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Study of P-Delta Effect on Tall Steel Structure

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Abstract- The high rise buildings require high frame structure stability for safety and design purposes. This research focused on P-delta effect on the Tall Steel Structures and compared with linear static analysis. In this study, a 40 storey steel frame structure with m has been modelled by using SAP2000 structural analysis software with the consideration of P-delta effect. At the same time the influence of different bracing patterns has been investigated. For this reason five types of bracing systems including X, V, Single Diagonal, Inverted V , with unbraced model of same configuration are modelled and analysed. The framed structure is analysed for Earthquake load . After analysis, results showed that displacement due to P-Delta effect is 40% more compared to linear analysis and increase in the Axial force is about 8% for bare frame. The X bracing proved to be more stiff and effective with respect to linear analysis and P-Delta analysis. The decrease in the displacement is about 47.5% and 47.9% for linear and second order analysis.

Keywords: P-Delta Analysis, Stability, Bracings, Steel frame structure, Earthquake load

I. . INTRODUCTION

Tall structures are structure that requires stability because they are affected by Earthquake and wind loads. Buildings and structures are considered stable with lateral supports by using either bracing systems to ensure the stability of the building. There have been so many cases in which the structures failed due to instability caused by lateral loads due to which the second order analysis has become significant in tall structure. Earthquake forces are generated due to displacement of the ground which generates seismic waves which effects the structures .The Earthquake forces is converted into Design lateral force as per IS 1893(Part-1):2002.

These lateral forces weaken the structures to resist the Earthquake loads. Therefore, To overcome this problems the structure must be Designed properly, It should be Braced and Connection between the Beam and Columns must be Stiff. All structures undergo some changes in shape under load. the. In an unstable structure, the deformations induced by a load are typically massive and often tend to continue increase as long as the load is applied.As example in Figure 1 is instability of frame structure under horizontal loads. Any horizontal load can cause deformations and clearly shows that the structure has no capacity to resist horizontal loads, nor does it have any mechanism that tend to restore it to its initial shape after the horizontal load is removed .

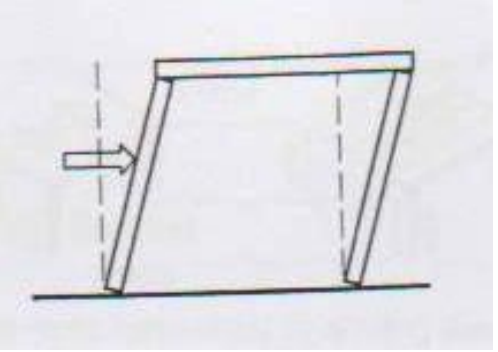

Figure 1

P-Delta analysis is a nonlinear analysis. Figure 2 show the straight elastic bar with horizontal and vertical load at edge of the bar. The axial force,P act on the top of the bar and Horizontal load is applied, due to the horizontal load there is displacement ‘Δ’. Due to the displacement there is increase in the displacement and increase in the moments at the base, these moments are called over turning moments.

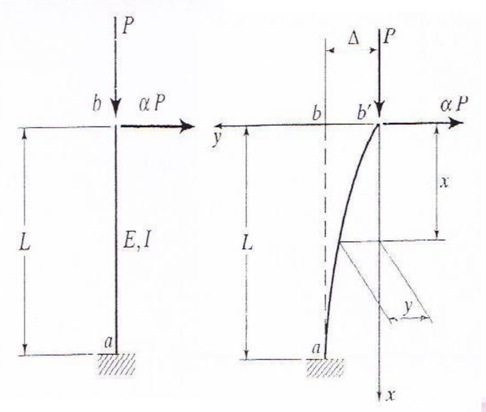

Figure 2

B. **Bracing System**

Braces are important parts in steel frames to resist lateral loads.. A brace is dominantly subjected to axial force and can be represented with a truss element. The force in braces is simple, but they are possibly buckled in compression deformations take place, which makes the relationship between the axial force and the axial deformation of braces becomes complex as shown in Figure 3. N represents the load acted at edge of the bracing and it can be in tension or compression, and at the same time it can becomes shorter or longer indicated as δ.

