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Study of Seismic Performance for Open Ground Storey of High Rise Buildings

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ABSTRACT: Open Ground Storey (OGS) means ground storey not having walls. Now a days, OGS is a typical feature in multi-storied building construction in order to provide facilities like car parking, restaurants, bank branches, reception lobbies, offices, etc., but this causes soft storey effect. A soft storey is characterized by vertical discontinuity in stiffness. When an individual storey in a building is made taller and/or more open in construction, it is called soft storey or flexible storey. Stiffness is to resist lateral displacement. The main aim of this project is to study seismic response of multi storey building after providing frustum of cone shaped column at ground storey. In this study a comparative analysis between typical rectangular shaped column & frustum of cone shaped column at open ground storey of multi storeyed building is done using ETABS. G+19, G+15 & G+11 building is modelled as bare frame & then considering infilled wall as equivalent diagonal strut. After analyzing the model using ETABS, storey stiffness is compared between typical shaped column & frustum of cone shaped column at open ground storey.

KEYWORDS: Storey stiffness, OGS, Soft storey, Frustum of cone shaped column, Response spectrum, ETABS

I. INTRODUCTION

A soft storey is characterized by vertical discontinuity in stiffness. When an individual storey in a building is made taller and/or more open in construction, it is called soft storey or flexible storey. The soft storey can occur at an upper level but it is more common at the ground level between a rigid foundation system and a relatively stiffer upper level floor system. Any storey for which the lateral stiffness is less than 60% of that of the storey immediately above, or less than 70% of the combined stiffness of the three storeys above, is classified as soft storey. Stiffness is to resist lateral displacement.

A building has the potential to 'wave' back and forth during an earthquake (or even a severe wind storm). This is called the 'fundamental mode', and is the lowest frequency of building response. Most buildings, however, have higher modes of response, which are uniquely activated during earthquakes. Nevertheless, the first and second modes tend to cause the most damage in most cases. Structural analysis methods can be divided into:

Equivalent Static Analysis: This approach defines a series of forces acting on a building to represent the effect of earthquake ground motion, typically defined by a seismic design response spectrum. It assumes that the building responds in its fundamental mode. The response is read from a design response spectrum, given the natural frequency of the building (either calculated or defined by the building code). To account for effects due to "yielding" of the structure, many codes apply modification factors that reduce the design forces (e.g. force reduction factors).

Response Spectrum Analysis: This approach permits the multiple modes of response of a building to be taken into account (in the frequency domain). The response of a structure can be defined as a combination of many special shapes (modes) that in a vibrating string correspond to the "harmonics". Computer analysis can be used to determine these modes for a structure. For each mode, a response is read from the design spectrum, based on the modal frequency and the modal mass, and they are then combined to provide an estimate of the total response of the structure. In this we have to calculate the magnitude of forces in all directions i.e. X, Y & Z and then see the effects on the building.

Combination methods include the following:

1. Absolute – peak values are added together
2. Square Root Of The Sum Of The Squares (SRSS)
3. Complete Quadratic Combination (CQC) – it is an improvement on SRSS for closely spaced modes.

II. RELATED WORK

Miss.Aadishri D Kadam, Dr. P.S.Pajgade (2018), “Designing of soft storey for RC structure using IS-1893(PART1)-2016, AND IS-13920-2016,” IRJET compared the behaviour of multi storey buildings having soft storey designed with and without shear wall and struts. Using ETABS, G+15 storey building of 6 model was made. They concluded that, (1) building with shear wall upto soft storey is also sufficient. (2) In bare frame model, deflection was not under permissible limits, but when effect of infill wall was considered as braces (masonry), deflection observed was under permissible limits.

Sukanya V Raj, Vivek Philip(2017),”Evaluation of seismic design magnification factor for regular and L shape OGS buildings”, IRJET studied the effect of strength and stiffness of infill walls in regular and irregular OGS buildings. The study was carried out on a (G+4), (G+9), (G+14)and (G+19) OGS building having rectangular and L shape plan with same plan area configurations. And they concluded that (1)The time period obtained for infilled frame was much less than bare frame. (2)The base shear obtained for infilled frame was much greater than bare. The increase in base shear is due to stiffness of infill walls, which proves that when OGS building are analyzed as bare frame Base shear are under estimated.

Vipin V. Halde, Aditi H. Deshmukh(2015),”Review on behaviour of soft storey in building”, IRJET carried out investigation on the effect of a soft storey on the behaviour of a structure and effect of masonry infill on structure. And concluded that (1) when the effect of soft storey is considered then the deflection has increase at that particular floor. (2)RC frame buildings with open first storeys are known to perform poorly during in strong earthquake shaking. (3) Since the behaviour of the soft storey is different during a quake, the structural member undergoes damage and to provide member to withstand that additional forces due to soft storey heavy or bulky member need to be provided. This increase financial input.

