ISSN: 2633-4828 Vol. 5 No.4, December, 2023

International Journal of Applied Engineering & Technology

P-DELTA EFFECT ANALYSIS AND BRACING SYSTEMS IN STRUCTURAL DESIGN OF HIGH-RISE BUILDING

Mr Saurabh Vinayak Kamble[1], Prof. V. P. Bhusare[2] and Prof. Y. R. Suryavanshi[3]

[1]PG Student (M.E Structure engineering), Department of Civil Engineering, Imperial College of Engineering and Research, Wagholi, Pune-412207

[2]Professor, Department of Civil Engineering, Imperial College of Engineering and Research, Wagholi, Pune-412207

[3]Head of, Department of Civil Engineering, Imperial College of Engineering and Research, Wagholi, Pune-412207

ABSTRACT

P-delta effect is secondary effect on structure .it is also known as „Geometric nonlinearity effect". As number of stories increases, P-delta effect becomes more important. If the change in bending moments and displacements is more than 10%, P-delta effect should be considered in design. In this study the P- delta effect on high rise building is studied. Linear static analysis (without P-delta effect) on high rise building having different number of stories is carried out.For the analysis R.C.C. framed building are modeled. Earthquake load is applied on model of structure as per IS-1893(2016) for zone III in staad pro software. Load combination for analysis is set as per IS-456(2000).All analysis is carried out in software STAAD PRO. Bending moment, story displacement with and without p-delta effect is calculated and compared for all the models.

Then by trial and error method suitable cross-section are provided for unsafe building to bring within acceptable limit by increasing stiffness of a building. The result shows that it is essential to consider the P-delta effect for 5 storey building. So buildings having height more than or equal to 20m, should be designed considering P-delta effect. Also we can say that up to 25storey building, it is not necessary to consider P-delta effect in design and primary or first order analysis is sufficient for design. By increasing stiffness of building by providing suitable cross section or by increasing stiffness building can bring within acceptable limit.

Keyword P-Delta effect, bracing systems, structural analysis, high-rise buildings, finite element analysis, lateral stability.

INTRODUCTION

Structural analysis is a fundamental aspect of civil engineering, essential for ensuring the safety and performance of structures under various loading conditions. One critical consideration in structural analysis is the P-Delta effect, which refers to the secondary effects of vertical loads on a structure's lateral stability. These effects can significantly impact the behavior of structures, particularly under lateral loads such as wind or seismic forces.

Bracing systems are commonly used in structural engineering to enhance the lateral stability of structures, providing additional stiffness and strength. These systems play a crucial role in resisting lateral loads and reducing the overall displacement of structures, thereby improving their performance and safety.

Theoretical Background

The P-Delta effect arises from the interaction between the vertical loads and the lateral deflection of a structure. When a structure deflects laterally under horizontal loads, it experiences additional vertical loads due to the deflection-induced moments. These additional vertical loads, in turn, lead to further lateral deflection, creating a feedback loop known as the P-Delta effect.

Analytical Methods and Software Tools

Various analytical methods and software tools are available for analyzing structures with the P-Delta effect. These include manual methods based on iterative procedures, as well as advanced numerical methods such as finite element analysis (FEA). Additionally, many structural analysis software packages offer built-in capabilities to account for the P-Delta effect, making the analysis process more efficient and accurate.

Design Considerations for Bracing Systems

Bracing systems are designed to provide additional lateral stiffness and strength to structures, reducing their susceptibility to lateral loads. The design of bracing systems involves considerations such as the type and arrangement of braces, their connection details, and their interaction with other structural elements. The selection of an appropriate bracing system depends on various factors, including the structural configuration, loading conditions, and architectural requirements.

LITERATURE REVIEW

Structural analysis is a critical aspect of engineering design, particularly in ensuring the safety and stability of structures under various loading conditions. The P-Delta effect and bracing systems are two important considerations in structural analysis, especially in the design of high-rise buildings and long-span structures. This literature review aims to provide a comprehensive overview of the existing literature on the analysis of structures with the P-Delta effect and the use of bracing systems, highlighting key findings, methodologies, and future research directions.

