International Journal of Materials, Mechanics, Mechatronics and Manufacturing
ISSN: 2583-5688 Volume: 002 (2023), pp. 107-128

Optimizing building design on sloping terrain: a comparative analysis of g+10 storied pre-engineered buildings on 10–degree slope and flat ground

NavaneethN[1], Sravani C[1], Koteswara Rao[1], Thiyagarajan [1], Lingeshwaran N [2] and Vudata Harsha Sai [2]

[1]*Department of Civil Engineering, Amirtha Sai Institute of Science, Paritala, Andhra Pradesh, India*
[2]*Department of Civil Engineering, Koneru Lakshmaiah Education Foundation (Deemed to be University), Guntur, Vaddeswaram, India*

Abstract

In almost every region of the globe, the steel sector is seeing fast growth. At a time when climate change is a real concern, steel buildings are both cost-effective and environmentally benign. Pre-engineered buildings (PEBs) are one example; these are steel constructions that are prefabricated and quickly assembled because time is of the essence. Construction of pre-engineered structures is more time-consuming and less expensive than those of traditional construction methods Pre-engineered structures typically weigh less, take less time to build, and are simpler to construct than their conventional equivalents. The building's loads are determined in advance, and the components are made at a factory; assembly takes place on-site. Using Staad Pro V8i software and following IS code, a 43.5m G+10 story pre-engineering building is developed in this research. We compare slope ground versus flat ground buildings in terms of deflection, shear, bending, story drift, and steel take off.

Keywords: Steel, Pre-Engineered Buildings, Staad Pro V8i, slope ground, flat ground.

1. Introduction

1.1 Conventional Steel Buildings

Rolling steel pieces that are specially planned, cut, and welded on location are used in the construction of conventional steel buildings. These structures typically feature a low profile and utilize a variety of support materials, including roof coverings. The choice of roof structure is determined by the pitch of the bracket. Often referred to as metal buildings, these structures rely on steel as the primary material in the construction process. The steel used is of a specific cross-section and composition, providing exceptional structural integrity.

1.2 Pre-Engineered Buildings

Steel structures known as pre-engineered buildings (PEBs) are constructed off-site and put together on-site with bolts. This construction method is particularly suitable for industrial buildings and warehouses due to its cost-effectiveness, rapid assembly time, and portability. The concept of PEBs originated in the 1960s, characterized by the use of standardized, mass-produced engineering drawings for a limited range of common features. This period was significant in the evolution of metal structures for several reasons.

First, technological developments continuously improved metal constructions' clear-span capacities. The earliest rigid-frame buildings were 40 feet wide by the late 1940s, and spans of 50, 60, and 70 feet were soon to be possible. The necessity for weathered corrugated facades was eliminated by the late 1950s when ribbed metal panels and 100-foot spans were commonplace. The first UL-approved metal roof, continuous span cold-formed Z purlins, factory-insulated panels by Butler, and collared panels by Strand-Steel Corp. all contributed to additional innovation in the early 1960s. Additionally, the use of computers in the early 1960s exponentially expanded design options, leading to a boom in metal-building construction.

The term "pre-engineered building" initially referred to structures limited to conventional designs. However, as companies began offering custom-designed metal structures tailored to individual customer needs, the term evolved. Despite its association with clunky prefab structures, "pre-engineered building" remains commonly used. The preferred industry term is now "metal building systems."

Globally, the steel sector is experiencing rapid growth, with steel buildings being both cost-effective and environmentally friendly. The term "economical" here encompasses both time and financial savings. Steel structures, also known as prefabricated buildings or PEBs, can be erected quickly, which is crucial in the context of climate change. PEBs are designed with tapered sections to optimize bending moments, reducing the use of surplus steel. Although the concept of PEBs is widely recognized, it remains underutilized due to a lack of awareness.

In contrast to conventional steel constructions, which are more time-consuming and expensive, PEBs can be completed within six to eight weeks. The entire design and fabrication process occurs in the factory, with prefabricated members transported to the construction site for assembly.

PEBs offer superior structural performance and comply with regulations ensuring resilience against windstorms. They also provide excellent strength-to-weight ratios compared to reinforced concrete constructions (RCC) and can be quickly dismantled. Their bolted connections allow for reuse after deconstruction, providing flexibility for relocation and expansion to meet future needs.

This study aims to compare PEBs with conventional steel constructions, highlighting their numerous advantages through three case studies. Modern software advancements have made it easier to achieve large column-free areas, a top priority for many industries. As computing power has increased, software programs have facilitated innovative designs, exemplified by the evolution of PEBs. By manufacturing PEBs entirely in the factory and transporting them in a "completely knocked down" (CKD) state, significant time savings are achieved. On-site assembly involves fastening all parts with nuts and bolts, streamlining the construction process.

1.3. Advantages of Pre-Engineered Buildings

1.3.1 Construction Time

Pre-engineered buildings (PEBs) significantly reduce construction time, typically taking just 6 to 8 weeks from plan approval to completion. This expedited schedule allows for faster occupancy and earlier revenue generation by cutting the project's overall duration by about 40%. One of the main benefits of employing pre-engineered construction components is this.

1.3.2.Lower Cost

A systems approach in PEBs leads to substantial cost savings in design, production, and construction. This holistic methodology integrates all aspects of the construction process, resulting in more efficient use of resources and lower overall expenses.

1.3.3.Flexibility of Expansion

PEBs offer exceptional flexibility for future expansion. Additional bays can be easily added to extend the building's length. With proper planning, expansions in width and height can also be accommodated, ensuring the building can grow with changing needs.

1.3.4.Large Clear Spans

One of the key benefits of PEBs is the ability to provide large clear spans, up to 90 meters, without internal columns. This feature offers vast, unobstructed interior spaces ideal for various industrial and commercial applications.

1.3.5.Quality Control

The controlled factory environment in which PEB components are manufactured ensures consistent quality. This precision in fabrication translates to higher reliability and performance of the finished structure.

1.3.6.Low Maintenance

PEBs are made to last thanks to premium steel and cladding paint techniques that are adapted to the site's unique environmental circumstances. PEBs are even more cost-effective because of these coatings' durability and low maintenance requirements.

1.3.7.Energy Efficient Roofing

PEBs feature energy-efficient roofing systems. Insulation materials such as fiberglass blankets or polyurethane insulated panels are used to achieve the desired "U" values (overall heat transfer coefficient). This results in better thermal performance and reduced energy consumption for heating and cooling.

1.4.Sloping Ground concept

One of nature's most astonishing and mysterious phenomena is the earthquake. Seismic forces don't directly endanger human life, but they do create structural damage that eventually leads to the building collapsing, which in turn harms the people within and their possessions. Particularly in a country like India, which relies on agriculture, the recent earthquakes have decimated both towering and low buildings, necessitating investigation. Damage from seismic and earthquake forces is inevitable for any structure exposed to these forces; however, the likelihood of damage increases dramatically on slopes or other buildings that are inclined with respect to the ground, as a result of increased sidelong forces on short sections on the hard side, necessitating the installation of plastic pivots. Because they are not uniformly spaced either horizontally or vertically, structures on slants differ from fields in this regard. A sizable area of hilly terrain in northern and northeastern India is included in seismic zones IV and V.

