A STUDY ON SEISMIC RESPONSE OF REINFORCED CONCRETE FRAMED BUILDINGS WITH AND WITHOUT INFILL WALLS

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Abstract - *Reinforced Concrete framed structures are frequently utilized in construction of buildings as a result of attributable to easiness of construction and speedy improvement of work, and often these frames are packed by masonry infill panels (or) concrete blocks in several of the countries set in seismical regions. Performance of building in earthquakes clearly shows that the existence of infill walls has vital structural implications. Infill panels significantly increase stiffness and strength of frames. This study provides the comparative study on summary of performance of RC frame buildings with and with-out infill walls. Here studied and design the masonry infill walls victimization equivalent diagonal strut thought in-order to assess their contribution in seismical resistance of normal Reinforced concrete buildings.*

Modelling the 2 totally different buildings with and while not infill walls were designed it and studied for lateral masses victimization software system (SAP2000). Analyse the strut buildings as single-strut, double-strut, triple strut models for each the structures. Relate the results obtained from the computerised model analysis with and while not infill structures. Results obtained were checked for modal participation mass quantitative relation and area of steel needed by buildings total weight of building, period of time, base shear, and connected the results achieved to spot the performance of RC framed structures.

***Key Words*: Reinforced concrete (RC), Bare-frame, Infill Walls, Equivalent Diagonal Strut, Strut Models**

1. INTRODUCTION

Reinforced concrete frame buildings with masonry infill walls were sometimes made for industrial, business and multi-family residential purpose in seismic-prone regions globally. Masonry infill sometimes contains brick masonry or concrete block walls, made between columns and beams of a RC frame. These panels were commonly not taken within the analyze method and preserved as non-structural elements. In country like Asian nation, Brick masonry infill panels are generally used as internal and external partition walls for appealing reasons and well-designed desires. Although the brick masonry infill is taken as a non-structural component, however it's had own strength and stiffness.so if the impact of brick masonry is taken in analysis and design, vital increase in strength and stiffness of total structure could also be detected. Code, IS 1893(Part-I): 2000 of follow doesn't embody provision of taking into concern the impact of infill. It will be declared that if the impact of infill is taken under consideration within the analysis of frame, the ensuing structure could also be significantly totally different. Substantial investigational and logical analysis is declared in varied works, which fits to explain the performance of infilled frames. Besides, infill, if situated in total storeys offers a considerable involvement to the energy dissipation capability, decreasing ominously the most displacements. Therefore the involvement of masonry is of excessive importance, even supposing powerfully rely on the properties of the bottom motion, notably for frames that has been designed while not taking the seismical forces. If abrupt modification in stiffness takes place on the peak of building, the storey at that extreme variation of stiffness arises is named a soft story. As per IS 1893(Part-I): 2000, a story referred to as a soft story if its lateral stiffness is a smaller amount than 50% of the level higher than or below.

Another vital downside is associated to the numerical imitation of infilled frames. The assorted ways for idealizing this structural model are going to be separated into 2 native or micro-models and simplified macro models. The primary cluster contains the models, within which the structure is separated into numerous elements taken under consideration of the native impact intimately, and the second cluster contains simplified models supported a physical understanding of the behaviour of the infill panel. During this topic the strength and stiffness of the brick masonry infill is measured and also the brick masonry infill is analyzed using diagonal strut. Exploitation software package SAP 2000 the diagonal strut has been analyzed. For understanding the improvement in stiffness parameters this analysis is performed by using the "Linear static analysis".

1.1_REVIEW OF LITERATURE

Earlier investigational studies conjointly distributed on the behavior of RC frames with in-fills and also the modeling, analysis of the RC frame with and while not in-fills. Stafford-Smith.B used associate degree elastic theory to propose the effective breadth of the equivalent strut and complete that strut breadth ought to be a perform of the stiffness of the in-fill with relevancy that of bounding frame and outlined the formulation of empirical equations for the calculation of infill wall parameter as strut model like contact length of strut, effective breadth of the strut.1 Holmes was the primary person within the exchange of the infill by identical pin-jointed diagonal strut. The modeling of infill wall because the diagonal strut and finding the effective breadth and speak to length of the diagonal strut are planned by him .2 Das and C.V.R. Murty distributed non-linear pushover analysis and declared that In-fills were found to extend the strength and stiffness of the structure, and scale back the drift capability and structural injury. In-fills scale back the structure plasticity, however increase the strength. Building designed by the equivalent braced frame technique showed higher overall performance.3 Haroon Rasheed Tamboli says that in presence of infill wall it affects the seismical behaviour of frame structure to massive extent and also the infill can increase the strength and stiffness of structure.4.5 A.Mohebkhah et al. performed varieties of numerical modeling methods to stimulate the in-plane non-linear static behavior of infilled frames with openings with small and macro modeling. conjointly analyzed the model of infill frame as three-strut model and checked capability of structures throughout non-linear analysis within which three-strut model shows a lot of strength and stiffness throughout the sturdy ground motion and perform well once stiffness of infill wall is taken into account.6 V.K.R.Kodur et al. thought of a 3 level RC frame building models were analyzed for 3 cases i) clean frame ii) Infilled frame iii) Infilled frame with openings. supported the analysis results they found that Base shear of infilled frame is over infilled frame with openings and clean frame. Time period of infilled frame is a smaller amount as compare to infilled frame with openings and clean frame. The natural frequency of infilled frame is a lot of as compare to infilled frame with openings and clean frame.7 Amato et al. mentioned the mechanical behavior of single storey-single bay in-filled frames performed careful numerical investigation on in-filled meshes has tested that within the presence of vertical masses it's potential that a robust correlation between the dimension of the equivalent diagonal strut model and one parameter, that depends on the characteristics of the system