S.R. Chowdhury, W. Hassan, S. I. Zaber, R. Mondal, M. N. Sirajee(2013), “Preventing Soft Storey Irregularity in RC Frame Buildings ”, ICERIE analyzed a 9 storied RC frame building modeled with the finite element software ETABS under the action of earthquake loads in equivalent static. It was concluded from this study that lateral displacement is reduced with increasing modulus of elasticity of masonry infill. Increasing the percentage of infill in the soft storey reduces the lateral displacement. The higher the percentage of infill the lower the lateral displacement. Incorporating shear walls at four corners proves the best approach in reducing soft storey irregularities as far as total lateral displacement is concerned. Increasing column stiffness than beam stiffness at soft storey level is effective approach for this purpose. Introducing steel bracing at periphery is also found an effective approach.

III. METHODOLOGY

Modelling of G+19 bare frame as well as infilled frame as equivalent diagonal strut with open ground storey building in ETABS. Typical rectangular shaped column is then replaced with frustum of cone shaped column at open ground storey. Seismic analysis (static as well as dynamic) is done as per IS 1893-2016 using ETABS. Storey stiffness at each floor of each model is compared. Observation and comparison of result using tables and bar graphs. Conclusion.

IV. STRUCTURAL MODELLING

In this study, structure will be modelled for the following 4 cases:

1. Typical shaped column
 - (a) G+19 Bare frame
 - (b) G+19 Infilled frame
2. Frustum of cone shaped column at ground floor.
 - (c) G+19 Bare frame
 - (d) G+19 Infilled frame

V. PRELIMINARY DATA

1.Length in X direction=20 m, 2.Length in Y direction= 12.5 m, 3. Typical storey height=2.9 m, 4.Ground storey height=4.2 m, 5.No. of storey =G+19 (a)Height of building =59.3 m (b)Beam size: 300 x 600 mm (c)Column size: 300 x 900 mm (d)Frustum of cone shaped column size: above dia: 900 mm & below dia: 1300 mm

Load Calculation:

Dead load: self-weight of the member (by ETABS), Floor finish= 0.5 kN/m², External wall load=0.23*2.3*6= 3.2 kN/m, Internal wall load=0.1*2.3*6= 1.4 kN/m, live load= 3 kN/m², seismic loading, Z=0.16 (for zone III, IS1893:2016), I=1.2

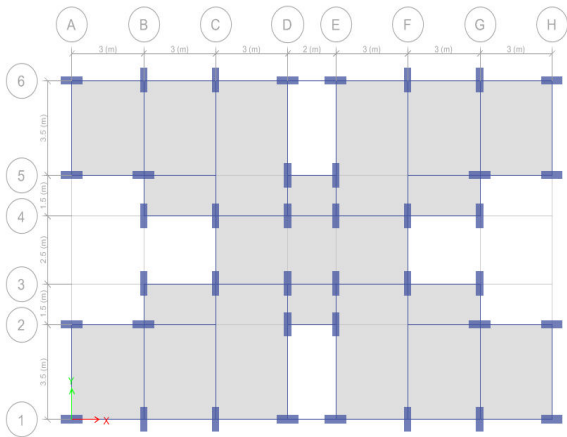


Fig.1: Plan- Typical rectangular shaped column
(Source: ETABS)

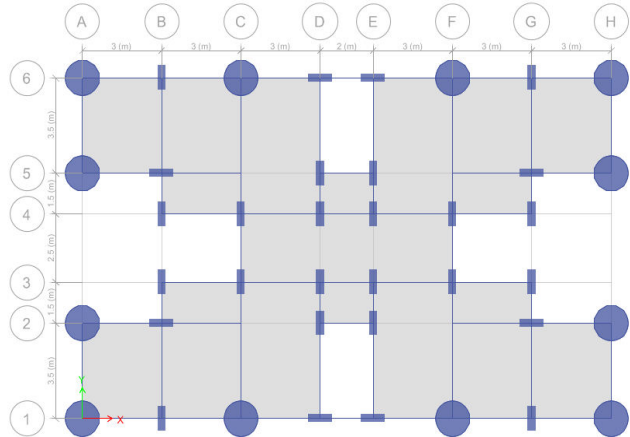


Fig.2: Plan- Frustum of cone shaped column at ground storey
(Source: ETABS)

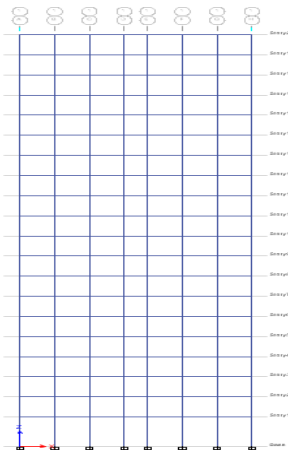


Fig.3: Elevation- Bare frame
(Source: ETABS)

