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Pre-Engineered Construction Analysis and Design of Portal Frame

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***Abstract*— Technological improvement over the year has contributed immensely to the enhancement of quality of life through various new products and services. One such revolution was the pre-engineered buildings. Through its origin can be traced back to 1960's its potential has been felt only during the recent years. This was mainly due to the development in design technology, and computerization.**

Engineers always try to find ways to increase the speed and efficiency of construction projects. Importance of pre-engineered building design has been discussed. Different design materials and methods have been studied. Apart from the typical applications like factories and warehouses, the recent years seminar halls, call centres, super markets, showrooms, shopping mol etc. are designed as PEB. Other traditional applications of PEB components are available for air craft hangars, residential buildings, petrol canopies, cold storages, telecom shelters, defence shelters, schools, health centres, community centres etc. This analysis will facilitate the choice of portal frames for high roof buildings with respect to their materials and cost of construction techniques. Experimental analysis of different materials and construction technology considered are:

(i) Conventional design of portal with steel section,
(ii) Pre-engineered design of portal with steel section,
(iii) Conventional design of portal with R.C.C. members, and
(iv) Pre-engineered design of portal with R.C.C. members
In the quest of economical and multipurpose

Solution of the problem conventional techniques and pre-engineered techniques have been analysed in this paper. Finally pre-engineered technique with modern construction materials resulted in most feasible solution.

Keywords*— Pre-engineered design, Portal Frame, Portal Construction Materials, High Roof Buildings*

I. INTRODUCTION

In Pre-engineered design a unique combination of materials make construction simple and trouble free. The buildings are Designed and erected by people without previous construction experience. In such constructions, more work is done at the manufacturing centre and less work on site. In such construction the building is up in just few days- not weeks, months or years. Pre-Engineered steel building (PEB) or Metal building systems with steel roofing are gaining popularity very fast for the following advantages. Though the concept is quite old with proven technology in advanced countries, the concept is still considered almost new in Indian context.

A recent survey of owners of structures identified the following five best features:

1. Ease of erection
2. Solid construction and strength
3. 100% usable space with no floor or ceiling obstructions
4. Sleek contemporary appearance
5. Easy interior to finish or insulate

Pre-engineered structures satisfy all the above requirements.

EXPERIMENTAL INVESTIGATION

The study of this research project aimed at selection of suitable construction materials and design procedure for superstructure of high roof buildings. The foundation and construction up to the plinth level is cast *in-situ* by R.C.C. Modular design of uniform shuttering plates for walls, columns, beams are first designed and made ready before the construction of superstructure is started.

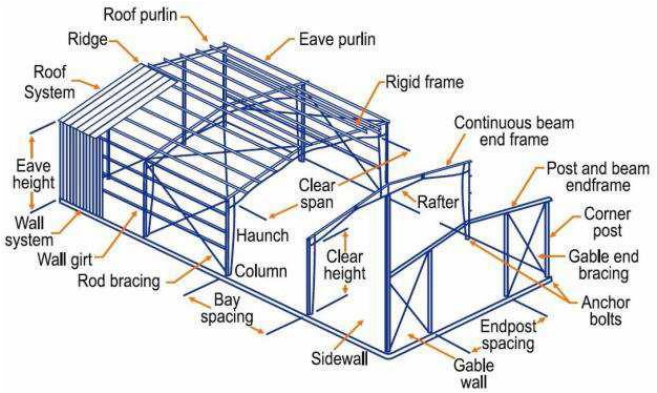


Fig. 1 –Component of PEB [1]

It is assumed that the entire construction of superstructure of the building above a made up plinth to support the G.C.I. sheets roofing on portal frames which may be made of R.C.C. or Steel Sections. If R.C.C portals are made then designed reinforcement is erected on the made up plinth and it is then enclosed with shuttering plates. Provisions of openings for doors and windows are made in the shuttering of walls. The slab shuttering is designed with flow pipes so that the concrete slurry poured at slab level runs through entire farm work for walls and slab.

In case steel portal frame sections are used then column section are welded on ms plates which are bolted with grouted long studs in R.C.C. columns at plinth level.

