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Seismic Evaluation of Pre-Engineering and Conventional Steel Structure

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Abstract: *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. The present work involves the comparative study and design of Pre-Engineered Building (PEB) and Conventional Steel Building. Design of the structure is being done in SAP 2000vs19 software according to IS 1893 code for seismic analysis. Six different models have been taken for the study. Several results are obtained from analysis done with the help of software and conclusions are made between models in reference to story drift, displacement and seismic base shear. 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.*

Keywords: Pre-Engineered building, Conventional steel building, Storey drift, SAP 2000vs19, Seismic base shear.

1. INTRODUCTION

The concept of seismic design approach has become the future direction for seismic design codes. In this approach, time history and response spectrum analysis procedures become important in determining the patterns and extent of damage to assess the structure response against the seismic event. Response spectrum analysis is a simplified procedure which is conducted on single degree of freedom system to analyse 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 behaviour 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.

2. 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 Bhadoria et al., Studied about technological 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 et al., 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 storey 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 colours; 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., In his research paper observed that 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,

3. PROBLEM FORMULATION

It is studied from literature that so many PEB varieties are designed and proposed by different researchers. There are number of choices available to manufacture and install PEB in terms of design parameters.

In this study we consider a thirteen storey (G+12) building with 3-dimensional frame. Six different models of PEB and CSB are to be simulated with SAP 2000vs19 software and to be analyzed by Equivalent Static Method and Response Spectrum Method. Six different models are as follows, Pre-engineered steel building terms as model-1, conventional steel building terms as model-2, Pre-engineered steel building with shear wall at centre terms as model-3, conventional steel building with shear wall at centre terms as model-4, Pre-engineered steel building with shear wall at corner terms as model-5, conventional steel building with shear wall at corner terms as model-6 were taken for study.

The geometrical parameters of the building are as follows:

- Height of each storey = 3 m
- Centre-to-centre span between each column along X = 4m
- Centre-to-centre span between each column along Y direction = 4 m
- Fixed type support at the bottom.

The loads on the building are as follows:

1) Dead Load:-
   - Self weight of the frame

2) Dead load of floors
   - Dead floor load of all the intermediate floors = 3.125 KN/m2
   - Dead load of the roof floor = 3.125 KN/m2

3) Dead load of walls
   - On outer beams = 12 KN/m2
   - On inner beams = 6KN/m2

4) Live load
   - Live load on all the intermediate floors = 3KN/m2
   - Live load on roof floor = 1.5 KN/m2

Earthquake load in X-direction & Y-direction as specified in IS 1893: 2002.

The seismic parameters of the building site are as follows:

- Seismic Zone: V
- Zone factor ‘Z’: 0.36
- Soil type= Type II (Medium Soil)
- Building Frame System: Moment resisting RC frame.
- Response Reduction Factor = 5
- Importance factor = 1

Since H= 39 m.

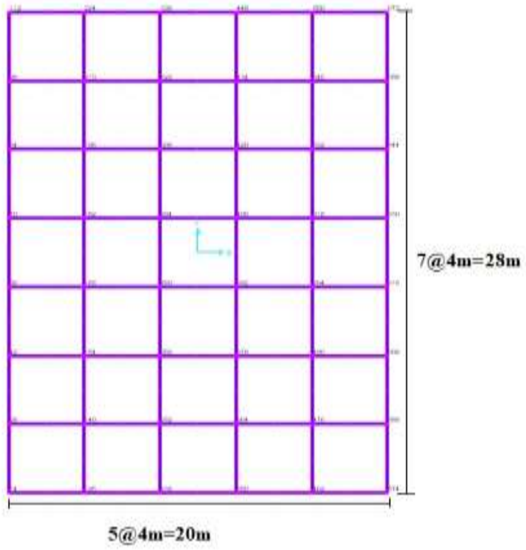

Figure1: Representation of plan area of all building models

4. METHODOLOGY

This project develops FEA models of a Pre-engineered building under an in-plane load. The models will be subjected to earthquake loading according to Indian standard code. The steps undertaken in the present study to achieve the above-mentioned objectives are as follows:

Step1: Design of beam and column sections

The frame is analyzed with dead and live loads for steel sections for beams and columns in SAP 2000. The maximum forces in columns and beams

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are determined from output file. The sections are designed manually for these maximum forces as Steel sections for the SIX types of frame separately. The codes IS 456-2000, IS 800-2007 are used for RCC, Steel column section design. The steel beam designed for steel frame is provided in composite frame too. The steel beam section provided.

Step 2: Analysis

Each type of frame is analyzed separately by using Equivalent Static Load Method and Response Spectrum Method by using SAP 2000.

The analysis is conducted for IS 1893(Part 1), 2002 specified combinations of loadings.

Step 3: Comparison of results

The results obtained are compared in terms of base shear, story deflections, story drifts, modal participation factor etc. and cost effectiveness with respect to material quantities are determined.

