International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 06 | June-2018 www.irjet.net p-ISSN: 2395-0072

STUDY OF EFFECT ON SEISMIC RESISITANT BUILDINGS WITH & WITHOUT INFILL WALLS

Anuj Kumar[1], Narayan Tiadi[2], B. S. Tyagi[3], Varun Tyagi[4]

[1,2,3,4] *Civil Engineering Department, RGGI Meerut, Uttar Pradesh, India*

Abstract - *Presence of infill walls in the frames alters the behaviour of the buildings under lateral loads. However, it is common industry practice to ignore the stiffness of infill wall for analysis of framed buildings. 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. Hence, the modelling of infill walls in the seismic analysis of framed buildings is imperative. Indian Standard IS 1893: intro with a multiplication factor 2.5 in compensation for the stiffness discontinuity. As per the code the columns & beams of the open ground storey are to be designed for 2.5 times the storey shears & 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. This calls for an assessment & review of the code recommended multiplication factor for low rise open ground storey buildings Infill walls can be modelled in commercial software using two-dimensional area element with appropriate material properties for linear elastic analysis. But this type of modelling may not work for non-linear analysis since the non-linear material properties for a two-dimensional orthotropic element is not very well understood. Seismic evaluation of an existing reinforcesd concrete (RC) framed buildings would invariably require a non-linear analysis. Published literature in this area recommends a linear diagonal strut approach to model infill wall for both linear (Equivalent Static Analysis & Response Spectrum Analysis) & nonlinear analyses (Pushover Analysis & Time History Analysis).An existing RC framed buildings (G+3) with open ground storey located in Seismic Zone-V is considered for this study. This buildings is analyzed for two different cases: (a) considering both infill mass & infill stiffness & (b) considering infill mass but without considering infill stiffness. Two separate models were generated using commercial software STAAD PRO. Infill weights were modelled through applying static dead load & corresponding masses considered from this dead load for dynamic analyses. Infill stiffness was modelled using a diagonal strut approach. Two different support conditions, namely fixed end support condition & pinned end support condition, are considered to check the effect of support conditions in the multiplication factors. Linear & non-linear analyses were carried out for the models & the results were compared.*

Key Words: **infill walls, diagonal strut, open ground storey, equivalent static analysis, response spectrum analysis, pushover analysis, low rise buildings**

1. INTRODUCTION

Due to increasing population since the past few years car parking space for residential apartments in populated cities is a matter of major concern. Hence the trend has been to utilize the ground storey of the buildings itself for parking. These types of buildings having no infill brick walls in ground storey, but infilled in all upper storeys, are called Open Ground Storey (OGS) buildings. They are also known as 'open first storey buildings' (when the storey numbering starts with one from the ground storey itself), 'pilotis', or 'stilted buildings'.

There is significant advantage of these category of buildingss functionally but from a seismic performance point of view such buildingss are considered to have increased vulnerability. From the past seismics it was evident that the major type of failure that occurred in OGS buildingss included snapping of lateral ties, crushing of core concrete, buckling of longitudinal reinforcesment bars etc. Due to the presence of infill walls in the entire upper storey except for the ground storey makes the upper storeys much stiffer than the open ground storey. Thus, the upper storeys move almost together as a single block, & most of the horizontal displacement of the buildings occurs in the soft ground storey itself. In other words, this type of buildingss sway back & forth like inverted pendulum (Fig. 1.2) during seismic shaking, & hence the columnss in the ground storey columnss & beamss are heavily stessesed. Therefore it is required that the ground storey columnss must have sufficient strength & adequate ductility. The vulnerability of this type of buildings is attributed to the sudden lowering of lateral stiffness & strength in ground storey, compared to upper storeys with infill walls.

Brick infill walls are widely used as partitions all over the world. Evidences are that continuous infill brick walls can reduce the vulnerability of the reinforcesd concrete structures. Often brick 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 & brittle but the frame is relatively flexible & ductile. The composite action of beams-columns & infill walls provides additional strength & stiffness. The Fig. 1.4 shows the equivalent diagonal strut model for the infilled frame.

