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STUDY ON STRUCTURAL DESIGN OPTIMIZATION OF STEEL BUILDING

Roshni Ramakrishnan, Dr.Dode Prasad Kumar, Avinash
Department Civil Engineering
Datta Meghe College of Engineering
Navi Mumbai - 400708
Maharashtra, India

***Abstract*— Pre-Engineered Building which has been gaining popularity over the past few years employs built-up sections for members as against hot rolled steel sections. The members' section profiles match closely with the bending moment diagram across the frames as the depth of the sections is greatly dependant on the moment across the sections and hence we see tapered section profiles in such building systems. A detailed study is carried out on the final optimized section profiles and the analysis results for the present paper. As a part of research paper "Comparitive Study of Pre-Engineered Building and Truss Arrangement Building for varying spans", models of industrial pitched roof steel building which were designed as both Pre-Engineered building system and conventional steel truss building system were analyzed and designed for dead loads, live loads and lateral load. The study focuses on the variation of member strength with respect to its dimensions,optimized section profile characteristics for a certain critical load combination and ways to reduce member forces by floating columns, lateral bracings etc.**

***Keywords*—Pre-Engineered Buildings, Truss, Staad. Pro, Optimization, longitudinal bracing, Industrial pitched roof building**

I. INTRODUCTION

There has been a steady rise in demand for steel buildings over the years due to the many advantages offered by steel over concrete with the most important one being that of re-usability. Steel sections are available as standard hot rolled sections of wide variety and shapes, cold formed steel sections of smaller gauge lengths and also built-up sections which are very widely used in Pre-Engineered Buildings. Due to the high price of steel, engineers have to work to bring down the steel consumption by working on built-up sections as per the forces profile across the frame, more economical shaping of member sections like going for hollow sections etc.

II. LITERATURE REVIEW

Nauman Khurram et al. in "Optimization of Flange and Web Slenderness for Pre-Engineered Steel Sections" intended to find the relationship between unbraced length ratio and flange local slenderness ratio. It showed that going fogoing for going for compact flanges is not always an economical solution and strength can sometimes be reduced. It showed that for members with high bending effects, a web slenderness ratio of 160 and above yielded good results. The web slenderness effects were more significant in compression members. Suitable no. of bracings so as to reduce the unbraced length can really help in economization of structural system.

Paolo Cicconi, et al. in "A design methodology to support the optimization of steel structures" talks of a design methodology to study the weight optimization of steel structure used in the modules of oil and gas power plants. A mass reduction of 5-15% could be arrived by using a FEM analysis methodology which involves preparation of models on the basis of a systematic variation of several parameters to generate various steel section profiles building systems. A database of section profile groups most suitable for buildings of various spans and dimensions is formed.

Roshni Ramakrishnan "Comparitive Study of Pre-Engineered Building and Truss arrangement building for varying spans". The study required optimized structural configuration as a conclusion on the preferred structural system for given dimensions of a building was based on the economy which involves the total steel quantity and the associated welding, erection and other manpower costs. The present paper is based on the analysis results of the models in the aforementioned paper.

III. MODELLING AND ANALYSIS

15 x 30m span building (pitched roof industrial building) which was modeled as Pre-Engineered and truss arrangement building system is used as reference for the present study. The model is subjected to loads as follows:
1)Dead loads - Roof sheeting, wall sheeting,15%of self weight for connections, steel section weights - IS 875(Part 1)
2)Live loads - IS 875(Part 2)
3)Wind loads - IS 875(Part 3)
3)Seismic loads - IS 1893-2002

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Refer Paper : IJERTV10IS100151 -"Comparitive Study of Pre-Engineered Building and Truss Arrangement Building for varying spans" for detailed analysis methodology.

IV. PROCEDURE FOR ANALYSIS

For the study, the analysis results of BMD (Bending Moment Diagram), SFD(Shear Force Diagram),AFD(Axial Force Diagram) are collected and compared with the section profiles of the model and conclusions are drawn on the effect of results on the parameters of the section.