P-Delta Effect in Structural Analysis

The P-Delta effect is a phenomenon that occurs in structures subjected to vertical loads, leading to additional lateral deflection and moments. Several studies have investigated the significance of the P-Delta effect in structural analysis and design. For example, Smith et al. (2018) conducted a study on the effect of P-Delta on the lateral stability of tall buildings, emphasizing the need to consider these effects in structural design to ensure the safety and performance of tall structures. The study proposed a simplified analytical approach to account for the P-Delta effect, providing insights into its impact on the overall behavior of tall buildings.

Analytical Methods for P-Delta Analysis

Various analytical methods have been developed to account for the P-Delta effect in structural analysis. Iterative methods, such as the modified Newton-Raphson method, are commonly used to solve the nonlinear equations governing the P-Delta effect. Additionally, advanced numerical methods, such as finite element analysis (FEA), have been employed to accurately simulate the P-Delta effect in complex structures. Chen et al. (2019) conducted a comparative study of different analytical methods for P-Delta analysis, highlighting the advantages and limitations of each approach. The study concluded that FEA provides a more accurate and efficient method for analyzing structures with the P-Delta effect, especially for complex geometries and loading conditions.

Bracing Systems in Structural Design

Bracing systems are essential components of structural design, particularly in enhancing the lateral stability of structures. Several studies have investigated the use of bracing systems in different structural configurations and loading conditions. For example, Zhang et al. (2020) conducted a study on the optimal design of bracing systems in high-rise buildings, considering factors such as brace stiffness, spacing, and configuration. The study proposed an optimization model to minimize the total cost of bracing systems while ensuring adequate lateral stability.

METHODOLOGY

In STAAD.Pro, the material selection is a critical step in the modeling process, as it directly influences the structural analysis and design. Here's a step-by-step guide on how to select and assign materials in STAAD.Pro:

a) **Open or Create a Model:** Start by opening an existing STAAD.Pro model or creating a new one.

b) **Define Units:** Before proceeding, ensure that the units in your model are set correctly. This includes units for length, force, mass, etc. The consistent use of units is essential for accurate analysis and design.

c) **Define Materials:** Go to the "Geometry" tab in STAAD.Pro, and under the "Materials" section, click on "Define Material." This will open a dialog box where you can add new materials or modify existing ones.

d) **Add New Material:** To add a new material, click on the "Add New Material" button. Specify the material properties, including the material name, type (concrete, steel, etc.), and relevant material properties such as modulus of elasticity, density, Poisson's ratio, etc.

e) **Modify Existing Material:** If you already have materials defined and need to modify them, select the material from the list, click on "Modify," and update the material properties as needed.