1.1 NEED FOR THE PRESENT STUDY

As experienced by the engineers at design offices the multiplication factor of 2.5 given by IS 1893:2002, for ground storey beamss & columnss, is not realistic for low rise buildingss. This calls for a critical assessment & review of the code recommended multiplication factor. Assessment of the multiplication factor (MF) requires accurate analysis of OGS buildingss considering infill stiffness & strength. The presence of infill walls in upper storeys of OGS buildingss accounts for the following issues:

- Increases the lateral stiffness of the buildings frame
- Decreases the natural period of vibration
- Increases the base shear
- Increases the shear forcess & bending moments in the ground storey columns.

There is a clear need to assess the design guidelines recommended by the IS code 1893:2002 based on accurate analysis.

- This study deals with two different types of support conditions commonly used in analysis & design i.e., fixed & pinned end support condition. All other types of support conditions are not considered in this project. Soil-structures interaction is ignored for the present study.
- Number of storey & number of bays in two orthogonal horizontal directions may have a great effect on the lateral load resisting behaviour of OGS buildingss. However, the conclusions drawn in the present study are based on a case study of a low-rise buildings (4 storeys).
- It is assumed in the present study that infill panels are having no window & door openings while modelling the infill walls.
- Point plastic flexural hinges only is considered for modelling the frame elements as the buildings is designed as per current design codes of practices & it is assumed no shear failure will precede the flexural failure.

1.2 SCOPE OF THE STUDY

Open ground storey (OGS) buildingss are commonly constructed in populated countries like India since they provide much needed parking space in an urban environment. Failures observed in past seismics show that the collapse of such buildingss is predominantly due to the formation of soft-storey mechanism in the ground storey columns.

- This study deals with two different types of support conditions commonly used in analysis & design i.e., fixed & pinned end support condition. All other types of support conditions are not considered in this project. Soil-structures interaction is ignored for the present study.
- It is assumed in the present study that infill panels are having no window & door openings while modelling the infill walls.
- Point plastic flexural hinges only is considered for modelling the frame elements as the buildings is designed as per current design codes of practices & it is assumed no shear failure will precede the flexural failure.

In the present study buildings models are analyzed only using linear static, dynamic analysis & nonlinear static (pushover) analysis. Although nonlinear dynamic analysis is superior to other analysis procedures, it is kept outside the scope of the present study due to time limitation.

1.3 OBJECTIVE

The salient objectives of the present study have been identified as follows:

i. To study the effect of infill strength & stiffness in the seismic analysis of OGS buildingss.

ii. To check the applicability of the multiplication factor of 2.5 as given in the Indian Standard IS 1893:2002 for design of low rise open ground storey buildings.

iii. To assess the effect of support condition on the seismic behaviour of OGS buildings.

2. METHODOLOGY

BUILDINGS DESCRIPTION

An existing OGS framed buildings located at Guwahati, India (Seismic Zone V) is selected for the present study. The buildings is fairly symmetric in plan & in elevation. This buildings is a G+3 storey buildings (12m high) & is made of Reinforcesd Concrete (RC) Ordinary Moment

Resisting Frames (OMRF). The concrete slab is 150mm thick at each floors level. The brick wall thicknesses are 230 mm for external walls & 120 mm for internal walls. Imposed load is taken as 2 kN/ m^2 for all floorss. Fig. 3.1 presents typical floors plans showing different columns & beams locations. The cross sections of the structural members (columnss & beamss 300 mm×600 mm) are equal in all frames & all stories. Storey masses to 295 & 237 tonnes in the bottom storyes & at the roof level, respectively. The design base shear was equal to 0.15 times the total weight.

