WWW.IJRPR.COM

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Secondary Effect on Highrise Building with Braced Core, Outrigger and Belt Truss Structural System

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ABSTRACT

High-rise structure is the demand of modern period as it provides accommodation to a satisfactorily quantity of public in a lesser area. Analysis of high-rise buildings is very complicated by conventional methods. Generally, the analysis of buildings is done by using linear elastic methods, which is first order structural analysis. The first order analysis is performed by assuming small deflection behaviour where the resulting forces, moments and displacements take no account of the additional effect due to deformation of the structure under vertical loads prior to imposing lateral loads. (i.e. In first order analysis of structures, the effects of change in the structure actions due to structure deformations are neglected.) However, when a structure deforms, the applied loads may cause additional actions in the structure this is called second order or p-delta effects.

P-delta effect is secondary effect on structure. It is also known as 'Geometric nonlinearity effect'. As number of storey's increases, P-delta effect becomes more important. If the change in bending moments and displacements is more than 10% for service loading conditions, The P-delta effect should be considered in design.

In this study the P-delta effect on (G+45) high rise building is studied. Both, Linear static analysis (without P-delta effect) and nonlinear static analysis (with P-delta effect) on high rise buildings with and without braced core system, outriggers and belt truss is carried out. The high-rise buildings with braced core, outriggers and belt truss are modelled and analyzed using ETABS v 19 software. Load combinations for analysis is set as per IS-456(2000). The variation in the story displacements, column bending moments, and shear forces with and without consideration of P-delta effect is for all cases are compared.

Keywords: ETABS 2019, High-Rise Building, Secondary Effects

INTRODUCTION

We know that the construction of high-rise buildings increases day by day because it gives accommodation to a large number of people in a small place. It is utilized as a residential, commercial building, or other purposes including motel, retail, or with numerous objectives integrated. An extremely tall high-rise structure is referred to as a skyscraper.

Construction of high-rise buildings evolved feasible with the invention of the elevator and more sufficient construction materials with less cost. Construction of high-rise structures has technological and financial benefits in regions of high population density.

1.1 Various Definitions of High-Rise Buildings:

- Historically, the term first referred to buildings with 10 to 20 floors in the 1880s.
- A building that has over 40 floors and is taller than 150 m (492 ft) then it said to be a Skyscraper. If the building's height above 300 m (984 ft), then the buildings are said to be supertall skyscrapers, while the building's height is beyond 600 m (1,969 ft) are known as mega tall skyscrapers.

- The multi-storied building height is between 35–100 meters (or) the number of floors is between 12–39 floors defined a high-rise building by Emporis Standards.
- In India, a building is one with four floors or more or 15 to 18 meters or more in height is known as a high-rise building by building code of Hyderabad.
- Most building engineers, inspectors, architects, and similar professionals define a high-rise as a building that is at least 75 feet (23 m).

1.2 HISTORICALLY BACKGROUND OF HIGH-RISE BUILDING:

- The E. V. Haughwout Building in Manhattan is the world's first skyscraper due to it was the first building to install successfully a passenger elevator, in 1857.
- The Home Insurance Building in Chicago is considered as the world's first skyscraper by many people due to its steel skeleton structural system.
- Later in 1930 the Chrysler Building took the lead as the tallest building in the world, scraping the sky at 1,046 feet (319 m) which is designed by William Van Alen. It is an Art Deco style masterpiece with an exterior crafted of brick.
- In 1931 "The Empire State Building", with a height of 1,250 feet (381 m), it took the top spot as tallest building, and towered above all other buildings until 1972. And also, it is the first building to have more than 100 floors it has 102. It structure is designed by Shreve, Lamb and Harmon in the modern Art Deco manner. The building grabs its caption from the sobriquet of New York State. The antenna pole augmented in 1951 gave rise to crown height to 1,472 feet (449 m), reduced in 1984 to 1,454 feet (443 m).
- In 1972 "The World Trade Center" officially reached full height, was completed in 1973. It consisted of two tall towers and several smaller buildings. The buildings existed for 28 years, until the September 11 incursions demolished the towers in 2001. Several governmental entities, economic companies, and legislation corporations named as towers home.
- The Sears Tower was finished in 1974, one year after the World Trade Center, and defeated it as the world's tallest structure. It is the first structure to utilize the "bundled tube" structural system, which is designed by Fazlur Khan. The structure was not exceeded in height until the Petronas Towers were built in 1998, but persisted the tallest in some districts until Burj Khalifa overtook in all aspects in 2010.

