American Journal of Engineering Research (AJER)
e-ISSN: 2320-0847 p-ISSN: 2320-0936
Volume-5, Issue-10, pp-121-128
www.ajer.org
Research Paper Open Access

"A Study of Affordable Roofing System with Rectangular Pyramidal Panels"

Ravindra R[1], Subramanya K.G[2], Tejus V[3]

[1]Associate Professor, Dept. of Civil Engineering, R.V. College of Engineering, VTU, India

[2]Assistant Professor, Dept. of Civil Engineering, GSKSJTI, VTU, India.

[3]Post Graduate student, Dept. of Civil Engineering, GSKSJTI, VTU, India.

ABSTRACT: *Affordable housing is a term used to describe dwelling units whose costs are deemed "affordable" to a group of people within a specified income range. Structural floors/roofs account for substantial cost of building in normal situation. Therefore any savings achieved in the roofing Systems considerably reduce the cost of the building unit. A focused investigation is to be made to check whether the prefabricated roofing would replace the normal roofing process. In the study undertaken, Pre-cast RCC roof infill elements are supported on precast RCC joist System. The rectangular pyramidal panels considered have a least size of 0.5m and 0.75m with the aspect ratio varying from 1.25 to 2 with a rise of 60mm at the center. The analysis of the roof System is made by using STAADPRO software and later designed using M20 grade concrete and steel corresponding to 415N/mm^{2}. The cost analysis made for the affordable roofing System proposed indicates a cost reduction between 0.4% to 34.7% when compared to the conventional RCC slab of same size. The panels weigh lesser and can easily be handled by three to five masons. It proves to be a strong alternative to the conventional RCC roofing System.*

Keywords –*Affordable Roofing, Precast Concrete, Cost Economics of Roofing System, Aspect Ratio. Affordable housing*

I. INTRODUCTION

Housing affordability has always been a worldwide concern. Roofs are the components installed at the top of the buildings to protect the occupants against adverse weather conditions such as temperature changes, solar radiation, rain, snow, and wind. So, any kinds of saving attained in the construction of roofing System substantially reduces the cost of the building unit. As other essential parts of buildings, roofs correspond to about 8-11% of the total project cost [1]. In India according to the World Bank estimates of 2013, around 23.6% of the residents are residing under the lower poverty line and the shortage in the urban dwelling units was assessed as 17 million units. In view of search of alternate roofing technology, the present work under taken has precast RCC roof infill elements which are supported on a grid work of precast RCC joist System and with an overlay of in-situ concrete. The components of roofing System are

(i).Roof infill element of rectangular panels with pyramidal shape of smaller thickness to have membrane action as well as arching action.

(ii). Primary and secondary RCC precast beams like grid System.

The necessity in the reduction of the cost in construction led to the development of alternative roofing technologies. Filler slab is one such technology, which is based on the principle that concrete can take up compression but is weak in tension. Thus in the conventional RCC slab, bottom portion of the concrete is substituted with a cheaper and lighter filler material for cost-effective advantage over RCC slab [2]. Precast RCC planks and joist System is another alternative roofing technology. Here, precast planks are supported above the partially precast joist System across and are then linked together by in-situ concrete poured over full roofing area and reinforced hooks project out from the joist Systems to have monolithic action [3]. B. V. Venkataramana Reddy, Jagadish K S et.al [4] have highlighted some issues relating to the environment, energy effects of alternative building techniques in the research work. Alternate building techniques developed were energy efficient and the embodied energy of the housing units constructed using these skills are found to consume less energy than half of the energy utilized by conventional housing units. Hira B N and Negi S K [5] have found out a number of aspects of prefabricated building practices for low cost housing by highlighting the various prefabrication techniques, and the economic benefits attained by its adoption. Adlakha P K and Puri H C [6] have suggested the use of the Precast RC Planks and joists, Precast RC Channel Roofing, Precast Concrete Panels, Prefabricated Brick Panels, Precast RB Curved Panels, and Precast Hollow Slabs etc. as roof elements. Research works carried by Adlakha P K [8], Vivian W. Y [9], Tiwari P [10], and Ian Holton [11] gives the cost effective construction and sustainable energy, and it is found that there is a need of environment-friendly and innovative housing techniques for the development of houses and structures with substantial reduction in the cost. William G. Davids [12], has given a study which mainly emphasizes on the in-plane load- deflections as well as buckling response of the pressurized prefabricated arches of continuous circular cross section. Immanuel G and Kharthi K [13], have found out behaviour of various types of shell elements in roof slabs or in any other structure. Research works were carried out on the optimization methods for roof slabs for the least possible cost. Richard J. Balling and Xiaoping Yao., Booz W et.al [14], have mentioned of optimization method for three-dimensional reinforced concrete framed structures and other floor/roof structures. It is noted that conventional roofing in a housing System is one of the most costly components and also contributes hugely to the embodied energy of the buildings as a whole. Hence, it is necessary to find a suitable cost effective alternative roofing technology by using precasting techniques. By using this technology, form work cost, Labour charges, cast in situ work to be carried out etc. can be avoided. This project aims at developing a cost effective roofing technology which is economical, less time consuming for construction and aesthetically pleasing roofing System. It also aims at developing a technology of providing roofing System with precast panels supported on precast beams.

