INTERNATIONAL JOURNAL OF ADVANCE RESEARCH, IDEAS AND INNOVATIONS IN TECHNOLOGY

ISSN: 2454-132X
Impact factor: 4.295
(Volume 5, Issue 3)
Available online at: www.ijariit.com

Comparative analysis and design of framed structure with different types of infill walls

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ABSTRACT

In the last few decades, the scientific community has been extensively involved in the investigation about the interaction between infill walls and RC frames in the seismic structural behaviour. The infill walls are seldom included in the numerical analysis of reinforced concrete structural Systems since infill panels are generally considered as non-structural components. However, these panels affect the structural response to a large extent, because the complexity they introduce to analysis, kept them unaccounted. Therefore, it is crucial to understand the contribution of infill walls to earthquake response of the Structures. In this study, an attempt is made to do comparative analysis and design of the structure when the structure is modelled using different types of infill walls. In this study, an R/C frame structure with a different type of infill walls like AAC Block, Clay Brick, are considered to investigate the effect of different types of infill walls on earthquake response of the structures. The RCC frame analyzed & designed by using STAAD-Pro software. The diagonal strut approach is adopted for modelling of infill walls. The analytical results of the building frame will be compared and analyzed to obtain are storey drift, base shear, Lateral displacement, shear force and bending moment when subjected to static earthquake loadings.

Keywords*— Infill, Caly bricks, AAC block, Equivalent diagonal strut, Staad pro*

1. INTRODUCTION

Structural design is the methodical investigation of the stability, strength and rigidity of structures. The basic objective in structural analysis and design is to produce a structure capable of resisting all applied loads without collapse during its intended life. The primary purpose of a structure is to transmit or support loads. If the structure is improperly designed or fabricated, or if the actual applied loads exceed the design specifications, the device will probably fail to perform its intended function, with possible serious consequences. A well-engineered structure greatly minimizes the possibility of costly failures.

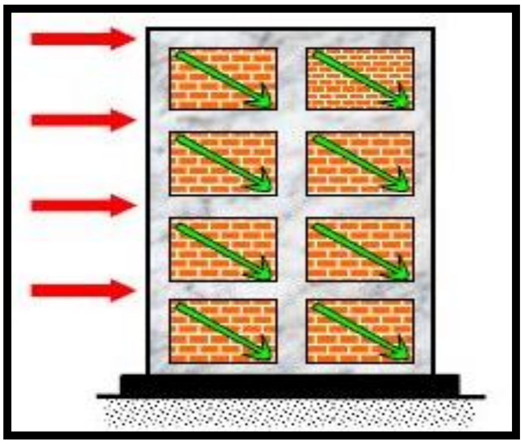

Fig. 1: Masonry infilled frame: Infill helps transfer lateral loads through diagonal strut action and reduces demand on columns

In recent decades, the use of high strength reinforced concrete (H.S.R.C) in buildings is widely spread in buildings. The behaviour and ductility of the high strength reinforced concrete frames with infill wall under the effect of lateral load still need a lot of investigations.

In reinforced concrete frame building, the wall is generally used in as infill's and specified by architects as partitions in such a way that they do not contribute to the vertical gravity load-bearing capacity of the structure. Infill walls protect the inside of the buildings from environmental hazards and create separation insides. In addition to this infill's have considerable strength and stiffness and they have a significant effect on the seismic response of the structural systems. Mostly two common structural damages observed caused by infill walls in earthquakes i.e. soft stories and short columns.

2. LITERATURE REVIEW

On the basis of the topic selected various literature was gone through on the reasons and findings related to infill. The literature were studies on

- The behaviour of reinforced concrete frames with infill.
- Study on earthquake analysis of multi-storeyed buildings.
- Modelling methodology of infills
- Study of various infills.

The secondary data from various research journals as well as reports are studied and some important learning are mentioned below

Polyakov (1956) et al[1] the study of the complicated behaviour of masonry infill by suggested that the infill and frame disparate excluding at two compression corners. He established the idea of the equivalent diagonal strut and proposed that transformation of stresses from the frame to infill occurs only in the compression zone of the infill.

