Seismic Analysis of Pre-Engineering Steel Structure Using Vertical Irregularity

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Abstract- *In recent years, the introduction of Pre-Engineered Building (PEB) design of steel structures has helped in optimizing design concept with reducing the dead load of structure. The construction of PEB in the place of Conventional Steel Building (CSB) design concept resulted in many advantages as the members are design. The design of PEB structure as per bending moment distribution diagram over the whole span of beam and column and thus reducing the steel requirement with the help of using tapered IS-section. In this study an industrial structure PEB frame and Conventional steel frame is wind analysis and designed according to the Indian standards, IS 800-1984, IS 800-2007 and IS 875(part3):2015. 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 present paper work was made in interest of studying various research work involved in analysis of PEB and conventional steel structure.*

Keywords- Pre-engineering, structure building, wind analysis, construction, residential etc.

I. INTRODUCTION

The concept of pre-engineering steel structure design approach has become the future direction for Indian standard design codes. In this approach, reduced section according to bending moment analysis procedures become important in determining the patterns and extent of damage to assess the structure response against the load and wind event. software analysis is a simplified procedure which is conducted on single and multi-degree of freedom system to analyses structure frame until collapse mechanism is formed.

This undying quest for height has laid out incredible opportunities for building profession. From early moment frames to today's ultra-efficient mega braced structures, the structural engineering has come a long way. The recent development of structural analysis and design software coupled with advances in finite element method has allowed the creation of many structural and architecturally innovative forms. However, increase reliance on computer analysis is not the solution to the challenges that lie ahead in the profession. The basic understanding of structural behavior while leveraging on computing tools are the elements that will change the way structures are designed and built. the design of structures is controlled by three governing elements strength, stiffness and serviceability, produced by the action of lateral loading such as earthquake and wind.

Pre-Engineered Steel Buildings use a combination of built-up sections, hot rolled sections and cold formed elements which provide the basic steel frame work with a choice of single skin sheeting with added insulation or insulated sandwich panels for roofing and wall cladding. The concept is designed to provide a complete building envelope system which is air tight, energy efficient, optimum in weight and cost and, above all, designed to fit user requirement like a well fitted glove.

II. LITRATURE REVIEW

A brief review of previous studies on the application of PEB (pre engineering building) on different structural configuration. This literature review also includes previous studies on different application of PEB (Pre engineering building). This literature review on recent contribution related to cost analysis of building structure with both PEB and Conventional Building.

Sudhir Singh Bhadoriais studied abouttechnological advancement over the year has contributed immensely to the enhancement of quality of life through various new products and services. One such revolution in the field of construction industry is the pre-engineered buildings. Pre-Engineered Buildings are custom designed to meet client's requirements. In Conventional steel structure, there has always been an issue of huge steel consumption and higher cost of the structure. This Paper deals to resolve such issues by replacing conventional steel structure with PEBs. The concept and attracting feature of PEB such as members are designed as per the bending moment diagram of the steel frame, in order to

make the structure economical in terms of steel consumption and cost. In this paper, various models of PEB span ranging from 10m to 50m i.e. 10m,20m, 30m,40m,50m are compared with another five models of conventional steel structure of span same as that of PEB. Models of both the system are designed using Staad Pro Software and analyzed under Dead, live, wind and Seismic load to find out which system is economical.

Swati Wakchaure in his research paper in recent years, the introduction of Pre-Engineered Building (PEB) design of structures has helped in optimizing design. The construction of PEB in the place of Conventional Steel Building (CSB) design concept resulted in many advantages as the members are design as per bending moment diagram and thus reducing the steel requirement. In this study, an industrial structure PEB Frame & CSB Frame is analyzed and designed according to the Indian standards, IS 800-1984, IS 800-2007. In this study, a structure with length 80m, width 60m, with clear height 11.4m and having R-Slope 5.71 Degree for PEB & 18 Degree for CSB is considered to carry out analysis& design for 2D frames. The economy of the structure is discussed in terms of its weight comparison, between Indian codes (IS800-1984, IS800-2007) & in between PEB & CSB building structure.

