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Study for Comparison on Design of Steel Frame using Rolled, Fabricated & PEB Sections

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ABSTRACT

Recently, the introduction of Pre-Engineered Building (PEB) design of structures has been as an optimised alternative for the construction of steel sheds. The adoption of PEB design concept instead of use of traditional rolled section resulted in many advantages as the sections are designed as per bending moment diagram thereby reducing the material requirement. This methodology is versatile not only due to its quality of predesigning and prefabrication, but also due to its light weight and economical construction. This concept has many advantages over the conventional method involving buildings with roof trusses.

In this paper, a study has been made for the industrial structure which are analysed and designed according to the Indian standards. Various configurations for PEB and Conventional sections are considered for analysis using rolled, fabricated, cold formed sections and parametric study is carried out to assess the cost effectiveness. Comparison is made in terms of weight and cost of steel material required.

KEYWORDS: *Conventional Buildings, steel portal frames, weight comparison, cost comparison*

1. Introduction

Industrial sheds are very commonly used structural configurations in all kinds of plants, industries and commercial sectors. During the start of design, engineers require the comparative data for selection of best optimal scheme regarding the type & selection of structural steel sections. The project is aimed at the analysis & design of shed structure of defined geometry and loading using FEA. This project will provide the comparison of cost and erection time for various structural sections.

For comparison, the shed structure of various configurations is considered. Various authors through the study have proved the advantages in the form of comparison by various methods. The shed is provided with columns, rafter or roof truss or portal, rafter bracings and longitudinal bracings at design interval for longitudinal stability. The shed does not have any ties across the cross section. It is closed at the Gable ends and the total opening area considered for ventilation is approx... 20% of total floor area through louvers.

2. LITERATURE REVIEW

More recently, Issa and Mohammad varied the length and depth of haunched part of rafter in a specified range with the use of fixed intervals to determine the optimum size of haunched member.

Hernández et al. (2005) proposed the optimum design software called PADO, based on mathematical programming, for optimizing the design of hot-rolled steel portal frame in accordance with Spanish code of practice (EA-95). Chen and Hu (2008) used genetic algorithms to optimize a hot-rolled steel portal frames having tapered members, based on the Chinese specification for portal frames (CECS-102).

In order to have the deep check in the subject under research various technical papers were scanned for the data availability and the research done. Few research papers are highlighted below specifically which touch the technicalities of the subject. A very brief preview of the papers is listed below for the topics covered and the future scope of research work.

1.0 Comparison Between Design And Analysis Of Various Configuration Of Industrial Sheds –

Vrushali Bahadure, Prof. R. V. R. K. Prasad / International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622

Paper includes the comparison between different configurations of industrial shed. There are various types of industrial sheds. But here comparison of different configurations of industrial sheds, such as hot rolled steel. shed using Howe truss, A-type, portal truss etc. This paper gives the suitable configuration of industrial shed by making and comparing design and analysis of various configurations of industrial sheds. STAAD-Pro 2007 is used to design of industrial shed, which gives results very quickly and accurately. This paper compares the design of different configuration of industrial shed and can be concluded that which is suitable & economical in all views.

The configuration of three type of geometries are considered and the design is carried out for 60m cross section of shed with intermediate column. The conclusion drawn is that the SAW type roof truss is economical than the conventional roof truss whereas Portal frame analysis using PEB is not carried out for the comparison.

2.0 Design & Comparison of Various Types of Industrial Buildings –

Sagar D. Wankhade, Prof. P. S. Pajgade / International Refereed Journal of Engineering and Science (IRJES)

In this paper Industrial Steel truss Building of 14m x 31.50m, 20m x 50m, 28m x 70m and bay spacing of 5.25m, 6.25m and 7m respectively having column height of 6m is compared with Pre-engineered Building of same dimension. Design is done using on IS 800-2007 (LSM) Load considered in modelling are Dead load, Live Load, Wind load along with combinations as specified in IS. Analysis results are observed for column base as hinge base. Results of Industrial steel truss buildings are compared with the same dimensions of Pre-Engineering Building.

