



A Study on Performance Evaluation of Infill Frame Structures with Different Arrangements of Shear Walls

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ABSTRACT

Though the infill wall and the shear wall had been generally considered as a non-structural element in analysis and design as a common practice but, now it is a well-known fact they have their own strength and stiffness. Therefore along with the study of the importance of infill walls and shear walls, their combined effect due to different arrangements and locations is a matter of study. The present study focuses on analyzing the seismic behaviour of a building structure to identify the basic effect of elements like in filled and shear walls by appropriately selecting and providing their respective material and geometrical properties. The purpose of an investigation is to study the response parameter such as base shear, lateral displacement, moments and column shear of a G+5 storied building for a reinforced concrete bare frame, un-reinforced brick masonry infilled frames and frames with combinations of shear walls. The study is carried out on five different cases by providing infill walls and shear walls at various locations in different Staad models being prepared and analyzed. Initially, the comparison of response parameter of the reinforced concrete building with bare frames and masonry infilled frames are made. Infill Stiffness has been modeled using an equivalent diagonal strut approach. Struts acting in compression against infill walls have been taken in consideration for the outer frames of the building. Further, the analysis is carried out is to determine that by providing shear walls at the particular location by how much amount the storey drift and column shear can be reduced. The shear walls are modeled as RC structural plate elements divided into small grids and are installed from foundation level to the full building height at their respective positions in the structure. The various cases of the building were modeled and analyzed for seismic requirements as per Indian seismic code IS : 1893-2002(Part I).

Key Words: Lateral Loads, Infill Walls, Shear Walls, Lateral Displacements, Storey Drifts, Base Shear.

1. INTRODUCTION

In present times, reinforced concrete buildings have become most widely used construction practice in world mainly for urban areas. It has been observed that because of inappropriate design and construction practices, the high rise structures are always under severe risk. Therefore any mistake related to seismic considerations can cause structural damage under seismic effect even if the effect is slight and distant. We know that along with gravity load, a structure has to resist lateral load also, which causes high stresses. It is evident that to resist lateral load due to earthquake, wind or any other horizontal thrust, provision of shear wall and infill wall in RC structure has become a most acceptable system. It is also observed that for design purpose, practicing structural engineers often consider unreinforced masonry infill walls and structural shear walls without actually understanding their combined effect and performance. This normally leads to inappropriate or over design without knowing its actual effect.

Since earthquake forces are mostly unpredictable, the engineering tools need to be enhanced for analyzing the structures under the action of such forces. Therefore seismic loads are to be appropriately modeled to understand the actual behavior of structure with a better approach in controlling the damage. There are two methods for analysis of seismic forces under clause 7.8.1 of IS 1893 (Part-1) 2002, that is Equivalent Static Method and Dynamic Analysis Method which depends on height and configuration of the building or structure. In both the methods, the structure is considered as a discrete system having concentrated weights lumped at floor levels which include half that of columns and walls above & below the floor and the specified amount of imposed loads is also added to it. This study focuses on analysis of RC bare frame and infill framed building with different arrangements of shear walls.

1.1 PROPERTIES OF MATERIALS

The material properties for main elements of building under study are given below:

Table-1 The Material Properties for Main Elements

Material	Mod. of Elasticity (N/mm ²)	Density (KN/m ³)	Poison's Ratio
Concrete	25000	25.0	0.20
Steel	2x10 ⁵	78.5	0.30
Masonry	2035	18.0	0.15

1.2 Parameters Considered

Table-2 Building Parameters and Geometries

DESCRIPTION	DATA
Storey Height	3M Each
Column Spacing	4M C/C
Column Sizes	0.5M x0.5M
Beam Sizes	0.3M x0.5M
Base Area	20M x 20M
Wall Thk. (External)	0.23M
Wall Load (External)	13.8 KN/M
Wall Thickness (Int.)	0.15M
Wall Load (Internal)	9.0KN/M
Shear Wall Thickness	0.23M
Slab Thickness	0.15M
Parapet Wall Height	0.9M
Parapet Wall Thickness	0.15M
Parapet Wall Load	2.7KN/M
Floor Finish Load	1KN/M ²
Waterproofing Load	2KN/M ²
Live load	3KN/M ²
Grade of Concrete	M-25
Grade of Steel	Fe500

1.3 Loads

- 01. Dead Load
- 02. Imposed Loads
- 03. Seismic Loads

1.4 Seismic Loads:

- 01. Seismic Zone – III
- 02. Zone Factor (Z) = 0.16
- 03. Importance Factor (I) = 1.0
- 04. Response Reduction Factor (R) = 5
(For ductile shear wall with SMRF)
- 05. Soil Type- Medium
- 06. Soil Structure (SS) = 1
- 07. Structure Type (ST) = 2
- 08. Damping Ratio (DM) = 0.05
- 09. Depth of foundation below GL (DT) = 3M

1.5 Load Cases:

01. Dead load (Downward)
02. Live load on Floor (Downward)
03. Live load on Roof (Downward)
04. Earthquake EQ_{X1} (Positive @ +0.05 bi in X-Direct.)
05. Earthquake EQ_{X2} (Positive @ -0.05 bi in X-Direct.)
06. Earthquake EQ_{Z1} (Positive @ +0.05 bi in Z-Direct.)
07. Earthquake EQ_{Z2} (Positive @ -0.05 bi in Z-Direct.)