Syed Firoz Et Al., The pre-engineered steel building system construction has great advantages to the single-story buildings, practical and efficient alternative to conventional buildings, the System representing one central model within multiple disciplines. Pre-engineered building creates and maintains in real time multidimensional, data rich views through a project support is currently being implemented by StaadPro software packages for design and engineering. Choosing steel to design a Pre-engineered steel structures building is to choose a material which offers low cost, strength, durability, design flexibility, adaptability and recyclability. Steel is the basic material that is used in the Materials that are used for Pre-engineered steel building. It negates from regional sources. It also means choosing reliable industrial products which come in a huge range of shapes and colors; it means rapid site installation and less energy consumption. It means choosing to commit to the principles of sustainability. Infinitely recyclable, steel is the material that reflects the imperatives of sustainable development.

Aijaz Ahmad Zende et al., Long Span, Column free structures are the most essential in any type of industrial structures and Pre-Engineered Buildings (PEB) fulfil this requirement along with reduced time and cost as compared to conventional structures. The present work involves the comparative study of static and dynamic analysis and design of Pre-Engineered Buildings (PEB) and Conventional steel frames. Design of the structure is being done in Staad Pro software and the same is then compared with conventional type, in terms of weight which in turn reduces the cost. Three examples have been taken for the study. Comparison of Pre-Engineered Buildings (PEB) and Conventional steel frames is done in two examples and in the third example, longer span Pre-Engineered Building structure is taken for the study. In the present work, Pre-Engineered Buildings (PEB) and Conventional steel frames structure is designed for dynamic forces, which includes wind forces and seismic forces. Wind analysis has been done manually as per IS 875 (Part III) – 1987 and seismic analysis has been carried out as per IS 1893 (2002). Pre-engineered steel structures building offers low cost, strength

SubhrakantMohakul Et Al., In this project work submitted, it is proposed to carry out the design of an industrial steel storage shed, and consideration of forces acting through the other members when one of the members fails, due to the failure of a connecting joint. This topic of work is decided as considering an accident which took place in R.I.N.L. Visakhapatnam, in November 2013, in which a Slag Yard collapsed, during a heavy rain. This Project is a study of the forces acting in the adjacent members when one of the members failed, and calculating the excess stresses and ratios induced in these connected members. Also, the moments and slenderness's produced are found and described. This structure is proposed to design according to IS: 800 - 2007 and the dead, live and the wind load analysis is done according to IS: 875 - 1987 (Part-I, Part-II, Part-III). A major portion of the analysis is carried out in Bentley Staad.Pro V8i.

Kavita K. Ghogare And Dr. S.K. Deshmukh, the present paper describes the stability analysis of industrial shed subjected to wind load. For present work the equivalent static analysis is carried out for single story steel building with pitched roof in zone II. It is nothing but the industrial structure. The industrial structures shall be designed and constructed to resist the wind effects in accordance with the requirements and provisions of IS:875 (Part 3):1987. This standard describes the procedure for wind resistant of such structures. The stability analysis of single-story steel building with pitched roof is carried out using Software Computer Aided Design i.e., (STAAD PRO). The main parameters consider in this paper to compare wind performance of buildings are bending moment, shear force, deflection and axial force. In this paper we only focus on industrial shed i.e., pitched roof truss.

A building has to perform many functions satisfactorily. Amongst these functions are the utility of the building for intended use and the occupancy, structural safety,

G. Durga Rama Naidu et al., Long Span, Column free structures are the most essential in any type of industrial structures and Pre-Engineered Buildings (PEB) fulfils this requirement along with reduced time and cost as compared to conventional structures. The present work involves the comparative study and design of Pre-Engineered Buildings (PEB) and Conventional steel frames. Design of the structure is being done in Staad Pro software and the same is then compared with conventional type, in terms of weight which in turn reduces the cost.

D V Swathi, Long Span, Column free structures are the most essential in any type of industrial structures and Pre-Engineered Buildings (PEB) fulfils this requirement along with reduced time and cost as compared to conventional structures. The present work involves the analysis and design of Pre-Engineered Buildings (PEB). Examples have been taken for the study. Wind analysis has been done manually as per IS 875 (Part III) – 1987.