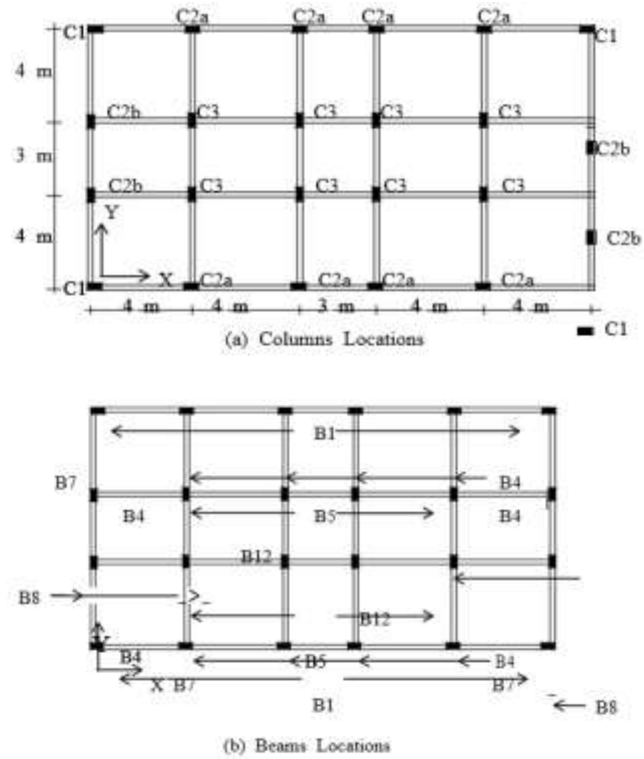


Fig. 1: Typical floor plan of the selected buildings

The amount of longitudinal reinforcesment in the columnss & beamss is given in Table 3.1. Although the columnss have equal reinforcesment in all storey level beams reinforcesment in floors & roof are different. Refer Fig. 3.1 (a) & (b) for columns & beams identification (ID).

Columns ID	Longitudinal Reinforcesment	Beams 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
		B8	3Y16	3Y16
		B12	3Y16	2Y16, 1Y12
		Roof Beamss	2Y16	2Y16

Chart 1: Longitudinal reinforcement details of frame section

Structural Elements

Beamss & columnss are modelled by 3D frame elements. The beams-columns joints are modelled by giving end-offsets to the frame elements, to obtain the bending moments & forcess at the beams & columns faces. The beams-columns joints are assumed to be rigid.

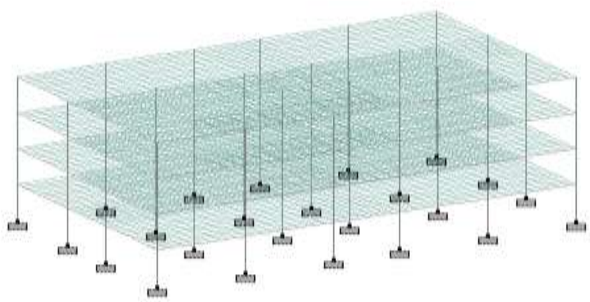
Beamss & columnss in the present study were modelled as frame elements with the centrelines joined at nodes using commercial software STAAD PRO. The rigid beams-columns joints were modelled by using end offsets at the joints (Fig. 3.2). The floors slabs were assumed to act as diaphragms, which ensure integral action of all the vertical lateral load-resisting elements. The weight of the slab was distributed as triangular & trapezoidal load to the surrounding beams.

Modelling of Columns Ends at the Foundation

The selected buildings is supported on a raft foundation. Therefore, the columns ends are modelled as fixed at the top of the raft & analysed. To study how the response of the buildings changes with the support conditions, the same buildings model also analysed by providing a hinge in place of fixity.

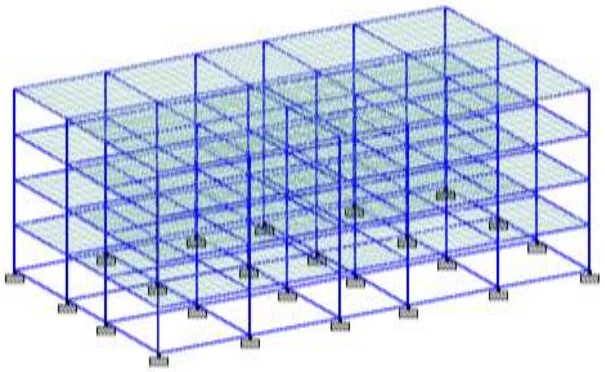
Modelling of Infill Walls

Infill walls are two dimensional elements that can be modelled with orthotropic plate element for linear analysis of buildingss 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 buildingss. Same buildings model with infill walls modelled as one-dimensional line element is used in the present study for both linear & nonlinear analyses. Infill walls are modelled here as equivalent diagonal strut elements. Section 3.5 explains the modelling of infill was as diagonal strut in detail.