1.6 Load Combinations:

01. 1.5 (DL + LL)
02. 1.5 (DL ± EQ_x)
03. 1.5 (DL ± EQ_z)
04. 1.2 (DL + LL ± EQ_x)
05. 1.2 (DD + LL ± EQ_z)
06. 0.9 DL ± 1.5 EQ_x
07. 0.9 DL ± 1.5 EQ_z
08. 1.2 (DL + LL ± RS_x)

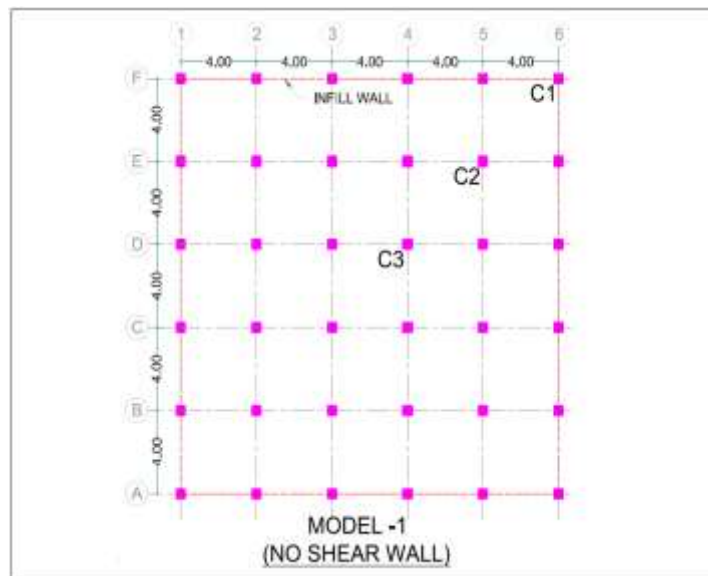
09. 1.2 (DD + LL ± RS_z)
10. 1.5 (DL ± RS_x)
11. 1.5 (DL ± RS_z)
12. 0.9 DL ± 1.5 RS_x
13. 0.9 DL ± 1.5 RS_z

1.7 Objective of Study

The present study aims at the following objectives:

- 1) To carry out analysis of frames with following models:
 - a. RC bare frame model
 - b. RC frame with infill masonry walls,
 - c. RC frame with infill walls and different arrangements of shear walls.
- 2) To compare the following results for the above mentioned frames:
 - a. Bending moments, Shear forces
 - b. Base shear verses displacement
 - c. Column displacements,
 - d. Storey drifts and their checks according to IS 1893 (Part1) 2002

1.8 Building Floor Plans



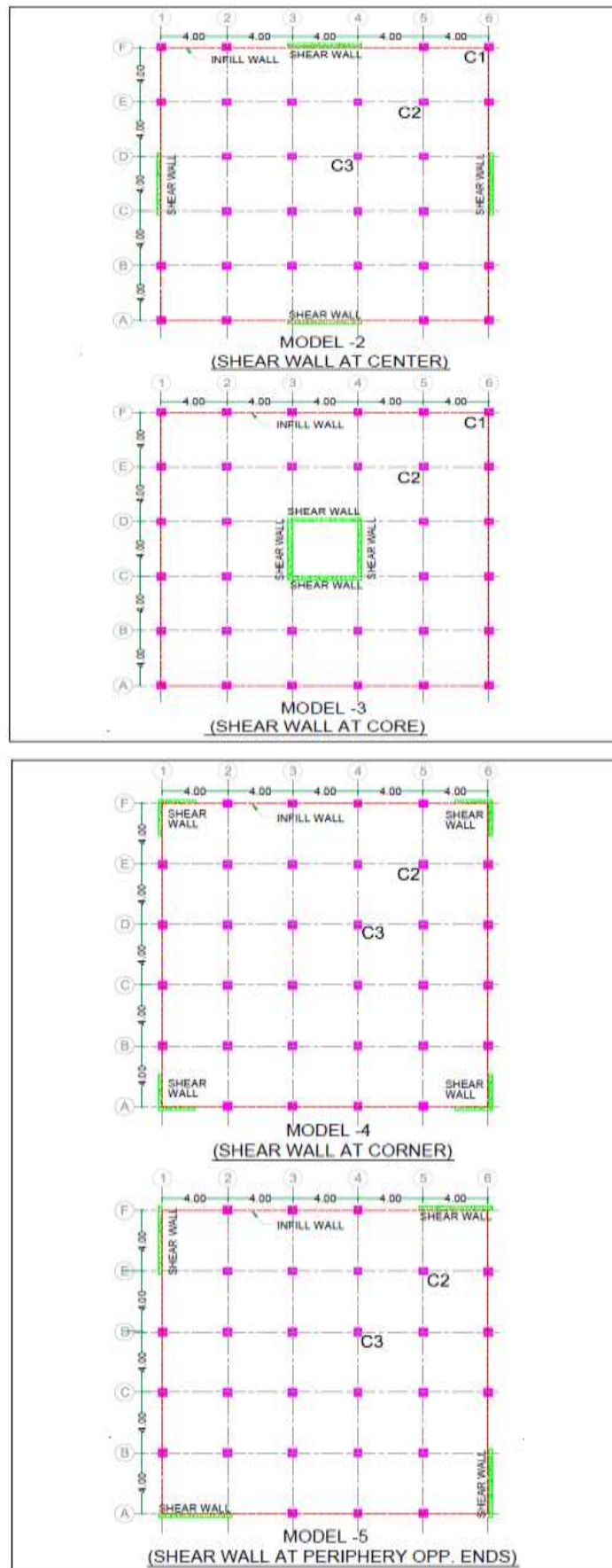


Fig-1 Floor Plans for Various Models

2. RESEARCH METHODOLOGY

A ground plus five storied building with four meter column spacing and typical three meter story height to be modeled using STAAD Pro V8i software for frame situated in Zone III. Reinforced concrete frame with infill masonry walls and with different arrangements of shear walls are taken into consideration in the analysis of this study for models as given below. The major steps for the analysis are as following:

- 1) The grid of plan is prepared as per the building parameters set.
- 2) The complete modeling of each type of configurations are prepared and Code IS 456-2000 is defined to the models
- 3) Properties of building elements (Slab, Beam & Columns) are given.
- 4) Infilled masonry walls are modeled by equivalent diagonal strut method as described earlier.
- 5) Define static load cases and apply to the building elements (Slab & Beams)
- 6) Assign the support conditions (Fixed supports at the base)
- 7) Apply diaphragm action to slabs (for rigid conditions)
- 8) Define mass sources, response spectrum functions as per IS 1893-2002
- 9) Define response spectrum case data.
- 10) Matching program calculated base shear with manually calculated base shear.
- 11) Defining the lateral load cases for earthquake and response spectrum, analysis.
- 12) Run the analysis to obtain the results
- 13) All results are obtained and compared.

2.1 Calculations of Time Period:

- a) In our case of model without infill walls;
- b) $T_a = 0.075 h^{0.75}$
Here $h = 21$ m
Therefore $T_a = 0.075 \times (21)^{0.75} = \mathbf{0.7357 \text{ sec}}$
- c) In our case of model with infill walls; $T_a = 0.09 h/\sqrt{d}$
Here $h = 21$ m, $D(z) = D(x) = 20$ m,
Therefore $T_a = (0.09 \times 21) / \sqrt{(20 \times 20)} = \mathbf{0.0945 \text{ sec}}$

2.2 Details of Various Cases

In this study, we have prepared various reinforced frame models for a G+5 storeyed building to analyze under equivalent and response spectrum analysis methods for bare frames and infilled frames with different arrangements of structural shear walls. The two cases undertaken for comparative study are:

1. **Case Study – 1; Equivalent static analysis** performed on different models (described below) to compare results obtained in the form of design forces, column displacements, inter-storey drifts, moments and shear forces generated on application of lateral earthquake loads.
2. **Case Study -2; Response spectrum analysis** performed for the above conditions to compare the overall results obtained by the two methods.

The various models prepared for the study are:

Model-1: G+5 storeyed building structure, situated in Seismic Zone-III is modeled without masonry infill walls and shear walls, prepared with geometrical and material properties given in the Tables above.

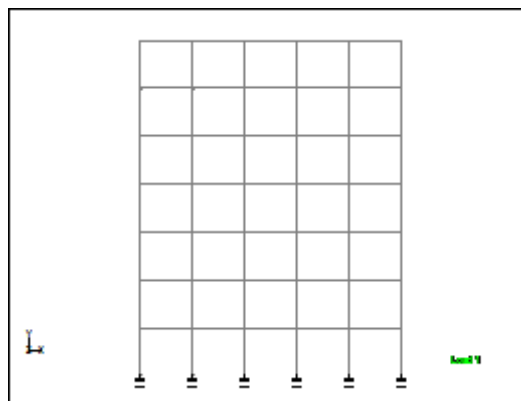


Fig. 2 STAAD Model-1

Model-2: The building structure is modeled with masonry infill walls and with inclusion of shear walls located at the center of peripheral outer frames. Its Staad model is given below:

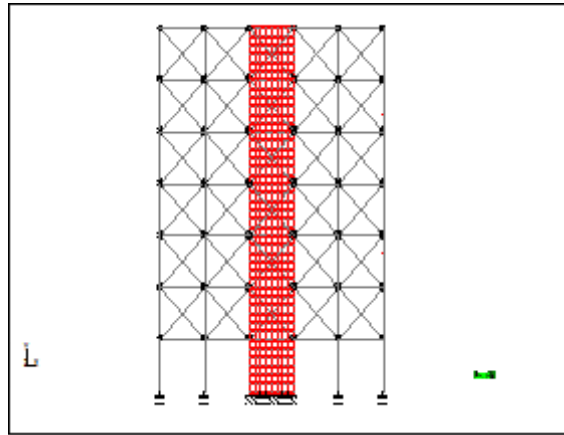


Fig. 3 STAAD Model-2

Model-3: The building structure is modeled with masonry infill walls and with inclusion of shear walls located at the center (core) of the building. Its Staad model is given below:

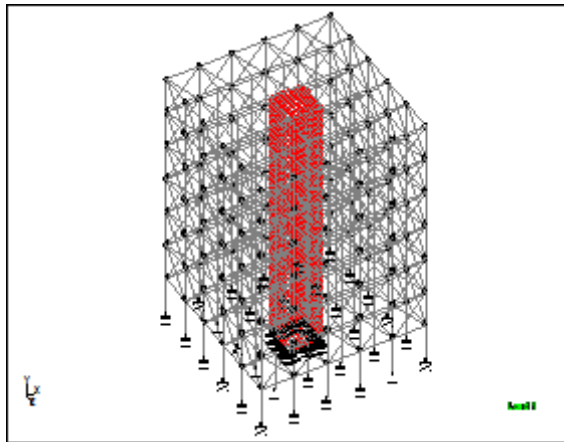


Fig. 4 STAAD Model-2

Model-4: The building structure is modeled with masonry infill walls and inclusion of shear walls located at the four corners of peripheral outer frames in an angular manner. Its Staad model is given below:

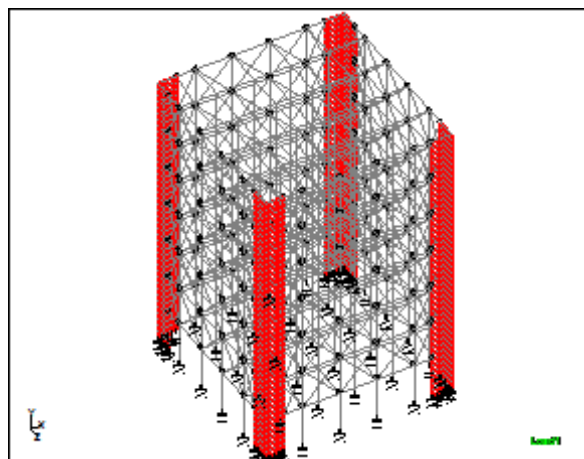


Fig. 5 STAAD Model-4

Model-5: The building structure is modeled with masonry infill walls and with inclusion of shear walls located at the side of four corners of peripheral outer frames. Its Staad model is given below:

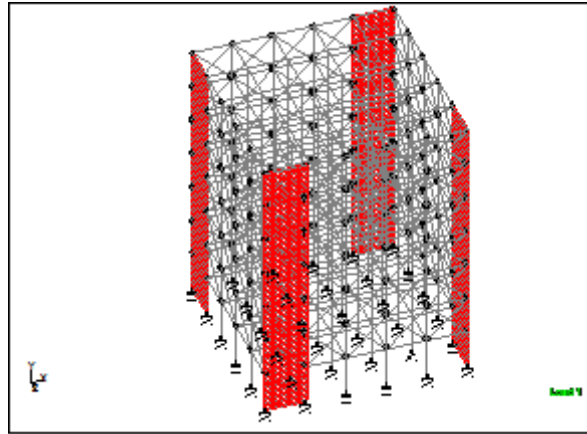


Fig. 6 STAAD Model-5

3. RESULTS & DISCUSSION

The performance of reinforced concrete building under the effect of lateral forces in Zone-3 due to the provisions of infill walls and shear walls at different locations are recorded for comparative study. The results obtained from static and dynamic analyses are given the Tables and Figures presented in this chapter. The results are as follows:

3.1 Results for CASE STUDY-1

Static Analysis (Equivalent Static Method):

Table-3 Result for Seismic Design Coefficient

COMARISION OF SEISMIC FACTORS		
S. No.	Bare Frame	Infilled Frame
T_a	0.7357	0.0945
S_a/g	1.8487	2.4175
A_h	0.02957	0.03868

Table-4 Result for Seismic Design Forces

COMPARISION OF DESIGN FORCES FOR VARIOUS MODELS					
S. No.	Model 1	Model 2	Model 3	Model 4	Model 5
W	26190	41513	42007	35441	41515
V_B	774.58	1605.7	1624.8	1370.9	1605.8

Table-5 Results for Column Displacements

DISPLACEMENT COLUMN (C2) FOR LOAD 1.5 (DL+EQX)					
Build. Ht. (m)	Model 1	Model 2	Model 3	Model 4	Model 5
	C2	C2	C2	C2	C2
	X Trans (mm)	X Trans (mm)	X Trans (mm)	X Trans (mm)	X Trans (mm)
0	2.525	1.133	0.69	1.018	1.114
3	6.555	3.077	1.855	2.74	3.118
6	10.71	5.605	3.367	4.865	5.691
9	14.597	8.292	5.052	7.044	8.429
12	17.938	10.876	6.774	9.069	11.063
15	20.441	13.199	8.431	10.807	13.429
18	21.898	15.129	9.894	12.182	15.396

Table-6 Results for Storey Drifts

STOREY DRIFT CALCULATED AT C2 FOR LOAD 1.5(DL+EQX)					
Build. Ht. (m)	Model 1	Model 2	Model 3	Model 4	Model 5
	C2	C2	C2	C2	C2
	Storey Drift (mm)	Storey Drift (mm)	Storey Drift (mm)	Storey Drift (mm)	Storey Drift (mm)
0	0	0	0	0	0
3	4.03	1.944	1.165	1.722	2.004
6	4.155	2.528	1.512	2.125	2.573
9	3.887	2.687	1.685	2.179	2.738
12	3.341	2.584	1.722	2.025	2.634
15	2.503	2.323	1.657	1.738	2.366
18	1.457	1.93	1.463	1.375	1.967

Table-7 Results for Variation in Moments

MAX. MOMENTS My & Mz FOR C2 AT EVERY SPAN										
Ht. (m)	Model 1		Model 2		Model 3		Model 4		Model 5	
	C2		C2		C2		C2		C2	
	My	Mz	My	Mz	My	Mz	My	Mz	My	Mz
0	-0.26	-35.865	-0.299	-16.566	-0.202	-9.97	0.839	-14.173	0.773	-16.697
3	0.041	5.78	0.021	6.077	0.044	3.414	0.884	4.236	1.228	6.38
6	-0.096	-0.904	-0.117	3.941	-0.097	2.681	0.496	2.001	0.187	4.112
9	-0.003	-3.898	-0.016	0.169	-0.001	0.992	0.511	-0.887	0.189	0.255
12	-0.052	-6.722	-0.065	-1.869	-0.059	-0.16	0.373	-2.497	-0.041	-1.855
15	0.214	-9.627	0.228	-2.768	0.225	-0.856	-0.043	-2.852	-0.525	-2.857
18	-0.759	-9.33	-0.883	-8.053	-0.798	-5.692	2.369	-7.802	2.096	-7.802

Table-8 Results Variation in Shear Forces

SHEAR FORCE (Fy) at C2 FOR LOAD 1.5(DL+EQX)					
B. Ht.	Model 1	Model 2	Model 3	Model 4	Model 5
	C2	C2	C2	C2	C2
0	70.038	30.567	18.799	28.774	30.924
3	74.118	32.374	19.723	32.651	32.933
6	71.858	45.35	27.124	42.929	45.856
9	66.243	46.358	29.64	43.731	46.741
12	56.439	43.96	30.11	41.721	44.042
15	41.425	38.387	28.528	36.073	38.266
18	20.092	37.269	30.17	36.256	36.471

