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Wind and Seismic Analysis of Pre-Engineered Building: A Review

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Abstract: ***With the development of science and technology in the field of structural engineering, it is possible to adopt pre-engineered buildings in both industrial and residential construction sectors. For important buildings it is more suitable to use pre engineered building as these are more safe and take less time in construction in comparison of RCC structures. The main objective of this paper is pre-engineered steel structure will be design and analyzed for wind loads, dead loads, live loads and different load combinations on structure. The pre-engineered construction concept involves pre-engineering and quality construction systems which will help to minimize the cost and time.***
Keyword: Pre engineered buildings, StaadPro software, RCC structures.

I. INTRODUCTION

Steel Industry is growing rapidly all around the world. To meet the increasing demand of construction, alternative ways of construction are developing. Advances in technology have greatly improved over the years, contributing tremendously to improving living standards through various new products and services. A pre-engineered building (PEB) is one such revolution. They use a defined stock of raw materials that have been time tested to meet a wide range of structural and architectural design specifications. The majority of steel structures being built are only low-rise buildings, which are generally of one storey only. Industrial buildings, a subset of low-rise buildings are normally used for steel plants, automobile industries, light, utility and process industries, thermal power stations, warehouses, assembly plants, storage, garages, small scale industries, showrooms, offices etc. The application of pre-engineered building concepts to low rise buildings is very economical due to its light weight and economical construction. PEB systems are extensively used in industrial and much other non-residential construction world-wide. These buildings were pre-designed or 'pre-engineered' into standard sizes, spans, bays and heights, and use standard details for fixing cladding, roofing, gutters, flashing, windows, doors etc. taking advantage of industrial practices of mass production of components economically.

II. PRE ENGINEERED BUILDING

In structural engineering, a pre-engineered building (PEB) is designed by a manufacturer to fabricated using a pre-determined inventory of raw materials and manufacturing methods that can efficiently satisfy a wide range of structural and aesthetic design requirements. Pre-engineering building primary frame structure is an assembly of I-shaped structural members. The I-shaped beams are usually formed in the factory by welding steel plates together to form the I-sections. The I-section beams are then assembled on site with bolted connections to form the entire frame of the pre-engineered building. Tapered sections are also used to achieve varying depth. The concept of PEB is the frame geometry which matches the shape of the internal stress (bending moment) diagram thus optimizing material usage and reducing the total weight of the structure. The use of steel structures is not only economical but also eco-friendly at the time when there is a threat of global warming. Here, “economical” word is stated considering time and cost. Time being the most important aspect, steel structures (Pre- fabricated) is built in very short period and one such example is Pre Engineered Buildings (PEB). Pre-engineered building are steel building wherein the framing members and other components are fully fabricated in the factory after designing and brought to the site for assembly, mainly by nut-bolts, thereby resulting into a steel structure of high quality and precision. Steel is an expensive material as compared to the rest but when it comes to the cost-savings during the life span of the structure, steel proves to be a very affordable material . Steel can also be made rust proof by the application of special coated paints. Apart from that, steel is an insect and termite resistant material and the maintenance cost is lower during its life span as compared to other materials. PEB are generally low rise buildings however the maximum eave height can go up to 30 metres, Clear span upto 90 meter wide are possible.

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III. WIND ANALYSIS

The force exerted by the horizontal component of wind is to be considered in the design of buildings, towers etc. The wind force depends upon the velocity of wind, shape, size & location of buildings. Wind analysis calculation given below according to IS code 875 part 3:1987 ;

Design wind speed $V_z = V_b\ k_1\ k_2\ k_3$

Where,

V_z =Design wind speed at any height z in m/s,

V_b =Basic wind speed calculated from wind speed map of India, k_1=Probability factor (risk coefficient clause 5.3.1),

k_2=Terrain, height and structure size factor (clause 5.3.2) and k_3=Topography factor(clause 5.3.3)

Design wind pressure P_z=0.6 Vz^2Where,

P_z=Design wind pressure in N/m^2 at height z and V_z =Design wind speed at any height z in m/s

Wind load on individual structural member such as roofs, walls and cladding given as:

$F=(C_{pe} – C_{pi})\ A\ P_z$Where,

C_{pe}=External pressure coefficient, C_{pi}=Internal pressure coefficient,

A=Surface area of structural member or cladding unit and P_z=Design wind pressure in N/m^2 at height z

IV. SEISMIC ANALYSIS

Earthquake is a natural procedure of shaking ground due to movement of tectonic plate. The force of earthquake is random so the design engineer need to care full predict of these force and analyze the structure under these random force. Earthquake loads are to be carefully modeled so as to assess the real behavior of structure with a clear understanding that damage is expected but it should be regulated. Earthquake plays an influential role in analysis and design of structures. Seismic analysis is a branch of structural analysis that involves calculation of a building's (or non building's) earthquake response. Analysis is the process to determine the behavior of structure under specified load combinations.