The earthquakes in Nepal (2015), Doda (2013), and late Sikkim (2011) all resulted in massive death tolls. Rapid urbanization, growth in the economy, and concomitant increases in population density have piqued the attention of building developers in this region in RC- outlined multi-story structures. There is a dedication to developing structures on the sloping terrain due to the paucity of flat land in this area. Here, we show a trial arrangement for a pre- engineered building that leans 10 degrees to the ground and is subject to sinusoidal ground movement; we code in a limited number of components, and we verify the results using straight time history analysis in our main exam and our planning software, Staad Pro.

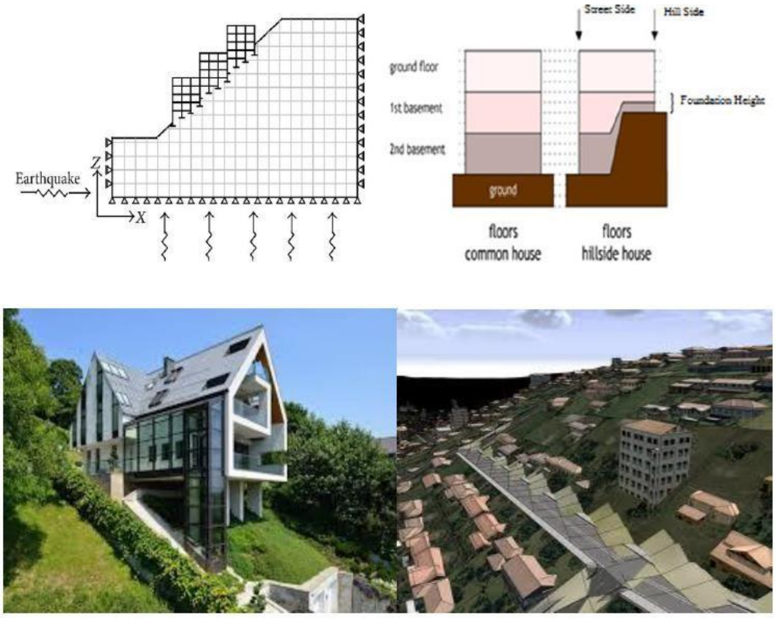

Figure 1 Buildings on sloping ground

1.5.Seismic Analysis

It is hard to fathom modern life without infrastructures, which have become ubiquitous in our rapidly modernizing environment. Concrete buildings are one of the most ubiquitous types of infrastructure. There are several distinct departments involved in the building process, including architects, structural designers, contractors, and more. Buildings are being constructed with the assistance of these departments to ensure they can endure the intense vertical stresses and ground motion caused by earthquakes. Due to the complexity of ground vibrations, the designer must exercise extreme caution while taking them into account; even a little error in estimation might cause the building to collapse. Consequently, there has been a significant uptick in studies examining how seismic rules affect building resistance and design. When these lateral pressures are too great to be handled by beams and columns alone, additional members may need to be added. The most recent edition of the Seismic Indian Code, IS: 1893-2016, includes revisions to the code's requirements for earthquake-proof structure design. The most significant change to this law was made to the rules and regulations pertaining to dynamic seismic analysis, but there were many others. Except for typical buildings below 15 meters in height, all structures in seismic zone II are required to use dynamic seismic analysis

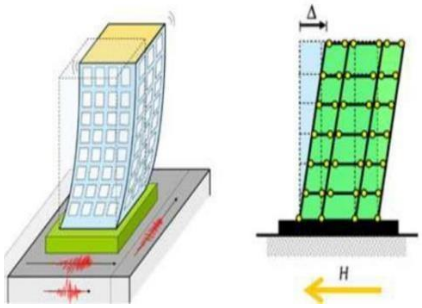

Figure 2 Ground Motion during Earthquake

Conventional wisdom held that static seismic analysis should be used until a building's height was more than 40 meters. As a result, a comparison between static analysis (as defined by 1893-2002) and dynamic analysis (as defined by 1893-2016) in seismic zone V has been carried out, taking into account both the new and old earthquake codes.When planning an earthquake-resistant building, it is important to take a number of seismic criteria into account, including the building's structure, the materials used, the soil type for the foundation, and so on. The buildings are being reinforced to withstand earthquakes using two distinct techniques:

1. Equivalent Static Seismic Analysis
2. Dynamic Seismic Analysis.
3. Response Spectrum Method
4. Modal Time History Method
5. Time History Method

2.Objectives of the study

For this the following objectives were made

1. To design the pre-engineering building by Staad pro
2. Using IS 1893:2002 to investigate the seismic behavior of multi-story buildings
3. to contrast the flat land with the pre-engineered building with a slope of 100.
4. to compare the outcomes of building torsion, shear force, bending moment, and story drift for structures with slopes of 10^0 and 0^0.
5. To study the buildings in Staad Pro V8i software package in Response spectrum analysis.

3.Literature Review

Because of its affordability and quick construction, pre-engineered buildings, or PEBs, have attracted a lot of interest in the civil engineering community. The design of an industrial warehouse utilizing PEBs was explored by Meera et al. (2013), highlighting the efficiency of PEBs compared to conventional structures [1]. A comparative study conducted by Gone et al. (2014) emphasized the distinct advantages of PEBs over traditional building methods, particularly in terms of material optimization and construction speed [2]. Similarly, Kumar and Rao (2014) investigated the design and analysis of PEBs, underscoring the flexibility and reduced construction costs associated with these structures [3].

Further evaluation of PEB designs using Indian and international standards was presented by Zoad (2012), who compared the IS-800 code against the AISC standards, illustrating significant differences in structural design approaches [4]. Atwal et al. (2017) conducted a detailed analysis using IS800:2007, reinforcing the structural robustness and compliance of PEBs with established engineering norms [5]. Wakchaure and Dubey (2016) performed a comparative study of PEBs, highlighting their superiority in terms of design efficiency and load-bearing capacity compared to conventional buildings [6].

Subramanian's works (2008) provided a comprehensive overview of the selection of framing systems, roofing, and wall materials for PEBs, contributing valuable guidelines for industry practitioners [8]. Rolphes (2006) examined the seismic considerations for industrial building design, emphasizing the importance of robust design practices in earthquake-prone areas [9]. The Metal Building Systems Manual (2006) offered detailed technical specifications and guidelines for the design and construction of metal buildings, which are integral components of PEBs [10]. Bhavikatti (2010) and Duggal (2010) both provided essential insights into the limit state design of steel structures, aligning with IS 800-2007 standards, which are pivotal for ensuring the safety and reliability of PEBs [19], [20]. The comparative study by Zende et al. (2013) on PEBs versus conventional frames showcased the economic and structural benefits of adopting PEB methodologies in industrial applications [17]. Furthermore, Lakshmi et al. (2015) explored the differences between PEBs and conventional steel buildings, highlighting PEBs' benefits in terms of construction time and cost effectiveness [18].

