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RESEARCH ARTICLE

A STUDY ON AFFORDABLE ROOFING SYSTEM USING BRICKS AS INFILL

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ABSTRACT

Affordable is the term used to describe the dwelling units which are affordable to a certain group of people. Providing adequate shelter for all people is a biggest challenge. It is known in construction of buildings that structural roofing system cost substantial amount compared to other structural components. Therefore any savings achieved in structural roofing system will considerably reduce the total cost of a building. The present study is carried to develop an alternative roofing system which is affordable. In this study, a grid consisting of primary and secondary beams is considered. The space between the primary and secondary beams is filled using bricks which are laid as linear arch. Different spans such as 7 bricks span (525mm), 9 bricks span (675mm) and 11 bricks span (825mm) are considered. Width wise multiple rows of bricks such as 2 layer and 3 layer are considered. Beams are designed using M20 grade concrete and reinforcing steel of yield strength of 415 N/mm2. Cost analysis made for proposed affordable roofing system, shows an average reduction of 36.37% compared to conventional RCC roofing system. The reliability of the proposed roofing system has high probability of survival and is on par with conventional RCC roofing.

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INTRODUCTION

Affordability of housing units is a worldwide concern. Roofs are the structural components provided at the top to protect against the adverse weathering conditions like sunlight, wind and rain. Structural roofing system cost sustainable amount in construction of buildings. Any savings achieved in construction of roof will reduce the total cost of the construction. Roofs can cost about 8-11% of the total project cost (Ulubeylia *et al.,* 2014). According to World Bank report published in 2016 on poverty in India, about 24.6% of population are under low income group. Government of India has launched housing schemes in 2015 – Pradhan Mantri Awas Yojana (PMAY). According to PMAY slum dwelling units are increasing at 34% per decade. It is estimated that a total 20million units is required by 2020. Hence it is important to develop a alternative roofing system which is affordable. Ravindra *et al.* (2016) carried work on affordable roofing system (ARS), to check whether prefabricated roofing system would replace the normal conventional RCC roofing system. In the study undertaken, pre-cast roof infill elements are supported over a pre-cast joist system. Rectangular pyramidal panels were considered with aspect ratio varying from 1.25 to 2. They concluded that the proposed alternative roofing system has a cost reduction of 0.4% to 34.2% when compared to normal conventional RCC roofing system. Ahmed *et al.* (2014) carried out experimental work to assess the strength of pre-cast roof slab system comprising of Ferro cement slab panels resting on a RC beam system. They concluded from the cost analysis that pre-cast system with Ferro cement panels with or without fly ash is economical compared to conventional RC slab system. Deshmuk and Attar (2013) states bamboo roofing system can be used as alternative roofing system which is naturally available, eco-friendly and economical compared to conventional RC slab system. Adalak and Puri (2003) discussed about different prefabricated methodologies in low cost housing which are economical. Maheri and Rahmani (2003) in his work discusses about the poor performance of the one-way jack arch system in seismic zones and mentions the advantages of using two-way jack arch system by providing secondary beams in the panel system. It is found that affordable roofing system is need of hour in our country and an attempt is made to develop an affordable roofing system. The present work is carried using bricks as infill in the slab panel system and to check whether the proposed roofing system would replace normal conventional RC slab. The main objective of the work is to develop an affordable roofing system using bricks as infill which is economical and take less time for construction. The proposed slab system consists of primary beams which are triangular in shape and held laterally by secondary beams at regular intervals. The infill is made by using bricks which are placed to form a linear arch. A typical layout of the proposed roofing system is shown in Figure 1.

Size of affordable roofing system considered in this study: The bricks are arranged as linear arch such that all the individual elements along span are inclined to the horizontal and the gap in between the bricks is filled with mortar. Therefore spans are considered based on number of bricks along the length and multiple rows of bricks along the width. The size of the brick considered is (150 x 105 x 75) mm. The following criteria is considered to fix the infill span and width.

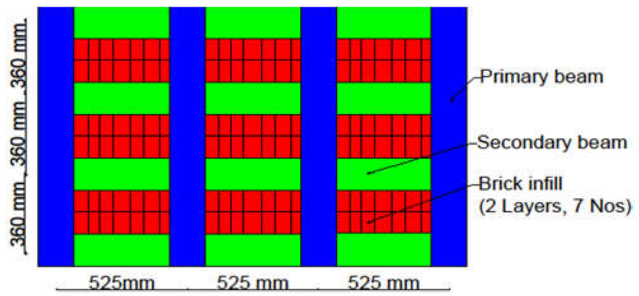

Figure 1a. Typical layout of ARS

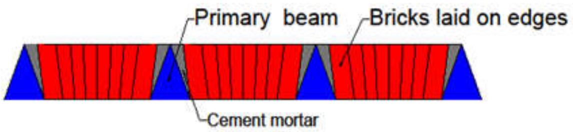

Figure 1b. Section A-A

Along spanning direction:
a). 7 bricks span = 7 x 75 = 525mm.
b). 9 bricks span = 9 x 75 = 675mm.
c). 11 bricks span = 11 x 75 = 825mm.

