Earthquake Resistant Design of Ground Storey Frame Building

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Abstract— Presence of infill walls in the frames adjusts the conduct of the working under horizontal burdens. Notwithstanding, it is regular industry practice to overlook the stiffness of infill divider for examination of confined building. Engineers trust that examination without considering infill stiffness prompts a preservationist outline. In any case, this may not be constantly valid, particularly for vertically unpredictable buildings with broken infill walls. Thus, the displaying of infill walls in the seismic examination of confined buildings is basic. Indian Standard IS 1893: 2002 permits investigation of open ground story buildings without considering infill stiffness however with a duplication element 2.5 in pay for the stiffness irregularity. According to the code the segments and light emissions open ground story are to be intended for 2.5 times the story shears and minutes computed under seismic heaps of uncovered frames (i.e., without considering the infill stiffness). Notwithstanding, as experienced by the architects at outline workplaces, the augmentation element of 2.5 is not reasonable for low ascent buildings. This requires an evaluation and audit of the code suggested duplication variable for low ascent open ground story buildings. Along these lines, the goal of this proposition is characterized as to check the material of the augmentation variable of 2.5 and to consider the impact of infill quality and stiffness in the seismic examination of low ascent open ground story building.

Key words: Ground Storey Frame Building, Earthquake Resistant Design

I. Introduction

Non-linear dynamic (NDA) analysis is considered to be the most accurate but at the same time it is most rigorous among all methods. Hence for the present study Equivalent static analysis (ESA), Response spectrum analysis (RSA) and Pushover analysis (PA) is considered for the comparative study. To carry out these analyses a typical building model with two different cases and support conditions are considered.

- Considering infill strength and stiffness
- Without considering infill strength and stiffness

Masonry infill walls are widely used as partitions all over the world. Evidences are that continuous infill masonry walls can reduce the vulnerability of the reinforced concrete structure. Often masonry walls are not considered in the design process because they are supposed to act as non-structural members or elements. Separately the infill walls are stiff and brittle but the frame is relatively flexible and ductile. The composite action of beam-column and infill walls provides additional strength and stiffness

II. Structural Modeling

It is very important to develop a computational model on which linear/non-linear, static/dynamic analysis is performed. Infill walls are modelled as equivalent diagonal strut elements.

III. Building Description

An existing OGS framed building located at Hyderabad, India (Seismic Zone V) is selected for the present study. The building is fairly symmetric in plan and in elevation. This building is a G+3 storey building (12m high) and is made of Reinforced Concrete (RC) Ordinary Moment Resisting Frames (OMRF). The concrete slab is 150mm thick at each floor level. The brick wall thicknesses are 230 mm for external walls and 120 mm for internal walls. Imposed load is taken as 2kN/ m^2 for all floors. Fig represents typical floor plans showing different column and beam locations. The cross sections of the structural members (columns and beams 300 mm×600 mm) are equal in all frames and all stories. Storey masses to 295 and 237 tonnes in the bottom storyes and at the roof level, respectively. The design base shear was equal to 0.15 times the total weight.

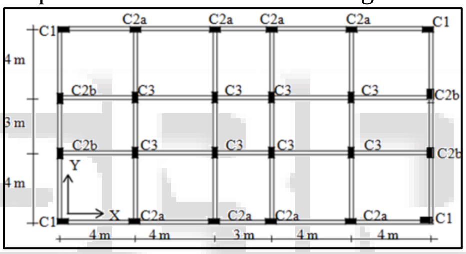

Fig. 1(a): Column Locations

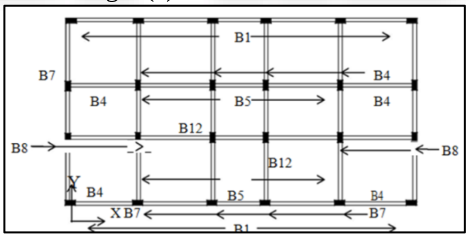

Fig. 1(b): Beam Locations

Fig. 1: Typical floor plan of the selected building

The amount of longitudinal reinforcement in the columns and beams is given in Table. Although the columns have equal reinforcement in all storey levels beam reinforcement in floor and roof are different. Refer Fig. (a) and (b) for column and beam identification (ID).

