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EARTHQUAKE RESISTANT DESIGN OF OPEN GROUND STOREY BUILDING

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ABSTRACT:Open ground building (OGS) has had its spot in the Indian urban condition because of the way that it gives truly necessary stopping office in the ground story of the building. Reviews of structures bombed in past tremors demonstrate that this sorts of structures are observed to be a standout amongst the most helpless. Nearness of infill dividers in the edge adjusts the conduct of the building under parallel burdens. Be that as it may, it"s basic industry practice to disregard the firmness of infill divider for investigation of confined building. Configuration in light of such investigation brings about under-estimation of building minutes and shear powers in the segments of ground story what's more, thus it might be one reason in charge of the disappointment watched. IS code 1893:2002 permits the investigation of open ground story RC confined working without considering infill firmness however with a duplication factor of 2.5 in remuneration for solidness irregularity. According to the code" The sections and Beams of delicate story building are to be intended for 2.5 times the story shears and bowing minutes computed under seismic heaps of exposed casings. Be that as it may, as experienced by the specialist at outline workplaces, MF of 2.5 in not reasonable for low and mid ascent structures. This calls for evaluation and survey of the code prescribed increase Factor for low ascent and mid ascent OGS structures. In this way goal of this investigation is to check the relevance of augmentation factor of 2.5 and to think about the impact of infill quality and solidness in seismic investigation of OGS structures. Three Different models of existing RC surrounded working with open ground story situated in Seismic Zone V is considered for the examination utilizing business Etabs Software. Infill Stiffness with openings was displayed utilizing a Diagonal Strut approach. Straight and Non-Linear examination is completed for these models and results were looked at.

Keywords: Infill Walls, Equivalent Diagonal Strut, Open First Story, Response Spectrum Analysis, Equivalent Static Investigation, Multiplication Factor, Pushover Analysis

I.INTRODUCTION

Open ground story (OGS) structures are generally developed in populated nations like India since they give much required parking spot in a urban domain. Disappointments saw in past seismic tremors demonstrate that the crumple of such structures is overwhelmingly because of the arrangement of delicate story instrument in the ground story sections. In ordinary outline rehearse, the commitment of firmness of infill divider shows in upper story of OGS encircled structures are overlooked in auxiliary demonstrating. From the past quakes it was apparent that the significant sort of disappointment that happened in OGS structures included snapping of sidelong ties, squashing of center cement, clasping of longitudinal support bars and so on. Because of the nearness of infill dividers in the whole upper story with the exception of the ground story makes the upper story substantially stiffer than the open ground story. Along these lines, the upper story move together as a solitary piece and the greater part of the flat relocation of the building happens in the delicate ground story itself. As it were, this sort of structures influence forward and backward like upset pendulum amid quake shaking, and henceforth the sections in the ground story segments and pillars are vigorously focused. In this way it is required that the ground story segments must have adequate quality and satisfactory malleability. The weakness of this kind of building is ascribed to the sudden bringing down of sidelong solidness and quality in ground story, contrasted with upper story with infill dividers. An uncovered edge is substantially less solid than a completely Infilled outline, it opposes the connected sidelong load through edge activity and shows very much disseminated plastic pivots at disappointment yet when, outline is completely Infilled, truss activity is presented. A completely Infilled outline indicates less between story float, in spite of the fact that it draws in higher base shear (because of expanded firmness). In the consequence of the Bhuj quake, the IS 1893 code was amended in 2002, joining new plan proposals to address OGS structures. Condition 7.10.3(a) states: "The sections and light emissions the delicate story are to be intended for 2.5 times the story shears and minutes ascertained under seismic heaps of uncovered casings. This MF should be in pay for the solidness brokenness. The traditionalist idea of this observational proposal of IS code was first called attention to by Kanitkar and Kanitkar (2001), Subramanian (2004) and Kaushik (2006). Thus the point of this proposition is to check the materialness of the increase factor of 2.5 in the ground story bars and section when the building is to be outlined as open ground story surrounded building and to ponder the impact of infill quality and firmness in the seismic investigation of low and medium ascent open ground story building.