Fardis (1996) et al[2] investigated the seismic response of an infilled frame which had weak frames with strong infill material. It was found that the strong infill which was considered as non-structural is responsible for earthquake resistance of weak reinforced concrete frames. However, since the behaviour of infill is unpredictable, with the likelihood of failing in a brittle manner, it was recommended to treat infill as a non-structural component by isolating it from frames. On the contrary, since infill is extensively used, it would be cost effective if the positive effects of infill are utilized.

Nasratullah Zahir, Dr Vivek Garg et al[3] paper present static and dynamic analysis of R.C building frame with infill The results obtained from the analysis indicates that story shear increase for infill frame models compare to bare frame model by equivalent static method and response spectrum method. This increase in the ratio is found to be more at the roof compared to the base of the structure. The story shear values obtained by Smith and Holmes models are found to be more compared to Paulay and infill panel models.

Rahul P. Rathi, Dr P.S. Pajgade et al[3] In this paper actual building such as college building (G+3) is considered by modelling of frame and Infills. Modelling of infills is done as per the actual size of openings with the help of equivalent diagonal strut method for the various model such as bare frame, infill frame and infill frame with the centre and corner opening. Results indicate that infill panels have a large effect on the behaviour of frames under earthquake excitation. In general, infill panels increase the stiffness of the structure. The increase in the opening percentage leads to a decrease in the lateral stiffness of the infilled frame.

3. METHODOLOGY

This research work on the comparison of seismic analysis and design of G+15 building using different types of infill walls. Which include

1. Bare frame model
2. Conventional Clay Bricks Masonry model
3. AAC Block model

4. DETAILS OF STRUCTURAL ELEMENTS AND MATERIAL USED

Type of Structure	G+15 RC Frame Building
Plan dimensions	13.62 m × 16.30 m
The total height of building	51.20 m
Height of each storey	3.2 m
Foundation Level to ground Level	3 m
Size of beams	300mm×450mm

Size of columns	750mm×750mm
The thickness of slab	125mm
Grade of Concrete	M25
Grade of Steel	Fe415
Seismic Analysis	Equivalent Static Method (IS1893-2002) clause 7.8.1 (a).
Design Philosophy	Limit State Method Conforming (IS456-2000)
Ductility Design	IS 13920-1993
Seismic zone	II
Response reduction factor (R)	5
The soil type of medium	
Importance Factor (I)	1
Damping	5%

4.1 Concrete

Density of Concrete	25 kN/m^3
Modulus of Elasticity	$5000\sqrt{fck}$ = 25000 N/mm^2
Poisson's ratio for concrete	0.17
Compressive strength	25 N/mm^2

4.2 Masonry clay brick infill

Size	210 mm x 100 mm x 75 mm
Density	19 kN/m^3
Poisson's ratio	0.16
Compressive strength	3.745 N/mm^2
Modulus of Elasticity	8675 N/mm^2

4.3 AAC Block infill

Size	200 mm x 200 mm x 624 mm
Density	5.5 kN/m^3
Poisson's ratio	0.25
Compressive strength	2.2 N/mm^2
Modulus of Elasticity	1600 N/mm^2