A steel portal frame construction of a high roof building to support G.C.I. sheet is shown in Fig. (1) This type of conventional practice of high roof building construction

without use of any brick work has inspired us to analyse construction of portal frames made with pre-engineered construction components.

STATEMENT OF PROBLEM

Portal Frame with high roof hall is designed with following specifications:

1. Portal beam span=15m Fig. (2)
2. Portal column height=6m above plinth level
3. Central height= 9 m above plinth
4. Bay spacing=5 m c/c

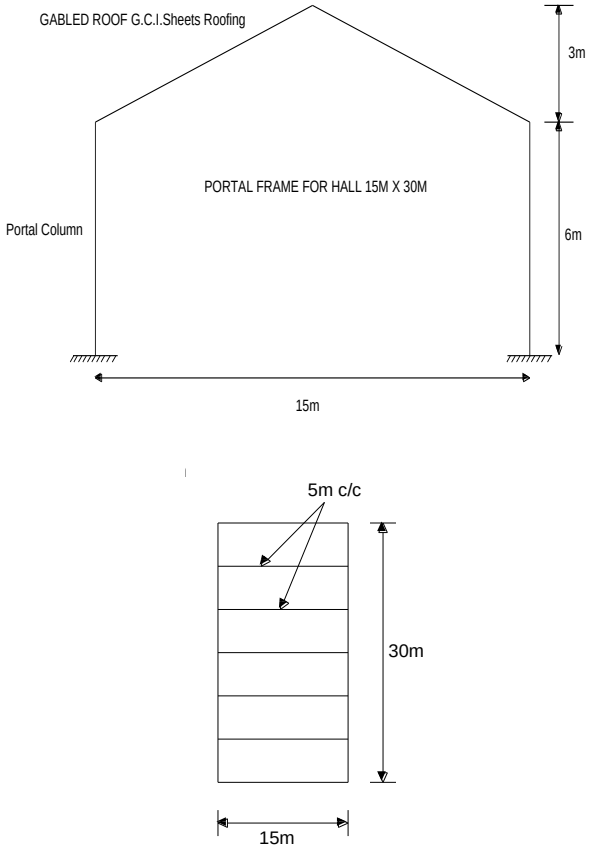


Fig.(2) Portal to be designed for the project work

The analysis is made with respect to:

1. Complete Portal frame with steel sections and G.C.I. sheets roofing with supporting purlins
2. R.C.C. design for Portal frame with Conventional concept
3. Portal Frame with Pre –engineered steel sections and G.C.I. sheets roofing with supporting purlins

Requirement of portal frames with above specifications is often felt for building designed for following purposes:-

i. Cinema halls , Public function halls e.g. marriage resorts, Theaters, Ygya-shala etc. in above types of building often mazzine floors is required for that R.C.C slab is cast at 3m height , besides enclosing the hall with brick walls. Therefore R.C.C portal columns are preferred for economic reasons.

ii. If the shed is open from all sides i.e. no brick wall enclosure is required then complete steel columns as well roof is viable solution.

iii. Pre-engineered concept of structure is nothing but steel building in which excess steel is avoided by tapering the section as per bending moment requirement.

iv. If the structure is to be planned away from city areas, where wind pressure can be predominant and the structure need to be enclosed with brick wall then structure is designed with column with R.C.C and beams and roof with steel.

Therefore our study is extended to above 4 type of pre-engineered portal frames construction.

The design problem of portal frame stated above has been analyzed with respect to following considerations:

As a first step of analysis the portal frame for above problem is designed by conventional design procedure for following construction materials and technology:

1 Steel section for Columns & Beams or R.C.C. Columns & Beams to support G.C.I. sheets Roof

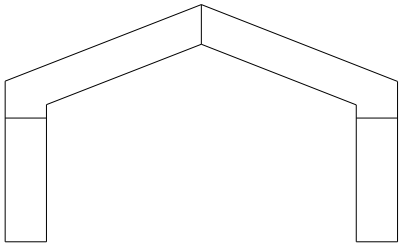


Fig (3)- Conventional Section

In conventional practice of design the Portal Sections are designed for maximum Bending Moment & Shear force in both cases i.e. R.C.C. as well as Steel design. Therefore the section is uniform throughout for all columns and Beams Fig.(3)