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".

Yash Patel et al., Many of the steel building are made up with orthodox sections of steels which are designed and built by conventional approaches. This directs to weighty or too expensive structures. Tubular steel is the best possible. Analysis of shed's elements was carried out by Staad Pro V8i computer software, with manually applying Indian Standards. Several excel sheets for various structural elements like Purlin, Roof Truss, compression member, 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.

Overall, 18% saving has been achieved during this project work. From the present study and results we can conclude that, the structural members having larger span length can be designed with tubular sections which will be benefitted in overall economy. For smaller span lengths one would have to design roof truss with minimum sections for both conventional steel sections and tubular steel sections which would affect overall economy due to larger initial cost. Even if cost for tubular sections is more compared to conventional sections, but because of comparatively less dead weight it has proved more economical for the industrial roof truss as well as for other steel structures.

Salem R.S Ghdoura and Vikas Srivastava, Due to limitations on maximum allowable deflection. The high strength properties of structural steel cannot always be utilized to best advantage. As a result, several new methods have been aimed at increasing the stiffness of the steel members without any increase in weight of the steel required. Steel frame is a building technique with a skeleton frame of vertical steel columns and horizontal I-beams, constructed in a rectangular grid to support the floors, roof and walls of a building which are all attached to the frame. The development of this technique made the construction of the skyscraper possible. In this research a steel framed structure is selected and is analyzed for different loading and support condition by using STAAD Pro and Robot Software. The deflection patterns at the Centre distance of the members are studied for different loading condition. The principle objective of this project is to analyses and design a steel framed structure by using building design software's. The design involves load calculations and analysis the whole structure by STAAD Pro and Robot Software.

In connection with the handling of structures it is noticed that steel is the simplest material to model since it is isotropic. Also, it should be noticed that Robot and STAAD Pro originally are developed for steel structures. This might also be the case for the links to the applications. Therefore, it is not surprising that the best results are obtained with the simple steel structure. Iterative optimization is inherent to every design process. This is especially important at the concept design stage, where the engineers explore a number of design options in terms of geometric forms, structural schemes, and individual member sizes before arriving at a working solution. The process continues through the detailed design stage, where more precise member sizes and connection specifications are detailed. In the majority of projects, the iterative design process is manual and trial-and-error based.

Sagar Wankhade and Dr. P. S. Pajgade, Pre-Engineered Building (PEB) concept is a new conception of single-story 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. 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.

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.

Monika Nakum et al., PEB systems are extensively used in industrial and many other constructions worldwide, it is relatively a new concept in India. That concept includes the technique of providing the best possible section according to the optimum requirement & cost effectiveness. In the present work, the study of PEB with CSB has been carried out; the observations made based on this study are very much useful to the practicing structural engineers. In this paper, CSB (Conventional steel building) & PEB (Pre-engineered steel building) were compared after analyzed in STAAD-pro & design using IS: 800:2007

