P-DELTA EFFECTS ON SCWB & WCSB STEEL FRAMES SUBJECT TO SEISMIC LOADING

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ABSTRACT:

With the increase in population worldwide, the demand for modern houses is increasing. Earthquakes take a huge toll on life and property. Since the effect of seismic forces on structures is quite significant, it is important that the design of the structures must be done in the best possible way to take into account these effects and thereby aiming for an adequate structural response. In this discussion we will address in a concise way, two methods in the design of steel structures, which are linear analysis and second order effects (P-Δ). It is known that a nonlinear analysis is more accurate than a linear analysis, but on the other hand is an inefficient analysis in terms of time consuming with calculations and computer memory. So static P-delta analysis is considered here and compared with the linear response spectrum analysis of SCWB and WCSB steel frames.

Keywords: Seismic Effects, Linear Analysis, Static P-Delta Analysis, Steel Frames

1. INTRODUCTION

As buildings are becoming tall and slender, reducing vibrations under frequent earthquakes for resident well-being and decreasing large forces induced by wind force creates bigger issues. In regions where earthquakes are regular, structural and non-structural parts and contents in high rise buildings can suffer significant damage due to seismic forces. Thus, how high buildings will act under natural catastrophes is necessary in finding total resilience of cities. The important objective of earthquake engineers is to design and build a structure in such a way that damage to the structure and its structural component during the earthquake is minimized.

A building should possess four main attributes, mainly having simple and regular configuration, adequate lateral strength, stiffness and ductility. Buildings having simple regular geometry in plan as well as in elevation, suffer much less damage than the irregular configuration. A building shall be considered as irregular as per IS 1893-2016, if it lacks symmetry and has discontinuity in geometry, mass or load resisting elements. These irregularities may cause problem in continuity of force flow and stress concentrations. Though past researchers worked on this area but detail analysis of steel frames including p-delta effect is not done yet very much [1] to [8].

1.1 AIMS AND OBJECTIVES

The aim of this paper is to evaluate the behavior of Steel buildings under linear analysis and p-delta analysis and thereby determine the differences when subjected under the two conditions. They are subjected to similar loads for the determination of the objective. The analyses have been done under dead load, live load and seismic load conditions. Various parameters such as lateral joint displacements, beam and column shear forces, reactions, bending moments, etc. have been considered for the purpose.

1.2 A BRIEF DESCRIPTION OF SOFTWARE USED

STAAD PRO

STAAD Pro is user-friendly software which is used for analyzing and designing of structure by the structural engineers. STAAD Pro provides a lot of precise and correct results than manual techniques. It's the foremost computer code for 3D model generation and multi-material design. The software is fully compatible with all windows operating system but is optimized for windows XP. STAAD Pro software is used for static or dynamic analysis for structures such as bridges, low rise or high-rise buildings, stadiums, steel structures, etc. First step in STAAD Pro is to specify the geometry of the structure and then the properties of the members are mentioned. Then the supports are generated and loadings are specified on the structure. Finally, the structure is analyzed.

1.3 METHODOLOGY

Here, a G+6 storey steel building frame has been modeled in STAAD PRO for two cases, namely, SCWB (Strong Column Weak Beam) and WCSB (Weak Column Strong Beam). On each frame, at first, linear analysis is carried out and then P-Delta analysis. In the linear analysis, response spectrum analysis has been included for Zone III. As for the P-delta analysis, seismic lateral loads have been given at every storey level. The software makes calculations of various parameters like beam and column forces, nodal displacement, reactions, bending moment, stress, etc. To make a comparative analysis, observations have been made at the same nodes, joints or members of consideration. The comparisons have been enlisted in a tabular format. Conclusions have been drawn based on results.

1. Assume building data
2. Dimensions and geographical location of building
3. Assign cross-section and material properties

The cross section properties used in analysis of building are shown in following table: -

