Morol	1:4	2.00	2.80	3.20	3.70
	1:5	1.80	2.50	3.00	3.60
	1:6	1.60	1.90	2.40	3.20
Jay	1:4	1.80	3.10	3.60	4.50
	1:5	1.50	3.00	3.30	3.80
	1:6	1.40	2.50	3.00	3.40

The construction costs of bamboo-reinforced slab per unit area at different ratio of cement mortar, averaging on 12 numbers of slabs in each ratio, is given in Table 5. The cost for slabs was estimated to be Tk. 228/m^2 for 1:4, Tk. 216/m^2 for 1:5 and Tk. 209/m^2 for 1:6 cement mortar ratio. This cost is comparable and is only about 40-45% of the construction cost of 5 inch thick conventional brick wall.

Table 5. Cost estimation of bamboo-made fence slabs at different cement mortar ratio

Cost items	Rate Tk.	Cement mortar ratio					
		1:4		1:5		1:6	
		Quantity	Taka	Quantity	Taka	Quantity	Taka
Bamboo	130/No.	1 No.	130.00	1 No.	130.00	1 No	130.00
Labour (collect, split & size down)	80/day	1 No. (2 days)	160.00	1 No. (2 days)	160.00	1 No (2 days)	160.00
Cement (OPC)	7840/ m^3	0.0312m^3	244.00	0.0261m^3	204.00	0.0224 m^3	175.00
Sand (FM = 2.25)	400/ m^3	0.1252m^3	50.05	0.1303m^3	52.00	0.134 m^3	58.00
Wooden frame, LS	-	-	12.00	-	12.00	-	12.00
Coal-tar	35/kg	1 kg	35.00	1 kg	35.00	1 kg	35.00
Polyethylene sheets	8/m run	3 m	24.00	3 m	24.00	3 m	24.00
Mason	120/day	1 No. (1/2 days)	60.00	1 No. (1/2 day)	60.00	1 No. (1/2 day)	60.00
Helper to mason	80/day	1 No. (1/2 days)	40.00	1 No. (1/2 day)	40.00	1 No. (1/2 day)	40.00
Total cost for 12 slabs, Tk.	-		755.05		717.00		694.00
Cost /slab, Tk.	-		62.92		59.75		57.83
Unit cost, Tk./m^2	-		228.00		216.00		209.00

Conclusions

The following conclusions may be drawn from the study:

1. Among the bamboo species tested, the splits of *Jay* possessed the highest tensile strength of 219.5 N/mm^2 which is about 50% of the tensile strength of mild steel rod. On the contrary, the splits of *Morol* species carried the highest compressive strength of 100.3 N/mm^2.

2. Among the bamboo-reinfoced slabs tested, the slabs made from splits of *Jay* species carried the highest ultimate load bearing capacity at different cement mortar ratio. The slabs made from splits of *Jay* with minimum of 1:6 cement mortar ratio was capable of withstanding 22.78 kN/m^2 wind pressure and strong enough in resisting the wind speed up to 692 km/hr having safety factor of 5.3.
3. The slabs made from splits of different bamboo species yields adequately rigid against impact loading without registering any imprints within minimum dropping height of 1.4 m.
4. The bamboo-reinforced slab can be used as walling component of rural house with unit construction cost of Tk. 228, 216 and 209 per square metre for the cement mortar ratio of 1:4, 1:5 and 1:6 respectively. This cost is comparable and is only about 40-45% of the construction cost of 5 inch thick conventional brick wall.
5. The 50 mm thick slabs reinforced with 13x10 mm rectangular bamboo splits with 1:6 cement mortar ratio can be used satisfactorily as fence for rural houses and suitable in respect of its strength and rigidity and would be the most economical ones.

References

Abedin, M.Z., Rashid, M.A. and Niraula, D. 1998. Use of cement plastered bamboo-mat as a fence of rural houses. Bangladesh Journal of Training and Devt., 11(1&2): 171-176.

Abedin, M.Z., Iqbal, M.Z. and Rahman, M.Z. 2000. An Investigation on strength properties of bamboo. Bangladesh Journal of Agricultural Engineering, 11 (1&2): 49-57.

Abedin, M.Z. and Rashid, M.A. 2000. Rural houses of Ferro-concrete shell roof and Plastered Bamboo-mat fences. The Journal of Rural Development, Bangladesh Academy for Rural Development, 30(2): 121-138.

Barre, H.J. and Sammet, L.L. 1963. Farm Structure . John Willy and Sons., New York.

Ben-George, M., Kankam, J.S. and Perry, S.H. 1988. Is bamboo-reinforced concrete really useful? Appropriate Technology. 14(4): 23-25.

Derek, M. and Parkes, M. 1984. Housing for the poor. Appropriate Technology, 11(3): 1-4.

Geymayer, H.G. and Cox, F.B. 1970. Bamboo reinforced concrete. ACI. J. Title no.67-51: 841-846.

Glenn, H.E. 1980. Bamboo Reinforcement of Portland Cement Concrete Structures. Clemson College Engineering Station, Bulletin 4, Clemson, South Corilina, USA.

IFIC (International Ferrocement Information Centre). 1978. Ferrocement Booklet No.2. Asian Institute of Technology, Thailand.

Janssen, J.J.A. 1981. Bamboo in Building Structures. PhD Thesis. Faculty of Architecture, Building and Planning. Eindhoven University of Technology, The Netherlands.

Janssen, J.J.A. 1987. Using bamboo as a reinforcement. Appropriate Technology. 14(2): 12-13.

Parkes, M. 1987. Shelter for all, Appropriate Technology, IT pub. Ltd, London, 13(4): 1-4.

Rahman, M., Khan, A., Abedin, Z. and Ilahi, M.F. 1991. Mechanical properties of Bamboo. Journal of IEB., 19(1&2): 15-18.

Manga, J.B. 1983. The feasibility of bamboo as reinforcement for Ferrocement housing wall. J. Ferrocement, 13(4): 345-349.

Mattone, R.1990. Ferrocement prefabrication -Self-help for low-cost housing. J. Ferrocement, 20(2): 143-148.

Samajpati, J.N. and Abedin, M.Z. 1992. Feasibility Study of Bamboo as reinforcing material in concrete beams. Bangladesh Journal of Agril. Sciences, 19(1): 51-54.

Singh, Y. 1972. Role of bamboo in rural building construction. CBRI, Roorkee, India.