
Analytical Study of Pre Engineered Building Subjected to Lateral Loads

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Abstract : Pre-Engineered Building (PEB) constructions are nowadays popular owing to their advantages over conventional Concrete and Steel constructions. Concrete structures are bulky and impart more seismic weight and less deflection whereas Steel structures instruct more deflections and ductility to the structure, which is beneficial in resisting earthquake forces. PEB Construction combines the better properties of both steel and concrete along with lesser cost, speedy construction, better quality control, sustainability etc. The pre-engineered steel building system construction has great advantages to the single storey buildings, practical and efficient alternative to conventional buildings. The design of Pre-Engineered Building structures using tapered sections as the primary frames has saved quantity of steel substantially when comparing to the steel used on Conventional Steel Building structures. The aim of the present research work is to study the Analytical behavior of PEB subjected to lateral loads. In this study a Pre Engineered warehouse building of span 76 meters and 36m width is considered. Seismic analysis is done on the PEB structure with two types of lateral bracing system i.e. diagonal bracing and chevron bracing and with three different types of roof systems i.e. Tapered roof, Mono slope roof and curved roof and three different slopes i.e. 1:8, 1:10 and 1:12.

The analysis is done with IS 800:2007 (Indian standard code). Parameters such as, bending moments, displacements, base shear, steel takeoff and utilization ratios are arrived. This study helps in achieving best roof and bracing combination for better performance of the building during lateral loads. It also includes achieving economy of the structure with IS 800:2007 codal provisions. The outcome of our extensive analysis reveal that, among the diverse combinations considered, the PEB with a 1:10 roof slope, utilizing diagonal bracing in conjunction with pitched roofs following the Indian code IS 800:2007, besides that exhibited superior structural integrity, the second most desirable bracing and roofing combination was 1:10 roof slope curved roof and diagonal bracings which emerged as another highly favourable and reliable configurations. adhering to IS 800:2007.

Keywords: PEB, seismic analysis, sloping roof, IS code, rafter, bracings

I. Introduction

1.1 General

Steel has one of the most extensively utilised building materials in the contemporary period because of its unique mix of features such as stronger strength, better flexibility, optimum cost, dependability, durability, and recyclability, eco-friendliness, and so on, which make it an ideal building material. Steel industries have grown dramatically in recent years across the globe, owing to growing use of steel structures, which provide benefits such as quick construction and the ability to support longer spans and high weights. Also, it is more earthquake-resistant than concrete buildings [1]. Steel building is expanding quickly over the globe [2]. Aside from making steel structures more affordable in term of cost, timing, and quality, specialists are also aiming to make steel buildings more Environmentally friendly & green throughout their entire cycle [3], [4]. Overall, steel is a costlier material than the others, but when it comes to cost savings throughout the life of the project, steel is a highly inexpensive material. Steel may also be rendered rust-proof by using special coated coatings [2]. Aside from that, steel has insect & termite resistant, & its maintenance costs are lower throughout its life cycle when compare to other materials[5]. Conventional steel buildings (CSB) are more stable, are often constructed with hot-rolled structural components, and are typically equipped with trusses. CSBs are often created from the ground up, necessitating significant design input and intricacy details by consultants. The building of CSB is done on-site using typical fabrication procedures; nevertheless, the process takes a long period. In addition, hot rolled steel sections that are easily accessible on the market are used in the building of CSB. However, because of their heavier variety or greater sectional features, such market-available steel sections that are selected are often inappropriate for building. Furthermore, even if the amount of stresses varies from one place to another throughout the length of these sections, the steel sections utilized in CSB have homogeneous cross-sections. This increases the total weight of the building, necessitating the use of heavier foundations[6]. All of CSB's constraints may be circumvented by using the concept of pre-engineered buildings. The fundamental notion of PEB is that the frame geometry was matched with the shape of it's internal stress diagrams or bending moment diagram, which helps to optimise the quantity of steel material and so minimises the overall weight of the structure [7]. According to the bending moment diagram, an cross-sectional dimensions of PEB members may change throughout their length. A PEB is a modern process in which construction components are transported to the site & assembled to form the structure. A PEB is a cohesive steel structure composed of stiff frames, cold-formed steel secondary structural components, bracing elements, and metal sheets on the roof and exterior walls. PEB has gained popularity in recent years due to it is more energy & cost-efficient, lighter in weight, & needs less erection time than CSB [8]. PEBs are used in a variety of applications, from industrial buildings & warehouses to restaurants & medical offices, & have shown to be the finest solution for a broad range of projects.

Pre-engineered steel structures are more cost effective and ecologically friendly than traditional steel frames. Pre-engineered steel constructions reduce elements that contribute to global warming and pollution. Pre-engineered steel structures often save a significant amount of landfill area. Steel frames that have been pre-engineered have a longer life expectancy. When the design life of a pre-engineered steel structure is ended, the majority of them wind up at a recycling center where they are melted and repurposed for other reasons rather than being dumped on local accessible land/ground, decreasing construction and demolition waste [5].

Pre-engineered steel building construction saves energy and, as a consequence, lowers heating and cooling expenditures. Because everything is pre-fabricated in the factory to millimeter precision, there is substantially less likelihood of mistake during construction of pre-engineered structures [9,10]. Once built, there is very little probability that the steel frames will creep and loosen over time, and windows and doors framed inside jambs and headers within the structure will stay snugly sealed, reducing the possibility of air leakage.

Pre-engineered design is a new phrase for avoiding superfluous steel by tapering the sections to the envelope of the bending moment[9]. The lightweight structural components that are produced by the section-moment simulation approach are the primary contributions to the structure's weight and cost reduction. In contrast to conventional steel, which involves the welding of structural members on site, PEBs are designed and fabricated in the factory and subsequently transported to a construction site in a completely knocked-down state. At the construction site, all structural components are assembled as well as erected using nut-bolts in accordance with the construction plan, resulting in a reduction in construction time and waste [10].

1.2 Components of PEB

The manufacturing facility manufactures pre-engineered steel buildings. The structural pieces are produced to the client's requirements. Steel utilised effectively makes pre-engineered structures about 30 percent lighter than ordinary steel constructions. Tapered built-up sections is used in main framing, having a shallower depth in areas of reduced stress and a deeper depth in areas of high stress. Secondary parts include lightweight cold-formed "Z" or "C" shaped sections. There may be no modifications, such as welding or cutting, that may be undertaken on-site during erection. No manufacturing procedure takes occur at the customer's premises[11].

For the most part, before 1990, the usage of pre-engineered structures was restricted to North America and the Middle East. Since then, the usage of pre-engineered buildings has extended across Asia and Africa, where the idea of PEB architecture is now generally recognized and appreciated. The pre-engineered steel construction approach is widely recognized as the most adaptable and cost-effective building method. The economics and speed of supply and installation of these structures are unrivalled in the construction industry[12]. In terms of time and cost from excavation to occupancy, no other building technology rivals the pre-engineered construction system.

A pre-engineered building is a steel structural concept that unites primary parts such as the main frame, columns and rafters, as well as subsidiary components such as purlins, bracings, tie rods, angle bracings, high tensile bolts and roofing or cladding cover sheets. To suit a broad variety of structural and aesthetic design criteria, pre-engineered buildings (PEB) are planned and constructed utilizing the best available inventory of raw materials from all sources and production processes. Depending on the demands of the customer, it may also include structural components such as mezzanines, canopies, and crane systems. Almost everywhere in the globe, the steel sector is expanding quickly. Steel constructions are not only cost effective, but also environmentally benign in an era of global warming. Here, the term "economical" is used in the context of time and cost, with time being the most significant factor. Steel constructions (prefabricated) are created in a relatively short amount of time, and one such example is pre-engineered buildings. Thus, with pre-engineered structures, the whole design is completed in the factory, and members are prefabricated and delivered to the site where they are constructed in less than 6 to 8 weeks. The structural performance of these structures is well studied, and suitable code measures are already in place to assure good performance in strong winds. Steel constructions offer substantially higher strength-to-weight ratios than RCC structures and can be removed much more simply. Because pre-engineered structures contain bolted connections, they may be reused after deconstruction. As a result, pre-engineered structures may be changed and/or extended as needed in the future [13].

The PEB consists of three parts: main members, secondary members, & miscellaneous members. The main components are built of hot-rolled steel sections & consist of columns and rafters that is often tapered in shape. Purlins & girts are secondary members that is often cold-formed. The miscellaneous members include sheeting, gutters, trims, and other accessories. Figure 1 shows the PEB structure & its many components[14].

