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Behaviour of Cold Formed Z-Section with Sag Rod in Pre-Engineered Building

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ABSTRACT

Pre-Engineered Building (PEB) concept is a new conception of multi-story 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. Pre-Engineered Buildings are metal building systems in which all the structural elements are factory-made and then assembled at the site in accordance to the design. In earlier days, these buildings were made cold form rolled steel. Cold formed rolled steel sections have higher thickness starting form 5mm or 6 mm.Thispaper is a study on PEB concept. The study is achieved by designing a typical frame of a proposed building using response spectrum method and analyzing frames using the structural analysis software ETABS 2016

Keywords: ConcretePre-Engineered Building, ETABS, Z- section, Cold formed steel (CFS).

I. INTRODUCTION

In India, construction industries contribute a large part to the development of the Indian economy. The construction industries play a very important role in the development of the Indian economy. For fast growth, structure engineering discovered the PEB concept. Instead of multiple suppliers, PEB has a single supplier which provide complete component including steel framework, cladding, and roofing component. According to specification, all components are erected on the site by using the bolted connection. PEB design is done by software.Steel is a material which has high strength per unit mass. Hence it is used in construction of structures with large column-free space. Most of the cold form Structures require this criterion. Apre-fabricated building and is usually characterized as multistory buildingstory steel structures with or without mezzanine floors. The enclosures of these structures may be brick masonry, concrete walls or GI sheet coverings. The walls are generally non-bearing but sufficiently strong enough to withstand lateral forces caused by wind or earthquake. The designing of cold form includes designing of the structural elements including column and column base, sag rods, tie rods etc. A combination of standard hot-rolled sections, cold-formed sections, profiled sheets, steel rods, etc. are used for the construction of industrial steel structures. Industrial buildings can be categorized as Pre-Engineered Buildings (PEB) and Conventional Steel Buildings (CSB), according to the design concepts. The paper starts with the discussion of methods adopted in the study. Introduction to PEB systems and CSB systems are then described followed by the details of case study. Loads and the load combinations adopted for carrying out the analysis of the structure is well defined in the further portions. A section depicting the importance of the software used and the software procedure followed is included. Final portion explains the results obtained from the software analysis of the case study and the inferences from the literature studies. The paper aims at developing a perception of the design concepts of PEB structures and its advantages over CSB structures.

A. Application of PEB

The most application of Pre-Engineered Building are as follows:

1) Industrial: Factories, Workshops, Warehouses, Cold stores, Car parking sheds, Slaughter houses, Bulk product storage.
2) Commercial: Showrooms, Distribution centres, Supermarkets, Fast food restaurants, Offices, Labor camps, Service station, Shopping centres, Schools, Exhibition halls, Hospitals, Theatres/auditorium, Sports halls.
3) Institutional: Schools, Exhibition halls, Hospitals, Theatres, Sport halls.
4) Recreational: Gymnasium, swimming pool enclosures, Indoor tennis courts.
5) Aviation &Military: Aircraft hangers, Administration buildings, Residential bar

B. Pre Engineered Building

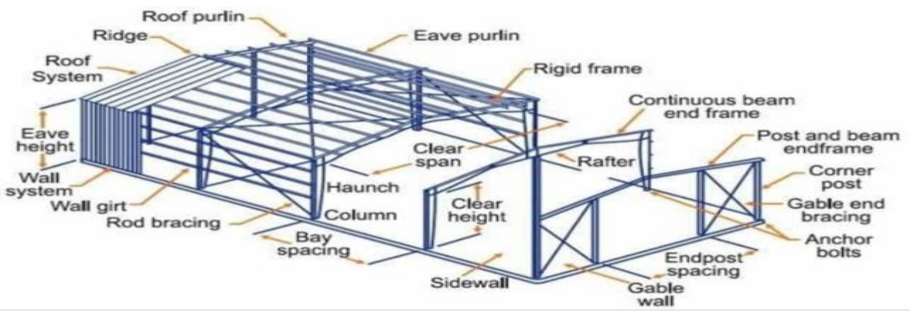

Figure1:Pre Engineering Truss Components

C. Advantages of PEB

There are many advantages of Pre Engineered Buildings, which are as followLower cost is due to the saving in design, manufacturing and on site erection cost.Quick Erection is as all the members are Pre Manufactured& skilled Labor is used for connections of different components.

