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Performance Comparison of PEB Structure for Lateral Loads Using Different Bracing Systems

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ABSTRACT:The main objective of this project is to analyse & study the comparative performance of PEB structure with and without bracings such as X, V, Inverted V, Forward Diagonal Bracing, Backward Diagonal Bracing, K Bracing using Staad Pro V8i software. In earthquake zone the displacement and deflections of the structures will be more so to have more stiffness to the structure bracings are provided, hence this study compares the structures results with various bracings to find the best structure for lateral loads. All the considered structures have been subjected to various loads such as dead loads, live loads, earthquake loads. This study is mainly based on Static Equivalent Method of Analysis. Analysis was done as per IS:1893-2016. The results provide good evidence about the various parameters and show their performance on different conditions of the structure. For the obtained results we will check and conclude the best performing structure among all the other considered structure.

KEYWORDS:X bracing, V bracing, Inverted V-bracing, Forward Diagonal braing, Backward Diagonal bracing, K bracing, Staad Pro, Equivalent Static Method of Analysis, Utilization Ratio, Nodal Displacement.

I. INTRODUCTION

India is one of the fastest steel manufacturing industry. In this era construction industries use steel extensively. Steel is recyclable and used throughout the world. Products made of steel are eco-friendly, their high tensile strength and ductility also makes it a reliable material. Steel is highly used in erection of steel structures or industrial structures of great variety. The ability to build industrial structures has led to many techniques, one such method is PEB, Pre-Engineered Buildings. The Pre-Engineered Buildings are designed by tapered sections with various plate sizes and usually has web and flanges with different thicknesses depending upon the internal and external incoming forces over the section. PEB have long open spans making it easier for factories and industrial structures for vehicle movement and they have lesser dead weight unlike conventional steel structures. Horizontal loading produces sway and therefore results in vibration and storey drift. Ductility, Strength and Stiffness are important aspects for the structure to keep itself in an equilibrium state upon action of any kind of load on it. This work involves in finding the better type of bracing for handling the seismic and wind effects on PEB for seismic zone II of India.

II. ADVANTAGES OF PEB

1. Clear Spans without Column – The possibility of column free spaces in PEB is good as it will yield more workable area thereby increases the effective utilization of area.
2. High Quality – The finished building is of high quality as every structural element is factory fabricated unlike conventional steel structures which are cut in the site.
3. Lower Time of Construction – The time taken for completion of PEB is less than a conventional steel building because every structural member comes with readymade section sizes to the site and only fitting with bolts is required which accelerates the completion of project.
4. Eco-friendly – Since steel can be recycled and reused n number of times we are constructing a structure that is eco-friendly.
5. Expansion Capabilities – The structure can be extended in plan and the workable area can be increased as per future requirement and this is a major advantage as flexibility of expanding the structure possible whereas building a whole new structure requires more capital.



6. Cost Effective – The structure can be built more economically than a conventional steel truss type or a RCC frame as the number of elements in PEB are less and strength to weight ratio is higher.

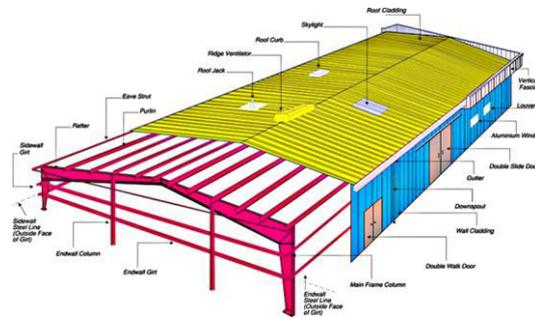


Fig. 1. Typical PEB Structures

III. BRACINGS

All structures could sustain the loads acting on those during the service life by possessing moderate strength and also limit the deformation by possessing enough stiffness but this high-rise structure is affected by lateral forces due to earthquake. This bracing used in high rise concrete structure to reduce lateral deflections. Bracing systems will reduce the buckling capacity of the compression forces significantly and hence it is lower than the yielding tension capacity of the tensile stresses in high rise structures. Which means as the bracings reach their resistance capacity, the load should be resisted in the bending of the horizontal member.

The principal bracings are divided into the following six types based on the diverse requirements in construction systems.