The following figures are used to understand the effects of parameters on the effectiveness of section profiles to carry the resulting forces and work efficiently within the limits of servicibility.

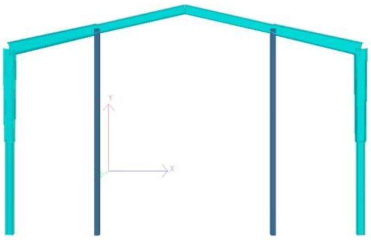


Fig 1. Model 1 : Pre-Engineered Building PEB1 of span dimensions 15 x 30m

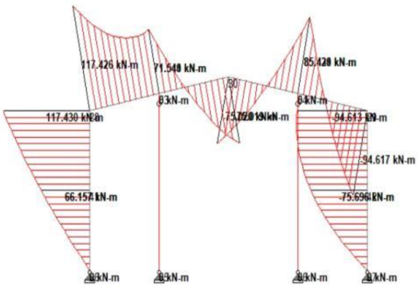


Fig 2. Bending Moment diagram along z axis for PEB1

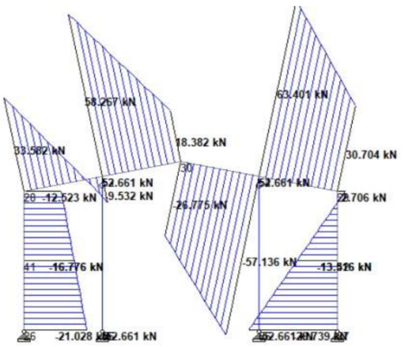


Fig 3. Shear Force diagram along y axis for PEB1

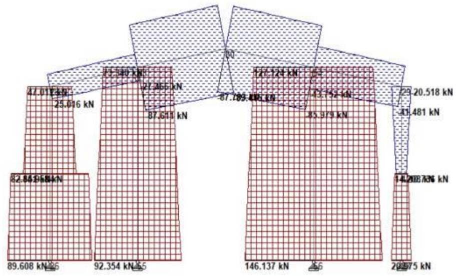


Fig 4. Axial Force diagram for PEB1

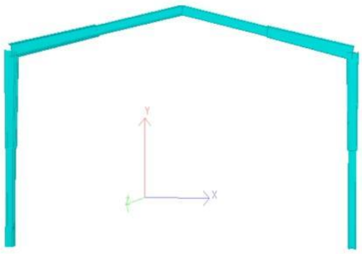


Fig 5. Model 2 : Pre-Engineered Building PEB2 of span dimensions 40x80m

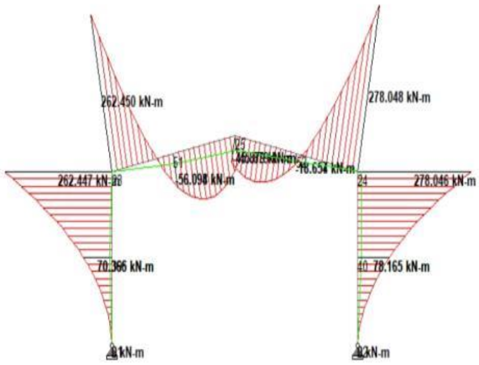


Fig 6. Bending Moment diagram along z axis for PEB2

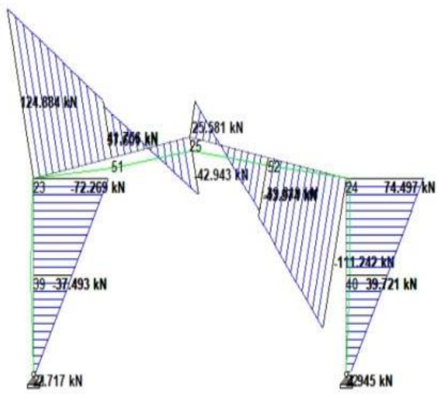


Fig 7. Shear Force diagram along y axis for PEB2

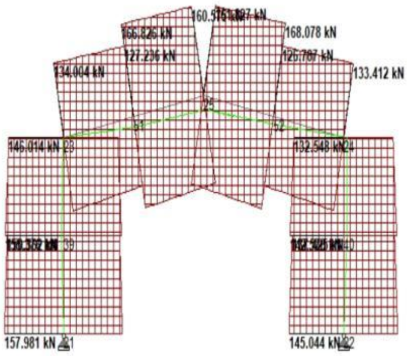


Fig 8. Axial Force diagram for PEB2

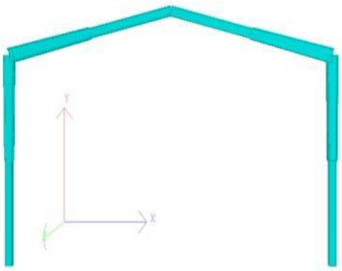


Fig 9. Model 2 : Pre-Engineered Building PEB3 of span dimensions 90x180m

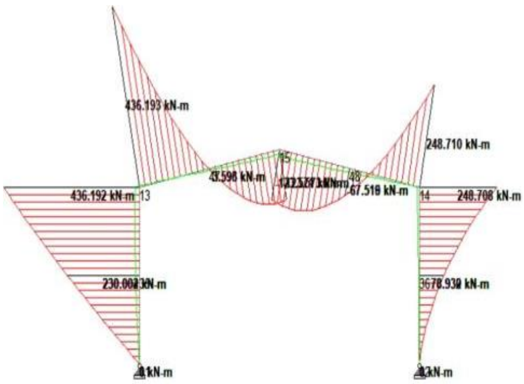
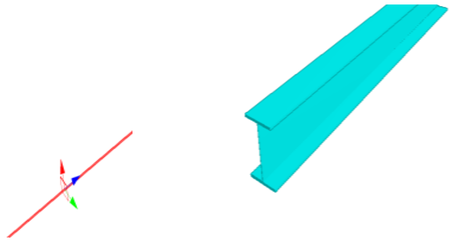


Fig 10. Bending Moment diagram along z axis for PEB3

Steps for optimization:

1)The effective lengths are to be assigned on the basis of the member action and the type of structural mechanism it is part of.



Note: The axes red, blue, green denote y, x & z axes respectively

The given section profile is that of rafter. The effective lengths are full length from one column to another column along transverse direction for effective length along z axis and centre to centre distance between purlins for effective length along x axis and y axis.

2)The “assign beam”, “assign column” properties in STAAD. Pro are used to assign members. The software designs members on the basis of assigning the member of least possible weight which satisfies all the codal provisions.