A. Equivalent Static Lateral Force Method

This is a very simple method of analysis. The main assumptions in these method are that the lateral force is equivalent to actual loading. In these method, the Base Shear which is total horizontal force on the structure is calculated on the basis of the structure mass and its fundamental time period of vibration. The total design lateral force or design seismic base shear (V_B) along any principal direction shall be determined with the help of following expression:

$$V_B = A_h\ W$$

Where,

A_h = Design horizontal acceleration spectrum using fundamental natural period T_a, W = seismic weight of all the Building

The Design horizontal Seismic Coefficient A_h for a Structure will be evaluated by expression:

$$A_h = \frac{Z\ I\ Sa}{2\ R\ g}$$

Z = Zone Factor,

I = Importance Factor

Sa/g = Average response Spectrum Coefficient using soil type and fundamental time period R = Response reduction factor

Above the Value of W, Z, I, Sa/g, and R are dependent on the IS 1893 (Part 1): 2016

V. LITERATURE REVIEW

A number of works have been presented on analysis of Pre Engineered Building. In this section some literature in brief are presentedby different scholars and researchers.

N. Subramanian (2008) had studied over the PEB. He has made a brief description on the selection of framing system. Also he has made a description on the type of materials used for roof and wall. He has stated the types of structure and the types of framing system that can be used. He states that braced frames may be more economical than unbraced frame in situations where the labour cost is low. He has described about one of the roofing system through-fastened lapped-seam roofing. He states that rather this roofing system is more economical it is susceptible to leakage and hence standing-seam metal roofs consisting of metal panel running vertically on the roof deck are used in present day constructions.

Syed Firoz (2012) observed that the pre-engineered steel construction system presents great advantages for single-story buildings, a practical and efficient alternative to conventional constructions, representing the system a central model within several disciplines. Pre-engineered construction creates and maintains support in real-time is currently being implemented by Staad Pro Choosing steel todesign a pre-engineered steel frame building is choosing a material that offers low cost, strength, durability, design flexibility , adaptability and recyclability. Steel is the basic material used in the materials used for pre-engineered steel construction. It also means choosing reliable industrial products that come in a huge variety of shapes and colors; means quick on-site installation and lower 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. A tall steel building is no longer in the total number of tall steel structures that are built all over the world. The large steel structures that are built are just one-story buildings for industrial purposes.

Muhammad Umair Saleem (2013) had carried out design of PEB all members i.e. hot rolled sections and cold-formed sections. Minimum weight design of CSB was carried out to achieve the design of the PEB. They state that Minimum Weight is directly proportional to Minimum Cost. These two structures were compared not only economically but also for structur al safety. They found that using cold-formed steel for secondary framing instead of hot rolled has decreased the weight by 60%, also by use of built-up sections in place of hot rolled sections for primary framing decreased the cost by 30%. The deflections and sway shown by hot rolled sections when used for primary and secondary framing is less when compared to others. They also stated that, rather built-up sections shows higher sway but is within the limits as specified in MBMA 2005

G. Sai Kiran (2014) had made a study over various codes. They have compared various structural parameters between PEB and CSB by using various codes viz IS800:2007, IS800:1984, MBMA-96 and AISC-89. They have found that there is increase in section weight when designed by IS800:1984 as compared to IS800:2007. The deflections stated in Indian standard are higher than MBMA. When the design was compared between IS800:2007 and AISC/MBMA the weight was greater. They also state that the loading provisions made in Indian code are higher than those made in MBMA. They have also stated that IS800:2007 does not consider slender sections which are often used in PEB. They have stated that the crane impact load in vertical direction is same as compared between Indian and American whereas in horizontal direction it is more in MBMA.

Fahid Aslam (2014) had carried out the analysis of a frame against the seismic forces. They have carried out comparison between ordinary moment resisting frame and special moment resisting frame. They have found that when there is increase in seismic load the steel required for ordinary moment resisting frame is much higher than special moment resting frame. They also stated that drift is more in ordinary moment frame as compared to special moment resisting frame. They found that steel can be saved by 7% for main frame and 60% to 30% for bracings by use of special moment resting frame.

