Comparative Study of Brick Infill Wall and Autoclaved Aerated Concrete (AAC) Blocks Using Response Spectrum Analysis

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Abstract - *Conventional clay brick is the most common infill material used in the construction of RC buildings. However, nowadays different innovative and environment-friendly infill materials that can be used in place of bricks are gaining more popularity day by day. i.e., AAC Blocks. Traditionally, since masonry is a non-structural element its influence in a building under seismic loading is often neglected but some studies have shown that infill wall panels play a significant role in the case of earthquakes.*

In order to assess the effect of brick and AAC infill walls, the seismic behaviour of a hypothetical G+6 storey RC building is studied. Here, the seismic analysis is carried out by response spectrum analysis, and infill walls are modelled using the equivalent diagonal strut method. Structural Engineering software CSI ETABS (Extended3D Analysis of building System) Version:18.0.2 is used.

Primary objective of this study is to compare the results of Storey displacement, storey drifts, bending moments, axial and shear force to find out how much cost can be saved by considering the infill influence under the seismic forces and how effective AAC blocks are compared to conventional clay brick.

***Key Words*: Infill frame, bare frame, RC frame, equivalent diagonal strut, response spectrum, seismic analysis, axial force, story drift and storey displacements.**

1. INTRODUCTION

Structural analysis is primarily concerned with obtaining the performance of the physical structures under the effects of loads. These loads can be in the form of the weight of objects such as furniture, people, wind, snow, etc. Or another form of loads such as imposed load, earthquakes, Soil and fluid pressure, Impact, etc. Structures in the world usually fall under two types of loads: Static and Dynamic. Static loads are constant with time whereas dynamic loads vary with time. Generally, most Civil Engineering buildings are designed with the assumption that all applied loads are static.

The effect of a dynamic load is not considered because the structure does not usually have to deal with dynamic loads; Moreover, its consideration makes the analysis much complicated and time-consuming. This element of negligence can sometimes lead to the cause of the disaster, especially in the event of an earthquake. The earthquake of Bhuj on January 26, 2001 is one of the examples. These Days, there is a rising interest in the development of designing Civil Engineering buildings that are able to withstand dynamic loads, in particular, the load caused by earthquakes [1].

The Response Spectrum is a method of estimation of maximum responses which can be in form of acceleration, velocity, and displacement, of a family of SDOF systems subjected to a specific ground motion [2].

1.1 Need for The Study

Customarily, heavy rigid materials such as conventional clay bricks or concrete blocks have been utilized as Infill wall materials. Although, AAC (Autoclaved Aerated Concrete) blocks which are lightweight building materials that provide better insulation and fire resistance and have a low environmental impact, can be used as masonry infill material in buildings [3]. Another reason is the increasing scarcity of clay and the deleterious environmental impact of conventional clay brick.

Most of the studies have focused on conducting experiments on AAC block for the static and dynamic loads, local compression effect, physical properties, structure on plain ground, thermal comfort, and block with an opening; However, very few researchers focused on the effect of seismic loading on completely filled AAC block and Brick infill building [4].

Inventive materials and technical solutions often make this constructive system more economically favorable with respect to the other structural options in terms of cheaper construction, maintenance, and operation [5]. Therefore, studying the comparison between the application and utilization of two materials in seismic prone areas still requires further verification of the anticipated structural performance of RC infilled frames.

2. OBJECTIVE OF THE STUDY

- To understand the effects of different dead loads and other qualities of the infill material towards its

response to the seismic force applied to the RC frame.
- To find out that a green substitute of conventional brick such as AAC blocks can perform better or not under seismic conditions.
- To find out how much cost & materials can be saved by reducing column and beam sizes as a result of lesser axial force and bending moments after comparing two infill materials.

3. METHODOLOGY

For seismic analysis response spectrum method is used and six models are generated as mentioned in table no 1.

Table 1: Model No and Names

Case 1: Brick Infill	Model 1	Brick infill without struts
	Model 2	Brick infill with 230mm wall struts
	Model 3	Brick infill with 230mm & 115 wall struts
Case 2: AAC Infill	Model 4	AAC infill without struts
	Model 5	AAC infill with 230mm wall struts
	Model 6	AAC infill with 230mm & 115 wall struts

Modelling: Preparing 3D models of RC G+6 building in ETABS software.

