Comparative Study of the Effect of Infill Material and Shear Wall on the Structure with Comparison of Seismic Codes

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***Abstract -**. In the present study an effort is made to study the effect of different infill material, shear wall and soft storey on the behavior of RC frame structure and to compare the behavior of the RC frame structure when seismic loads are applied as per the code IS 1893 (part 1) 2002 and IS 1893 (part 1) 2016. In this study G+15 high rise building is modal in ETABS. Seismic zone is zone IV. Response Spectrum Analysis (Linear dynamic analysis) is done using ETABS software. Soil conditions are to be medium and importance factor is to be taken as 1.5 in all the models. For all the models compared with Parameters like base shear, displacement, story drift, stiffness, story shear.*

***Key Words*: ETABS, AAC blocks, Red bricks, Shear wall, Soft story, Equivalent diagonal strut, IS 1893 (part 1) 2002, IS 1893 (part 1) 2016, base shear, displacement, story drift, stiffness, story shear, stiffness modifiers.**

1.INTRODUCTION

The number of people living in urban areas has been increasing rapidly. It is been estimated that by 2050 7 out of 10 people will be living in urban areas. The buildings constructed for this increasing population have to be made taller vertically due to restricted space in urban areas. For construction of high rise structure technological advancement and selection of proper construction material is very important. There are mainly two types of loads acting on tall buildings as gravity loads and lateral loads. Loads are transferred through frames. The network of columns and beams that make up a frame. Infill walls are considered as non structural elements but it is very important to know the behavior of infill panel not only in case of gravity but in lateral loads as well. In India red brick is the most commonly used material for infill panels but now more light weight and eco-friendly material such as AAC blocks are also being used as infill material. It has been recognized that infill materials have significant effect on the performance of building. To design the building properly and to resist the lateral loads on building, shear wall is one of structural member. Shear wall is provided from foundation level to over all height of the structure. As height of the building increases lateral stiffness decreases. When lateral stiffness is low buildings are more vulnerable to wind and earthquake forces. To prevent the structure from the damage of lateral forces like wind and earthquake shear wall is provided as shear wall resist lateral forces and increase lateral stiffness of the structure. With the increasing population there is increase in housing requirement. Due to this construction of high structures became very often. Problem arises when the high rise buildings are not design and constructed properly. With the increase in material cost we need to find more cost saving alternatives to maintain cost of construction which can be affordable to people. Pollution is also increasing day by day so we also have to look for eco-friendly alternatives.

1.1Comparison of Red Bricks & AAC blocks:

AAC blocks are made from fly ash, gypsum, cement, lime and water. AAC block is a green building material which is light weight hence reduces the dead load of the structure. Dry density of AAC block ranges from 5 to 7 KN/m3 where as dry density of red brick ranges from 16 to 20 KN/m3. Compressive strength of AAC block and red brick are 5 N/mm2 and 3.5 N/mm2 respectively. Size of one AAC block is equal to eight red bricks. Currently AAC block are generally used in high rise structures due to its light weight but red bricks are used in all types of constructions from multistory building to low rise buildings. Although red bricks are being used more, AAC blocks can be a viable alternative offering reduction in dead load, cost saving and green building material.

1.2 Shear wall:

Shear wall is a structural member used to resist lateral forces like seismic load & wind load. In high-rise buildings, shear walls are commonly used. Shear wall increases the strength and stiffness of the structure as an part of an earthquake resistant building design. Under earthquake stress, a shear wall lowers lateral displacements. Shear wall also resist shear as well as uplift forces on building. Generally, minimum thickness of shear wall is 150 mm and maximum is up to 400mm in high rise buildings. Shear wall also have energy dissipation capability and also reduces lateral sway. Damages can be minimized in structure by using shear wall.

1.3 Comparison of code IS 1893 (part 1) 2002 and IS 1893 (part 1) 2016:

Table 1.1: Comparison of code IS 1893 (part 1) 2002 and IS 1893 (part 1) 2016

SL. NO	IS 1893 (part 1) 2002	IS 1893 (part 1) 2016
1	Importance Factor (I): For important structures importance factor is 1.5 and for all other structures it is 1.0	Importance Factor (I): For buildings with a capacity of more than 200 persons, whether residential or commercial importance factor 1.2 is included.
2	Moment of inertia (I): Analysis is carried out considering full moment of inertia because clause according to moment of inertia is not mentioned. i.e. Un cracked section is considered.	Moment of inertia (I): Cracked section is considered. For structural analysis, the moment of inertia is calculated as follows: For RC and masonry structures: Moment of inertia is 70% for columns and moment of inertia is 35% for beams.
3	The value of damping For steel: 2% of the critical For reinforced concrete: 5% of the critical	Damping should be selected irrespective of material. The value of damping shall be taken as 5% of critical damping.
4	Criteria for dynamic analysis: a)Regular buildings: Buildings greater than 40 m in height in zones IV and V and buildings greater than 90 m in height in zone IIand III. b) Irregular buildings: All framed buildings higher than 12 m in zones IV and V and those greater than 40 m in height in zones II and III.	Criteria for dynamic analysis: For all the buildings other than regular buildings lower than 15 m in seismic zone II Linear dynamic analysis shall be performed.