II. SCOPE AND OBJECTIVE OF THE STUDY

The main objective of this analytical investigation undertaken is to examine the behaviour and performance of the precast joists and panel roofing System. It also aims at developing a technology of providing roofing System with precast panels supported on precast beams. Rectangular precast panels having shorter side of length 0.5m and 0.75m are considered in the study. The aspect ratio of the panel is varied from 1.25 to 2 with a rise of 60mm at the centre. Table 1 shows the details of the proposed slab System undertaken for study. A typical layout of the roofing System is shown in Fig 1.
ARS refers to affordable roofing system

Table 1 Parameters Undertaken For the Present Study

SL NO	Rectangular panel Dimension in (m)	Aspect Ratio	No. of Panels		Total Size of the ARS Slab
			Along shorter	Along longer	
1	0.5 X 0.625	1.25	5	4	2.50 X 2.50
2	0.5 X 0.75	1.50	5	4	2.5 X 3.0
3	0.5 X 0.875	1.75	5	4	2.5 X 3.5
4	0.5 X 1.0	2.00	4	3	2.0 X 3.0
5	0.75 X 0.9375	1.25	4	4	3.0 X 3.75
6	0.75 X 1.125	1.50	4	3	3.0 X 3.375
7	0.75 X 1.3125	1.75	4	3	3.0 X 3.94
8	0.75 X 1.5	2.00	4	3	3.0 X 4.5

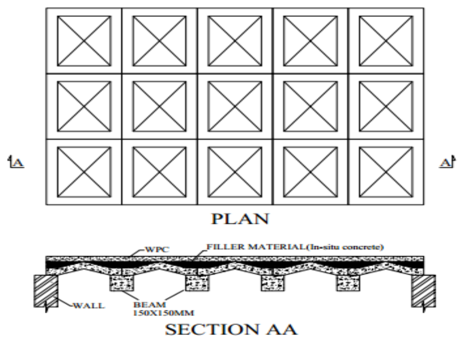

Fig1. Typical Layout of the Roofing System

III. LOADS CONSIDERED

- A live load (LL) of 1.5 KN/m^2 is considered, in accordance to IS 875:1987 (Part 2).
- Dead load is considered to be the self-weight of beams and panels. The Density is taken as 25KN/m^3. In accordance to IS 875:1987 (Part 1).
- Screed Concrete is assumed as floor finishing. Density of screed concrete is assumed as 20KN/m^3, the thickness of screed concrete is calculated based on rise. Fig 2 shows the cross sectional details.
- Water proofing coat: The Density of WPC is taken as 20.40KN/m^3 in accordance to IS 875:1987 (Part 1) and the Thickness of WPC is taken as 50mm fig 2 gives the details of panel thickness and WPC thickness.
- The analysis is carried for a load combination of 1.5(DL+LL) as per IS 456:2000