Analysis: Analyze the model for gravity and seismic loads and their combinations using Response Spectrum Analysis in ETABS.

Infill Analysis: Infill modelling as equivalent diagonal strut and Seismic Analysis of all models for both infill materials.
Design: Designing and detailing of Column and Beam and for achievable economical sections.

Comparison: The result of the analysis for axial force, bending moment, shear force, storey displacements, storey drifts will be studied and compared.

Quantity Survey: Overall cost comparison by determining variation in reinforcement steel and concrete among all six models.

4. CASE DESIGN

Design basis of a hypothetical case of G+6 storey residential building is mentioned in the table below.

Table 2: Design Basis of Hypothetical Case Study

Type of Building	Residential Building
Type of structure	RCC Frame
Typical Storey Height	3m
Depth of Footing	1.50 m
Plinth Height	0.50 m
Plan area	20 m x 16 m
Grade of concrete	M 25
Grade of steel	HYSD Fe 500
Beam size	230 mm x 450 mm
Column size	450 mm x 650 mm
Primary Wall thickness (Brick)	230 mm
Secondary Wall thickness (Brick)	115 mm
Primary Wall thickness (AAC)	230 mm
Secondary Wall thickness (AAC)	100 mm
Density of Brick masonry	20.00 kN/m^3
Density of AAC Block	6.5 kN/m^3
Density of concrete	25 kN/m^3
Yield strength of steel	500 N/m^2
Seismic Zone	3
Type of soil	Type II (Medium soil)

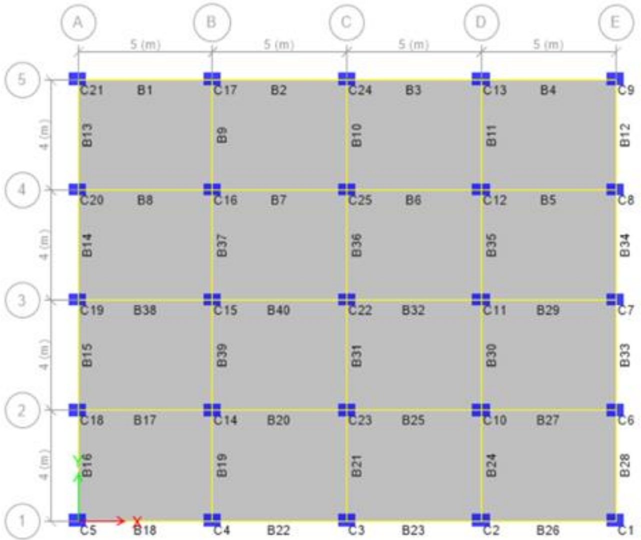

Fig -1: ETABS Model Plan Layout

Structural wall Layouts are prepared for the purpose of analysis and evaluation of this study. (Figure 1,2)

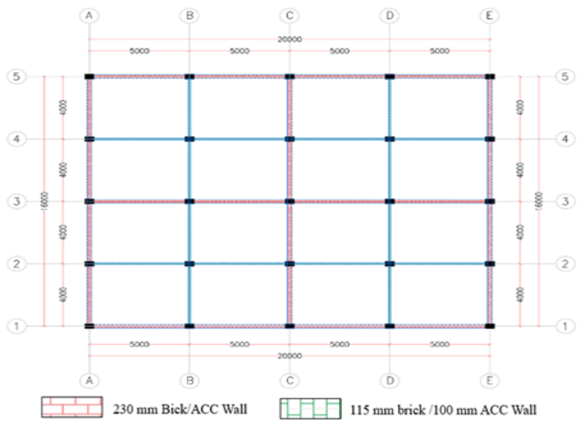

Fig -2: Wall Layout for Typical Floor (Case 1 & 2)

4.1 Infill Wall Modelling

The 'Equivalent Diagonal Strut' method is probably the most popular method for assessment and modelling of infill walls in which the structural system is modelled as a braced frame with infill walls as a web element. Finding the effective width for the equivalent diagonal strut is the main challenge in this method. To determine the increased stiffness of the infilled frame due to strut, the material and geometric properties of the equivalent diagonal strut are necessary [6]. The geometric properties include effective width and thickness of the strut. The thickness and material properties of strut should be same as infill wall [7].