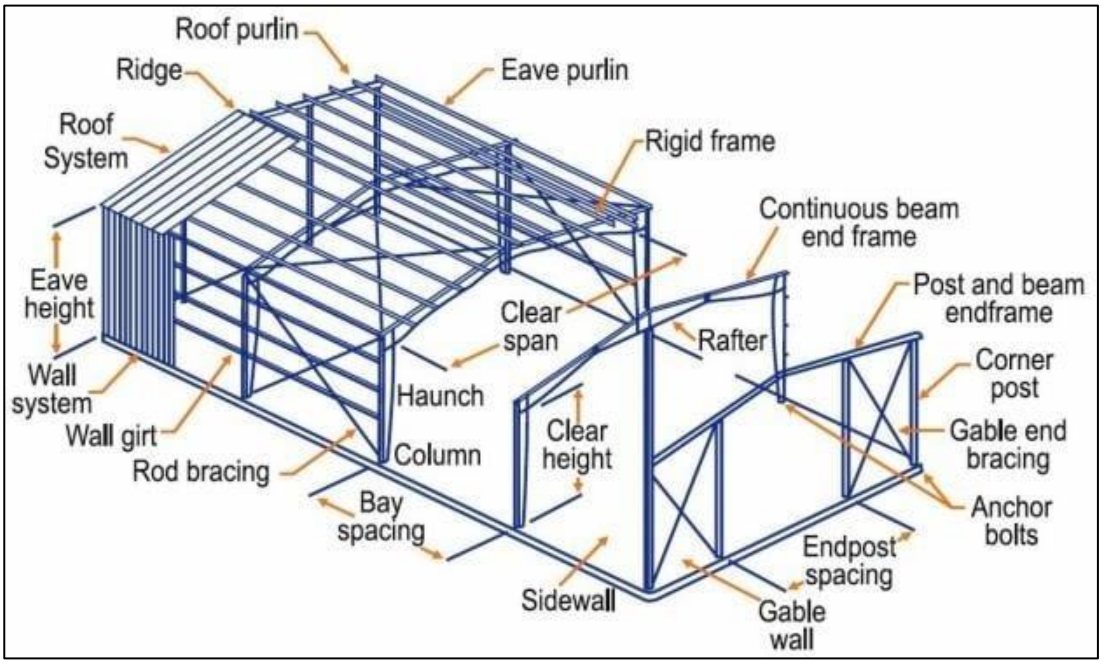

Fig 1: Components of PEB

Source: [15]

1.2 Benefits of PEB

The benefits of Pre-Engineered Buildings (PEB) are multifaceted, making them a preferred choice in construction projects. One of the key advantages lies in their economical and speedy construction, contributing to a significant reduction in project time by 30% to 40%. PEBs are synonymous with good quality, both in manufacturing and erection processes, ensuring durability and structural integrity. Their suitability for long-span construction further enhances their versatility. These buildings exhibit resilience against various weather conditions and fire, adding a layer of safety to the structures.

In terms of design, PEBs are known for their economical design, leading to a reduction in overall weight without compromising strength. The modular nature of PEBs facilitates easy expansion and modification, providing adaptability for future changes to the structure. This not only offers flexibility but also contributes to cost savings in the long run, as maintenance costs are notably reduced. Additionally, the ease with which PEBs can be disassembled and shifted adds to their practicality, making them suitable for diverse construction scenarios. Lastly, the eco-friendly nature of PEBs aligns with sustainable construction practices, making them a conscientious choice in the modern construction landscape[16].

II. Literature review

Harish et al. conducted a parametric analysis on three distinct PEB frames of 20m span (Regular, mono slope, and curved) using ANSYS software to determine stress ratios and weight[17]. The study took into account combinations of dead load, live load, and wind load in accordance with IS 800:2007 rules. The weight and stress ratio findings for the PEBs under investigation are compared. The research found that the curved PEB frame saves 8.84% of the steel amount, but the mono slope frame uses 1.3 times more steel than the standard frame. Kaveh and Ghafari et. al., optimised the geometry and dimension of steel-pitched roof frames with tapered I section beams and columns made of steel plates[18]. The design was optimised utilizing nine metaheuristic algorithms for varying apex heights and tapering lengths, as well as various load combinations in accordance with ASCE 7 requirements. The study's major goal was to examine the optimal design of various shaped pitched roofs in order to discover the most suited ones. The findings showed that by adjusting the apex height and tapering length of the steel-pitched roof frame, the optimal weight of the structure could be changed by 10%. Kumar and Varghese et. al., used Staad Pro software to compare the behavior of PEB and CSB with diagonal bracings (60mm x 60mm x 12mm). PEB columns and rafters were fitted with an unsymmetrical tapered I section, while CSB elements were fitted with channel sections [11]. In addition, the investigation was carried out by adjusting the diameters of the flange width and web thickness in order to determine deflection and steel amount. According to the study's findings, the deflection of PEB with a tapered I section was decreased by 35.93%, while it was reduced by 50.54% for CSB with channel sections. Furthermore, the amount of steel in PEB was decreased by 25.48% when compared to the amount of steel in CSB. The researchers determined that the PEB outperforms the CSB in terms of deflection and steel usage. Sai et al. investigated the structural performance of a PEB with multiple bay systems in various wind zones (Vijayawada and Hyderabad) by analyzing and designing it using Staad Pro software [19]. The magnitudes of shear force (SF) and bending moment (BM) were used to evaluate the performance of PEB. The weight of the construction in Vijayawada grew by 11.04% more than the weight of the building in Hyderabad, according to the results. According to the research, seismic stress and wind load are crucial criteria that influence the structural weight and section sizes of PEB. Sah et al. conducted a state-of-the-art review research on the analysis and design of PEB structures and presented their many features, including characteristics, configuration, and performance in comparison to conventional steel buildings. The design requirements of several international codes of practice are also evaluated [20]. The authors found from the comprehensive review research that PEB works better and adds to the reduction of steel weight as well as vertical and lateral displacements when compared to CSB. Furthermore, the research revealed that using tapered I-sections and cold-formed sections for PEB members reduces structural weight by roughly 50% and reduces cost by 35% when compared to CSB. Varma and Chandak et.al., used Staad Pro software to analyses and design an industrial warehouse PEB building that was optimised for the least amount of weight [7]. The study took into account loads such as dead load, live load, collateral load, wind load, and their combinations. The study's findings suggested that it is feasible to construct and optimize the PEB structure to achieve the lightest achievable weight of 253 kN. When compared to CSB structures, the scientists determined that PEB structures perform better and are more cost effective. Bharmal and Kumbhar et.al., conducted a comparative study and design of CSB and PEB using various kinds of bracings (viz. X, diagonal, V, and K) while taking seismic zone II and medium type of soil into account to determine displacement and natural time period[6]. When compared to the similar values of CSB, the displacement and natural time period of PEB supplied with diagonal bracing were reduced by 20.53% and 13.41%, respectively.

III. Problem Statement and Modeling

In the realm of structural engineering and design, the effectiveness and efficiency of Pre-Engineered Buildings (PEB) are pivotal considerations for architects and engineers alike. This study addresses the critical need to optimize PEB structures by exploring the impact of varying roof types and bracing configurations on structural performance. The problem at hand revolves around the challenge of identifying the most suitable combination of roofing and bracing elements, particularly under different design codes such as IS 800:2007. To tackle this issue, our modeling approach involves a systematic examination of PEB structures with roof slopes of 1:8, 1:10 and 1:12, employing both diagonal and chevron bracing.

Table 1: Geometrical details of PEB structures

Parameters	Particulars
Size of the structure in the plan	36 m x 76.8 m
Roofing sheets, side wall sheets	GI
Steel sections considered for PEB :	
a) Columns and principal rafters	Tapered I section
b) Purlins	Angle section (ISA)
Type of support	Fixed
Type of soil	Medium
Seismic zone	Zone IV
Roof types:	Pitched roof
	Curved roof
	Mono slope roof
Bracing types:	Diagonal bracing
	Chevron bracing
Roof Slope:	1:8
	1:10
	1:12
Dead load	1.6 KN/m
	0.8 KN/m
Live load	4.8 KN/m
	2.4 KN/m