The structural integrity of PEBs depends on the assessment of design loads, as outlined in IS: 875 (Parts 1-3), and the requirements for earthquake-resistant design in IS 1893: 2002, which guarantee that they satisfy the relevant safety standards [14–16], [24]. The studies by Mc Entee (2009) on the evolution of steel moment frames and the analysis by Jinsha and Mathew (2016) on PEB structures further contribute to the body of knowledge, supporting the development and implementation of PEBs in various construction projects [12], [27].

In conclusion, a great deal of research and comparative studies on PEBs show how much better they are than traditional building techniques. PEBs are a preferred option in contemporary industrial and commercial building because of these benefits, which include shorter construction times, cost effectiveness, and adherence to strict safety and design standards. [1]-[33].

4.Structure Modeling

4.1.Pre-Engineering structure specifications

1.Location of the Site: Delhi

2.Storage space dimensions: 56 x 28 m,

3.with 8 bays.

4.Building Type: Standard G+10 stories

5.The wind speed is 47 meters per second.

6.The roof slope is 0.00 degrees. 14.

7.8 meters at the bays

8.Road Conditions: Class 2.

9.Medium permeability

10.9.5 meters is the minimum clearance from the front loading dock to the lower chord of the truss.

11.Color-coated steel sheet will be used to cover the roof structure.

12.The highest point of the structure is 43.5 meters.

13.The building has eleven stories.

4.2. Modelling of Building in STAAD Pro Software

Below is a breakdown of the entire study and design process.

4.2.1. Inputting the job Information

All project information is submitted as soon as STAAD Pro opens. Numerous details must be supplied, such the name of the project or task, the client, the start date, the engineer, and many more.

4.2.2 Generating the 3d model geometry

When working with STAAD, you have two options for building structural data.

a."The STAAD editor method" refers to the command file that is used.

b. Making use of the GUI.

We have utilized the GUI method for all of our programming requirements as it is the most sophisticated and intuitive tool of STAAD. The Snap Node/Beam dialog box appears when we select the grid from STAAD's top menu bar. It creates the framed structure model. The nodes and beams are then constructed using this command at the proper intervals in accordance with our specifications.

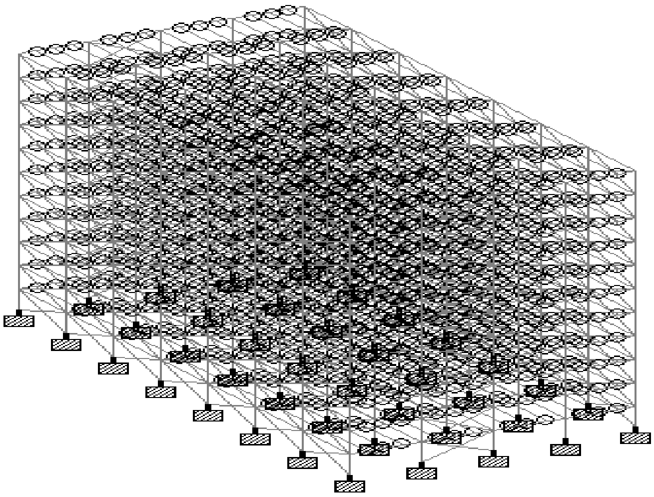

Figure 3. The Model of Structure with All the Beams and Nodes

4.2.3. Assigning the material

We allocate material to the beams and columns when they are created. Because this is a steel design, we've given the beams and columns the characteristics of steel.

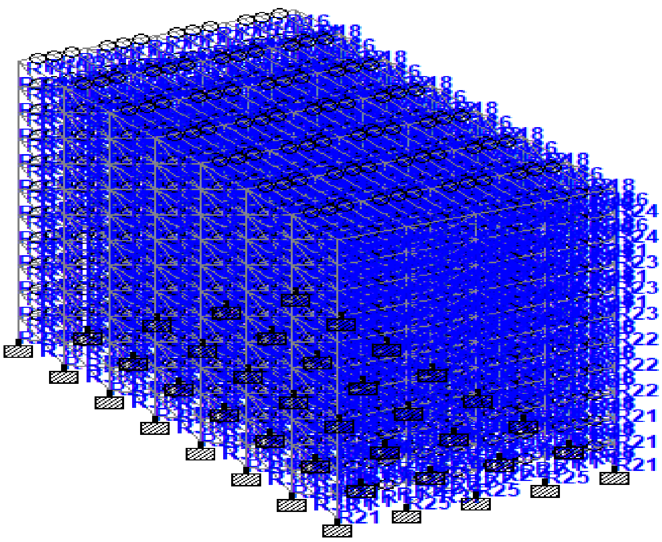

Figure 4. Assigning Steel Material to Multi Story Building

4.2.4 Specifying member properties

Beams and column are defined by their dimensions, which include their width and depth of cross-section. We have used this command to give certain members the requested attributes, which might be round, rectangular, square, or I.

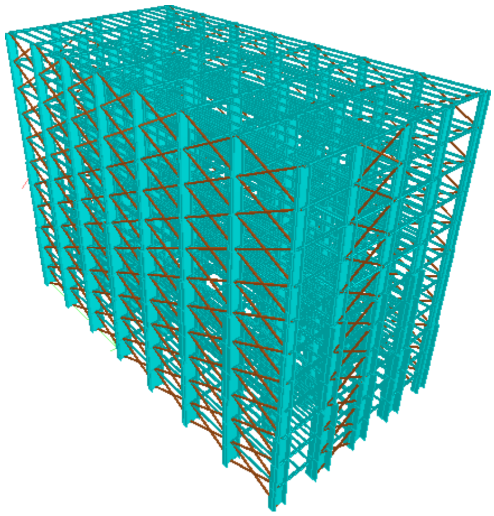

Figure 5. Rendered model after specifying the properties to member

4.2.5 Specifying material constant

Since we allocated the steel material, we already know the concrete constants, so we don't need to execute this command separately. The constants can also be changed with this command.

4.2.6 Specifying member offset

After properties are assigned, the Staad automatically aligns the beams and columns canter- to-centre. To change this, we may use the beam offset command to make the beams extend end-to-end over the columns.

4.2.7 Printing member information

We may obtain a report that contains all of the members' information, including start and end joint numbers and the length of each member in the stat output file, by selecting the Commands — Pre-Analysis Print — Member information command from the top menu bar.

4.2.8 Specifying Supports

We begin by creating the supports, then distributing them to each of the lowest nodes in the structure where the foundation would be created, just like with fixed supports.

