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Affordable Roofing System with Square and Rectangular Dome Panels

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Abstract
Affordable roofing is a word, which refers to residence units or habitation units whose prices are assumed/expected to be affordable or economical to a category of community with an identified remuneration limit or scale. Structural roofs are taken in to computation for considerable or valuable price of building in ordinary condition. Thus some savings accomplished in roofing operation or roofing system, significantly decreases the price of the structural units or building unit. In India, BMTPC (Building material and technology promotion council) and HUDCO (Housing and urban development corporation limited) are the main tow organization or council who have been advertising or promoting appropriate building material and construction technologies in different territory or division of the country. In this roofing, systemized, standardized, advanced roofing units or parts have been used to avoid the temporary structures like shuttering. Hence, the roofing will be economical and progress of work is fast which ensures better in quality. Even though the studies, experiments or researching on this affordable roofing system as not been completely utilized as in other sector or region, a concentrated examination or exploration is to be done to verify the prefabricated roofing which would change the common roofing procedure. The major requisite of choosing affordable roofing system is to develop or advance the rapidity in construction and to decrease the price. In the current work, staadpro software is used for designing the precast RCC roofs and analysis of joist by analytical study using the finite element method. The outcomes which manifest the satisfactory volume of price or cost depletion for various set of panels. In this design, we have considered two least dimensions of 0.5m and 0.75m panels. The aspect ratios which is varying from 1 to 2 and the price depletion is of 0.4% to 9.4% for the least dimension of 0.5m panels. Likewise aspect ratio varying from 1 to 2 with a price depletion from 19.7% to 34.7% for a least dimensions of 0.75m panel size. As the size of the panels increases it becomes cost effective. The preferred roofing system was found to be more cost beneficial as compared with regular RCC roofing system with the increase in dimension of the slab. The roofing system is designed considering M20 concrete and fe415 steel. The beam system panels are precasted and can be easily placed in the position. 3 to 5 masons are enough to easily handle the loads of panels and primary, secondary beam because of weights of panels are less as compare to Conventional slabs. The affordable roofing systems requires lesser time for construction when compare to conventional RCC slab. The major

advantage of this roofing is that false roofing works is not required for the dome shaped portion. This dome shaped portion sealing gives good attractive or decorative appearance. The cost analysis made between conventional roofing system and proposed roofing system indicates a cost reduction or depletion of 40% when compare to RCC slab of same size.

Key-words: Affordable Roofing, Precast Concrete, Cost Economics of Roofing System, Aspect Ratio, Affordable Housing.

1. Introduction

Construction of affordable house has become fiendishly difficult task for both development and developing country. Government has undertaken to construct the affordable houses with the entire necessary requirement such as public utility and services and a clean environment to the people. Construction of affordable house are not only for the poor people but also to help the people who have lost their houses during natural calamities such as earthquake,tsunami etc. people are migrating from rural to urban area in search of education, job opportunities and good standard of living. As there is increase in migration of people, there is a rapid change in growth of urbanization which requires the need of affordable housing. According to the 2001 census the number of people migration from rural to urban areas stood up to 52 million out of 1.2billion.Within the inner boundary of the India migration was about 450million of 1.2billion.Building Material and Technology Promotion Council (BMTPC) and Housing and Urban Development Corporation Limited (HUDCO) have been promoting effective building material and construction techniques in different region of the country.

Roof is the top most covering component of the building, which protects from the sunlight, rain, wind, snow etc. The word affordable refers to reduction in construction cost as well as construction time by using improved technological skills and by using available waste material. When compared to all other component of the building roof consumes about 8-11% of the total project cost and any saving achieved in structural roofing system will considerably reduce the total cost of the building. Concrete is a non-linear and brittle material that is strong in compression and weak in tension. Here primary and secondary beams are considerably spaced which frames a grid system. The spacing between these joists is filled by using precast RCC infill element. The space between each joist depends on the different design factor. The roofing system consists of two major components they are:

1. Roof infill element of rectangular panels with dome shape of lesser thickness to have membrane action as well as arching action.