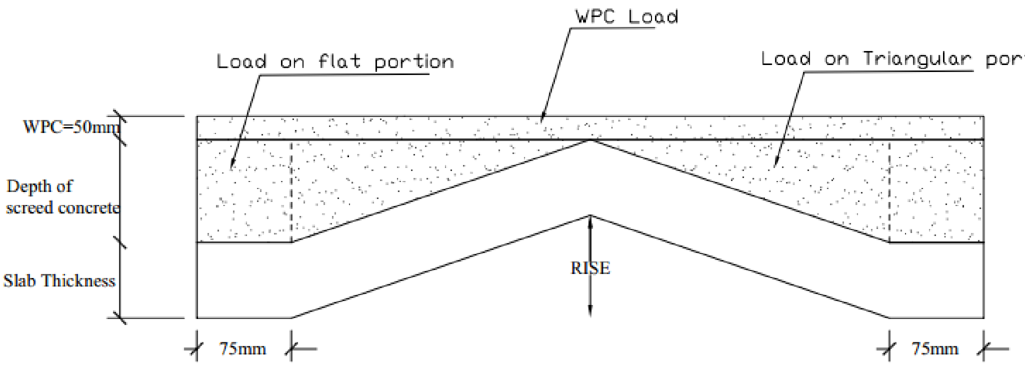

Fig 2 Panel Thickness and Floor Finishes Considered For Slab

IV. ANALYSIS AND DESIGN

Rectangular Panels

The sizing of the main beam and the secondary beam is made by preliminary analysis of the roofing System proposed. The size of the beam of 150mm width and 150mm depth was sufficient for all the types of the slabs considered. The detailed analysis of the roofing System is made using STAADPRO software. The rectangular panels are discretised into three noded and four noded elements. A typical discretised model of a rectangular panel is shown in Fig 3(a) and 3(b).T he slab thickness of the rectangular panels are assumed to be 75mm in the initial phase of analysis which was later revised based on analysis results. The secondary beams are supported on the bracket provided on the main beam as shown in Fig 4. The analysis of the roofing System using the software yielded the critical values of bending moment (M_x and M_y), shear stress (Sqx and Sqy), and in-plane stresses (Sx and Sy). The notations for the critical values for bending moment shear stress and in-plane stresses are the same as used in the STAADPRO software. The typical stress contours of a rectangular panel measuring 0.5m x 0.625m is shown in Fig 5 (a), 5(b), and 5(c). The rectangular panels are designed by limit state method in accordance to IS 456:2000. The rectangular panels are designed for Bending Moment, Shear and also for the combined action of bending moment and in-plane stresses. A typical reinforcement details in the rectangular panel is shown in Fig 6. M20 grade of concrete and reinforcement having yield strength of 415 N/mm^2 is assumed in the design.