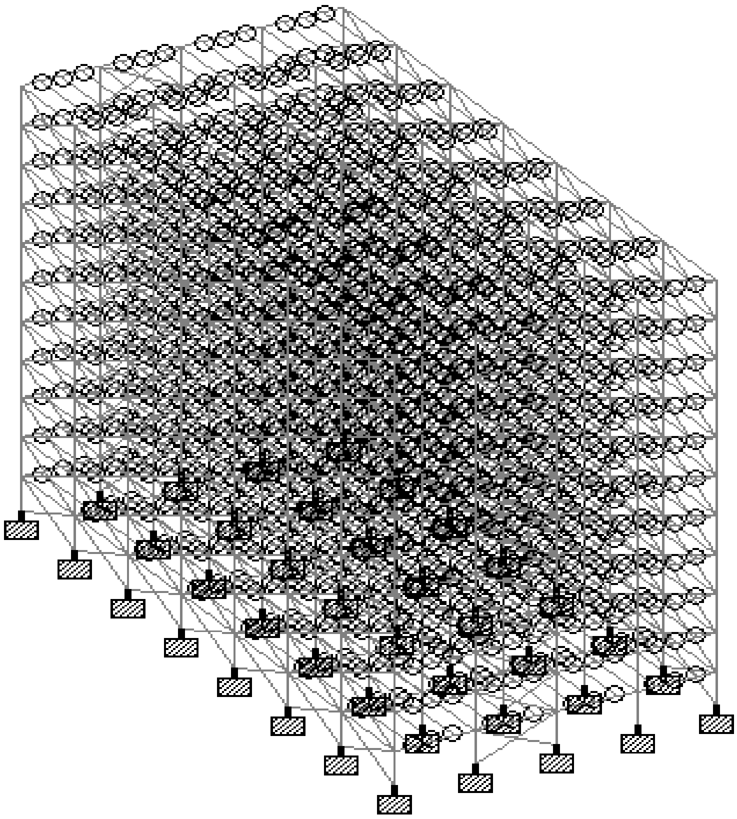

Figure 6. The model with the fixed supports

4.2.9 Specifying Loads

This is done in following two steps:

1. Firstly, creating all the load cases.
2. Then assigning them to respective members and nodes.

Any kind of load may be generated and applied to the building by use of the Staad software. It may also impart dead load to the building if needed. Particular load scenarios (such as seismic or wind loads) are not developed until certain load definitions are established in accordance with IS regulations. Some of the loads that we have allocated are listed below.

4.2.10 Dead Load

what a framed building goes through because to the weight of its individual parts, including walls, slabs, beams, and columns. This weight will be evenly distributed over the supporting beams.

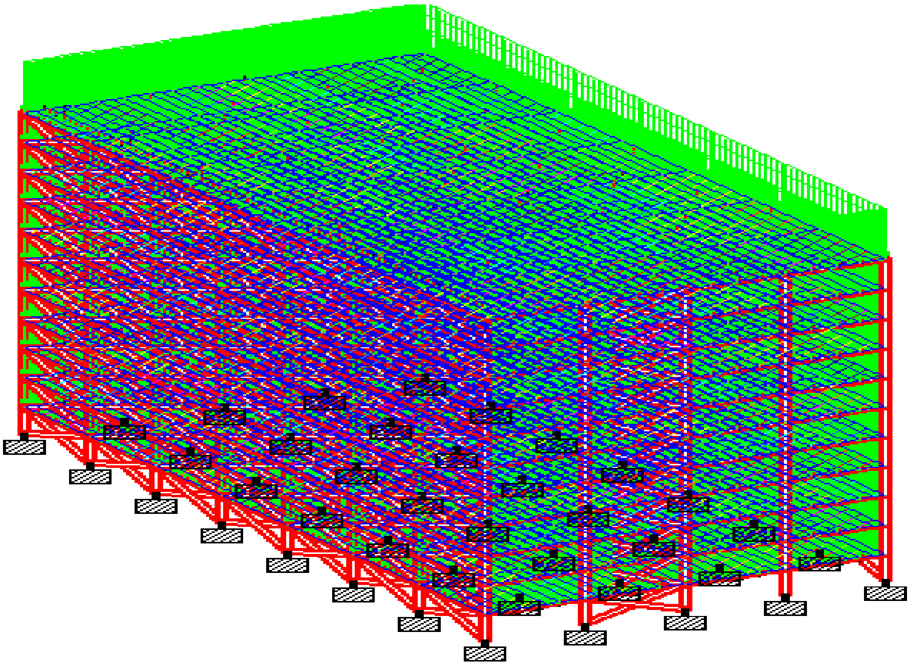

Figure 7. Assigning Dead Load

4.2.11 Live Load

The additional essentials in the home put a living burden on the structure. Because buildings serve various purposes, the Live Loads acting on them will also vary. The structure here makes advantage of a wide variety of live loads.

