Comparative Study of RC Structures with Different Types of Infill Walls with Effect of SSI by Pushover Analysis

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Abstract - *Brick is the most frequently used material for building construction. In India it is common practice to construct reinforced concrete buildings with unreinforced infill. Infill panels have traditionally been made of heavy rigid materials such as red bricks or concrete blocks. Now in India more light weight and flexible infill materials such as light weight bricks (AAC) or hollow blocks are to be used as masonry infill material in reinforced concrete buildings. On the performance of RC buildings, it has been recognized that infill materials have significant effect.*

In the present study an effort is made to study the behavior of RC frame structure using conventional bricks, CC blocks, hollow blocks and light weight bricks infill. Linear static and non-linear static pushover analysis has been carried out for fixed and flexible support in different types of soil condition, to know the effect of earthquake loading. The various results such as base shear, top storey displacement, natural period and pushover results are compared to know the suitable infill material in seismic prone zones. From the results obtained the light weight brick system gives better performance than the other infill materials.

***Key Words*: Fixed support structure, flexible support structure, linear analysis, Pushover analysis, Soil Structure Interaction.**

1. INTRODUCTION

In present construction the reinforced cement concrete is most widely used material in the world. A bare frame of R.C. buildings consist of many horizontal components and vertical components. Horizontal components such as beams and slabs and vertical components such as columns and walls which are under side of slabs. All these components which are cast at a time called monolithic and this type of construction is known as monolithic R.C. frame building or each component might a chance to be casted apart and gathered at the site is known as pre cast R.C. frame structures.

The opposition of the lateral load and gravity load that is dead load and live load which can contributed by the combined action of slab, beams and columns. Satisfactorily ductile property shall be provided for the R.C. structures which are contributed at the earthquake zones or they ought to at least possess the capacity with support specific deformity under that movement for overwhelming staking states.

In vertical plane the walls are constructed with beams and columns at the required locations in structures. The most commonly used brick infill is conventional burnt clay brick masonry. Along with this or combination of light weight bricks such as autoclaved aerated concrete bricks, hollow concrete blocks are also used.

1.1 Conventional Brick Infill Structures

In the world most commonly R.C. building with infill of brick masonry is used including in the region of earthquake zone. Reinforced concrete building with brick infill walls are analyzed and designed as bare frame neglecting strength contribution and infill stiffness. Moreover the infill acts along with the response of the structures infill behaviour is different from that anticipated for building without infill.

The lateral force resisting capacity and stiffness of structure can be increase by infill also up to a same level of response. The structures initial period is decreased because of increased initial stiffness of structures. Infill with brick masonry is verge to brittle failure, for evaluation of seismic. The infill wall modeling should be proper within the structure is beneficial and also to reduce the damage and consequences for proper solution of retrofit.

1.2 Autoclaved Aerated Concrete (AAC) Block Infill Structures

In the present practice of construction the architects, designers and owners prefer the eco-friendly and green building material. Now a day's AAC material is being used as replacement of conventional brick and AAC is most commonly used eco-friendly material. AAC is a light weight, durable, high insulating and load bearing material hence it is said to be eco-friendly material.AAC material improves the construction practice quality and simultaneously cost of construction decreases. The dead load of the structure is reduced by the use of AAC material and which intern decreases the seismic design base shear of the structure.

Today AAC material is revolutionary precast and offers distinctive of high strength and durability, lower in weight unmatched ability and superior features of green ecology. In other part of country the AAC materials is used as replacing ordinary clay bricks and fly ash brick since the material in the state of art green ecological building. The panels and blocks are adopted in all types of walls, internal or external, load bearing and non-load bearing walls etc.