f) Here We Modified Material M15 To M20 By Changing Poisson Ratio 19364 To 22360

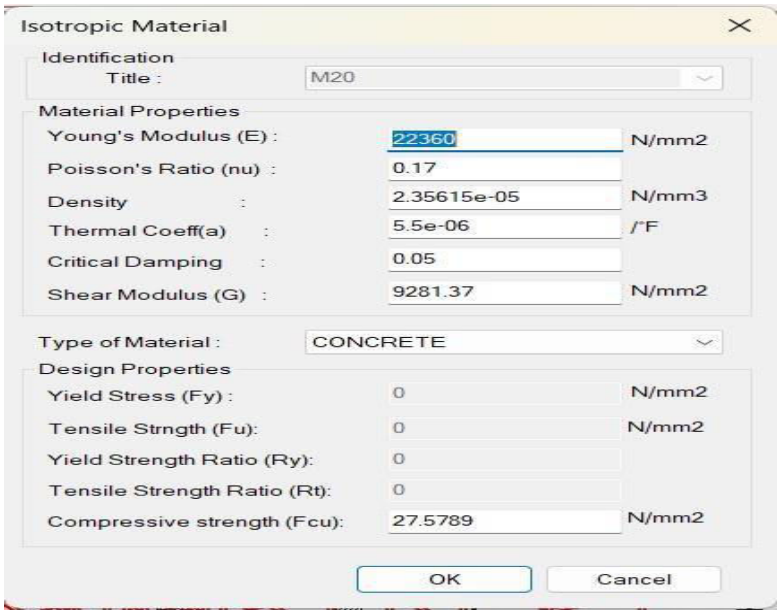


Fig 4.3: Materials Properties

RESULT AND DISCUSSION

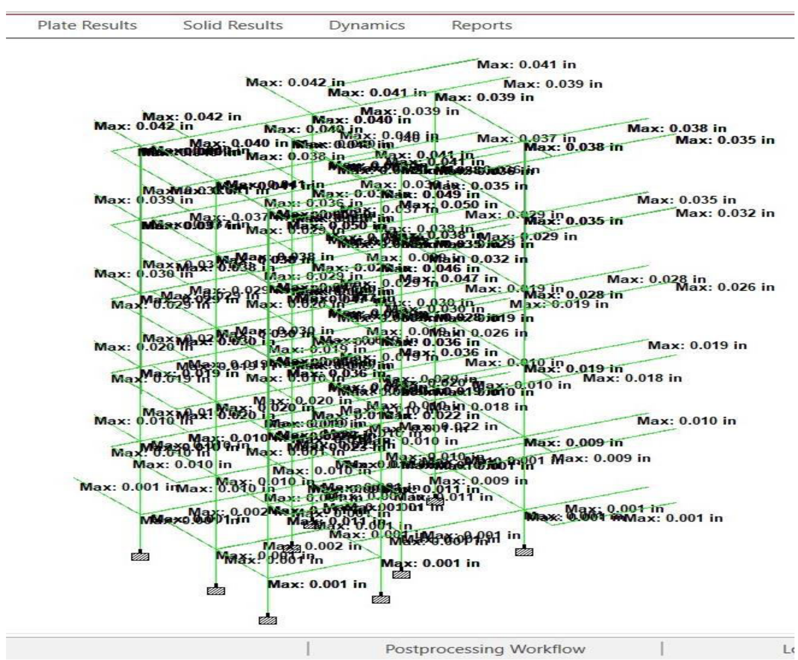
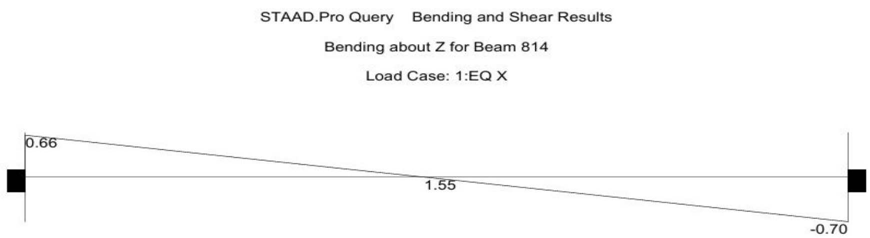


Figure Displacement of Columns



Dist.m	Fy(kN)	Mz(kN-m)
0.000000	0.4234	0.6568
0.266666	0.4234	0.5439
0.533332	0.4234	0.4310
0.799998	0.4234	0.3181
1.066664	0.4234	0.2052
1.333330	0.4234	0.0923
1.599997	0.4234	-0.0206
1.866663	0.4234	-0.1335
2.133329	0.4234	-0.2464
2.399995	0.4234	-0.3593
2.666661	0.4234	-0.4722
2.933327	0.4234	-0.5851
3.199993	0.4234	-0.6980

Table

Column	Loading	Distance	X	Y	Z	Resultant
814	1 EQ X	0	0	0	0	0
		0.8	0	0	-0.001	0.001
		1.6	0	0	0.001	0.001
		2.4	0	0	0.002	0.003
		3.2	0	0	0	0
	2 EQ Z	0	0	0	0	0
		0.8	0	0	0.002	0.002
		1.6	0	0	0.007	0.007
		2.4	0	0	0.008	0.008
		3.2	0	0	0	0
	3 EQ-X	0	0	0	0	0
		0.8	0	0	0.001	0.001
		1.6	0	0	-0.001	0.001
		2.4	0	0	-0.002	0.003
		3.2	0	0	0	0
	4 EQ-Z	0	0	0	0	0
		0.8	0	0	-0.002	0.002
		1.6	0	0	-0.007	0.007
		2.4	0	0	-0.008	0.008
		3.2	0	0	0	0
	5 DEAD LOAD	0	0	0	0	0
		0.8	0	-0.001	0.001	0.001
		1.6	0	0.001	0.002	0.002