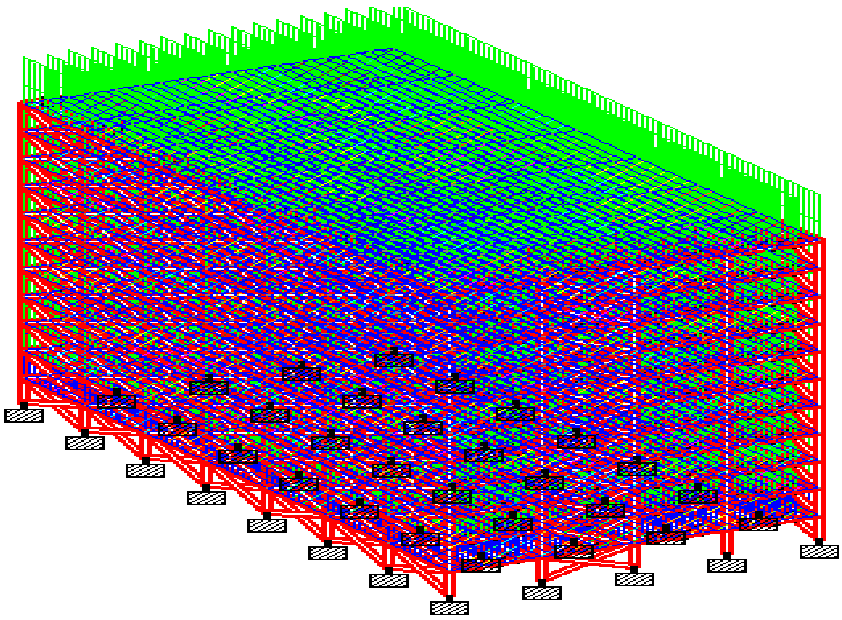

Figure 8. Assigning area load to the building

4.2.12 Seismic load

In X-Direction

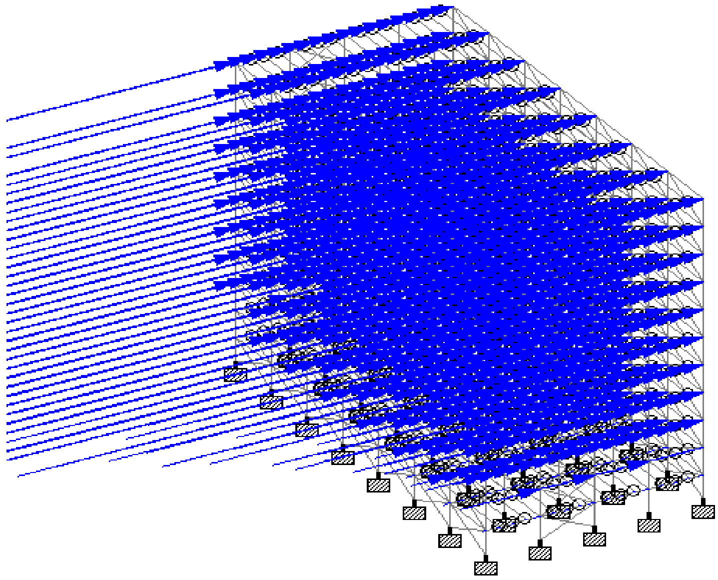

Figure 9. Assigning seismic load in +X Direction in Staad pro

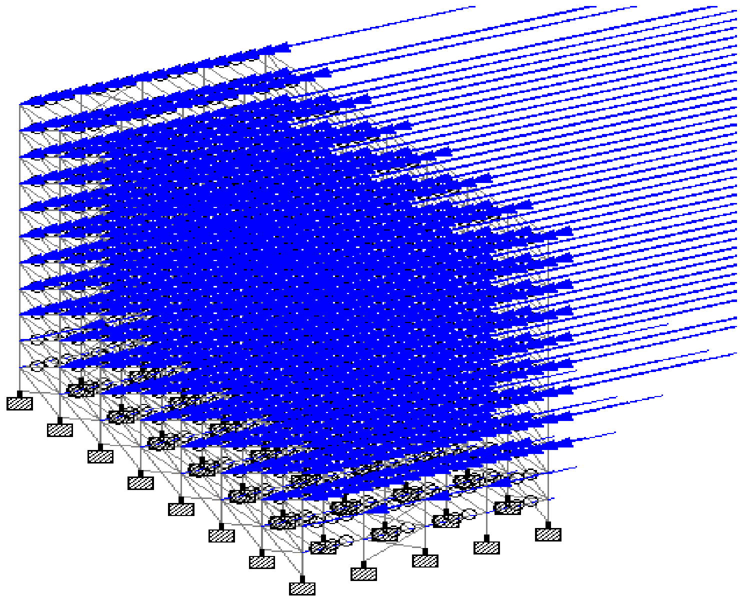

Figure 10. Assigning seismic load in –X Direction in Staad pro

In Z-Direction

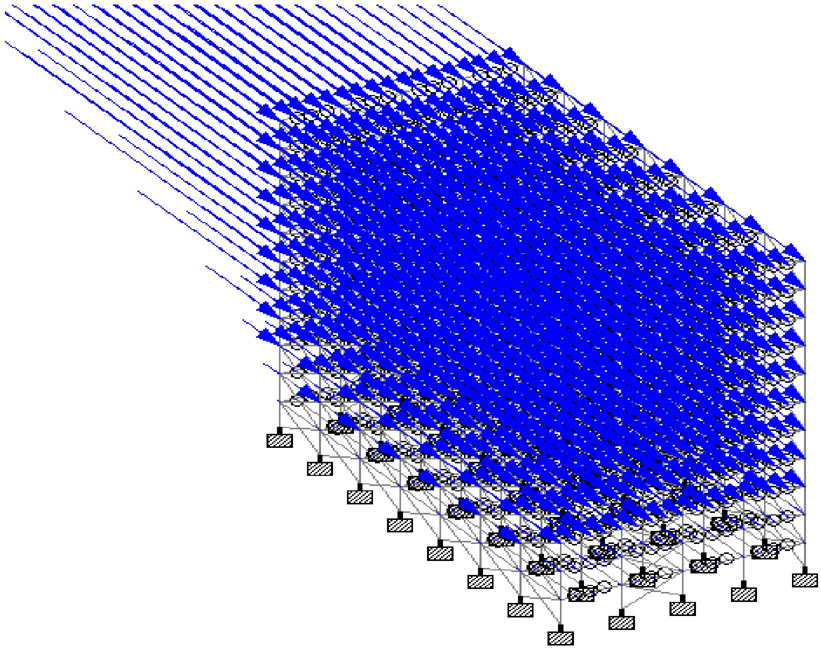

Figure 11. Assigning seismic load in +Z Direction in Staad Pro

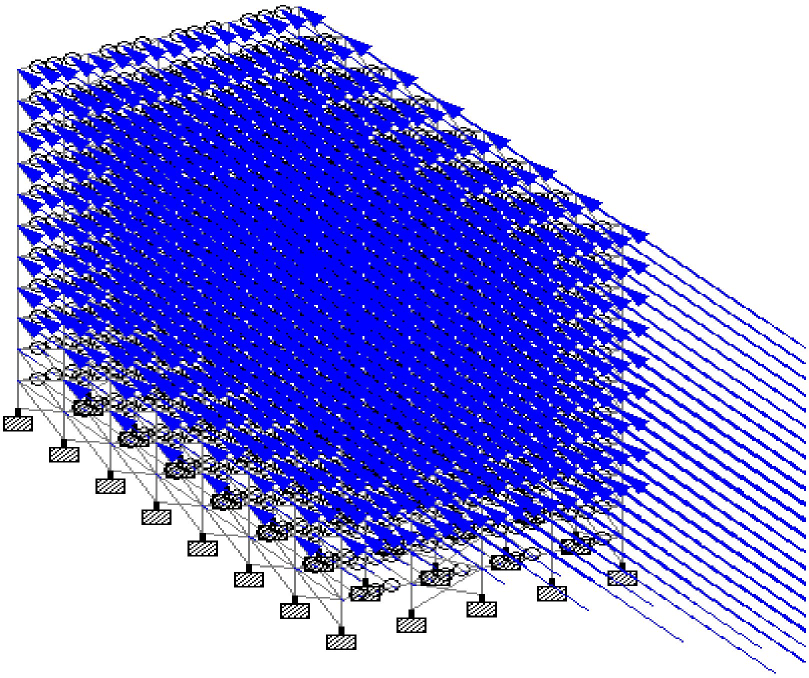

Figure 12. Assigning seismic load in -Z Direction in Staad Pro

4.2.13 Wind load

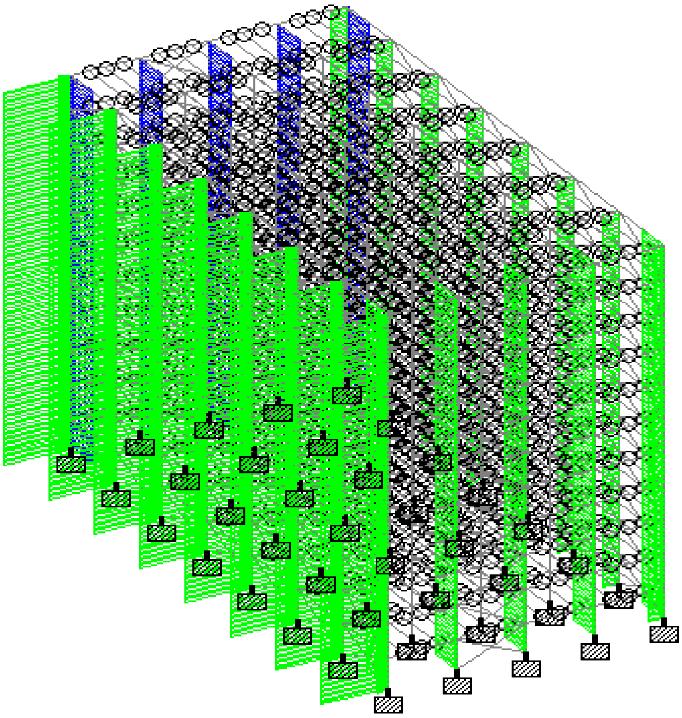

Figure 13. Assigning wind load in X Direction