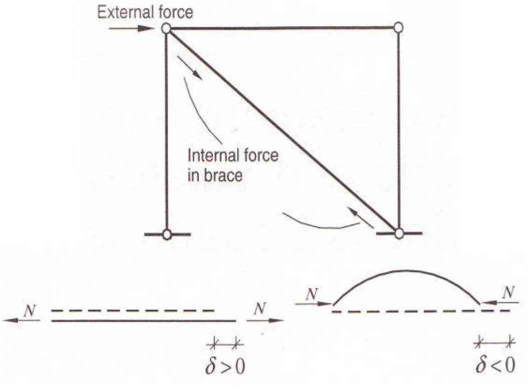

Figure 3

II. **DETAILS OF THE STRUCTURE**.

The plan of the Building is 7by6 having equally spaced columns of 5m.
Different types of bracing that are considered in the analysis

1. X Bracings
2. V Bracings
3. Inverted V Bracings
4. Diagonal Bracing

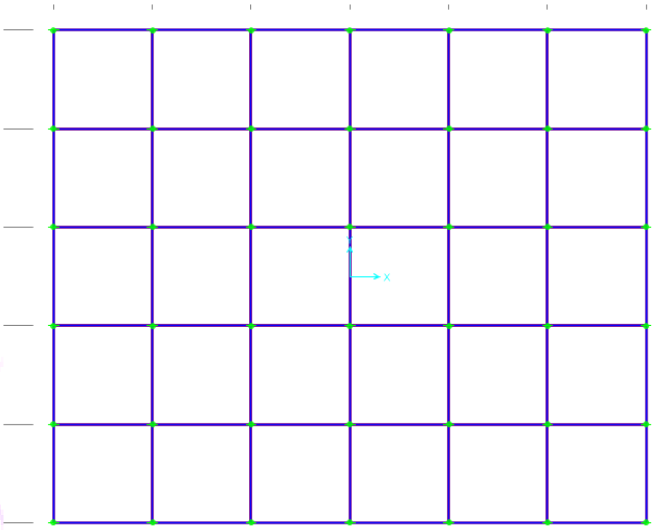

Figure 3. Plan of the Building

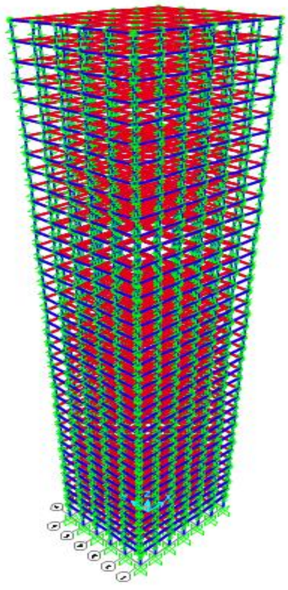

Figure 4. Unbraced Steel Building

System

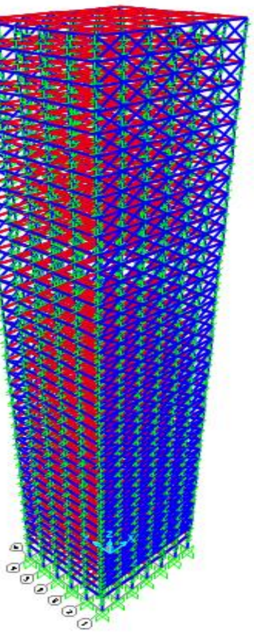

Figure 5. X bracing System

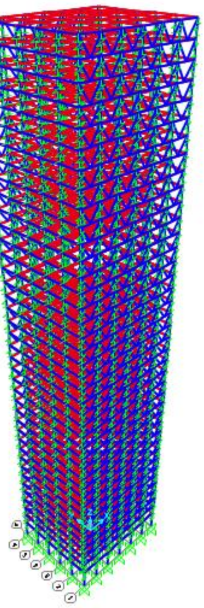

Figure 6. V- Bracing System

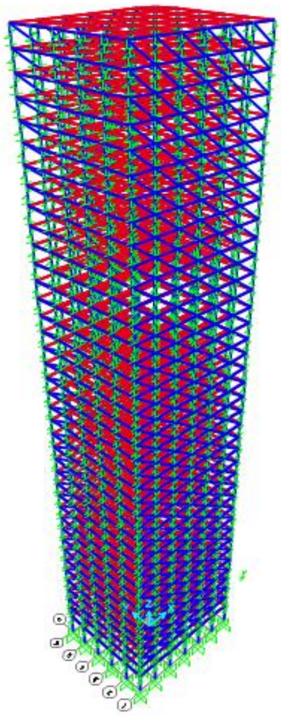

Figure 7. Diagonal bracing System

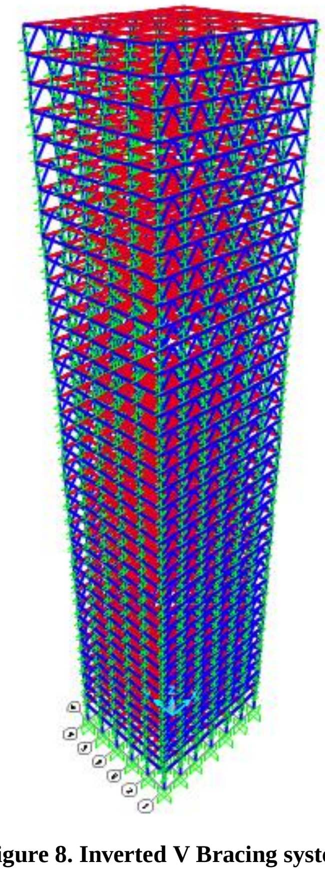

Figure 8. Inverted V Bracing system

TABLE1. **Details of the Building**

Plan Dimension	35m by 30m
Height of Ground storey. Height of the typical storeys	6m 3.5m
Seismic Zone	4
Soil type	2
Beam	ISMB500
Column	I 600*400
Connection of composite floor	Shear studs
Slab	150mm
Bracings	ISA 200*200*25