2. Primary and secondary RCC precast beams like grid system.

To make this RCC slab cost effective flat portion of the dome structure is filled by using cheaper and lighter filler material. In this study, we have used precast RCC plank and joist system as an alternate roofing system technology. RCC precast plank has been laid on the grid system and they are then connected together by in-situ concrete poured on the roofing hooks projecting out from the joist system to achieve monolithic action. It is known that conventional roofing system is one of the most costly method and contributes hugely to the embodied energy of the building as a whole and this can be overcome by using precast technology. Design of the affordable roofing is analyzed by using the STAAD-PRO software. This project aims at evolving a cost effective roofing technology, which is low cost, consumes less time for the construction and forms an aesthetically pleasing roofing system.

2. Literature Review

E. HENIN et al, MOROCOUS GHAVE examined on the hollow core planks. These are widely used and has less thermal insulation and initial investment is higher for production. The hollow cores are pre cast and pre stressed which consists of internal Wythe and has two Wythe of concrete. The dissimilarity between other panels and wall panels are design of shear connector for concrete. [1]

HAMZAH ABDUL-RAHMAN et al, have mainly focused on the defects in the affordable housing projects and hence to find out the solution, which is triggering the building with defects, hence the assessment was carried out on 310 dwellers for cost effective houses in the different location of Klang Valley. The common defects were the leakage in pipes, defects in water supply system, faulty knobs, cracks in concrete walls etc. hence suggest to use superior quality of material and to have a proper supervision. [2]

BEATRICE BELLETTI et al, has described the analytical method to calculate the connections between floor to floor, floor to beam, Multi- bay Frame and single span which are categorized by the stiffness and mass distribution. This process was adopted in view of the methodology of capacity of design by valid experimental formula for design and retrofitting of Structural members. [3]

KARAM – OBAIDI et al, has described the alternative roofing system (ARS) to improve the climatic condition in indoor and to separate natural light with solar heat. It was found that ARS could

decrease the effect of radiant and air temperature without any insulation and to have a constant level of natural light in the building. [4]

NEIL THOMPSON examined the potential of initial cost involved in the construction with on-going utilities and transport cost reduction, through the combination of energy efficient building design and transit oriented design principles in a Commuter Energy and Building Utilities System (CEBUS). They have also proposed a research on the progress and growth of a dynamic simulation model for CEBUS applications in the Australian property development and building industry. [5]

PALANICHAMY M S et al, has given the construction process and methods for exclusive individual or private building utilizing a frame work of precast assembly for beams, columns, walls and roofs. Prefabricated RCC panels and partially precasted RCC beams are considered for roofing operation framework in the studies and experiments. A special type of prefabricated wall panels, precast columns, staircase utilities and beams are advised in the paper. A unique selection has been made with regard to the various joints and connections that finally differentiates between conventional and affordable roofing, and also a considerable cost reduction in affordable roofing system is found. [6]

VANESSA CRISTINA DE CASTILHO described the use of an improved genetic algorithm (GA) which is an optimization technique for structural engineering and economizing the manufacture costs of slabs constructed by prefabricated pre-stressed concrete joists. The research primarily finds and explains the multiple expenditures associated in the construction of the slabs and then combines them into a function which will be subjected to 28 equality and inequality constraints. [7]

T K VARADAN proposed solutions for classified plate theory equations for rectangular and square panels with some set of boundary conditions. Naviers method valid for plates having all edges simply supported is given which rests on theory of expansion of load and deflection functions in Fourier series forms. The basic thought behind Naviers method is to search for the solution for deflection in infinite series form such that the conditions are fulfilled and the governing differential equation gets reduced to a single algebraic equation. [8]

3. Scope and Objective

Most of the examination carried out in present work is with an objective to conduct and assess the working of precast joist and board material framework. It also aims at creating an innovative roofing system with precast boards upheld on precast bars. Rectangular precast boards having shorter side of length 0.5m and 0.75m are considered with in the ponder. The angle proportion of the board is

shifted from 1 to 2 with rise of 60mm at the middle. Table 1 appears the points of interest of the proposed Framework embraced. A typical format of the material framework is presented in fig (1). Affordable roofing system alludes to reasonable material framework.