2. LIERATURE REVIEW:

Tushar[1]et al [2019] in this paper presented analysis and comparison of structure having infill material as red brick, AAC block& hollow concrete block using ETABS software. In this paper 20 storey high rise building is model in ETABS. Earthquake zone is zone V time history analysis is done. Soil conditions are medium and importance factor taken as 1.2 They found displacement of structure with AAC block in all three modal cases is less than conventional brick masonry.

Shailender[2]et al [2017] paper focuses on behavior and effect of infill in building using different type of infill walls. Four models have been model in ETABS software, first is RCC frame taking infill masonry weight by not considering effect of stiffness. In second model effect of stiffness is considered. In third model weight of infill excluding soft ground story, fourth is weight of infill including soft story. All models perform under static analysis, AAC block give appropriate result as compare to other infill walls.

Gulam Rizwan Gulam Firoz[3]et al [2019] paper presented comparative of building with AAC block and conventional blocks. Analysis done on G+10 RCC building. Two models have been modeled in ETABS software.Model1 is conventional brick infill frame that does not have any openings. Second is RCC building with AAC block as infill material. Base shear, lateral forces and story shear for a structure with AAC block infill is significantly less as compared to brick masonry.

Shahzad[4]et al [2013] In this project ,study of 25 story building in zone V presented with some investigation which is analyzed by changing location of shear wall for determining parameters like storey drift, storey shear and displacement is done by ETABS.

Chethana[5]et al [2018] paper focuses on analysis of regular and irregular buildings with different location of shear wall. ETABS software is used to model the structure. Analysis is carried on G+24 structures of same area. Two models are modeled and shear walls are located in different locations. In regular and irregular buildings 5 each models are created by ETABS.

Vikas[6]et al [2016]Main attention of paper is to compare the behavior of building when applied with seismic load as per the code IS 1893(part1) 2002 and IS 1893 (part1) 2016 and seismic analysis of high rise building G+12 high rise building in ETABS. The loads applied separately based on code IS 1893(part1) 2002 and IS 1893 (part1) 2016 and analysis of structure is done on ETABS than results are compared.

3. METHODOLOGY:

Equivalent diagonal strut is provided in place of infill wall. Equivalent compression strut method is used for infill panel modeling, According to method frame is modeled as truss element and infill wall is modeled as diagonal strut.
Width of diagonal strut is calculated by using IS 1893 (part 1) 2016 formula for both red brick wall and AAC block wall by taking Compressive strength of AAC block and red brick as 5 N/mm2 and 3.5 N/mm2 respectively. Width of diagonal strut for AAC block Wall = 750 mm and Width of diagonal strut for red brick Wall = 770 mm. Dry density of AAC block is taken as 7 KN/m3 where as dry density of red brick is taken as 20 KN/m3.

3.1Geometrical Properties

Table 3.1: Geometrical Properties

S.No.	Structural Part	Dimensions
1	Length in X-direction	45m
2	Length in Y-direction	40m
3	Floor to floor height	3m
4	Bottom story height	3m
5	Wall thickness	230mm
6	Column size	350 X 750 mm
7	Beam size	300 X 450 mm
8	Slab thickness	150 mm
9	Shear wall thickness	230 mm

3.2 Material properties:

Table 3.2: Material properties

S.No.	Material	Grade
1	Concrete	M30
2	Rebar	HYSD 500

3.3 Loading:

A) Dead Load

a) floor finish = 1 kN/ m2

B) Live Load

a) Live load at floors = 3 kN/ m2

b) Live load at roof = 1.5 kN/ m2

3.4 Models:

For seismic analysis response spectrum method (Linear dynamic analysis) is used & six models are generated using ETABS software as mentioned in table no . Width of the strut for red brick is 770 mm and width of the strut for AAC is 750 mm. While analyzing the structure considering IS 1893 (part 1) 2016 stiffness modifiers are applied. Moment of inertia is 70% for columns and moment of inertia is 35% for beams. In analysis of models with IS 1893 (part1) 2002 un cracked section is considered i.e 100% moment of inertia is taken for both columns and beams. Sizes of columns, beams, slabs & shear wall is same in all the models. Seismic zone is zone IV (0.24), soil condition is medium and importance factor is 1.5 for all the models.