2. MODELING

In the present study, four different types infill materials viz, conventional brick, cement concrete block, hollow block and light weight brick is taken into consideration. The building models with different types infill materials is modeled and analyzed using the computer software ETABS-2009 and the results are compared

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Table -2.1: Analysis Data

Plan Size	20m X 20m
No. Of Storeys	12 No
Storey Height	3.5m
Thickness Of Slab	0.13m
Wall Thickness	0.23m
Column Size	0.6m X 0.6m
Beam Size	0.23m X 0.45m
Grade Of Steel	Fe 415
Grade Of Concrete	M 25
Floor Finish	1kN/m²
Live Load on Floor	3kN/m²
Live Load on Roof	1.5kN/m²
Response Reduction Factor	5
Importance Factor	1
Soil Condition	Medium
Type	II
Zone	IV
Zone Factor	0.24

2.1 Modelling of Infill Wall as a Equivalent Diagonal Strut Member

According to Smith proposal the width of equivalent diagonal strut is given by

Effective width, $w = \frac{1}{2}\sqrt{\alpha_h{}^2 + \alpha_l{}^2}$

Where α_h and α_l are given by

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

Where

W = Width of equivalent strut
E_m = Elastic modulus of material
E_f = Elastic modulus of frame
t = Thickness of infill wall
L = Length of infill wall
I_c = Moment of Inertia of
I_b = Moment of inertia of beam

Calculation of width of Equivalent Diagonal Strut for light weight bright

Beam size = 0.23m X 0.45m
Column size = 0.6m X 0.6m
Young's Modulus of light weight brick = 1840MPa
Young's Modulus of concrete =25000MPa
Moment of Inertia = $\frac{bd^3}{12}$
Moment of Inertia of beam I_b= 0.00175 m^4
Moment of Inertia of column I_c= 0.01080 m^4
$\Theta = \tan^{-1}\frac{(3.5-0.45)}{(5-0.5)} = 34.73°$
$\alpha_h = 3.709$ m
$\alpha_l = 2.668$ m
$w = \frac{1}{2}\sqrt{3.709^2 + 2.668^2} = 2.284$ m

Similarly width of other infill materials are calculated and tabulated as bellow

Table -2.2 Equivalent Diagonal Strut

Type of infill	Concrete Block	Hollow Block	Conventional Brick	Light Weight Brick
Young's Modulus (MPa)	3500	3000	3500	1840
width (m)	1.954	2.022	1.954	2.284

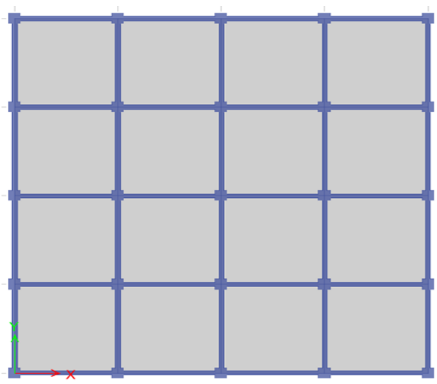

Fig. 2.1 Plan of building.

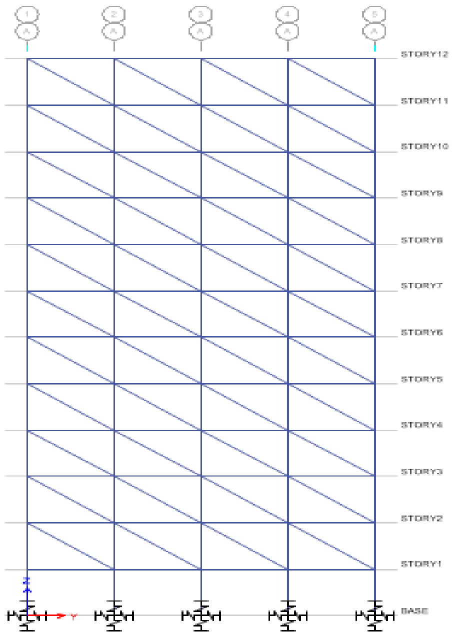

Fig. 2.3 Elevation of flexible support building.

2.2 Soil Structure Interaction

All the buildings which are situated on ground, act like cantilever which is fixed at base and free at top. The soil structure interaction in the present study considered to understand the behaviour of 3D frame structure which is prone to earthquake forces for different types of soil conditions along with different types of infill such as conventional brick, CC blocks, hollow blocks and light weight bricks.

"The process in which the response of the soil media influences the motion of the structure and motion of the structure influences the response of the soil medium is termed as Soil Structure Interaction".