Column ID	Longitudinal Reinforcement	Beam ID	Top steel	Bottom steel
C1	12Y16	B1	4Y16	3Y16
C2(a)	8Y20	B4	3Y16	2Y16
C2(b)	8Y20	B5	2Y16, 1Y12	2Y16
C3	8Y16	B7	3Y16	3Y16
		B12	3Y16	2Y16, 1Y12
		Roof Beams	2Y16	2Y16

Table 1: Column and Beam Identification

IV. STRUCTURAL MODELING

Modelling a building involves the modelling and assemblage of its various load-carrying elements. The model must ideally represent the mass distribution, strength, stiffness and deformability. Modelling of the material properties and structural elements used in the present study is discussed below.

A. Material Properties

M-20 grade of concrete and Fe-415 grade of reinforcing steel are used for all the frame models used in this study. Elastic material properties of these materials are taken as per Indian Standard IS 456: 2000. The short-term modulus of elasticity (*Ec*) of concrete is taken as:

$$E=5000\ N/mm^2$$

B. Structural Elements

Beams and columns are modelled by 3D frame elements. The beam-column joints are modelled by giving end-offsets to the frame elements, to obtain the bending moments and forces at the beam and column faces. The beam-column joints are assumed to be rigid.

The structural effect of slabs due to their in-plane stiffness is taken into account by assigning 'diaphragm' action at each floor level. The mass/weight contribution of slab is modelled separately on the supporting beams.

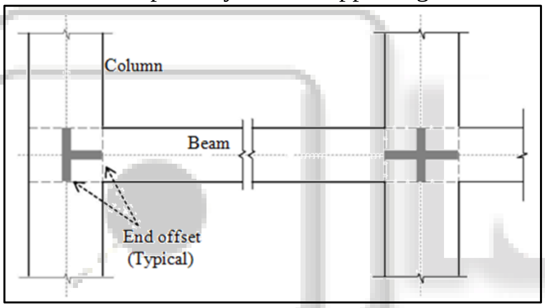

Fig. 2: Structural Effect

C. Modelling Infill Walls

Infill walls are two dimensional elements that can be modelled with orthotropic plate element for linear analysis of buildings with infill wall. But the nonlinear modelling of a two dimensional plate element is not understood well. Therefore infill wall has to be modelled with a one-dimensional line element for nonlinear analysis of the buildings. Same building model with infill walls modelled as one-dimensional line element is used in the present study for both linear and nonlinear analyses. Infill walls are modelled here as equivalent diagonal strut elements.

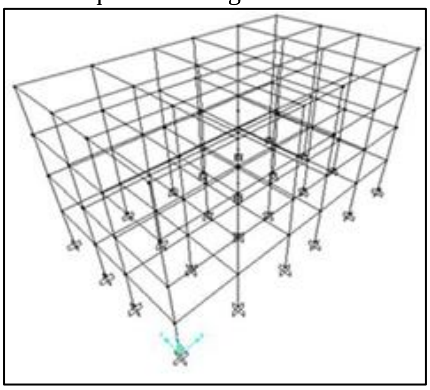

Fig. 3: Without Infill

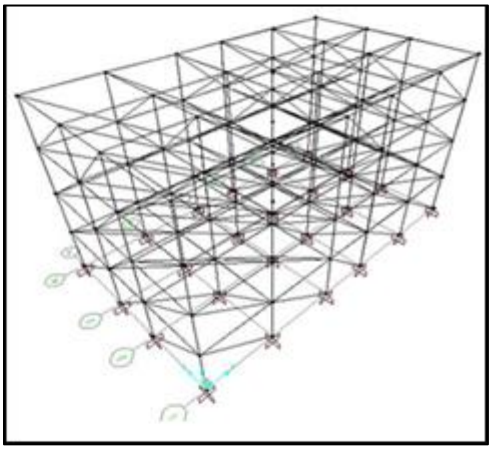

Fig. 4: With Infill

D. Strength of Equivalent Strut

The strength of the equivalent strut is governed by the lowest of the failure loads corresponding to the following failure modes.