Table 3.4: Model Details

S.No.	Model Name	Description	IS Code (For seismic analysis)
1	M-1	Brick infill with wall strut	IS 1893 (part 1) 2016
2	M-2	AAC infill with wall strut	IS 1893 (part 1) 2016
3	M-3	AAC infill with wall strut and soft story at story 9	IS 1893 (part 1) 2016
4	M-4	AAC infill with wall strut ,soft story at story 9 and shear walls are provided	IS 1893 (part 1) 2016
5	M-5	AAC infill with wall strut and soft story at story 9	IS 1893 (part1) 2002
6	M-6	AAC infill with wall strut ,soft story at story 9 and shear walls are provided	IS 1893 (part1) 2002

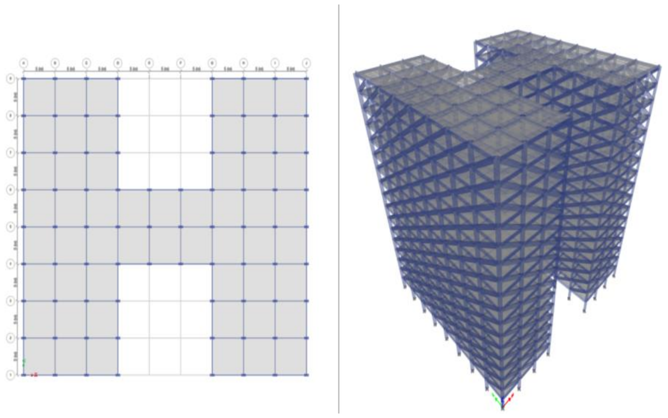

Fig 3.4 (a): Plan and 3D view of Model M-1

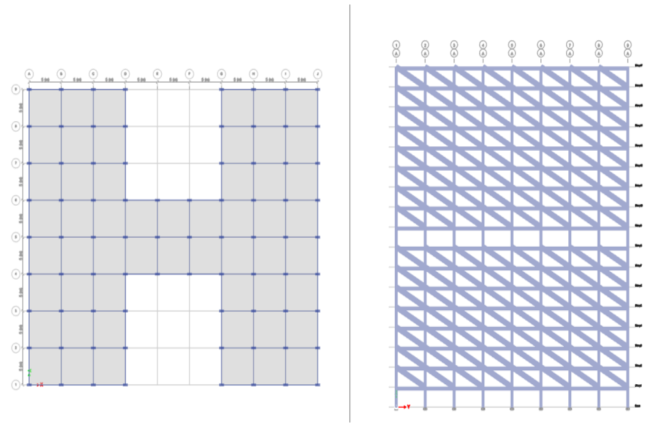

Fig 3.4(b): Plan and Elevation View of model M-3

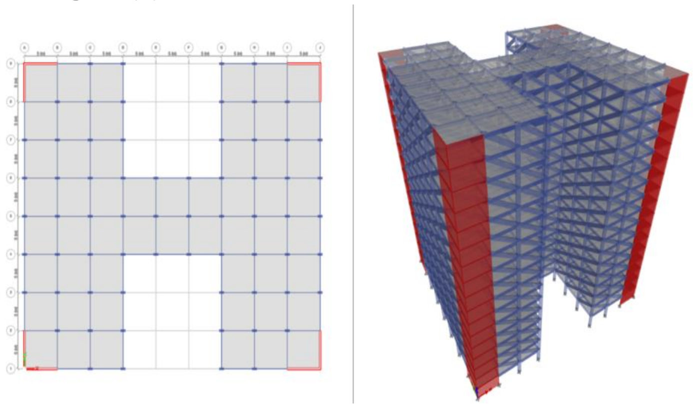

Fig 3.4(c): Plan and 3D view of model M-4

4. RESULTS AND DISCUSSION:

Analysis of "H" shape irregular high rise building is done. In the case of high-rise buildings which are irregular in shape, the response spectrum analysis method is more efficient. During the seismic analysis, data in both the "X" and "Y" directions is employed in response spectrum analysis, resulting in a more accurate and faster evaluation of the structure.