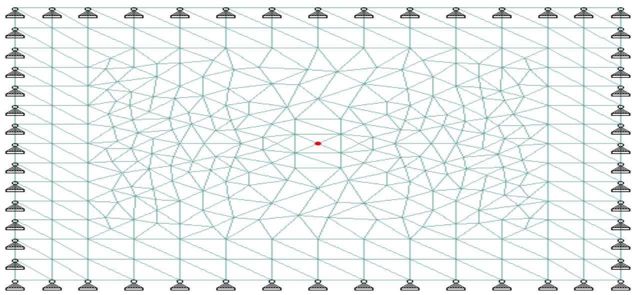

Fig 3(a) Top view of Discretised Slab panel

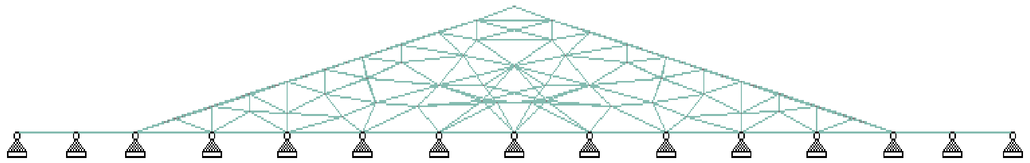

Fig 3(b) Front view of Discretised Slab panel

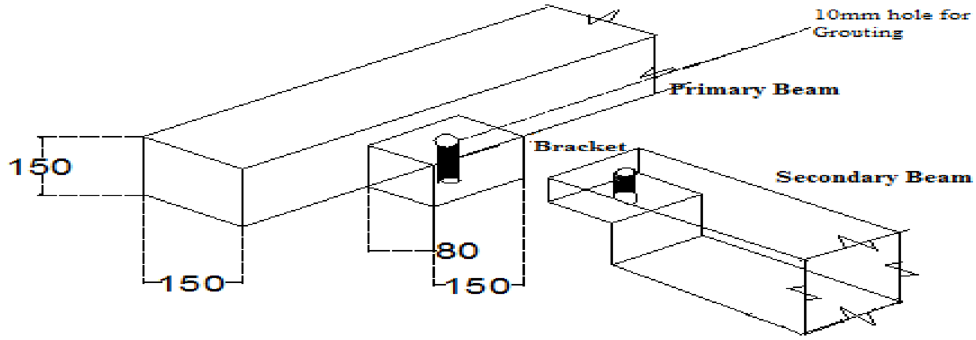

Fig 4 Connection between Bracket and Secondary Beam

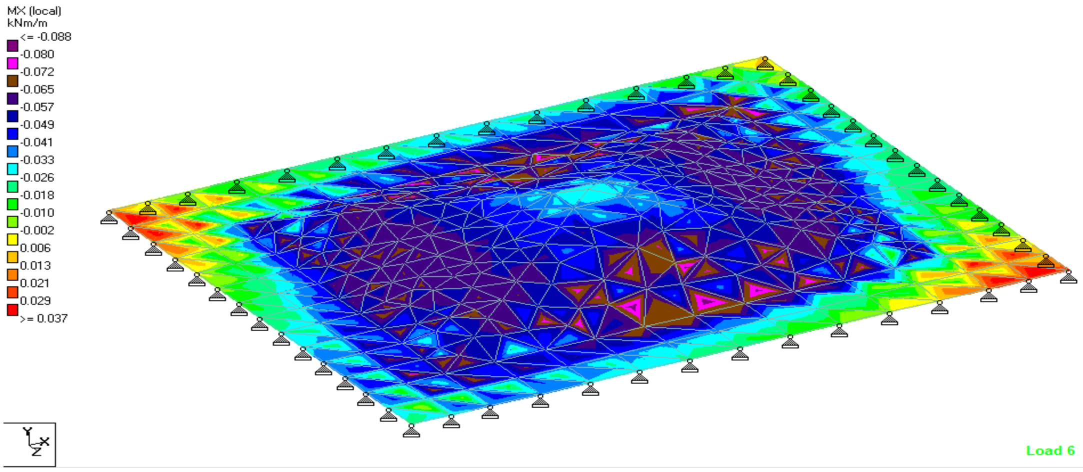

Fig 5(a) Mx Local Stresses (for0.5mx0.625mPanel)

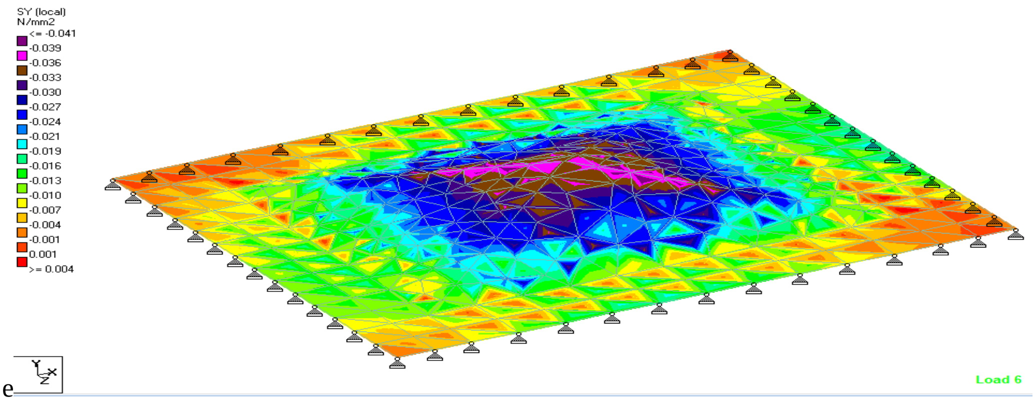

Fig 5(b) Sx Local Stresses(for0.5mx0.625mPanel)