The design of roof purlin of Steel Truss building and Pre-Engineering Building (PEB) is carried out. Various configurations of roof purlins using rolled channel sections, angle truss section and cold formed Z section purlin are considered. The most economical section for weight is Cold formed section but considering the cost effect, angle truss section is economical. Again the same shed with dimensions is analysed for the truss frame. With the usage of Pipe section in truss and purlin, Truss Building is found economical compared with PEB. Also the design using angle section for Truss and channel section for purlins, Steel Truss Building using pipe section and PEB is found to be economical compared to Steel Truss Building using angle section.

Concluding all above the configuration of Steel truss purlin using angles, roof truss using pipe sections is economical as compared to PEB portal and cold formed or channel purlins.

3.0 Analysis and Design of Conventional Industrial Roof Truss and Compare it with Tubular Industrial Roof Truss –

Yash Patel, Yashveersinh Chhasatia, Shreepalsinh Gohil, Het Parmar / IJSTE - International Journal of Science Technology & Engineering.

Almost all of the steel building sheds are made up with orthodox sections of steels which are designed and built by traditional approaches. This results in weighty or too expensive structures. Tubular steel is the best possible alternatives to the traditional with their comparatively better specifications. Dead weight is tending to be decreased for many structural members so it is clear that because of the tube section, it helps in reducing overall economy. This is regarding the economy, load carrying capacity of all members and their relative safety measures. Economy is main aim of the present work including comparing conventional structures and tubular structures. Results imply that up to 15 to 25% saving in cost is accomplished by usage of tubular sections. Analysis of shed's elements was carried out by Staad Pro V8i computer software, with manually applying Indian Standards. Several spread sheets for different structural elements like Purlin, compression member, Roof Truss, Tension member etc. were carried out using Microsoft office excel. Lastly estimation sheet. is prepared for each Conventional Roof Truss section. as well as Tubular roof truss section.

Total weight of one roof truss in Kg was calculated for Top chord members, Bottom chord members and other members of conventional steel section as well as Tubular steel section. Comparison is made between both type of sections and from the results of weight of roof truss members cost estimation sheet is carried out.

Tubular section has proved to be more economical.

4.0 Design of industrial storage shed and analysis of stresses produced on failure of a joint –

Subhrakant Mohakul, Dr. Shaik. Yajdani, Abhay Dhurde / International Journal Of Civil Engineering And Technology (IJCIET)

In this project work submitted, it is proposed to carry out the exact design of an industrial steel shed and then consideration of forces coming through the other members when one of the member fails, due to failure of end connecting joint. In this Project Case study for an accident in nearby area was done and root cause for failure is found out. The main aim of the study to provide the analysis of practical industrial building by limit state method and also which method is a most economical method and, high bending strength, additional load carrying capacity and high flexural strength by analysis of both working stresses and limit state method.

The sections designed using Limit State Method are more economical than the sections that are designed by Working Stress Method. In this study, the total roofing load system is same in both the working stress and limit state method. In IS 800 (1984) the local buckling is overcome by specifying b/t limits. However, In IS 800 (2007), the local buckling is the first aspect as far as the beam design is concerned (by using section classification). The section designed as per LSD is having more reserve capacity for BM and SF as compared to WSM. In this study with the help of the results obtained, we can conclude that limit state method is more reliable and economical than the working stress method for designing structure. The results of the limit state method of bending moment and load carrying capacity are higher than working stress method. The limit states provide a checklist of the basic structural requirements for which design calculations may be required. Limit states to design, provide consistent safety and serviceability.

5.0 Design of Industrial Steel Building by Limit State Method-

Dinesh Kumar Gupta, Mirza Aamir Baig / International Journal of Advance Research, Ideas And Innovations in Technology.

In this project work it is proposed to carry out the design of an industrial steel storage shed by limit state method based on IS 800-2007 (LSM) and comparing the results with the same obtained by working stress method based on IS 800-1984, for a structure with the same dimensions & loading. The fink type roof trusses have the span of 16 meters. The structure is modelled in STAAD Pro, analysis and design software. A full 3D model is generated. This project is all about analysis of loads & forces acting on the members of the above structure & their design. Loads acting on the structure are gravity loads (dead & live), Crane Loads, wind loads, and seismic loads calculated using Indian Standard code IS 875-1987 (part I), IS 875-1987 (part II), IS 875-1987 (part III) and the section properties of the members are obtained using steel table. In this structure snow loads are not considered as Delhi does not encounter snowfall at all. The main aim of the project is to provide which method is economical and provide more load carrying capacity and high flexural strength.

