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Study on Dynamic P Delta Effects of a Building with Soft Storey

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Abstract: **In modern multi-storey buildings stiffness irregularities are usually found within the building which may be due to the occupancy and architectural appearance. Such irregularities in elevation can lead to buildings with soft stories. Soft story refers to the existence of a building floor that presents a significantly lower stiffness than the others. As per IS1893 (part 1) – 2002, in a soft storey lateral stiffness of the storey is less than 70% of the above storey or less than 80% of the average lateral stiffness of the above three stories. Usually open soft storey is provided at ground level to accommodate parking, reception lobbies etc. also, the soft storey may be constructed at the intermediate level for the purpose such as offices, function halls, supermarkets etc. Such soft storey configuration may lead to serious earthquake damage. To experience minimum damage and less psychological fear in the minds of people during the earthquake, IS1893 (part1):2002, permits maximum inter-storey drift as 0.004 times the storey height. Inter storey drift always depends upon the stiffness of the respective storey. To understand the behavior of p delta effects different types of 20 storey building is modeled using ETABS software and subjected to earthquake loading. Building parameters are varied by introducing shear wall, exterior walls, bracing system and further parameters such as inter-storey drift, roof displacement and column moments are computed and variations in these parameters are discussed and it is observed that building with open soft storey has the least capacity to resist failure during earthquake.**

***Keywords*:-- soft storey, seismic, P-delta analysis, linear static analysis.**

I. INTRODUCTION

An earthquake is a sudden and abrupt shaking of the ground causing great damage to life and property due to movements within the earth's crust thereby releasing energy in the form of seismic waves. Thus earthquake resistant design has gained lot of importance in multistorey building construction.

There are various factors that play a key role in behavior of building during earthquake such as irregularity in stiffness which leads to formation of soft storey. Introduction of different lateral load resisting system such as shear walls, bracing etc..,

In the case of high rise structures with enormous amount of dead load and live loads P-Delta effect takes place when its subjected to lateral loads thus it should be considered in the analysis as it causes considerable changes in moments and drifts when soft storey at different level is considered which is explained by Palankar et.al., this effect varies with ductility of columns which is explained by Rupali B et. al., the variation in P-Delta effect for varying height of building is explained by Yousuf et. al., considering all this studies variation is considered by changing the lateral load resisting system of the building by providing shear wall, bracing and open base type structure which is explained in this paper.

II. SOFT STOREY

As per IS1893 (part 1) – 2002, in a soft storey lateral stiffness of the storey is less than 70% of the above storey or less than 80% of the average lateral stiffness of the above three stories. Usually open soft storey is provided at ground level to accommodate parking, reception lobbies etc. also, the soft storey may be constructed at the intermediate level for the purpose such as offices, function halls, supermarkets etc. A extreme soft storey is one in which the lateral stiffness is less than 60 percent of that in the storey above or less than 70 percent of the average stiffness of the three storeys above. For example, buildings on STILTS will fall under this category.

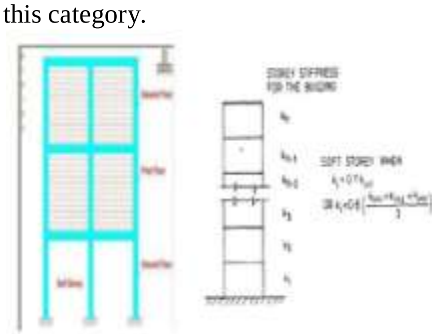

***Figure 1 : soft storey and stiffness irregularity*.**

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III. THE P-DELTA EFFECT

The **P-Delta effect** refers specifically to the nonlinear geometric effect of a large tensile or compressive direct stress upon transverse bending and Study on dynamic P-Delta effects of a building with soft storey shear behavior. A compressive stress tends to make a structural member more flexible in transverse bending and shear, whereas a tensile stress tends to stiffen the member against transverse deformation. This option is particularly useful for considering the effect of gravity loads upon the lateral stiffness of building structures, as required by certain design codes (ACI 2002; AISC 2003). It can also be used for the analysis of some cable structures, such as suspension bridges, cable-stayed bridges, and guyed towers. Other applications are possible. The basic concepts behind the P-Delta effect are illustrated in the following example. Consider a cantilever beam subject to an axial load P and a transverse tip load F as shown in Figure The internal axial force throughout the member is also equal to P.