2. Modeling and Analysis of Bare-frame Buildings

Two buildings of G+5 & G+9 storeys having floor height same and like properties were Considered. These 2 buildings were analyzed as bare-frame it means that buildings while not take into account infill walls between the horizontal and vertical parts of the building. These were evaluated for seismical loads and gravity loads within the package as per IS 1893(Part-1):2002.

2.1 Preliminary Data

To analyze the seismical performance of the building we considered 2 totally different building of various heights as G+5 and G+9 constructions RC framed buildings of same storey levels. The overall parameters needed for the modeling of the two buildings has a similar parameter are as follows:

- Type of frame : Special RC moment resisting frame mounted at the bottom
- Seismic zone : V
- Number of storeys : G+5 & G+9
- Floor height : 3.5 m
- Plinth height : 1.5 m
- Depth of Slab : 150 mm
- Spacing between frames : 5 m along each directions
- Live load on floor level : 4 kN/m2
- Live load on roof level : 1.5 kN/m2
- Floor finish : 1.0 kN/m2
- Terrace water proofing : 1.5 kN/m2
- Materials : M 20 concrete, Fe 415 steel and Brick infill
- Thickness of infill wall : 250 mm (Exterior walls)
- Thickness of infill wall : 150 mm (Interior walls)
- Density of concrete : 25 kN/m3
- Density of infill : 20 kN/m3
- Type of soil : Medium
- Response spectra : As per IS 1893(Part-1):2002

• Damping of structure : 5 %

**Live load on floor level and roof level are taken from IS-875 (Part-) considered RC framed buildings as business usage.

2.2 Member and Material Properties

The Beams and columns dimensions are determined on basis of trial and error method in analysis of SAP2000 by considering nominal sizes for beams and columns that are as show within the table below.

Table 2.1: Properties of Bare – Frame, Strut Model Buildings

Type of Analysis	Building Models	Gravity Building		Seismic loaded building	
		BEAM (m)	COL. (m)	BEAM (m)	COL. (m)
G+5 storey Building	Bare-frame	0.40 x 0.40	0.50 x 0.50	0.50 x 0.50	0.60 x 0.60
	Single-strut	0.40 x 0.40	0.55 x 0.55	0.45 x 0.45	0.60 x 0.60
	Double-strut	0.40 x 0.40	0.45 x 0.45	0.45 x 0.45	0.50 x 0.50
	Triple-strut	0.45 x 0.35	0.45 x 0.45	0.40 x 0.40	0.50 x 0.45
G+9 storey Building	Bare-frame	0.50 x 0.50	0.60 x 0.60	0.55 x 0.55	0.70 x 0.70
	Single-strut	0.50 x 0.50	0.60 x 0.60	0.55 x 0.55	0.65 x 0.65
	Double-strut	0.50 x 0.50	0.55 x 0.55	0.55 x 0.50	0.65 x 0.65
	Triple-strut	0.45 x 0.40	0.55 x 0.55	0.45 x 0.45	0.65 x 0.65

The Building material properties are like Grade of concrete M20, FE415 steel and Modulus of elasticity of brick masonry in the buildings is 13800 N/mm^2.

2.3Modelling & Analysis of RC Framed buildings Without Infill Walls (Bare Frame Model)

RC framed buildings were analyzed in SAP2000 software package supported the preliminary information mentioned in earlier sections. The building is analyzed as 3D-framed building with member and material properties as blank frame model while not infills walls however thought of the load and strength of the brick masonry on the beams. Analyzed 2 buildings that were G+5 and G+9 level buildings with same floor height of 3.5m and support height of 1.5m and lengths in each x, y-direction is 5m and with same properties of the building while not infill walls. The model of the building is shown within the figures.