Fig. 1- Typical layout of Roofing System

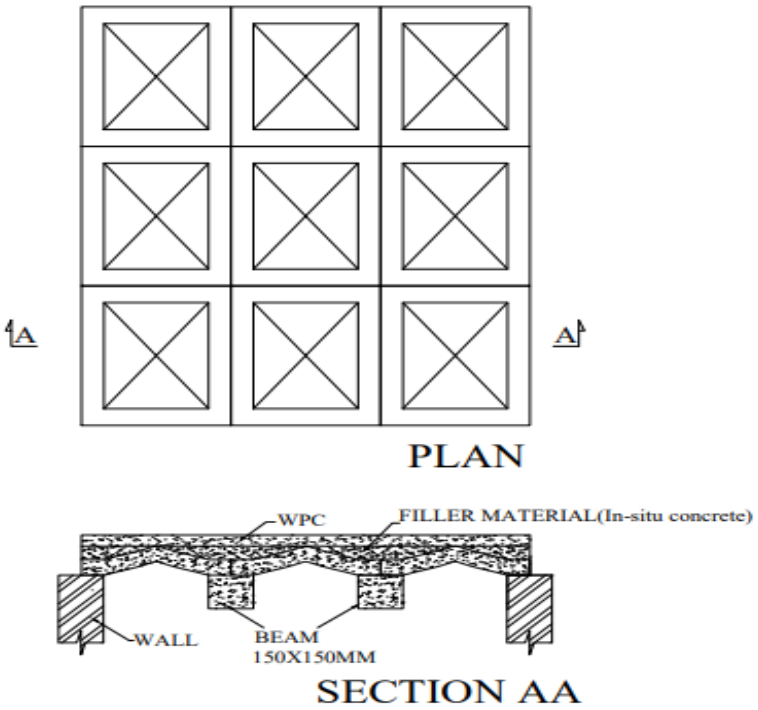


Table 1 - Parameters Under Taken for Study

Sl No	Rectangular panel dimension in m	Aspect ratio	No of panels		Total size of the ARS slab
			Along shorter span	Along longer span	
1	0.5*0.50	1.00	3	3	1.50*1.50
2	0.5*0.625	1.25	3	3	1.50*1.88
3	0.5*0.75	1.50	3	3	1.50*2.25
4	0.5*0.875	1.75	3	3	1.50*2.65
5	0.5*1.0	2.00	3	3	1.50*3.00
6	0.75*0.75	1.00	3	3	2.30*2.30
7	0.75*0.938	1.25	3	3	2.30*2.81
8	0.75*1.125	1.50	3	3	2.30*3.38
9	0.75*1.313	1.75	3	3	2.30*3.93
10	0.75*1.50	2.00	3	3	2.30*4.50

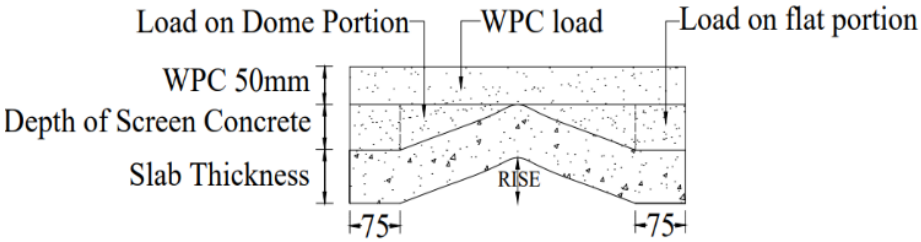
4. Methodology

Preparing the panels using AutoCAD software, the co-ordinates are then generated to Staad pro. The coordinates are manually entered in to Staad pro. The panels are joined using plates which are triangle and quadrantile shaped. The single panel size is predefined in to a slab dimensions and supporting joist is laid out across the slab with no fixity. Then the design criteria is defined to all the members and model is analyzed the design values are extracted. The values are evaluated using MS-excel. The conventional slab of same dimensions is designed. The cost and material is carried out.