II. AIM AND OBJECTIVE OF MY WORK

The particular objectives of the study are:

1) To Study the applicability of the Multiplication Factor of 2.5 as given by IS Code 1893 Part-1(2002), for Low Rise and Medium Rise Open ground storey Building.
2) To study the effect of infill strength and stiffness (with infill Opening) in the seismic

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analysis of Open ground storey building.

III.OPEN GROUND STOREY BUILDING

The presence of infill walls in the upper storey of the OGS building increases the stiffness of the building, as seen in a typical Infilled framed building. Due to increase in the stiffness, the base shear demand on the building increases while in the case of typical Infilled frame building, the increased base shear is shared by both the frames and infill walls in all the storey. In OGS buildings, where the infill walls are not present in the ground storey, the increased base shear is resisted entirely by the columns of the ground storey, without the possibility of any load sharing by the adjoining infill walls. The increased shear forces in the ground storey columns will induce increase in the bending moments and curvatures, causing relatively larger drifts at the first floor level. The large lateral deflections further results in the bending moments due to the P-Δ effect. Plastic hinges gets developed at the top and bottom ends of the ground storey columns. The upper storey‟s remain undamaged and move almost like a rigid body. The damage mostly occurs in the ground storey columns which is termed as typical „soft-storey collapse‟. This is also called a „storey-mechanism‟ or „column mechanism‟ in the ground storey as shown in the figures below. These buildings are vulnerable due to the sudden lowering of stiffness or strength (vertical irregularity) in the ground storey as compared to a typical Infilled frame building.

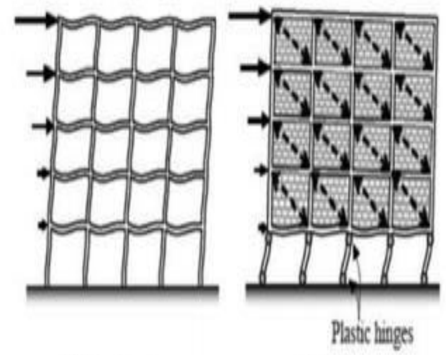

Fig. 1: Showing Difference in Behavior between Bare, Infill OGS Building Frame

IV.TYPICAL MASONRY INFILLED BUILDINGS

Typical masonry Infilled frames contain infill walls throughout the building in all storey uniformly. Although infill walls are known to provide the stiffness and strength to the building globally, these are considered as „non-structural‟ by design codes and are commonly ignored in the design practice for more convenience. The presence of infill walls in a framed building not only enhance the lateral stiffness in the building, but also alters the transmission of forces in beams and columns, as compared to the bare frame. In a bare frame, the resistance to lateral force occurs by the development of bending moments and shear forces in the beams and columns through the rigid jointed action of the beam-column joints. In the case of Infilled frame, a substantial truss action can be observed, contributing to reduced bending moments but increased axial forces in beams and columns, (Ridding ton and Smith, 1977; Holmes, 1961).The infill in each panel behaves somewhat like a diagonal strut as shown in Fig. below.

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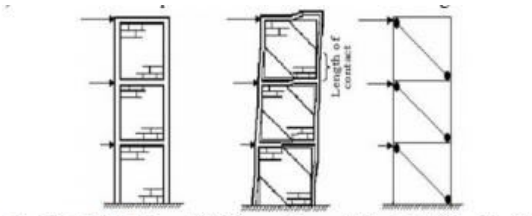


Fig. 2: a) Infilled Frame b) Deformed Frame c) Equivalent Strut Model

Hence these infill walls are beneficial to the building, only when they are evenly placed in plan and elevation. These infill walls come to rescue the structure at worst lateral loads such as seismic loading and wind loading owing to its high stiffness and strength.