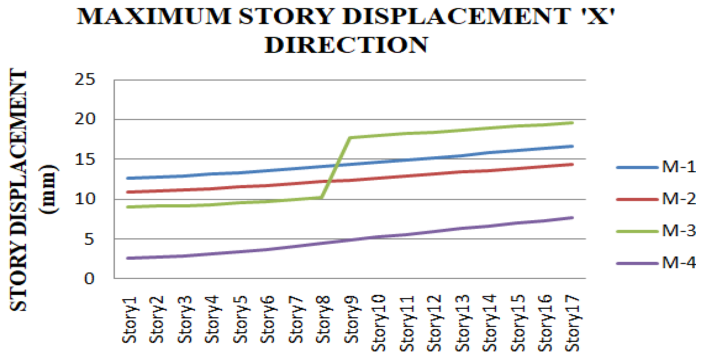

Fig 4.1(a): Maximum story displacement in 'X' direction

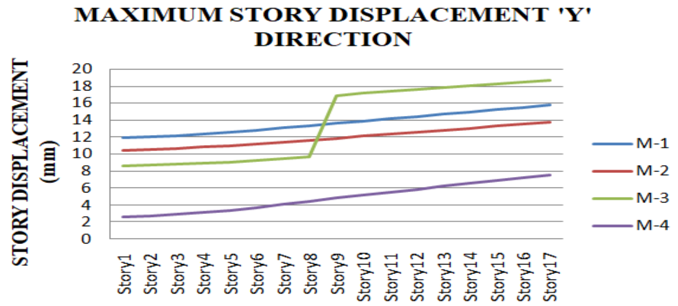

Fig 4.1(b): Maximum story displacement in 'Y' direction

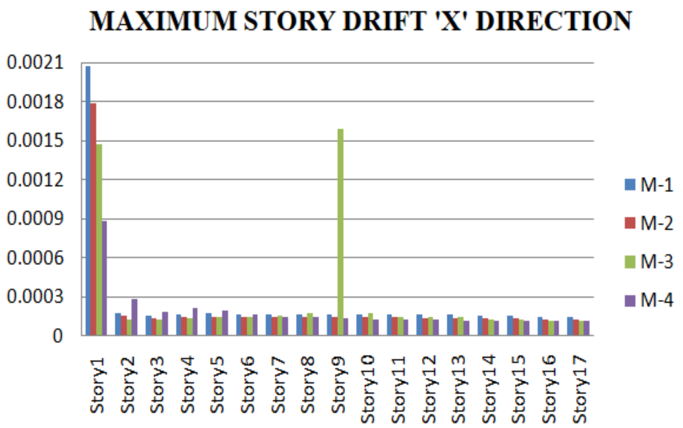

Fig 4.2(a): Maximum story drift in 'X' direction

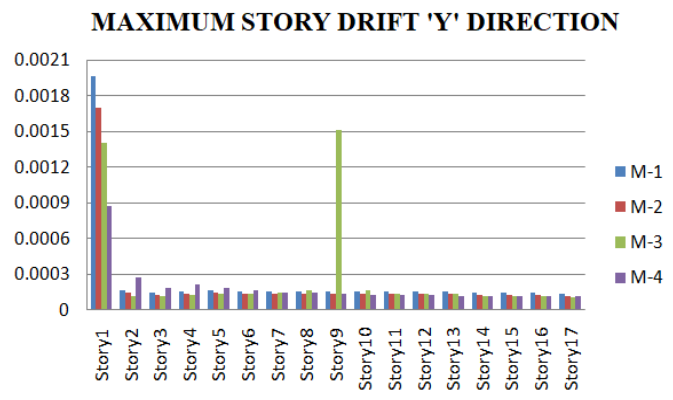

Fig 4.2 (b): Maximum story drift in 'Y' direction

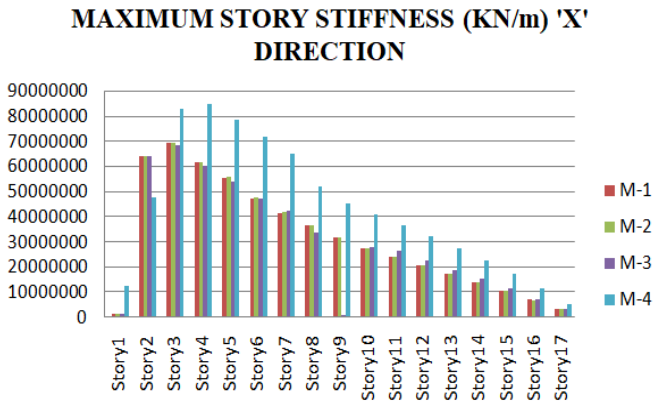

Fig 4.3(a): Maximum story stiffness in 'X' direction

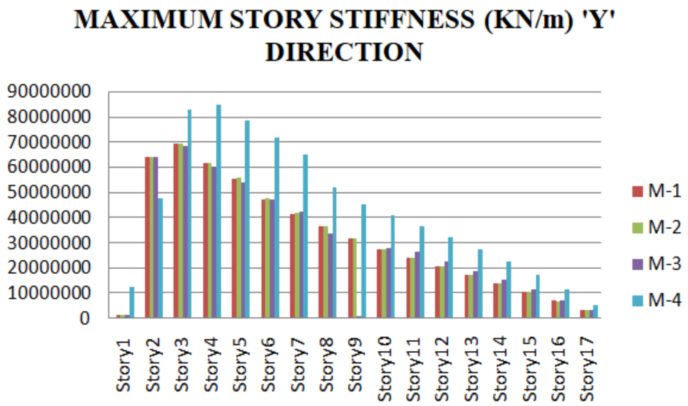

Fig 4.3(b): Maximum story stiffness in 'Y' direction

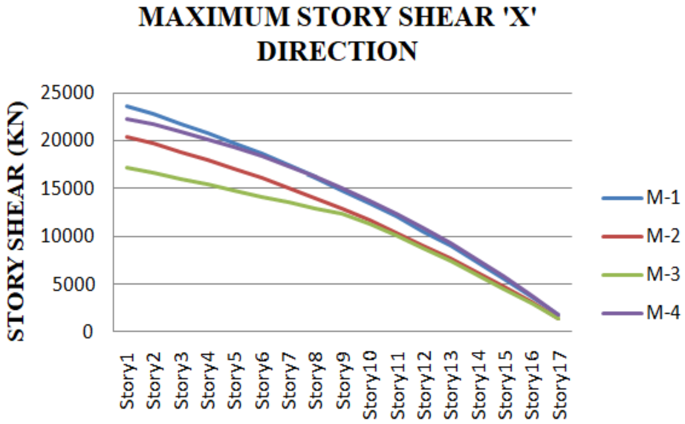

Fig 4.4(a): Maximum story shear in 'X' direction

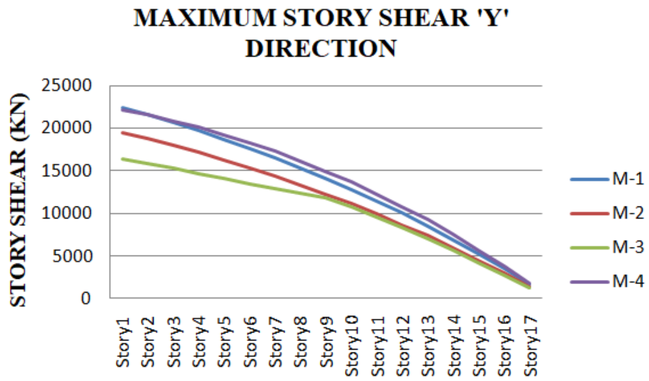

Fig 4.4(b): Maximum story shear in 'Y' direction

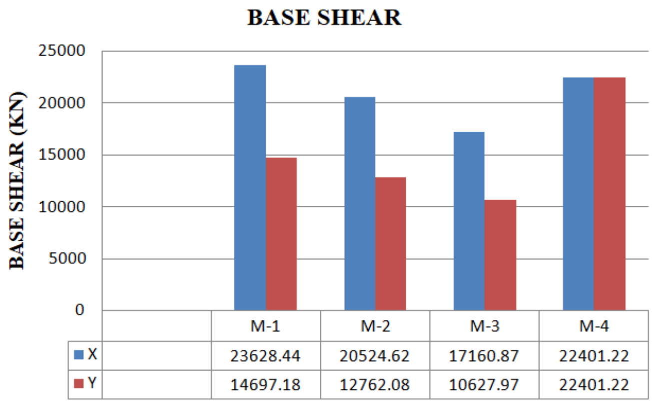

Fig 4.5: Base shear in 'X' and 'Y' directions

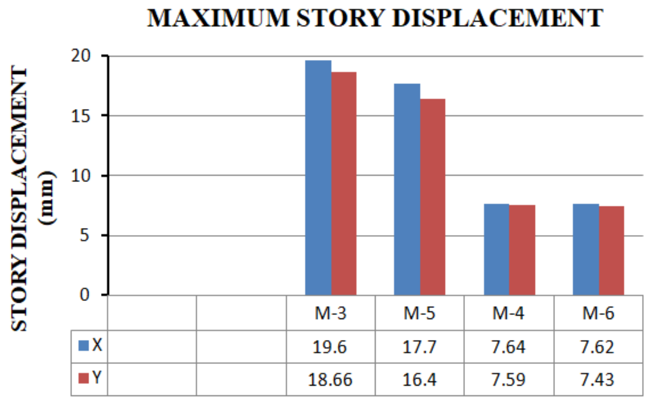

Fig 4.6(a): Maximum story displacement in ‘X’ and ‘Y’ directions

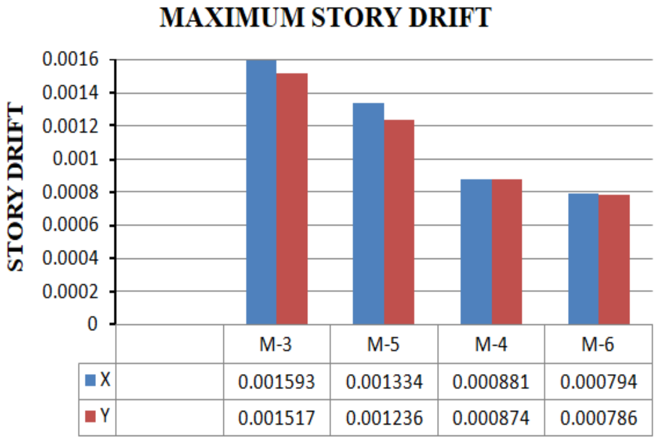

Fig 4.6(b): Maximum story drift in ‘X’ and ‘Y’ directions

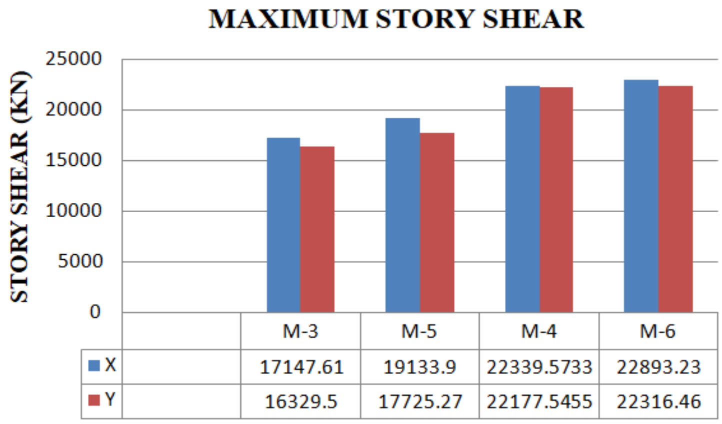

Fig 4.6(c): Maximum story shear in ‘X’ and ‘Y’ directions

4.1 Effect of infill materials:

Model M-1& model M-2 are compared. Model M-1 is with brick infill wall strut and Model M-2 is with AAC infill wall strut.