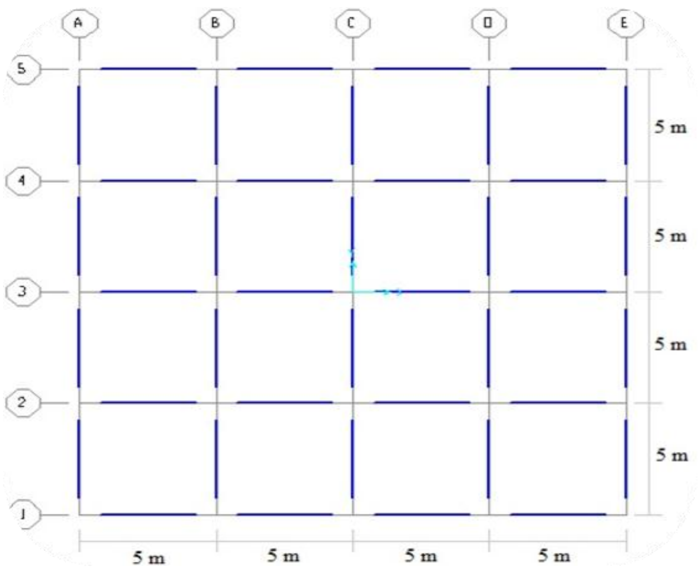

Fig-2.1: Plan of G+5 & G+9 storey building of all models

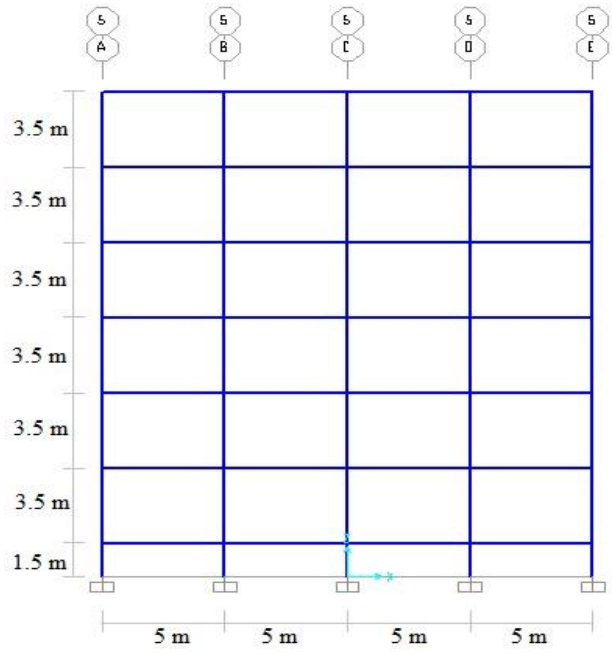

Fig-2.2: Elevation of G+5 storey Bare-frame model

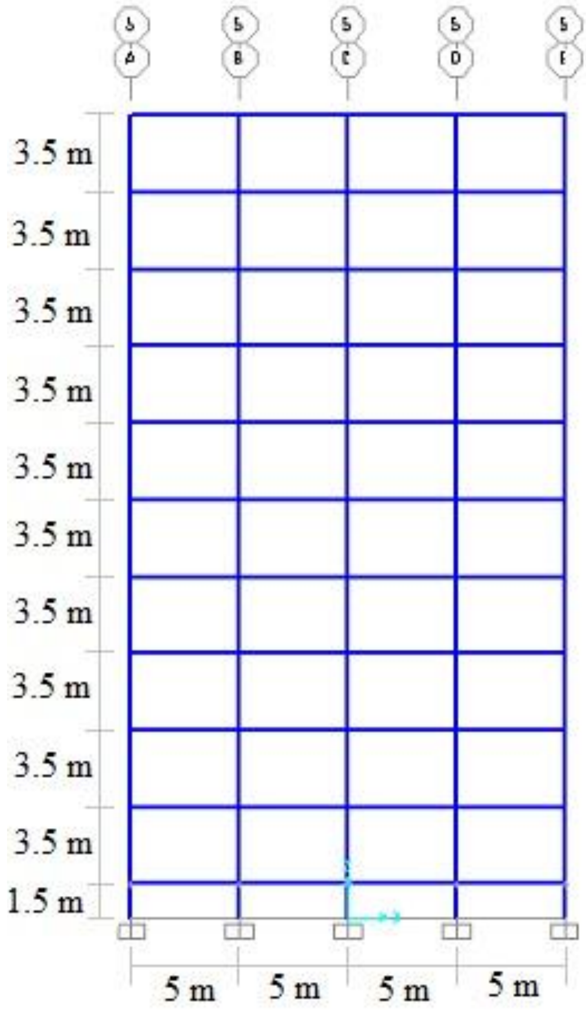

Fig-2.3: Elevation of G+9 storey Bare-frame model

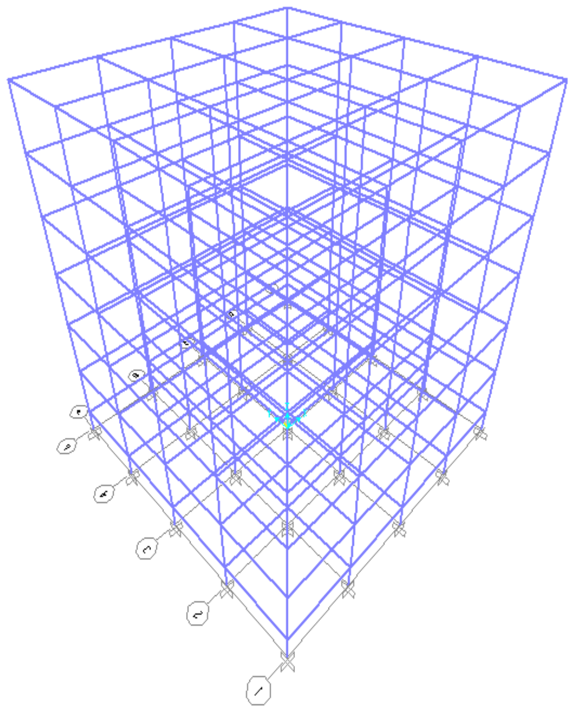

Fig-2.4: 3D-view of G+5 storey Bare-frame model

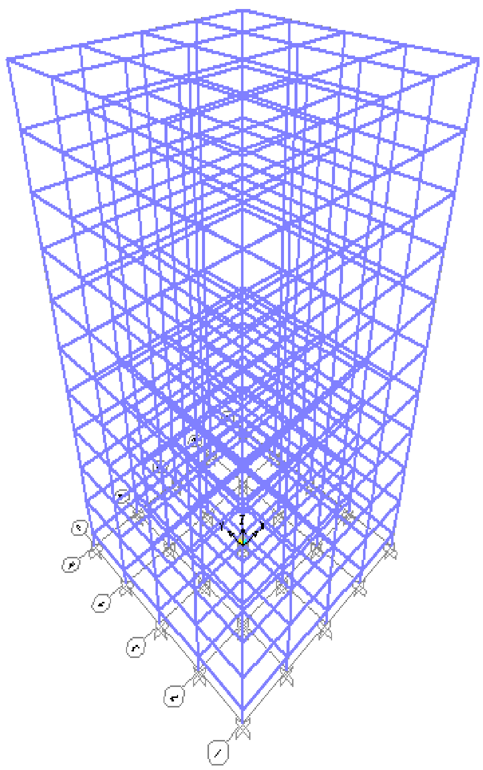

Fig-2.5: 3D-view of G+9 storey Bare-frame model

As is the structures are analyzed as beam-column members the load due to slab and walls are transfer onto the beams using yield line theory.

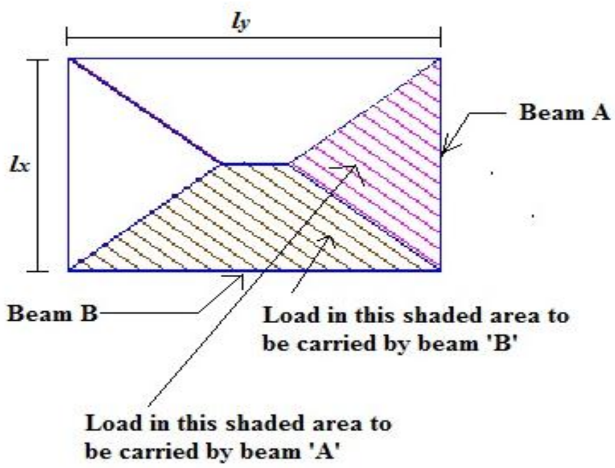

Fig-2.6: Load Carried By Supported Beams

As per IS CODE- SP-24-(1983) bending moments in the beams may be determined with sufficient accuracy by assuming that the loading is equivalent to a uniform load per unit length of the beam is as follows:

On the short span UDL = $\frac{W l_x}{3}$

On the long span UDL = $\frac{W l_x}{6}\left[3-\left(\frac{l_x}{l_y}\right)^2\right]$

Where,

l_x = Shorter span,

l_y = Longer span

W = Load per unit length

The load on beams due to slab loads calculated is shown in table:

Table 2.2: Slab loads on beam using Yield line theory

Type of load	Position	DL of slab	LL of slab	DL of Wall
	Units	(kN)	(kN)	(kN)
Load on roof beams	Exterior beams	10.416	2.5	6.0
	Interior beams	20.832	5.0	0
Loads on Floor beams	Exterior beams	7.916	6.66	15.5
	Interior beams	15.83	13.33	9.3
Loads on Plinth beams	Exterior beams	0	0	15.5
	Interior beams	0	0	9.3

These loads are induced on each G+5 & G+9 construction buildings having same and equal loads.

For this loads each the bare-frame buildings are analyzed for gravity loads and seismical loads as per IS 1893-2002 (Part-1) exploitation SAP2000 code and brought out the results like total weight of the building, time period, base shear and modal participation mass quantitative relation of the buildings. For identical bare-frame structures perform the manual analysis of scheming total, weight ,Time period and base shear of the building as per code book and compared the results.