Spring stiffness values are calculated from **FEMA-356 page No. 136** after designing footing.

Table -2.3 Computation of Soil Stiffness from FEMA 356

DOF	Stiffness of foundation at surface
Translation along x - axis	Kx=$\frac{GB}{2-\nu}[3.4(\frac{L}{B})^{0.65}+1.2]$
Translation along y - axis	Ky=$\frac{GB}{2-\nu}[3.4(\frac{L}{B})^{0.65}+0.4(\frac{L}{B})+0.8]$
Translation along z- axis	Kz=$\frac{GB}{1-\nu}[1.55(\frac{L}{B})^{0.75}+0.8]$
Rocking about x - axis	Kxx=$\frac{GB^3}{1-\nu}[0.4(\frac{L}{B})+0.1]$
Rocking about y- axis	Kyy=$\frac{GB^3}{1-\nu}[0.47(\frac{L}{B})^{0.24}+0.034]$
Torsion about z - axis	Kzz=$GB^3[0.53(\frac{L}{B})^{2.45}+0.51]$

Table 2.4 Computation of Soil Stiffness in Medium soil

DOF	Cement Concrete Block	Hollow Block	Conventional Brick	Light Weight Brick
Kx	639024.20	607852	584473	562074
Ky	639024.20	607852	584473	562074
Kz	828701.20	788277	757958	715724
Kxx	2963929.05	2550998	2267828	2028773
Kyy	2572690.42	2214266	1968474	1760975
Kzz	4007232.08	3448949	3066103	2827298

3. RESULTS AND DISCUSSION

The various observations obtained from the analysis of conventional brick, Cement Concrete block, hollow block and light weight brick infill by linear and nonlinear cases with **Soil Structure Interaction.** The observations such as base shear, natural period, and displacement and pushover results are discussed in brief in medium soil.

3.1 Base Shear for medium soil

Table 3.1 Base Shear (kN)

Types of Infill	Elastic Base Shear (kN)	Inelastic Base Shear (kN)
Conventional Brick	2147.54	3547.88
CC Block	2001.88	3423.82
Hollow Block	1859.08	3326.49
Light Weight Brick	1628.36	3190.30

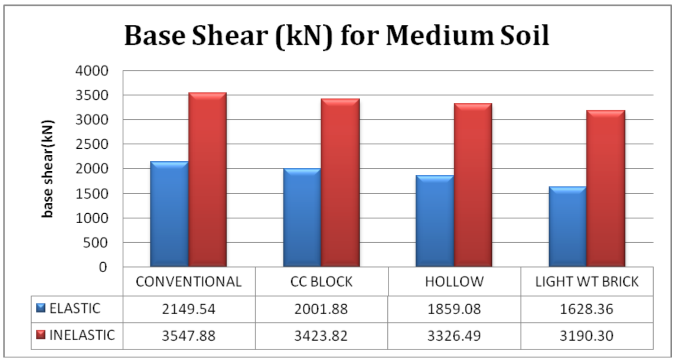

Fig. 3.1 Comparison of Base Shear (kN).

Table no.3.1 shows the elastic and inelastic base shear for different types of infill materials. Fig 3.1 shows the variation of elastic and inelastic base shear. From the above table we can say that the inelastic base shear is more as compared to elastic base shear. The conventional brick infill gives higher value since it is having large mass and stiffness. The light weight brick infill gives lower value since it is having large mass and stiffness

3.2 Natural Period for medium soil

Table 3.2 Natural Period (Sec)

Type Of Infill	Natural Period
Conventional Brick	0.871
CC Block	0.882
Hollow Block	0.890
Light Wt Brick	0.906

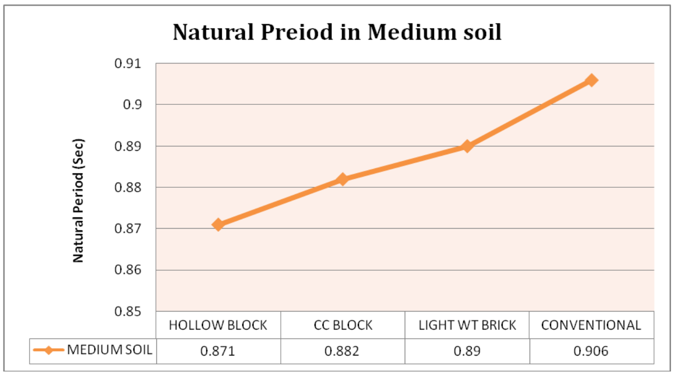

Fig. 3.2 Comparison of Natural Period (Sec).