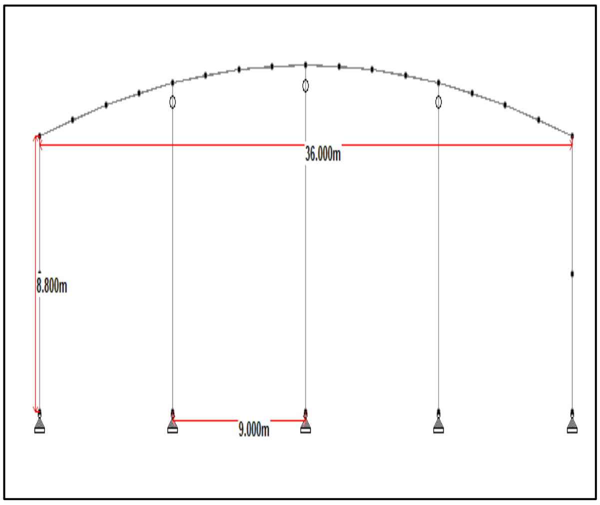

Fig 2: Curved roof front view

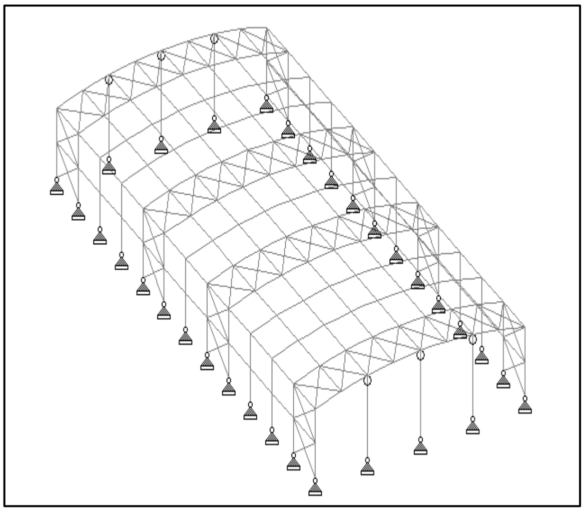

Fig 3: Curved roof 3D view

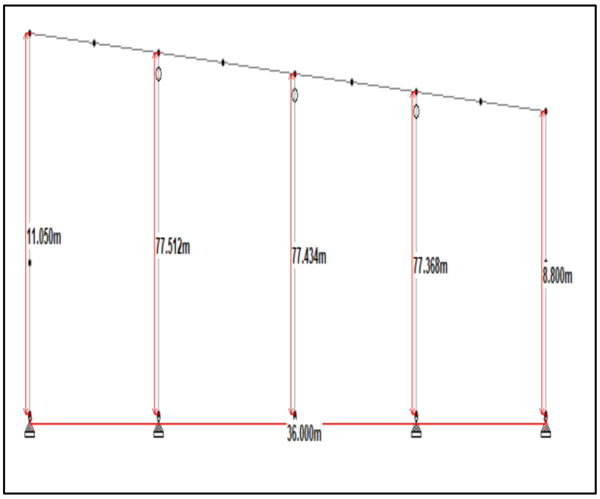

Fig 4: Mono slope roof front view

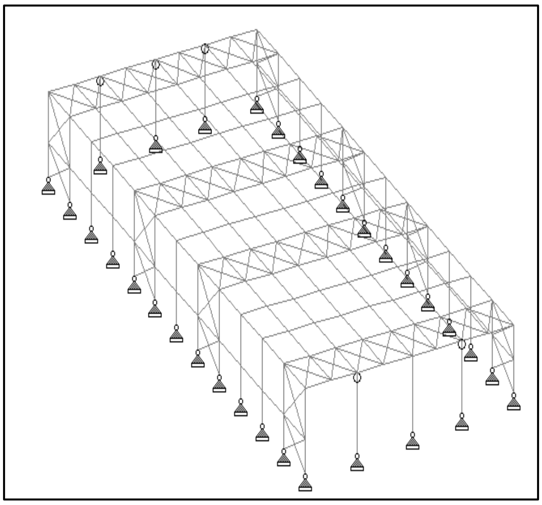

Fig 5: Mono slope roof 3D view

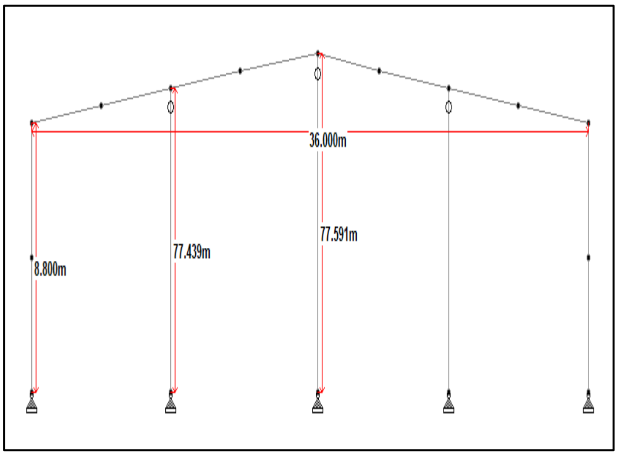

Fig 6: Pitched roof front view

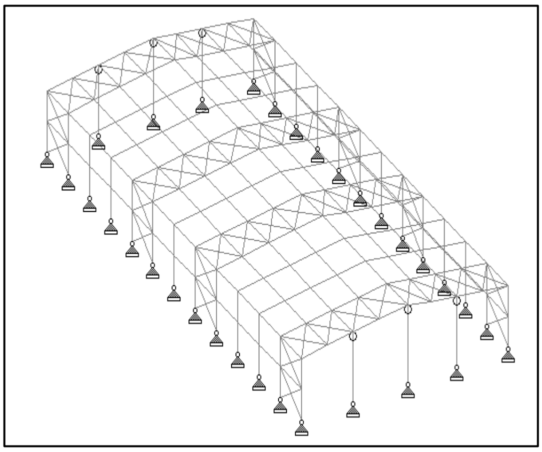

Fig 7: Pitched roof 3D view

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IV. Results and Discussion

4.1General

In this chapter, discussions on the analysis and results based on the analytical models developed using STAAD pro are presented. In this study we investigated the structural performance of pitched roofs, curved roofs and mono slope roofs under different bracing configurations, specifically with diagonal and chevron bracing at 1:8 ,1:10 and 1:12 roof slopes with Indian code. Our examinations encompassed displacement and bending moment data obtained at various rafter location points for each roof type and bracing location. The comprehensive analysis of displacement percentages and bending moments provides valuable insights into comparative behavior of these roof configurations, shedding light on their respective strengths and weaknesses. The results underscore the significant influence of bracing type and ratio on the structural response, with noteworthy variations observed across the three types of roofs. The explorations lay the ground work for a detailed discussion that delves into the implications of these findings for the design and optimization of roof structures in diverse architectural applications. The analysis of base shear gives the significant insights of the seismic analysis of the structure into comparative behavior of different roofs and bracing combinations the response of the structure is noted. Similarly, as we are analyzing with codal provisions i.e. IS 800:2007, this give us the stability criteria and steel takeoff for the structure. This results will give us a clear result of the stability and steel takeoff for the different roofing and bracing combinations. The Utilization ratios is the critical value which give the suitability of the member usually a higher value than 1 indicated the how much the member is overstressed and the value less than 1 tells us the reverse capacity available, it denotes the pass and fail status of the slenderness limits.

4.2. Displacements of Rafter IS 800: 2007

4.2.1. Displacements of rafter with Pitched roof and diagonal bracings with 1:8, 1:10, 1:12 roof slopes IS 800:2007

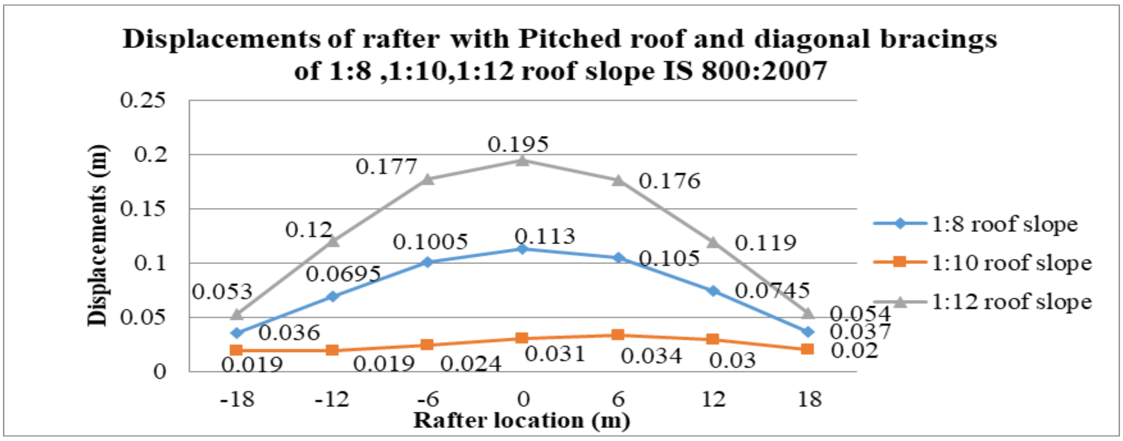

Figure 4.1: Displacements of rafter with Pitched roof and diagonal bracings of 1:8, 1:10, 1:12 roof slopes IS 800:2007

The graph shown in fig4.1 provides displacement values at different rafter location points for pitched roof with diagonal bracing and 1:8, 1:10, 1:12 roof slopes have been analyzed. The displacement values are expressed as percentages. Analyzing the data, it is evident that the pitched roof with 1:12 roof slope is giving us more displacement compared to 1:8 and 1:10 roof slopes. At each point, the pitched roof with 1:12 slope shows the greatest percentage of displacement, indicating a greater degree of structural movement compared to the other three roof slopes. Specifically, the pitched roof has the highest displacement at rafter location i.e. at 0-point center of the rafter. This information suggests that, the 26.4% increase and 38% increase in the displacement compared to 1:10 roof slope. Under the specified conditions and bracing, the pitched roof with 1:8 and 1:12 roof slopes are experiencing more significant deformations than the 1:8 roof slopes.

4.2.2. Displacements of rafter with Pitched roof and Chevron bracings with 1:8, 1:10, 1:12 roof slopes using IS 800:2007

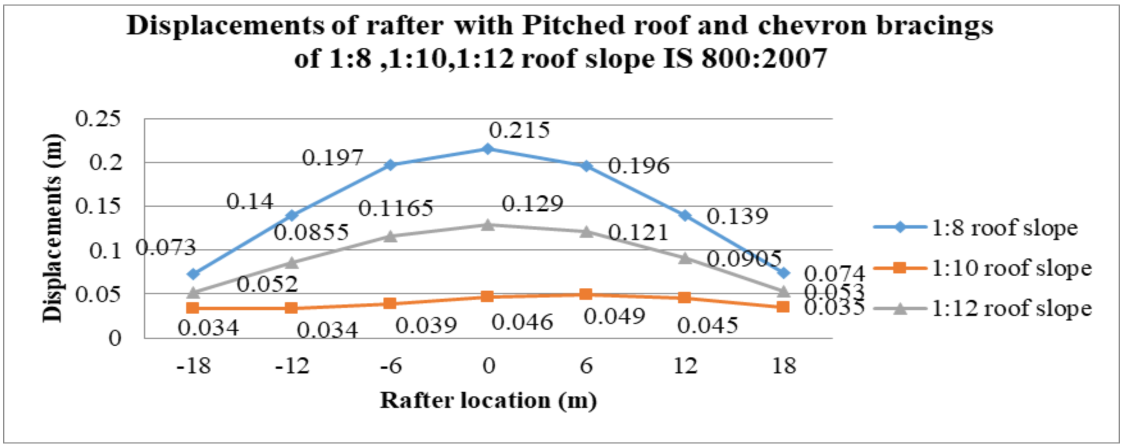

Figure 4.2: Displacements of rafter with Pitched roof and Chevron bracings of 1:8, 1:10, 1:12 roof slopes using IS 800:2007

From fig 4.2 Notably, at rafter location points -18, -12, -6, 0, and 6, 12, 18 the pitched roof with 1:8 and 1:12 demonstrates the highest displacement values compared to the pitched roof with 1:10 roof slopes with chevron bracings. The differences in displacement percentages highlight the varying degrees of structural deformation at each point. For instance, at rafter location point -18, the pitched roof with 1:8 and 1:12 roof slopes surpass the pitched roof with 1:10 roof slopes by 5.2% and 11.4%. Similarly, at points-6 and 0, the mono slope roof exhibits displacement values higher than the other roofs by 2.3% to 3.5%. However, at rafter location 0 all the roof slopes are exhibiting higher displacements compared to other locations. Displacements compared with the diagonal bracings in fig4.1, the displacement with chevron bracings is on the higher side when compared to the diagonal i.e. the maximum displacement due to chevron bracings is 0.215m whereas the displacements due to diagonal bracings are 0.195, with the increase in 10.25%.