V. STRUCTURAL MODELLING

It‟s very important to develop a computational model on which linear static, non-linear static, dynamic analysis is performed. Accurate modeling of non linear properties of various structural elements is very important in non-linear analysis. In present study, frame elements were modeled with inelastic flexural hinges using point plastic model. Infill wallis modeled as equivalent diagonal strut elements.

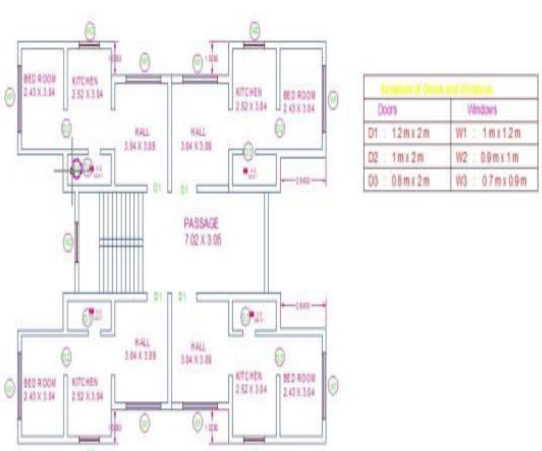


Fig. 3: Building Model Plan

Beam and columns are modeled by 3D frame elements. Beams and columns are modeled by giving end-offsets to the frame elements, to obtain the bending moments and forces at the beam and column faces. Beams-Column joints are assumed to be rigid. Beams and columns in present study were modeled as frame elements with centre lines joined at the nodes using commercial Etabs Software. Rigid beam-column joints were modeled by using end offsets at the joints. Floor slabs were assumed to act as diaphragms, which ensure integral action of all vertical lateral load resisting elements.

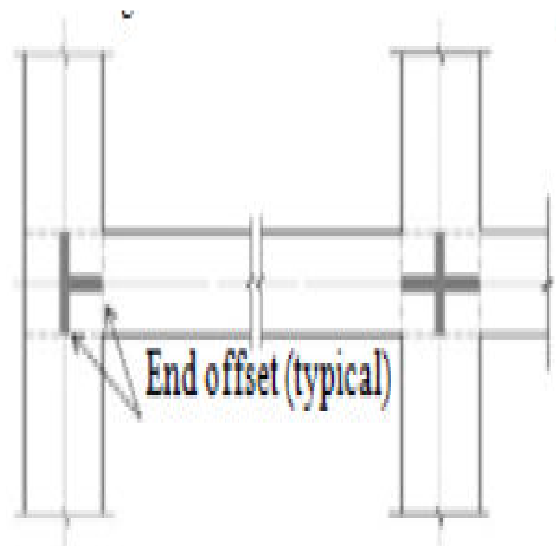


Fig. 4: Use of End Offsets at Beam-Column Joint

An existing RC framed Open ground storey building is considered in Seismic zone-V with Special Moment Resisting Frame (SMRF) is analyzed and Modeled in Etabs Software. Three Different models (G+10,G+7 & G+4)having Fixed End support condition with medium Soil is considered. The Concrete slab is 125mm thick at each floor level

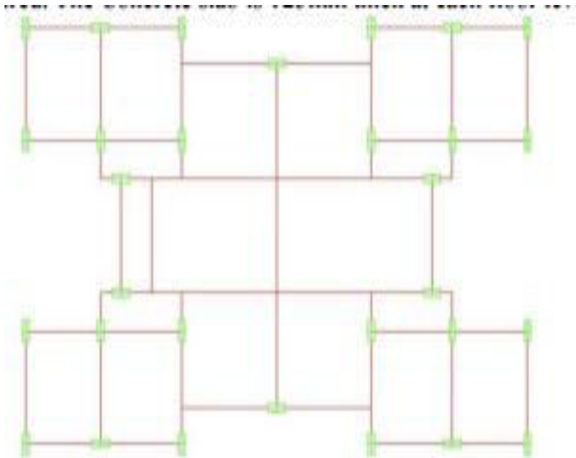


Fig. 5: Center Line plan Used in Etabs

1)Model A

Case 1: (G+4) storey building in which Ground storey is open and other stories are having infill wall,(Model A-1).