(a) Without Infill

Fig. 3.3 presents a three-dimensional computer model of buildings without & with considering infill stiffness.



(b) With Infill

Fig. 2: 3D Computer model of buildings without & with considering infill stiffness respectively

MODELLING OF FLEXURAL PLASTIC HINGES

In the implementation of pushover analysis, the model must account for the nonlinear behaviour of the structural elements. In the present study, a point-plasticity approach is considered for modelling nonlinearity, wherein the plastic hinge is assumed to be concentrated at a specific point in the frame member under consideration. Beams & columns elements in this study were modelled with flexure (M3 for beamss & P-M2-M3 for columnss) hinges at possible plastic regions under lateral load (i.e., both ends of the beamss & columnss). Refer Fig. 3.4 for the local axis system considered. Properties of flexure hinges must simulate the actual response of reinforcesd concrete components subjected to lateral load. In the present study the plastic hinge properties are calculated by STAAD PRO. The analytical procedure used to model the flexural plastic hinges are explained below.

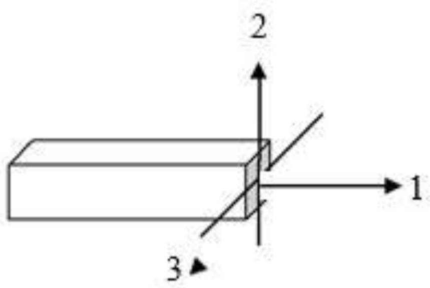


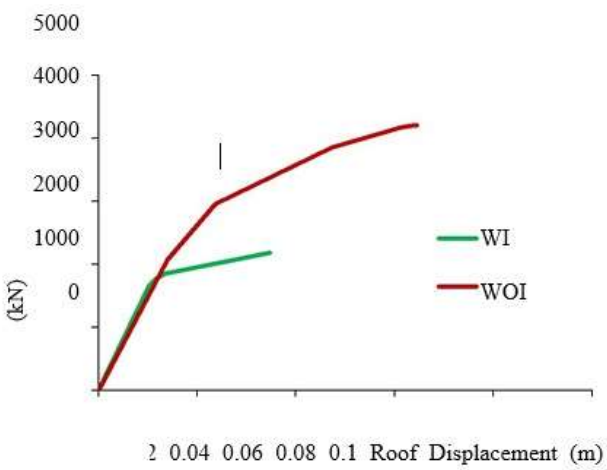
Fig. 3: The coordinate system used to define the flexural & shear hinges

Flexural hinges in this study are defined by moment-rotation curves calculated based on the cross-section & reinforcesment details at the possible hinge locations. For calculating hinge properties it is required to carry out moment–curvature analysis of each element. Constitutive relations for concrete & reinforcing steel, plastic hinge length in structural element are required for this purpose. The flexural hinges in beamss are modelled with uncoupled moment (M3) hinges whereas for columns elements the flexural hinges are modelled with coupled P-M2-M3 properties that include the interaction of axial forces & bi-axial bending moments at the hinge location. Although the axial forces interaction is considered for columns flexural hinges the rotation values were considered only for axial forces associated with gravity load.