5. BUILDING PLAN

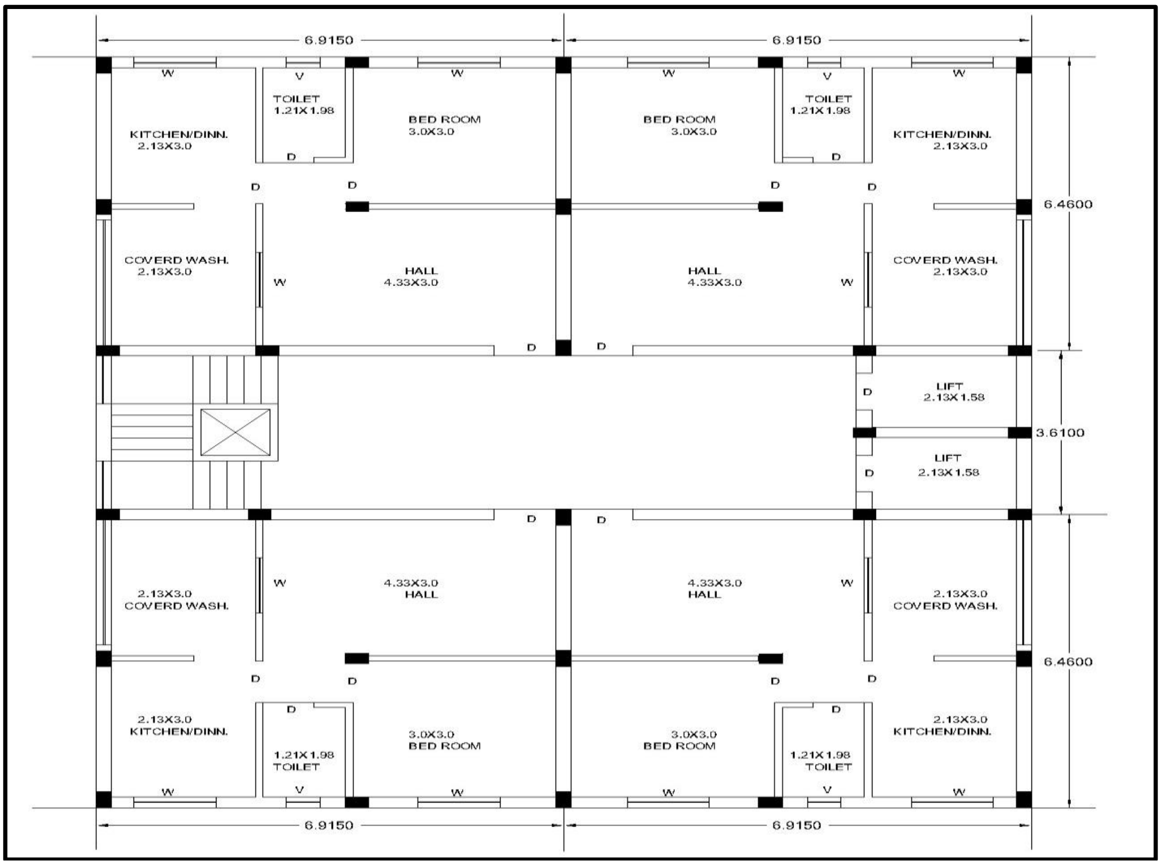

Fig. 2: Building Plan

6. CALCULATION OF THE WIDTH OF EQUIVALENT DIAGONAL STRUT

In this method, the analysis is carried out by simulating the action of infills similar to that of diagonal struts bracing the frame. The infills are replaced by an equivalent strut of length D, and width W and the analysis of the frame-strut system is carried out using usual frame analysis methods. Second stage analysis and design have been carried out by software STAAD- Pro then different parameters have been computed. The relationships proposed by Mainstone Walls have to resist the shear forces that try to push the walls over for computing the width of the equivalent diagonal strut, is widely used in the literature and is given by.

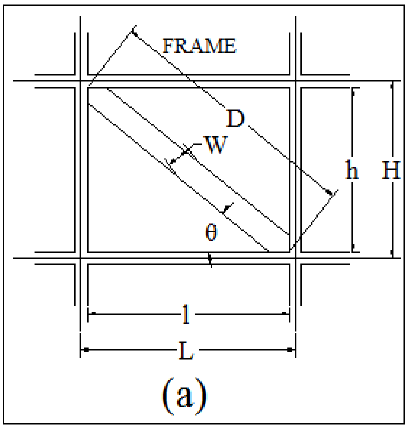

Fig. 3: shows equivalent diagonal strut model

$$\lambda = \sqrt[4]{\frac{E_i t \sin(2\theta)}{4E_f I_c h'}}$$

Where
λ =Stiffness reduction factor
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
t = the thickness of infill, mm
H =the centre line height of frames
h = the height of infill
L =the centre line width of frames
l = the width of infill
D = the diagonal length of the infill panel
θ = the slope of infill diagonal to the horizontal.
Width of strut (W) = 0.175 $(\lambda H)^{-0.4}$ D