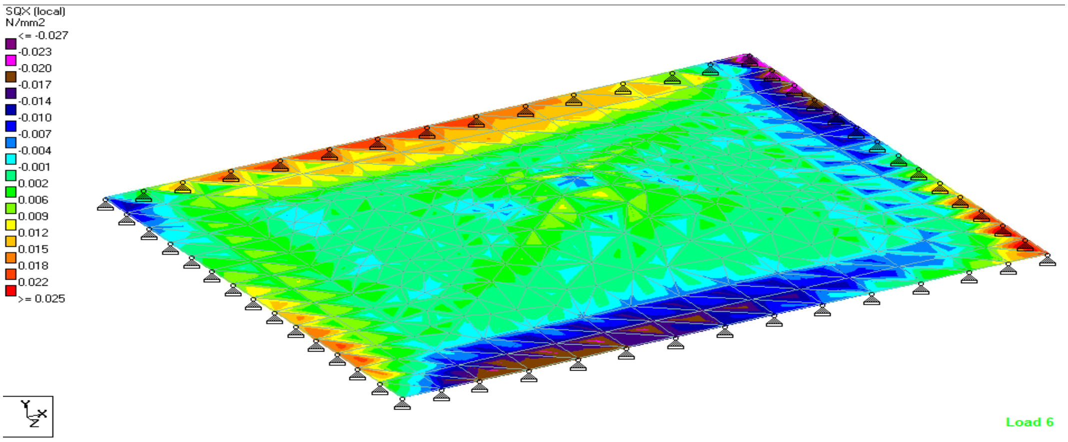

Fig 5(c) Sqx Local Stresses(for0.5mx0.625mPanel)

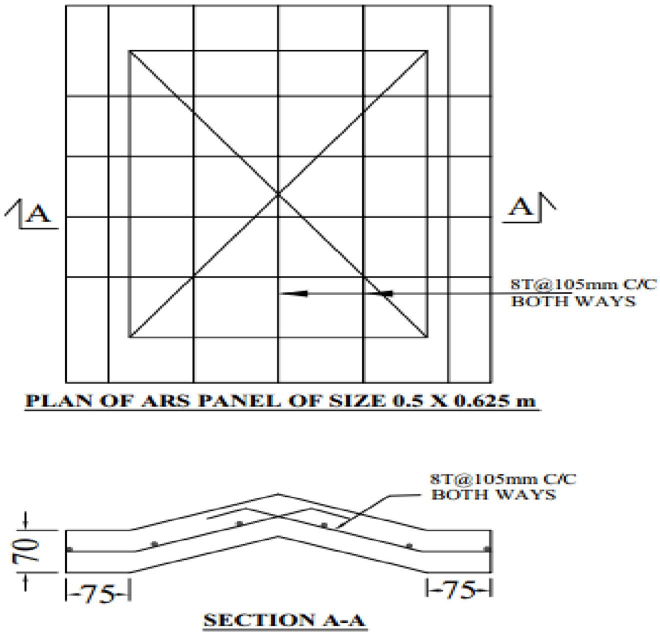

Fig6 Reinforcement Layout (forPanelofSize0.5mX0.625m)

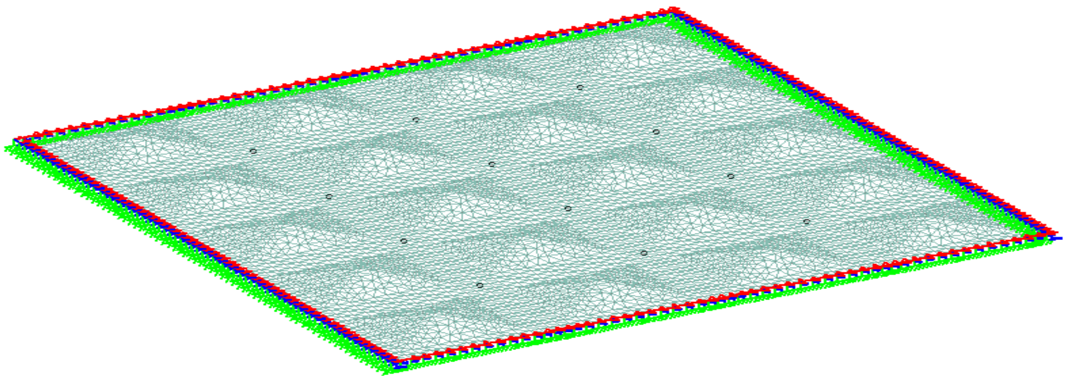

Fig7 Slab of Size 2.5mx2.5m (For0.5mx0.625mPanel)