3. Modeling & Analysis of RC framed Buildings With Infill Walls – Diagonal Strut Models

In the previous chapters, bare frame buildings are analyzed for each gravity and seismical loads singly and have seen the results of it. Now, by considering the wall as a structural component and also the building is analyzed here for each gravity and seismical loads. These masonry infill walls are sculptural because the equivalent diagonal strut. The fabric properties of the strut are kind of like that of masonry infill wall. The model of equivalent diagonal strut is sculptural as single-strut, double-strut, and triple-strut model for each the buildings severally with similar properties and hundreds. The models of equivalent diagonal strut are shown within the fig. below

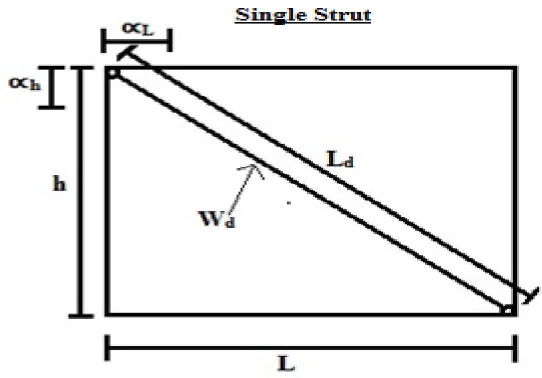

Fig-3.1: Equivalent Diagonal Single-strut Model

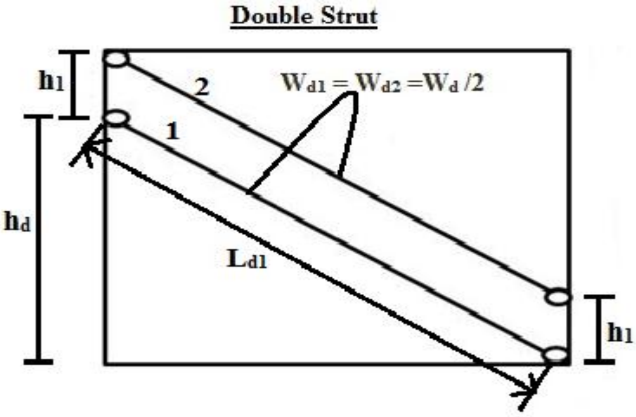

Fig-3.2: Equivalent Diagonal Double-Strut Model

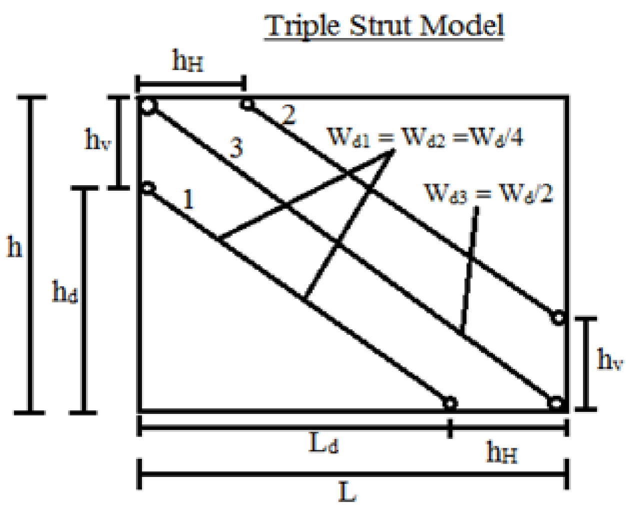

Fig-3.3: Equivalent Diagonal Triple-Strut Model

In modeling the equivalent diagonal strut major half is to search out the effective dimension of the strut within which it rely on length of contact between wall and column and between wall and beam. Stafford smith developed the formulations for αh and αL on the premise of beam on an elastic foundation. Hendry planned the equation to search out the equivalent diagonal strut dimension. the subsequent equations square measure planned to see αh and αL, that rely on the relative stiffness of the frame and infill walls, and on the pure mathematics of panel.

$$\propto_h = \frac{\pi}{2}\sqrt[4]{\frac{4\,E_f I_c h}{E_m t \sin 2\theta}}$$

$$\propto_L = \frac{\pi}{2}\sqrt[4]{\frac{4\,E_f I_b L}{E_m t \sin 2\theta}}$$

Where,

E_m and E_f = Elastic modulus of the masonry wall and frame material (i.e., concrete), respectively

L, h, t = Length, height and thickness of the infill wall, respectively

I_c, I_b = Moment of inertial of column and the beam of structure, respectively

$\theta = \tan^{-1}\left(\frac{h}{L}\right)$ = angle of inclination of diagonal strut

The equation to see the equivalent or effective strut dimension (wd), length (Ld) and space of strut (Ad), wherever the strut is assumed to be subjected to uniform compressive stress. The formulae for crucial the properties of the strut square measure as follows:

$$w_d = \frac{1}{2}\sqrt{\propto_h^2 + \propto_L^2}$$

$$L_d = \sqrt{h^2 + L^2}$$

$$A_d = t\, w_d$$

By exploitation these formulas the effective dimension, length and space of the diagonal strut is set. victimization higher than formulae will verify the properties of diagonal single-strut needed as shown within the fig-3.1, whereas for the double-strut model the 2 struts parallel to every different square measure replaced by single-strut diagonally within the model. For the amendment in properties shown in fig.3.1 were calculated victimization the formulae shown below.