7. INTRODUCTION OF ANALYTICAL MODELS CONSIDERED

1) Model 1: Bare Frame (RC frame without considering infill)
2) Model 2: RC frame building model with brick infill.
3) Model 3: RC frame building with AAC block infill.

8. RESULTS

Result obtain from StaadPro analysis are discussed below.

Table 1: Lateral displacements of all models in the X direction and Z direction

	Lateral Displacement (mm)		
	Model No 1	**Model No 2**	**Model No 3**
X (mm)	21.1100	0.2320	4.0850
Z(mm)	34.3900	2.5730	6.6040

Table 2: Storey Drift of All Models in X direction & Z direction

Storey no	Height m	Storey drift					
		Model No 1		Model No 2		Model No 3	
		X (cm)	Z(cm)	X (cm)	Z(cm)	X (cm)	Z(cm)
Base 1	0	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
2	3	0.0445	0.0597	0.0704	0.0765	0.0473	0.0539
3	6.2	0.0993	0.1408	0.1335	0.1482	0.0936	0.1095

4	9.4	0.1206	0.1744	0.1393	0.1521	0.1016	0.1187
5	12.6	0.1298	0.1884	0.1405	0.1487	0.1036	0.1189
6	15.8	0.1343	0.1941	0.1414	0.1452	0.1045	0.1176
7	19	0.1359	0.1934	0.1413	0.1404	0.1046	0.1147
8	22.2	0.1362	0.1898	0.1407	0.1352	0.1042	0.1114
9	25.4	0.1367	0.1856	0.1395	0.1295	0.1035	0.1077
10	28.6	0.1374	0.1814	0.1380	0.1236	0.1025	0.1039
11	31.8	0.1366	0.1759	0.1353	0.1172	0.1006	0.0997
12	35	0.1326	0.1665	0.1314	0.1096	0.0974	0.0940
13	38.2	0.1270	0.1540	0.1267	0.1013	0.0936	0.0872
14	41.4	0.1194	0.1404	0.1212	0.0924	0.0889	0.0796
15	44.6	0.1090	0.1239	0.1148	0.0830	0.0830	0.0713
16	47.8	0.0970	0.1049	0.1075	0.0733	0.0764	0.0625
17	51	0.8390	0.0843	0.1003	0.0632	0.0639	0.5290
18	54.2	0.0711	0.0654	0.0928	0.0534	0.0620	0.0435
19	57.4	0.0858	0.0478	0.1280	0.0451	0.0979	0.0349

Table 3: Base Shear Vb

Model		
1	**2**	**3**
552.7 kn	940.08 kn	629.08 kn

Table 4: Shear Force

Shear Forces (kN)							
Storey	**Member**	**Model 1**		**Model 2**		**Model 3**	
No.	**No.**	**(+ve)**	**(-ve)**	**(+ve)**	**(-ve)**	**(+ve)**	**(-ve)**
1	88	55.974	-53.656	57.224	-65.496	40.097	-48.950
2	125	71.473	-67.651	7.005	-71.828	17.354	-57.193
3	249	77.728	-72.560	11.380	-63.891	18.171	-54.398
4	373	79.986	-73.632	11.122	-57.131	18.338	-50.757
5	497	80.639	-72.759	11.133	-51.540	10.332	-47.062
6	621	80.310	-71.018	11.015	-46.410	18.194	-43.513
7	745	79.417	-68.707	10.798	-41.754	18.994	-39.998
8	869	77.952	-66.202	10.522	-37.370	20.067	-36.590
9	993	75.780	-63.456	10.146	-33.284	20.710	-33.236
10	1117	72.709	-60.050	9.646	-29.296	20.905	-29.797
11	1241	68.886	-55.525	9.012	-25.270	20.798	-26.070
12	1365	63.882	-50.039	8.257	-21.155	20.235	-22.159
13	1489	57.641	-43.627	7.468	-17.030	19.496	-18.370
14	1613	50.153	-36.186	7.548	-12.700	18.707	-14.722
15	1737	41.177	-27.997	7.357	-8.387	17.398	-10.936
16	1861	30.212	-19.395	8.123	-4.362	14.881	-6.989
17	1985	24.508	-9.244	7.681	-1.914	17.173	-2.268