1.3 TYPES OF HIGH-RISE BUILDINGS:

a) Office high-rise buildings
b) Hotel high-rise buildings
c) Residential and apartment high-rise buildings
d) Mixed-use high-rise buildings

1.4 Objective of Study:

1) To know how to analyse tall building with and without P-Delta analysis by using ETABS.
2) To determine P-delta analysis influence on the variation of responses of the structure such as bending moments, displacements, axial force and story stiffness when compared to linear static analysis.
3) To study the effect of braced core, outriggers, belt truss on the parameters bending moments, displacements, axial force and story stiffness.
4) To study the effect of outriggers and belt truss system on the parameters bending moments, displacements, and axial force.
5) And to understand the variation in the performance of the tall building with braced core, outrigger and belt trusses with and without considering P-Delta effect.

2.0 Analysis of the Structure:

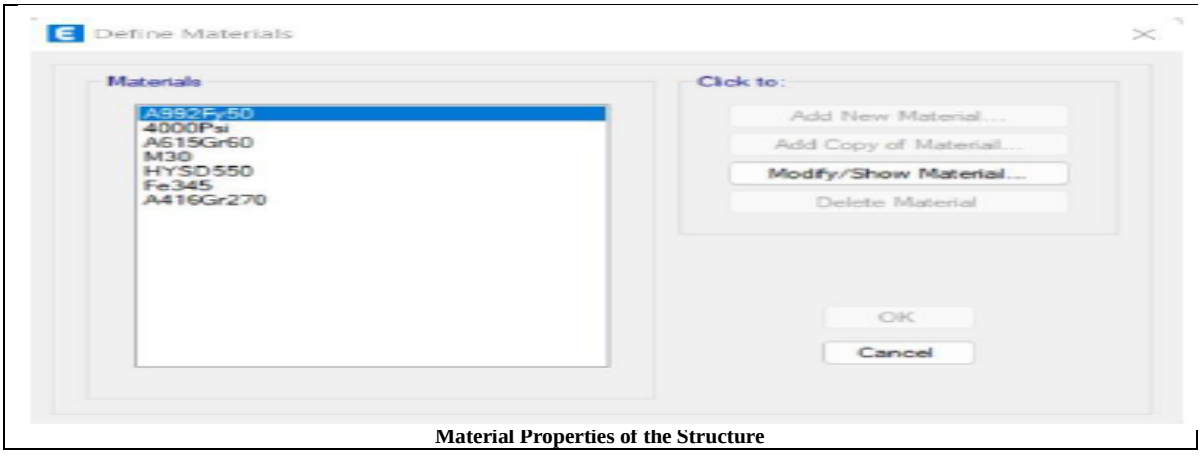
To observe the effects of P-delta, three different cases are taken.

- Model 1: A G+45 High-Rise building without braced core.
- Model 2: A G+45 High-Rise building without braced core.
- Model 3: A G+45 High-Rise building with braced core.
- Model 4: A G+45 High-Rise building with braced core and outriggers.
- Model 5: A G+45 High-Rise building with braced core, outriggers & belt truss.