TABLE 1: CROSS SECTION PROPERTIES

MEMBER	SCWB	WCSB
BEAM	ISMB 400	ISMB 500

COLUMN	ISMB 600	ISMB 400

4. Preparation of 2D Model
5. Different types of methods
6. Apply boundary conditions & Loads
7. Design of structure

2. ANALYSIS OF MULTI-STOREY BUILDING FRAME

2.1 STRUCTURAL MODELING

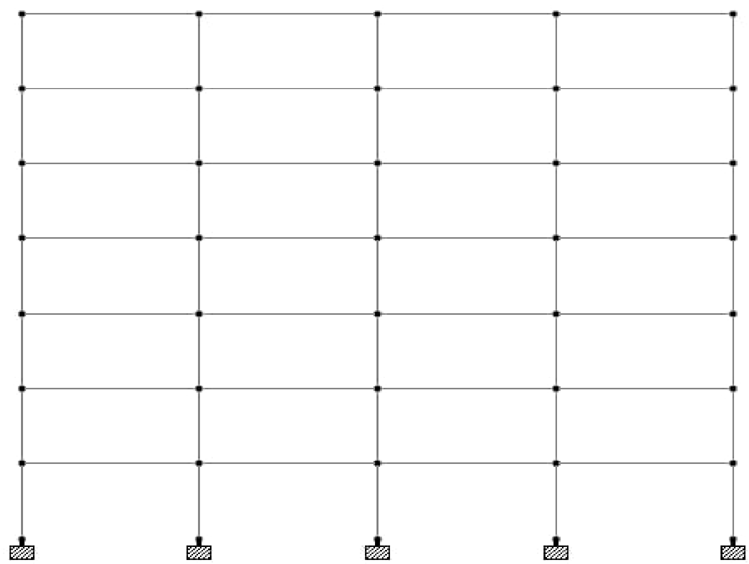

FIG. 1: ELEVATION OF BUILDING FRAME

RESPONSE SPECTRUM ANALYSIS

Seismic analysis is a major tool in earthquake engineering which is used to understand the response of buildings due to seismic excitations in a simpler manner. It can be done in a number of ways. In this project, Response Spectrum Analysis method has been used**.** It is a method to estimate the structural response to short, transient events like earthquakes. As exact time history of the load is unknown, a time-dependent analysis cannot be used. This method is based on a special type of mode superposition. In this, response spectrum is used which is a function of frequency or period, showing the peak response of a simple harmonic oscillator that is subjected to a transient event. The following types of combination methods are used:

- Absolute - peak values are added together
- Square root of the sum of the squares (SRSS)
- Complete Quadratic Combination (CQC)

P-DELTA(Δ) EFFECT ON BUILDING

P-Delta is a non-linear effect that occurs in every structure where elements are subject to axial loads. It is a genuine effect that is associated with the magnitude of applied axial load "P" and displacement "delta". P-delta is a second order loading considering analysis which is required for structures consisting slender columns, slender structure as a whole, steel structure for preventing collapse and for heavy dead load consisting structures.

3. PROBLEM DESCRIPTION

There are two different types of building frames: SCWB and WCSB. The problem arises with WCSB. When it is used in seismic-prone zones, there is high possibility of hinge formation in columns. The column gets weaker in due course of time. Retrofitting of columns is extremely difficult. What happens next is that the column fails eventually. This is highly undesirable. The building is then subjected to high risk as it can pose serious danger to the lives of the residents. Even in zones which are not quite seismic-prone, the risk remains, although to a lower extent.

Naturally, when a building is being constructed, we should ensure the total safety of the building. Thereby, WCSB building frames are almost always avoided. If such frames are used, it will only be a matter of time when collapse comes into effect. When it comes to choosing the material for frames, RCC has been found to be not quite favorable for high seismic-prone areas. Especially in Zone IV and Zone V, when the major earthquakes hit, the strong bond between concrete and steel fails to counteract the shock. The bond breaks, leading to failure of the member.

Many such instances have come into headlines over the years in some cases, the building has been seen to get destroyed like a house of cards. Be it the 2001 Bhuj earthquake or the 2005 Kashmir earthquake, where thousands of casualties have been reported, the above stated reasons played a major part in enhancing the devastation. Had there been a better alternative, engineers would have opted for that. It's high time that the problem should be eradicated.

4. RESULT

The reaction provided in case of P-delta analysis as compared to linear analysis is more for SCWB than by WCSB. The percentage increase from linear to P-delta in case of SCWB is much lesser when we compare it with WCSB, thereby illustrating that SCWB Steel frame is better in resisting nodal displacements. The percentages have been listed below:

TABLE 2: NODAL HORIZONTAL DISPLACEMENT VALUES

DESIGN FEATURE	FRAME TYPES	LINEAR ANALYSIS	P-DELTA ANALYSIS
NODAL HORIZONTAL DISPLACEMENTS AT DIFFERENT FLOOR LEVELS	SCWB	32.599 mm	39.106 mm
		30.561 mm	36.163 mm
		26.836 mm	31.293 mm
		21.976 mm	25.198 mm
		16.159 mm	18.218 mm
		9.717 mm	10.796 mm