Hemant Sharma (2015) The Researcher have studied comparison and analysis of PEB & CSB staad Pro. In this case study comparison for industrial building is done for bending moments at different sections & the results are compared for economy and time saving in construction. After analysis and design the report is concluded with 37% material saving in case of PEB than that of CSB.

D.Rakesh (2016) had carried out a comparison between CSB and PEB. They have obtained the results by analyzing and designing of an Industrial shed. They have found that the total steel takeoff of the PEB is about 60% as that of CSB. The author have observed that the weight of the frame is dependent on the bay spacing; with increase up to certain limit there is decrease in weight while after that limit it increases. They also found that displacement is more in CSB as compared to PEB whereas axial force is more in PEB as compared to CSB.2.5.

Sudhir Singh Bhadoria (2017) The paper titled “COMPARATIVE STUDY OF PRE-ENGINEERED BUILDING AND CONVENTIONAL STEEL STRUCTURES”, Published by: International Research Journal of Engineering and Technology (IRJET)- September 2017. They observed that a comparative study made on various models of Pre-Engineered buildings and Conventional steel structures shows that PEB is economical. The provision of a tapered section in PEB makes it economical and tapering of the section is done as per the bending moment diagram. From all the analyses made it can be concluded that steel consumption in PEB is on average 30% lesser than a conventional steel structure. PEB frames are light and more flexible than conventional steel frames and provide higher resistance to seismic forces.

Katkar & Phadtare (2018) In this work recent years, the introduction of Pre-Engineered Building (PEB) concept in the design of structures has helped in optimizing design. 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 to conventional structures. This methodology is versatile not only due to its quality predesigning and prefabrication, but also due its light weight and economical construction.

The present work presents the comparative study and design of conventional steel frames with concrete columns and steel columns and Pre Engineered Buildings (PEB). In this work, an industrial building of length 44m and width 20m with roofing system as conventional steel truss and pre-engineered steel truss is analyzed and designed by using STAAD Pro V8i.

Mitaali Jayant Gilbile (2020) The paper titled "A Review on Comparative Study on the Structural Analysis and Design of Pre-Engineered Building [PEB] with Conventional Steel Building [CSB]", Published by: International Journal of Engineering Research & Technology (IJERT)-September 2020. In this paper, an industrial structure (PEB & CSB Frames) is analyzed and designed according to Indian standards. They observed that PEB structures are proven to be more economical. The researches show that PEB structures are easy to design. These structures are more reliable than CSB.

D. Mahaarachi, M.Mahendran (2019) The paper described an advance finite element model that accurately predicts the true behaviour of Crest-fixed steel claddings under Wind uplift. The results from the FEA and experiments agreed well for the trapezoidalsteel claddings with wide pans used in this investigation. This demonstrates that non-linear finite element analysis can be used with confidence to carry out extensive parametric studies into the structural behaviour of profiled steel claddings, which undergo local pull-through failures associated with splitting or local dimpling failures. Once the use of finite element analysis to determine the most important pull-through failure load was validated using large scale two-span experiments, it was used to investigate the behaviour of trapezoidal steel claddings with varying geometry and material properties. Based on these FEA, improved design formulae have been developed for the local failures of trapezoidal steel claddings with wide pans. This paper has also discussed the disadvantages of using the Conventional one rib FEA model for multispan steel Cladding assemblies.

Vrushali Bahadure (2020) Comparison Between Design And Analysis Of Various Configuration Of Industrial Sheds" Shows examination between different setups of mechanical shed. There are different kinds of mechanical sheds. However, here we look at the different setups of modern sheds, for example, hot moved steel shed, for example, shed utilizing Howe bracket, A-type, entrance support and so on. This paper will gives us the reasonable arrangement of modern shed by making and looking at structure and investigation of different designs of mechanical sheds. Plan of mechanical shed, by utilizing STAAD-Pro 2007 which gives results rapidly and precisely.

Shaikh Kalesha (2020) In this work Pre-engineered building concept involves pre-designed and prefabricated steel building systems. The current construction approach calls for the best architectural look, high quality & quick construction, cost-effective & creative touch. One has to think of alternative building systems such as pre-engineered steel buildings. The implementation of the Pre Engineered Building (PEB) is a modern-day concept in which utilizing the steel structure and optimizing the design by ensuring economical integrity. The main objective of this paper is to understand the concepts of PEB and to minimize the usage of cost and time. While compared to other technologies in construction Pre Engineered Building is more sustain-able and stands top position when compared with other technologies. If we go for standard steel structure the time frame will be longer and the price will be higher in comparison with PEB. The materials which are used in this concept are reusable.