Table 5: Bending Moment

Bending Moment (KN.m)							
Storey	**Member**	**Model 1**		**Model 2**		**Model 3**	
No.	**No.**	**(+ve)**	**(-ve)**	**(+ve)**	**(-ve)**	**(+ve)**	**(-ve)**
1	88	105.701	-108.999	70.322	-165.706	68.371	-108.910
2	125	75.292	-82.485	48.248	-83.916	35.222	-53.064
3	249	61.873	-73.259	48.410	-45.874	40.609	-42.152
4	373	62.490	-70.838	49.142	-46.670	42.381	-41.919
5	497	67.770	-69.298	49.135	-45.573	43.316	-41.423
6	621	70.401	-68.097	48.672	-44.256	43.769	-40.897
7	745	71.210	-67.552	47.774	-42.715	43.682	-40.278
8	869	71.518	-67.273	46.335	-40.806	43.209	-39.387
9	993	71.342	-66.309	44.310	-38.381	42.197	-38.037

10	1117	71.480	-63.970	42.191	-35.445	41.193	-36.099
11	1241	71.335	-60.224	40.729	-32.609	40.422	-33.960
12	1365	69.333	-55.971	38.085	-30.055	38.670	-31.874
13	1489	66.471	-50.456	35.601	-26.363	36.837	-28.848
14	1613	63.058	-44.724	33.096	-23.086	34.883	-25.952
15	1737	58.346	-38.411	30.077	-19.402	32.404	-22.649
16	1861	53.384	-31.229	27.754	-14.962	31.299	-18.530
17	1985	55.408	-23.689	26.886	-10.381	29.781	-13.077

9. CONCLUSIONS

9.1 Lateral Displacement & Storey Drift

From the observation of the results in table 1 and table 2, In addition to that, the total horizontal displacement and the storey drift of the structure are greatly reduced by the introduction of infill in moment resisting reinforced concrete frame. Here it is seen that strut model buildings have less displacement and drift than bare-frame buildings which can say those strut model buildings are stiffer and safer during the earthquakes than the bare-frame models. From table 1 it’s observed that the conventional brick have minimum lateral displacement then AAC block infill model because the diagonal compressive strength of conventional brick is more than AAC Block as AAC blocks are lightweight and less compressive strength. Its show presence of infill contributes to the stiffness of the building. This effect is clear from Model 1.

9.2 Base Shear

From the observation of the results in table 3, it’s concluded that due to infill walls in building the base shear is increased because of increased in seismic weight of the structure. Model 2 conventional infill model has maximum base shear as its seismic weight is more compared to model 3 and model 3 AAC infill model have less base shear as its seismic weight is less than model 2. The lateral force is distributed along with the building height of all model. Similarly, model 2 has a maximum lateral force as it has maximum base shear.

9.3 Shear Force and Bending Moment

From the observation of the results in table 4 & 5, it’s concluded the response of the structure in terms of bending moments and shear forces is greatly enhanced by the introduction of the infill. Both bending moment and shear force in beams and columns are reduced appreciably due to infill. Again from the observation, it's observed that the bare frame model have the maximum shear force and bending moment in structural members, on the other hand, conventional brick infill model have the minimum shear force and bending moment as compared to all other models.

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