4.2.3. Displacements of rafter with Curved roof and diagonal bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

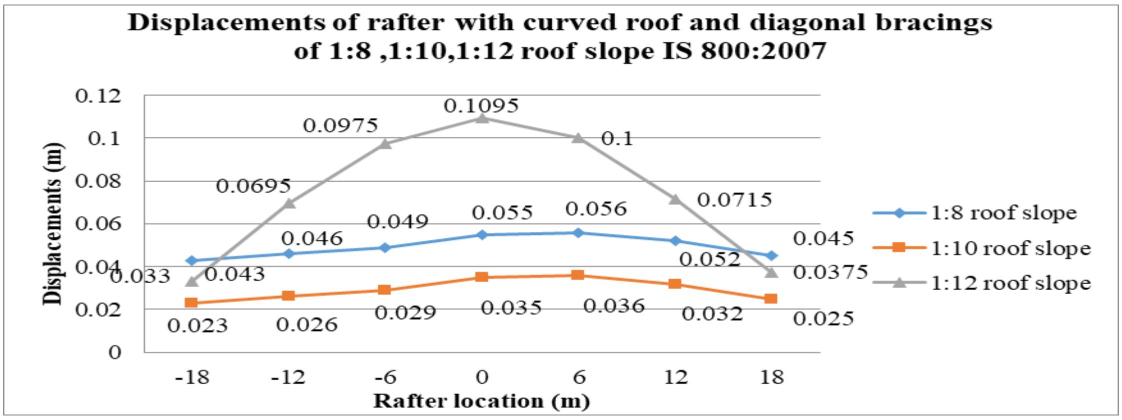

Figure 4.3: Displacements of rafter with Curved roof and diagonal bracings with 1:8, 1:10, 1:12 roof slopes using IS 800:2007

From fig 4.3 the displacement values, presented as percentages, for three distinct roof slopes with 1:8, 1:10, 1:12 slopes with curved roof and diagonal bracing are examined across various rafter location points. The data elucidates noteworthy trends in structural movement for the, curved roof. At rafter location points -18, -12, -6, 0, 6, 12, and 18, the curved roof consistently displays the highest displacement values in comparison to the pitched and mono slope roofs. The differences in displacement percentages highlight the varying degrees of structural deformation at each point. For instance, at rafter location point -18, the curved roof surpasses the pitched roof by 6.5% and the mono slope roof by 4.4%. Similarly, at points -12 and -6, the curved roof exhibits displacement values higher than the other roofs by 7.5% to 15%. Conversely, at rafter location point -18, the pitched roof stands out with the highest displacement, exceeding the curved roof by 7.2% and the mono slope roof by 1.1%.

4.2.4. Displacements of rafter with Curved roof and chevron bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

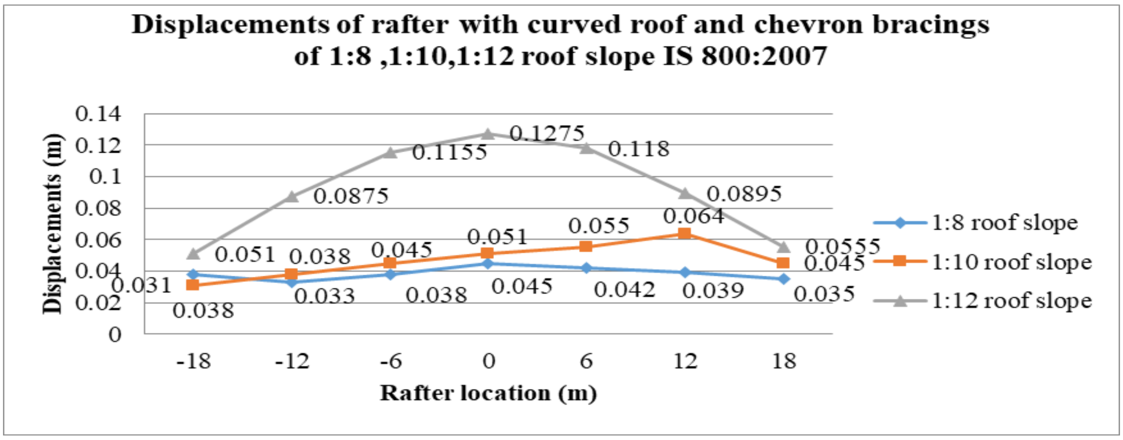

Figure 4.4: Displacements of rafter with Curved roof and Chevron bracings with 1:8, 1:10, 1:12 roof slopes IS 800:2007

The displacement values, expressed as percentages, for three distinct roof slopes with 1:8, 1:10, 1:12 with curved roof and chevron bracing are analyzed across various rafter location points. The data reveals distinctive patterns in structural movement for the pitched roof, curved roof, and mono slope roof. At rafter location points -18, -12, -6, 0, 6, 12, and 18, the curved roof consistently exhibits the little higher displacement values compared to the pitched and mono slope roofs. The disparities in displacement percentages underscore the varying degrees of structural deformation at each point. For instance, at rafter location point -18, the curved roof surpasses the pitched roof by a substantial 39% and the mono slope roof by 5.7%. Similarly, at points -12 and -6, the curved roof displays displacement values higher than the other roofs by 21.7% to 27.6%. Conversely, at rafter location point 0, the pitched roof stands out with the highest displacement, exceeding the curved roof by 10.4% and the mono slope roof by 8.4%.

4.2.5. Displacements of rafter with Monoslope roof and Diagonal bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007.

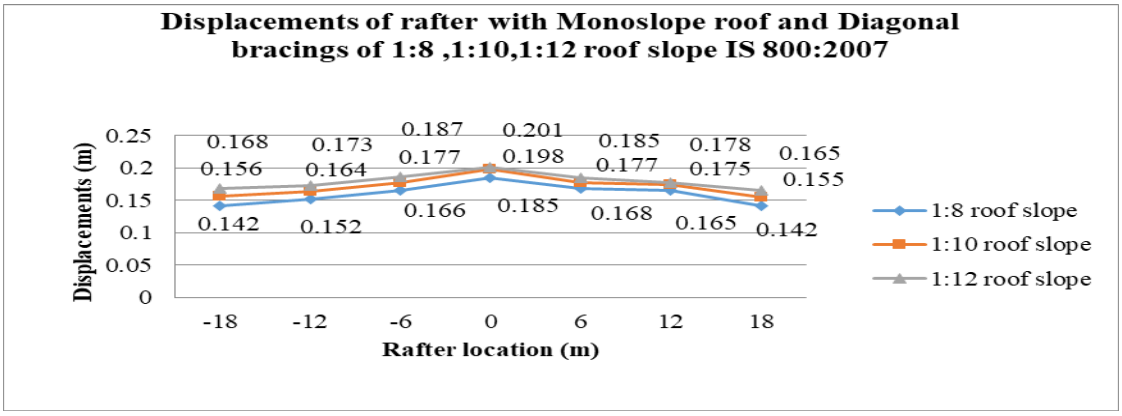

Figure 4.5: Displacements of rafter with Monoslope roof and Diagonal bracings with 1:8, 1:10, 1:12 roof slopes IS 800:2007

From fig 4.3 the displacement values, presented as percentages, for three distinct roof slopes with 1:8, 1:10, 1:12 slopes with Monoslope roof and diagonal bracing are examined across various rafter location points. The data elucidates noteworthy trends in structural movement for the, curved roof, at rafter location points -18, -12, -6, 0, 6, 12, and 18, the Monoslope roof consistently displays the highest displacement values in comparison to the pitched and curved roofs.

The differences in displacement percentages highlight the varying degrees of structural deformation at each point. For instance, at rafter location point -18, the curved roof surpasses the pitched roof by 8.3% and the curved roof by 6.4%. Similarly, at points -12 and -6, the curved roof exhibits displacement values higher than the other roofs by 9.6% to 18%. Conversely, at rafter location point -18, the Monoslope roof stands out with the highest displacement, exceeding the curved roof by 3% and the pitched roof by 1.6%.

4.2.6. Displacements of rafter with Monoslope roof and Chevron bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007.