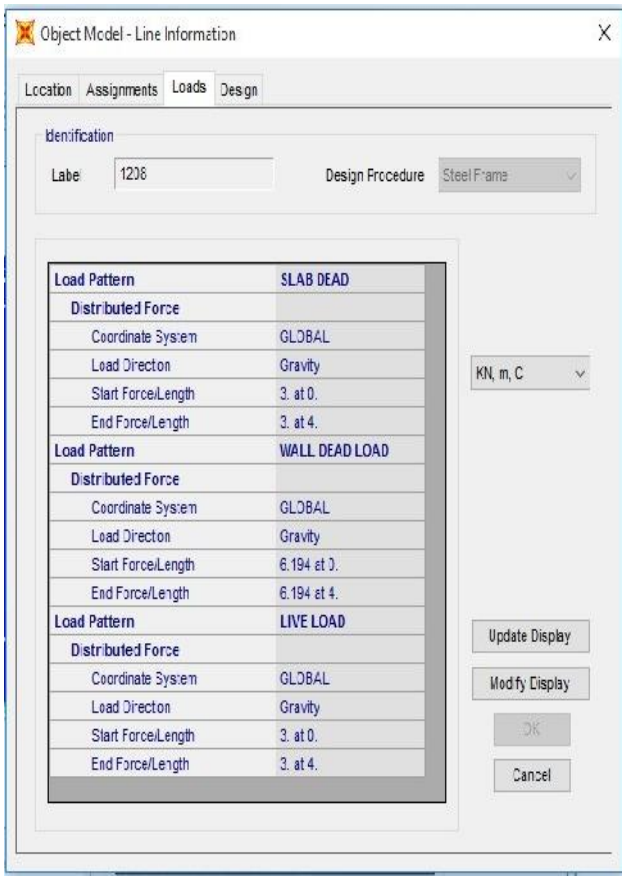
Syed Firoz and S. Kanakambara Rao the steel (I-section) building construction has great advantages to the residential buildings, improving practical and material efficiency, energy efficiency, consumption, impact on natural resources, CO_2 emissions due to recycled building material, the system representing the model within multiple disciplines. The steel building creates and maintains in real time multi-dimensional, data rich views through a project support is currently being implemented by Tekla software packages for design, modelling and detailing of the sustainable steel building.

III. METHODOLOGY

G+12 building with steel frame structure were taken or the study. Six different building models with bay width of 4m in X-direction, 4m in Y-direction and story height equal to 3m were considered for this study. The structures are modeled by using computer software SAP 2000vs19. The column section defined for the frame satisfies both the requirement for strength and stiffness. All the selected models were designed with Fe-250, Fe-415 grade of reinforcing steel as per Indianstandards.

Detail of structure and Finite element modeling, the basic geometries of pre- engineered and conventional structure with eight different models with same plans are as following; Computer modelling the basic assumption on geometry of steel frame structure with six different models with same plan area are asfollows

1) Plan area (20*28 m2) which is similar from 1ststory to 12thstory shown in (fig 3.01) with their detail.



Load carried by supporting beams in all models

3.1 STRUCTURE ELEMENTDEFINITION

In SAP vs. 19, after definition of material properties then cross-section is defined by clicking at>>Define Menu Bar >> Section Properties >> Add New Property >> Select Section Shape >> input the required value>>OK

Use of section designer for definition the column and beam properties as per (Table-3.1)

Table3.1: Cross-section of column and beam

Name	Shape	Area	Material
Column	Rectangular	0.2025 m2	STEEL
Beam	Rectangular	0.09 m2	STEEL

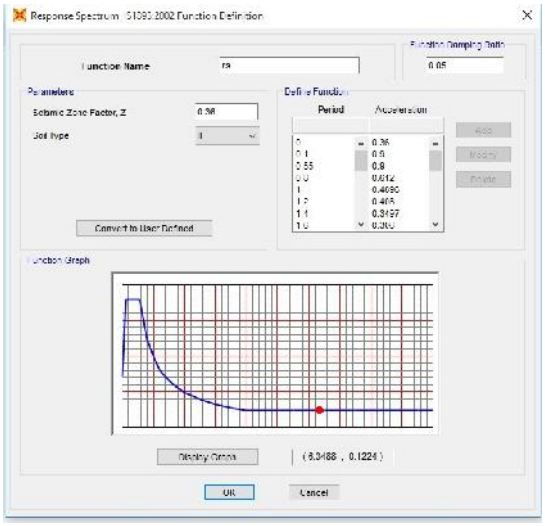


Figure:-Definition of response spectrum function as per IS 1893:2002

3.2 SUPPORTCONDITION.

To provide the fixed support condition at the base of frame structure model and simply support at the base of shear wall. Select the base node of all the base columns and shear wall then go to Assign menu >> Joints>>Restrain>>OK