III. LOAD CALCULATION

A .**Gravity loads**

The loads considered for the following study are as below which are according to the IS codes.

1. Dead load: The self-weight of the structural members is calculate according to the code provisions and is taken care in the software.

2. Live load: 3kN/m2 on roof and 4 kN/m2 of the floors reduction of the loads as per (of IS 875 (Part-2) :1987

B. E**arthquake load**

The Earthquake loads are calculated as per IS 1893(part 1):2002.

Design seismic base shear

Vb=Ah*W
Ah= Design horizontal acceleration spectrum.
W= Seismic weight of building.

$$Ah=\frac{ZISn}{2Rg}$$

Z= Zone Factor as per 1893(part1):2002.= 0.36

I= Importance factor = 1
R= Response Reduction factor = 5

IV. RESULTS AND DISCUSSIONS

A two storey frame is analysed to know the stiffness variation for different types of bracings.

TABLE 2. Stiffness Variation

Stiffness variations		
Types of Bracings	**Linear analysis**	**Second order analysis**
Without Bracings	106179.7	141063.6
X bracing	292825.8	292825.8
V bracing	230414.7	230414.7
Inverted Bracing	234414.7	234414.7
Diagonal Bracing	283446.7	283446.7

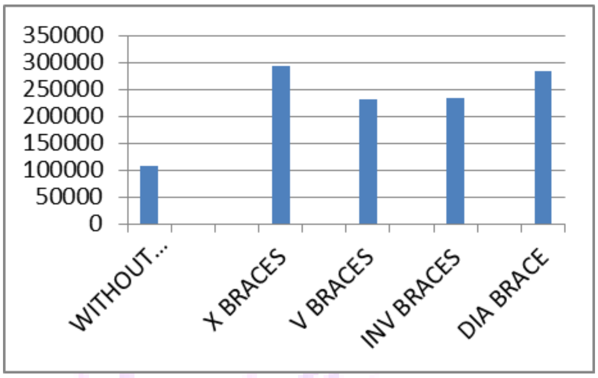

Figure 9 Variation of stiffness for different bracing

A. Storey Displacement in linear analysis

TABLE-3 Displacements at 40 storey for linear analysis

Types of Bracing	Displacements at 40 storey in m
No braces	0.162086
X braces	0.085988
Inverted V Braces	0.092511
V Braces	0.087819
Diagonal Braces	0.084354

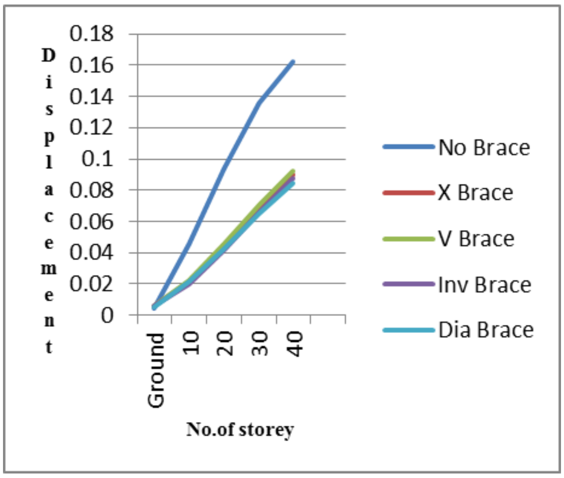

Figure 10 Variations of the Displacement for different Bracings

*A.*Storey displacements in Second order analysis

TABLE-4 Displacement at 40 storey for second order analysis

Types of Bracing	Displacements at 40 storey in m
No Braces	0.17145
X Braces	0.089162
Inverted V Braces	0.095789
V Braces	0.090725
Diagonal Braces	0.087506