		2.4	0	0.002	0.002	0.003
		3.2	0	0	0	0
	6 LIVE LOAD	0	0	0	0	0
		0.8	0	0	0	0
		1.6	0	0	0	0
		2.4	0	0.001	0	0.001
		3.2	0	0	0	0
	7 WL X	0	0	0	0	0
		0.8	0	0	0	0
		1.6	0	0	0	0
		2.4	0	0	0	0
		3.2	0	0	0	0
	8 WL -X	0	0	0	0	0
		0.8	0	0	0	0
		1.6	0	0	0	0
		2.4	0	0	0	0
		3.2	0	0	0	0
	9 WL Z	0	0	0	0	0
		0.8	0	0	0	0
		1.6	0	0	0	0
		2.4	0	0	0	0
		3.2	0	0	0	0
	10 WL -Z	0	0	0	0	0
		0.8	0	0	0	0
		1.6	0	0	0	0
		2.4	0	0	0	0
		3.2	0	0	0	0
	11 COMB - 1.5 DEAD + 1.5 LIVE	0	0	0	0	0
		0.8	0	-0.002	0.001	0.002
		1.6	0	0.001	0.003	0.004
		2.4	0	0.004	0.004	0.006
		3.2	0	0	0	0
	12 COMB - 1.2 DEAD + 1.2 LIVE + 1.2 WIND (1)	0	0	0	0	0
		0.8	0	-0.002	0.001	0.002
		1.6	0	0.001	0.003	0.003
		2.4	0	0.003	0.003	0.005
		3.2	0	0	0	0
	13 COMB - 1.2 DEAD + 1.2 LIVE + 1.2 WIND (2)	0	0	0	0	0
		0.8	0	-0.002	0.001	0.002
		1.6	0	0.001	0.003	0.003
		2.4	0	0.003	0.003	0.005
		3.2	0	0	0	0

	14 COMB - 1.2 DEAD + 1.2 LIVE + 1.2 WIND (3)	0	0	0	0	0
		0.8	0	-0.002	0.001	0.002
		1.6	0	0.001	0.003	0.003
		2.4	0	0.003	0.004	0.005
		3.2	0	0	0	0
	15 COMB - 1.2 DEAD + 1.2 LIVE + 1.2 WIND (4)	0	0	0	0	0
		0.8	0	-0.002	0	0.002
		1.6	0	0.001	0.002	0.003
		2.4	0	0.003	0.003	0.004
		3.2	0	0	0	0
	16 COMB - 1.2 DEAD + 1.2 LIVE + -1.2 WIND (1)	0	0	0	0	0
		0.8	0	-0.002	0.001	0.002
		1.6	0	0.001	0.003	0.003
		2.4	0	0.003	0.003	0.004
		3.2	0	0	0	0
	17 COMB - 1.2 DEAD + 1.2 LIVE + -1.2 WIND (2)	0	0	0	0	0
		0.8	0	-0.002	0.001	0.002
		1.6	0	0.001	0.003	0.003
		2.4	0	0.003	0.003	0.005
		3.2	0	0	0	0
	18 COMB - 1.2 DEAD + 1.2 LIVE + -1.2 WIND (3)	0	0	0	0	0
		0.8	0	-0.002	0.001	0.002
		1.6	0	0.001	0.002	0.003
		2.4	0	0.003	0.003	0.004
		3.2	0	0	0	0
	19 COMB - 1.2 DEAD + 1.2 LIVE + -1.2 WIND (4)	0	0	0	0	0
		0.8	0	-0.002	0.001	0.002
		1.6	0	0.001	0.003	0.003
		2.4	0	0.003	0.003	0.005
		3.2	0	0	0	0
	20 COMB - 1.2 DEAD + 1.2 LIVE + 1.2 SEISMIC-H (1)	0	0	0	0	0
		0.8	0	-0.001	-0.001	0.001
		1.6	0	0.001	0.004	0.004
		2.4	0	0.002	0.006	0.007
		3.2	0	0	0	0
	21 COMB - 1.2 DEAD + 1.2 LIVE + 1.2 SEISMIC-H (2)	0	0	0	0	0
		0.8	0	-0.001	0.003	0.003
		1.6	0	0.001	0.01	0.011
		2.4	0	0.003	0.013	0.014
		3.2	0	0	0	0
	22 COMB - 1.2 DEAD + 1.2 LIVE	0	0	0	0	0
		0.8	0	-0.002	0.002	0.003