1. X bracings
2. V bracings
3. Inverted V bracing
4. Forward Diagonal bracing
5. Backward Diagonal bracing
6. K bracing

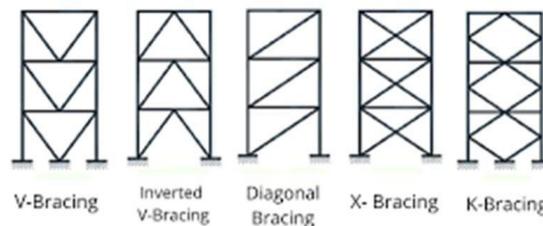


Fig. 2. Different types of bracings

IV. SEISMIC ZONES

On the basis of historical earthquake activity, India is classified into 4 zones. Zone II is the region that is least likely to have seismic activity or earthquakes, whereas zone V is very susceptible, and zone factors are established based on the zones. For the purpose of estimating design seismic forces, zone factors are used. The zones help in designing the structure in a most economical and appropriate method using the IS code books.

V. OBJECTIVES

1. The objective of this study is to find the best suited braced PEB Structure among the available concentric braces such as X, V, K, Inverted V, Forward diagonal and Backward diagonal.
2. The structure is analysed for various loads like dead loads, live loads, wind loads, earthquake loads.



3. The structure is compared for both WSM and LSM. A bare frame with no bracings is modelled and then analysed, then other models with various bracings are analysed and their results are compared.
4. The objective involves comparison of various parameters such as steel take-off, utilization ratio, displacements.
5. We analyse and compare the structure with LSM and WSM to finalize in which design method the structure is economical and also safe.

VI. METHODOLOGY

A model with no bracings is first modelled in Staad Pro V8i software and checked for its behaviour using Equivalent Static Method in both WSM & LSM. Loads such as dead loads, live loads, wind loads, seismic loads are considered for the analysis of PEB structure using the software. Next few more Pre Engineered Structures with various concentric bracing types (K, V, Inverted V, X, Forward diagonal and Backward diagonal) are modelled to check their behaviour in both WSM & LSM. Then check which structural system behaves well enough, based on the output results from the software tool. Then compare various parameters like Nodal displacements, Beam displacements, Deflections, Utilization Ratio, Steel quantity required for construction to finalize the better structure of all the considered structures both in WSM & LSM. On the basis of obtained results, conclusion can be made about how one model with certain bracing compares with other braced model.

Table -1: Description of particulars

SL. NO.	PARTICULARS	SIZE/VALUE/ DIMENTIONS
1.	Design Code	IS Codes
2.	Extra Load To Be Considered	10 kg/m ²
3.	Site Location	Mysore
4.	Type Of Material	345/350 N/mm ²
5.	Type Of Building	PEB
6.	Steel Section Type	Taped Built-up sections
7.	Width Of The Structure	37.2m
8.	Length Of The Structure	102.7m
9.	Clear Span	37.2m
10.	Clear Height	9.75m
11.	Bracings	X, V, Inverted V, Forward & Backward Diagonal, K
12.	Bay Spacing Provided	7.9m
13.	Gable End Wall Column Spacing	6.2m
14.	Roof Slope	1 in 10 (5o)
15.	Roof Sheeting	Class 1 Protected Galvanized Steel Sheets and Plain (0.63mm thick)= 5.7kg/m ²



16.	Wall Cladding Sheet	Class 1 Protected Galvanized Steel Sheets and Plain (0.63mm thick)= 5.7kg/m ²
17.	Brick Wall Height	3m
18.	Bracing Positioned At	1st, 5th and 9th bays

VII. RESULTS AND DISCUSSIONS

In this Chapter, the discussion is mainly on the results obtained after analysis. The parameters like Displacements, Utilization ratio, Steel takeoff are compared by Equivalent Static Method of Analysis. Among the compared structures with different bracings, we will finally conclude which structure is best fit for the lateral loads.