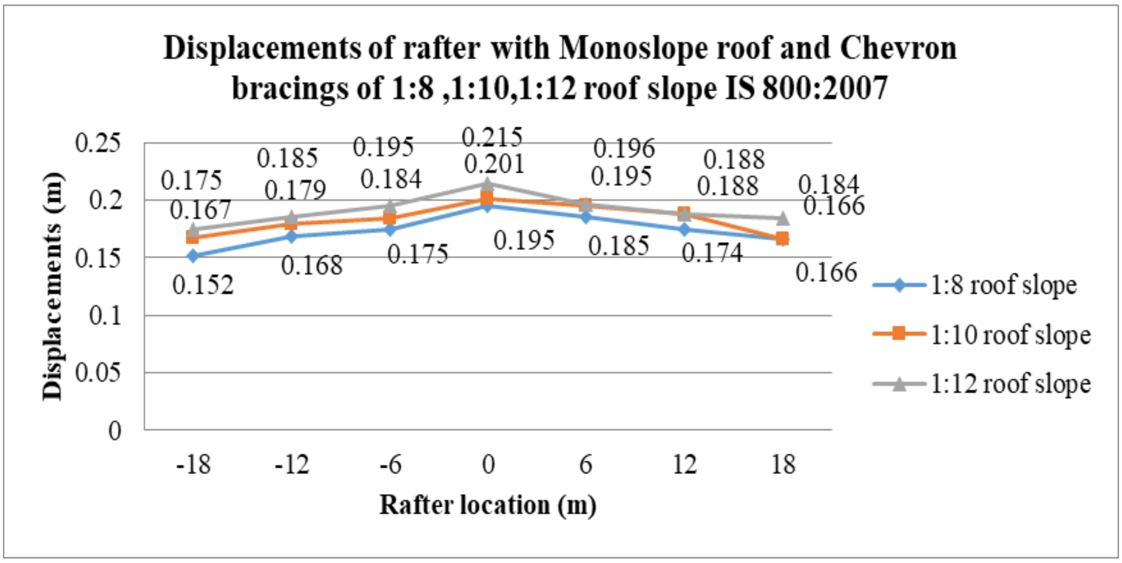

Figure 4.6: Displacements of rafter with Monoslope roof and Chevron bracings with 1:8, 1:10, 1:12 roof slopes IS 800:2007

The graph shown in fig4.6 provides displacement values at different rafter location points for Monoslope roof with chevron bracings and 1:8, 1:10, 1:12 roof slopes have been analyzed. The displacement values are expressed as percentages. Analyzing the data, it is evident that the Monoslope roof with 1:12 roof slope is giving us more displacement compared to 1:8 and 1:10 roof slopes.

At each point, the Monoslope roof with 1:12 slope shows the greatest percentage of displacement, indicating a greater degree of structural movement compared to the other three roof slopes. Specifically, the Monoslope roof has the highest displacement at rafter location i.e. at 0-point center of the rafter.

This information suggests that, the 36% increase and 42% increase in the displacement compared to 1:10 roof slope. Under the specified conditions and bracing, the pitched roof with 1:8 and 1:12 roof slopes are experiencing more significant deformations than the 1:8 roof slopes.

4.3. Bending Moment IS 800:2007

4.3.1. Bending moment of rafter with Pitched roof and diagonal bracings with 1:8, 1:10, 1:12 roof slope using IS 800:2007

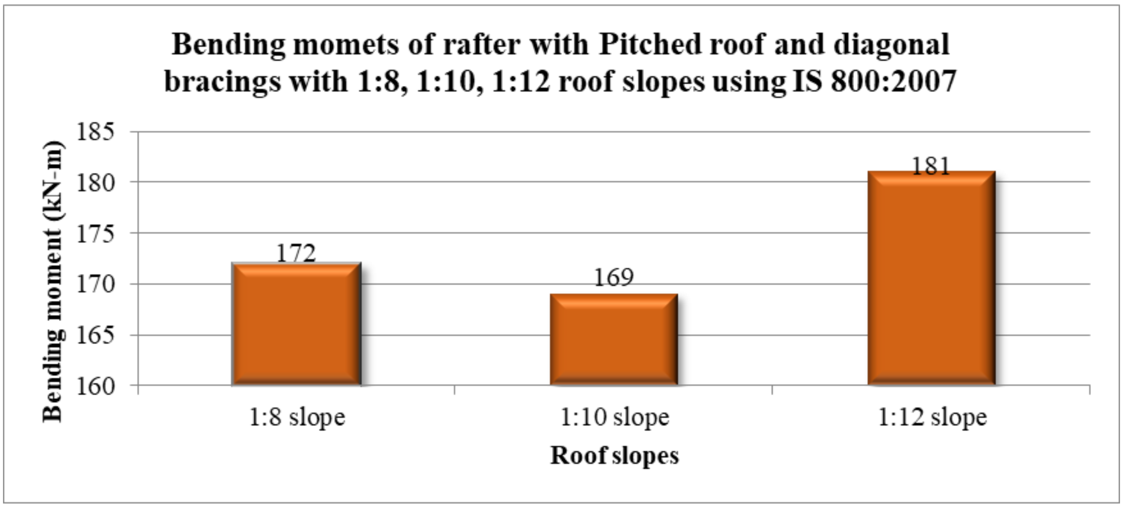

Figure 4.7: Bending moments of rafter with Pitched roof and diagonal bracings with 1:8, 1:10, 1:12 roof slopes IS 800:2007

The graph shown in fig 4.7 provides bending moments for three distinct roof slopes with 1:8, 1:10 and 1:12 diagonal bracing at a specific rafter location point. The bending moments, measured in units not specified, are as follows: 172 for the 1:8 roof slope, 169 for 1:10 roof slope and 181 for 1:12 roof slope Clearly, the pitched roof with 1:12 roof slope exhibits the highest bending moment, exceeding that of roof slopes of 1:8 and 1:12 roof slopes, the pitched roof by. This data implies that, under the specified conditions and diagonal bracing, the pitched roof experiences a significantly greater bending moment compared to the other roof types at the given rafter location point. Considerably the percentage increase is 1.8% with respect to 1:8 roof slope and 7% with respect to 1:12 roof slopes. This implicated that the bending moment is higher for 1:12 roof slopes. The increase in the bending moment in the 1:12 roof slopes gives us the maximum displacement values.

4.3.2. Bending moment of rafter with Pitched roof and chevron bracings with 1:8 1:10, 1:12 roof slope IS 800:2007

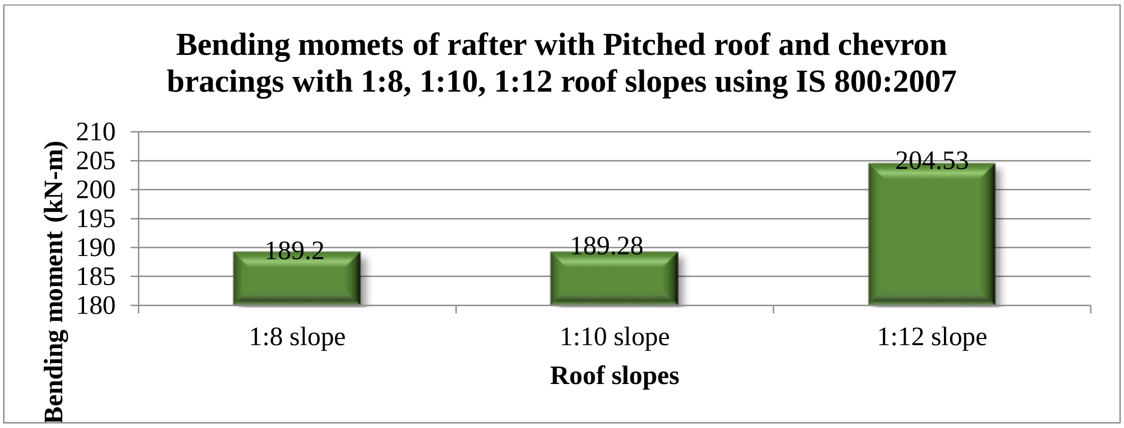

Figure 4.8: Bending moments of rafter with Pitched roof and Chevron bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

The graph shown in the fig 4.8 presents bending moments for three distinct roof slope of 1:8, 1:10, 1:12 with pitched roof and chevron type of bracings. The bending moments, measured in kN-m, are as follows: 189.2 for 1:8 roof slope, 189.28 for 1:10 roof slope and 204.53kN-m-m for 1:12 roof slope. Evidently, the pitched roof with 1:12 roof slopes roof exhibits the highest bending moment, surpassing that of the 1:8 slope by 15.33kN-m and the 1:10 roof slope by 15.25kN-m units. This data indicates that, under the given conditions and chevron bracing, the pitched roof experiences a notably greater bending moment compared to the other roof slopes at the specified location. As discussed above the there is 10-12% increase in the bending moments when compared with the diagonal bracings and chevron bracings, with chevron bracings are on the higher side of it. The bending moment of the pitched roof with 1:12 roof slope has surpassed the diagonal bracings by 23.53 kN-m as shown in the fig 4.7. with the bending moment as 181kN-m and that of the chevron bracings is 204.53kN-m.