	+ 1.2 SEISMIC-H (3)	1.6	0	0.001	0.002	0.002
		2.4	0	0.004	0	0.004
		3.2	0	0	0	0
	23 COMB - 1.2 DEAD + 1.2 LIVE + 1.2 SEISMIC-H (4)	0	0	0	0	0
		0.8	0	-0.002	-0.001	0.002
		1.6	0	0.001	-0.005	0.005
		2.4	0	0.003	-0.007	0.007
		3.2	0	0	0	0
	24 COMB - 1.2 DEAD + 1.2 LIVE + -1.2 SEISMIC-H (1)	0	0	0	0	0
		0.8	0	-0.002	0.002	0.003
		1.6	0	0.001	0.002	0.002
		2.4	0	0.004	0	0.004
		3.2	0	0	0	0
	25 COMB - 1.2 DEAD + 1.2 LIVE + -1.2 SEISMIC-H (2)	0	0	0	0	0
		0.8	0	-0.002	-0.001	0.002
		1.6	0	0.001	-0.005	0.005
		2.4	0	0.003	-0.007	0.007
		3.2	0	0	0	0
	26 COMB - 1.2 DEAD + 1.2 LIVE + -1.2 SEISMIC-H (3)	0	0	0	0	0
		0.8	0	-0.001	-0.001	0.001
		1.6	0	0.001	0.004	0.004
		2.4	0	0.002	0.006	0.007
		3.2	0	0	0	0
	27 COMB - 1.2 DEAD + 1.2 LIVE + -1.2 SEISMIC-H (4)	0	0	0	0	0
		0.8	0	-0.001	0.003	0.003
		1.6	0	0.001	0.01	0.011
		2.4	0	0.003	0.013	0.014
		3.2	0	0	0	0
	28 COMB - 1.5 DEAD + 1.5 WIND (1)	0	0	0	0	0
		0.8	0	-0.001	0.001	0.002
		1.6	0	0.001	0.003	0.003
		2.4	0	0.003	0.004	0.005
		3.2	0	0	0	0
	29 COMB - 1.5 DEAD + 1.5 WIND (2)	0	0	0	0	0
		0.8	0	-0.001	0.001	0.002
		1.6	0	0.001	0.003	0.003
		2.4	0	0.003	0.004	0.005
		3.2	0	0	0	0
	30 COMB - 1.5 DEAD + 1.5 WIND (3)	0	0	0	0	0
		0.8	0	-0.001	0.001	0.002
		1.6	0	0.001	0.003	0.003
		2.4	0	0.003	0.004	0.005
		3.2	0	0	0	0
	31 COMB - 1.5	0	0	0	0	0

