Earthquake Resistant of Low-Rise Open Ground Storey Building in Different Seismic Zones

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Abstract— The principle objective of this project is to analyse the low-rise (G+3 storied) building (3-D frame) using STAAD PRO. Presence of infill walls in the frames alters the behaviour of the building under lateral loads. However, it is common industry practice to ignore the stiffness of infill wall for analysis of the framed building. Engineers believe that analysis without considering infill stiffness leads to a conservative design. But this may not be always true, especially for vertically irregular buildings with discontinuous infill walls. Indian Standard IS 1893: 2002 allows analysis of open ground storey buildings (OGS) without considering infill stiffness but with a multiplication factor 2.5 in compensation for the stiffness discontinuity. As per the code, the column and beams of the open ground storey (OGS) are to be designed for 2.5 times the storey shears and moments calculated under seismic loads of bare frames (i.e., without considering the infill stiffness). However, as experienced by the engineers at design offices, the multiplication factor of 2.5 is not realistic for low rise buildings. In this study, the seismic response of the structures is investigated under earthquake excitation expressed in the form of member force, joint displacement. This response is investigated for G+3 building structure by using STAAD PRO. designing software.

Keywords: Open Ground Storey (OGS), Low Rise Building, Seismic Analysis, STAAD PRO

I. Introduction

When planning a building against natural hazards like earthquakes, we can design it to behave in one of the following three limit states depending on the importance of the structure:

Serviceability limit state: In this case, the structure will undergo little or no structural damage. Important buildings such as hospitals, places of assembly, atomic power plants, which are structures affecting a community, should be designed for elastic behaviour under expected earthquake forces. These structures should be serviceable even after the earthquake has taken place.

Damage controlled (Damageability) limit state (Damage threshold level): In this case, if an earthquake occurs there can be some damage to the structure but it can be repaired after the event and the structure can again put to use. Most of the permanent buildings should come under this category. For this purpose, the structure should be designed for limited ductile response only.

Survival (Collapse threshold level) Limit state: In this case, the structure may be allowed to be damaged in the event of an earthquake, but the supports should stand and be able to carry the permanent loads fully so that in all cases there should be no caving in of the structure and no loss of life.

Earthquakes produce large magnitude forces of short duration that must be resisted by a structure without causing collapse and preferably without significant damage to the structural element. The lateral forces due to earthquakes have a major impact on structural integrity. Lessons from past earthquakes and research have provided technical solution that will minimize loss of life and property damage associated with earthquake. Special detailing is required, and for materials without inherent ductility, such has concrete and masonry, a critical part of the solution is to incorporate reinforcement in the design and construction to assure a ductile responds to lateral forces. The ductility of the building can be increased by increasing the reinforcement in the structure. In the case of Earthquake design, ductility is an essential attribute of a structure that must respond to strong ground motions (Andreas, 2001). So, the ductility is related to the control of whether the structure is able to dissipate the given amount of seismic energy considered in structural analysis (Pankaj Agarwal, 2006). Ductility serves as the shock absorber in building, for it reduces the transmitted force to one that is sustainable. But the reinforcement plays an important role in the economy of the structure. The present IS code 1893: 2002 provides information regarding the excess amount of reinforcement to be used in the earthquake design but it does not provide the information about the percentage of the steel that should be increased in the earthquake resistant design when compared with the normal design as per IS:456-2000. When the building is designed for earthquake forces in different earthquake zones as per IS 1893:2002. This gives the approximate percentage in the economy compared with normal design (H J Shah, 2008).

II. Methodology

Seismic analysis of the structures is carried out on the basis of lateral force. The base shear which is the total horizontal force on the structure is calculated on the basis of structure mass and fundamental period of vibration and corresponding mode of shape. The base shear is distributed along the height of the structure in terms of lateral forces according to codal provisions (Kazuhiro, 1987). In this study, G+3 storied RC building has been analysed using the equivalent static method in STAAD PRO. The plan of the building taken for analysis is shown in Figure1. Three Dimensional view of the whole structure is shown in Figure2. Figure3 & Figure4 are showing the structure subjected to loading of earthquake in "+X" and "+Z" directions.