Case 2: (G+4) storey building in which all stories are open (Bare framed Building),(Model A-2).

2)Model B

Case 1: (G+7) storey building in which Ground storey is open and other stories are having infill wall,(Model B-1).

Case 2: (G+7) storey building in which all stories are open (Bare framed Building),(Model B-2). 3)

3)Model C

Case 1: (G+10) storey building in which Ground storey is open and other stories are having infill wall,(Model C-1).

Case 2: (G+10) storey building in which all stories are open (Bare framed Building),(Model C-2).

Table – 1
Details of Building Models

Type Of Structure	*Multi-storey Rigid Jointed Plane Frame (SMRF)*
Seismic Zone	*V*
Number of Stories	*G+10 (34.2m), G+7 (25.6m), and G+4 (16.2m)*
Floor Height	*Ground Floor=4.2m, Intermediate Floors=3m*
Infill Wall	*230mm outer external wall, 120mm Internal wall, 150mm Parapet wall*
Type of soil	*Medium*
Size of Column	*G+10-(230x800)mm G+7-(230x700)mm G+4-(230x600)mm*
Size of Beam	*230mm x 600 mm*
Depth of Slab	*125 mm*
Materials of Concrete	*Column and Beam: M30 Slab:M25*
Damping of Structure	*5%*
Modulus of Elasticity of Concrete	*M30-27386 N/mm2 M25-25000 N/mm2*
Modulus of Elasticity of Brick	*550*fm*
Z	*0.36*

A. Loads Considered:

1) Wall Load: Unit weight of brick wall = 20 KN/m2

i) External 230mm = 11.02KN/m2

ii) Internal Wall 120mm =5.76 KN/m2

iii) Parapet Wall 150mm = 3KN/m2

2) Live Load: 1) Intermediate floors = 2KN/m2

2) Terrace =1.5 KN/m2

3) Floor Finish:

1) For Intermediate Floors: FF =1 KN/m2

2) For Terrace Floors: FF=1.5 KN/m2 .

VI.DESIGN OF INFILL STRUT

The simplest equivalent strut model includes a single pin-jointed strut.

Holmes who replaced the infill by an equivalent pinjointed diagonal strut made of the same material and having the same thickness as the infill panel suggest a width defined by,

$$\frac{w}{d} = \frac{1}{3}$$

Paulay and Priestley suggested the width of equivalent strut as, Where $w = 0.25d$

d= Diagonal length of infill panel.

W=Depth of diagonal Strut.

However, researchers later found that this model overestimates the actual stiffness of Infilled frames and give upper bound values. Another model for masonry infill panels was proposed by Mainstone in 1971 where the cross sectional area of strut was calculated by considering the sectional properties of the adjoining columns. The details of model are as shown in Figure 6.The strut area As was given by the following equation

$$A_e = W\,t$$
$$W = 0.175\,(\lambda H)^{-0.4}\,D$$

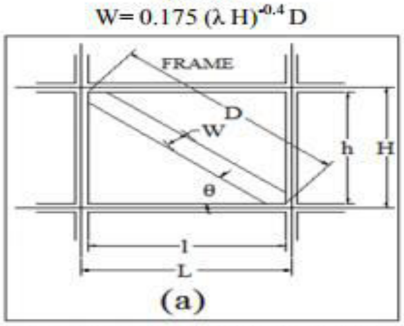


Fig. 6: Brick Infill Panel as Equivalent Diagonal Strut.

$$\lambda = \sqrt[4]{\frac{E_i\, t\, Sin(2\theta)}{4\, E_f\, I_c\, h}}$$

Where,

Ei = the modules of elasticity of the infill material, N/mm2

Ef= the modules of elasticity of the frame material, N/mm2

Ic= the moment of inertia of column, mm4

l = the width of infill

D = the diagonal length of infill panel

θ = the slope of infill diagonal to the horizontal.