5. 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 is reached.

5.5.1 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 clause 6.4.6 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 (Part I):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.2)

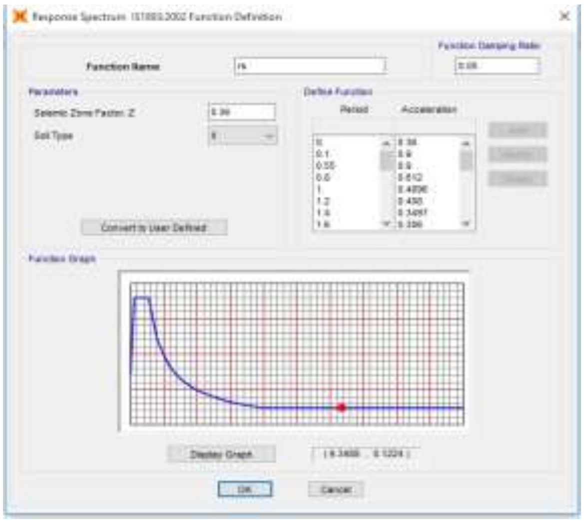

Figure2: Definition of response spectrum function as per IS 1893:2002

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

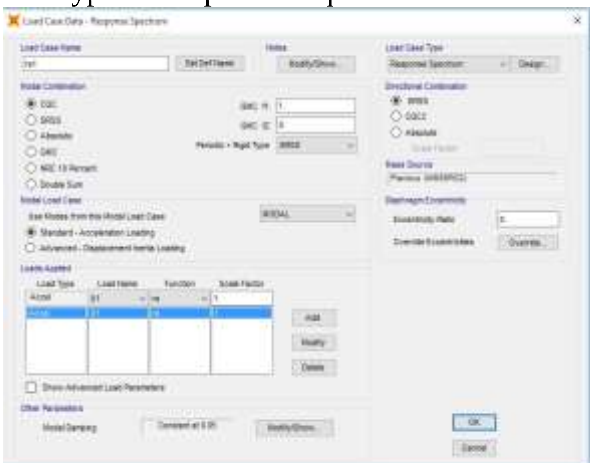

Figure3: Definition of response spectrum load case

6. RESULT AND DISCUSSION

6.1 GENERAL

Seismic analysis conducted over pre-engineered structure with different plan configuration using SAP 2000 VS.19. The various results obtained after the analysis presented and discussed in this chapter.

6.2 STORY FORCE DISTRIBUTION AND STORY DISPLACEMENT

- 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 X direction.
- 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 by 500.

Table 1 Story Force distribution in X-direction of all Models

Story number	Story force distribution in X direction (KN)					
	Model1	Model2	Model3	Model4	Model5	Model6
Story 13	80.748	156.379	161.648	281.414	162.582	282.756
Story 12	158.343	307.021	309.408	544.633	311.195	547.229
Story 11	133.052	257.983	259.988	457.643	261.49	459.825
Story 10	109.96	213.209	214.866	378.217	216.108	380.02
Story 9	89.068	172.699	174.042	306.356	175.047	307.816
Story 8	70.375	136.454	137.515	242.059	138.309	243.213
Story 7	53.881	104.472	105.285	185.326	105.893	186.21
Story 6	39.586	76.755	77.352	136.158	77.799	136.807
Story 5	27.49	53.302	53.717	94.554	54.027	95.005
Story 4	17.594	34.113	34.379	60.515	34.577	60.803
Story 3	9.896	19.189	19.338	34.04	19.45	34.202
Story 2	4.398	8.528	8.595	15.129	8.644	15.201
Story 1	1.1	2.132	2.149	3.782	2.161	3.8

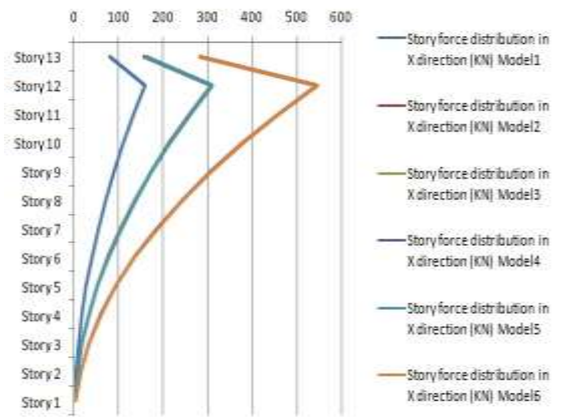

Figure 4: Story Force distribution in X-direction of all models

Table 2 Seismic Base force of all models in X and Y directions

Models	Base force	
	X direction	Y direction
Model 1	1460.552	1049.227
Model 2	1542.237	1091.443
Model 3	2646.664	2413.238
Model 4	2739.825	2479.59
Model 5	2661.951	2427.717
Model 6	2752.888	2490.872