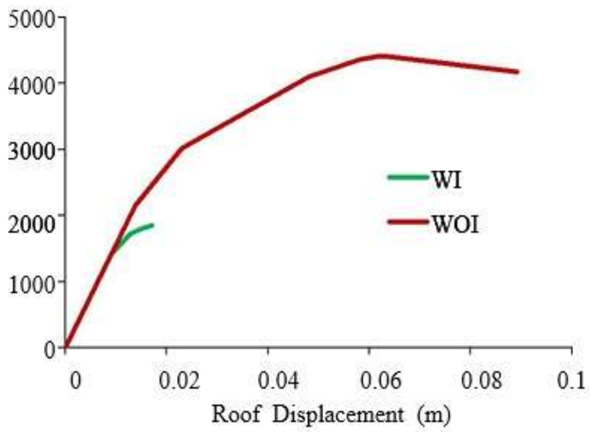
4. RESULT AND DISCUSSION

RESULTS FROM PUSHOVER ANALYSIS

Pushover analysis is carried out for both of the two buildings models. First pushover analysis is done for the gravity loads (DL+0.25LL) incrementally under load control. The lateral pushover analysis (PUSH-X & PUSH-Y) is followed after the gravity pushover, under displacement control. The buildings is pushed in lateral directions until the formation of collapse mechanism. The capacity curve (base shear versus roof displacement) is obtained in X- & Y- directions & presented in Figs. 5.3(a) & 5.3(b). These figures clearly show that global stiffness of an open ground storey buildings hardly changes even if the stiffness of the infill walls is ignored. If there is no considerable change in the stiffness elastic base shear dem& for the buildings will also not change considerably if the stiffness of the infill walls is ignored. The variation of pushover curves in X- & Y- directions is in agreement with the linear analysis results presented in the previous section with regard to the variation of elastic base shear dem& for different buildings models.



(a) X- Direction Push



(b) Y- Direction Push

Fig. 4: Pushover curves for pinned-end buildings

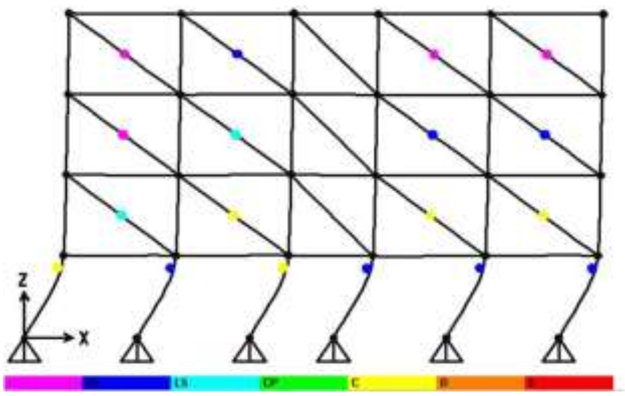


Fig. 5: Distribution of plastic hinges for WI buildings model

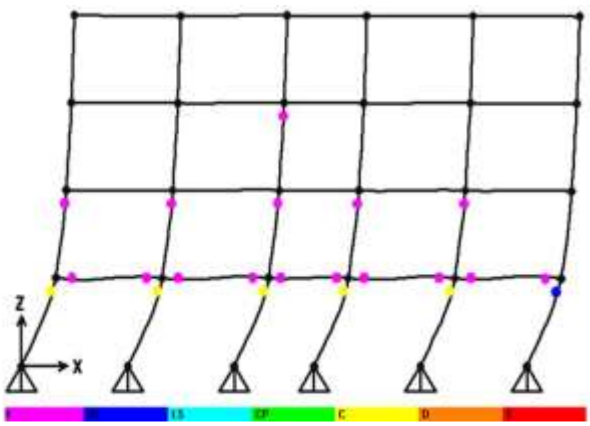


Fig. 6: Distribution of plastic hinges for WOI buildings model

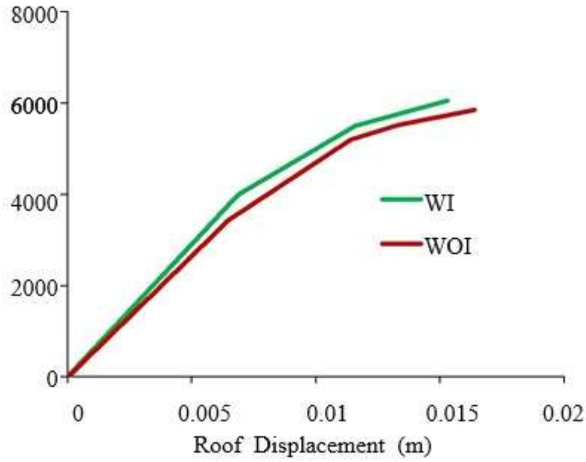


Fig. 7: Storey displacement at collapse for pinned end case (Push X)