Infill wall modelling in all six models is done by finding strut's width using formula given in (IS 1893 (Part 1), 2016) [8]. Infill wall materials are capable of taking compression load only, so it is necessary to ensure that assigned equivalent diagonal struts also behaves the same.

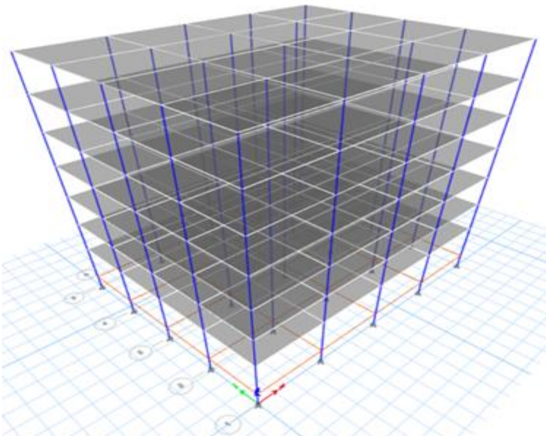

Fig -3: Bare Frame Model (Model 1 & 4)

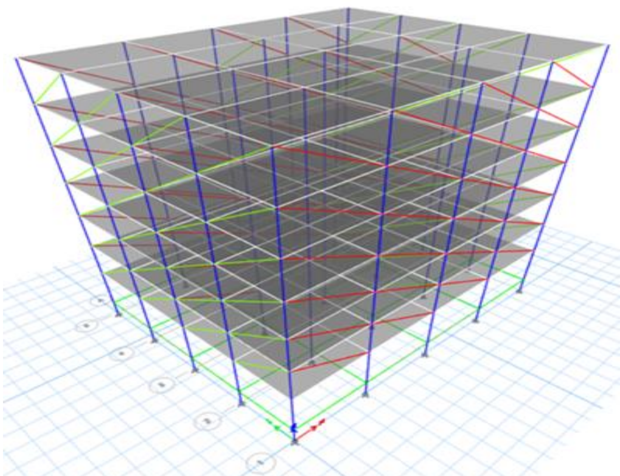

Fig -4: Infill with 230mm Wall Struts (Model 2 & 5)

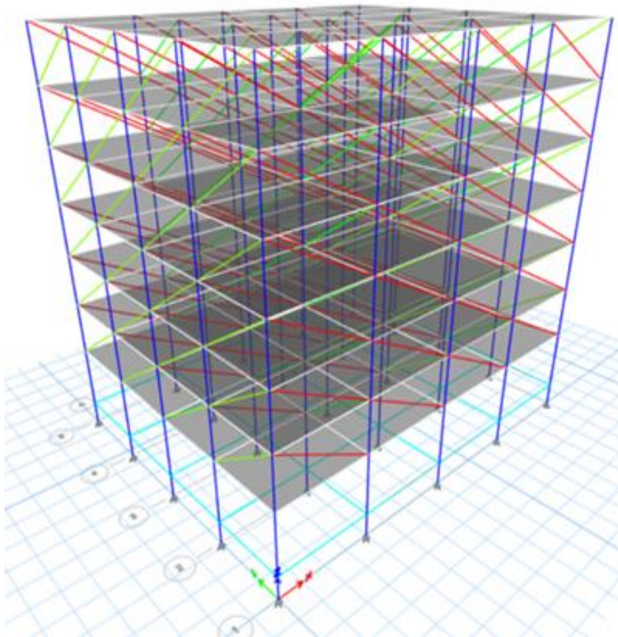

Fig -5: Infill with 230 & 115mm Wall Struts (Model 3 & 6)

4.1 Column and Beam Dimensions

As per IS 1893 (Part-1) Moment of inertia for column (Ieq) is considered as 70% of the Igross of column and for beam (Ieq) is 30% of the Igross of beam. Percentage steel (Pt) in column is restricted to 3% and 1.75% in beams.