4.3.3. Bending moment of rafter with Curved roof and Diagonal bracings with 1:8, 1:10, 1:12 roof slopes using IS 800:2007

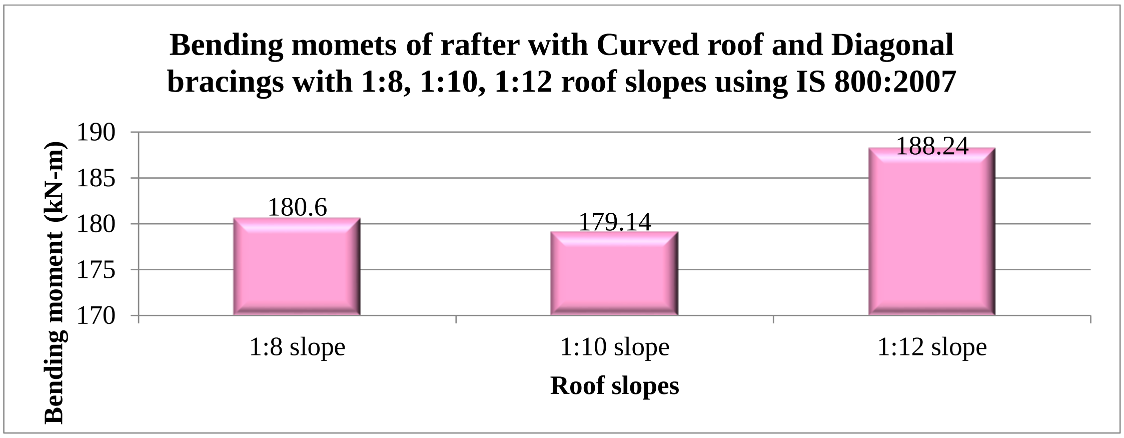

Figure 4.9: Bending moments of rafter with Curved roof and Diagonal bracings with 1:8, 1:10, 1:12 roof slopes IS 800:2007

The graph shown in fig4.9 provides bending moments for three distinct roof slopes with 1:8, 1:10 and 1:12 slopes diagonal bracing and curved roof at a specific location. The bending moments, measured in kN-m specified, are as follows: 180.6kN-m for 1:8 roof slope, 179.14 for 1:10 roof slope and 188.24kN-m for 1:12 roof slope. In this case, the curved roof demonstrates the highest bending moment, exceeding that of the pitched roof by 10.6kN-m for 1:8 roof slope 10kN-m for 1:10 roof slopes and 8.24kN-m units for 1:12 roof slopes. This data indicates that, under the given conditions and with 1:12 diagonal bracing, the curved roof experiences a substantially greater bending moment compared to the other roof slopes at the specified location. When compared with the pitched roof with diagonal bracings in fig 4.7, the bending moments have increase from 172 to 180.6kN-m for 1:8 roof slope, 169 to 179.14kN-m for 1:10 roof slopes and 181 to 188.24 kN-m for the 1:12 roof slopes. There is a substantial increase in the bending moments of about 6-8% in the bending moments when compared to pitched roofs.

4.3.4. Bending moment of rafter with Curved roof and Chevron bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

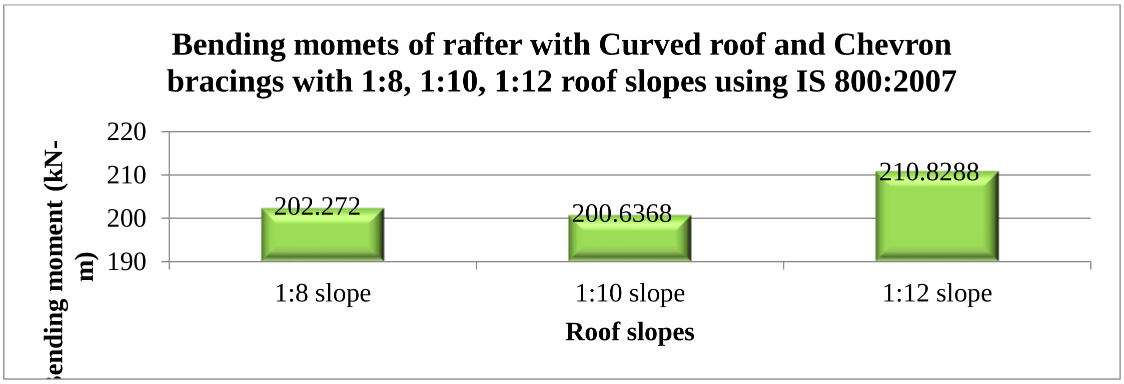

Figure 4.10: Bending moment of rafter with Curved roof and Chevron bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

The graph shown in fig 4.10 presents bending moments for three distinct roof slopes with 1:8, 1:10 and 1:12 with curved roof and chevron bracings at a specific location. The bending moments, measured kN-m specified, are as follows: 202.27kN-m for the 1:8 roof slope, 200.63kN-m for 1:10 roof slope and 210.82 roof slope for 1:12 roof slope. Clearly, the bending moment due to 1:12 roof slope is having more bending moment when compared to 1:8 and 1:10 roof slope by 8.54 kN-m and 10.19kN-m. This data suggests that, under the specified conditions and with 1:12 chevron bracing has given maximum bending moments when compared to 1:8 and 1:10 roof slopes. The percentage increase is found out to be 4.22% in case of 1:8 slope and 5.07% in case of 1:10 roof slopes. When compared it with pitched roof with chevron bracings as shown in the fig4.8, there is 6.9% increase in bending moment in 1:8 roof slope, 6% increase in bending moment in case of 1:10 roof slope and 3.07% increase in bending moment in case of 1:12 roof slope.

4.3.5. Bending moment of rafter with Monoslope roof and Diagonal bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

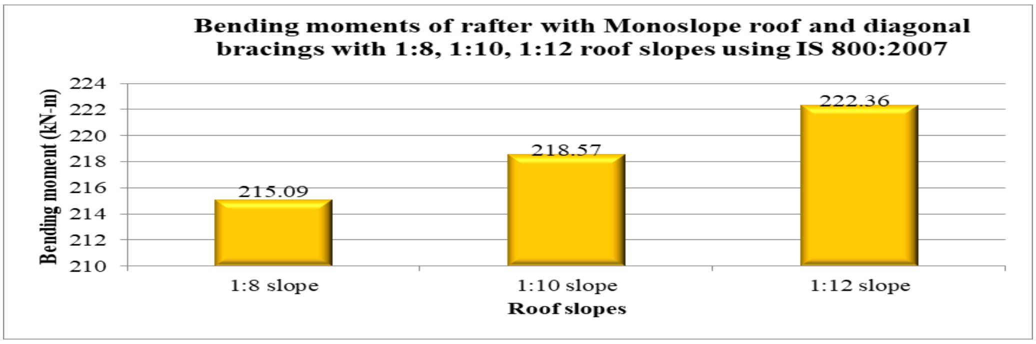

Figure 4.11: Bending moment of rafter with Monoslope roof and Diagonal bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

The graph shown in the fig 4.11 presents bending moments for three distinct roof slope of 1:8, 1:10, 1:12 with Monoslope roof and diagonal type of bracings. The bending moments, measured in kN-m, are as follows: 215.09 for 1:8 roof slope, 218.57 for 1:10 roof slope and 222.36 kN-m for 1:12 roof slope. Evidently, the Monoslope roof with 1:12 roof slopes roof exhibits the highest bending moment, surpassing that of the 1:8 slope by 7.27 kN-m and the 1:10 roof slope by 3.79 kN-m units. This data indicates that, under the given conditions and diagonal bracing, the Monoslope roof experiences a notably greater bending moment compared to the other roof slopes and roof types like the pitched roof and curved roof at the specified location. As discussed above the there is 19% increase in the bending moments when compared with the curved roof with diagonal bracings as shown in the fig 4.9 and 25% increase in the bending moments when compared to the pitched roof with diagonal bracings.

4.3.6. Bending moment of rafter with Monoslope roof and Chevron bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

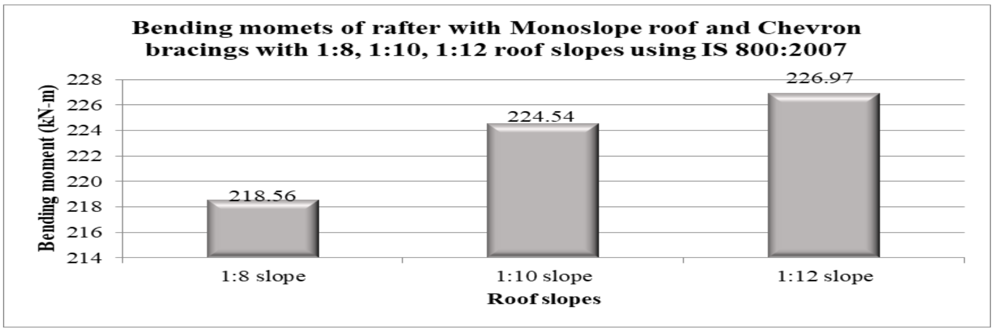

Figure 4.12: Bending moment of rafter with Monoslope roof and Chevron bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

The graph shown in fig 4.12 provides bending moments for three distinct roof slopes with 1:8, 1:10 and 1:12 diagonal bracing at a specific rafter location point. The bending moments, measured in units not specified, are as follows: 218.56 for the 1:8 roof slope, 224.54 for 1:10 roof slope and 226.97 for 1:12 roof slope, Clearly, the Monoslope roof with 1:12 roof slope exhibits the highest bending moment, exceeding that of roof slopes of 1:8 and 1:10 roof slopes, This data implies that, under the specified conditions and chevron bracing, the Monoslope roof experiences a significantly greater bending moment compared to the other roof types at the given rafter location point. Considerably the percentage increase is 3.84% with respect to 1:8 roof slope and 1.08% with respect to 1:12 roof slopes. This implicated that the bending moment is higher for 1:12 roof slopes. The increase in the bending moment in the 1:12 roof slopes gives us the maximum displacement value compared to all the other roof types and roof slopes. The increase in the bending moment and displacement values gives us the large foundation sizes compared with less displacement and bending moment values.