3)The unity ratios have to be made as close to 1 as possible so as to have an optimized structural system. One can group members as axial, shear and moment members. The members can be arranged into groups and assigned a common section based on the maximum forces in the group. The optimization by variation of parameter depth, thickness of flange, thickness of web and material grade can be done on the basis of the dominant force type in members.

V. RESULTS

The gable end, intermediate and middle frame section profiles with the corresponding shear force, bending moment and axial force diagrams are shown the preceding section. From the 3d models, it can be observed that towards the end, bracings are provided which help to transfer the longitudinal forces to bottom. The forces are transferred from bracings through the joints to the footings by truss action. Following are the observations:

1) Through the study of section profiles, it is observed that the depth and thickness of flange are the parameters that predominantly affect the moment carrying capacity of the section. Hence the maximum depth of the profile is given at the beam- column joint which tapers along the length of the rafter or column. A similarly large depth is found at the apex if there is no release of restraint. So one can go for a tapered section profile with maximum depths at apex(unreleased) and beam-column intersection. For demonstration purposes, consider the middle frame of PEB1 model of span dimensions 15mx30m.The section under consideration is profile with beam no. 10 with the loading combination of 1D.L. + 1LL whose values are given in the figure. The member highlighted will be checked for the variation in its design flexural strength as the depth and flange thickness are varied.