	DEAD + 1.5 WIND (4)	0.8	0	-0.001	0.001	0.002
		1.6	0	0.001	0.003	0.003
		2.4	0	0.003	0.003	0.004
		3.2	0	0	0	0
	32 COMB - 1.5 DEAD + -1.5 WIND (1)	0	0	0	0	0
		0.8	0	-0.001	0.001	0.002
		1.6	0	0.001	0.003	0.003
		2.4	0	0.003	0.003	0.005
		3.2	0	0	0	0
	33 COMB - 1.5 DEAD + -1.5 WIND (2)	0	0	0	0	0
		0.8	0	-0.001	0.001	0.002
		1.6	0	0.001	0.003	0.003
		2.4	0	0.003	0.004	0.005
		3.2	0	0	0	0
	34 COMB - 1.5 DEAD + -1.5 WIND (3)	0	0	0	0	0
		0.8	0	-0.001	0.001	0.002
		1.6	0	0.001	0.003	0.003
		2.4	0	0.003	0.003	0.004
		3.2	0	0	0	0
	35 COMB - 1.5 DEAD + -1.5 WIND (4)	0	0	0	0	0
		0.8	0	-0.001	0.001	0.002
		1.6	0	0.001	0.003	0.003
		2.4	0	0.003	0.004	0.005
		3.2	0	0	0	0
	36 COMB - 1.5 DEAD + 1.5 SEISMIC-H (1)	0	0	0	0	0
		0.8	0	-0.001	-0.001	0.001
		1.6	0	0.001	0.004	0.004
		2.4	0	0.002	0.007	0.007
		3.2	0	0	0	0
	37 COMB - 1.5 DEAD + 1.5 SEISMIC-H (2)	0	0	0	0	0
		0.8	0	-0.001	0.003	0.003
		1.6	0	0.001	0.013	0.013
		2.4	0	0.003	0.016	0.016
		3.2	0	0	0	0
	38 COMB - 1.5 DEAD + 1.5 SEISMIC-H (3)	0	0	0	0	0
		0.8	0	-0.002	0.003	0.003
		1.6	0	0.001	0.002	0.002
		2.4	0	0.004	0	0.004
		3.2	0	0	0	0
	39 COMB - 1.5 DEAD + 1.5 SEISMIC-H (4)	0	0	0	0	0
		0.8	0	-0.002	-0.001	0.002
		1.6	0	0.001	-0.007	0.007
		2.4	0	0.003	-0.009	0.009
		3.2	0	0	0	0
	40 COMB - 1.5 DEAD + -1.5 SEISMIC-H (1)	0	0	0	0	0
		0.8	0	-0.002	0.003	0.003
		1.6	0	0.001	0.002	0.002

		2.4	0	0.004	0	0.004
		3.2	0	0	0	0
	41 COMB - 1.5 DEAD + -1.5 SEISMIC-H (2)	0	0	0	0	0
		0.8	0	-0.002	-0.001	0.002
		1.6	0	0.001	-0.007	0.007
		2.4	0	0.003	-0.009	0.009
		3.2	0	0	0	0
	42 COMB - 1.5 DEAD + -1.5 SEISMIC-H (3)	0	0	0	0	0
		0.8	0	-0.001	-0.001	0.001
		1.6	0	0.001	0.004	0.004
		2.4	0	0.002	0.007	0.007
		3.2	0	0	0	0
	43 COMB - 1.5 DEAD + -1.5 SEISMIC-H (4)	0	0	0	0	0
		0.8	0	-0.001	0.003	0.003
		1.6	0	0.001	0.013	0.013
		2.4	0	0.003	0.016	0.016
		3.2	0	0	0	0
	44 COMB - 0.9 DEAD + 1.5 WIND (1)	0	0	0	0	0
		0.8	0	-0.001	0.001	0.001
		1.6	0	0.001	0.002	0.002
		2.4	0	0.002	0.002	0.003
		3.2	0	0	0	0
	45 COMB - 0.9 DEAD + 1.5 WIND (2)	0	0	0	0	0
		0.8	0	-0.001	0.001	0.001
		1.6	0	0.001	0.002	0.002
		2.4	0	0.002	0.002	0.003
		3.2	0	0	0	0
	46 COMB - 0.9 DEAD + 1.5 WIND (3)	0	0	0	0	0
		0.8	0	-0.001	0.001	0.001
		1.6	0	0.001	0.002	0.002
		2.4	0	0.002	0.002	0.003
		3.2	0	0	0	0
	47 COMB - 0.9 DEAD + 1.5 WIND (4)	0	0	0	0	0
		0.8	0	-0.001	0	0.001
		1.6	0	0.001	0.001	0.002
		2.4	0	0.002	0.002	0.003
		3.2	0	0	0	0
	48 COMB - 0.9 DEAD + -1.5 WIND (1)	0	0	0	0	0
		0.8	0	-0.001	0.001	0.001
		1.6	0	0.001	0.002	0.002
		2.4	0	0.002	0.002	0.003
		3.2	0	0	0	0
	49 COMB - 0.9 DEAD + -1.5 WIND (2)	0	0	0	0	0
		0.8	0	-0.001	0	0.001
		1.6	0	0.001	0.002	0.002
		2.4	0	0.002	0.002	0.003
		3.2	0	0	0	0