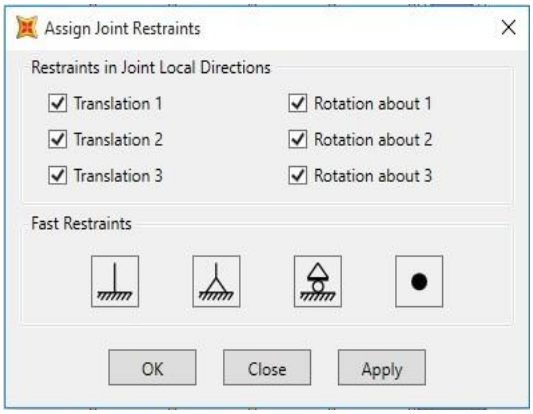


Figure3:-Support condition at base of frame structure models

3.3 ANALYSIS

Response spectrum was conducted over all building's models using SAP software. The member was assigned with their self-weight and the analysis was carried out for dead and 25% of live load (DL+.25LL) incrementally under control. The frame is analysis in internal direction till the collapse mechanism isreached.

3.4 RESPONSE SPECTRUM LOAD (RSA)

Response spectrum method of analysis shall be performed using the design spectrum specified in clause 6.4.2 or by a site-specific design spectrum mentioned in clause6.4.6 of IS 1893 (part I):2002.Zone Factor: As per IS 1893 (part I):2002 the behavior of the model is checked for seismic zone V. The zone factor value is taken as Z=0.36 from table -2, clause no.6.4.2 IS 1893 (PartI):2002.

Importance of Structure: The proposed model is assumed to be general building the importance factor for building is taken as I=1.0 from table 6, clause no.6.4.2 of IS 1893(Part I):2002.

Soil Type: Calculation of seismic load it becomes necessary to know the type of soil for that medium soil is considered. The average response spectrum coefficient (Sa\g) depends on type of soil taken from clause no.6.4.2 and fig.2 of IS 1893(Part I):2002 and fundamental natural time period (Ta) is taken from clause no. 7.6.1 of IS 1893(Part I):2002.

Types of Structure: the structure is assumed to be special steel moment-resisting frame therefore the response reduction factor value is taken as R=5 from table 7, clause 7.2 of IS 1893 (Part I):2002

To define the response spectrum, go to >> Define menu >> Define function >> Select response spectrum >> Add code IS 1893 (Part I):2002>> Add new function >> Input the function name as Sa/g IS 1893:2002 and input all the required parameter shown in (Fig.3.29)

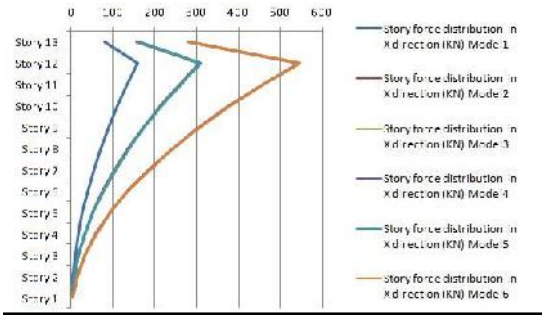


figure:-Story Force distribution in X-direction of all Models

To define the response spectrum load case, go to >> Define menu >> Define load case >> Add new load case >> select the response spectrum as load case type and input all required data as shown in

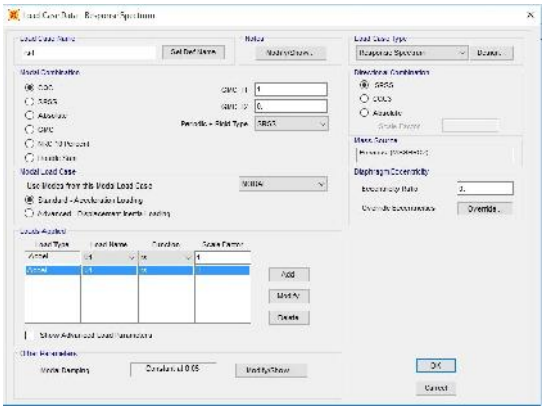


Figure:-Definition of response spectrum load case

3.5 STORY FORCE DISTRIBUTION AND STORYDISPLACEMENT

- The analysis of models by earthquake done with the help of IS 1893 code (design of earthquake resisting structure) with building importance factor equal to 1, Zone factor equal to .36 and soil type 2 is used in this analysis and story shear and story displacement is calculated in Xdirection.
- Lateral displacement refers to the lateral movement of stories from each other or from its original position by the action of seismic forces on the structures. As per IS 456:2000 the displacement should not be greater than the ratio of height of the structure taken for the analysis by500.
- The story drift in any story due to minimum specified design lateral force, with partial load factor of 1 shall not exceed 0.004 times the storyheight