i. Maximum story displacement of M-1 in X and Y are 16.688 mm and 15.836 mm respectively. Maximum story displacement of M-2 in Both X and Y are reduced to 14.403 mm and 13.742 mm respectively. So displacement in model with AAC infill is less in comparison with model of red brick infill.[refer Fig 4.1(a) & Fig 4.1(b)]

ii. Maximum story drift of M-1 in X and Y are 0.002071 and 0.001965 respectively. Maximum story drift of M-2 in Both X and Y are reduced to 0.001786 and 0.001704 respectively. Which means drift in model with AAC infill is less in comparison with model of red brick infill. As per IS 1893 (part 1) 2016 clause 7.11.1.1 allowable story drift in a building should not exceed 0.4% of the story height and both the models satisfy this condition. [refer Fig 4.2(a) & Fig 4.2 (b)]

iii. Maximum story stiffness of M-1 in both X and Y is 69172904 KN/m. Maximum story stiffness of M-2 in Both X and Y is increased to 69371507 KN/m. So the stiffness in model with AAC infill is more in comparison with model of red brick infill. [refer Fig 4.3(a) & Fig 4.3(b)]

iv. Maximum story shear of M-1 in X and Y are 23593.78 KN and 22390.02 KN respectively. Maximum story shear of M-2 in Both X and Y are decreased to 20411.46 KN and 19474.2 KN respectively. So model with AAC infill attracts lesser shear than model of red brick infill. [refer Fig 4.4(a) & Fig 4.4(b)]