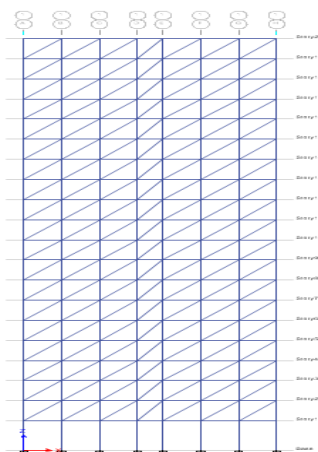


Fig.4: Elevation- Infilled frame
(Source: ETABS)

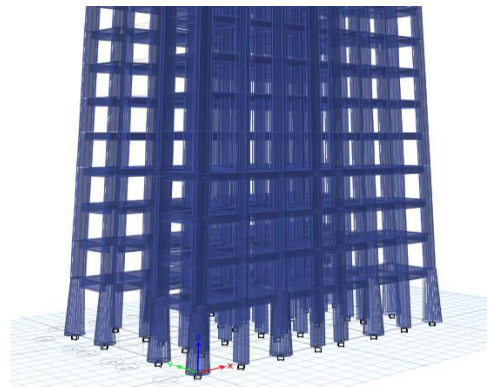


Fig.5: 3D – Frustum of cone shaped column
(Source: ETABS)



VI. EXPERIMENTAL RESULTS

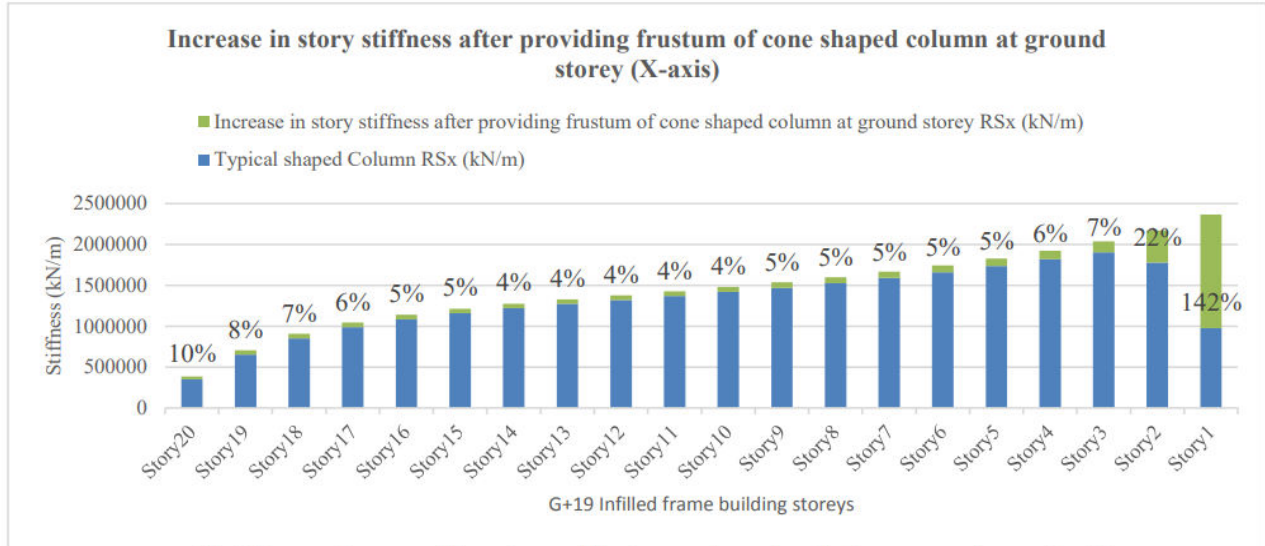


Fig.6.1 Increase in storey stiffness after providing frustum of cone shaped column at ground storey (X-axis)

G+19 Infilled frame building	Typical shaped Column	Frustum of cone shaped column at ground storey	Increase in storey stiffness	% increase in storey stiffness
Storey	RSx (kN/m)	RSx (kN/m)	RSx (kN/m)	RSx (kN/m)
Storey20	349492	385068	35576	10%
Storey19	652078	707119	55041	8%
Storey18	849959	908959	59000	7%
Storey17	986415	1043874	57459	6%
Storey16	1084656	1139627	54971	5%
Storey15	1159474	1213026	53552	5%
Storey14	1220238	1273857	53619	4%
Storey13	1272900	1327725	54825	4%
Storey12	1321441	1378253	56811	4%
Storey11	1368867	1428397	59530	4%
Storey10	1417646	1480743	63097	4%
Storey9	1469736	1537210	67473	5%
Storey8	1526505	1598934	72429	5%
Storey7	1588867	1666720	77853	5%
Storey6	1657648	1741738	84090	5%
Storey5	1733987	1826011	92025	5%
Storey4	1818587	1922303	103716	6%
Storey3	1903642	2035620	131977	7%
Storey2	1777153	2169199	392046	22%
Storey1	976284	2366456	1390172	142%