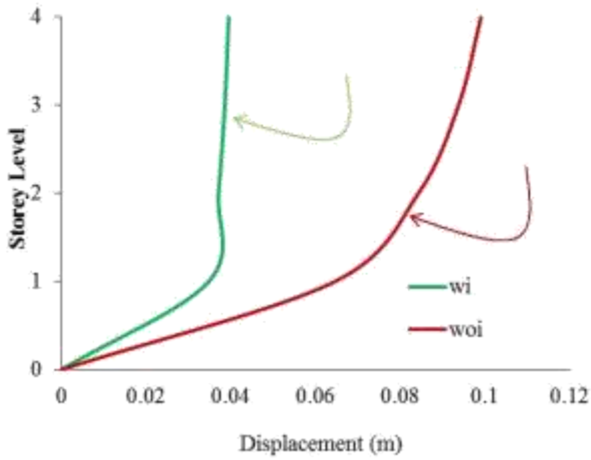


Fig. 8: Pushover curves for fixed-end buildings model

4. CONCLUSIONS

Followings are the salient conclusions obtained from the present study:

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

- Problem of OGS buildingss cannot be identified properly through elastic analysis as the stiffness of OGS buildings & Bare-frame buildings are almost same.

- Nonlinear analysis reveals that OGS buildings fails through a ground storey mechanism at a comparatively low base shear & displacement. & the mode of failure is found to be brittle.

- Both elastic & inelastic analyses show that the beamss forcess at the ground storey reduce drastically for the presence of infill stiffness in the adjacent storey. & design forces amplification factor need not be applied to ground storey beamss.

- The linear (static/dynamic) analyses show that Columns forcess at the ground storey increases for the presence of infill wall in the upper storeys. But design forces amplification factor found to be much lesser than 2.5.

From the literature available it was found that the support condition for the buildingss was not given much importance. Linear & nonlinear analyses show that support condition influences the response considerably & can be an important parameter to decide the forces amplification factor.

REFERENCES

[1] A. Asokan, (2006) Modelling of Brick Infill Walls for Nonlinear Static Analysis of Buildingss under Seismic Loads. M. S. Thesis, Indian Institute of Technology Madras, Chennai.

[2] Agarwal P. & Shrikh&e M. (2006) Seismic resistant design of structuress, PHI Learning Pvt. Ltd., New Delhi.

[3] Al-Chaar, G. (2002) Evaluating strength & stiffness of unreinforcesd brick infill structuress. U.S. Army Corps of Engineers. Technical Report NO. ERDC/CERL TR-02-1. Construction Engineering Research Laboratory. Campaign. USA

[4] Al-Chaar, G., M. Issa & S. Sweeney (2002) Behaviour of brick infilled non-ductile RC frames. Journal of Structural Engineering. American society of Civil Engineers. 128(8). 1055-1063.

[5] Arlekar, J.N.; S. K. Jain & C.V.R Murty (1997) Seismic response of RC frame buildingss with soft first storeys. Proceedings of CBRI golden jubilee conference on natural hazards in urban habitat. New Delhi.

[6] Asteris P. G. (2003) Lateral stiffness of brick brick infilled plane frames. Journal of Structural Engineering. 129(8). 1071-1079.

[7] Chopra A. K. (1973) Seismic resistance of buildingss with a soft first storey. Seismic & Structural Dynamics. 1. 347-355.

[8] Chug, R. (2004) Studies on RC Beamss. Columnss & Joints for Seismic Resistant Design. M. Tech Project Report. Indian Institute of Technology Madras, Chennai. India.

[9] Crisafulli F. J. (1999) Seismic Behaviour of reinforcesd concrete structuress with brick infills. Ph.D. Thesis. University of Canterbury. New Zealand.

[10] Das, S. (2000) Seismic design of vertically irregular reinforcesd concrete structuress. Ph.D. Thesis. North Carolina State University. Raleigh. NC.

[11] Das, S. & J. M. Nau (2003) Seismic design aspects of vertically irregular reinforcesd concrete buildingss. Seismic Spectra. 19. 455-477.

[12] Deodhar, S. V. & A. N. Patel (1998) Ultimate strength of brick infilled steel frames under horizontal load. Journal of Structural Engineering. Structural Engineering Research Centre. 24. 237-241.