4.1. Load Consideration

- According to IS 875:198S7 (part2), Live load is taken as 1.5kN/m2.
- According to IS 875:1987 (part1) Dead load is considered by the self-weight of the panels and beams, density of concrete is taken as the 25kN/m2.
- Screen concrete is considered as the floor finish. The thickness of screen concrete is based on the rise. Density is taken as the 20kN/m2.
- According to IS 875:1987 (part1) water proofing coat is applied and density is taken as the 20.40kN/m2.
- Load combination is considered according to IS 456:2000 (1.5(DL+LL).

Fig. 2 - Panel and Floor Finishes Thickness



4.2 Analysis and Design

a) Square and Rectangular Panels

The preliminary process of analysis in roofing system is fixing the size of the main beam and secondary beam. The size of the beam 150 X 150mm wide and depth were sufficient to consider for

all types of slab loads. The analysis of this panels and beams is made using Staad pro software. The nodes of the square and rectangular panels joined by triangular plates which is three nodded and quadrantile plates which is four nodded elements. A typical layout plan is shown in fig (3a) and (3b). The panels were raised in the center from 10mm to 100mm to get a foremost optimum size of the panel. The slab thickness of 10mm to 100mm were analyzed. Based on the analysis results 75mm were fixed as the slab thickness for panels. The brackets as shown in fig (4) connected the main beams and secondary beams. Roofing system analyzed in the software yields the critical values such as shear stress, bending moment and in –plane stresses. The notations of shear stress, bending moment and in-plane stresses is (sqx & Sqy), (Mx & My) and (Sx & Sy) in the Stadd Pro software. The post-processing layout, which shows the contour stress of the panels of the size 0.5 x 0.625m, is shown in the fig (5a) (5b) and (5c). The panels are analyzed on limit state method accordance with IS 456:2000 the panels are analyzed for bending moment, shear stress, in-plane stresses and for combined action of bending stresses. The concrete of M20 grade and yield strength of the steel is 415N/mm2 is taken for the design. A typical layout of the reinforcement details of panels is shown in the fig (6).