v. Base shear of M-1 in X and Y are 23628.44 KN and 14697.18 KN respectively. Base shear of M-2 in Both X and Y are decreased to 20524.62 KN and 12762.08 KN respectively. So model with AAC infill has lesser base shear value than model of red brick infill. [refer Fig 4.5]

4.2 Effect of soft story:

Model M-2 and M-3 are compared. Model M-2 does not have soft story and there is soft story present at story 9 in Model M-3.

i. At story 9 displacements in both X and Y directions in model M-2 are 12.43 mm and 11.859 mm respectively. At story 9 (soft story) displacement in both X and Y direction in model M-3 are increased to 17.744 mm and 16.897 mm. Maximum story displacement of M-2 in X and Y are 14.403 mm and 13.742 mm respectively. Maximum story displacement of M-3 in Both X and Y are increased to 19.601 mm and 18.665 mm respectively. So at soft story displacement increases considerably and due to soft story maximum story displacement of the building also increases. [refer Fig 4.1(a) & Fig 4.1(b)]

ii. At story 9 drift in both X and Y direction in model M-2 are 0.00014 and 0.000138 respectively. At story 9 (soft story) drift in both X and Y direction in model M-3 are increased to 0.001593 and 0.001517 respectively. So due to soft story drifts increases considerably. Story drifts in both the models are within allowable limits.[refer Fig 4.2(a) & Fig 4.2 (b)]