4.4. Base Shear for the structure using IS 800:2007

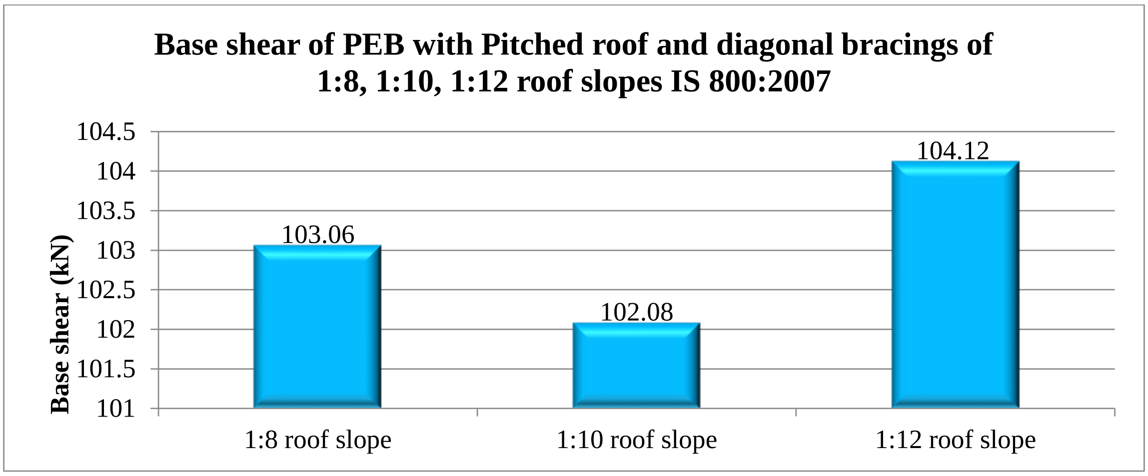

Figure 4.13: Base shear of rafter with Pitched roof and Diagonal bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

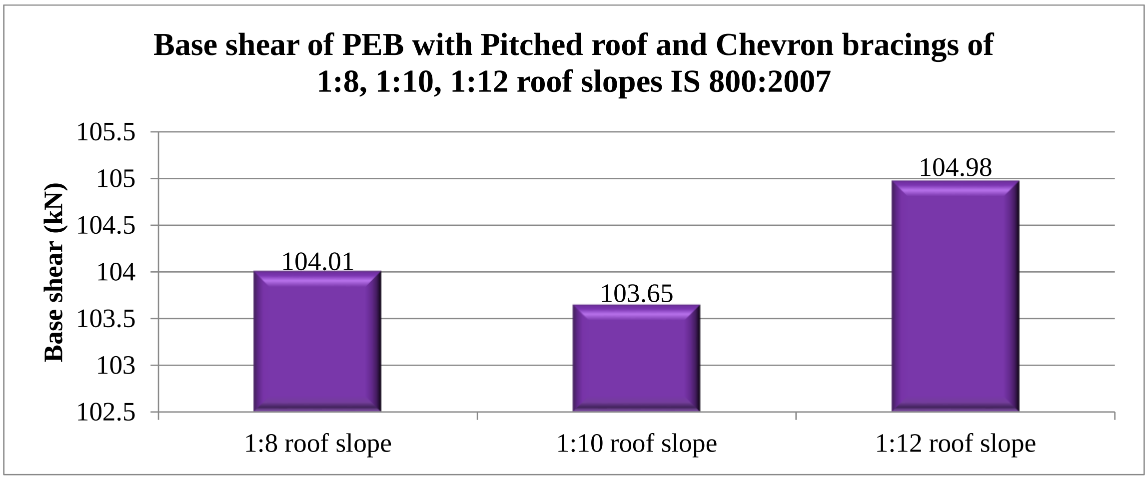

Figure 4.14: Base shear of rafter with Pitched roof and Chevron bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

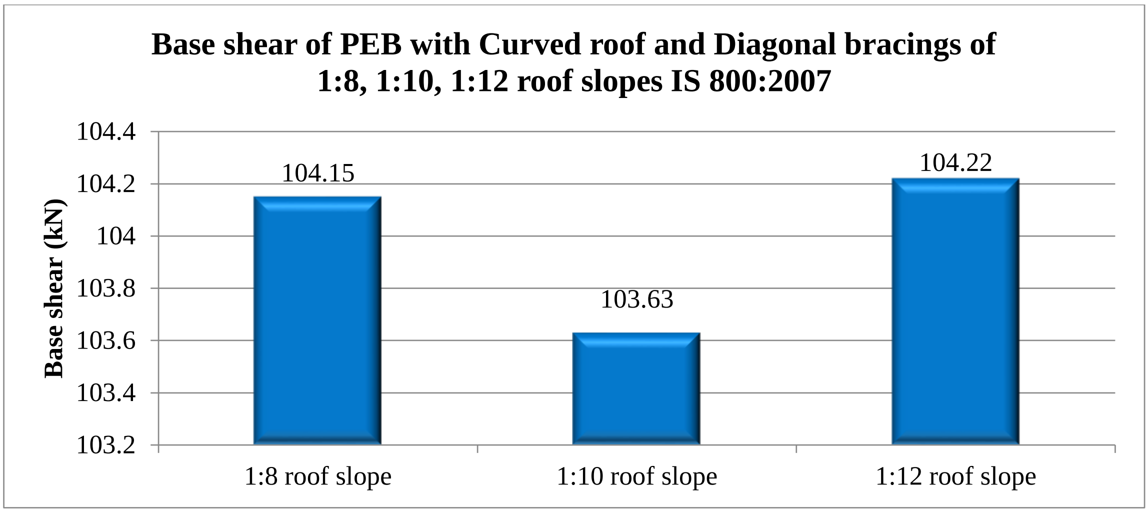

Figure 4.15: Base shear of rafter with Curved roof and Diagonal bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

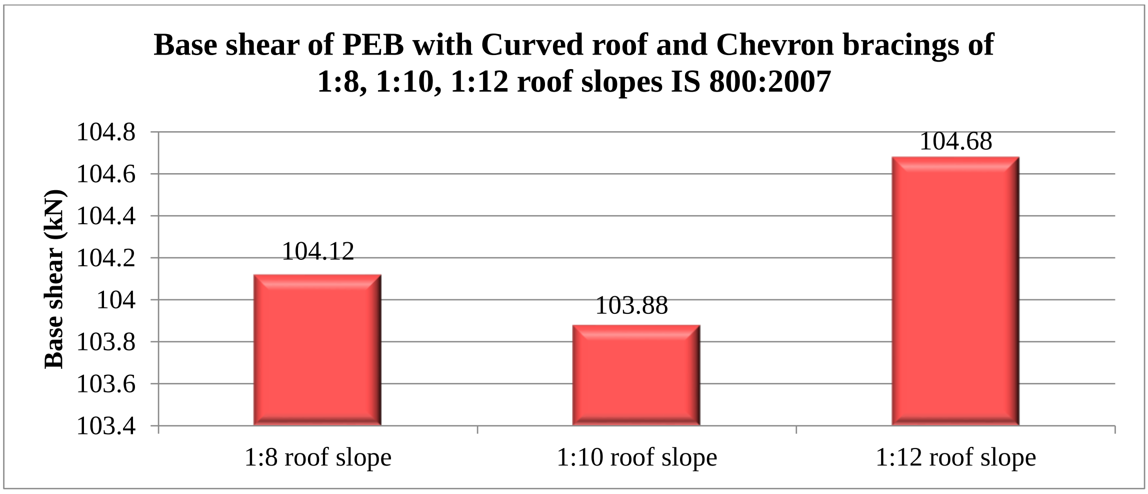

Figure 4.16: Base shear of rafter with Curved roof and Chevron bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

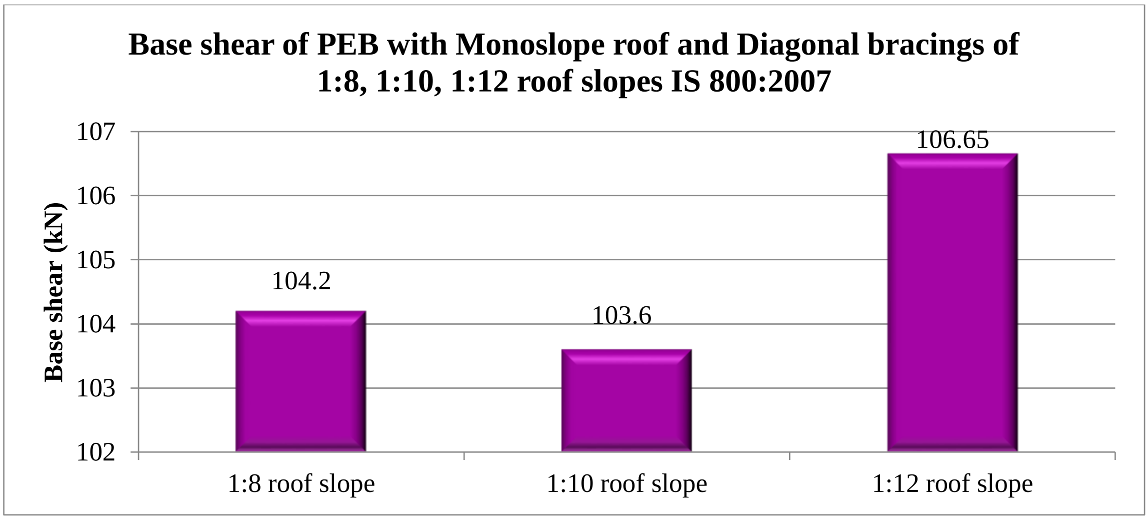

Figure 4.17: Base shear of rafter with Monoslope roof and Diagonal bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