VI. CONCLUSION

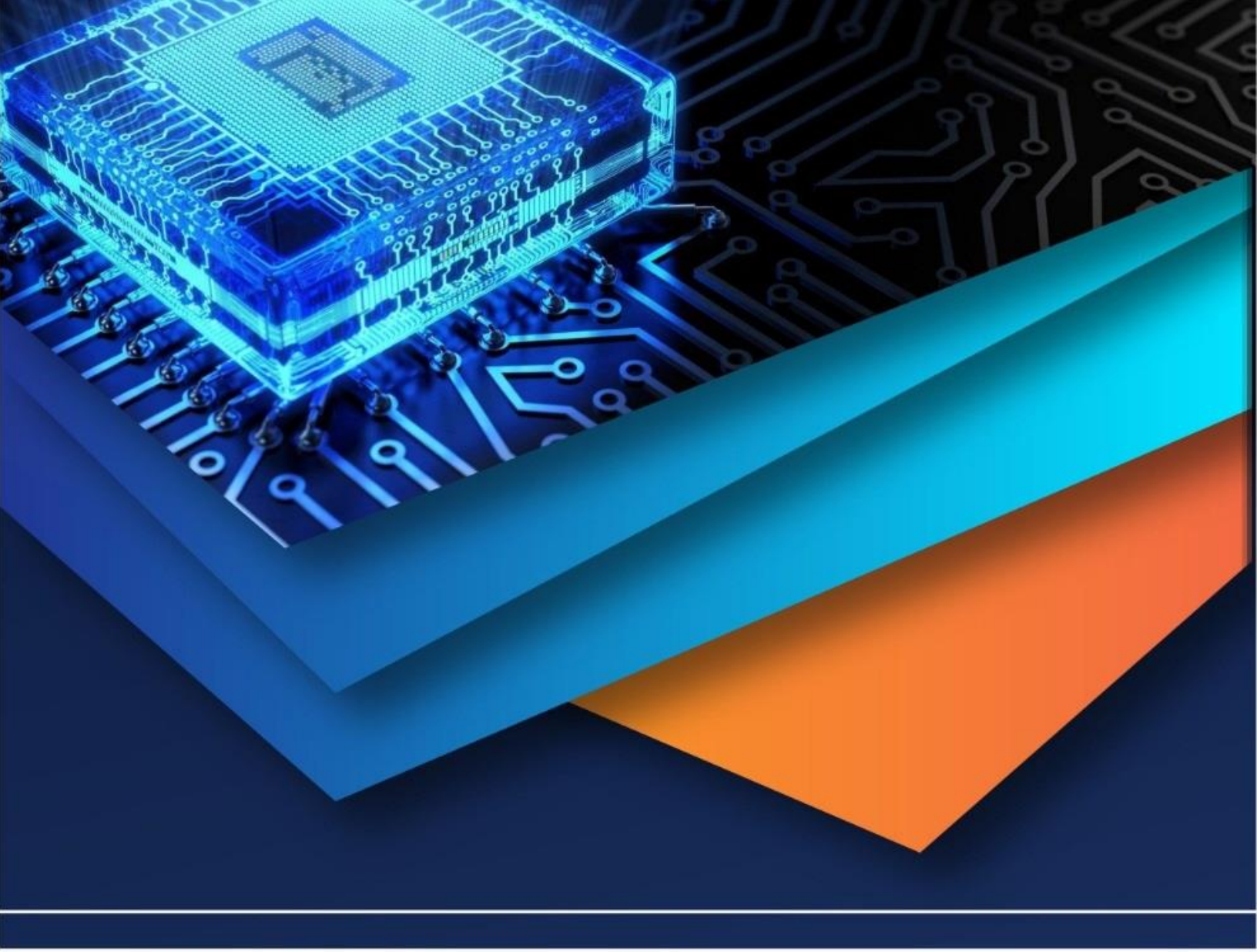
There are various work have been performed on analysis of pre engineered building considering various load combinations. The typeof the structure single slope or double slope pitched roof, type of usage of structure The shape of structure such as regular and irregular, type of structure on the basis of material, the position of bridge which links the tower, height of the building are most important parameters which affects the stability of building greatly that is why these factors need to be analyzed more with different kind of combinations.

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