A. Infill Frame with openings: Area of opening, Aopis normalized with respect to area of infill panel, Ainfilland the ratio is termed as opening percentage (%)

$$\text{Opening percentage (\%)} = \frac{\text{Area of openning } (A_{op})}{\text{Area of infill} (A_{infill})}$$

Openings For (G+10, (G+7) and (G+4) are calculated as below by Mainstone Equation:

Table – 2
Width calculated as per Mainstone Equation

Sr.no	Infill wall	Total area of Infill	Total area of opening	W For (G+4)	W For (G+7)	W For (G+10)
Bed Room	W11	7.87	1.2	0.7	0.74	0.77
	W12	7.87	2	0.62	0.63	0.64
	W21	6.24	0	0.61	0.64	0.67
	W22	6.24	0	0.61	0.64	0.67
Kitchen	W11	7.87	2	0.62	0.63	0.64
	W12	7.87	2	0.7	0.64	0.77
	W21	6.74	1.2	0.64	0.67	0.7
	W22	6.74	1.6	0.68	0.71	0.74

Hall	W11	8.06	2	0.63	0.64	0.78
	W12	8.06	0	0.63	0.64	0.65
	W21	7.87	1.2	0.58	0.59	0.6
	W22	7.87	2.4	0.62	0.63	0.64
WC	W11	2.66	0.63	0.49	0.48	0.39
	W12	2.66	0	0.4	0.41	0.42
	W21	6.74	1.6	0.68	0.71	0.74
	W22	6.74	0	0.53	0.53	0.54

Openings of Doors and windows are deducted using the Equation given by Panagiotis:

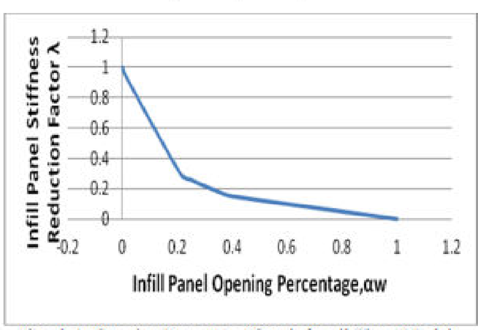
λ = 1-2αw 0.54+αw 1.14

αw =Opening Percentage.

Openings Reduces the Strut stiffness and hence Infill panel reduction (λ) factor is given by Panagiotis.Width from Maintone is multiplied by Reduction factor "λ"

Table – 3
Reduction Factor Is Calculated From Opening Percentage

α_w	λ
0	1
0.17	0.36
0.19	0.33
0.26	0.25
0.28	0.23
0.33	0.18
0.9	0.004
1	0



Graph 1: Opening Percentage Graph for all Three Models

Table – 4
Reduced Width is as given below

Descriptions	Infill walls	Final width for (G+4)	Final width for (G+7)	Final width for (G+10)
Bedroom	W11	0.28	0.3	0.31
	W12	0.16	0.16	0.17
	W21	0.61	0.64	0.67
	W22	0.61	0.64	0.67
Kitchen	W11	0.16	0.16	0.17
	W12	0.18	0.17	0.2
	W21	0.22	0.23	0.25
	W22	0.18	0.19	0.2
Hall	W11	0.16	0.16	0.2
	W12	0.63	0.64	0.65
	W21	0.23	0.24	0.24
	W22	0.13	0.13	0.13
WC	W11	0.13	0.13	0.11
	W12	0.4	0.41	0.42
	W21	0.18	0.19	0.2
	W22	0.53	0.53	0.54

VII. RESULTS

A. Comparison of Base Shear: Base shear in case of Response Spectrum analysis is compared between Bare frame model and Infill model to See the difference between them and also to get the Multiplication Factor