3.1.2 Graphical Representation of Various Results:

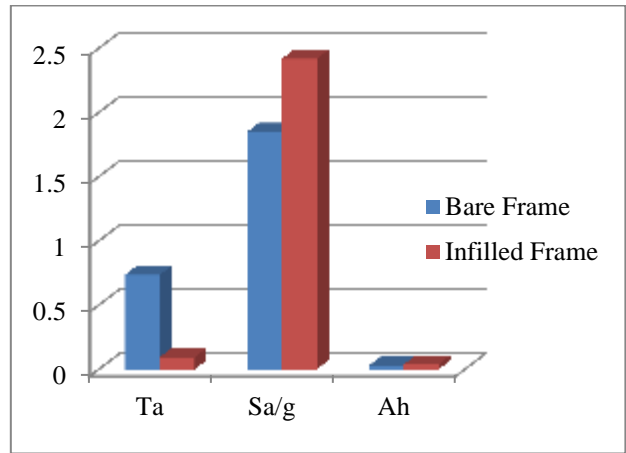


Fig-7 Comparison of Seismic Design Coefficient

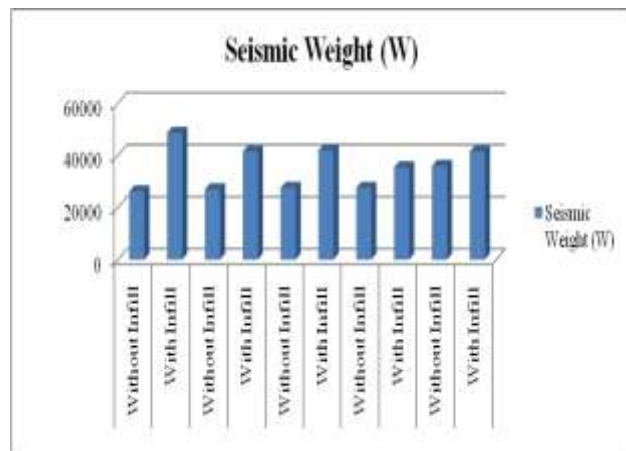


Fig-8 Comparison of Seismic Weight

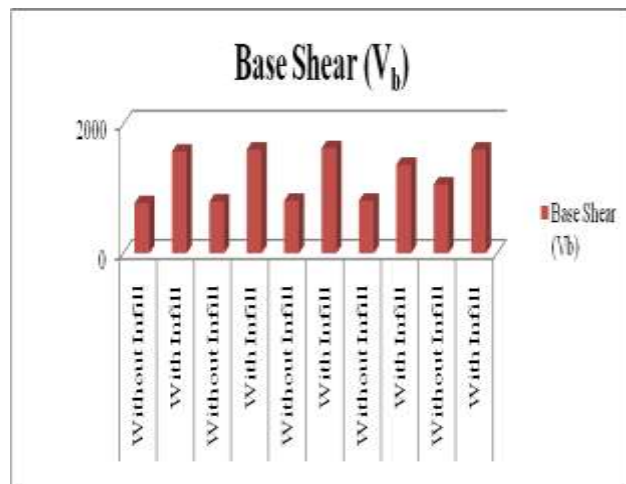


Fig-9 Comparison of Base Shear

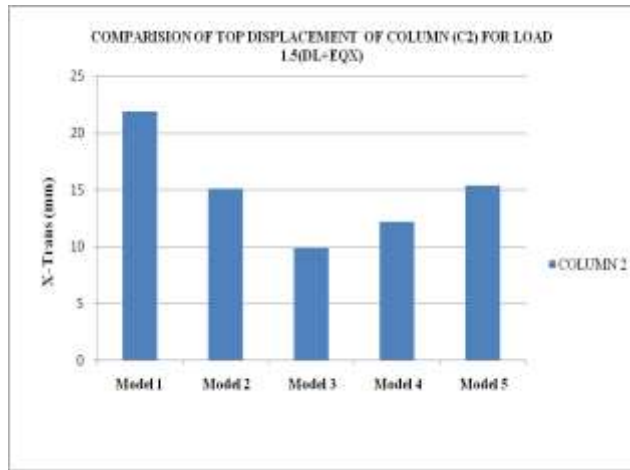


Fig -10 Comparison of Top Displacements for Various Models

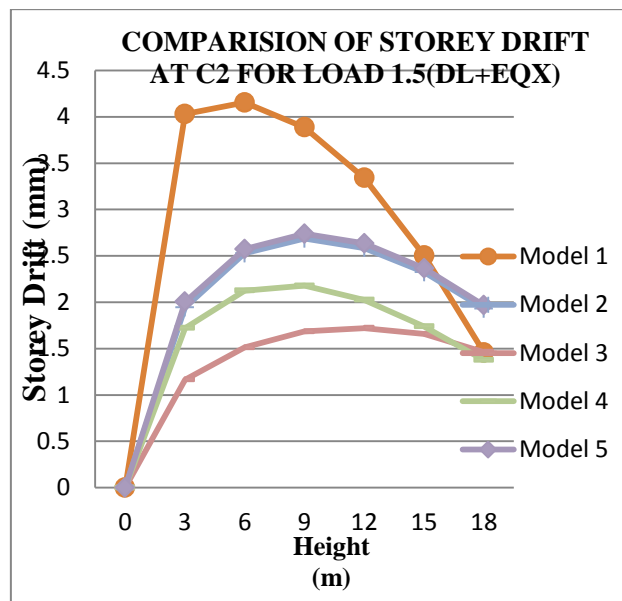


Fig-11 Comparison of Story Drift for Various Models

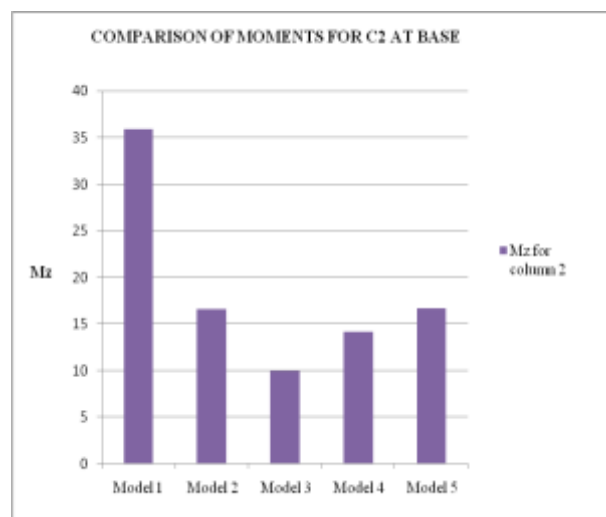


Fig-12 Comparison of Bending Moments for Various Models

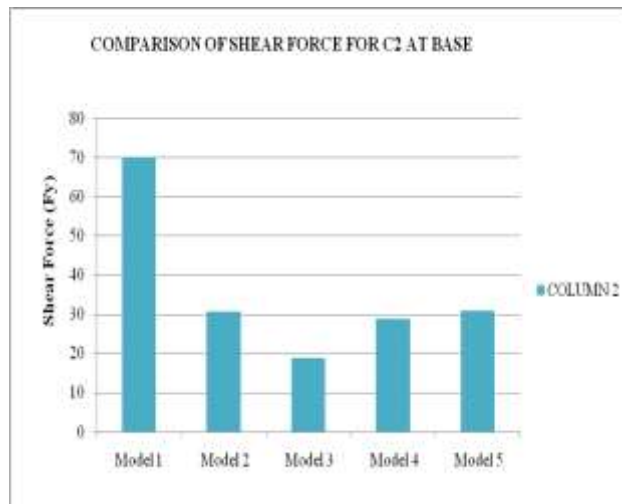


Fig-13 Comparison of Bending Moments for Various Models

3.2 Result for CASE STUDY – 2

Dynamic Analysis Method (Response Spectrum Analysis):

Table-9 Results for Column Displacements

DISPLACEMENT AT COLUMN (C2) FOR LOAD 1.5(DL+EQX)					
Bld. Ht (m)	Model 1	Model 2	Model 3	Model 4	Model 5
	C2	C2	C2	C2	C2
	X Trans (mm)	X Trans (mm)	X Trans (mm)	X Trans (mm)	X Trans (mm)
0	3.027	1.219	1.136	1.062	1.566
3	7.703	3.214	2.892	2.794	4.035
6	12.236	5.771	4.848	4.882	6.914
9	16.163	8.416	6.813	6.948	9.786
12	19.278	10.895	8.659	8.802	12.431
15	21.437	13.081	10.291	10.35	14.748
18	22.61	14.89	11.615	11.566	16.673

Table-10 Results for Storey Drifts

STOREY DRIFT AT C2 FOR LOAD 1.5(DL+EQX)					
Build. Ht. (m)	Model 1	Model 2	Model 3	Model 4	Model 5
	C2	C2	C2	C2	C2