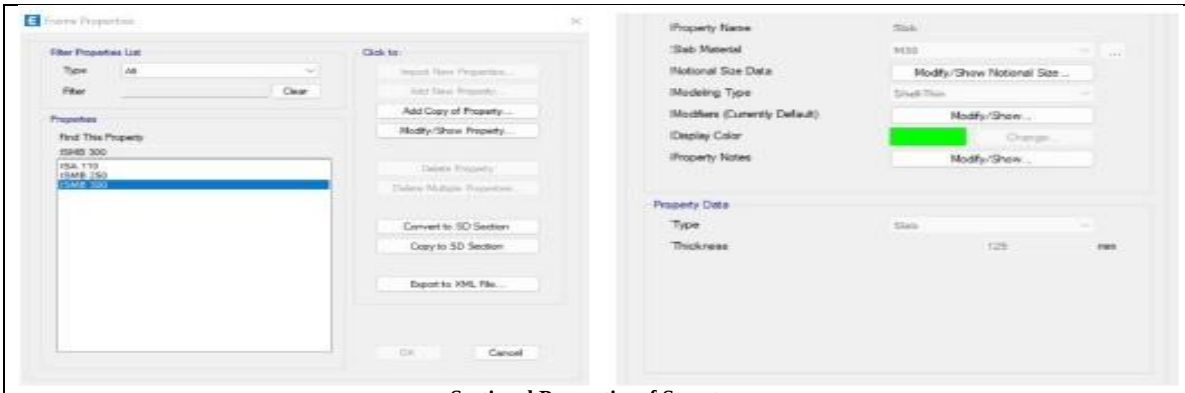
Plan size	36m x 23m
No. of floors	G+44
Storey Height	135.5m
Type of soil	II
Grade of concrete	M30
Grade of Steel	Fe500
Column Size	450mm x 450mm
Slab Thickness	150mm
Zone	II
Live Load	3 kn/m^2
Floor Furnish Load	1.5 kN/m^2
Earthquake Load	As per IS:1893(Part-I)-2002
Zone Fzctor	0.10
Response Reduction Factor	5
Wind Load	As per IS:1987(Part-3)
Wind Speed	50m/s
Terrain Category	3
Structure Class	C