Fig. 3a - Top View of the Panel

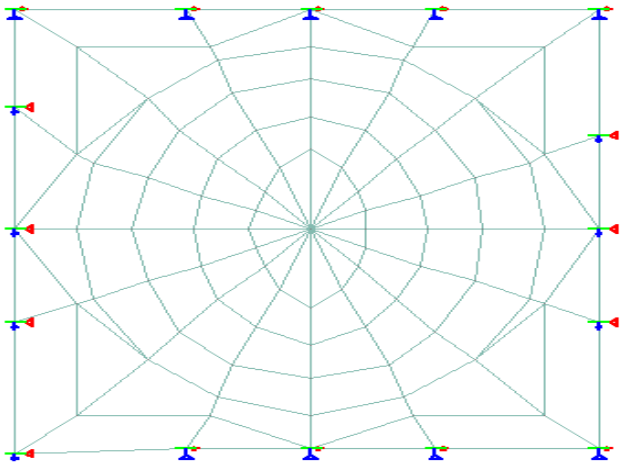


Fig. 3b - Front View of the Panel

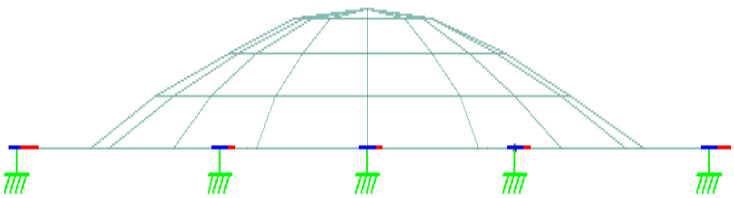


Fig. 4 - Connection between Secondary Beam and Bracket

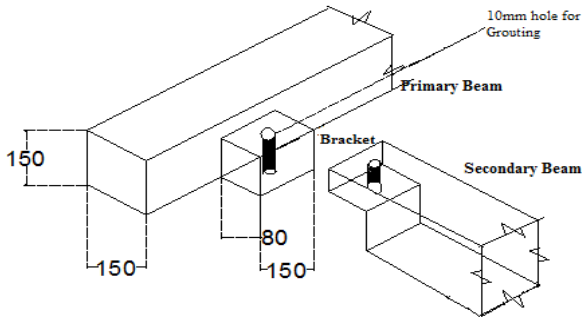


Fig. 5a - Mx local Stress of Panel 0.5m X 0.625m

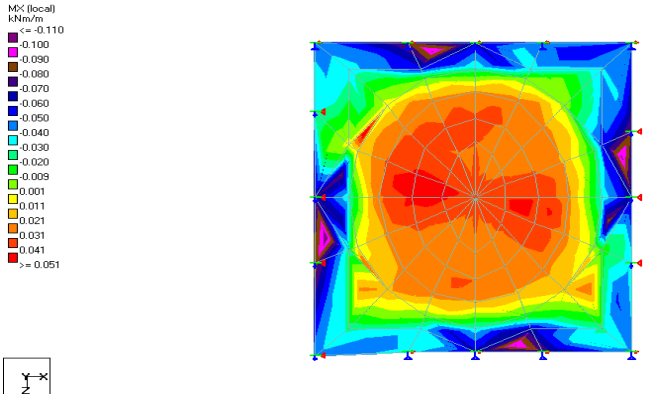


Fig. 5b - Sx Local Stress of Panel 0.5m X 0.625m

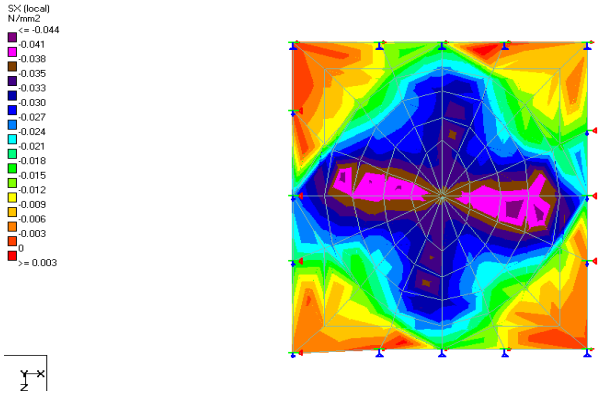


Fig. 5c - Sqx Local Stress of Panel 0.5m X 0.625m

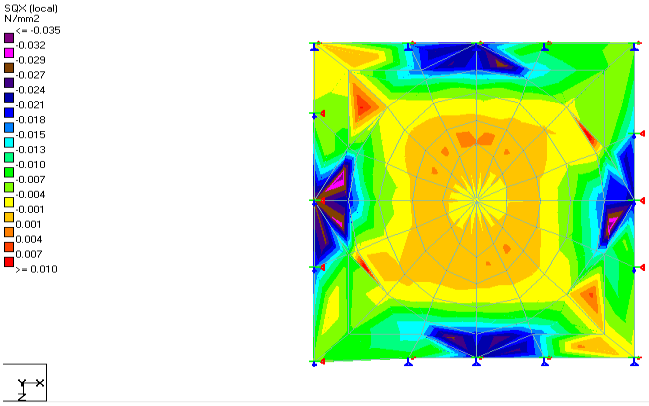
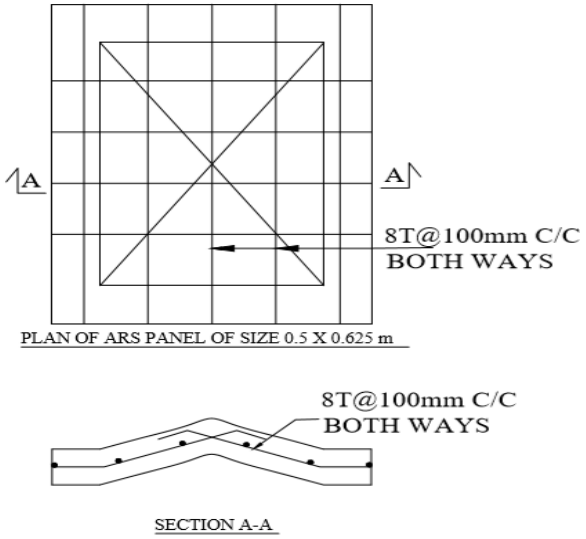