In the earthquake analysis along with earthquake loads, vertical loads are also applied. For the earthquake analysis, IS 1893-2002 code was used .The total design seismic base shear (Vb) along any principal direction shall be determined by multiplying the design horizontal acceleration in the considered direction of vibration (Ah) and the seismic weight of the building.

The Design base shear

$$(Vb) = Ah * W$$

Ah = design horizontal acceleration in the considered direction of vibration

$$= (Z/2)*(I/R)*(Sa /g)$$

W = total seismic value of the building

The design base shear (Vb) computed shall be distributed along the height of the building as per the following expression (BIS1893: 2000)

$$Qi = Vb*(Wi*hi2/ Wi*hi2)$$

Where,

Qi is the design lateral forces at floor i,

Wi is the seismic weights of the floor i, and

hi is the height of the floor i, measured from base

The lateral force on each storey is again distributed based on the deflection and stiffness of the frame.

The total lateral load in proportion to the stiffness of each frame in all the four zones (H M Salem, 2011) .The distributed lateral forces shown in the Figure3 and Figure4.

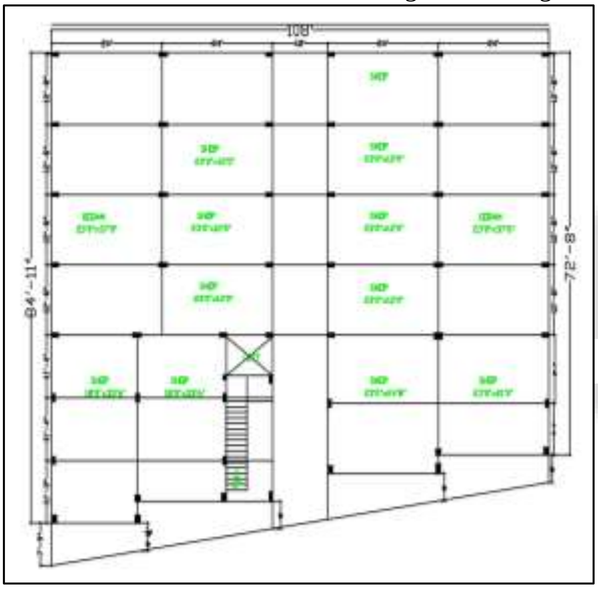

Fig. 1: Plan of Building

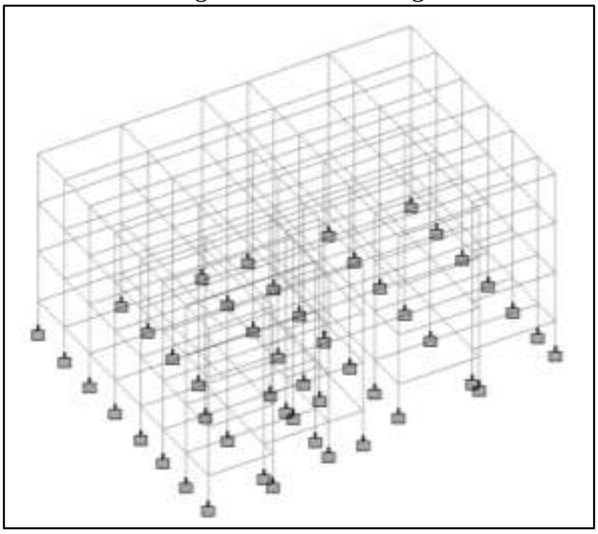

Fig. 2: 3D View of the Whole Structure