Along width wise:
a). 2 Rows bricks = 360mm.
b). 3 Rows bricks = 465mm.

The dimensions of the size of infill panels and the corresponding total size of the slab system shown are Table 1.

Table 1: Parameters considered in the study

Sl No	Size of Panel (m x m)	No of Panels		Total Size of ARS Slab (m x m)
		Along Shorter Span	Along Longer Span	
1	0.525 x 0.360	3	3	1.575 x 1.080
2	0.675 x 0.360	3	3	2.025 x 1.080
3	0.825 x 0.360	3	3	2.475 x 1.080
4	0.525 x 0.465	3	3	1.575 x 1.395
5	0.675 x 0.465	3	3	2.025 x 1.395
6	0.825 x 0.465	3	3	2.475 x 1.395

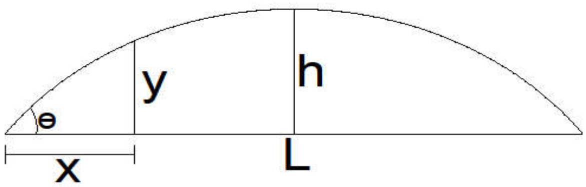

Figure 2. Simple parabolic arch

Angle of Inclination of Bricks: The concept of linear arch is adopted in placing the bricks at a suitable inclination. Angle of inclination of bricks to the horizontal is obtained by evaluating first order differential of the parabolic Eq. (1), such that the locus thrust forms a parabola along the span. The slope at any point of a parabola as shown in the Figure 2 having span L and rise h, can be obtained by Eq.(2).

$$y = \frac{4hx}{l^2}[l - x] \quad (1)$$

$$\frac{dy}{dx} = \frac{4h}{l^2}[l - 2x] \quad (2)$$

$$\text{At supports, } x=0, \frac{dy}{dx} = \frac{4h}{l} \quad (3)$$

The slope at supports is evaluated using Eq. (3) and hence the angle of inclination of bricks to the horizontal (θ) at supports for different span are calculated and tabulated as shown in Table 2. Positioning of bricks for a typical span consisting of 7 bricks is shown in Figure 3.

Table .: Angle of inclination of bricks for different span

Span (l) (mm)	Rise (h) (mm)		Angle of inclination ( ) at supports
525	50	21.83°	68.17°
675	50	16.97°	73.03°
825	50	13.89°	76.11°

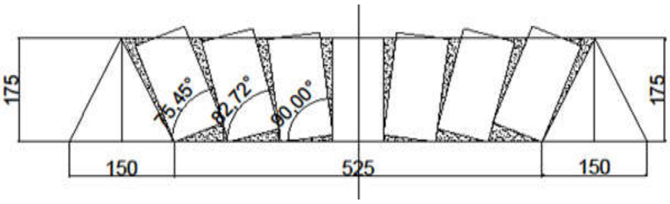

Figure 3. Typical sketch of 7 bricks span.

Analysis

The load considered for the analysis are as per IS: 875(part1)-1987 and IS: 875(part-2)-1987 are tabulated in Table 3. After positioning the bricks by obtaining the angle of inclination (θ) for different spans, analysis is performed to obtain the normal reaction (N) at the face of the mortar and face of the bricks. Analysis of system of bricks is carried out as shown below (refer Figure 4).

Table 3. Loads for analysis

Live load	1.5kN/m^2
Self- weight of brick	18.85kN/m^3
Self-weight of mortar	20.40kN/m^3

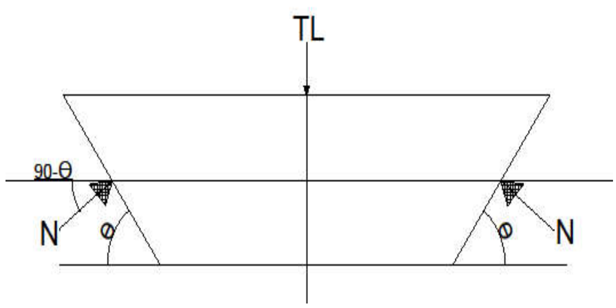

Figure 4. Forces on the system of bricks

The normal reaction, N is given by Eq.(4).

$$N = \frac{TL}{2\cos\theta} \quad (4)$$

Where, TL = total load, N = normal reaction, θ = angle of inclination of bricks.