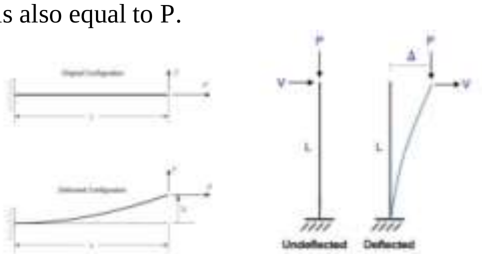

Figure 2 : p delta effect in a cantilever beam

In this example, a column of length L is encountering an axial load (P) and a lateral load (V). In a standard linear static analysis we would calculate the lateral deflection (Δ) as:

$$\Delta = \frac{ML^2}{3EI} = \frac{VL^3}{3EI} \text{ since M=VL}$$

Notice that in the case of a linear static analysis the lateral deflection, Δ, depends on the lateral load (V). However, if the column is encountering an axial load (P) then wouldn't the column deflect even more? This is obvious because the axial load would induce a secondary moment with a value of P×Δ. To see this let's sum the moments about the base of the column:

$$\sum M = (V \times L) + (P \times \Delta) = VL + P\Delta$$

So really the deflection would be closer to:

$$\Delta_{new} = \frac{ML^2}{3EI} = \frac{(VL + P\Delta)L^2}{3EI} = \frac{VL^3}{3EI} + \frac{P\Delta L^2}{3EI}$$

We can see that compared to the original deflection value there is an extra term on the right in terms of P and Δ. If P or Δ are siginificant values then the a standard linear static analysis would be underestimating the deflection of the column. It should be obvious by now that a P-Delta Analysis is named after the secondary moment PΔ. Therefore, P-Delta effects are caused due to geometric non-linearity and for this reason a P-Delta Analysis is often called a Non-Linear Analysis. A proper P-Delta Analysis would continue to iterate the process above to update the value of Δnew.

IV. METHODOLOGY

4.1 Linear static analysis

1. A twenty storey 3-D RC frame structure is modeled using Extended 3D Analysis of Building System (ETABS) software.

2. The properties adopted for the structure are as follows

Type	Dimensions
Beams	500*500mm
Columns	500*500mm
Slabs	150mm

3. Loads applied:

Live load : 3Kn/m2
Floor finish :2 Kn/m2
Wall load : 20Kn/m at 1st storey level and 12Kn/m at rest of the storeys.
Seismic load : In both X and Y direction
Zone factor – 0.1
Response reduction factor-3
Importance factor – 1

4. Load combinations: The loads were applied as per IS 875 part 2 and the load combinations considered are as follows:

1.5 (DL+/- EQ)
1.5 (DL+ LL)
1.2(DL+LL+/-EQ)

5. A unit load of 1 Kn/m is applied at the mass center of the structure at the top most level and the storey stiffness is obtained for this load and check for soft storey is done for this load case.

6. Now analysis is done without considering the P-delta effects and results are obtained then for the same structure once again analysis is carried out using P-delta effect and results are compared for both the cases.

7. **P-Delta effect** : The **P**-Δ or **P-Delta effect** refers to the abrupt changes in ground shear, overturning moment, and/or the axial force distribution at the base of a sufficiently tall structure or structural component when it is subject to a critical lateral displacement. This effect is caused in a

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Vol 2, Issue 4, April 2017

building when it is subjected to lateral loads such as earthquake or wind and it has significant effect on the building . Study on dynamic P-Delta effects of a building with soft storey

8. To check the behavior of soft storey different types of buildings are adopted by changing certain parameters such as A) Introducing periphery walls and providing open base (also known as STILTS) this leads to formation of extreme soft storey condition.

B) Introducing shear walls to increase the lateral load carrying capacity of the structure.

C) Introducing X braces in all four directions to increase the load carrying capacity of the building.

9. Analysis is carried out for all the structures with and without considering the P-delta settings and results are discussed below.

