Design Optimization and Economic Analysis of Precast Wall Panels

Mr. Akash Tanaji Londhe[1]* Prof. U. J. Phathak[2] Prof. S. T. Londhe[3]

[1] M.E Civil Engineering, TSSM's, Padmabhooshan Vasantdada Patil Institute of Technology, Pune, India

[2] Department of Civil Engineering, TSSM's, Padmabhooshan Vasantdada Patil Institute of Technology, Pune, India

[3] Department of Mechanical Engineering, JSPM's, Bhagwant Institute of Technology, Barshi, India

Abstract – The technology involving the fabrication and pre-assembly of constructional elements and components before they are installed into their final location. The precedent of prefab industry is the significant for the development of new technology in construction business of any nation. The present age demands a great need for affordable and fast housing facilities so the projects need to be completed at competitive fast rates. Conventional construction methods fail to deliver the desired speed of construction. So we opt for some other methods of construction. Total time of construction can be lowered through application of be precast construction. Despite of the advantageous features of fast and speedy erection, low cost precast construction. It is found in the literature review that majority of the research work limited to the static cost analysis and subsequent cost control However, considering that the cost of prefabricated building differs from that of traditional manufacturing industry and construction industry. I can also be seen that the cost influence factors are not only diverse in nature but and the cost relationship is more complex. It can also be seen that cost increase may be as a result of different reasons, or in some cases a single reason may induce several cost increases. In short, the cost rise is a function of the dynamic relation between the diverse cost drivers, and it is necessary to study the effect of a factor on the whole from a scientific perspective.

Although construction cost is a dominating constraint in affordable shelters, their durability and strength are equally important. Project aims at evaluating various pr-fabrication technology on their role with perspective of strength-durability and cost. Optimization of the various parameters using Minitab software the optimal technology has been done. Although construction cost is a dominating constraint in affordable shelters , their durability and strength are equally important. Paper aims at presenting the evaluation of the design and optimization of the various parameters using structural analysis using Ansys workbench and minitab 18.0 software. Economic analysis is done and presented in paper.

Keywords — Prefabrication, Structural Analysis, Minitab 18.0, Optimization, Economic Analysis

- X -

DESIGN & ANALYSIS OF PRECAST BEARING WALL PANEL

Several advantages of precast concrete are observed over conventional in-situ cast concrete. Increased quality control is possible as the precast is cast and cured under controlled environment which allows stringent tolerances. Parallel production is permitted by precast a design which improves considerably the speed of production and efficiency.

As the precast elements are manufactured offsite the construction process of construction less labur intensive and faster. But the precast elements require assembly on-site which needs still some work in form of different concrete joints or in form of joints made up of mortar cast in place. Behaviour of the structure prepared from precast elements depends upon these joints, and also the design of these precast wall elements is rarely done using finite element analysis (FEA).

At first we shall discuss the layout of the wall panels.

At first we shall discuss the layout of the wall panels.

Figure 1 Layout of Precast wall panel design

Wall Panel Design using Precast Concrete

(Reference ACI 318-11)

A wall panel made from precast reinforced concrete for a single-story building is seen to deliver gravity and resistance to lateral loads and other loads listed below:

Data for 20 ft long wall

Weight of Panel = 634.52 N-m (468 plf)

Roof dead load = 0.957 kN/m2 (20 psf)

Roof live load = 1.436 kN/m2 (30 psf)

Wind load = 1.436 kN/m2 (30 psf).

Calculation of maximum wall forces

The calculation of maximum factored wall forces in accordance with 14.8.3 is summarized in Figure 2 including moment magnification due to second order (P-Δ) effects.