Table 1.1: Increase in storey stiffness after providing frustum of cone shaped column at ground storey (X-axis)

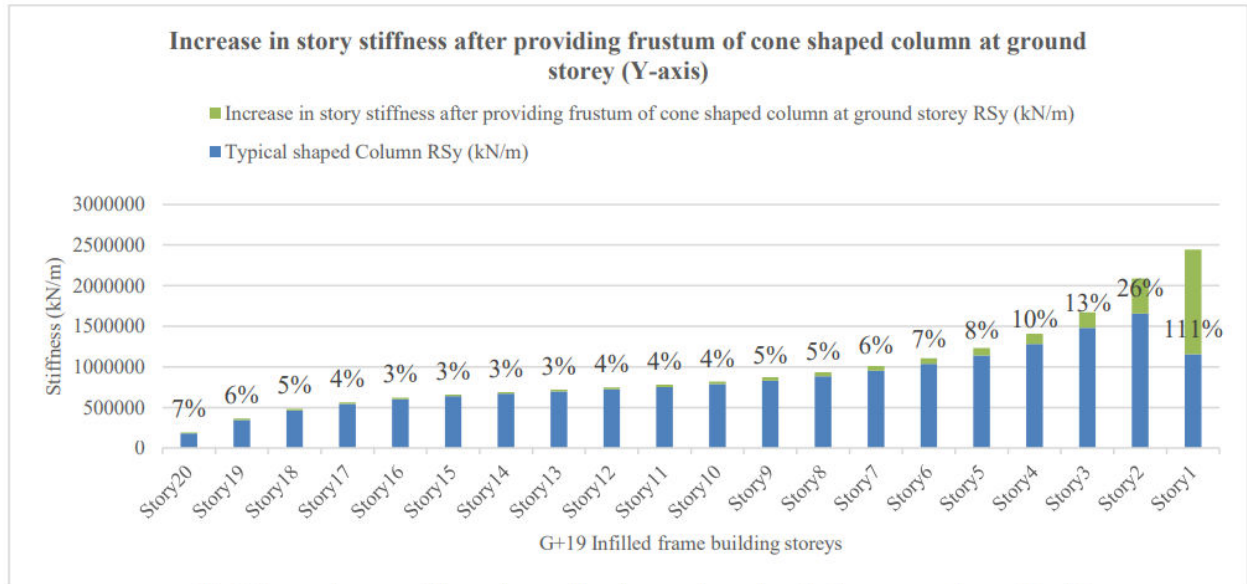


Fig.6.2 Increase in storey stiffness after providing frustum of cone shaped column at ground storey (Y-axis)

G+19 Infilled frame building	Typical shaped Column	Frustum of cone shaped column at ground storey	Increase in storey stiffness	% increase in storey stiffness
Storey	RSy (kN/m)	RSy (kN/m)	RSy (kN/m)	RSy (kN/m)
Storey20	180832	192827	11995	7%
Storey19	345385	364695	19310	6%
Storey18	463176	484380	21204	5%
Storey17	544242	564537	20295	4%
Storey16	599801	618854	19052	3%
Storey15	639404	658343	18939	3%
Storey14	670122	690348	20226	3%
Storey13	696850	719339	22488	3%
Storey12	723186	748583	25398	4%
Storey11	752296	781422	29125	4%
Storey10	787258	821341	34082	4%
Storey9	830831	871276	40445	5%
Storey8	885246	933405	48159	5%
Storey7	952637	1010233	57596	6%
Storey6	1036273	1106660	70387	7%
Storey5	1142426	1232567	90141	8%
Storey4	1283093	1407204	124111	10%
Storey3	1480642	1671044	190402	13%
Storey2	1655996	2086911	430915	26%
Storey1	1157736	2445616	1287880	111%

Table 1.1: Increase in storey stiffness after providing frustum of cone shaped column at ground storey (X-axis)



VII. CONCLUSION

Following are the conclusions obtained from this study:

1. Linear (static/dynamic) analysis shows that the stiffness of each storey increases after providing frustum of cone shaped column at ground storey.
2. Increase in storey stiffness is maximum for ground storey in the range of 105% to 140%, then storey just above increases 15% to 25%, whereas middle stories show 3% to 8% increase and top storey 9% to 13% for different building heights G+19, G+15 & G+11 bare frame as well as infilled frame.

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