Table – 5
Base Shear for (G+4) Building

Model-(G+4) Storey		With infill	Bare Frame	M.F
Base Shear	Along X-Axis	1624	1108	1.47
	Along Y-Axis	1458	1020	1.43

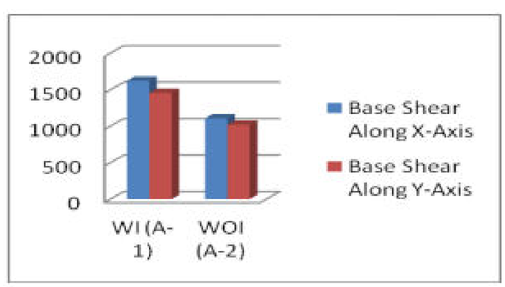


Table – 6
Base Shear for (G+7) Building

Model-(G+7) Storey		With infill	Bare Frame	M.F
Base Shear	Along X-Axis	1941	1214	1.60
	Along Y-Axis	1629	1078	1.50

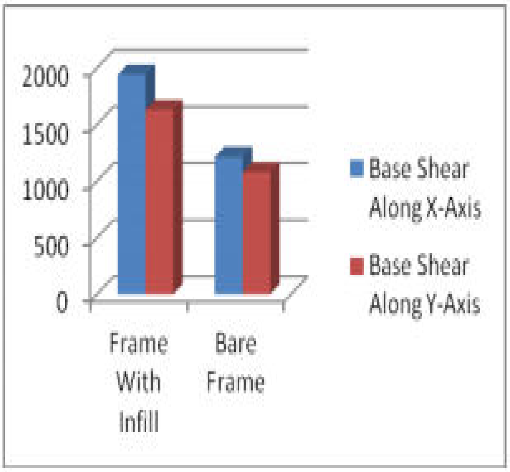
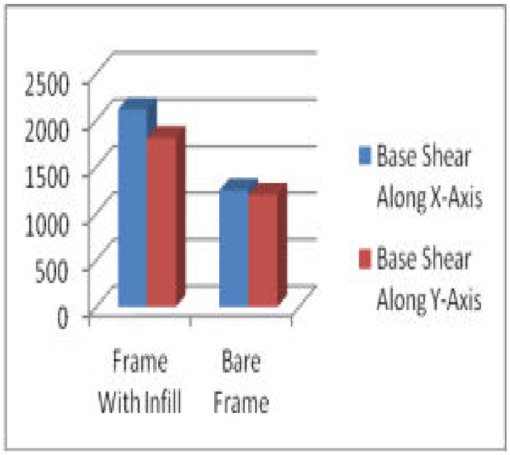


Table – 7
Base Shear for (G+10) Building

Model-(G+10) Storey		With Infill	Bare Frame	M.F
Base Shear	Along X-Axis	2116	1252	1.69
	Along Y-Axis	1809	1202	1.51



B. Comparison of ESA Results:

Table – 8
ESA Result for (G+4) Building

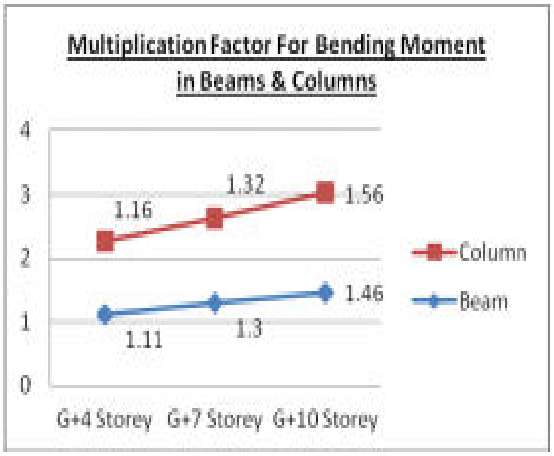
ESA Result for (G+4) Storey Building Model				
Model		*With infill*	*Bare Frame*	*M.F*
Column(G.S)	*Max.BM*	*212.81*	*189.07*	*1.16*
Beam(G.S)	*Max.BM*	*1445.33*	*1298.92*	*1.11*