Table 3: Final Dimensions of Columns and Beams

Model No	Brick Model	Columns	Beams	
1	Without Strut	450×650	230×500 (TIE + GF)	230×400 Rest
2	230mm wall Strut	400×550	230×500 (TIE + GF)	230×300 Rest
3	230 & 115mm wall Strut	400×550	230×500 (TIE + GF)	230×300 Rest
Model No	**AAC Model**	**Columns**	**Beams**	
4	Without Strut	350×500	230×500 (TIE + GF)	230×350 Rest
5	230mm wall Strut	350×500	230×500 (TIE + GF)	230×300 Rest
6	230 & 115mm wall Strut	350×500	230×500 (TIE + GF)	230×300 Rest

5. RESULTS

After the seismic analysis of all six models in ETABS various results are obtained and based on it some comparative graphs are prepared.

5.1 Storey Displacement and Inter Storey Drift

According to Clause 7.11.1.1 of IS 1893 (Part 1: 2016) maximum allowable storey drift in a building should not exceed 0.004 times (0.4%) of the storey height and here all models satisfy this condition.

Here, the graphs of displacements and drifts caused by RSx are only shown as the graphs of RSy illustrate the same pattern due to the symmetry of the model.

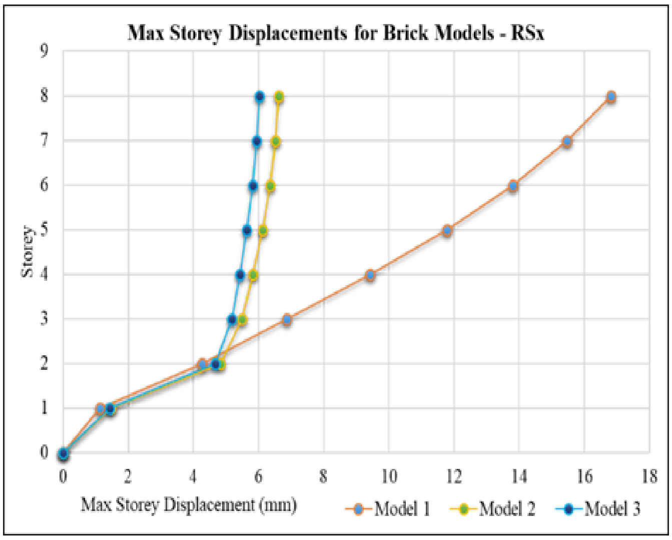

Chart -1: Max Storey Displacements for Brick Models - RSx

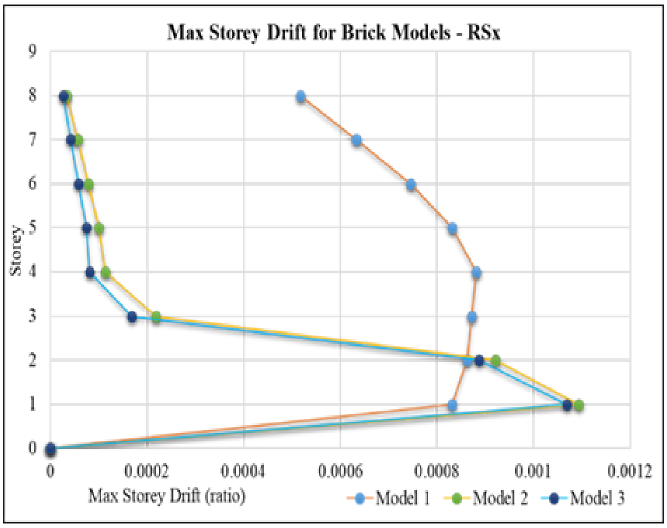

Chart -2: Max Storey Drift for Brick Models - RSx

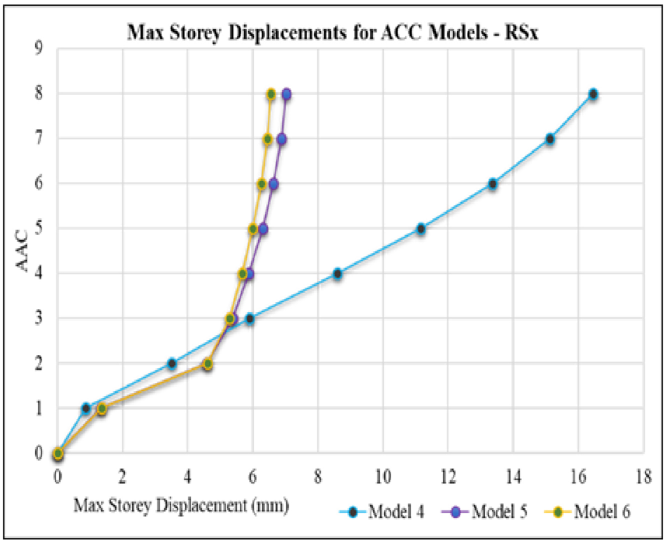

Chart -3: Max Storey Displacements for AAC Models - RSx

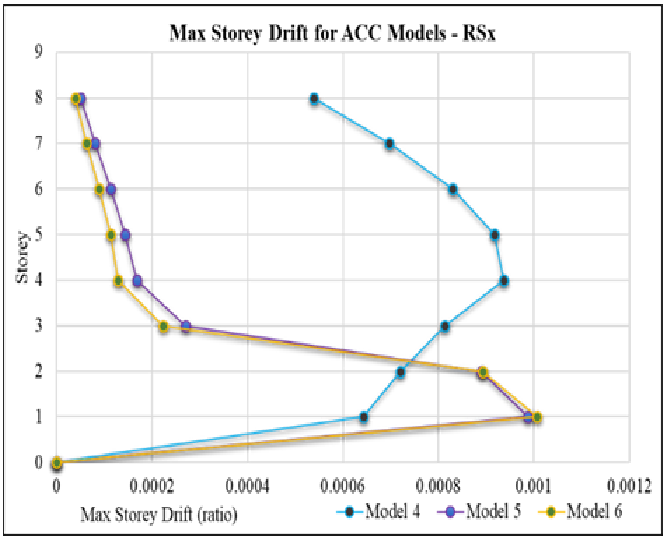

Chart -4: Max Storey Drift for AAC Models - RSx

5.2 Cost Estimation and Comparison