2.1 P-DELTA ANALYSIS AND RESULTS OF TALL BUILDING BY USING ETABS:

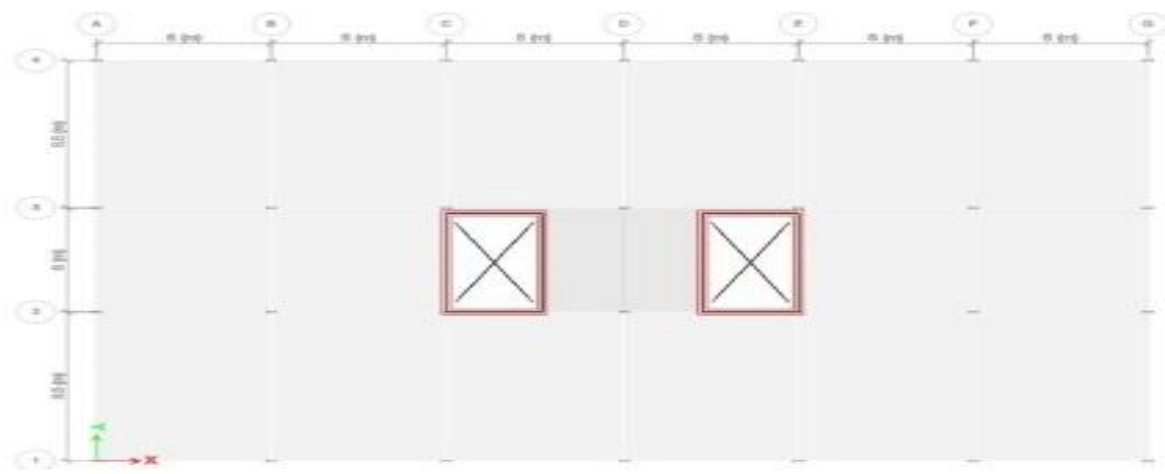
Step by Step Process



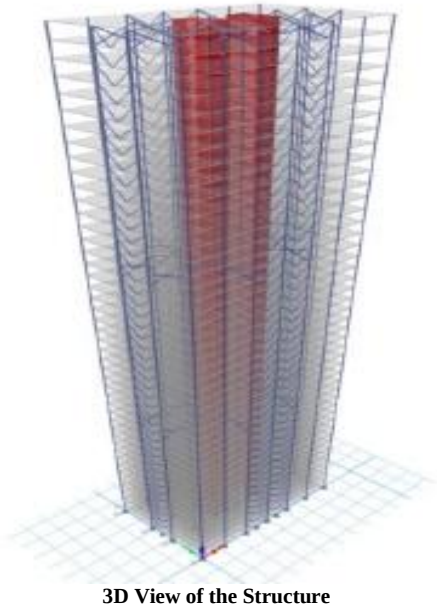
Material Properties of the Structure



Sectional Properties of Structure

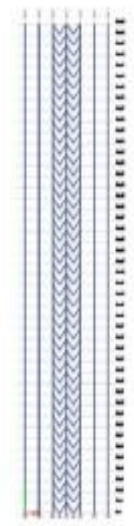
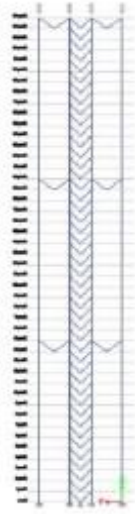


Structural Plan of the Structure



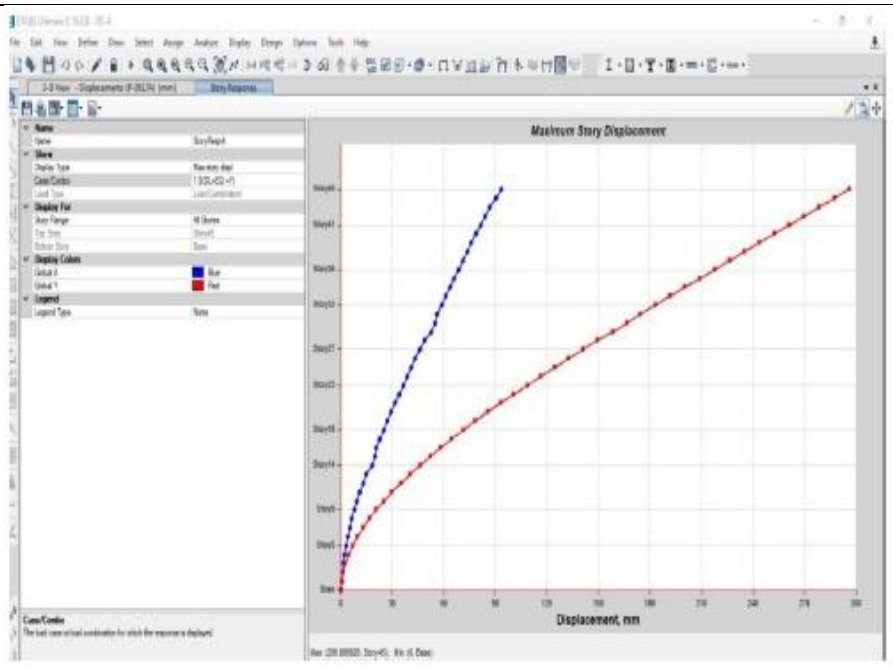
3D View of the Structure

Similarly, the modelling of buildings for remaining cases is also done by same procedure but with addition of outriggers and belt truss systems.

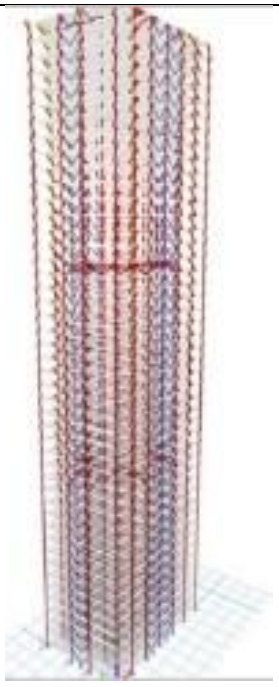
		
Structure With Braced Core System	**Structure With Braced Core System and Outriggers**	**Structure With Braced Core System, Outriggers and belt truss**

- After completion of modelling, then we need to define load pattern.