2 Pre-engineered Steel section or R.C.C. for Columns & Beams to support G.C.I. sheets Roof

There are two types of curtailment of construction materials (Steel/Concrete) as per the ease of construction and design requirements:

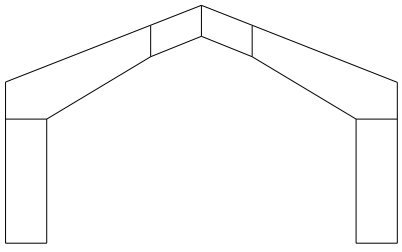


Fig.(4):- Pre-engineered tappered section

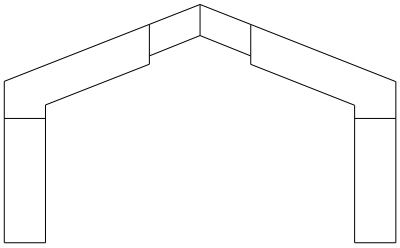
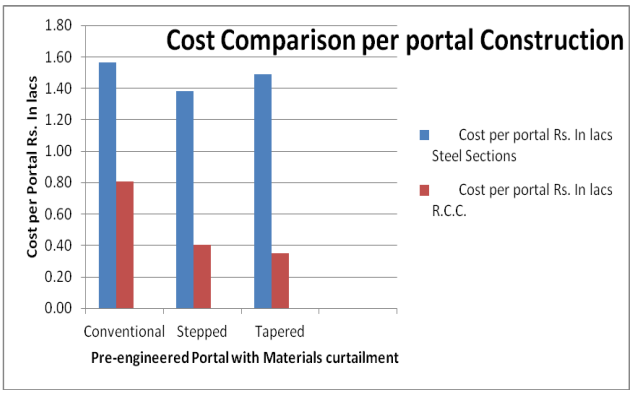


Fig.(5):- Pre-engineered stepped section

R.C.C portal for problem under study.



CONCLUSION -

Cost Comparison of Portal design –

***** Roofing materials its section members are same for all type of portal designs consider for the hall

* Footing also in all case be same. It is designed as in case of R.C.C. Portal and adopted same for all types of construction i.e. steel and pre-engineered type.

Hence cost comparison is meaning full w.r.t.to portals column and beam section size and their materials.

* Rate analysis for different construction materials is given in Appendix – I: (A) Steel Sections, (B) Reinforced Cement Concrete Portals

* Construction cost analysis for R.C.C. portal is given in Appendix. The cost is found Rs. 19925 per m^3

* Cost of steel section in case of conventional type steel section is Rs. 120 per Kg.

* Cost of steel sections in case of Pre-engineered components is Rs. 200 per Kg

The result is tabulated from table 1 to 6. The bar chart representation clearly shows that portal with tapered R.C.C. section is most economical. It costs only 35000 to build one

The literature survey shows that construction of high roof buildings like Cinema hall, studios, a mol etc. Portal Frames is best solution to construct large span buildings. The top floor may be sheet roofing and there may be intermediate floors with R.C.C. slab and partition brick walls. The finding of this research study clearly reveals that in such buildings R.C.C. portals with tapered section will be economical and easy in construction because the tapering can be achieved by wooden form work. Many researchers have worked on design of portals with steel sections and specially recommend tapered section for economical reasons. But the availability of required tapered steel section is difficult and costly affairs. Hence for pre-engineered construction works R.C.C. portals will be an ideal solution of high roof buildings.

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TABLE 1 : Cost of Steel Portal Frames Construction

No.	Particulars	Kg. per m	Length	Rate	Amount
1	Portal - conventional steel Sections				
	ISMB Section 250 columns	37.3	12	104	46550.4
	ISMB Section 250 Beams	37.3	16.14	104	62610.3
	Sub Total				109161
	M.S. plate for joints 10%				10916.1
	Sub total				120077
	Labour Cost 30% of above				36023
	Cost of One Portal Frame conventional design				156100
	Total			Say Rs.	156500

TABLE 2 : Cost of Pre-engineered Steel Portal stepped curtailment

A	Pre-engineered - Steel Curtailment Stepped Sections				
	ISMB Section 250 columns	37.3	12	120	53712
	ISMB Section 200 Beams	25.4	10.76	120	32796.5
	ISMB Section 150 Beams	14.9	5.38	120	9619.44
	Sub Total				96127.9
	M.S. plate for joints 10%				9612.79
	Sub total				105741
	Labour Cost 30% of above				31722.2
	Cost of One Portal Frame with conventional design				137463
	Total			Say Rs.	138000