$W_{d1} = W_{d2} = W_d$ = Width of the double strut

$h_1 = \frac{\propto_h}{3}$ = Vertical distance between the struts

$h_d = h - \frac{\propto_h}{3}$ = Height of the strut vertically

$L_{d1} = \sqrt{h_d^2 + L^2}$ = Inclined Length of Diagonal Strut

$A_{d1} = \frac{t\,W_d}{2}$ = Area of each strut

Similarly, for the triple-strut model the change in the properties are calculated using the formulae

$W_{d1} = W_{d2} = \frac{W_d}{4}$ =Width of side struts

$W_{d3} = \frac{W_d}{2}$ = Width of middle strut

$h_V = \frac{\propto_h}{2}$ =Vertical distance between struts

$h_H = \frac{\propto_L}{2}$ =Horizontal distance between struts

$h_d = h - \frac{\propto_h}{2}$= Height of side struts along Vertical direction

$L_d = L - \frac{\propto_L}{2}$ =Length of side struts along horizontal direction

$L_{ds} = \sqrt{{h_d}^2 + {L_d}^2}$= Inclined Length of Side struts

$L_{dm} = \sqrt{h^2 + L^2}$ = Inclined Length of Middle struts

$$A_{d1} = A_{d2} = \frac{t\,W_d}{4} = \text{Area of side struts}$$

$$A_{d3} = \frac{t\,W_d}{2} = \text{Area of middle strut}$$

From the higher than formulae for single-strut, double-strut and triple-strut models the properties were calculated victimization the parameters shown within the table for G+5 & G+9 storeys buildings.

Table 3.1 Parameters of G+5& G+9 storey Diagonal Strut Models

Parameters	Data			Units
	G+5 storey		G+9 storey	
Grade of concrete	20		20	MPa
Modulus of elasticity of concrete E_f	22360.68		22360.68	MPa
Modulus of elasticity of brick masonry E_m	13800		13800	MPa
Size of beam (Depth x Width)	0.50 x 0.50		0.55 x 0.55	M
Size of column	0.60 x 0.60		0.70 x 0.70	M
Moment of inertia of beam I_b	5.2 x 10^{-3}		7.6 x 10^{-3}	m^4
Moment of inertia of column I_c	10.8 x 10^{-3}		20.0 x 10^{-3}	m4
Thickness of External Infill wall t_e	0.25		0.25	M
Thickness of internal infill wall t_i	0.15		0.15	M
Length of masonry	4.4		4.3	M
Height of masonry h_m	Floor level	3.0	2.95	M
	Plinth level	1.0	0.95	M
Angle of inclination of strut $\left(\theta = \tan^{-1}\frac{h_m}{L_m}\right)$	Floor level	34.28°	34.45°	Deg.
	Plinth level	12.80°	12.45°	Deg.

Using the on top of parameters and properties of the strut is calculated and sculptural within the software package and analyzed for gravity and seismic loads as per the IS codes. From the analysis the determined the results like total weight, period of time, base shear and modal participation mass magnitude relation of the building.

4. Comparison of Results

From the analysis of G+5 & G+9 structure buildings were analyzed as bare-frame and strut models. Each the structures were analyzed for gravity and seismical loads utilization software system and extracted the results. For the vacant frame buildings manual calculations were done compared with the software system results.

Analysis is completed and therefore by using the bending moment, shear force and axial forces were taken from seismical analysis buildings of bare-frame, single-strut, double-strut and triple-strut models. Exploitation this results the planning of beams and columns were done as per IS-456 and SP16 and calculated the specified area of steel for the all models of buildings. The comparison of results is show within the tables below.

Table 4.1: Manual Results of G+5 & G+9 storey Bare-frame Buildings

Comparison of Manual & SAP 2000 Results of Bare – frame Buildings							
Type of structure	**Analysis**	**Total weight (kN)**		**Time period (Sec.)**		**Base shear (kN)**	
		Manual	SAP 2000	Manual	SAP 2000	Manual	SAP 2000
G+5	Gravity	42114	51195	-	1.75	-	-
	Seismic	46235	55892	0.774	1.185	3935	4759
G+9	Gravity	76309	92123	-	2.003	-	-
	Seismic	81688	97976	1.113	1.67	4868	5802

Table 4.2: Comparison of Gravity Load Analysis Results of all Struts Models of Buildings