- Low Maintenance due to use of standard quality of paints over steel members, which increases the ability to withstand & finally the maintenance cost will be low as compare to conventional Steel building.
- Quality control is the main advantage as all the structural member are engineered beforehand, standards of different codes also taken into consideration & these components are made in factory under the supervision of Quality Control Engineer.
- Minimizing time of construction due to the use of software for design of the structure components.
- Warranty on PEB mostly warranty period of 20 years given by manufactures for PEB.
- Larger Spans buildings can be supplied to around 80M clear spans.
- Lower cost is due to the saving in design, manufacturing and on site erection cost.

- Quick Erection is as all the members are Pre Manufactured& skilled labor is used for connections of different components.
- Low Maintenance due to use of standard quality of paints over steel members, which increases the ability to withstand & finally the maintenance cost will be low as compare to conventional Steel building.
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- Minimizing time of construction due to the use of software for design of the structure components.
- Warranty on PEB mostly warranty period of 20 years given by manufactures for PEB.
- Larger Spans buildings can be supplied to around 80M clear spans.

D. Disadvantages of PEB

- PEB have many advantages in the field of Industrial structure but there are some disadvantages of Pre-Engineered Buildings, which are as follows,
- Insulation Cost as insulating the building to an agreeable benchmark will furthermore add to your construction costs.
- Corrosion Sensitive as if the quality of steel used or paint used for coating of steel members is not of good quality,then it can damage the structure and thus reduces the life of structure.
- Appearance of steel Sections can be unattractive when left exposed.

E. Project Statement

The study will give more knowledge which result into benefits for future implementation with the help of pre-fabricated cold form building actual Analysis. To study the effect of cold form structural behaviour.

F. Objective Statements

- Analysis of G+2 story building with IS401.Design of cold form building using ETABS 2016.
- Study base shear result using pre-fabricated section with IS 1893-2016 Criteria for earthquake resistant design of structures.
- Calculate displacement due to earthquake loading and wind loading.
- Determine story force at various story levels in G+2 story building.

II. LITERATURE REVIEW

Several investigators studied the influence of cold form structural buildings. They performed the studies by changing various parameters of cold form section and found that due to the flexibility structural forces are altered. Some of noteworthy configuration of researchers in this field is discussed below.

Mrunal S. Hatwar1, Vaishali Mendhe2 & Dr. Ramesh Meghrajani3 (2020)studied low cost ministry of housing, 1.77 million number of peoples don’t have one of basic amenities i.e. house. Basically Cold Formed Steel are Pre-Engineered Building structures which can enhance easy and faster mode of construction which can overcome this concern. These structures are designed using semi rigid connections which makes the system earthquake resistant in addition to the safety, durability, performance and long-term low operational costs for the 50-year design life of a typical low rise residential house.

HumanaazArifQureshi, Dr. Kuldeep R. Dabhekar, AmolShahakar (2019)Analysed structural engineering, the Pre- Engineering Building (PEB) is a system that provides economical and less time-consuming design and construction of the building. From the past few years, by the use of PEB design, we get optimizing the design of the structure.

Kanchan S Takale (2018)StudiedZ profile has a complex deformation behavior and the severe buckling issues leads to reduction in strength of the member. Lateral torsional buckling is the governing deformation leading to overall distortion of the member. It is important to eliminate or delay these buckling problems to achieve higher sustainability of the structure.

Kanchan S Takale (2017)studied Pre-Engineered Buildings are metal building systems, in which all the structural elements are factory-made and then assembled at the site in accordance to the design. In earlier days, these buildings were made from wood and later in hot rolled steel. Hot rolled steel sections have higher thickness starting form 5mm or 6 mm.