1) Load Patterns which consider for the Analysis
2) P-Delta Function
3) Defining Mass Source
4) Load Cases
5) Load Combinations

	
Deformed shape of Structure	**Response Plot of the Structure**

Support Reactions



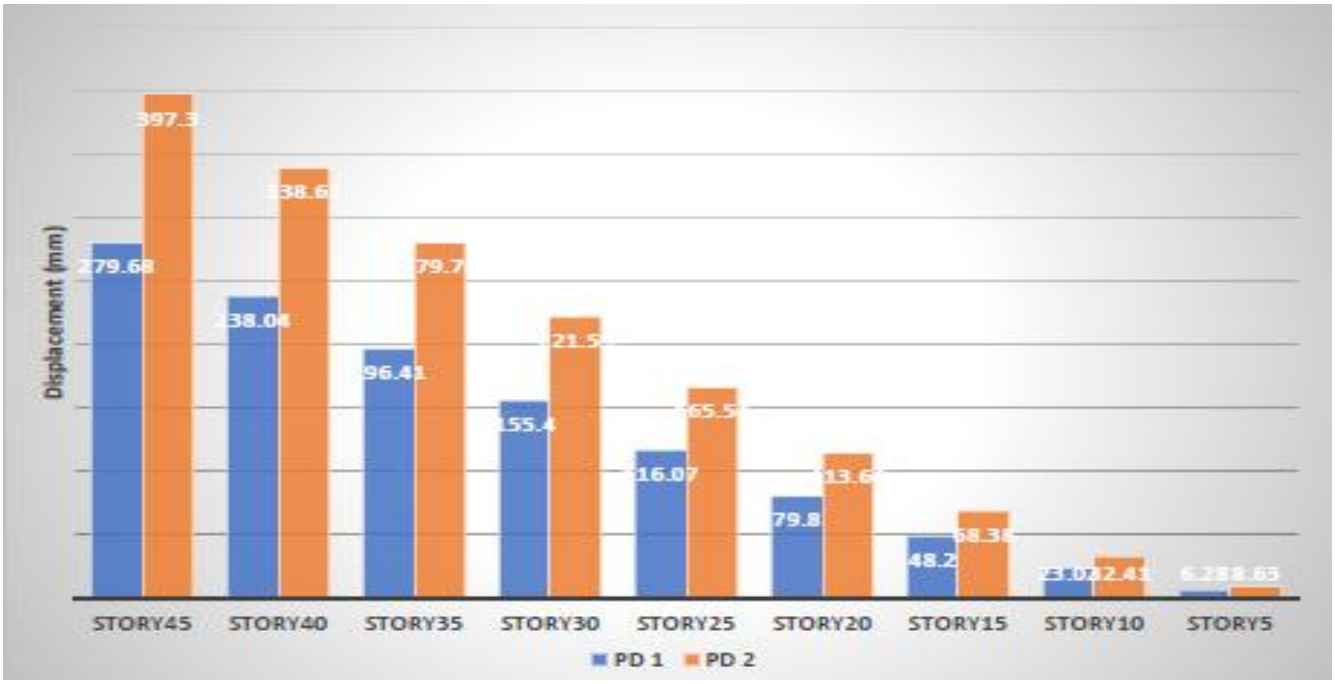
Bending Moments of the Structure

3.0 Results and Discussions:

As mentioned earlier, to observe the effects of P-delta, four different storey cases are taken where storey variation starts from storey 5 to storey 20. Each of the storey case is performed linear Static and P-delta analysis separately with appropriate command. In order to study P-Delta effect on tall buildings, I have taken a (G+55) tall building with and without outrigger and Belt truss. The variation of displacements, storey shear, axial force and bending moment obtained from linear static analysis and P-delta analysis.

tory No.	Displacement		% of Difference
	PD 1	PD 2	
Story 45	279.68	397.3	29.60483262
Story 40	238.04	338.61	29.70083577
Story 35	196.41	279.78	29.79841304
Story 30	155.4	221.59	29.87048152
Story 25	116.07	165.54	29.88401595
Story 20	79.8	113.66	29.79060355
Story 15	48.20	68.38	29.51155309
Story 10	23.02	32.41	28.97253934
Story 5	6.28	8.63	27.23059096
		Avg	29.37376287