Table -2: Horizontal Displacement Values

MAXIMUM DISPLACEMENT VALUES (mm)		
Bracing Type	LSM	WSM
No Brace	62.25	62
X	42.28	34.07
V	54.35	29.22
Inv. V	52.18	33.51
F.Diagonal	57.52	29.22
B.Diagonal	61.18	35.26
K	40.94	27.24

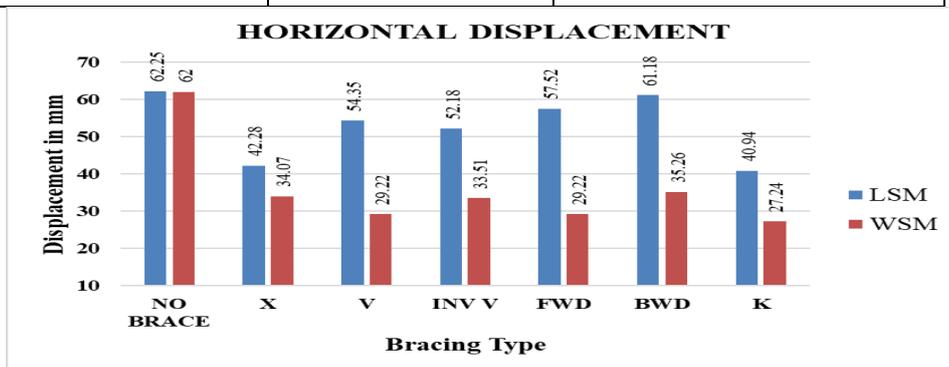


Fig. 3. Graphical Representation of Horizontal Displacement

Table -3: Vertical Displacements Values

MAXIMUM DISPLACEMENT VALUES (mm)		
Bracing Type	LSM	WSM
No Brace	92.7	98.17
X	100.86	91.97
V	101.59	67.47
Inv. V	96.82	64.45
F.Diagonal	102.94	67.22
B.Diagonal	95.88	68.31
K	102.04	67.93

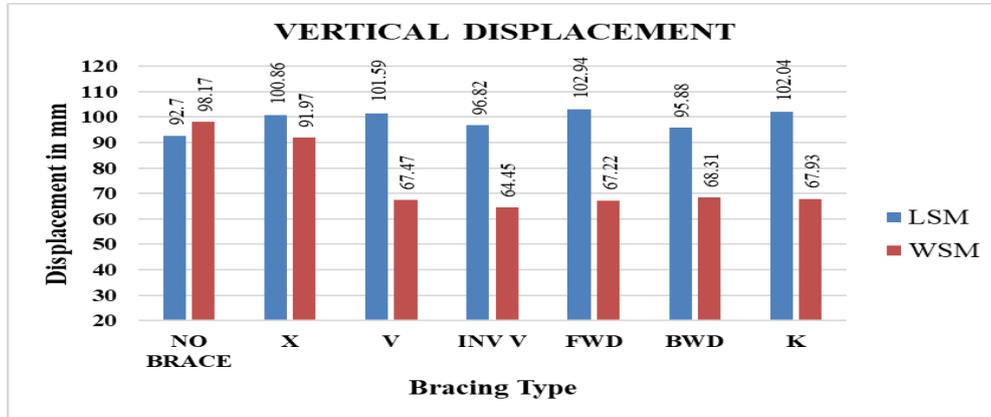


Fig. 4. Graphical Representation of Vertical Displacement

Table -4: Maximum Force Fx Values

MAXIMUM FORCE F _x (kN)		
Bracing Type	LSM	WSM
No Brace	337.55	221.51
X	345.793	222.44
V	351.5	241.76
Inv. V	358.14	241.25
F.Diagonal	341.86	230.94
B.Diagonal	353.87	233.72
K	328.89	222.55

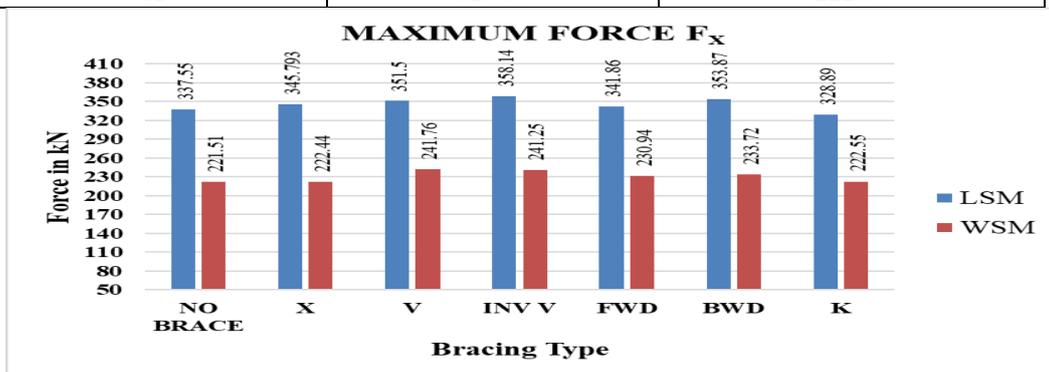


Fig. 5. Graphical Representation of Maximum Force Fx

Table -5: Maximum Force Fy Values

MAXIMUM FORCE F _y (kN)		
Bracing Type	LSM	WSM
No Brace	158.69	103.81
X	162.86	104.72
V	167.12	111.46
Inv. V	169	112.67
F.Diagonal	160.35	108.57
B.Diagonal	165.94	109.87
K	156.23	104.182