Fig 3: bare frame structure

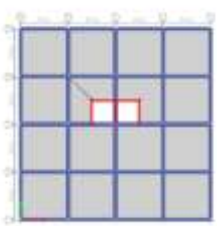

Fig 4 : shear wall structure

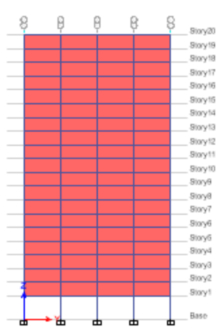

Fig 5: open base structure

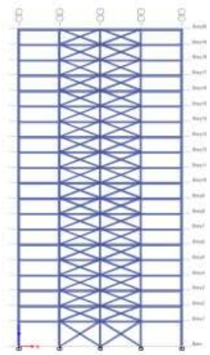

Fig6: braced structure

V. RESULTS AND DISCUSSION

***5.1 Top storey displacement*:**

As per IS codes the maximum permissible roof displacement is h/500 where, "h" is the total height of the building. The variation in roof displacement is observed for different types of buildings below.

Table1: for bare frame Table 2: shear wall structure

Story	Without p-delta(mm)	with p-delta(mm)	Story	without p-delta(mm)	with p-delta(mm)
Story1	11.874	21.877	Story1	5.834	7.699
Story2	19.016	34.222	Story2	10.008	13.145
Story3	25.901	45.344	Story3	14.671	19.13
Story4	32.747	55.934	Story4	19.668	25.457
Story5	39.575	66.152	Story5	24.876	31.945
Story6	46.367	76.026	Story6	30.222	38.494
Story7	53.096	85.542	Story7	35.657	45.041
Story8	59.727	94.675	Story8	41.136	51.536
Story9	66.223	103.394	Story9	46.615	57.933
Story10	72.542	111.666	Story10	52.05	64.184
Story11	78.636	119.454	Story11	57.395	70.246
Story12	84.456	126.718	Story12	62.605	76.075
Story13	89.947	133.419	Story13	67.632	81.629
Story14	95.051	139.515	Story14	72.433	86.87
Story15	99.704	144.961	Story15	76.963	91.762
Story16	103.841	149.712	Story16	81.183	96.275
Story17	107.392	153.723	Story17	85.062	100.391
Story18	110.287	156.952	Story18	88.577	104.099
Story19	112.473	159.376	Story19	91.716	107.4
Story20	113.961	161.04	Story20	94.251	110.071

Table 3: open base structure Table 4: Braced structure

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Story	without p-delta(mm)	with p-delta(mm)	Story	without p-delta (mm)	with p-delta (mm)
Story1	14.151	16.6	Story1	4.485	5.342
Story2	14.304	16.751	Story2	7.558	9.01
Story3	14.483	16.903	Story3	10.763	12.809
Story4	14.623	17.02	Story4	14.063	16.698
Story5	14.757	17.136	Story5	17.439	20.653
Story6	14.901	17.262	Story6	20.87	24.647
Story7	15.05	17.394	Story7	24.334	28.652
Story8	15.201	17.528	Story8	27.809	32.641
Story9	15.353	17.661	Story9	31.268	36.585
Story10	15.504	17.795	Story10	34.688	40.454
Story11	15.655	17.928	Story11	38.041	44.221
Story12	15.806	18.061	Story12	41.3	47.856
Story13	15.958	18.195	Story13	44.436	51.331
Story14	16.109	18.329	Story14	47.421	54.616
Story15	16.261	18.463	Story15	50.221	57.68
Story16	16.413	18.597	Story16	52.806	60.494
Story17	16.569	18.735	Story17	55.145	63.029
Story18	16.729	18.877	Story18	57.204	65.258
Story19	16.874	19.004	Story19	58.966	67.165
Story20	17.11	19.823	Story20	60.35	68.668

Study on dynamic P-Delta effects of a building with soft storey

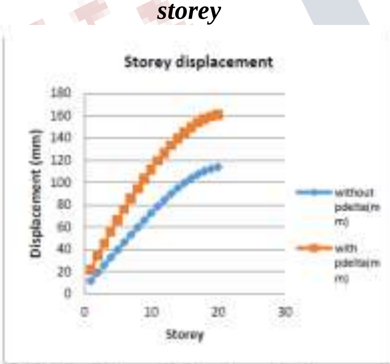

Fig 6: storey displacement for bare frame structure

From the above data it is observed that there is significance amount of variation in roof displacement after considering P-delta effect roof displacements has increased by 29.8% after considering P-delta effect in case of bare frame structure and 14.7% for shear wall structure , 13.6 % for open base structure and 12.2% for X braced structure.