		3.624 mm	4.004 mm
		0 mm	0 mm
	WCSB	34.049 mm	44.648 mm
		32.670 mm	42.419 mm
		29.468 mm	37.874 mm
		25.082 mm	31.879 mm
		19.624 mm	24.715 mm
		13.184 mm	16.497 mm
		6.059 mm	7.539 mm
		0 mm	0 mm

TABLE 3: VARIATION OF NODAL HORIZONTAL DISPLACEMENTS

FLOOR LEVELS	**Percentage Increase**	
	SCWB	**WCSB**
Roof	19.96%	31.13%
6th	18.38%	29.84%
5th	16.60%	28.53%
4th	14.66%	27.10%
3rd	12.74%	25.94%
2nd	11.10%	25.13%
1st	10.48%	24.43%

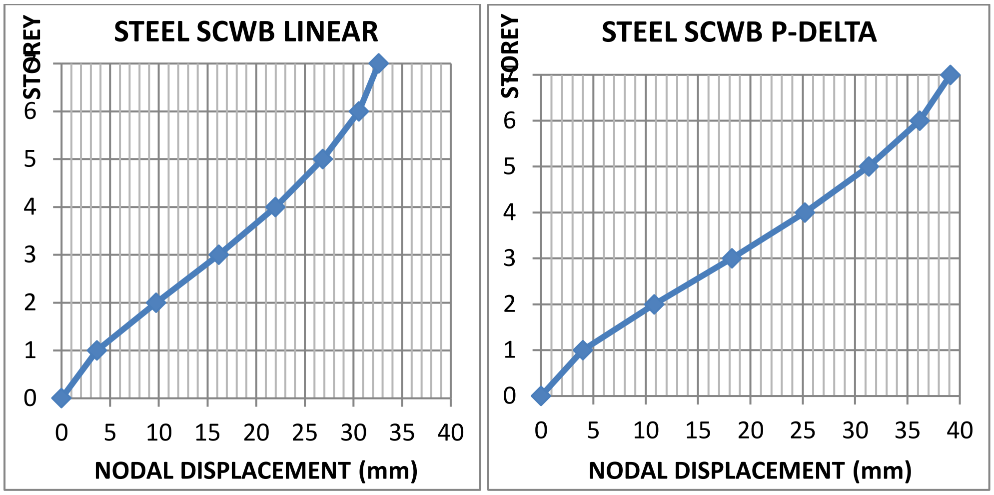

FIG 2: STEEL SCWB NODAL DISPLACEMENT GRAPHS

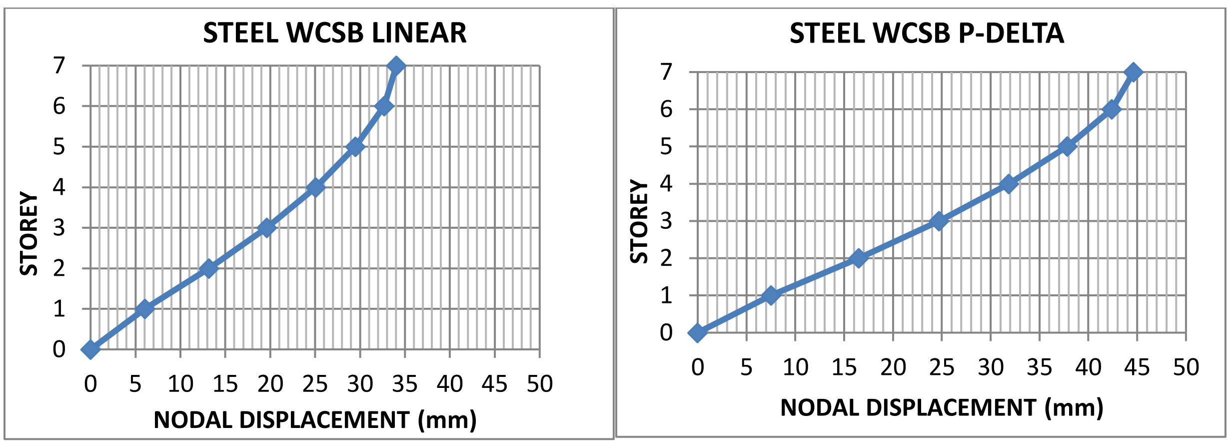

FIG 3: STEEL WCSB NODAL DISPLACEMENT GRAPHS

TABLE 4: STEEL FRAME RESULTS

DESIGN FEATURES	FRAME TYPES	LINEAR ANALYSIS	P-DELTA ANALYSIS
TIP DEFLECTION	SCWB	33.504 mm	40.518 mm
	WCSB	34.674 mm	45.097 mm
COLUMN FORCES			
a) AXIAL FORCE	SCWB	1693.524 kN	1868.638 kN
	WCSB	1712.947 kN	1913.340 kN
b) SHEAR FORCE	SCWB	79.557 kN	77.48 kN
	WCSB	69.820 kN	75.189 kN
c) BENDING MOMENT	SCWB	200.677 kN	210.260 kN
	WCSB	114.037 kN	133.015 kN
TIME PERIOD	SCWB	1.820 sec	
	WCSB	1.878 sec	