Type of structure	Model	Analysis	Total Weight (kN)	Time period (Sec.)
G+5	Bare frame	Gravity	51195	1.705
	Single strut	Gravity	51933	0.203
	Double strut	Gravity	50527	0.282
	Triple strut	Gravity	49827	0.253
G+9	Bare frame	Gravity	92123	2.003
	Single strut	Gravity	92123	0.413
	Double strut	Gravity	90811	0.499
	Triple strut	Gravity	86961	0.452

Table 4.3: Comparison of Seismic Load Analysis results of all Struts Models of Buildings

Type of structure	Model	Total Weight (kN)	Time period (Sec.)	Base shear (kN)
G+5 Seismic Load Analysis	Bare frame	55892	1.185	4759
	Single strut	54229	0.194	6547
	Double strut	52682	0.260	6338
	Triple strut	50843	0.245	6090
G+9 Seismic Load Analysis	Bare frame	97976	1.67	5802
	Single strut	96436	0.394	8643
	Double strut	94924	0.437	8492
	Triple strut	90936	0.401	8093

Table 4.4: Comparison of Modal Participation of Mass ratio for Gravity Analysis of all Model Buildings

Comparison of Modal Participation Mass Ratio for Gravity Analysis							
Type of structure	**Model**	**Mode 1 (Unit-less)**		**Mode 2 (Unit-less)**		**Mode 3 (Unit-less)**	
		U_x	U_y	U_x	U_y	U_x	U_y

G+5 Gravity Analysis	Bare	0.717	0.717	0.089	0.089	0.074	0.074
	Single Strut	0.308	0.308	0.244	0.244	0.132	0.132
	Double Strut	0.378	0.333	0.298	0.342	0.121	0.109
	Triple Strut	0.340	0.332	0.279	0.286	0.142	0.135
G+9 Gravity Analysis	Bare	0.791	0.791	0.89	0.89	0.021	0.021
	Single Strut	0.274	0.274	0.306	0.306	0.112	0.112
	Double Strut	0.331	0.340	0.321	0.313	0.115	0.120
	Triple Strut	0.271	0.325	0.353	0.299	0.123	0.129

Table 4.5: Comparison of Modal Participation of Mass ratio for Seismic Analysis of all Model Buildings

Comparison of Modal Participation Mass Ratio for Seismic Analysis							
Type of structure	Model	Mode 1 (Unit-less)		Mode 2 (Unit-less)		Mode 3 (Unit-less)	
		U_x	U_y	U_x	U_y	U_x	U_y
G+5 Seismic Analysis	Bare	0.788	0.788	0.061	0.061	0.035	0.035
	Single Strut	0.313	0.313	0.250	0.250	0.133	0.133
	Double Strut	0.377	0.338	0.302	0.341	0.121	0.109
	Triple Strut	0.323	0.354	0.300	0.271	0.122	0.154
G+9 Seismic Analysis	Bare	0.786	0.786	0.097	0.097	0.018	0.018
	Single Strut	0.277	0.277	0.308	0.308	0.113	0.113
	Double Strut	0.336	0.340	0.321	0.317	0.116	0.119
	Triple Strut	0.318	0.343	0.315	0.290	0.118	0.126

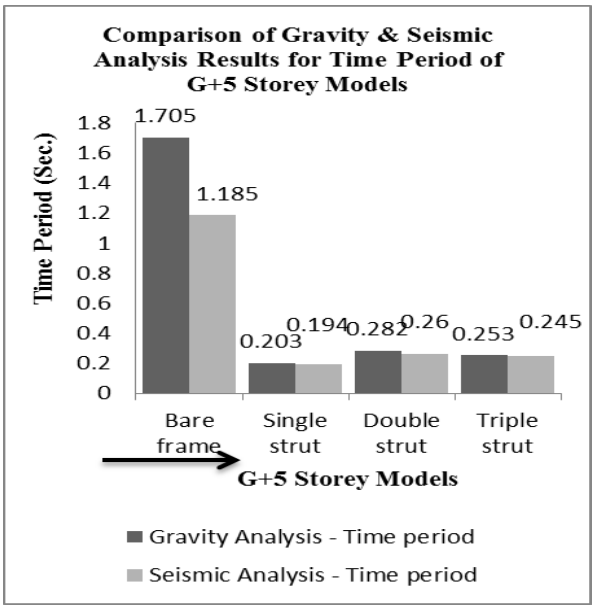

Fig- 4.1: Comparison of Gravity & Seismic Analysis Results for Time Period of G+5 storey Models