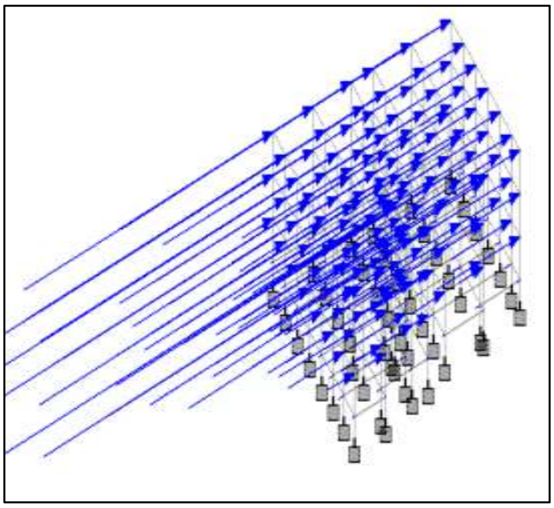

Fig. 3: Structure subjected to Earthquake loading in +X direction

1) Building Description

Number of Storey = G+3 , Beam size = 300 x 600, 300 x 400 (cover = 25 mm) Column size = 200 x 400 , 200 x 500 , 300 x 500 ,400 x 200 , 200 x 200 , 400 x 300 , 500 x 300 (cover = 40 mm) Concrete grade = M25, steel = Fe415

2) Earthquake Parameters

Seismic zone = II, III, IV, V , Response Reduction factor = 5 , Importance Factor = 1

Type of soil = Medium soil, Damping of structure = 0.05, Passion ratio = 0.2

Density = 23.5616 , Reinforcement factor= 4 , Earthquake load = As per IS: 1893 (part1)

3) Load Combinations:

The following load combinations are used in the seismic analysis, as mentioned in the code IS1893(part-1): 2002, Clause no. 6.3.1.2.

1) X axis
2) Z axis
3) Dead load (Self-load)
4) Live load (Imposed load)

Earthquake load was considered in +X, -X, +Z and –Z directions. All the load combinations are analyzed using software STAAD PRO. All the load combinations are mentioned above.

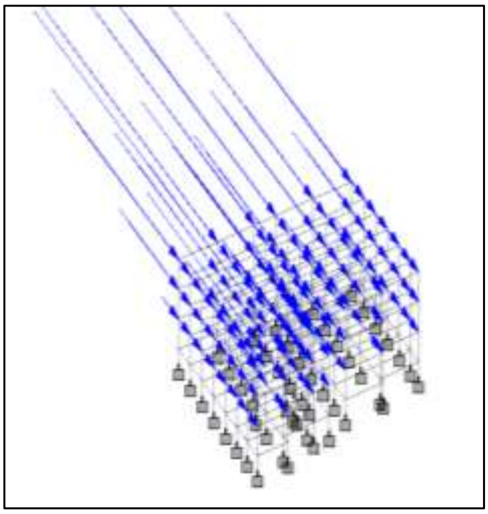

Fig. 4: Structure subjected to Earthquake loading in +Z direction

III. RESULTS:

1) *Concrete Column Design:*

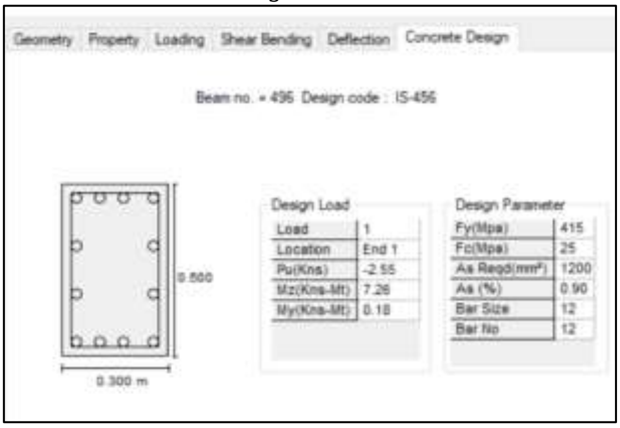

Fig. 5: Column Reinforcement Details (Max Fx)