After validating the obtained percentage reinforcement results from ETABS, based on it detailing and quantity estimation in accordance with [9] (IS 456, 2000) and [10] (IS 13920, 1993) is done to determine the conclusion of the study.

Table 4: Cost Estimation and Comparison

Infill	Model No	Concrete m^3	Reinfo MT	Concrete ₹	Reinfo ₹	Total Cost ₹
Brick	1	291.74	63.46	1083404	3,566,452	4,649,856
	2	230.18	52.02	854800	2,923,524	3,778,324
	3	230.18	50.25	854800	2,824,050	3,678,850
AAC	4	216.84	52.74	805261	2,963,988	3,769,249
	5	205.60	46.93	763495	2,637,466	3,400,961
	6	205.60	46.78	763495	2,629,036	3,392,531

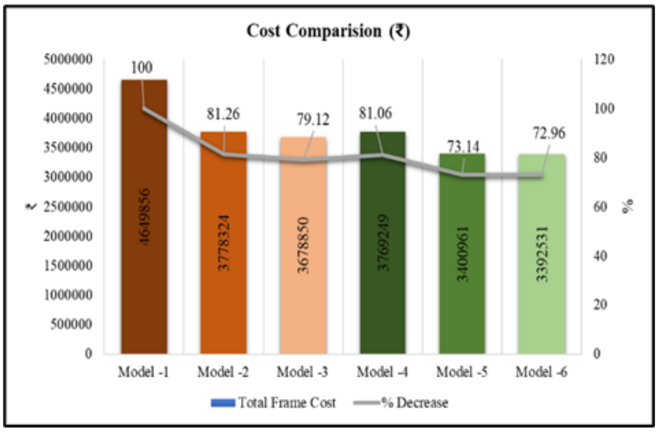

Chart -5: Graph for Cost Comparison

6. CONCLUSIONS

In this study, seismic analysis of six models was carried out using the response spectrum analysis and the equivalent diagonal strut method from which some compelling conclusions are inferred.

1. Significant decrease in Storey displacements and Storey drifts was observed in case of strut models due to increased stiffness of the building. [Refer Chart 1,2,3 & 4]

2. Infill wall modelling and analysis using equivalent diagonal strut method should be performed as the models with struts show lesser bending moments, lesser axial force and lesser shear force compared to bare frame model (with only dead load of wall on beams) evaluated for the same frame sections under similar seismic condition. Hence, it can be said that further economical sections are possible for the same building.