The main aim of the study to provide the analysis of practical industrial building by limit state method and also which method is a most economical method and, high bending strength, more load carrying capacity and very high flexural strength by analysis of both WSM and limit state method.

The sections designed using Limit State Method are more economical than the sections that are designed by Working Stress Method. In this study, the total roofing load configuration is same in both the working stress and limit state method. In IS 800 (1984) the local buckling can be avoided by specifying b/t limits. However, In IS 800 (2007), local buckling is the first aspect for the beam design is concerned (by using section classification). The members designed as per LSD have more reserve capacity for BM and SF with respect to WSM. In this study with the help of the results obtained, we can conclude that limit state method is more reliable and economical than the working stress method for designing structure. The results of the limit state method of bending moment and load carrying capacity are higher than working stress method. The LSM provide a checklist of the basic structural requirements which should be considered in design calculations. Limit states to design, provide reliable safety and serviceability.

6.0 Design of Tapered Member Portal Frames –

D. J. Fraser / University of New Southwales, Australia.

This research paper is mainly regarding the Non-uniform steel frames, incorporating tapered or haunched members, have proved to be economical solutions for warehouses and factory buildings over a wide range of spans. A parametric study of the buckling of tapered member and haunched member frames, rectangular and pitch-roofed, has been reported. The aim of the study was to develop formulae that would allow the designer to convert the non-uniform frame into an equivalent uniform frame carrying the same buckling load.

The research does not focus on the fabrication point of view of the selected geometry and the transportability of the structure along with shop and site splice joints in the structure.

7.0 Comparison of optimal designs of steel portal frames including topological asymmetry considering rolled, fabricated and tapered sections-

Ross McKinstray, James B.P. Lim, Tiku T. Tanyimboh, Duoc T. Phan, Wei Sha / Engineering structures – Journal Department of Civil and Construction Engineering, Faculty of Engineering and Science

A structural design optimisation is carried out to allow for asymmetry and fully tapered portal frames. The additional weight of asymmetric structural arrangement was found to be on average 5–13% with additional photovoltaic (PV) loading having a negligible effect on the optimum design. It was also observed that fabricated and tapered frames got an average percentage weight reduction of 9% and 11%, respectively, as compared to comparable hot-rolled steel frames. When the deflection limits as recommended by Steel Construction Institute were checked, frames were shown to be additionally deflection controlled with industrial limits yielding up to 40% saving.

8.0 Pre-engineered building design of an industrial warehouse –

C. M. Meera / International Journal of Engineering Sciences & Emerging Technologies

Pre-Engineered Building (PEB) concept is a new conception of single storey industrial building construction. This methodology is versatile not only due to its quality pre-designing and prefabrication, but also due to its light weight and economical construction. The concept includes the technique of providing the best possible section according to the optimum requirement. This concept has many advantages over the Conventional Steel Building (CSB) concept of buildings with roof truss. This paper is a comparative study of PEB concept and CSB concept. The study is achieved by designing a typical frame of a proposed Industrial Warehouse building using both the concepts and analysing the designed frames using the structural analysis and design software StaadPro.

This paper effectively conveys that PEB structures can be easily designed by simple design procedures in accordance with country standards. In light of the study, it can be concluded that PEB structures are more advantageous than CSB structures in terms of cost effectiveness, quality control speed in construction and simplicity in erection. The paper also imparts simple and economical ideas on preliminary design concepts of PEBs. The concept depicted is helpful in understanding the design procedure of PEB concept.

9.0 Design and Analysis of Conventional and Pre-Engineered Building (R.C.C and Steel) –

D. Rakesh, V. Sanjay Gokul, G.Amar / IJEDR Volume 4, Issue 2 | ISSN: 2321-9939

Conventional steel building and Pre-Engineered building concept is a new conception of single storey industrial building construction. This methodology is versatile not only due to its quality pre-designing and prefabrication, but also

due to its light weight and economical construction. The concept includes the technique of providing the best possible section according to the optimum requirement. In Conventional steel building and Pre-Engineered building concept, the complete designing is done at the factory. The Conventional steel building and Pre-Engineered building calls for very fast construction of buildings and with good aesthetic looks and quality construction. Conventional steel building and Pre-Engineered building can be used extensively for construction of industrial and residential buildings. The buildings can be multi storied (4-6 floors).