Total load (TL) is load contributed due to live load, dead load of bricks, dead load of mortar provided at the top(assumed thickness =100mm),at bottom ceiling(assumed thickness = 10mm) and dead load of mortar between the bricks. Using Eq.(4) the normal reaction at the face of the brick and mortar is obtained and are tabulated in Table 4 to 6.

Table 4. Normal reaction for 525mm span

No of bricks	Normal reaction (at the face of brick) (N)	Normal reaction (at the face of mortar) (N)
1	0	274.00
3	689.67	384.94
5	599.28	430.53
7	578.28	503.39

Table 5. Normal reactions for 675mm span

No of bricks	Normal reaction (at the face of bricks) (N)	Normal reaction (at the face of mortar) (N)
1	0	406.31
3	1112.84	596.79
5	955.47	665.42
7	908.56	702.86
9	891.77	619.87

Table 6. Normal reaction for 825mm span

No of Bricks	Normal Reaction (At face of the brick)(N)	Normal Reaction (At the face of mortar)(N)
1	0	576.77
3	631.19	871.77
5	1416.98	969.48
7	1335.27	1022.44
9	1299.37	1058.58
11	1282.59	736.53

Design of beams: The beams provided are triangular in shape, the design of triangular beams done by limit state method. The normal reactions obtained from the linear arch are adopted for the analysis and design of primary beams. Parameters considered for design are follows,

Width of beam = 150mm.
Grade of concrete = M20.
Grade of steel = 415 N/mm^2
Factored design bending moment, M_z on the beam due to external loads is given by

$$M_z = 1.5[\frac{w*l^2}{8} + (w*a)]$$

The moment of resistance, M_r of triangular beam is given by $M_r = K_2bd^2f_{ck}$ (Dayaratnam, 1983), the depth of the beams is proportioned so that they are singly reinforced and the details of beams adopted in the study are shown in Table.7.

Table 7. Details of beam for different spans

Size of ARS (m)	Design bending moment (M_z) kN-m	Moment of resistance (M_r)kN-m	Depth provided (mm)
1.575 x 1.080	0.87	1.19	150
2.025 x 1.080	1.25	1.49	165
2.475 x 1.080	1.52	1.71	175
1.575 x 1.395	1.32	1.38	160
2.025 x 1.395	1.84	1.95	185
2.475 x 1.395	2.20	2.32	200

Cost Analysis

Cost estimate is made for the proposed affordable roofing system and a conventional RCC roof of same size in plan. The cost per square meter of ARS and the corresponding conventional RCC slab is calculated. The cost ratio of ARS with respect to conventional RC slab is found and tabulated in Table 8. If the cost ratio is less than one, it indicates that the proposed affordable roofing system is economical compared to conventional RCC slab. Cost comparison of the proposed affordable roofing system and conventional RCC slab is shown in Table.8.

Table 8. Cost comparison between the ARS and conventional RCC roofing system.

Sl No	Panel	Slab Size, m		Total Cost /m^2			% Cost saving w.r.t RCC Slab
				ARS	RCC Slab	Cost Ratio	
1	S1	1.08	1.575	2836	4284	0.662	33.79
2	S2	1.08	2.025	2718	4285	0.634	36.57
3	S3	1.08	2.475	2583	3846	0.672	32.85
4	S4	1.395	1.575	2701	4243	0.636	36.35
5	S5	1.395	2.025	2598	4115	0.631	36.87
6	S6	1.395	2.475	2482	4261	0.582	41.75
						Average :	36.37

Table 9. Weight of primary and secondary beams

Sl No	Panel	Panel Size (m)	Slab Size (m)	Primary Beam			Secondary Beam			Weight (Kg)	
				L(m)	B(m)	D(m)	L(m)	B(m)	D(m)	Primary Beams	Secondary Beam
1	S_1	0.525 x 0.360	1.575 x 1.080	1.08	0.15	0.15	0.525	0.15	0.15	60.75	29.53
2	S_2	0.675 x 0.360	2.025 x 1.080	1.08	0.15	0.165	0.675	0.15	0.15	66.83	37.97
3	S_3	0.825 x 0.360	2.475 x 1.080	1.08	0.15	0.175	0.825	0.15	0.15	70.88	46.41
4	S_4	0.525 x 0.465	1.575 x 1.395	1.395	0.15	0.16	0.525	0.15	0.15	83.7	29.53
5	S_5	0.675 x 0.465	2.025 x 1.395	1.395	0.15	0.185	0.675	0.15	0.15	96.78	37.97
6	S_6	0.825 x 0.465	2.475 x 1.395	1.395	0.15	0.2	0.825	0.15	0.15	104.63	46.41

Table 10. System reliability analysis for ARS and conventional RCC slab.