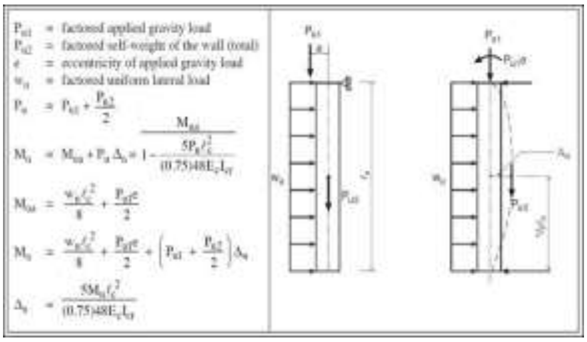
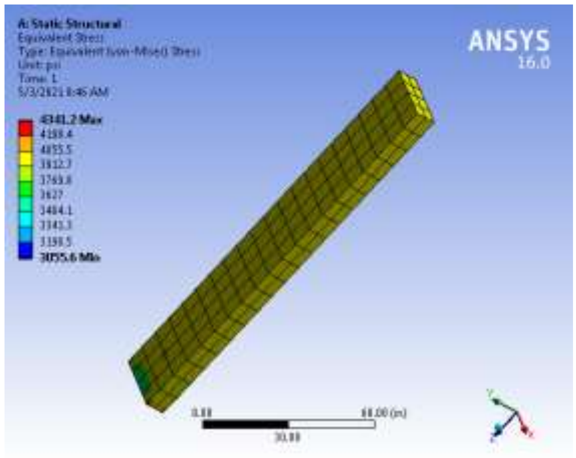


Figure 2 – Wall Structural Analysis According to the Alternative Design of Slender Walls Method

	Load combination	P_u, kips	M_{ua}, in.-kips	E_c, ksi
1	1.4 D	4.2	3.8	3,605
2	1.2 D + 1.6 L_r + 0.8 W	5.0	19.2	3,605
3	1.2 D + 0.5 L_r +1.6 W	4.1	32.4	3,605
4	0.9 D + 1.6 W	2.7	31.2	3,605

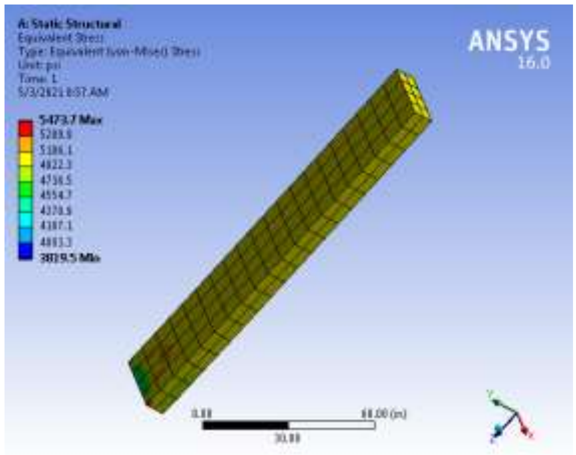
The above loads are considered for iterative design of the wall panes with three arrays of design

Analysis of Wall panel @ 1.4D load



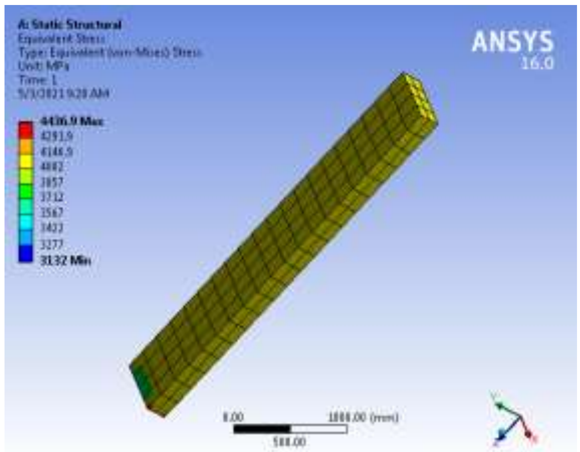
The maximum stress induced is 4341 psi (29.91MPa) < maximumum permissible stress 413.6 Mpa hence the wall panel is safe.