Primary and Secondary Beam

The analytical model developed for a roof of size 2.5mx2.5m is shown in Fig 7. The primary beam and the secondary beam of size 150mm x 150mm are designed by limit state method using M20 grade concrete and steel having yield strength 415 N/mm^2. The secondary beams are assumed to be simply supported at the ends. The assumed dimension of the beams of 150mm x 150mm is found to be adequate for the critical values of bending moment and shear obtained from the detailed analysis using the software.

Brackets

The arrangement of a bracket System is shown in Fig 4. The bracket size is made considering the maximum shearing force transmitted by the secondary beam. Based on this condition the width of the bracket is kept same as the width of the beams, while a bearing length of 80mm was sufficient to ensure the bearing stresses within the permissible limits (0.45 f_{ck}). Depth of the bracket of 50mm is sufficient to take care of the bending moment generated due to the eccentricity of the reactions of the secondary beam. Limit state adopted for the design of the brackets [18]. The central beam is a primary beam which supports two secondary beams on either side. Secondary beam transfers a reaction on the primary beam which in turn induces a moment causing the upper face of the bracket to act as a tension region and the bottom region as a compression. The bracket is designed as per the guidelines of IS 456:2000. Fig 8 shows a primary beam with bracket connection on both the side of it and secondary beams resting over it. A typical reinforcement of secondary beam resting over the brackets of the primary beam is shown in Fig 8. Slot is provided in the bracket and the secondary beam for placing a 10mm bar and grouted with the cement mortar for a depth of 25mm. The slot is grouted with cement slurry for better connectivity.