5.2 Inter storey drift:

IS1893 (part1):2002, permits maximum inter-storey drift as 0.004 times the storey height. Inter storey drift always depends upon the stiffness of the respective storey. The variation in storey drift has been discussed

.

Table 5: bare frame drift Table 6: shear wall drift

Story	without p-delta	with p-delta	Story	without p-delta(mm)	with p-delta(mm)
Story1	11.874	21.877	Story1	5.834	7.699
Story2	7.193	12.406	Story2	4.231	5.504
Story3	6.889	11.129	Story3	4.663	5.986
Story4	6.848	10.592	Story4	5	6.33
Story5	6.828	10.218	Story5	5.209	6.49
Story6	6.793	9.874	Story6	5.348	6.55
Story7	6.729	9.516	Story7	5.436	6.549
Story8	6.632	9.133	Story8	5.481	6.497
Story9	6.496	8.72	Story9	5.481	6.398
Story10	6.319	8.272	Story10	5.436	6.253
Story11	6.095	7.788	Story11	5.347	6.063
Story12	5.82	7.265	Story12	5.211	5.831
Story13	5.491	6.701	Story13	5.029	5.556
Story14	5.104	6.096	Story14	4.802	5.243
Story15	4.654	5.446	Story15	4.532	4.893
Story16	4.137	4.752	Story16	4.222	4.515
Story17	3.551	4.012	Story17	3.879	4.116
Story18	2.897	3.23	Story18	3.522	3.716
Story19	2.193	2.43	Story19	3.171	3.312
Story20	1.536	1.713	Story20	3.077	3.211

Table 7: open base drifts Table 8: X braced drifts

Story	without p- delta	with p-delta	Story	without p delta (mm)	with p delta (mm)
Story1	14.151	16.6	Story1	4.485	5.342
Story2	0.434	0.415	Story2	3.135	3.733
Story3	0.216	0.19	Story3	3.208	3.8
Story4	0.15	0.132	Story4	3.303	3.893
Story5	0.15	0.132	Story5	3.379	3.959
Story6	0.15	0.132	Story6	3.434	3.997
Story7	0.15	0.133	Story7	3.468	4.009
Story8	0.152	0.134	Story8	3.478	3.992
Story9	0.152	0.134	Story9	3.463	3.947
Story10	0.152	0.134	Story10	3.423	3.873
Story11	0.152	0.134	Story11	3.357	3.77
Story12	0.152	0.134	Story12	3.262	3.638
Story13	0.152	0.134	Story13	3.139	3.476
Story14	0.152	0.135	Story14	2.985	3.285
Story15	0.153	0.135	Story15	2.802	3.065
Story16	0.152	0.135	Story16	2.586	2.815
Story17	0.156	0.138	Story17	2.339	2.536
Story18	0.16	0.142	Story18	2.063	2.233
Story19	0.163	0.146	Story19	1.769	1.915
Story20	0.242	0.224	Story20	1.437	1.556

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Vol 2, Issue 4, April 2017

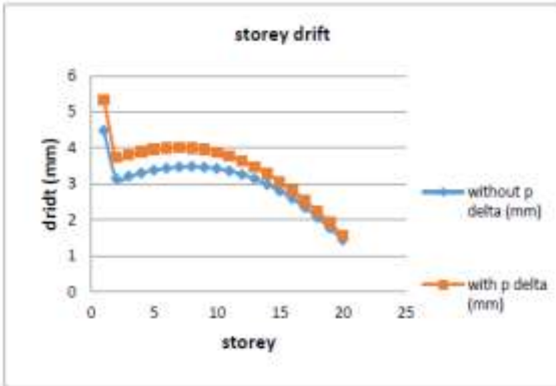

Fig 7: Inter storey drift for X braced structure

From the above data there has been a significance increase in drifts after considering P-delta effect .