Mr. Aditya P. Mehendale (2016)Buildings& houses are the basic requirements of any human being. There are several changes in construction technology since the beginning. The basic requirements of construction nowadays are best aesthetic look, fast, economical & high quality. Pre- engineered building is best option for these all requirements

Swati Wakchaure and N.C. Dubey (2016) discussed 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 analysed 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.

III.RESEARCH METHODOLOGY

Earthquake motion causes vibration of the structure leading to inertia forces. Thus, a structure must be able to safely transmit the horizontal and the vertical inertia forces generated in the super structure through the foundation to the ground. Hence, for most of the ordinary structures, earthquake-resistant design requires ensuring that the structure has adequate lateral load carrying capacity. Seismic codes will guide a designer to safely design the structure for its intended purpose.Seismic codes are unique to a particular region or country, In India, IS 1893 is the main code that provides outline for calculating seismic design force, this force depends on the mass and seismic coefficient of the structure and the latter in turn depends on properties like seismic zone in which it rests, and its ductility. Part of IS1893:2016 deals with assessment of seismic loads on various structures and building. Whole the code centres on the calculation of base shear and its distribution over height. Depending on the height of the structure and zone to which it belongs, type of analysis i.e., static analysis or dynamic analysis is performed.

A. Response spectrum method

This method is applicable for those structures where modes other than the fundamental one affect significantly the response of the structure. In this method the response of multi degree of freedom system is expressed as the superposition of modal response, each modal response being determined from the spectral analysis of single degree of freedom system, which is then combined to compare the total response. Modal analysis of the response history of structure to specified ground motion; however, the method is usually used in conjunction with a response spectrum.

B. Seismic Base Shear

According to IS 1893 (Part-I): 2002, Clause 7.5.3 the total design lateral force or design seismic base shear (VB) along any principal direction is determined by

Vb= Ah. *W

Ah is the design horizontal acceleration spectrum

W is the seismic weight of building

C. Design Horizontal Acceleration Spectrum Value

For the purpose of determining the design seismic forces, the country (India) is classified into four seismic zones (II, III, IV, and V). Previously, there were five zones, of which Zone I andII Are merged into Zone II in fifth revision of code. According to IS 1893: 2016 (Part 1), Clause6.4.2 Design Horizontal Seismic Forces Coefficient Ah for a structure shall be determined by following expression

Ah = (z/2) *(I/R) *(sa /2g)

Where,

- Z = Zone Factor Seismic Intensity
- I= Importance Factor
- R= Response Reduction Factor

TABLE I SEISMIC ZONES OF INDIA SHOWING TENTATIVE PERCENTAGE OF LAND AREA

Seismic Intensity	Low	Moderate	Severe	Very Severe
Zone	II	III	IV	V
Z	0.10	0.16	0.24	0.36

India has been divided into four seismic zones. Zone II and Zone III are major zones covering more percentage of land area in India. Eastern India has higher seismic intensity. It fails under zone V. North-East India falls under zone IV. Geographical statistics of India show that almost 54 % of the land is vulnerable to earthquakes. Table 3.1 & Fig.3.2 shows various seismic zones of India with tentative percentage of land area.

I = Importance factor is used to obtain the design seismic force depending on the functional use of the structure, characterized by hazardous consequences of its failure, its post.Earthquake functional need, historic value, or economic importance (IS 1893-2016 cl.no.6.4.2/table6/pg.no.18).

R = Response reduction factor depending on the perceived seismic damage performance of the structure characterized by ductile or brittle deformations which is shown in Table 3.2 (IS 1893-2016 cl.no.6.4.2/Table7/pg.no.23).

Sa/g = Average response acceleration coefficient (dimensionless value). The value of Sa/g is obtained from fig.3.3 from IS: 1893 (Part 1): 2016.

