Effect of Opening On Reinforced Concrete Coupled Shear Wall

Sruthy K S, Dr. C Justine Jose

Abstract - Reinforced concrete shear wall is considered to be an important structural member for high rise buildings. It helps to resist lateral forces in the building like earthquake force, wind load etc. Shear walls are most effective when located along exterior perimeter of the building. Such a layout increases resistance of the building to twisting. But when the wall is provided as an external shear wall there might be doors and windows for functional purposes. So during design of external shear wall effect of such opening in the shear wall must be taken into consideration. The effect of such opening mainly depends on its size. Recently coupled shear walls systems are introduced, these Coupled shear walls are specially designed shear walls which are generally provided in case of shear wall with opening. Here in this project the external shear wall with openings are coupled with steel plates and effect of these coupling on the RC shear wall are analysed under normal working condition and in seismic condition. They were analysed using ANSYS.15. In the analysis both axial loading and seismic loadings were considered. Then the same walls are modelled as steel coupled shear wall, then both the analysis i.e., In axial condition and in seismic conditions were carried out. Considering different openings the effective thickness of steel plates are optimized.

Index Terms -ANSYS, Coupled shear wall, ductility, slits.

1 INTRODUCTION

Reinforced concrete shear walls are one of the structural member in high rise and midrise building in addition to slabs, beams and columns. It is a reinforced concrete wall generally starts from the bottom level or foundation level and extends throughout the height of the building. These shear walls are provided in a building to resist lateral forces acting on buildings such as wind and earthquake forces. Shear walls are highly efficient structural system to resist lateral loads mainly to resist earthquake loads. So shear wall should be properly designed and detailed to ensure the good performance under such loads.

Most RC buildings with shear wall, to carry gravity loads ie due to self-weight and content of the building vertical columns are provided. Shear wall provide large strength and stiffness to buildings in the direction of their orientation, which significantly reduces lateral sway of the building and thereby reduces damages to the structure Also these shear walls must be symmetrically located in plan to reduce ill-effects of twist in building. They could be placed symmetrically along one or both directions in plan. Shear walls are most effective when located along exterior perimeter of the building. Such a layout increases resistance of the building to twisting.

When shear wall is provided along the exterior perimeter there might be door and window openings in the wall. Also during the refurbishment of an existing building may involve cutting out an opening over the wall. So during design of external shear wall effect of such opening in the shear wall must be taken into consideration. It is generally believed that the size of the opening must be small to avoid disruption of force flow. Also structural stiffness and load carrying capacity reduces with introduction of openings in a building. Anyway effect of small opening can often be neglected while a large opening significantly alters the structural system (Seddon 1956b). Since openings considerably reduces the load bearing capacity a measure should be taken to improve the load bearing capacity of the member.

Recently coupled shear walls systems are introduced which sufficiently improves the ductility, energy dissipation capacity and strength of the member. In recent years these steel plate shear walls (SPSWs) are used as an effective dampers to dissipate energy to improve the lateral load resisting system. Traditional SPSWs are composed of unstiffened thin infill steel plates and boundary frames of reinforced concrete beams and columns. The infill plates will buckle under very small shear loads and as the plates are anchored by the boundary beams and columns, the post buckling tension field action of SPSWs can provide considerable stiffness and strength (Thorburn et al.1983). A new type of steel plate shear wall was suggested by providing numerous slits slotted in panels without the need of heavy transverse stiffening (Toko Hitaka 2003). Such a system was proved to be effective to provide good ductile response in steel plate shear wall. Coupled shear walls are specially designed shear walls which are generally provided in case of shear wall with opening.

1.1 Objectives

- To develop finite element model of RC shear wall without opening.
- To develop finite element model RC coupled shear wall with centric and eccentric door and window openings
- To conduct static, modal and response spectrum analysis in the RC coupled shear wall with and without opening.
- To optimize the thickness of coupling plate in RC coupled shear wall for obtaining the full wall capacity.

- *Sruthy.K.S., PG student, M Tech Structural Engineering, Vidya Academy of Science and Technology, Thrissur, Kerala, India, sruthyksaji@gmail.com*
- *Dr. C. Justine Jose, Professor, Department of Civil Engineering, Vidya Academy of Science and Technology, Thrissur, Kerala, India, justin@vidyaacademy.ac.in*

2 METHADOLOGY

From the papers referred a model of shear wall is considered with length 3600mm width 2700mm and thickness of 120mm. A model was validated for reinforced concrete shear wall was designed according to AS 3600 (standards Australia 2009) and EN 1992-1-1 (CEN 2004). And the results were validated by using ANSYS 15.0. By using finite element software ANSYS 15.0 a 3D model was designed and analysed. A control specimen and 16 cases of shear walls with different conventionally used openings and opening locations were designed, in which 8 were door openings and 8 were window opening. Concentric and eccentric opening locations are also considered during the study. For all openings the sill level is fixed at 2100 mm height. The specimens with door opening D1 (800 x 2100) D2 (1000 x 2100) D3 (1200 x 2100) D4 (1800 x 2100) and window opening W1 (500 x 1500) W2 (1000 x 1500) W3 (1500 x 1500) W4 (2000 x 1500) were provided concentrically. And the same walls are provided at an eccentricity of 600mm from the left end of the specimen they are D5, D6, D7, D8 and W5, W6, W7 and W8. Full wall was analysed first to obtain the response of the reinforced concrete shear wall under the given earthquake load.