5 CONCLUSION

P-delta investigations and linear analysis are carried out for G+6 storey Steel framed structure using STAAD. On the basis of results obtained, following conclusions are drawn.

We can conclude that we cannot take liberty in using any type of frame at any region. We have to know that the building in question is in which type of zone. If the building is situated in a seismic-prone area like Zone IV or Zone V, we should opt for steel structure. In a RCC frame, there is high chance that the bond between concrete and steel will not be able to resist when an earthquake of high magnitude strikes. This is not the case with steel structures. Steel will be a much safer option in high seismic zone areas. Also, the ductility of steel is high whereas that of concrete is low. However, nowadays, steel structures are being used even in zones of lower earthquake susceptibility to provide protection for the worst case.

We should go for SCWB type because if we opt for WCSB, hinge formation may occur in column. In SCWB, cracks will occur in beam as it is the beam which is weaker. This can be corrected by retrofitting. But in WCSB, hinge formation will occur in column, which will eventually lead to failure of column, and ultimately, the collapse of the building.

This concludes P-delta has more effect in designing of a structure rather than first order effect. P-Delta and Linear static analysis of all the models reveals that P-Delta effects significantly influence the displacement and have higher value than linear analysis.

1) Our study shows that SCWB is preferable over WCSB. The post- seismic hazard for WCSB is high. Also, for SCWB, there is just 10-20% increase in p-delta analysis, whereas in WCSB, the increase is 40-50%. Thus, it is evident that the effects of P-delta are also better resisted in SCWB frames than WCSB frames.
2) On comparing linear to P-delta analysis, lateral displacement keeps on increasing with the number of storeys after applying P-Delta effect. After applying P-Delta for both cases SCWB and WCSB, the value of axial forces is increased. The bending moment in columns increased after applying P-Delta effect. Hence, it is certain that these effects of p-delta are also better resisted in SCWB frames than WCSB frames.

This paper presented the variation of displacement with increasing height, slenderness; considering P-Delta analysis keeping linear analysis as base. Variation of displacement for each case under two analysis procedures identified that displacement increases with increase in height, but it is more severe for P-Delta analysis. P delta effect is a secondary effect. It is the abrupt change in the base shear or overturning moment of a tall structure when it is subjected to a lateral displacement. Usually it is not considered in the analysis of structure. From this project I conclude that P delta effect is very important in the case of high-rise building. Considering this effect will lead to the collapse of buildings in earthquake or heavy wind. For regular building the p delta effect will increase the displacement, shear, moment. For irregular buildings the effect may increase or decrease the displacement, shear, moment. The P-delta effect on irregular buildings is unpredictable. It will depend on irregularity.

Linear Analysis and P-Delta Analysis both are necessary for Steel structures and have to be used after proper understanding to prevent any catastrophe.

6 FUTURE SCOPE

Earthquake resistant structures are important nowadays to withstand the seismic effects. The reinforced concrete building can be damaged during earthquake due to its brittle condition. Lack of proper awareness regarding structural behaviour needs to be addressed to reduce the damages to structures. The role of structural engineers is important in planning and designing the earthquake-resistant structures. So in future by using proper techniques, earthquake effects on the structures can be mitigated to save lives and property and economy.

The knowledge of the design principles for seismically-resistant structures and earthquake engineering technology enable an architect to utilize the structural measures for seismic resistance while designing the solution and together, with the structural designer, to accept the responsibility for the building realization in these conditions. By designing buildings with a high degree of seismic architecture, the architect achieves the set aesthetic building qualities without endangering the stability of a structure.

Non-symmetric and irregular buildings can also be analyzed which will provide even higher variations in results. In the coming days, studies should be done to observe how other aspects influence the effects of P-Delta. Like nonlinear dynamic analysis could be used to simulate to suggest the designers the most suitable analysis for medium to high-rise structures with storey limit. Further work and studies on the P-delta effect is highly recommended to eliminate the risk of failures.

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