Table 3.2 shows the natural period value for the first mode that is the fundamental mode of various infill models. Fig 3.2 shows the variation of natural period. From the above results the natural period for the light weight brick model is higher as compared with other infill models, it can be seen from the results that model with conventional brick is stiffer than the model with other infill model. The light weight brick infill model is more flexible than the other infill models.

3.3 Displacement for medium soil

Table 3.3 Displacement (mm) values

Storey	Conventional Brick	Light Weight Brick	Cement Concrete Block	Hollow Block
12	13.2	12.9	12.8	12.6
11	12.5	12.3	12.2	12
10	11.7	11.5	11.4	11.2
9	10.8	10.7	10.5	10.4
8	9.9	9.7	9.6	9.5
7	8.9	8.7	8.6	8.5
6	7.8	7.7	7.6	7.5
5	6.8	6.6	6.6	6.5
4	5.7	5.5	5.6	5.5
3	4.7	4.4	4.6	4.5
2	3.7	3.4	3.6	3.5
1	2.7	2.2	2.6	2.5
base	0.1	0.1	0.1	0.1

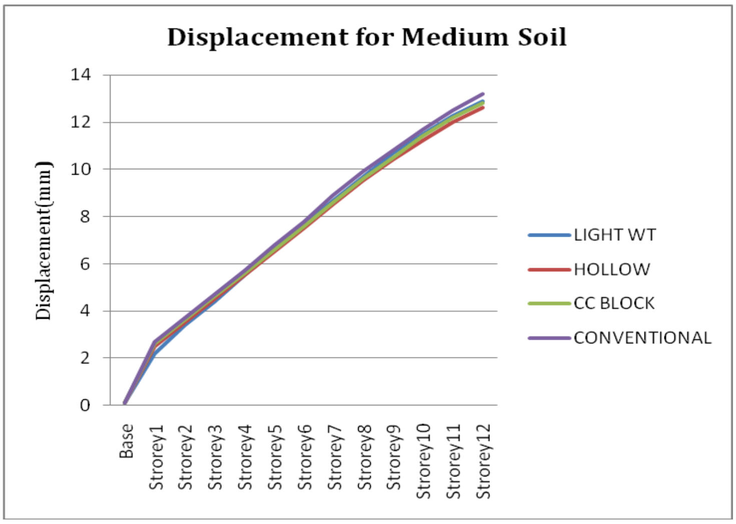

Fig. 3.3 Comparison of Displacement (mm)

Table 3.3 shows the displacement values of different types of infill material. And fig 3.3 gives the comparison plot between conventional brick, light weight brick, CC block and hollow brick infill. Here the conventional brick model gives the larger value as comparing with other type infill model. Since base shear for conventional brick model is more and lateral forces over the structure is more and hence more will be the displacement value as compared with other infill material.

3.4 Nonlinear Static Pushover Results

Table 3.4 Capacity Spectrum parameters in Medium Soil

Parameter	Conventional Bricks	CC Blocks	Hollow Blocks	Light Weight Bricks
Base Shear (kN)	3547.88	3423.8	3326.4	3190.2
Top Roof Displacement (m)	0.373	0.352	0.335	0.306
Spectral Acceleration Sa(m/s)	0.069	0.074	0.078	0.086
Spectral Displacement	0.287	0.270	0.257	0.235

Sd(m)				
Effective Time Period Teff(s)	4.069	3.831	3.633	3.315
Effective Damping	0.161	0.161	0.16	0.159

Table 3.4 shows the nonlinear static pushover results for various infill models by capacity spectrum method in medium soil condition. The inelastic base shear of flexible support in medium soil is lesser than the inelastic base shear of hard soil.