3. Infill modelled as strut materially influences a RC building behaviour under the seismic loading especially in the case of conventional clay brick infill. [Refer Chart 5]
   i. Considering 230mm infill struts → **21.10%** concrete, **18.03%** reinforcement and **18.74%** cost can be conserved in case of **Clay Bricks**.
   ii. Considering 230mm+115mm infill struts → **21.10%** concrete, **20.82%** reinforcement and **20.88%** cost can be conserved in case of **Clay Bricks**.
   iii. Considering 230mm infill struts → **5.19%** concrete, **11.02%** reinforcement and **9.77%** cost can be conserved in case of **ACC Blocks**.
   iv. Considering 230mm+100mm infill struts → **5.19%** concrete, **11.30%** reinforcement and **9.99 %** cost can be conserved in case of **ACC Blocks**.

4. There is not much difference between the results of the only primary modelled wall (230mm) and primary modelled with the secondary wall (115/100mm) models. Hence, to avoid complexity in modelling and for time-saving modelling of secondary walls can be omitted.

5. Building with infill wall modelling and soft storey on the ground floor shows greater moments and shear forces in columns and beams of the 1st floor due to sudden stiffness change. Hence, it is concluded from this study that when the effect of infill walls is neglected the column and beams of the 1st floor in such case are to be designed for 1.5 times the storey shears and moments calculated under seismic loading.

6. ACC blocks that are Lightweight, Earthquake resistant, Environment friendly, Faster in construction, Superior fire resistance and thermal insulation should be preferred as a green substitute of conventional clay brick due to following reasons.
   i. Without considering infill struts → **25.67%** concrete, **16.89%** reinforcement and **18.94%** cost can be conserved by adopting AAC.
   ii. Considering 230mm infill struts → **10.68%** concrete, **9.78%** reinforcement and **9.99%** cost can be conserved by adopting AAC.
   iii. Considering 230mm+115/100mm infill struts → **10.68%** concrete, **6.91%** reinforcement and **7.78%** cost can be conserved by adopting AAC.

REFERENCES

[1] Pankaj Agarwal and M. Shrikhande, Seismic Retrofitting Strategies of Reinforced Concrete Buildings. 2007.

[2] T. Kim, O. S. Kwon, and J. Song, "Clustering-based adaptive ground motion selection algorithm for efficient estimation of structural fragilities," Earthq. Eng. Struct. Dyn., vol. 50, no. 6, pp. 1755–1776, 2020, doi: 10.1002/eqe.3418.

[3] P. Nayakar, "A Comparative Study Of The Effect Of Infill Walls On Seismic Performance Of Reinforced Concrete Buildings," Int. J. Curr. Eng. Sci. Res., vol. 5, no. 1, pp. 5–6, 2018.

[4] H. Thakkar and M. A. Hardiya, "Comparative Study of AAC Block and Brick Infill Building with Soft Storey at Different Floor," Compliance Eng. J., vol. 11, no. 3, pp. 1–9, 2020.

[5] A. A. Costa, A. Penna, and G. Magenes, Seismic performance of Autoclaved Aerated Concrete (AAC) masonry: From experimental testing of the in-plane capacity of walls to building response simulation, vol. 15, no. 1. 2011.

[6] B. Yamuna, "Analysis of Multistoried Building with Masonry infills under Earthquake Loading," Int. J. Innov. Eng. Technol., vol. 6, no. 2, pp. 317–323, 2015.

[7] M. Adnan and A. Kumar, "Earthquake Resistance Design Of Open Ground Story Building," Int. Res. J. Eng. Technol., vol. 06, no. 03, pp. 4459–4464, 2019.

[8] IS 1893 (Part 1), "Criteria for earthquake resistant design of structures (Part 1)," Bur. Indian Stand., vol. 1893, no. December, 2016.

[9] IS 456, "PLAIN AND REINFORCED CONCRETE CODE OF PRACTICE," Bur. Indian Stand. Dehli, pp. 1–114, 2000.

[10] IS 13920, "Ductile Detailing Of Reinforced Concrete Structures Subjected To Seismic Forces -Code Of Practice," Bur. Indian Stand., 1993.