TABLE 3 : Cost of Pre-engineered Steel Portal Tapered Curtailment

B	Pre-engineered - Steel Curtailment in Tappered Sections				
	ISMB Section 250 columns to	37.3	12	140	62664
	ISMB Beam 200 to 150 sect	20.15	10.76	140	30354
	ISMB Section 150 Beams	14.9	5.38	140	11222.7
	Sub Total				104241
	M.S. plate for joints 10%				10424.1
	Sub total				114665
	Labour Cost 30% of above				34399.4
	Cost of One Portal Frame with conventional design				149064
	Total			Say Rs.	149000

TABLE 4 : Cost of Portal Frames Conventional Section of RCC

2	Portal - Conventional R.C.C. Sections				
	Columns 400x250	12	1.2		
	Beam 400x250	16.14	1.614		
	Sub Total		2.814	19925	56069
	Extra for form work 10%				5606.9
	Sub total				61675.8
	Labour Cost 30% of above				18502.8
	Cost of One Portal Frame with conventional design				80178.6
	Total			Say Rs.	80500

TABLE 5 : Cost of Pre-engineered R.C.C. Portal stepped curtailment					
A	Pre-engineered - R.C.C. Stepped Sections				
	Columns 400x250	12	1.2		
	Beam 400x250	10.76	1.076		
	Beam 250 x 250	5.38	0.33625		
	Sub Total		1.41225	19925	28139.1
	Extra for form work 10%				2813.91
	Sub total				30953
	Labour Cost 30% of above				9285.9
	Cost of One Portal Frame with conventional design				40238.9

TABLE 6 : Cost of Pre-engineered R.C.C. Portal Tapered Curtailment					
B	Pre-engineered - R.C.C. Tapered Sections				
	Columns 400x250	12	1.2		
	Beam 400x250 to 250x250	10.76	0.87425		
	Beam 250 x 250	5.38	0.33625		
	Sub Total		1.2105	19925	24119.2
	Extra for form work 10%				2411.92
	Sub total				26531.1
	Labour Cost 30% of above				7959.34
	Cost of One Portal Frame with conventional design				34490.5

Appendix –I Rate Analysis					
A-Rate Analysis for Portal Steel Sections					
No.	Particulars		Sec modulus	Kg./m	Amount
1	ISMB Section 250	1 m length	37.5	80	material
2	ISMB Section 200	1 m length	25.2	80	cost
3	ISMB Section 150	1 m length	14.5	80	
4	Labour Cost				
i)	Conventional section 30%			24	
	Total			104	
ii)	Pre-engineered stepped section 50%			40	
	Total			120	

B- Rate Analysis for Portal R.C.C. Section									Steel % by volume of Concrete	
RCC mix	1	: 2	:4			3			SLAB	1.00%
Wet Volume					1.00	m^3			BEAM	2.00%
Dry Volume					1.54				COULMN	2.50%
									Road	0.60%
MATERIAL					Qty.	Units	Rs. / Unit	AMOUNT (Rs.)	SUBTOTAL (Rs.)	
CEMENT BAGS					6.34	bags	300	1902		
SAND					0.44	m^3	900	396		
Aggregate					0.88	m^3	700	616		
Reinforcement					196.25	Kg	60	11775		
									14689.02	
LABOUR With Mechanical Mixer & Vibrator					Days					
MASON					0.37		300	111.00		
LABOUR					3.50		200	700.00		
WATER CARRIER					1.39		200	278.00		
BAR BENDER					1.96		200	392.50		
MIXER OPERTOR					0.071		200	14.28		
MIXER VIBRATOR					0.071		200	14.28	1510.06	
PRIME COST (Rs.):								16199		
Water Charges 1.5%								243		
Sundries (including mixer machine, transportation etc) 7.5 %								1215		
Contractor's Profit					14	%		2268		
					Total Cost per m^3 of RCC =			19925		
					Cost of RCC for Given Data = Rs.			19925		