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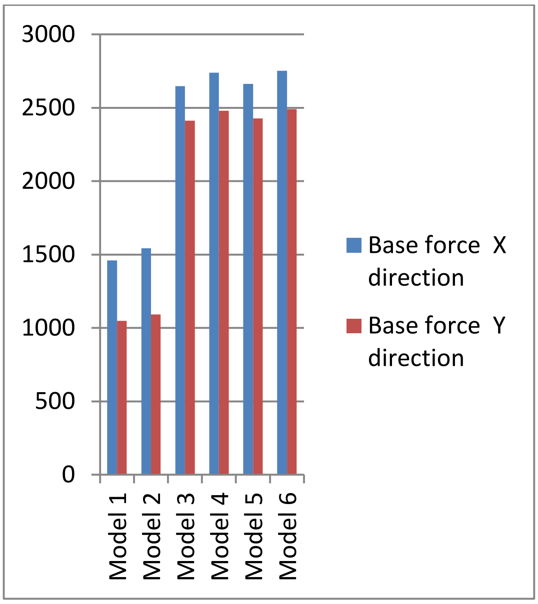

Figure 5: Seismic Base force of all models in X and Y directions

Table 3 Story displacement in X-direction of all Models

Story number	Story displacement in X direction (m)					
	Model1	Model2	Model3	Model4	Model5	Model6
Story 13	0.0492	0.0504	0.0357	0.0362	0.0349	0.0303
Story 12	0.0477	0.0489	0.0327	0.0332	0.0319	0.0278
Story 11	0.0457	0.0468	0.0295	0.0301	0.0287	0.0251
Story 10	0.0429	0.044	0.0263	0.0268	0.0255	0.0223
Story 9	0.0394	0.0404	0.0229	0.0234	0.0221	0.0194
Story 8	0.0354	0.0363	0.0195	0.0200	0.0188	0.0165
Story 7	0.0308	0.0316	0.0161	0.0165	0.0154	0.0136
Story 6	0.0259	0.0266	0.0128	0.0131	0.0122	0.0108
Story 5	0.0208	0.0214	0.0096	0.0099	0.0092	0.0081
Story 4	0.0156	0.0160	0.0067	0.0069	0.0064	0.0057
Story 3	0.0104	0.0108	0.0041	0.0043	0.0039	0.0035
Story 2	0.0057	0.0059	0.0021	0.0022	0.0020	0.0018
Story 1	0.0018	0.0019	0.0006	0.0007	0.0006	0.0005

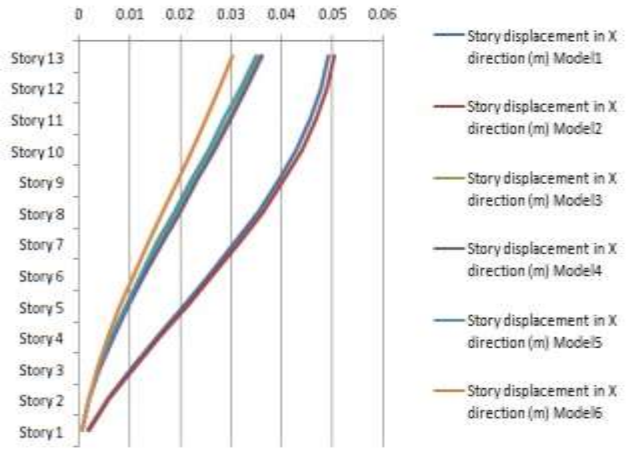

Figure 4.4: Story displacement in X-direction of all Models

7. CONCLUSIONS

In this study six 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 is done between them. The results are obtained from 3-dimensional modelling of PEB and CSB steel frame structure from SAP 2000Vs19 software. The various conclusion are made as follows,

- From Seismic analysis on all Six models target displacement in **model-6** in X-direction are comparatively lesser than of all others **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.
- The story force distributions of model-1 in X-direction are comparatively lesser than of all others **models** because of reduced seismic weight of Pre-Engineering building in **model-1.**
- From earthquake analysis on all models according to IS-1893 the Base reaction in **model-1** are 94.70% of **model-2,** 55.18% of **model-3,** 53.30% of **model-4,** 54.86% of **model-5,** 53.05% of **model-6,** due to the

reduced seismic weight of Pre-Engineering building.

- From Seismic analysis on all Six models story drift in **model-6** in X-direction are comparatively lesser than of all others **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.
- response spectrum analysis done on all models give response spectral acceleration in **model-5** in X-direction are comparatively lesser than of all others **models** due to larger lateral stiffness provided by shear wall at centre in Pre engineering steel building.
- From different results of analysis we conclude that Pre-engineered building models are more stable and reduced in seismic weight under the condition of seismic analysis due to using of tapered steel section in PEB structure.

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