TABLE II RESPONSE REDUCTION FACTOR R FOR BUILDING SYSTEMS

Sr. No.	Lateral Load Resisting System	R
1	Ordinary RC Moment Resisting Frame (OMRF)	3.0
2	Special RC Moment Resisting Frame (SMRF)	5.0
3	Ductile Shear Wall With SMRF	5.0

IV. PARAMETRIC INVESTIGATION

A. Introduction

In this title of parametric investigation, a detailed study and analysis of pre-fabricated building using IS codes has been presented. Study has been done on cold form structure. Analysis of all the above-mentioned structures has been carried out by using Indian Standard with response spectrum Method. Cost effectiveness of structures has also been studied only from material point of view.

B. Problem Formulation

G+2 storied pre-fabricated building, moment resisting space frame have been analysed using professional software. Model (G+2) of structural frame with regular shear wall and dumbbell shaped shear wall is analysed by response spectrum Method. The pre-fabricated plan dimensions of buildings are shown in table below. The plan view of building, elevation of different frames is shown in figuresbelow

Figure2:Cold formed Z-sections

C. Load case and load combination

Unless otherwise specified, all loads listed, shall be considered in design for the Indian Code following load combinations shall be considered,

D. Load combination

- 1.5DL+1.5LL
- 1.2DL+1.2LL + 1.2EX
- 1.2DL+1.2LL- 1.2EX
- 1.2DL+1.2LL+1.2EY
- 1.2DL+1.2LL -1.2EY
- 1.2DL+1.2LL+1.2WLX
- 1.2DL+1.2LL-1.2WLX
- 1.2DL+1.2LL+1.2WLY
- 1.2DL+1.2LL-1.2WL

E. All Screenshot

1) 3D line models:

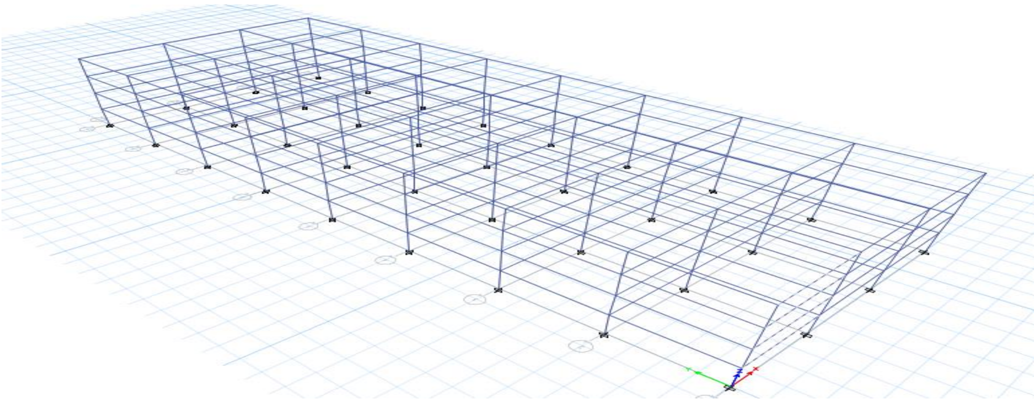

Figure3:3D line model

2) 3D rendering models:

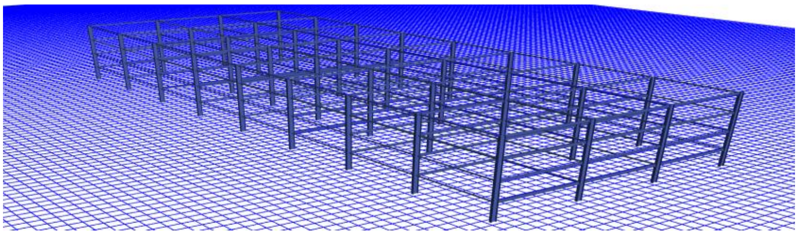

Figure4:3D rendering model

V. RESULTS

A. Base shearresults

TABLE IIII Seismic Base Shears

Auto Seismic - IS 1893:2002								
Load Pattern	Z	Soil Type	I	R	Period secrecy Used	Coeff Used	Weight kNUsed	Base kNShear
EQ+X	0.16	II	1	5	1.1	0.019785	16307.8989	322.6484
EQ-X	0.16	II	1	5	1.1	0.019785	16307.8989	322.6484
EQ+Y	0.16	II	1	5	1.845	0.011794	16307.8989	192.3318
EQ-Y	0.16	II	1	5	1.845	0.011794	16307.8989	192.3318