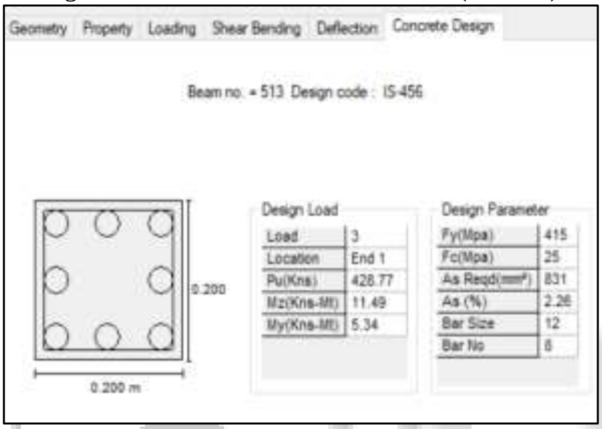

Fig. 6: Column Reinforcement Details (Min Fx)

Fig. 7: Column Reinforcement Details (Max Fy)

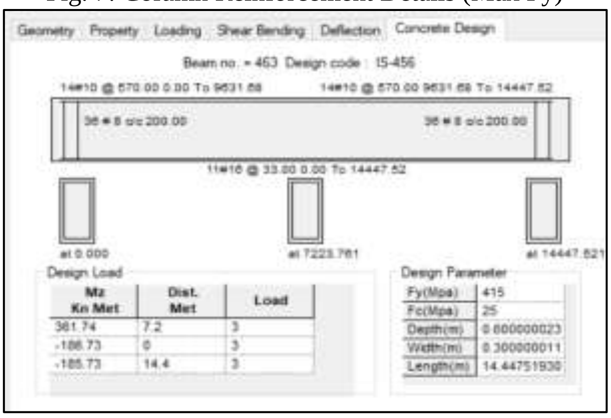

Fig. 8: Column Reinforcement Details (Min Fy)

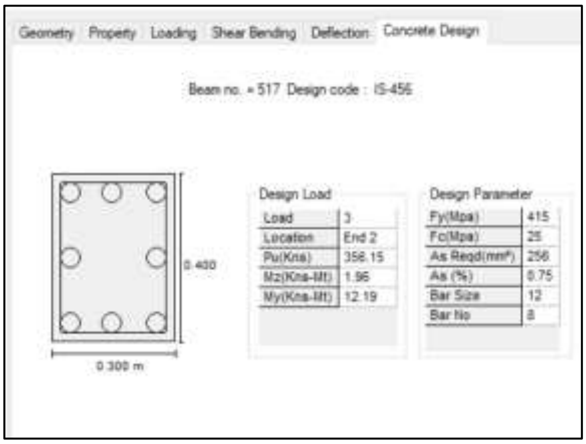

Fig. 9: Column Reinforcement Details (Max Fz)

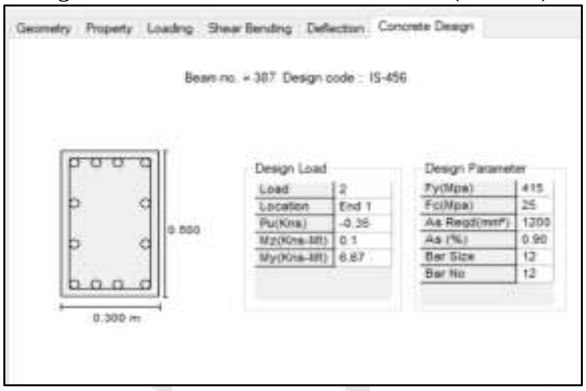

Fig. 10: Column Reinforcement Details (Min Fz)

Fig. 11: Column Reinforcement Details (Max Mx)

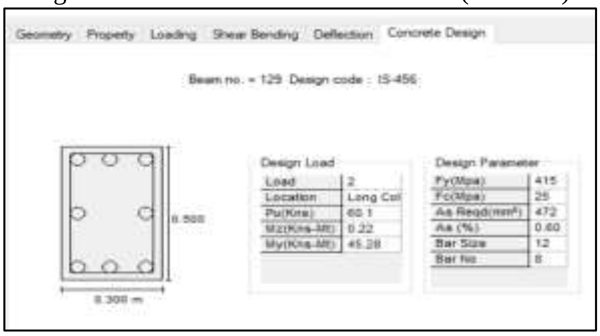

Fig. 12: Column Reinforcement Details (Max My)