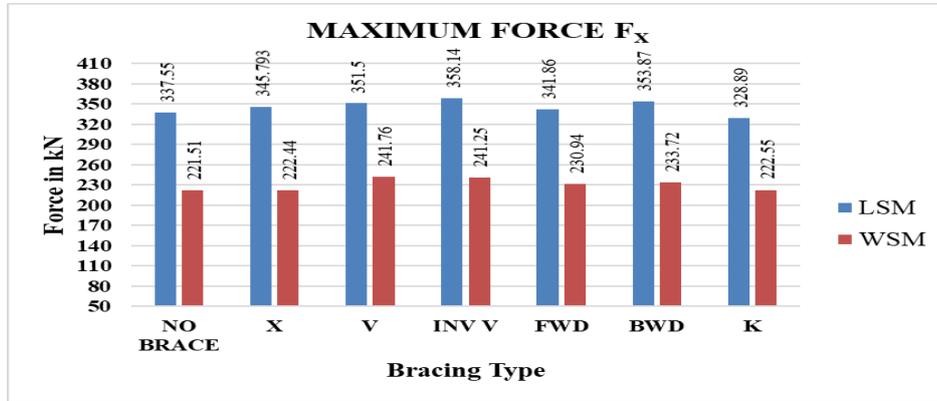


Fig. 6. Graphical Representation of Maximum Force F_y

Table -6: Maximum Force M_z Values

MAXIMUM MOMENT M_z (kNm)		
Bracing Type	LSM	WSM
No Brace	656.87	435.75
X	714.18	440.8
V	752.18	502.1
Inv. V	778.2	518.8
F.Diagonal	653.67	476.16
B.Diagonal	724.2	483.28
K	686.56	457.98

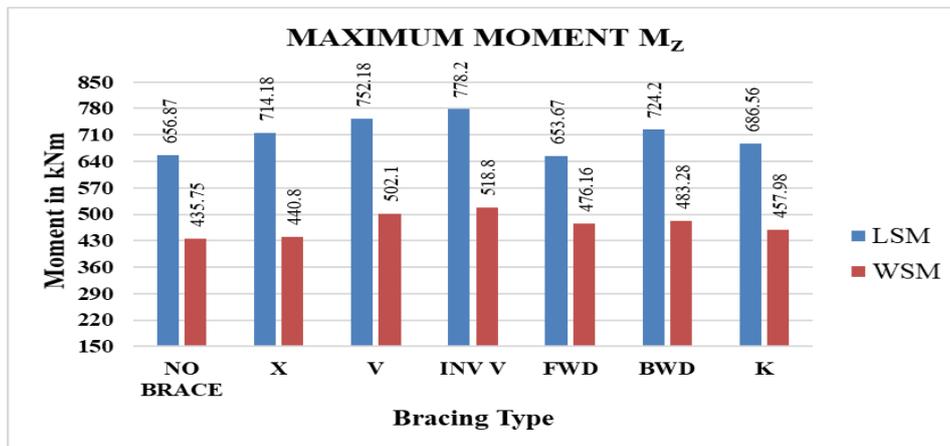


Fig. 7. Graphical Representation of Maximum Force M_z

Table -7: Steel Take-Off Values

STEEL TAKE-OFF		
Bracing Type	LSM	WSM
No Brace	144.6	152.35
X	118.8	122.61
V	129.02	146.41
Inv. V	137.22	139.83
F.Diagonal	123.02	124.94
B.Diagonal	125.54	137.68
K	126	130.17