Fig. 6 – Reinforcement Details of Panel 0.5m X 0.625m



b) Primary and Secondary Beam

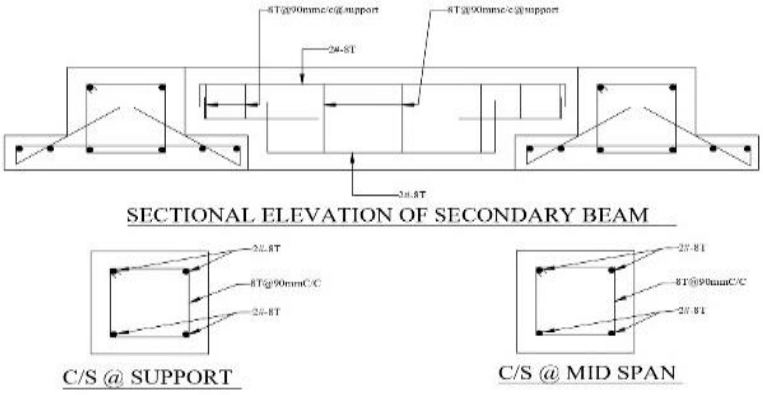
The beam is designed by limit state method the concrete of M20 grade and reinforced steel of 415N/mm2 is considered for the design. Roof model of 1.5 X 1.875m is shown in Fig (7). The size of the main and secondary beam is 150 X 150mm the main beams are laid along the shorter span and secondary beam is laid along longer span. The main beam is fixed butt at the end. Fixed butt is used to release the moments in a specific direction and secondary beams is supported by simply supported at the end. The dimensions of beam 150 X 150mm is sufficient to yield the valued of bending moments, shear stresses those values are obtained by the detailed analysis by Staad pro software.

c) Bracket

The typical layout of bracket system with secondary beam is shown in the fig (4). The maximum shearing force that is transmitted by secondary beam considers the size of the bracket. The bearing length of 80mm is adequate to take bearing stress within permissible limits, the size of the bracket is same the width of beams. The bending moment caused due to the eccentricity reaction of secondary beam, the depth of 50mm is provided for bracket. The design is bracket is done based on limit state method. The main beams along shorted span supports the secondary beams on either sides. The reaction from secondary beams is transferred to main beam, which in turn the moment making upper face as a tension region of the bracket and compression as bottom region. The design of bracket is done as per the guidelines of IS 456:2000. Primary beams is provided with bracket connection on

both the sides of the beam and the secondary beam is resting on both the sides of the primary beams with bracket connection. A typical layout of reinforcement details of secondary beam with the brackets of primary beams is shown in fig (7). Secondary beam is placed with 10mm bar in slot provided for brackets and it is grouted with cement mortar to a depth 25mm. then the slot provided is grouted with cement slurry to have better connectivity.

Fig. 7 - Reinforcement Details of Secondary Beam Resting on Primary Beam



4.3 Cost Analysis

Cost analysis is carried out to show an affordability between the roofing system and conventional slab. The cost analysis is done for concreting, shuttering, bar bending, and labor cost shown as shown in table 2. Economy is the prime factor in construction industry apart from safety and durability. The cost of the conventional RCC slab and Roofing system cannot be same as the cost varies for material and labor. Cost ration is the ration between the conventional RCC slab and affordable roofing slab. It is the slab/m2 in Rupees.