By observing the values in four different infill model the time period goes on decreasing hence spectral acceleration goes on increasing from conventional brick model to light weight brick model. The light weight brick model produces lesser base shear as compared to hollow block, CC block and conventional bricks.

4.6.5 Hinge Results in Medium Soil

Fig 4.3 shows the various hinge formation of flexible support in medium soil during earthquake. From hinge steps observations, the first hinge formation takes place in beams and in column the hinges start to develop as the seismic load goes on increasing. From the theoretical background, the performance of the structure should not go beyond the immediate occupancy level and life safety level of performance.

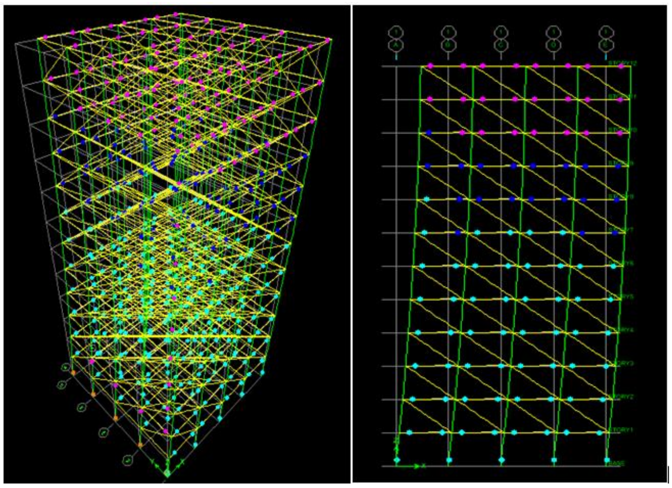

Fig 3.4 Hinge formation in conventional brick model

The various hinge formation of conventional brick model and CC brick model are studied. From the hinge results, the top storeys are having flexural hinges, the middle storeys are having immediate occupancy level hinges and most of the bottom storeys are having life safety hinges. The more life safety hinges are formed in columns of the ground storey because of absence of infill. And very few collapse prevention hinges are formed in columns of bottom storey.

The various hinge formation of hollow block model and light weight brick model are studied. From the hinge results, the top storeys are having flexural hinges, the middle storeys are having immediate occupancy hinges and bottom storeys are having more life safety hinges. It shows that the structure has damaged and before re-occupying it has to be retrofitted.

3. CONCLUSIONS

The present study of analysis makes an effort to understand the effect of brick infill (conventional brick infill, concrete block infill, hollow block infill and light weight brick infill) and SSI on the behaviour of RC structues. The analysis is been carried out using Non-linear analysis, with code specified design responce spectrum, using ETABS. The results of the study lead to the following conclussions.

1) From the observations larger the mass of the structure larger will be the seismic force acting on the structure. Hence the light weight brick model gives the lesser seismic force as compared with hollow block, CC block and conventional brick. Hence it is better to use light weight bricks in seismic prone zones.
2) For conventional brick infill model it has been observed that base shear, lateral forces and storey shear are large as compared with other infill models. Hence design with conventional brick infill is non-conservative.
3) The light weight brick infill model is having significantly smaller base shear as compared with other infill models which results in decrease in reinforcement to resist member forces, hence economy in construction can be achieved.
4) The study shows that the effect of SSI may appreciably influence the natuaral periods as well as base shear of building structure. These are the parameters, which affect the seismic response of the building frames. Thus evaluation of these parameters without conducting SSI cause significant error in seismic design.
5) The study shows that, light weight brick infill gives lesser seismic force as compared with other infills. Therefore using light weight brick infill the seismic design is more conservative as compared with other infill materials.
6) The influence of SSI in general decreases the base shear (increase the natural period) which the influence of brick infill in general increases the base shear (decreases the natural period), hence to some extent they are compensatory and however the influence of brick infill is very predominant.
7) Immediate occupancy hinges are formed in the light weight brick infill as compared with hollow block, CC block and conventional brick infills, hence performance of light weight brick infill is better.

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