TABLE IIIV Earthquake Displacement Results

Diaphragm Center of Mass Displacements						
Story	Load Case/Combo	UX (m)	UY (m)	RZ rad	X (m)	Y (m)
Story4	EQ+X	0.013357	0	0	12	32
Story3	EQ+X	0.008053	0	0	12	32
Story2	EQ+X	0.003296	0	0	12	32
Story1	EQ+X	0.000331	0	0	12	32

Base	EQ+X	0	0	0	12	32

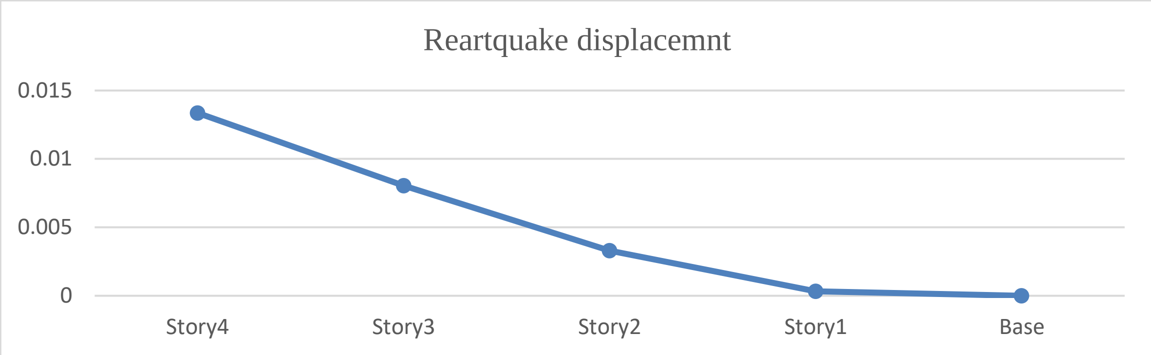

Figure5:Earthquake Displacement Vs. Story

B. Wind Displacement Results

TABLE V WIND DISPLACEMENT

Diaphragm Centre of Mass Displacements							
Story	Load Case/Combo	UX (m)	UY (m)	RZ rad	X (m)	Y (m)	Z (m)
Story4	W L+X	0.016108	0	0	12	32	10.2
Story3	W L+X	0.010087	0	0	12	32	7.2
Story2	W L+X	0.004367	0	0	12	32	4.2
Story1	W L+X	0.000473	0	0	12	32	1.2
Base	W L+X	0	0	0	12	32	0