Analysis of Wall panel @ 1.2 D + 1.6 Lr + 0.8 W load



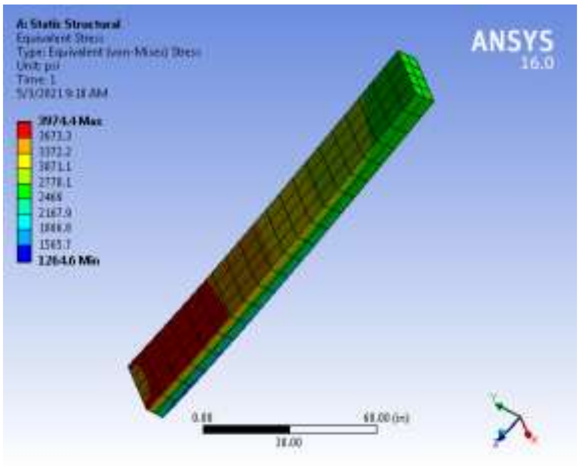
The maximum stress induced is 5473.7psi (37.73MPa) < Maximumum permissible stress 413.6 Mpa hence the wall panel is safe

Analysis of Wall panel @ 1.2 D + 0.5 Lr +1.6 W load



The maximum stress induced is 4436.9.9psi (30.589 MPa) < Maximum permissible stress 413.6 Mpa hence the wall panel is safe

Analysis of Wall panel @ 0.9 D + 1.6 W load



The maximum stress induced is 3974.4psi (27.4MPa) < Maximumum permissible stress 413.6 Mpa hence the wall panel is safe

Result Table

Analytical stress under calculated wall loads

	Load combination	Analytical stress MPa	Result
1	1.4 D	29.91	safe
2	1.2 D + 1.6 L_r + 0.8 W	37.73	safe
3	1.2 D + 0.5 L_r +1.6 W	30.589	safe
4	0.9 D + 1.6 W	27.74	safe

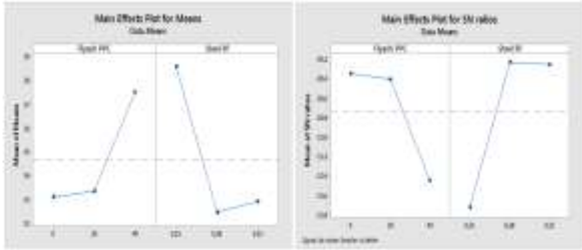
Design of Experiment (DoE) by using Taguchi Technique in Minitab 18

Parameters	Levels 1	2	3
Fly-ash PPC	0	20	*40*
Steel reinforcement	0.25	0.28	*0.32*

Analytical results considering stress for designed analysis layout

Based on the experimental layout depicted i, the analysis were performed and results are tabulated below

Test No	Flyash (PPC)	Steel reinforcement in2/ft	Max .Stress (MPa)
1.	0	0.25	37.73
2.	0	0.28	32.64
3.	0	0.32	28.97
4.	20	0.25	38.76
5.	20	0.28	31.65
6.	20	0.32	29.68
7.	40	0.25	39.189
8.	40	0.28	33.15
9.	40	0.32	40.15

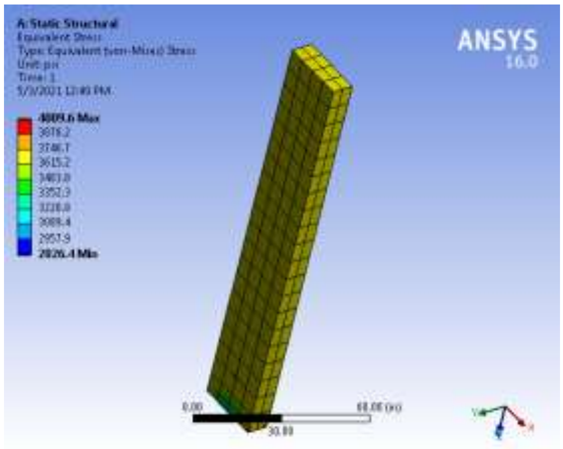


EFFECT OF PROCESS PARAMETERS ON MAXIMUM STRESS (MPa)