	50 COMB - 0.9 DEAD + -1.5 WIND (3)	0	0	0	0	0
		0.8	0	-0.001	0	0.001
		1.6	0	0.001	0.001	0.002
		2.4	0	0.002	0.002	0.002
		3.2	0	0	0	0
	51 COMB - 0.9 DEAD + -1.5 WIND (4)	0	0	0	0	0
		0.8	0	-0.001	0.001	0.001
		1.6	0	0.001	0.002	0.002
		2.4	0	0.002	0.002	0.003
		3.2	0	0	0	0
	52 COMB - 0.9 DEAD + 1.5 SEISMIC-H (1)	0	0	0	0	0
		0.8	0	0	-0.001	0.001
		1.6	0	0	0.003	0.003
		2.4	0	0.001	0.006	0.006
		3.2	0	0	0	0
	53 COMB - 0.9 DEAD + 1.5 SEISMIC-H (2)	0	0	0	0	0
		0.8	0	-0.001	0.003	0.003
		1.6	0	0.001	0.012	0.012
		2.4	0	0.002	0.015	0.015
		3.2	0	0	0	0
	54 COMB - 0.9 DEAD + 1.5 SEISMIC-H (3)	0	0	0	0	0
		0.8	0	-0.001	0.002	0.003
		1.6	0	0.001	0.001	0.001
		2.4	0	0.002	-0.002	0.003
		3.2	0	0	0	0
	55 COMB - 0.9 DEAD + 1.5 SEISMIC-H (4)	0	0	0	0	0
		0.8	0	-0.001	-0.002	0.002
		1.6	0	0.001	-0.008	0.008
		2.4	0	0.002	-0.01	0.01
		3.2	0	0	0	0
	56 COMB - 0.9 DEAD + -1.5 SEISMIC-H (1)	0	0	0	0	0
		0.8	0	-0.001	0.002	0.003
		1.6	0	0.001	0.001	0.001
		2.4	0	0.002	-0.002	0.003
		3.2	0	0	0	0
	57 COMB - 0.9 DEAD + -1.5 SEISMIC-H (2)	0	0	0	0	0
		0.8	0	-0.001	-0.002	0.002
		1.6	0	0.001	-0.008	0.008
		2.4	0	0.002	-0.01	0.01
		3.2	0	0	0	0
	58 COMB - 0.9 DEAD + -1.5 SEISMIC-H (3)	0	0	0	0	0
		0.8	0	0	-0.001	0.001
		1.6	0	0	0.003	0.003
		2.4	0	0.001	0.006	0.006
		3.2	0	0	0	0
	59 COMB - 0.9 DEAD + -1.5	0	0	0	0	0
		0.8	0	-0.001	0.003	0.003

	SEISMIC-H (4)	1.6	0	0.001	0.012	0.012
		2.4	0	0.002	0.015	0.015
		3.2	0	0	0	0

CONCLUSION

1. P-delta effect increase as a height of building increases. Hence, we have to prefer P-delta analysis over normal stability analysis in high rise building.
2. in normal analysis displacement in columns are (0.114- 0.135 m), After the P-delta analysis it increase upto (0.311 to 0.689 m)
3. After providing X bracings deflection in column decreases upto(0.012 to 0.112 m)
4. Displacement in p-delta analysis is greater than normal analysis of building. It is upto 10% gtreater
5. Only gravity loads does not effects on p-delta analysis. It is combination of lateral and gravity loads
6. P-delta effect can be minimized by providing X bracing in structure. It decreases P-delta effect upto 95%

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