3.6 SPECTRAL ACCELERATION IN x DIRECTION DUE TO RESPONSE SPECTRUMMETHOD

The value of response spectral acceleration is compared in table and graph for the comparison between all the models

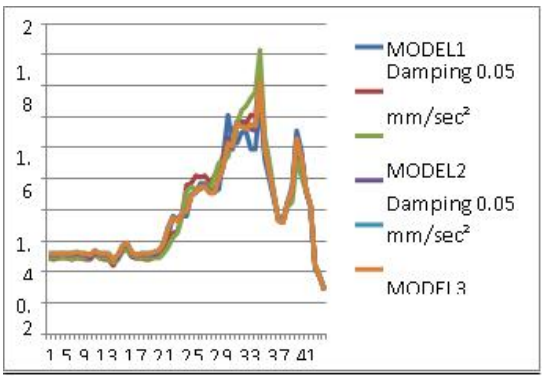


Table:-Minimum force and bending moment table

IV. RESULT

Following discussions are made from results.

- The value of lateral displacement in X direction for different models are compared in (Table-4.4) and (Fig.4.4). It observed that minimum lateral displacement value of model 6 (3-Dimensional model of Conventional Steel Building with shear wall at corner) .0303 m because of larger lateral stiffness perpendicular to the directionof earthquake forceapplied.
- The value of lateral force in X direction for different models are compared in (Table-4.1) and (Fig.4.1). It observed that minimum lateral force value of model 1 (PEB steel structure) because of reduced seismic weight as compare to the other models because of reduced section of PEB steel structure.
- The value of seismic base shear in X direction for different models are compared in (Table-4.3) and (Fig.4.3). It observed that maximum seismic base shear value of model 3 and model 5 (of Conventional Steel Building with shear wall) are 2739.825kN and 2752.888kN because of increase in dead load of conventional building with shear wall as compare to the othermodels.
- Shear wall at corner of the structure shows the least lateral displacement and reduced the story drift of the structure as compare to the middle of thestructure.

V. CONCLUSIONS

The results of 3-dimensional modelling of PEB and conventional steel frame structure from SAP 2000Vs. 19 software with the help of IS1893. Eight different models having constant Beam-column Cross-sectional area and same plan section are prepared by software with the help of IS code and comparative analysis studied between them. This project has introduced Steel Shear wall frame structure which analysing to determine its structuralperformance.

5.1.1 From Seismic analysis on all Eight models target displacement in **model6** in X-direction are comparatively lesser than of others all **models** due to the larger moment of inertia in perpendicular direction of laterally applied distributed force and shear wall at corner as compare to othermodels.

5.1.2 The story force distribution of **model1** in X-direction are comparatively lesser than of others all **models** because of reduced

seismic weight of Pre- Engineering building in**model1.**

5.1.3 From earthquake analysis on all models according to IS-1893 the Base reaction in **model 1** are 94.70% of **model2,** 55.18% of **model3,** 53.30% of **model4,** 54.86% of **model5,** 53.05% of **model6,** 91.67% of **model7** and 87.20% of **model8** due to the reduced seismic weight of Pre-Engineering building.

5.1.4 From Seismic analysis on all Eight models story drift in **model6** in X- direction are comparatively lesser than of others all **models** due to the larger moment of inertia in perpendicular direction of laterally applied distributed force and shear wall at corner as compare to other models.

5.1.5 response spectrum analysis done on all models give response spectral acceleration in **model5** in X-direction are comparatively lesser than of others all **models** due to larger lateral stiffness provided by shear wall at centre in conventional steel building.

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