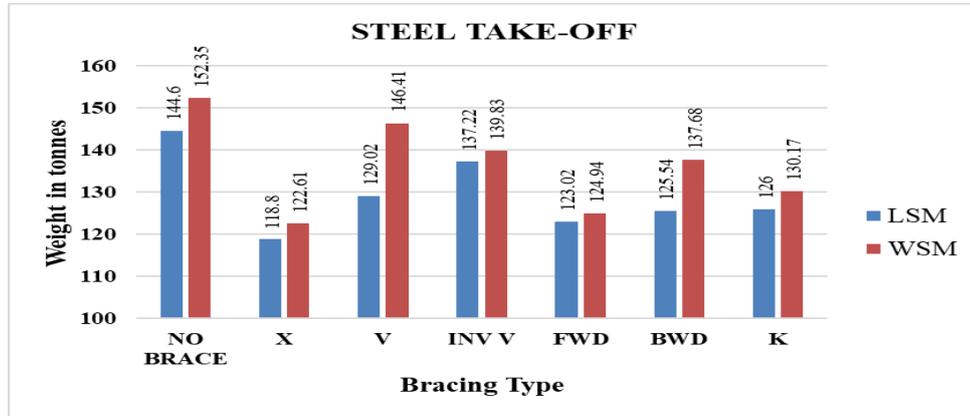


Fig. 8. Graphical Representation of Steel Take-Off

Table -8: Maximum Utility Ratio Values

MAXIMUM UTILITY RATIO		
Bracing Type	LSM	WSM
No Brace	1.042	1.026
X	1.247	1.237
V	1.112	1.112
Inv. V	1.112	1.22
F.Diagonal	1.19	1.247
B.Diagonal	1.167	1.156
K	1.247	1.273

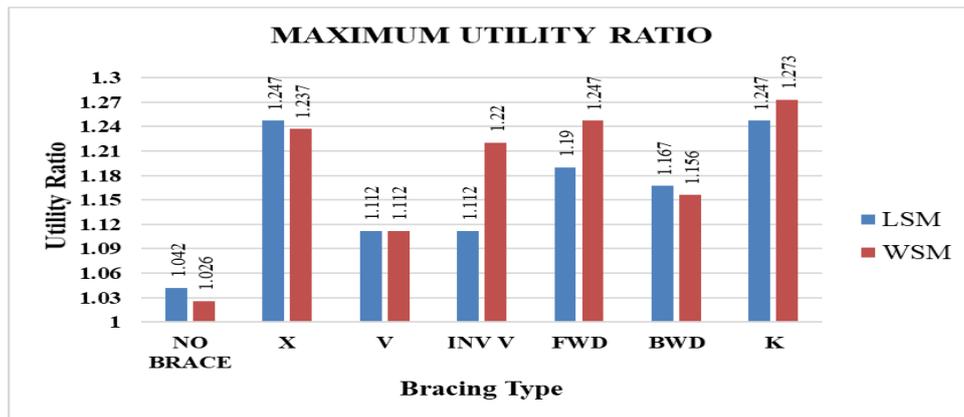


Fig. 9. Graphical Representation of Maximum Utility Ratio Values

VIII. CONCLUSIONS

1. The steel take-off in X Bracing with LSM is the least making it the most economical type of bracing to use whereas PEB with No Brace in WSM has the highest steel take-off.
2. The maximum utility ratio is observed in K braced PEB in WSM method having a value of 1.237 which indicates that the members of the structure are fully utilized to their potential strength.
3. The maximum moment is observed in Inverted V Braced PEB in LSM method.
4. K Braced PEB has the least horizontal displacement in WSM whereas X Braced PEB has least horizontal displacement in LSM.



5. The deflections are well under control in all the types of braced PEB structure, Hence all the structures are safe.
6. Since the steel take-off is more in Working Stress Method it's better to consider the X-braced PEB with Limit State Method to get more economical structure out of all the considered structures.
7. It's advisable to use braced structure than a conventional frame without bracings because both the steel-take off and deflections are higher in the later structure.
8. In both LSM & WSM case it's better to consider X braced PEB structure among all the bracing types since it takes very less steel compared to other braces.

IX. SCOPE FOR FUTURE WORK

1. The structure can be studied for other seismic zones of India using same or different bracings.
2. The comparison of Multistorey, Multi-Gable PEB can be studied with bracings.
3. The study with mezzanine floor in PEB can be studied with bracings.
4. The effects of blast load on braced PEB can be further studied for different zones.
5. The PEB structure can compared with different Standard Codes from different countries to check the behaviour of the same.

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