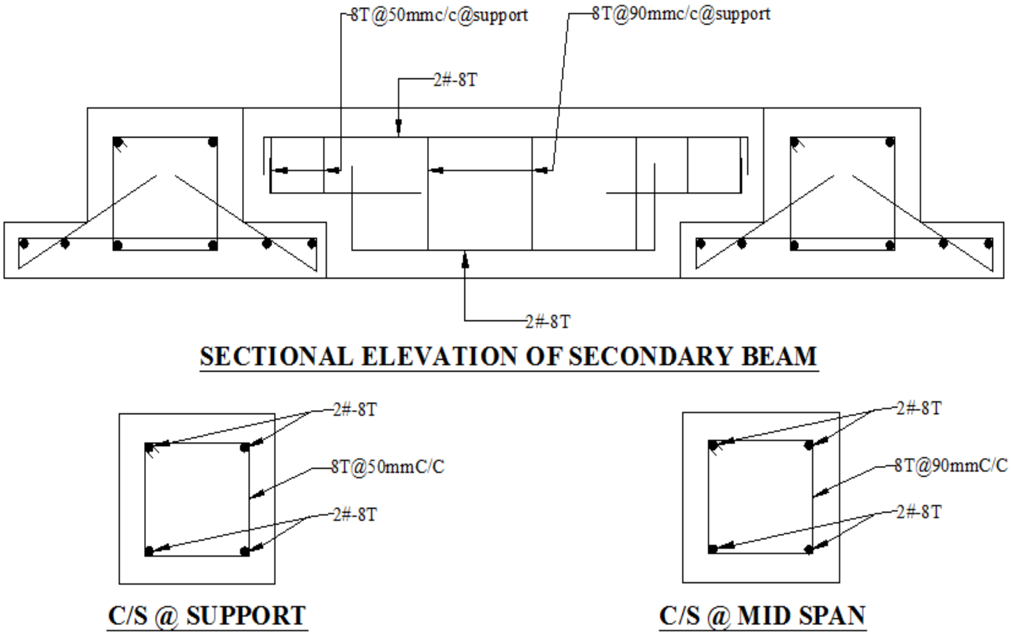

Fig8 TypicalReinforcementofSecondaryBeamRestingovertheBracketsofthePrimaryBeam

V. COST ANANLYSIS

Economy in the construction industry is one of the prime factors apart from safety and durability. Cost analysis is made for proposed affordable roofing System and conventional RCC slab. For a conventional RCC slab System concreting, shuttering and bar bending is done in-situ, where as in case of the proposed Affordable roofing System it is done in the casting yard. Hence same rate cannot be considered for both Conventional RCC slab and Affordable roofing System (ARS) slab, Rate analysis is done for the above said items and the respective rates are considered for cost analysis.
Cost ratio is the ratio of cost of ARS slab to cost of conventional RCC slab per Sqm in Rupees (Rs)

Table 2 Cost Comparison of ARS and Conventional RCC Roof (Rise 60mm)

SL NO	Size of Slab in m			Rise in mm	Conventional slab		ARS slab		Cost Ratio
					Total Cost in Rs	Cost Per Sqm in Rs	Total Cost in Rs	Cost Per Sqm in Rs	
1	2.5	X	2.5	60	14460.12	2313.62	13193.54	2110.97	0.912
2	2.5	X	3.0	60	17093.63	2279.15	15493.87	2065.85	0.906
3	2.5	X	3.5	60	21428.18	2448.94	20628.69	2357.56	0.963
4	2.0	X	3.0	60	13979.66	2329.94	13923.87	2320.65	0.996
5	3.0	X	3.75	60	25996.53	2310.80	19623.45	1744.31	0.755
6	3.0	X	3.38	60	23591.83	2330.06	18934.42	1870.07	0.803
7	3.0	X	3.94	60	27463.86	2324.98	21966.41	1859.59	0.800
8	3.8	X	4.5	60	43033.79	2550.15	28109.10	1665.72	0.653

Table3 Weights of Panel, Primary Beam and Secondary Beam

Sl. No.	SizeofSlab in m	PanelDimensionswith Thickness(m)	SizeofPrimaryBeam(m)	SizeofSecondary Beam(m)	Weights(kg)		
					Panel	Primary Beam	Secondary Beam
1	2.5 X 2.5	0.5 X 0.625X 0.07	0.15 X 0.15X 2.5	0.15X0.15X0.625	62	143	36
2	2.5 X 3	0.5 X 0.75 X 0.07	0.15 X 0.15 X 2.5	0.15X0.15X0.75	76	143	43
3	2.5 X 3.5	0.5 X 0.875 X 0.07	0.15 X 0.15 X 2.5	0.15X0.15X0.875	162	143	50
4	2.0 X 3.0	0.5 X 1.0 X 0.075	0.15 X 0.15 X 2	0.15X0.15X1.0	165	114	57
5	3.0X3.75	0.75 X 0.9375 X 0.085	0.15 X 0.15 X 3	0.15X0.15X0.9375	94	171	54
6	3.0X3.375	0.75 X 1.125 X 0.085	0.15 X 0.15 X 3	0.15X0.15X1.125	214	171	64
7	3.0X3.9375	0.75 X 1.3125 X 0.09	0.15 X 0.15 X 3	0.15X0.15X1.3125	243	171	75
8	3.75X4.5	0.75 X 1.5 X 0.10	0.15 X 0.15 X 3.75	0.15X0.15X1.5	264	214	86

VI. CONCLUSION

Based on all the analytical investigations carried out in the project the following conclusions may be drawn.

- The precast beam and panel roofing System designed in the work proves to be a strong alternative to the conventional RCC roofing System.
- There is 0.4%-34.7% of cost reduction in the precast roofing Systems when compared to the RCC roofing System, which advocates the adoption of this technology in low cost housing projects.
- The alternative roofing System proposed has a pleasing aesthetic appearance in the soffit of the pyramid portion. It requires no plastering work and false roofing work can be avoided which reduces the cost of the roofing unit.
- The roofing Systems proposed in the current project is designed to take the factored load of 1.5 times the dead load and live load.
- The important factor during the construction is the total time consumed for construction. The kind of roofing System adopted in the project would reduce the time of construction as the panels and joists are readily available precast and can be just placed avoiding the cast in-situ construction.
- The panel weighs lesser and can easily be handled by three to five masons. Thus reduces the cost in using Labour for construction and can be erected in a very short period of time.