iii. At story 9 stiffness in M-2 in both X and Y is 31711671 KN/m. At soft story in model M-3 in both X and Y direction is bring down to 987935.1 KN/m. Maximum story stiffness of M-2 in both X and Y is 69371507 KN/m. Maximum story stiffness of M-3 in Both X and Y is decreased to 68392931 KN/m. So at soft story stiffness decreases considerably. The stiffness in model with soft story is less in comparison with model without soft story. [refer Fig 4.3(a) & Fig 4.3(b)]

iv. Maximum story shear of M-2 in X and Y are 20411.46 KN and 19474.2 KN respectively. Maximum story shear of M-3 in Both X and Y are 17147.62 KN and 16329.5 KN respectively. So model M-3 attracts lesser shear than model M-2. [refer Fig 4.4(a) & Fig 4.4(b)]

v. Base shear of M-2 in X and Y are 20524.62 KN and 12762.08 KN respectively. Base shear of M-3 in Both X and Y are 17160.87 KN and 10627.97 KN respectively. So model M-3has lesser base shear value than model M-2. [refer Fig 4.5]

4.3 Effect of shear wall:

Model M-3 and Model M-4 are compared. Soft story is present in both M-3 & M-4 but shear wall is provided in model M-4 and not in model M-3.

i. Maximum story displacement of M-3 in X and Y are 19.601 mm and 18.665 mm respectively. Maximum story displacement of M-4 in Both X and Y are reduced to 7.649 mm and 7.594 mm respectively. So displacement in model with shear wall is significantly less in comparison with model without shear wall. [refer Fig 4.1(a) & Fig 4.1(b)]

ii. Maximum story drift of M-3 in X and Y are 0.001593 and 0.001517 respectively. Maximum story drift of M-4 in Both X and Y are reduced to 0.000881 and 0.000874 respectively. Which means drift in model with shear wall is less in comparison to model without shear wall. Story drifts in both the models are within allowable limits. [refer Fig 4.2(a) & Fig 4.2 (b)]

iii. Maximum story stiffness of M-3 in both X and Y is 68392931 KN/m. Maximum story stiffness of M-4 in Both X and Y is increased to 84672925 KN/m. So the stiffness in model with shear wall is more in comparison to model without shear wall. [refer Fig 4.3(a) & Fig 4.3(b)]

iv. Maximum story shear of M-3 in X and Y are 17147.62 KN and 16329.5 KN respectively. Maximum story shear of M-4 in Both X and Y are 22339.57 KN and 22177.55 KN respectively. So model with shear wall attracts more shear than model without shear wall. [refer Fig 4.4(a) & Fig 4.4(b)]

v. Base shear of M-3 in X and Y are 17160.87 KN and 10627.97 KN respectively. Base shear of M-4 in Both X and Y is 22401.22 KN respectively. So model with shear wall have more base shear value than model without shear wall. [refer Fig 4.5]

4.4 Comparison of IS 1893 (part 1) 2002 & IS 1893 (part 1) 2016:

Model M-3 & model M-5 are compared. In model M-3 seismic analysis is done according to IS 1893 (part 1) 2016 and in model M-5 seismic analysis is done according to IS 1893 (part 1) 2002.

i. Maximum story displacement of M-3 in X and Y are 19.601 mm and 18.665 mm respectively. Maximum story displacement of M-5 in Both X and Y are reduced to 17.7 mm and 16.4 mm respectively. So displacement in model with IS 1893 (part 1) 2016 is more as compared to model with IS 1893 (part 1) 2002.[refer Fig 4.6(a)]

ii. Maximum story drift of M-3 in X and Y are 0.001593 and 0.001517 respectively. Maximum story drift of M-5 in Both X and Y are reduced to 0.001334 and 0.001236 respectively. Which means drift in model with IS 1893 (part 1) 2016 is more when compare to model with IS 1893 (part 1) 2002. Story drifts in both the models are within allowable limits. [refer Fig 4.6(b)]

iii. Maximum story shear of M-3 in X and Y are 17147.61 KN and 16329.5 KN respectively. Maximum story shear of M-5 in Both X and Y are increased to 19133.9 KN and 17725.27 KN respectively. So model with IS 1893 (part 1) 2016 attracts less shear as compared to model with IS 1893 (part 1) 2002.[refer Fig 4.6(c)]

Model M-4 & model M-6 are compared. In model M-4 seismic analysis is done according to IS 1893 (part 1) 2016 and in model M-6 seismic analysis is done according to IS 1893 (part 1) 2002. Shear walls are present in both the models.