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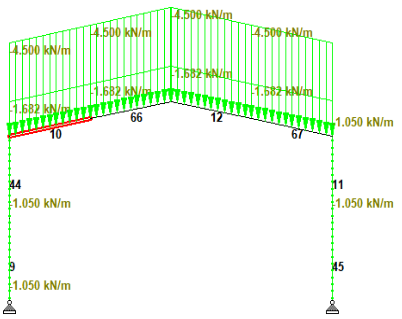

The member 10 with initial member depth of 450 mm has a utility ratio of 0.543. With an increase in depth to 550 mm which is a 22.22% increase, the utility ratio changes to 0.44 which is an increase of 18.96%. This shows a direct proportional increase in moment capacity with respect to depth. If we increase the flange thickness to 25mm which was initially 18mm which is 38.88 % increase, the utility ratio changes to 0.386 which is an increase of 28.93 %.

So we can conclude that the increase in strength due to variation in flange thickness is lesser in comparison to the strength increase obtained on variation on depth which showed a direct proportional increase. It is observed that the minimum thickness of 7mm is found to be sufficient in the models due to the large depths involved. The areas where the action is predominantly axial are provided uniform depth of section with the increase in flange width and thickness helping to increase the total area which helps to bring down the stresses induced in the member.

2) The addition of floating columns helps to reduce the analysis forces. In the considered models, the maximum moment, shear and axial forces for the various building models are tabulated as follows from the figures taken from the model PEB1 of 15x30m given as follows:

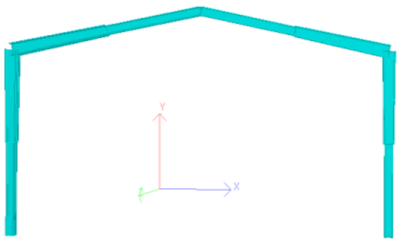

Fig 13. Intermediate frame of model PEB1

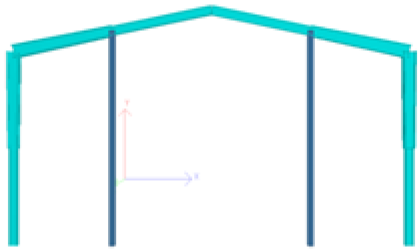

Fig 14. Gable end frame of model PEB1

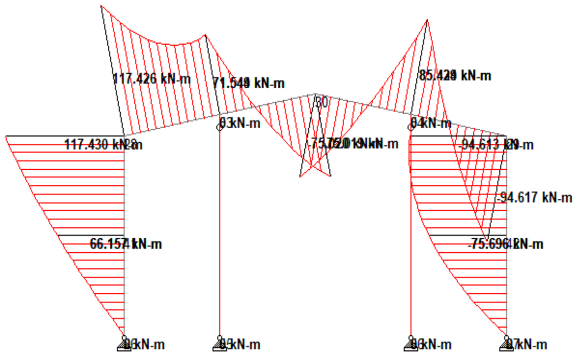

Fig 15. Bending Moment diagram for gable end frame for model PEB1

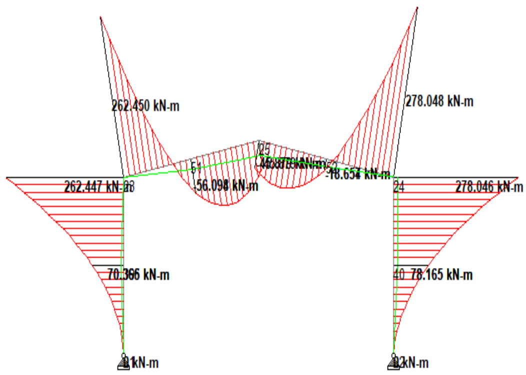

Fig 16. Bending Moment diagram for intermediate frame for model PEB1

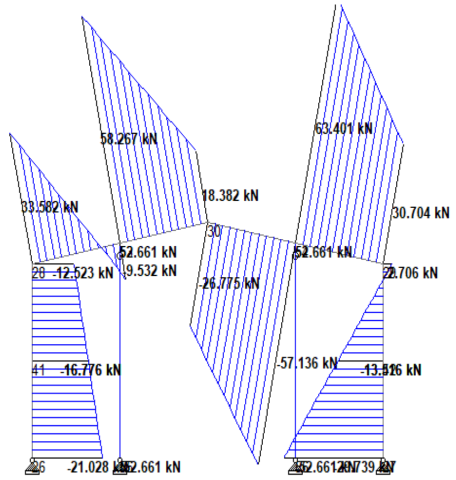

Fig 17. Shear Force diagram for gable end frame for model PEB1

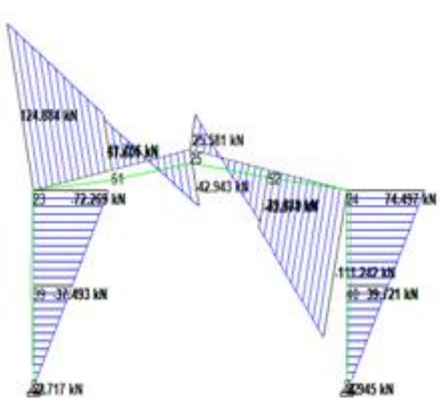

Fig 18. Shear Force diagram for intermediate frame or model PEB

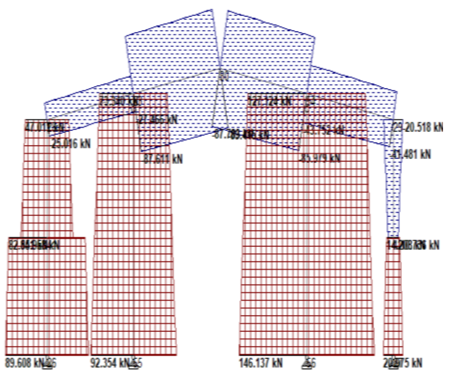

Fig 19. Axial Force diagram for gable end frame for model PEB1

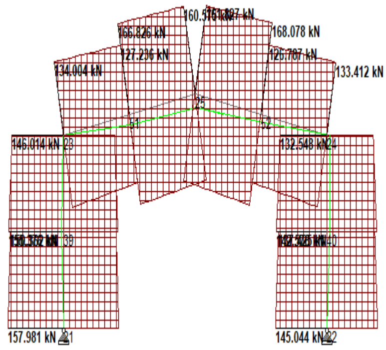

Fig 20. Axial Force diagram for intermediate frame for model PEB1

The maximum forces in gable end frame with floating columns:
Maximum Bending Moment=117.426knm
Maximum Shear Force =63.401kn
Maximum Axial Force =146.137kn

The maximum forces in intermediate frame:
Maximum Bending Moment=262.450knm
Maximum Shear Force=124.884kn
Maximum Axial Force=157.981kn

The bending moment, shear force and axial force show a variation of 55.25%,49.22% and 7.49 respectively. So the addition of floating columns help in providing additional supports which bring down the bending moments and shear forces considerably down.

3) In order to study the effect of bracing on the frame analysis results, a comparitive study between the results is done. It is observed that a large reduction of value around 50% is observed due to the bracing. The maximum axial force in intermediate frame is 47.01kn and in middle frame is 146.014kn. There is an increase in axial force of 67%.

VI. CONCLUSIONS

1) Floating columns result in conversion of a two support beam system into multi support beam system. There is a reduction of values at around 50% on the addition of a single prop on both sides of apex.
2) Longitudinal bracings which are used to brace in the longitudinal direction also reduce the bending moments and shear strength due to additional strength provided.
3) It has been observed that there is a drop in member depth in the range of 50-25% for members with predominantly axial reaction as compared to those with bending reaction. If there are large depths of member sections involved, a minimum thickness of beam web is found to be sufficient.

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