In this study comparison of displacement and steel quantity is done in conventional type of truss and pre-engineered structure. In this study pre-engineered structure shows less displacements in columns and less consumption of steel. Pre-engineered steel structures building offers low cost, strength, durability, design flexibility. Based on the analytical and design results thereon of conventional and pre-engineered steel buildings. The total steel take-off for PEB with primary frame spacing of 5 m is 60% of the conventional steel building. It is also seen that the weight of PEB depends on the Bay Spacing, with the increase in Bay Spacing up to certain spacing, the weight reduces and further increase makes the weight heavier. To conclude "Pre-Engineered Building Construction gives the end users a much more economical and better solution for long span structures where large column free areas are needed. In this study the displacements are more in conventional building compared to the pre-engineered building and the axial force are more in pre-engineered building compared to the conventional steel building. Hence author propose Pre-Engineered Building Construction are more cost effective and economical when compared to Conventional steel building and construction time and cost also reduces.

3. THE NEED FOR OPTIMISATION

The design process makes sure that a given structure fulfils the architectural requirement, on one hand, and is safe, serviceable and durable for a cost-effective design, on the other hand. For a simple structure which is meant to be designed, it is common practice to use the experience and intuition of the structural engineer. Due to the complexity of large structures, it is somewhat difficult to achieve an economical design solution just by using the designer's experience, particularly when the structure experiences various load case scenarios. This is because there are so many criteria which should be considered during the design and all of them have influences on the response of the structure if the member properties are slightly changed. On the other hand, there is an obvious gap between the progress of optimisation techniques and their practical applications in structural engineering. This is because the complexity of available optimisation techniques represents major obstacles for the design even though the designer is keen to use optimisation techniques. There is a reluctance to use optimisation techniques in practice because of the difficulty of formulating a comprehensive set of equations for the design problem so that it could be easily used by anyone. This is very true when the technique which is supposed to be used is a mathematical programming method, as they are based on gradient and a derivative has to be taken.

In recent years, the world has witnessed a number of novel and innovative techniques for optimisation of structural schemes which have had various degree of success. Most of them involve a stochastic search. They are structurally and functionally simple to use in practice. However, they are slow-process techniques and some changes need to be addressed to speed up their performance. In addition, rapid development of the domestic personal computer over the past years has increased the motivation to formulate design problems using one of the stochastic optimisation techniques and implement them in the practical field of structural engineering. Nevertheless, efforts should be made to reduce the computation time and make the optimisation technique robust to obtain global optimum and cost effective solutions for design problems. To achieve this, consequently, it is necessary to investigate more studies to modify the available optimisation techniques so that they will be capable of handling real life design problems in the offices of structural engineers.

4. PROBLEM STATEMENT

Findings of the research studies listed above:

Comparison of the use of rolled sections with truss and cold formed sections are compared for the weight but the comparison for fabrication ease and transportation is not done.

Vast studies are done for the analysis of the economical sections by comparison of various configurations using conventional or PEB structures. Cost comparison of very few cases according to the weight of steel is carried out but the comparison is not done for time taken for the procurement, transportation and erection of structures.

Hence to provide the optimal design solution for sheds of medium spans during engineering the above project is formulated.

5. FUTURE SCOPE

The Project study is limited to the shed portal frames, comparison of various types of trusses and does not provide the comparison for sheds of smaller sizes and non-regular shapes such as Dome, spherical or circular. Use of hollow sections for bracings is also excluded from the scope of study since the procurement cost is much higher.

The Project study can be made for the cost and time including the fabrication cost and time, accuracy and quality of fabrication, transportation cost and erection time.

6. METHODOLOGY

1. Analysis is done for the Shed of size 36m x 30m x 15m height. The spacing between the portals will be 6m c/c apart.
2. Firstly side runner and roof purlin will be analysed for section optimization.
3. Steel portal will be analysed for rolled, fabricated and PE design based on the forces transferred from side runner and roof purlins.
4. The material take off, prices for steel procurement, fabrication & erection, time required for material procurement, steel fabrication, transportation & erection will be compared.

CONCLUSION

The overall savings in the structures with the configuration by the use of Cold formed section Purlin & Girts with the Pre-fabricated building structures (PEB) is 11%. The aspect of

transportation of structures is not covered in the research since the transportation price will be the same for both type of structures. Hence with precise engineering of prefabricated structures, we can conclude that approx... 11% overall savings is possible.

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