Table – 9
ESA Result for (G+7) Building

ESA Result for (G+7) Storey Building Model				
Model		*With infill*	*Bare Frame*	*M.F*
Column(G.S)	*Max.BM*	*291.86*	*221.09*	*1.32*
Beam(G.S)	*Max.BM*	*1711.87*	*1317.02*	*1.30*

Table – 10
ESA Result for (G+10) Building

ESA Result for (G+4) Storey Building Model				
Model		*With infill*	*Bare Frame*	*M.F*
Column(G.S)	*Max.BM*	*379.27*	*242.92*	*1.56*
Beam(G.S)	*Max.BM*	*1936.9*	*1328.29*	*1.46*



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C. Comparison of RSA Results:

Table - 11
RSA Result for (G+4) Building

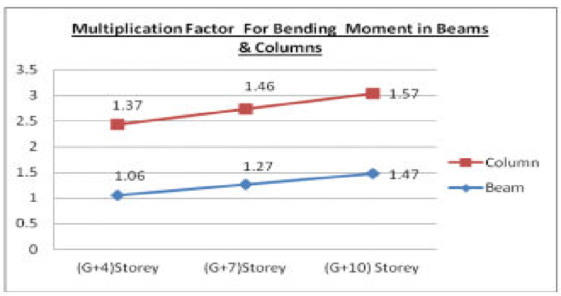
RSA Result for (G+4) Storey Building Model				
Model		*With infill*	*Bare Frame*	*M.F*
Column(G.S)	*Max.BM*	*943.8*	*689.95*	*1.37*
Beam(G.S)	*Max.BM*	*1381.9*	*1298.98*	*1.06*

Table – 12
RSA Result for (G+7) Building

RSA Result for (G+4) Storey Building Model				
Model		*With infill*	*Bare Frame*	*M.F*
Column(G.S)	*Max.BM*	*1213.76*	*832.06*	*1.46*
Beam(G.S)	*Max.BM*	*1574.78*	*1239.23*	*1.27*

Table – 13
RSA Result for (G+10) Building

RSA Result for (G+10) Storey Building Model				
Model		*With infill*	*Bare Frame*	*M.F*
Column(G.S)	*Max.BM*	*1532.44*	*978.93*	*1.57*
Beam(G.S)	*Max.BM*	*1714.60*	*1167.39*	*1.47*



From the above analysis we conclude that M.F required for (G+4) storey model is in the range of (1.37-1.47) for column and (1.06-1.43) for beam, which is nearly 41.2% and 42.8% less than, which is prescribed by IS code. i.e 2.5. Similarly for (G+7) storey model,M.F is in range of (1.27-1.51) for beam and (1.46-1.60) for column, which is 36% and 40% less than value of 2.5.and for (G+10) Storey Model BM is in the range of (1.47-1.50) for beam and (1.57-1.69) for column which is again 32.4% and 40% less than 2.5.We also conclude that, Base shear demands for Infilled frame is higher than bare frame, which may be one of the possible mode of failure in Ogs building.

D. Pushover Analysis:

Table - 14
POA Result for (G+4) Building

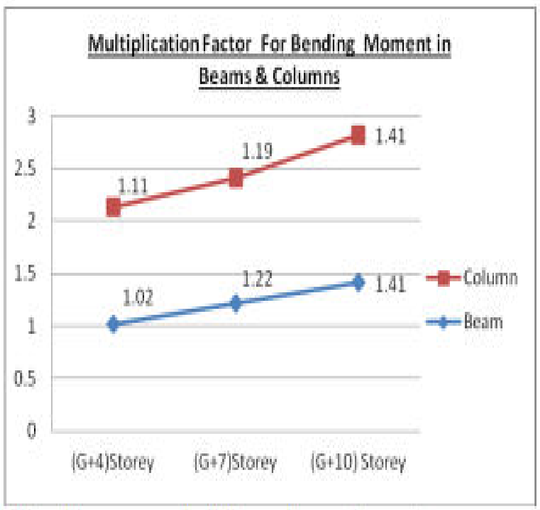
POA Result for (G+4) Storey Building Model				
Model		*With infill*	*Bare Frame*	*M.F*
Column(G.S)	*Max.BM*	*631.17*	*569.07*	*1.11*
Beam(G.S)	*Max.BM*	*1043.31*	*1018.75*	*1.02*