	Storey Drift (mm)	Storey Drift (mm)	Storey Drift (mm)	Storey Drift (mm)	Storey Drift (mm)
0	0	0	0	0	0
3	4.676	1.995	1.756	1.732	2.469
6	4.533	2.557	1.956	2.088	2.879
9	3.927	2.645	1.965	2.066	2.872
12	3.115	2.479	1.846	1.854	2.645
15	2.159	2.186	1.632	1.548	2.317
18	1.173	1.809	1.324	1.216	1.925

Table-11 Results for Variation in Moments (in KN-M)

MAX. MOMENTS My & Mz AT C2 FOR LOADS 1.5(DL+EQX) AT EVERY SPAN										
Build. Ht. (m)	Model 1		Model 2		Model 3		Model 4		Model 5	
	C2		C2		C2		C2		C2	
	My	Mz	My	Mz	My	Mz	My	Mz	My	Mz
0	28.025	128.08	5.43	51.402	24.111	48.425	2.922	44.395	3.646	68.327
3	30.402	133.13	6.502	52.16	25.574	48.049	2.589	45.154	6.282	66.807
6	26.881	121.24	9.215	71.134	19.688	52.465	2.183	56.188	6.943	79.692
9	23.279	104.83	9.713	70.771	16.831	52.106	1.813	53.129	6.896	77.175
12	18.508	84.567	9.484	65.828	13.111	48.906	1.638	46.885	6.257	70.585
15	13.026	58.949	8.761	56.037	8.931	42.111	1.646	37.458	5.113	59.873
18	5.361	30.305	8.915	56.956	1.99	41.454	4.662	32.41	5.931	61.421

Table-12 Results Variation in Shear Forces (in KN)

SHEAR FORCE (Fy) AT C2 FOR LOAD 1.5(DL+EQX) AT EVERY SPAN					
Build. Ht. (m)	Model 1	Model 2	Model 3	Model 4	Model 5
	C2	C2	C2	C2	C2
0	85.263	34.115	32.365	38.456	44.185
3	87.635	33.753	31.637	36.589	42.805
6	79.672	46.476	34.919	41.254	50.792
9	68.58	46.135	34.731	39.347	48.751
12	54.944	41.736	32.574	36.182	44.028
15	38.354	36.706	28.471	33.275	37.324
18	17.592	35.739	26.863	31.389	35.635