The storey drift at the soft story level has increased by 45% after considering the P-delta effect for bare frame structure, 24% increase for shear wall structure, 16% increase for open base structure and 15% for X braced structure.

4.3 Variation in column moments

The variations in column moments at different storey level for column C11 is shown below for different types of structure to understand the effects of these variations in parameters on the building.

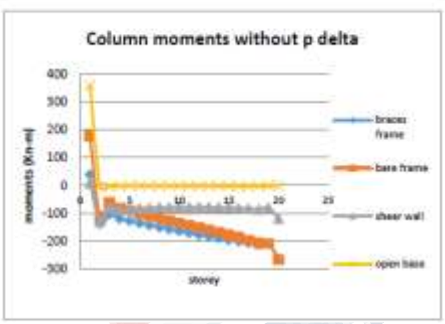

Figure 8 : column moments without p-delta

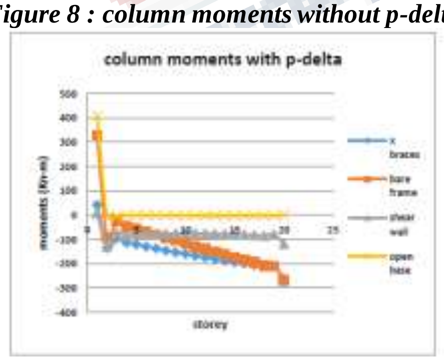

Figure 9: column moments with p-delta

Maximum change in column moment has occurred in the case of bare frame structure at the bottom soft storey level. The moments have varied by 46% after p delta effects are considered for this case.

VI. CONCLUSIONS

From the results and discussions following conclusions can be drawn.

1. When P-Δ effect is considered, there is a considerable increase in displacement, storey drift and column moments which indicates the significance of P-Δ.
2. Maximum variation in roof displacement of 29.6% and it keeps decreasing with introduction of different types of load resisting system.
3. Maximum variation in storey drift at soft storey level is observed in all the structures and highest drift is observed in open base structure due to formation of extreme soft storey.

REFERENCES

[1]. Bryan Stafford Smith and Regina Gaiotti (1989- April).P-Δ Analysis of Building Structures, American Society of Civil Engineers, Journal of structural division, No-4, vol,-115.

[2] Prashant Dhadve, Alok Rao, Atul Rupanvar and Deokate K.,(2015- May). Assesment of P-Δ effect on high rise buildings. International Journal on Research and Innovation Trends in Computing and Communication, 3(5), 3231-3236.

[3] Yusuf Dinar and Saminul Karim,(2013- November)P-Δ effect in reinforced concrete structure of rigid joint. IOSR Journal of Mechanical and Civil Engineering, 10, 42-49.

[4] Mallikarjuna B.N, Ranjith,(August 2014) ―Stability Analysis of Steel Frame St ructures: P-Delta Analysis, International Journal of Research in Engineering and Technology. Volume 03, Issue 08.

[5] Rafae l Shehu,(February 2014). ―The P-Δ-Ductility Effect: Overview the Effect of the Second Order in the Ductile Structures‖, European Scientific Journal, Volume 3.

[6] MacRae, G. A. (1994).‘‘P-Delta effects on single-degree-of-freedom structures in earthquakes.’’ Earthquake Spectra, 10(3) .

[7] Prof.C.G.Konapure, Mr.P.V.Dhanshetti,(January 2014)―Effect of P-Delta Action on Multi-Storey Buildings‖, International Journal of Engineering Research & Technology, Volume 4, Issue 1,.

[8] Dr. S. K. Dubey, Prakash Sangamnerkar, Deepak Soni(2014). ―Dynamic Behavior of Renforced Concrete Framed Buildings under Non Linear Analysis‖, International Journal of Engineering Development and Research, Volume 2, Issue 4.

[9] IS1893, Indian seismic code, Part 1,(2002) .Criteria for Earthquake Resistant Design of Structures, General Provisions and Buildings, Bureau of Indian Standards, New Delhi