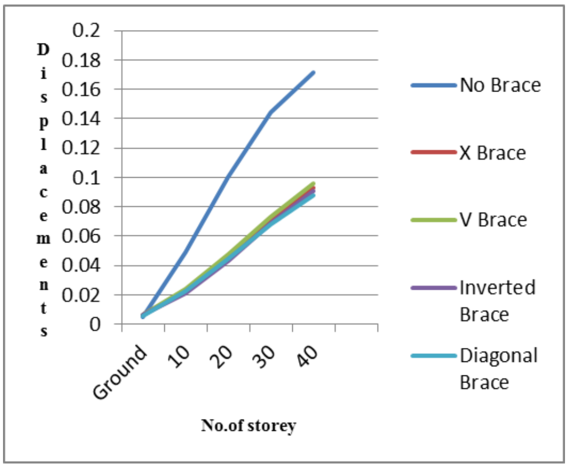

Figure 11 Variation of the Displacements for second order analysis

Table 5. Percentage Reduction in Displacements Due to Braces in Linear Analysis

Types of Bracings	Displacement at 40 Storey	Percentage Reduction
X Braces	0.085988	47.5%
Inverted Braces	0.092511	42.9%
V Braces	0.087819	45.8%
Diagonal Braces	0.084354	47.9%
Without Braces	0.162086	-

Table .6 Percentage Reduction for different braces for second order analysis

Types of Bracing	Displacements at 40 Storey	Percentage Reduction
X Braces	0.089162	47.9%
Inverted Braces	0.095789	44.44%
V Braces	0.090725	47.3%
Diagonal Braces	0.087506	49.1%
No Brace	0.17145	-

A. Axial force variations for different types of bracing linear and second order analysis.

Table 7 Comparison of Axial force with Linear and Second order analysis

Types of braces	Linear analysis	Second order analysis
Without brace	7012	7526.3
X Brace	7718.45	7870.45
V Brace	7757.91	7967.3
Inverted V Brace	5648.02	7472.3
Diagonal Brace	7365.73	7477.3

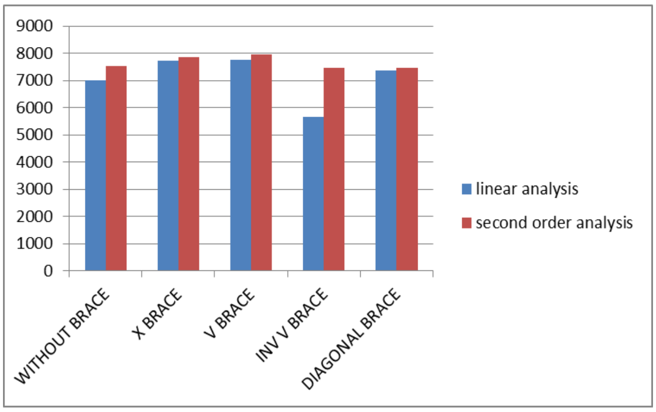

Fig 12 Variations of axial forces for different types of Braces

B. Increase in the Bending moment of the columns

Table8. **Comparison of B.M values for Linear and Second Order analysis**

Types of Braces	Linear analysis	Second order analysis
No Braces	400.2	440.68
X braces	401	420.68
V Braces	527.2	566.06
Inverted V Braces	383.68	486.68
Diagonal braces	356.83	400.78

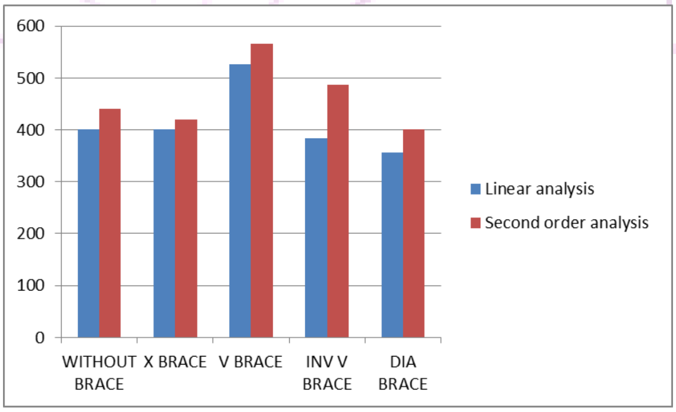

Fig.ure 13 Variation of Bending moments for different types

V. Conclusions

- The Second Order Effect increases the Displacement of the Storey at all the levels.
- The results show that by providing the Braces there is decrease of about 40% in the displacements of the Storey for both linear and Second order analysis

- By comparison there is a percentage Reduction of about 47.5% when X bracing are provided in linear analysis.
- Percentage reduction is of about 47.9% in Second Order analysis when X bracing are provided.
- There is increase of about 10% in axial force in Second order analysis for a bare structure.
- When X Bracing are provided the percentage increase in the axial force in second order analysis is 5% when X bracing are provided.
- The X Bracing are more stiff and they are effective in linear and in second order analysis.
- The Second Order analysis must be done for Tall structure. Because Second Order analysis increases the Bending Moment and Axial forces. So as the structural engineer must consider the Second order analysis.

VI. References

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