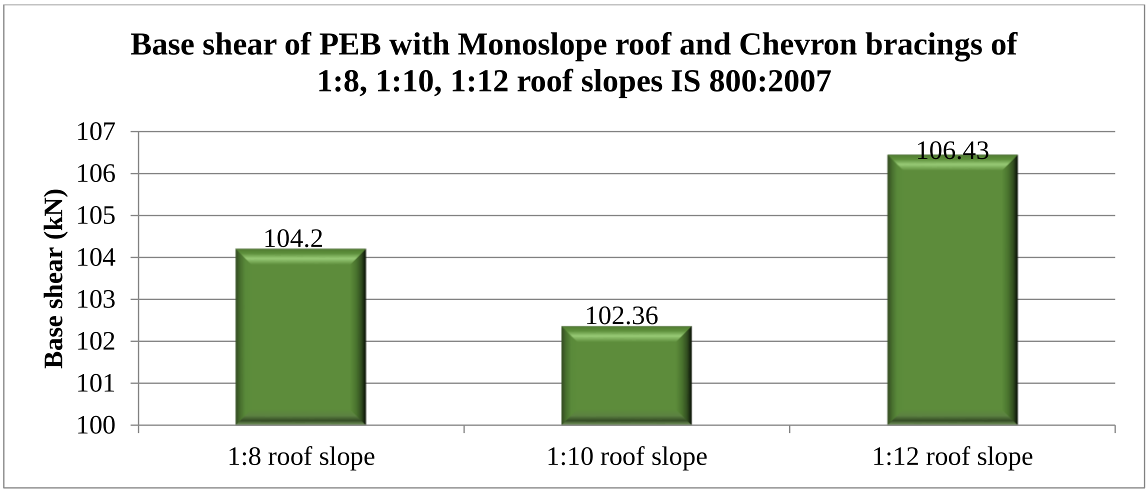

Figure 4.18: Base shear of rafter with Monoslope roof and Chevron bracings with 1:8, 1:10, 1:12 roof slope IS 800:2007

The graph shown in fig 4.13 to 4.18 provides the base shears value for three distinct roof slopes with 1:8, 1:10 and 1:12 with diagonal and chevron type bracings. The base shears are measured in kN, from the above results it is observed that the pitched roof has less base shear values compared to other two types i.e. curved roof and monoslope roof. Clearly, the Monoslope roof with 1:12 roof slope exhibits the highest base shear value compared to other two types of roofs. exceeding that of roof slopes of 1:8 and 1:10 roof slopes, this data implies that, under the specified conditions and chevron bracing, the Monoslope roof experiences a significantly greater base shear compared to the other roof types at the given rafter location point. When monoslope roof is compared with curved roof there is slight increase of 1% and when compared to pitched roof, the increase is about 2%. When comparing the pitched roof with curved roof the base shear values are on the higher side for the curved roof with percentage increase of 1%. This makes the pitched roof having less base shear as shown in fig 4.18 with good structural performance.

V. Conclusions

In this comprehensive study exploring the structural behavior of Pre-Engineered Buildings (PEB) with varying roof types and bracing configurations, our investigation focused on the influence of different design parameters, particularly roof slope and bracing types, guided by the Indian code IS 800:2007. The primary objective was to discern the most effective combination of roofing and bracing elements for optimal structural performance, as indicated by bending moments and displacements.

- The displacement values, presented as percentages, for three distinct roof types with 1:10 diagonal bracing are examined across various rafter location points. The data elucidates noteworthy trends in structural movement for the pitched roof, curved roof, and mono slope roof. At rafter location points -18, -12, -6, 0, 6, 12, and 18, the Monoslope consistently displays the highest displacement values in comparison to the pitched and curved roofs.
- The differences in displacement percentages highlight the varying degrees of structural deformation at each point. For instance, the Monoslope roof has the displacement ranging from 0.15m to 0.2m when compared to pitched roof the displacement values are 36% less and in case of curved roof the displacement values are 30% less when compared to Pitched roof.
- The comparison of displacements in case of roof slopes i.e. 1:8, 1:10 and 1:12, the 1:12 roof slope is being giving maximum displacement value due to its flatter gradient when compared to other two roofs. The

values are as follows for pitched roof 1:8 min and 1.8 max are 0.113, 0.215, for curved roof values are 0.045, 0.055, for monoslope roof the values are 0.142 and 0.195, The values for pitched roof 1:10 min and 1:10 max as follows 0.036, 0.046, for cured roof 0.038, 0.05, for monoslope roof 0.156 and 0.201. Similarly, the values for 1:12min and 1:12 max the values for pitched roof are as follows 0.129, 0.195, for curved roof 0.10, 0.12 and for the mono slope roof the values are 0.16 and 0.21

- The following are the comparisons of displacement in case of Diagonal and chevron bracings systems for pitched roof the minimum and maximum values for diagonal bracings are 0.019, 0.195, for curved roof 0.023, 0.109, for monoslope roof 0.142, 0.201, In case of chevron type bracings the minimum and maximum values for pitched roof are 0.034, 0.215 for curved roof 0.038, 0.127 and for the monoslope roof is 0.152 and 0.216.
- The above results show the comparison of displacement in diagonal and chevron bracings, in pitched roof there is 10% increase in displacements, in the curved roof the chevron bracings have 16% increase in displacements and in case of monoslope roof the displacement increase is 52% in case of chevron bracings.
- The comparison of Bending moments in case of 1:8, 1:10 and 1:12 roof slopes is compared for three different types of roofs, the results are as follows, for pitched roof 1:8 roof slope the value is 172 kN-m, curved roof is 180.6 kN-m, monoslope roof is 215 kN-m, Similarly the values for 1:10 roof slope for pitched roof is 169kN-m, for curved roof is 179 kN-m, for monoslope roof is 218.5 kN-m, Similarly for 1:12 roof slope, the pitched roof values are 181 kN-m, curved roof is 188.24 kN-m and Monoslope roof is 222.36 kN-m.
- The above results show that the bending moments are more in case of Monoslope roof due to the flatter gradient, which is 18% less in case of curved roof and 22.85% less in case of pitched roof.
- The following is the comparisons of bending moments in case of the diagonal bracings and the chevron bracings. For pitched roof and diagonal bracings the value is 181 kN-m, curved roof is 188.24 kN-m, for monoslope roof is 222.36 kN-m, in case of chevron bracings the value for pitched roof is 204.43 kN-m, for curved roof is 210.82 kN-m, for monoslope roof is 226.97 kN-m.
- The above results, the bending moments are more in case of chevron bracings where the percentage increase is 13% in case of pitched roof, 12% in case of curved roof and 2.07% in case of monoslope roof.
- The following are the steel takeoffs comparisons for different roof slopes i.e. for 1:8 roof slope and pitched roof is 792 kN, for curved roof is 814 kN for monoslope roof is 836 kN, for 1:10 roof slope the pitched roof value is 796 kN, for curved roof 823.74 kN, for monoslope roof is 845 kN, similarly for 1:12 roof slope for pitched roof 798 kN, curved roof is 821.47 kN and monoslope roof is 850 kN.
- The steel takeoff for the monoslope roof is more when compared to curved roof and pitched roof, the steel takeoff is 3.47% less when compared with curved roof and 6.51% less when compared with the pitched roof.
- The comparisons of steel takeoffs according to type of bracings i.e. in case of diagonal bracings the pitched roof is giving a steel takeoff of 786 kN, curved roof is 815 kN and Monoslope roof is 818 kN, in case of chevron bracings the pitched roof is giving a takeoff of 798 kN, curved roof is 821 kN and 850 in case of monoslope roof.
- From the above given results it is clear that the chevron bracings are giving more steel takeoff and hence considered uneconomical, the percentage increase in case of pitched roof is 1.52%, 0.73% in case of curved roof and 4% in case of Monoslope roof.
- Upon analysis, it is evident that the Monoslope generally exhibits higher displacement values compared to the curved roof and pitched roof at various rafter location points.

- Upon analysis as shown in fig 4.1 the pitched roof with diagonal bracings and 1:10 roof slope has exhibited greater structural stability and integrity when compared to other roof types and slopes, as shown in fig 4.1 at rafter locations -18, -12, -6, 0, 6, 12, 18 following are the displacements 0.019, 0.019, 0.024, 0.031, 0.034, 0.03, 0.02 which are found out be less when compared to other values. PEB with Pitched roof with 1:10 roof slope and diagonal bracing is considered first best combination.
- Consistently exhibited superior structural integrity. Concurrently, adherence to IS 800:2007 standards for PEB with a 1:10 roof slope, employing diagonal bracing alongside curved roofs, emerged as another highly favorable and reliable configuration where at rafter locations -18, -12, -6, 0, 6, 12, 18 the displacements were found out to be 0.023, 0.026, 0.029, 0.035, 0.036, 0.032, 0.025.
- While comparisons of utilization ratios for the PEB, the pitched roof has values ranging from 0.5 to 0.8, whereas curved roof has values ranging from 0.7 to 1.0 and monoslope roof has values almost 1, by these values we can say that the members in the monoslope roof are overstressed, as the utilization values are slightly more than 1.
- The utilization of diagonal bracing, in accordance with the prescribed codes, contributed to the mitigation of structural stresses, resulting in minimized bending moments and displacements.
- The findings advocate for the adoption of these specific bracing and roofing combinations, emphasizing their potential to enhance structural performance, ensure safety, and inform more efficient design practices in the realm of Pre-Engineered Buildings.
- The observed data on bending moments and displacements consistently showcased these particular combinations outperforming alternative setups, underscoring their suitability for PEB structures. This conclusion is pivotal for the design and construction industry, offering valuable insights for architects and engineers involved in the selection of optimal configurations for PEB structures.

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