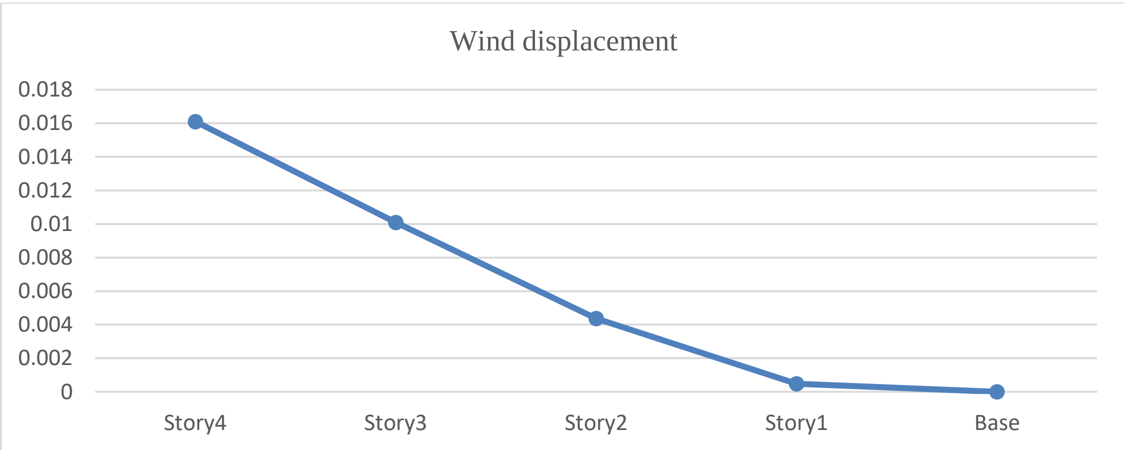

Figure6:Wind Displacement Vs. Story

C. Story Force Result

TABLE VI STORY FORCE

Story Forces						
Story	Load Case/Combo	Location	PkN	VXkN	MXkN-m	MYkN-m
Story4	1.5(DL+LL)	Bottom	7487.9803	0	239615.3689	-89855.7634

Story3	1.5(DL+LL)	Bottom	14975.9606	0	479230.7379	-179711.5267
Story2	1.5(DL+LL)	Bottom	22463.9408	0	718846.1068	-269567.2901
Story1	1.5(DL+LL)	Bottom	29816.8666	0	954139.7305	-357802.3989

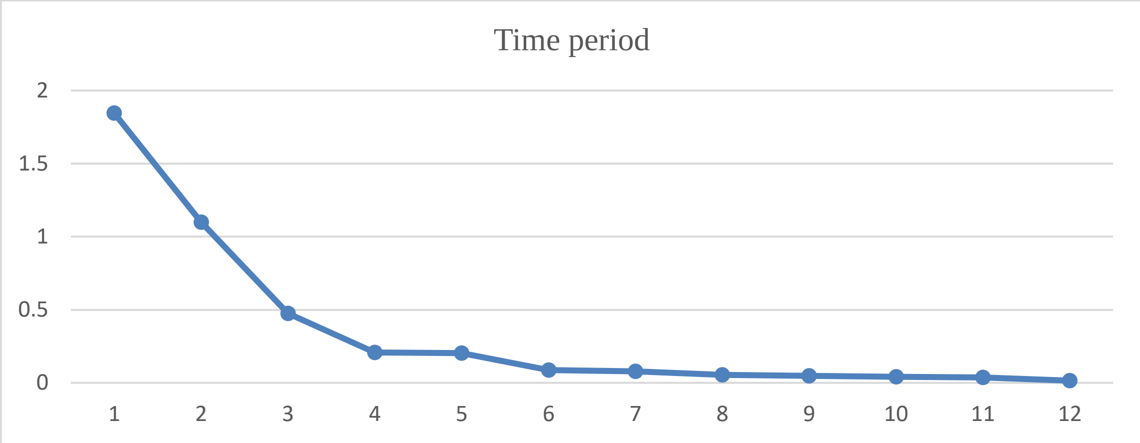

Figure7:Modal Time Period Vs. Mode Shape

VI. CONCLUSION

In the present study, analysis of cold formed pre-fabricated structural building with zone III has been carried out for 3 story. The buildings are analyses for earthquake load (zone III). it has been made on different structural parameters viz. base shear, Earthquake displacement and wind displacement story force and modal time period etc. Based on the analysis results following conclusions have been drawn

- Analysis of cold form building at zone IIIwith medium soil. The base shear in x- direction, is maximum as compare to base shear in Y-direction.
- Building analysis in dynamic analysis method with zone III, earthquake displacement results indicate that pre-fabricated building safe in earthquake displacement.
- Pre-fabricated building analysis in response spectrum method with zone III at medium soil, wind displacementresults indicate that pre-fabricated building safe in wind displacement.

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