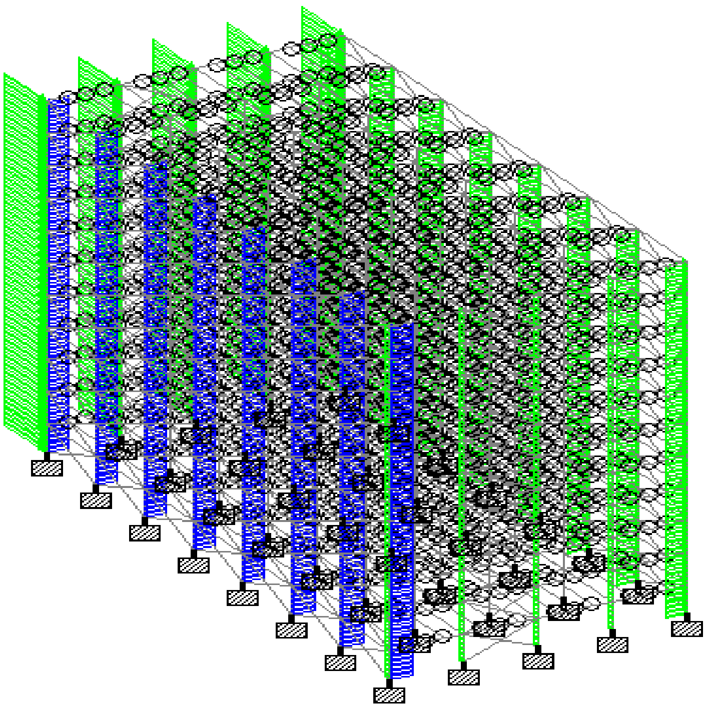

Figure 14. Assigning wind load in Z Direction

4.2.14 Load Combinations

The load combinations were generated using the auto load combinations command. It is possible to create loads that correspond to the Indian code by picking that code and then combining them together. Members are not obligated to be given these combinations.Now that the structure has all the loads it needs, we may go on to the next phase.

4.2.15 Specifying the analysis type

The analysis command, which must be of the linear static type, must be specified before the loads may be analyzed. This command will be added while selecting statics check.