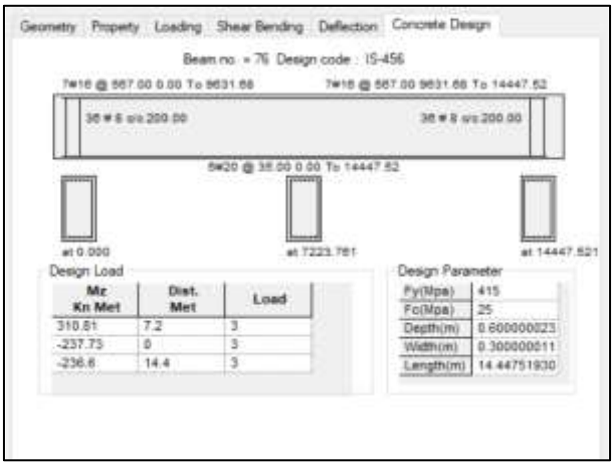

Fig. 12: Column Reinforcement Details (Max Mz)

B. Beam Force:

	Beam	L/C	Node	Fx KN	Fy KN	Fz KN
Max Fx	496	3DL	230	1440.716	20.465	14.888
Min Fx	513	2Z	47	-61.313	-0.132	3.836
Max Fy	334	3DL	145	-5.865	145.684	0.336
Min Fy	463	3DL	196	50.640	-144.281	0.713
Max Fz	517	3DL	51	350.975	-1.476	24.330
Min Fz	387	3DL	150	178.267	11.251	-26.215
Max Mx	457	3DL	188	12.289	7.438	-4.444
Min Mx	439	3DL	197	26.327	-61.182	18.465
Max My	129	2Z	50	60.096	-0.284	-20.730
Min My	387	3DL	200	165.340	11.251	-26.215
Max Mz	76	3DL	45	35.358	145.549	0.051
Max Mz	511	3DL	45	892.892	-77.365	-4.783

Table 1: Beam end forces (Shear Force)

	Beam	L/C	Node	Mx KNm	My KNm	Mz KNm
Max Fx	496	3DL	230	0.405	-8.487	12.923
Min Fx	513	2Z	47	0.001	-3.510	-0.154
Max Fy	334	3DL	145	0.576	-2.397	233.260
Min Fy	463	3DL	196	0.878	5.473	185.731
Max Fz	517	3DL	51	-0.082	-32.307	-0.739
Min Fz	387	3DL	150	-2.819	40.059	18.036
Max Mx	457	3DL	188	70.295	3.912	-28.061
Min Mx	439	3DL	197	-52.202	-13.488	-16.396
Max My	129	2Z	50	0.101	45.283	-0.483
Min My	387	3DL	200	-2.819	-55.824	-23.117
Max Mz	76	3DL	45	0.401	-0.282	237.730
Min Mz	511	3DL	45	0.039	5.257	-94.997

Table 2: Beam end forces (Bending Moment)

IV. CONCLUSION

IS code gives a value of 2.5 to be multiplied to the ground storey beam and column forces when a building has to be designed as open ground storey (OGS) building or stilt building. The ratio of IR values for columns and DCR values of beams for both the support conditions and building models were found out using ESA and RSA and both the analyses supports that a factor of 2.5 is too high to be multiplied to the beam and column forces of the ground storey. This is particularly true for low- rise OGS buildings.

This linear analysis show that column forces at the ground storey increases for the presence of infill wall in the upper storeys. But design force amplification factor found to be much lesser than 2.5.

Beam and Column are the research paper enables to analysis the G+3 structure in all zones under seismic as well as static loads where in the displacements observed are the nearly same.

The moment obtained in z- direction is very high in case of seismic analysis as compared to that in static analysis in beam. Because we can conclude that with the effect of seismic forces the moment on the load carrying member gets increased.

The change in moment in z-direction is nearly same but the change in moment in y- direction is very high in case of seismic analysis. Because of the higher moment, we have to provide higher amount of reinforcement.

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