Table 2 - Cost comparison of Conventional and Affordable Roofing system

Sl No	Slab dimension	Affordable roofing system		Conventional slab		Cost Ratio
		Total cost	Cost /m^2	Total cost	Cost /m^2	
1	1.50*1.50	5676.09	2,523.00	6,523.50	2,899.00	0.84
2	1.50*1.88	6676.08	2,374.00	7,986.10	2,840.00	0.80
3	1.50*2.25	7815.18	2,316.00	9,494.42	2,813.00	0.80
4	1.50*2.65	8776.49	2,206.00	11,052.77	2,807.00	0.77
5	1.50*3.00	10076.5	2,239.00	12,234.23	2,719.00	0.80
6	2.30*2.30	10367.2	2,048.00	13,778.54	2,722.00	0.73
7	2.30*2.81	12760.8	2,018.00	16,924.33	2,676.00	0.74
8	2.30*3.38	14920	1,968.00	20,628.39	2,716.00	0.70
9	2.30*3.93	17143.5	1,936.00	23.379.60	2,640.00	0.71
10	2.30*4.50	19592.7	1,935.00	26,454.17	2,613.00	0.72

5. Conclusions

Based on the analytical investigation following conclusion is drawn.

- Affordable roofing reduces the cost from 0.4% to 34.7% hence it advocates in adoption of low cost housing technology.
- The precast beams and panels roofing system design proves to be a strong alternative.
- Affordable roofing provides a good aesthetic appearance in the soffit of dome portion, hence it doesn't require plastering and false ceiling.
- Progress of work will be fast in this type of construction as the panels and joists are precasted hence it can be just placed in position.
- The factored loads considered in this project for dead load and live load is 1.5.
- The weight of the joist and panels is lesser hence it can be easily handled by 3 to 5 masons.

References

E Henin, G. Morcous, and M. K. Tadros "Precast/prestressed concrete Sandwich Panels for Thermally Efficient Floor/Roof Applications", *ASCE Practice Periodical on structural Design and Construction,* 2014.

Hamzah Abdul-Rahman, Chen Wang, Lincoln C. Wood and You Min Khoo, "Defects in Affordable Housing Poject in Klang Valley, Malaysia", *Journal of Performance of Construction Facilities,* Vol. 25, No. 2, April 1, 2014, pp 272-285.

Beatrice Belletti, Antonello Gasperi, and Andrea Spagnoli, "Capacity Design – Based Seismic Froces in Floor-to-Beam Connections of Precast Concrete Frames", *ASCE Journal of performance of construction Facilities,* 2008.

Karam M, AL-Obaidi, Mazran Ismail, Abdul Rahman, "Design and performance of a novel innovative roofing system for tropical landed houses, *Energy Conversion and management,* 2014.

Neil Thompson and Jay Yang, "Developing Affordable and Sustainable Housing through Energy, Transport, and Building Utility Integration, *Journal of Urban Planning and Development, © ASCE,* 15th feb 2014.

M S Palanichamy, K L Muthuramu, G Jeyakumar, "Prefabricated techniques for residential building", *27th Conference on Our World in Concrete & Structures,* Singapore 29 – 30 August 2002.

Vanessa Cristina de Castilhoa, Mounir Khalil El Debsa, Maria do Carmo Nicoletti., "Using a modified genetic algorithm to minimize the production costs forslabs of precast prestressed concrete joists", *Engineering Applications of Artificial Intelligence* 20 2007 pp. 519–530.

T K Varadan,, "Analysis of plates by naviers equations", *National Conference on Engineering Structures* 2000.

IS 456-2000 " Indian standard code of Practice for Plain and Reinforced Concrete. *Bureau of Indian Standards,* New Delhi – 2.

Reinforced Concrete design, By S Unnikkrishna Pillai and Devdas menon.

Limit State Design of Reinforced Structure by P Varghese.