Table – 15
POA Result for (G+7) Building

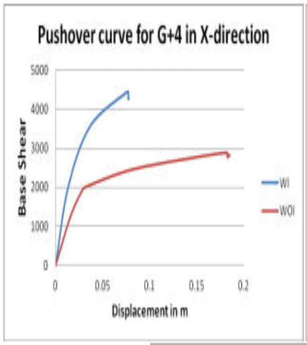
POA Result for (G+7) Storey Building Model				
Model		*With infill*	*Bare Frame*	*M.F*
Column(G.S)	*Max.BM*	*874.89*	*735.11*	*1.19*
Beam(G.S)	*Max.BM*	*1174.37*	*960.57*	*1.22*

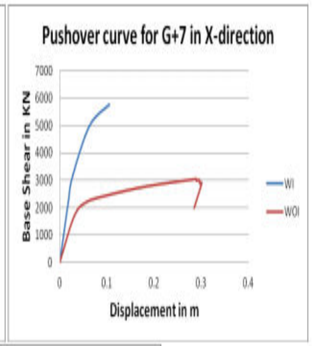
Table – 14
POA Result for (G+10) Building

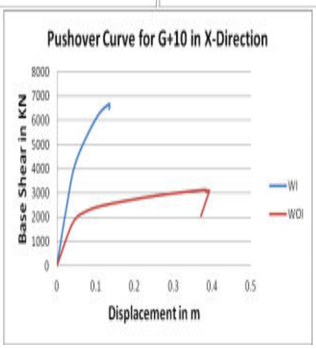
POA Result for (G+10) Storey Building Model				
Model		*With infill*	*Bare Frame*	*M.F*
Column(G.S)	*Max.BM*	*1155.82*	*820.61*	*1.41*
Beam(G.S)	*Max.BM*	*1262.50*	*898.05*	*1.41*



To study the Effect of strength of infill and bare Frame building using Pushover Curve







Similarly we can show for Y-Direction.This figure clearly shows the global stiffness of an open ground storey building changes considerably when infill wall is ignored.There is also considerable change in stifness elastic base shear demand,if stiffness of wall is ignored.The varition of pushover analysis is an agreement with linear analysis result presented in previous section with regard to variation of elastic base shear demand for different Building models.

VIII. CONCLUSIONS

Following are the conclusions obtained from the present study. 1) Linear(Static/Dynamic) analysis shows that column forces at the ground storey increase for the presence of infill wall in upper storeys. But design force Multiplication factor found to be much less than 2.5. 2) Seismic analysis of Bare frame structure leads to under estimation of base shear. Under estimation of base shear leads to collapse of structure during earthquake shaking. Therefore its important to consider the infill walls in the seismic analysis of structure. 3) ESA and RSA results shows that, Multiplication factor for (G+4) varies 41.2 %(Column) and 42.8 %(Beam) less than what is prescribed by IS Code of 2.5 Value. Similarly For (G+7) its 36% and 40% and for (G+10) its 32.4 and 40% less value than which is given by IS Code of 2.5. 4) From Pushover analysis, its conclude that there is even no need for a MF of 2.5 for Low rise (G+4) structure. And for (G+7) its 52.4% (Beam) & 51.2%(Column) less than value which is given by IS Code 1893:2002 of 2.5,while for (G+10) it comes out to be 40% less than value given by IS Code. 5) Pushover curve shows that global stiffness and elastic base shear demand of OGS building changes considerably when infill wall is ignored.

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