4.3 Models in STAAD Pro Software

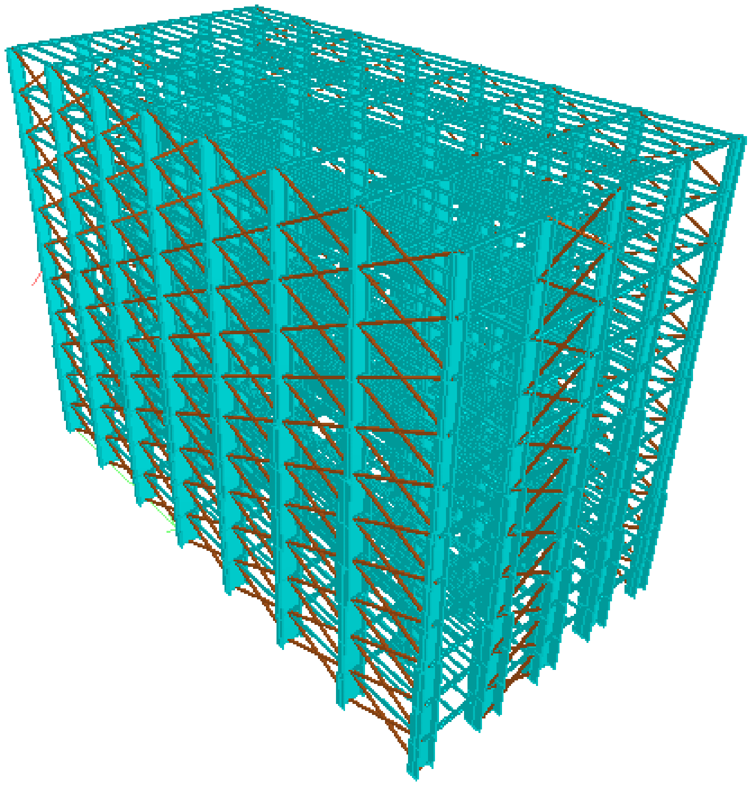

Figure 15. Building model in Flat ground

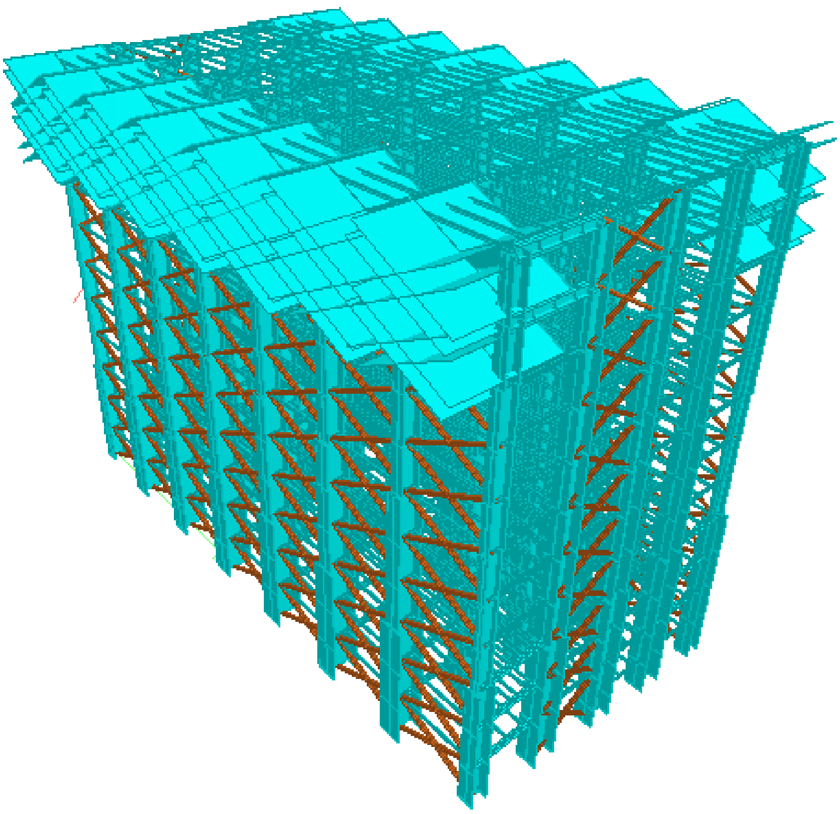

Figure 16. Building model in slope ground

5. Results And Analysis

5.1 Storey Displacement

5.1.1 Storey Displacement in X direction

Table 1. Comparison of storey displacements in X direction

Storey Number	Displacement in mm for flat ground	Displacement in mm for slope ground
1	1.032	0.806
2	4.068	3.042
3	8.66	7.339
4	15.115	13.506
5	23.239	22.095
6	32.069	33.337
7	40.767	46.534
8	48.254	61.292
9	54.67	76.584
10	60.43	90.357
11	65.097	98.67

The above table show the comparison of storey displacement in X direction for flat ground and sloping ground PEB. From the above observations it was concluded that the values of displacements is same till storey 6 after storey 6 the intensity of displacements increases for slope ground and it has higher values than flat ground building. The major reason of increasing the values is that in case of PEB the lateral loading action is high when we compared with flat ground do to this higher values of lateral loads the displacement values increases.

5.1.2 Storey Displacement in Y direction

Table 2 Comparison of storey displacements in Y direction

Storey Number	Displacement in mm for flat ground	Displacement in mm for slope ground
1	0.093	0.025
2	0.136	0.819
3	0.019	1.129
4	0.037	1.377
5	0.143	1.581
6	0.267	1.581
7	0.248	1.513
8	0.36	1.457
9	0.608	1.544
10	0.75	1.625
11	1.736	0.645

When compared to models with flat ground, the value of storey displacements is larger for PEB with sloping ground. The defection of PEB is higher on sloped terrain than on flat ground because of the action of lateral loads, which are more intense.

5.2 Storey Shear

5.2.1 Storey Shear in X Direction

Table 3 Comparison of Storey Shear in X Direction

Storey Number	Shear in X direction for flat slab building (KN)	Shear in X direction for slope ground building (KN)
1	143.469	170.929
2	148.346	173.306
3	152.098	191.852
4	139.388	209.052
5	140.135	140.101
6	140.337	141.345
7	139.739	142.124
8	138.985	142.43
9	138.488	141.909
10	138.147	140.209

11	137.638	140.026

The above table denotes the comparison of shear values for the PEB for flat ground and slop ground from the above results it was concluded that the shear value is more for story 1 to story 6 in case of slop ground building model than flat ground building system and it has equal values from storey 5 to storey 11 In both cases.

5.2.2 Storey Shear in Y Direction

Table 4 Comparison of Storey Shear in Y Direction

Storey Number	Shear in Y direction for flat slab building (KN)	Shear in Y direction for slope ground building (KN)
1	0.109	0.154
2	0.031	2.59
3	0.427	3.12
4	0.513	3.33
5	0.802	0.652
6	1.1	0.615
7	1.402	0.58
8	1.779	0.732
9	2.234	1.089
10	2.708	1.946
11	3.493	2.082

Due to the influence of gravity loads, it was determined from the aforementioned findings that the shear in the Y direction was more intense in the case of a slop ground building system than in a flat ground system.

5.3 Storey Bending

5.3.1 Storey Bending in X Direction

Table 5 Comparison of Storey Bending in X Direction

Storey Number	Bending in X direction for flat slab building (KN-m)	Bending in X direction for slope ground building (KN-m)
1	0.039	0.125
2	0.223	1.391

3	0.665	1.406
4	0.742	0.857
5	1.14	0.545
6	1.543	0.491
7	1.985	0.456
8	2.508	0.688
9	3.107	1.183
10	3.778	2.403
11	4.656	2.524

The maximum bending in X direction values is obtained in flat ground building model than sloping ground system which is shown in the above graph and table the less values are obtained in case of sloping ground PEB model.

5.3.2 Storey Bending in Y Direction

Table 6 Comparison of Storey Bending in Y Direction

Storey Number	**Bending in Y direction for flat slab building (KN-m)**	**Bending in Y direction for slope ground building (KN-m)**
1	212.954	290.018
2	229.992	309.421
3	243.02	374.367
4	206.713	435.374
5	209.296	209.258
6	209.948	213.648
7	208.005	216.45
8	205.394	217.649
9	203.616	215.772
10	202.099	209.044
11	199.946	208.042

In case of bending in Y direction has obtained high values in storey 5 with sloping ground PEB. The values are less in case of flat ground PEB model. Due to the effect of lateral loads it obtained high values for sloping ground model than flat ground model.

5.4 Storey Drift

Table 7 Comparison of Storey drift

Storey Number	**Storey drift in flat ground (mm)**	**Storey drift in slope ground (mm)**
1	0.0684	0.0597
2	0.1917	0.1326
3	0.2802	0.1769
4	0.3599	0.2223
5	0.4168	0.2594
6	0.4351	0.2724
7	0.4132	0.2643
8	0.3662	0.237
9	0.3328	0.1956
10	0.3271	0.1319
11	0.3193	0.0861

The above table indicates the storey drift values for sloping and flat ground model the amount of storey drift is high in case of the flat ground model than slope ground building models due to effect of more lateral loads in flat ground PEB the drift values are more.

5.5 Steel Take off

Table 8 Comparison of Steel take off

S. No	Steel takeoff for flat ground building in kg	Steel takeoff for slope ground building in kg
1	1783987	6830874

The steel take off comparison values are shown in the above results from those results it was concluded that to construct PEB with slope ground we required large amount of steel rather that flat ground building model

6. Conclusions

1. In contrast to flat ground structures, slope ground structures showed the highest displacement values. In contrast to flat ground structures, slope ground structures exhibited the highest shear and
2. The flat ground model had a larger value of tale drift compared to the slope ground model. The PEB's lightweight and flexible frames provide superior protection against wind loads.
3. The quantity of steel is determined by the primary members and purlins. As the frame's spacing expanded, less steel was used for the primary members and more for the subsidiary members.

4. Material waste substantially contributes to lowering the structure's cost and decreasing the amount of steel needed, since the construction of traditional steel frames is done on-site, leading to substantial material wastage.

5. In comparison to flat-ground building models, the value of steel take is larger in the case of sloped ground structures. We may infer that compared to flat ground construction; the cost of the slope ground model is greater.

References

1. C. M. Meera, et al.,(2013), "PRE-ENGINEERED BUILDING DESIGN OF AN INDUSTRIAL WAREHOUSE", International Journal of Engineering Sciences & Emerging Technologies, June 2013. ISSN: 2231 – 6604 Volume 5, Issue 2, pp: 75-82.