Sl No	Panel	Slab Size	ARS	Conventional RCC slab
			Probability of survival of system (Pss)	Probability of survival of system (Pss)
1	S_1	1.575 x 1.080	0.999387741	0.9999998766
2	S_2	2.025 x 1.080	0.999229743	0.9999998549
3	S_3	2.475 x 1.080	0.999104101	0.9999997788
4	S_4	1.575 x 1.395	0.999286231	0.9999998828
5	S_5	2.025 x 1.395	0.998997577	0.9999998472
6	S_6	2.475 x 1.395	0.998793386	0.9999998766

Weight of primary beams and secondary beams are less and beam can be easily handled by two or three masons, which reduces the labour cost. Table 9 shows the weight of primary and secondary beams.

System reliability analysis: Safety of the structure is one of the important parameter to be considered during design. In the present study reliability analysis is carried to evaluate the level of safety of the proposed affordable roofing system. A system reliability model of the proposed roofing system shown in Figure 5 to obtain the reliability. Table 10 shows the probability of survival from the reliability analysis for proposed roofing system and conventional RCC slab.

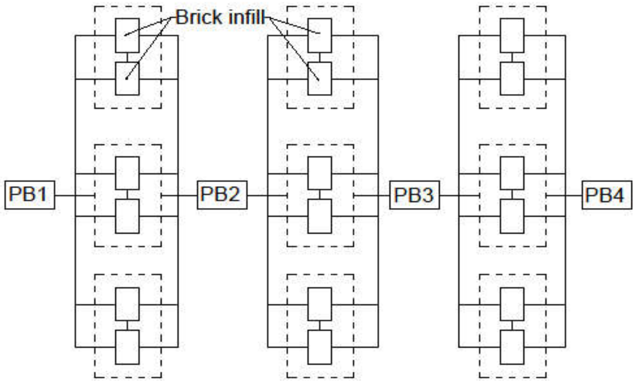

Figure 5. System reliability model

Conclusion

The conclusions drawn from the investigation carried out are as follows,

1. Cost estimation indicates an average reduction of 36.37% when compared to conventional RCC roofing system.
2. Weight of beams are less, they can be handled by only two or three masons. Hence, it reduces the cost of labour during construction.
3. Reliability analysis indicates the proposed roofing system has level of safety on par with the conventional RCC slab.
4. Considering the cost, level of safety, the proposed affordable roofing system proves to be a strong alternative to the conventional RCC roofing system

REFERENCES

Adlakha P K. and Puri H C. 2003. Prefabrication Building Methodologies for Low Cost Housing, Institute of Engineers(I) Journal, Vol.84.

Ahmad T., M. Arif, A. Masood, 2014. Experimental Investigations on Ferro cement Roof Slab System for Low Cost Housing, Vol.95,No.1, pp.9-18.

Deshmukh P. and A.C. Attar, 2013. Development and Construction of Bamboo Roofing system- An Eco-friendly system, International Journal of Scientific & Engineering Research, Vol.4, No.8, pp.12-20.

Design of Reinforced Concrete Structures by P. Dayaratnam, 5th edition (MedTech), ISBN No 9386479788, 1983.

Maheri M.R., H. Rahmani, 2003. Static and Seismic Design of one-Way and Two-Way Jack Arch Masonry Slabs, Engineering Structures, pp.1639–1654.

Pradhan Mantri Awas Yojana, “Housing for all 2022”, Scheme guidelines, www.pmaymis.gov.in.

Ravindra R, Subramanya K.G, Tejus V. 2016. A Study of Affordable Roofing System using Rectangular Pyramidical Panels, *American Journal Engineering Research,* Vol.5, No.10, pp.121-128.

Ulubeylia S., A. K. Bayram, and M. Talat Brigonulc, 2014. Comparison of Different Roofs Types in Housing Projects in Turkey: Cost Analysis, Procedia – Social Behavioural Sciences, Vol.119 No.20-29, pp. 221-228.

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