i. Maximum story displacement of M-4 in X and Y are 7.64 mm and 7.59 mm respectively. Maximum story displacement of M-6 in Both X and Y are reduced to 7.62 mm and 7.43 mm respectively. So displacement in model with IS 1893 (part 1) 2016 is more as compared to model with IS 1893 (part 1) 2002.[refer Fig 4.6(a)]

ii. Maximum story drift of M-4 in X and Y are 0.000881 and 0.00874 respectively. Maximum story drift of M-6 in Both X and Y are reduced to 0.000794 and 0.000786 respectively. Which means drift in model with IS 1893 (part 1) 2016 is more when compare to model with IS

1893 (part 1) 2002. Story drifts in both the models are within allowable limits. [refer Fig 4.6(b)]

iii. Maximum story shear of M-4 in X and Y are 22339.57 KN and 22177.55 KN respectively. Maximum story shear of M-6 in Both X and Y are increased to 22893.23 KN and 22316.46 KN respectively. So model with IS 1893 (part 1) 2016 attracts less shear as compared to model with IS 1893 (part 1) 2002.[refer Fig 4.6(c)]

5. CONCLUSIONS:

From the obtained results following conclusions can be made:

[1] Displacement in structure with AAC block infill is less compared to structure with red brick infill.

[2] Story drift in structure with AAC block is found less than structure with red brick infill.

[3] Structure with AAC block has more stiffness than that of red brick.

[4] Story shear is less in structure with AAC block is less than structure with red bricks.

[5] Structure with AAC block infill have less base shear value compare to that of red brick. Density of AAC block is less so the dead load is also less which results in lesser base shear and story shear (lateral forces).

[6] So it can be concluded that AAC block give better results than conventional bricks. Especially in earthquake prone areas AAC blocks can replace red bricks which are widely used in India.

[7] Due to presence of soft story overall displacement of the structure increases because there is sudden increase in the displacement at soft story. At soft story, story drift also increases considerably. There is a sudden decrease in the stiffness at soft story level.

[8] So, in the context of seismic forces, soft story is a weak aspect. A sudden variation in stiffness characteristics could be the source vulnerability. These differences are unfavorable for the structure.

[9] Shear wall reduces the story drift and displacement of the structure significantly. Shear wall also reduces the effect of soft story on the structure.

[10] Stiffness of the structure also increases considerably due to shear wall. Due to shear wall mass of the structure increases which results in the increase in base shear value.

[11] It can be concluded that shear wall is very significant in high rise structure for resisting the seismic forces that are coming on the structure.

[12] Displacement and story drift values are increased in the structure with IS 1893 (part 1) 2016 compare to IS 1893 (part 1) 2002. Whereas story shear value is more in structure in which analysis is done according to IS 1893 (part 1) 2002 compare to IS 1893 (part 1) 2016.

[13] When same structures are analyzed but with the presence of shear wall the difference in the values of IS 1893 (part 1) 2016 compare to IS 1893 (part 1) 2002 is less. This is because stiffness modifiers for moment of inertia is only considered for columns and beams and not for shear walls. In other words cracked section is only considered for columns and beams not for shear walls in1893 (part 1) 2016.

[14] In the structure with shear wall, shear wall attracts more forces because it has more stiffness than other structural elements. For more accurate results along with columns and beams stiffness modifiers should also be provided for shear wall.

[15] It can be concluded that with reduction in moment of inertia for column and beam in IS 1893 (part 1) 2016 there is decrease in seismic forces on the structure but it will result in increased displacement and story drift due to increased in flexibility of the structure.

REFERENCES

[1] Tushar Raju[1],Dr Rakesh Patel[2]" Analysis and Comparison of Structure having different infill Material (Red Brick, AAC Block, Hollow Concrete Block) using ETABS software". (Internatinal Journal For Research in Applied Science and Engineering Technology (IJRASET) Volume : 7 Issue : 9 , September 2019)

[2] Prof Omprakash Netula[1], Shailender Pal Singh[2], ER. Rohan Bhomia[3] "Study and Comparison of Structure Having Different Infill Material (Bricks, AAC Blocks and Hollow Concrete Blocks) using ETABS". (International Journal of Engineering Technology Science and Research (IJETSR) Volume 4 Issue 12 December 2017)

[3] Gulam Rizwan Gulam Firoz [1], Prakash Suresh Waghode[2], R.R.Sarode [3] "Comparative Analysis Of G+10 with AAC Blocks and Conventional Blocks"(International Research Journal of Engineering and Technology(IRJET) Volume:06 Issue:04, April 2019)

[4] Chethana[1], Sowmya K B[2] " Study and Analysis of Regular and Irregular Building with Different Shear wall Position using ETABS". (International Research Journal of Engineering and Technology(IRJET) Volume:05 Issue:06, June 2018)

[5] Shahzad Jamil Sardar [1], Umesh N.Karadi[2] " A Review on Performance of Shear wall". (International Journal of Applied Engineering Research Volume : 11 NO.3, 2016)