2. Sai Kiran Gone, Kailash Rao, Pradeep Kumar Ramancharla, et al.,(2014), "Comparison of Design Procedures for Pre-Engineering Buildings (PEB): A Case Study", World Academy of Science, Engineering and Technology International Journal of Civil, Architectural, Structural and Construction Engineering Vol:8 No:4, 2014.

3. A. SRAVAN KUMAR1 , SANJEEV RAO2 , et al.,(2014)," Design and Analysis of Pre-Engineered Industrial Buildings (PEB) ", International Journal of Applied Sciences, Engineering and Management ISSN 2320 – 3439, Vol. 03, No. 06, November 2014, pp. 26 – 29.

4. Ms. Darshana P. Zoad, et al.,(2012), "Evaluation Of Pre-Engineering Structure Design By IS-800 As Against Pre-Engineering Structure Design By AISC", International Journal of Engineering Research & Technology (IJERT) Vol. 1 Issue 5, July - 2012 ISSN: 2278-0181.

5. Pratik R. Atwal , VinaysinghChandrakar , PravinsinghTomar, et al,.(2017), "Analysis and Design of Pre-Engineered Building Using IS800:2007 and International Standards", International Advanced Research Journal in Science, Engineering and Technology ISO 3297:2007 Certified Vol. Four, Issue eleven, November 2017.

6. Swati Wakchaure, N.C.Dubey, et al.,(2016), "Design and Comparative Study of Pre-Engineered Building", International Journal of Engineering Development and Research, 2016 IJEDR four, Issue 2 8, PP: 250 - 255 , OCT -DEC -2014.

7. Dr. N. Subramanian, 'Design of steel structures'

8. Dr. N. Subramanian (2008), "Pre-engineered Buildings Selection of Framing System, Roofing and Wall Materials", The Masterbuilder, pp. 48-6.

9. John A. Rolphes (2006), "Industrial Building Design - Seismic Issues", The Iron and Steel Technology, pp. 282-298.

10. Metal Building Systems Manual 2006, http://www.mbma.com.

11. Ms. Darshana P. Zoad (2012), "Evaluation of Pre-Engineering Structure Design by IS-800 as against Pre-Engineering Structure Design by AISC", International Journal of Engineering Research & Technology (IJERT), Vol. 1, Issue 5.

12. Paul Mc Entee, S.E. (2009), "Steel Moment Frames – History and Evolution", Structural Engineer Magazine.

13. IS-800:2007, "General Construction of Steel- Code of Practice", Bureau of Indian Standards, New Delhi.

14. IS: 875(Part 1)-1987, "Code of Practice for Design Codes (Other than Earth Quake) for Buildings and Structures", Bureau of Indian Standards, New Delhi.

15. IS: 875(Part 2)-1987, “Code of Practice for Design Codes (Other than Earth Quake) for Buildings and Structures”, Bureau of Indian Standards, New Delhi

16. IS: 875(Part 3)-1987, “Code of Practice for Design Codes (Other than Earth Quake) for Buildings and Structures”, Bureau of Indian Standards, New Delhi.

17. Aijaz Ahmad Zende, Prof. A. V. Kulkarni , Aslam Hutagi,” Comparative Study of Analysis and Design of Pre-Engineered- Buildings and Conventional Frames”, OSR Journal of Mechanical and Civil Engineering (IOSR-JMCE), Volume 5, Issue 1 (Jan. - Feb. 2013), PP 32-43

18. B.Meena Sai Lakshmi, M. K. M. V. Ratnam, M. K. S. S. Krishna Chaitanya, “Comparative Study of Pre Engineered and Conventional Steel Building”, International Journal Of Innovative Research In Technology (IJIRT), Volume 2, Issue 3, August 2015,pp 124-129.

19. Bhavikatti S.S, “Design of steel structures by limit state method as per IS 800-2007”, I.K.International publishing house Pvt.Ltd. New Delhi, (2010).

20. Duggal S.K, “Limit State Design of steel Structural” Tata McGraw Hill education private limited, New Delhi, (2010). 5. G. Sai Kiran, A. Kailasa Rao, R. Pradeep Kumar, “Comparison of Design Procedures for Pre Engineering Buildings (PEB): A Case Study”, International Journal of Civil, architectural, Structural and Construction Engineering, Vol.8, No: 4, 2014,
pp. 480-484.

21. IS: 875 (Part 1) – 1987 Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures (Dead Load).

22. IS: 875 (Part 2) – 1987 Code of Practice for Design Loads (Other than Earthquake) for Buildings and Structures (Imposed Load).

23. IS: 875 (Part 3) – 1987 Code of Practice for Design Loads (Other than Earthquake) for Buildings And Structures (Wind Load)

24. IS 1893: 2002 Criteria For Earthquake Resistant Design of Structures.

25. IS: 800 – 2007 Indian Standard General Construction In Steel – Code of Practice.

26. IS: 801 – 1975 Code of Practice For Use of Cold Formed Light Gauge Steel Structural Members in General Building Construction.

27. Jinsha M S, Linda Ann Mathew,” Analysis of Pre – Engineered Buildings”, International Journal of Science and Research (IJSR), Volume 5 Issue 7, July 2016,pp 1049-1051

28. Kankuntla Ashok Y. Kankuntla Ashok Y., NirantarShalaka R., Rajgiri Dinesh,” Optimum Design of an Industrial Ware House”, International Journal of Science and Research (IJSR), Volume 6 Issue 6, June 2017,pp 2562-2566

29. M Meera C.M, “Pre-Engineered Building Design of an Industrial Warehouse”, International journal of Engineering Sciences and Emerging Technologies, Volume 5, Issue 2, June – 2013, pp: 75-82.

30. Prof. P. S. Lande, Vivek. V. Kucheriya,” Comparative Study Of Pre- Engineered Building With Conventional Steel Building”, International Journal Of Pure And Applied Research In Engineering And Technology(IJPARET), Volume 3 Issue 8,April 2015,pp28-39

31. Shrunkhal V Bhagatkar, Farman Iqbal Shaikh, Bhanu Prakash Gupta and Deepak Kharta,” A Study On Pre-Engineered Building – A Construction Technique”, International Journal of Engineering Research and Applications(IJERA), Vol. 5, Issue 3, (Part -2) March 2015, pp.05-09

32. Sudhir Singh Bhadoria , Yash Pathak," Comparative Study Of Pre- Engineered Building And Conventional Steel Structures", International Research Journal Of Engineering And Technology (Irjet) Volume: 04 Issue: 09 ,Sep -2017,Pp 1172- 1183

33. Syed Firoz et al, "Design concept of Pre Engineered Building",International Journal of Engineering Research and Applications(IJERA), Vol. 2, Issue 2, April 2012, pp.267-272.

34. T D Mythili, " Analysis and Comparative Study of Conventional Steel Structure with PEB Structure", International Journal of Science and Research (IJSR), Volume 6 Issue 4, April 2017.pp 1876- 1883