Graphical Representation of Various Results

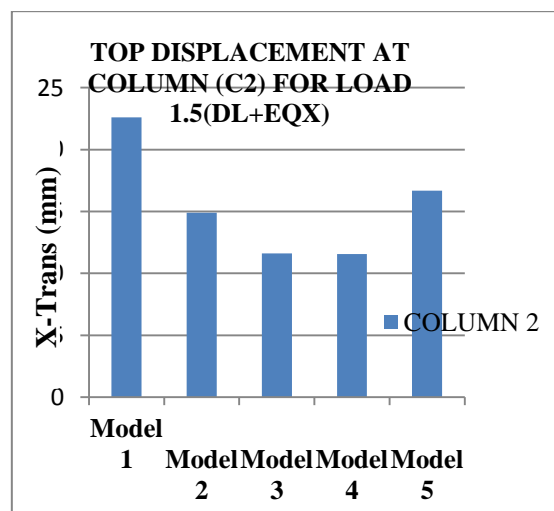


Fig-13 Comparison of Top Displacements for Various Models

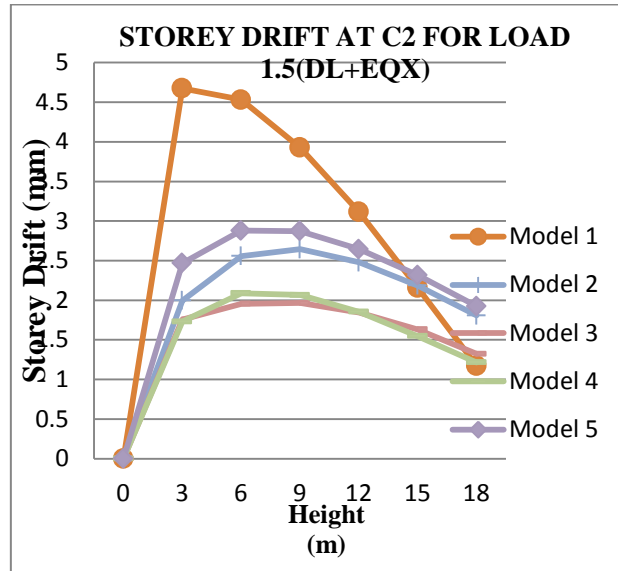


Fig-14 Comparison Of Story Drifts For Various Models

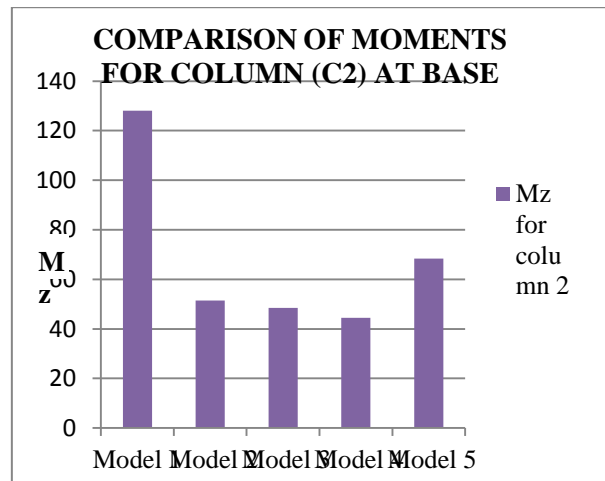


Fig-15 Comparison of Bending Moments for Various Models

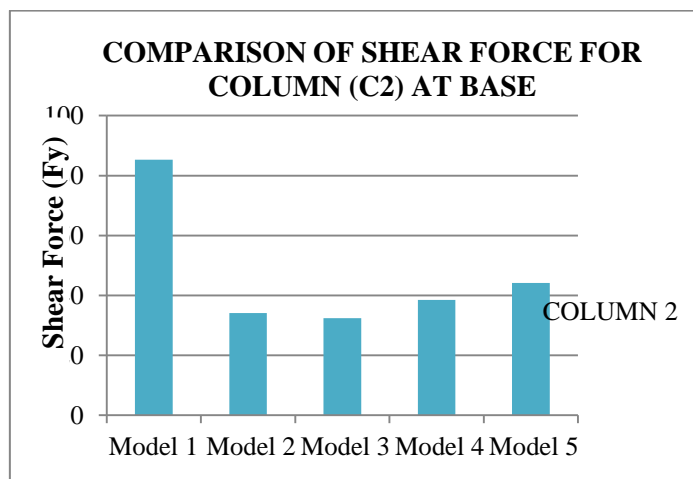


Fig-16 Comparison of Shear Force for Various Models

3.3 Results Comparison

Table-13 Results For Percentage Increase in Base Shear for Static and Dynamic Analyses

COMPARISON OF DESIGN FORCES FOR VARIOUS MODELS										
S. N.	Model 1		Model 2		Model 3		Model 4		Model 5	
V_b	W/O Infill	With Infill	W/O Infill	With Infill	W/O Infill	With Infill	W/O Infill	With Infill	W/O Infill	With Infill
Values	774.58	1573.5	799.16	1605.7	813.83	1624.8	813.83	1370.9	1064.6	1605.8
Inc.	103.14%		100.92%		99.65%		68.45%		50.83	
Av. Inc.	84.60%									

Table-14 Results for Percentage Reduction in Deflections for Static and Dynamic Analyses