In order to see the effect of process parameters on maximum stress analysis test were performed as per L9 orthogonal array and then raw data have been converted into S/N ratio. Before optimizing the parameters, adequacy of the results have been analysed by residual plots. Residual plots are used to evaluate the data for the problems like non normality, non-random variation, non-constant variance, higher-order relationships, and outliers (Kanlayasiri and Boonmung, 2007; Kanagarajan et al., 2008).

From the graph of signal to noise ratios considering lower the better the minimal stress is observed for parameters **A1B2** ie, Flyash PPc -0 & Steel reinforcement 0.28 in2/ft is optimal for maximum strength of wall panel**.**

Analysis of optimized Wall panel @ 1.2 D + 0.5 Lr +1.6 W load for , Flyash PPc -0 & Steel reinforcement 0.28 in2/ft



Analytical results considering stress for designed analysis layout

Based on the experimental layout depicted i, the analysis were performed and results are tabulated below

The maximum stress induced is 4436.9.9psi (30.589 MPa) < Maximumum permissible stress 413.6 Mpa hence the optimized wall panel is safe

ECONOMIC ANALYSIS

Assumptions:-

Size of brick→ 19x9x9 cm (0.19×0.09×0.09 m)

Thickness of mortar = 10 mm

Thickness of wall = Full or 1 brick thick wall

No. of bricks = Volume of brickwork/ volume of 1 brick with mortar

Volume of 1 Brick with mortar = 0.20×0.10×0.10=0.002 m^3

Volume of brickwork = Thickness of wall x Area of brickwork

Volume of brickwork = 0.19mx4m^2 = 0.76 m^3

No. of bricks = 0 .76 /0.002 =380

Cost of brickwork work (4m^3)

Sr. no.	Description	Qty	Rate	Amount
1	Bricks	380	9	3420
2	Cement	1.5	380	570
3	Sand	0.2483	9000	2234
Total cost of brickwork				6224

Cost analysis of labour

Sr. No.	Description	Quantity	Rate	Total Amount
1	Labour (brickwork)	3		
	1) Skilled	1	600	1200
	2) Unskilled	2	300	600
	3) Supervision	1	900	900
Total cost of laboring brickwork=				2700
2	Labour (plastering)			
	1)Skilled	1	500	500
	2)Unskilled	1	300	300
3	Bhisti	1	150	150
Total cost of laboring plaster=750				

Total cost of Brickwork = 9764 Rs

Cost of Precast wall panel (4 m2) manufacturing

Sr. No.	Description	Area	Rate /m2 (Rs.)	Total cost (Rs)
1	Precast wall panels	4	1600	6400

Cost of Precast wall panel (4 m2) assembly

Sr. No.	Description	No's	Rate /m2 (Rs.)	Total Cost (Rs)
1	Precast wall panels	1	1100	1100

COMPARISON OF COST:

Total cost of Brickwork = 9764 Rs.

Total cost of Precast wall panel = 6400+1100 = 7500

Percentage reduction in cost by application of Precast panel = (9764-7500) x 100/9764 = 23.18 %

Thus total saving in cost by application of precast pane is over conventional brick work = 23 %

CONCLUSION

- ► It is found in the literature review that majority of the research work limited to the static cost analysis and subsequent cost control
- ► The cost rise is a function of the dynamic relation between the diverse cost drivers, and it is necessary to study the effect of a factor on the whole from a scientific perspective.
- ► As the precast elements are manufactured offsite the construction process of construction less labor intensive and faster.
- ► Design & Analysis of Precast Bearing wall Panel, behaviour of the structure prepared from precast elements depends upon these joints, and also the design of these precast wall elements is rarely done using finite element analysis (FEA).
- ► The maximum stress induced is at 1.2 D + 1.6 Lr + 0.8 W hence it is considered to load for optimization of the wall panel for strength and weight:
- ► Several advantages of precast concrete are observed over conventional in-situ cast concrete. Increased quality control is possible as the precast is cast and cured under controlled environment which allows stringent tolerances.
- ► As the precast elements are manufactured offsite the construction process of construction less labor intensive and faster. But the precast elements require assembly on-site which needs still some work in form of different concrete joints or in form of joints made up of mortar cast in place