1) Local crushing of the infill at one of the loaded corners.
2) Shear cracking along the bedding joints of the brickwork.

The diagonal tensile cracking need not be considered as a failure mode, as higher load can be carried beyond tensile cracking.

V. RESULTS

A. Results from Linear Analysis

Seismic analysis is a subset of structural analysis and is the calculation of the response of the building structure to earthquake and is a relevant part of structural design where earthquakes are prevalent. The seismic analysis of a structure involves evaluation of the earthquake forces acting at various level of the structure during an earthquake and the effect of such forces on the behaviour of the overall structure. The analysis may be static or dynamic in approach as per the code provisions.

Thus broadly we can say that linear analysis of structures to compute the earthquake forces is commonly based on one of the following three approaches.

1) An equivalent lateral procedure in which dynamic effects are approximated by horizontal static forces applied to the structure. This method is quasi-dynamic in nature and is termed as the Seismic Coefficient Method in the IS code.
2) The Response Spectrum Approach in which the effects on the structure are related to the response of simple, single degree of freedom oscillators of varying natural periods to earthquake shaking.
3) Response History Method or Time History Method in which direct input of the time history of a designed earthquake into a mathematical model of the structure using computer analyses.

B. Equivalent Static Analysis

This is a linear static analysis. This approach defines a way to represent the effect of earthquake ground motion when series of forces are act on a building, through a seismic design response spectrum. This method assumes that the building responds in its fundamental mode. The applicability of this method is extended in many building codes by applying factors to account for higher buildings with some higher modes, and for low levels of twisting.

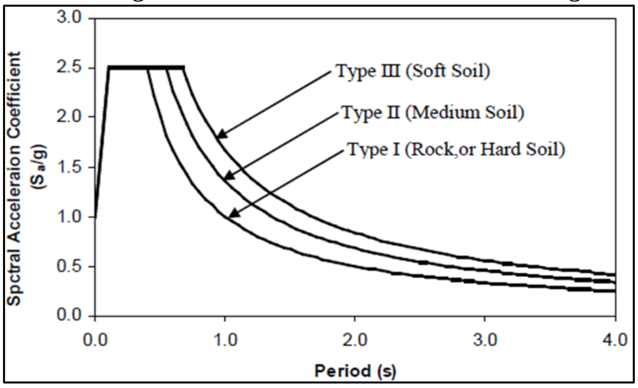

Fig. 5: Linear Static Analysis

C. *Calculation of Time Period and Base Shear*

The design base shear (*VB*) was calculated as per IS 1893: 2002 corresponding to the fundamental period for moment-resisting framed buildings with brick infill panels as follows:

$$V_B = A_h W$$

$$A_h = \frac{Z}{2}\frac{I}{R}\frac{S_a}{g}$$

$$T_a = \frac{0.09h}{\sqrt{d}}$$

	With infill		Without infill	
	Vx (kN)	Vy (kN)	Vx (kN)	Vy (kN)
Equivalent Static	1566	1566	1566	1566
Response Spectra	1427	1427	1300	1310
Equivalent static/ Response spectra	1.1	1.1	1.2	1.9

Table 2: Comparison of fundamental time periods for with and without infill for pinned and fixed end support condition

VI. RESULTS FROM NON-LINEAR ANALYSIS

A. *Pushover Analysis*

The pushover analysis is a nonlinear static method which is used in a performance based analysis. The method is relatively simple to be implemented, and provides information on strength, deformation and ductility of the structure and distribution of demands which help in identifying the critical members likely to reach limit states during the earthquake and hence proper attention can be given while designing and detailing.