COMPARISON OF TOP DISPL. AT COLUMN (C2) B/W DYNAMIC & STATIC ANALYSIS					
ANALYSIS	Model 1	Model 2	Model 3	Model 4	Model 5
	C2	C2	C2	C2	C2
	X Trans (mm)	X Trans (mm)	X Trans (mm)	X Trans (mm)	X Trans (mm)
ST.	21.898	15.129	9.894	12.182	15.396
Redn. %		30.92	54.82	44.36	29.63
Av. Rdn.		39.93%			
DYN.	22.61	14.89	11.615	11.566	16.673
Rdn.%		34.15	48.62	48.84	26.25
Av. Rdn.		39.46%			

Table-15 Results for Percentage Reduction in Story Drifts for Static and Dynamic Analyses

COMPARISON OF STOREY DRIFT AT LEVEL-1 FOR COLUMN (C2) B/W DYNAMIC AND STATIC ANALYSIS					
ANALYSIS	Model 1	Model 2	Model 3	Model 4	Model 5
	C2	C2	C2	C2	C2
	Storey Drift (mm)	Storey Drift (mm)	Storey Drift (mm)	Storey Drift (mm)	Storey Drift (mm)
STAT.	4.03	1.944	1.165	1.722	2.004
Redn.%		52.85	77.09	57.27	50.27
Av. Redn.		59.37%			
DYN.	4.676	1.995	1.756	1.732	2.469
Redn.%		57.33	62.44	62.95	47.91
Av. Redn.		57.65%			

Table-16 Results for Percentage Reduction in Bending Moments for Static and Dynamic Analyses

COMPARISON OF MOMENT (M_z) AT COLUMN (C2) B/W DYNAMIC AND STATIC ANALYSIS					
ANALYSIS	Model 1	Model 2	Model 3	Model 4	Model 5
	C2	C2	C2	C2	C2
STAT.	-35.865	-16.566	-9.97	-14.173	-16.697
Redn.%		53.81	72.20	60.48	53.45
Av. Redn.		60.00%			
DYN.	128.081	51.402	48.425	44.395	68.327
Redn.%		59.86	62.19	65.39	46.65
Av. Redn.		58.52%			

Table-17 Results for Percentage Reduction in Shear Forces for Static and Dynamic Analyses

COMPARISON OF SHEAR FORCE (Fy) FOR C2 AT BASE B/W DYNAMIC AND STATIC ANALYSIS					
ANAL-YSIS	Model 1	Model 2	Model 3	Model 4	Model 5
	C2	C2	C2	C2	C2
STAT	70.038	30.567	18.799	28.774	30.924
Redn.%		56.35	73.15	41.26	39.12
Av. Redn.		52.47%			
DYN.	85.263	34.115	32.365	38.456	44.185
Redn.%		59.98	62.04	54.89	48.18
Av. Redn.		56.35%			

4. CONCLUSIONS

Based on the present study the following conclusions are drawn:

- a) The analysis of the building was carried out by equivalent diagonal strut approach for modeling infill panels, seismic coefficient method and response spectrum analysis method for static and dynamic analysis respectively using STAAD PRO V8i software.
- b) In this study the storey drift, storey displacements, column shear & moments for a RC frame regular building with infill brick walls and different locations of shear walls have been investigated. The structural behavior of seismic coefficient method and seismic response of the building was analyzed in terms of storey drifts and average displacement. It was observed that with the incorporation of shear walls, storey drifts and average displacement decreased considerably. It was also noticed that from the building models prepared and investigated in the present study, the shear walls located at external corners were found to be more effective in reducing the storey drifts and average displacements.
- c) The study suggests most suitable location of shear walls for deriving maximum advantage of them i.e when they are placed in outer periphery at corners and at core of the building.
- d) It is found that the base shear values show considerable increase on introduction of infilled masonry walls on the bare framed structure (i.e. upto 84.60%).
- e) The infilled walls inclusions suggested marginal reduction in deflections (Average 3.76%) but its combinations with shear walls show higher reduction in deflections (Average 39.93% in static analysis & 39.46% in dynamic analysis), as given in the result Table above. The effect of shear wall decreases with the height of the building.
- f) The infill & shear wall inclusions in the models suggested noticeable reduction in storey drifts (Average 59.37% in static analysis & 57.65% in dynamic analysis), as given in the result Table. The storey drifts increases with increase in height.
- g) The infill & shear wall inclusions in the models suggested noticeable reduction in bending moments M_x & M_z responsible for biaxial bending (Average 60% in static analysis & 58.52% in dynamic analysis), as given in the result table above.
- h) The infill & shear wall inclusions in the models suggested noticeable reduction in shear forces (Average 52.47% in static analysis & 56.35% in dynamic analysis), as given in the results tables above.
- i) In this study the storey drift two reinforced frame regular buildings with different locations of shear walls have been investigated. The structural behavior of seismic coefficient method and seismic response of the building was analyzed in terms of storey drifts and average displacement. It was observed that with the incorporation of shear walls, storey drifts and average displacement decreased considerably. It was also noticed that from the building models prepared and investigated in the present study, the shear walls located at external corners and core of the building were found to be more effective in reducing the storey drifts and average displacements.
- j) It is concluded that masonry infills also have considerable strength and participates in lateral load resisting system. It can provide supplemental stiffness to the structure where provisions of shear walls are inadequate.
- k) It is also concluded that neglecting the effects of masonry infills in the presence of shear walls may lead to wrong results.

4.1 Scope for Future Studies

- a) This analysis can be applied to different structures.
- b) In the present study full masonry infill and shear wall is considered in the frames but partial with openings (doors, windows etc.) and varying percentages can also be taken and analysed.
- c) Case for irregularities in plan and vertical irregularities (storey heights) and soft stories can also be considered.
- d) Provisions from latest code IS 1893 – 2016 to be studied and implemented.

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