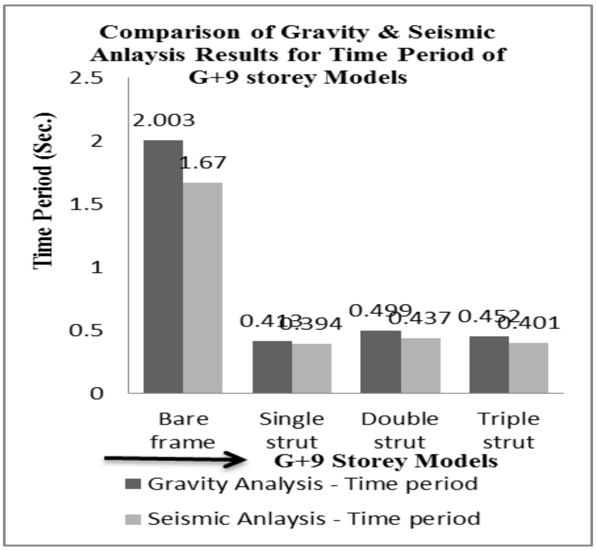

Fig-4.2: Comparison of Gravity & Seismic Analysis Results for Time Period of G+9 storey Models

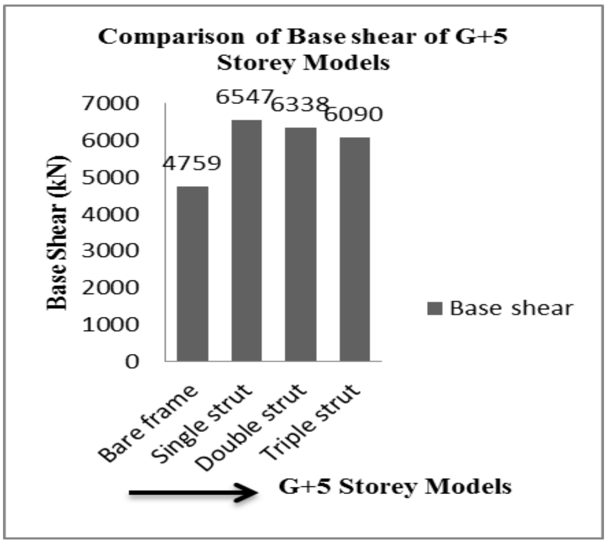

Fig-4.3: Comparison of Base shear of G+5 Storey Models

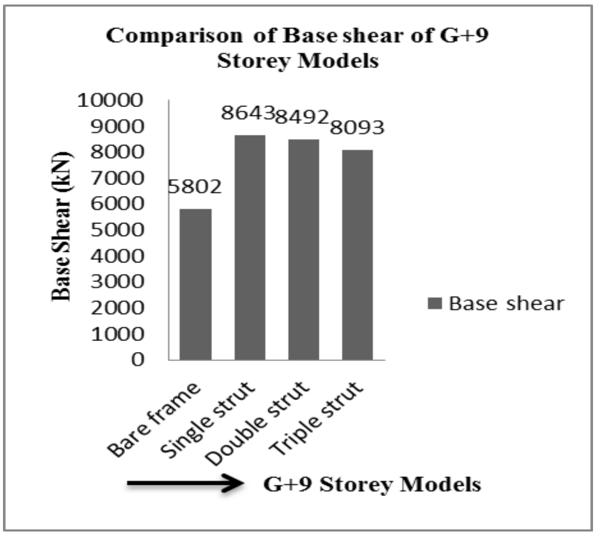

Fig-4.4: Comparison of Base shear of G+9 Storey Models

Table 4.6: Total Required Area of Steel for G+5 storey Models

G+5 storey Building	Bare-frame (m^2)	Single-Strut (m^2)	Double-Strut (m^2)	Triple-strut (m^2)
A_{st} of Beams in XZ-direction	1.316	0.329	0.325	0.258
A_{st} of Beams in YZ-direction	1.316	0.314	0.324	0.262
A_{st} of Columns	1.951	0.527	0.567	0.579
Total Req. A_{st}	**4.583**	**1.17**	**1.216**	**1.099**

Table 4.7: Total Required Area of Steel for G+9 storey Models

G+9 storey Building	Bare Frame (m^2)	Single-Strut (m^2)	Double-Strut (m^2)	Triple-strut (m^2)
Ast of Beams in XZ-direction	2.281	0.452	0.471	0.407
Ast of Beams in YZ-direction	2.264	0.452	0.47	0.381
Ast of Columns	2.929	1.414	1.416	1.497
Total Req. Ast	**7.474**	**2.318**	**2.357**	**2.285**

5. Conclusion

By comparing the bare-frame model and equivalent diagonal strut models results for both seismic load analysis and gravity load analysis it is observed that without considering the stiffness of infill frame in bare model stiffness of the building is very less whereas the strut models which considered the stiffness of infill as strut has more stiffness of the building and also economical in section area of steel. . When comparison takes places between the strut models triple-strut model shown better performance than that of other strut model in view of time period, base shear and modal mass participation ratio of the structure.

So triple-strut model gives the accurate performances during the seismic analysis of buildings. When compared with the G+5 & G+9 storey models the consideration of infill wall plays a major role in the during the earthquakes in the high seismic prone regions which can with stand for high seismic intensity also

So, to know the actual performance of the building it is better to analyze the structures by considering stiffness of infill walls and modeled as triple strut, which also make the structure economical and stiffer.

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