- Design of Experiment (DoE) by using Taguchi Technique in Minitab 18 for maximum stress & minimum weight a comprehensive study of Labour Productivity in Prefabrication panel casting has be done

- From the graph of signal to noise ratios considering lower the better the minimal stress is observed for parameters A1B2 i.e., Flyash PPc -0 & Steel reinforcement 0.28 in2/ft is optimal for maximum strength of wall panel.

- From the graph of main effect plots for means considering lower the better the minimal stress is observed for parameters A3B1 ie, Flyash PPc - 40 & Steel reinforcement 0.25 in2/ft is optimal for minimal weight of wall panel.

Structural Analysis of optimized wall panel shows that the maximum stress induced is 4436.9.9psi (30.589 MPa) < Maximumum permissible stress 413.6 Mpa hence the optimized wall panel is safe

- A comprehensive study of Labour Productivity in Prefabrication element assembly\has been done

- A comprehensive study of Day wise Labour Productivity Observations has beene done

- A comprehensive study of Overall productivity has been done and it was found to be close to 81 %

- A comprehensive economic analysis has been done the total cost of Brickwork Rs 9764 Rs. and Total cost of Precast wall panel Rs. 7500

- The total saving in cost by application of precast paneis over conventional brick work = 23 %

ACKNOWLEDGMENT

We express our sincere thanks to Project Guide Prof. U.J. Phathak for his continuous support. We also thankful to our Head of Department of Civil R.R. Sorate For support

REFERENCES

1. Chinmay Ramesh Khadtare (2019). “Methodology of 3S Construction Method” Prefabrication Technology, Volume: 06 Issue: 12 | Dec 2019 International Research Journal of Engineering and Technology

2. Joseph L. Hartmann (2013). “Engineering Design and Erection of Prefabricated bridges and Systems” June 2013, U. S. Department of transportation Federal Highway Administration

3. Prof. Peter Newman (2014). “Strengths, Weaknesses, Opportunities and Threats of Manufactured Buildings" A Sustainable Built Environment National Research Centre (SBEnrc) Research Report.

4. Tharaka Gunawardena (2016). Behaviour of Prefabricated Modular Buildings Subjected to Lateral Loads” Department of Infrastructure Engineering University of Melbourne.

5. Suraj Kumar (2018). “A comparative study on Precast/ prefabricated structures an casuist structures "International journal of Science and Research.

6. Prajjwal Paudel (2016). Study on prefabricated modular and steel structures, Glasgow Caledonian University, International journal of Civil engineering.

7. Zhenmin Yuan et. al. (2020). “Research on the Barrier Analysis and Strength Measurement of a Prefabricated Building Design" MDPI Sustainability April 2020

8. Alireza Baghchereisa (2015). “Using Prefabrication in building Construction” International Journal of Applied Engineering Research.

9. Dr. Jalindar Patil et. al. (2019). “Prefabrication Technology- A Promising Alternative in Construction Industry”, International Journal of Science and Research (IJSR), Vol.8 Issue 8th August 2019

10. Li, Z.; Shen, G.Q.; Xue, X. (2014). Critical review of the research on the management of prefabricated construction. Habitat Int. 43, pp. 240–249

Corresponding Author

Mr. Akash Tanaji Londhe*

M.E Civil Engineering, TSSM's, Padmabhooshan Vasantdada Patil Institute of Technology, Pune, India