REFERENCE

1. Serdar Ulubeylia, Aynur Kazazb, Bayram Erb, M. Talat Birgonulc, "Comparison of Different Roof Types in Housing Projects in Turkey: Cost Analysis", *Procedia – Social and Behavioural Sciences* 119 (2014) 20 – 29 pp. 221-228.
2. K S Jagadish, K S Nanjunda Rao, K R Ganesh And B V Venkataramana Reddy,
3. "National Seminar on Alternative Building Methods", *Proceedings Alternative Building Methods", 2002,* pp. 24-32.
4. Rinku Taur and Vidya Devi T, "Low cost housing" ACSGE *BITS Pilani*, October 25- 27 2009.
5. B. V. Venkataramana Reddy, "Sustainable building technologies", current science, vol. 87, no. 7, 10 October 2004.
6. Jagadish, K. S. and Venkataramana Reddy, B. V., Experiments in building technologies for rural areas and Alternative buildings in the Ungra region, Alternative buildings, ASTRA, *Indian Institute of Science*, Bangalore, 1981.
7. Hira B.N. & Negi S.K., "Up gradation of Housing & Amenities in Rural Areas" *Journal of Indian Building Congress*, Vol. 11, No. 2, 2004; ; Seminar on *Appropriate Building Techniques for Rural Housing. BMTPC at* Bhubaneswar, *December*, 22nd- 23rd2004.
8. P K Adlakha and Shri H C Puri, "Prefabrication Building Methodologies for Low Cost Housing*", IE (I) Journal.AR,* June 30 2003.
9. P K Adlakha, "Cost Reduction in Roofing through Small Panel Prefabrication "*National Seminar on New Building Materials and Technology*, Delhi, May 19- 21, 1989.
10. Vivian W. Y. Tam, Cost Effectiveness of using Low Cost Housing Technologies in Construction*, The Twelfth East Asia-Pacific Conference on Structural Engineering and Construction*, Western Sydney, 2011 pp. 156-160.
11. Tiwari P, Parikh K and Parikh J, "Structural design considerations in house builder construction model: a multi objective optimization technique", *Journal of Infrastructure System.* 5(3), 1999. Pp.75-90.
12. Ian Holton a, b, Jacqui Glass, Andrew D.F. Price, "Managing for sustainability: findings from four company case studies in the UK precast concrete industry" *Journal of Cleaner Production 18*, 2010 152–160.
13. William G. Davids, "In-Plane Load-Deflection Behaviour and Buckling of Pressurized Fabric Arches", Journal *of Structural Engineering*, Vol. 135, No. 11, November 1, 2009, pp.1320-1329.
14. G. Immanuel and K. Kharthi, Jorgen Juncher "Structures for Sports Centre", Indian Journal of Science and Technology, *Vol 7(S5), 10-15 June 2014.*
15. Richard J. Balling, and Xiaoping Yao, "Optimization of Reinforced Concrete Frames", *Journal of Structu1'al Engineering,* Vol. 123, No.2, February 1997, pp.193-202.
16. Booz W., Legewie, G., and Thierauf, G. "Optimization of reinforced concrete structures according to German design regulations."*Int. Conf. on Computer.-Aided Analysis. And Design. Of Concrete Structures*, 1984.
17. IS 456-2000 "Indian Standard Code of Practice for Plain and reinforced concrete, Bureau of Indian Standards, New Delhi.
18. "Reinforced Concrete design", By S Unnikkrishna Pillai and Devdas menon, Tata McGraw Hill Education Private limited New Delhi, Third Edition,ISBN NO:978-0-07-014110-0
19. "Limit State design of Reinforced concrete" Second edition by P.C Varghese, PHI learning private limited, New Delhi,ISBN:978-81-203-2039-0
20. https://en.wikipedia.org/wiki/Demography.