Displacement Analysis of ex: G+45 Building



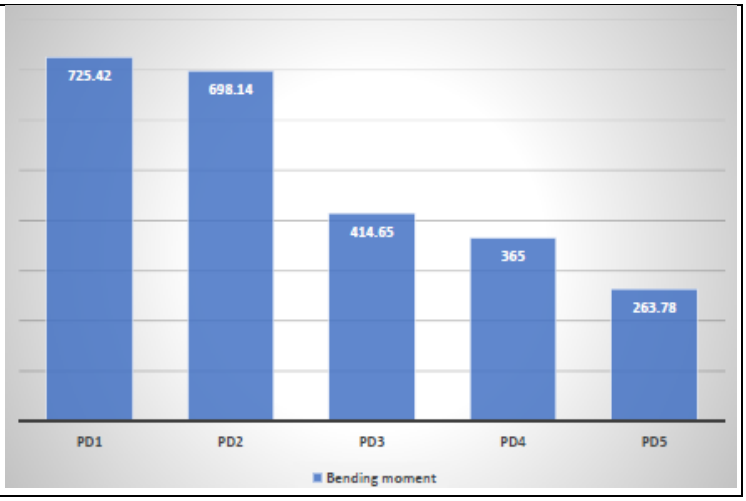
Displacement of (G+45) High-Rise Building with & without P-Delta

In the same manner all the other storey buildings will get the displacements in the same manner, lastly we find out bending moments of each models.

3.1Analysis of Bending Moment, Column Shear& Axial Forces:

Model	Bending Moment
PD1	725.42
PD2	698.14
PD3	414.65
PD4	365.00
PD5	263.78

3.1 (a) Bending moment Analysis

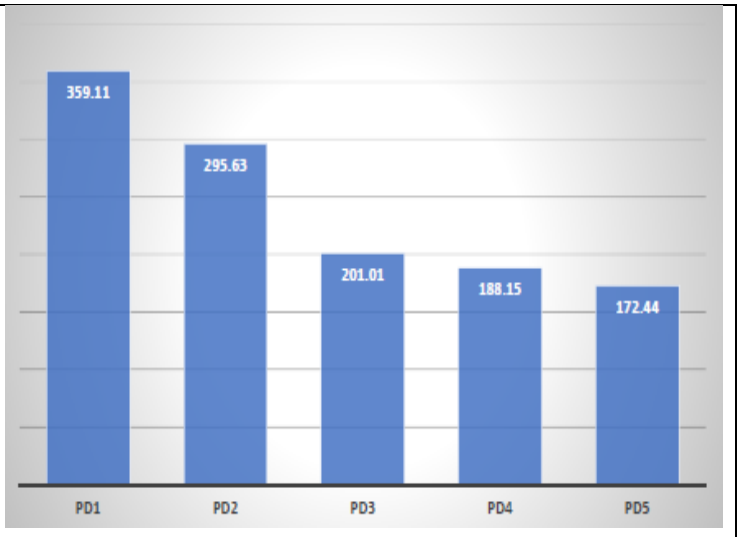


(a) Representation of Bending Moment

Model	Shear Force
PD1	359.11
PD2	295.63
PD3	201.01
PD4	188.15
PD5	172.44

3.1 (b) Column Shear Force Analysis **(b) Representation of Column Shear Force**

Model	Shear Force
PD1	359.11
PD2	295.63
PD3	201.01
PD4	188.15
PD5	172.44



3.1 (c) Axial Force Analysis **(c) Representation of Axial Force**

Conclusions:

In this study, P-delta investigations and linear static analysis are carried out for (G+55) tall building and tall building with outriggers and belt truss is studied. ETABS software is used for P-Delta Analysis for all cases. By studying the results of analysis, following conclusions are drawn.

1) From the results we conclude that, before designing the any structure it is necessary to check the P-delta analysis is required are not especially for tall buildings. And also, it shows that the P-delta effects have more effect in designing of a structure rather than first order effects.
2) Displacements, bending moments, shear force results without P-delta effect is higher when compared with P-delta effect.
3) The storey displacements, bending moments reduces and stiffness increases with increasing lateral resistance by providing braced core, outrigger and belt trusses.
4) Axial forces in column at ground floor is increases after the P-delta analysis.
5) The result obtained that axial force decreases with addition of braced core, outriggers and belt trusses.
   And building with braced core, outriggers and belt truss are more effective.

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