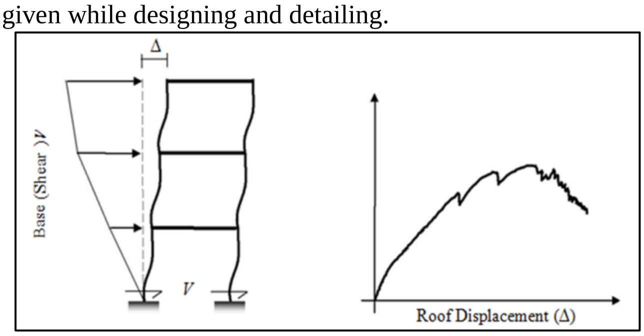

Fig. 6: Schematic representation of pushover analysis procedure

B. *Results from Pushover Analysis*

Pushover analysis is carried out for both of the two building models. First pushover analysis is done for the gravity loads (DL+0.25LL) incrementally under load control. The lateral pushover analysis (PUSH-X and PUSH-Y) is followed after the gravity pushover, under displacement control. The building is pushed in lateral directions until the formation of collapse mechanism.

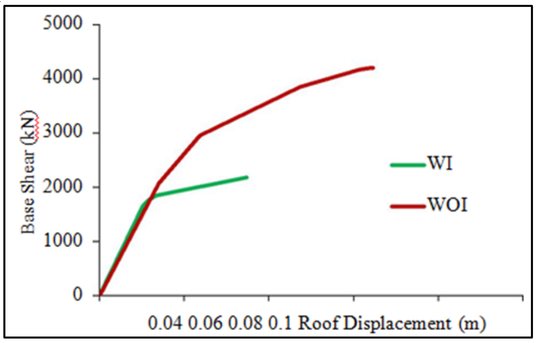

Fig. 7(a): X-direction Push

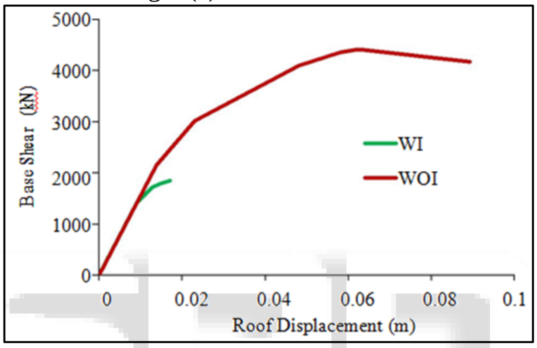

Fig. 7(b): Y-direction Push

C. *Pushover Curves for Pinned-End Building*

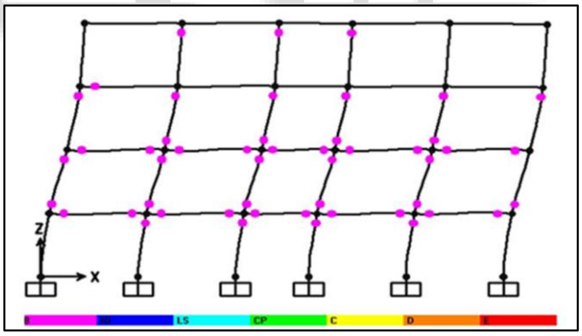

Fig. 8(a): Modelled without infill stiffness

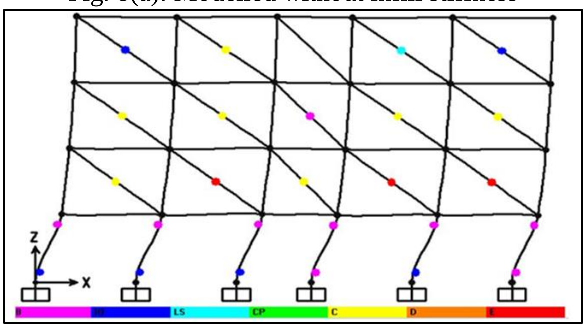

Fig. 8(b): Modelled with infill stiffness

VII. CONCLUSIONS

Followings are the salient conclusions obtained from the present study:

1) 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 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.
2) Problem of OGS buildings cannot be identified properly through elastic analysis as the stiffness of OGS building and Bare-frame building are almost same.
3) Nonlinear analysis reveals that OGS building fails through a ground storey mechanism at a comparatively low base shear and displacement. And the mode of failure is found to be brittle.

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