A steel coupling plate with a seating length 200mm and width 600mm are provided. In order to analyse the static condition a uniformly distributed load is provided at an eccentricity of 50mm at the top of the wall. 10mm diameter bars are provided with 200 mm centre to centre. Also slits having length 336mm and width 2mm used here. Section details are represented in fig1 and reinforcement details are provided below in fig 2

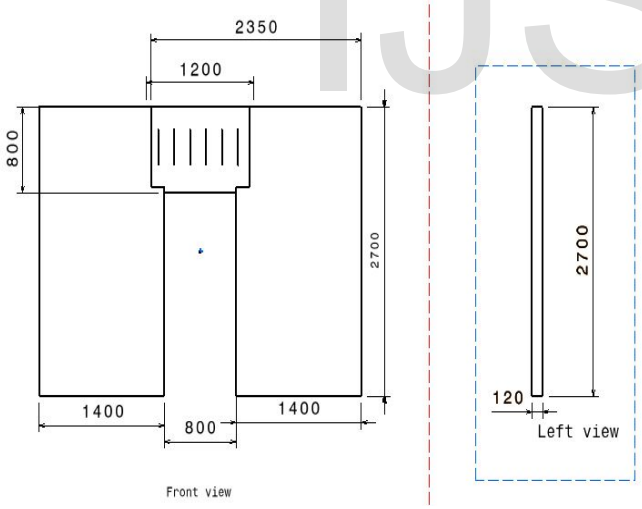


Fig1: front view of coupled shear wall

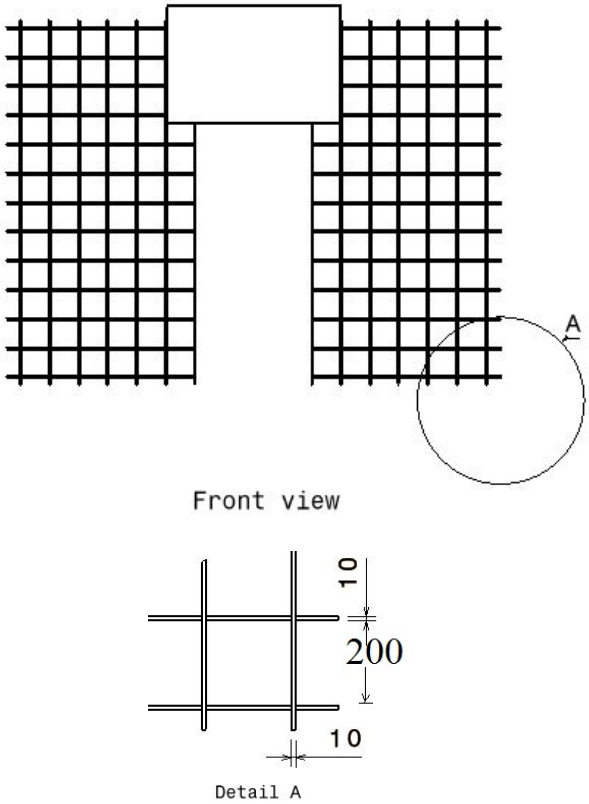


Fig 2 reinforcement details of coupled shear wall

2.1 Material properties

To model coupled shear wall mainly three type of materials were used. They are concrete, steel reinforcement and steel plate. The material properties of the three are listed below in table 1.

TABLE 1
MATERIAL PROPERTIES OF COUPLED SHEAR WALL

Properties	Value
Concrete	
Density	2400 kg/m3
Uniaxial compressive strength	40 MPa
Modulus of elasticity	30000 MPa
Structural steel	
Density	7850 kg/m^3
Poisson's ratio	0.3
Modulus of elasticity	200000 MPa

Yield stress	460 MPa
Steel plate	
Density	7850 kg/m^3
Poisson's ratio	0.3
Modulus of elasticity	200000 MPa
Yield stress	359 MPa

2.2 Thickness optimization

The major objective of the study was concentrated to improve the efficiency of shear wall with opening by providing steel coupling in the wall. By providing such coupling the effect of openings should be nullified. For different sizes of openings the plate thickness will be different. So different cases were considered and the coupling plate thickness corresponding to response spectrum deformation of fully reinforced wall were found out during the study. Modal analysis system were coupled with response spectrum system and the structure was analysed for RS acceleration corresponding to Delhi zone.

3. Results And Discussion

During the research work a fully reinforced concrete shear wall of length 3600mm width 2700mm and thickness 120mm with 10mm diameter reinforcing bars at 200mm center to center spacing is provided and analysed for a RS acceleration along with a vertical load. The response spectrum deformation of the wall was found to be 2mm which was very less indicates that the wall is very rigid under the given boundary conditions.

All the 16 specimens with openings were analysed for the same earthquake load and deformations were obtained. In each of the 16 specimens with steel plate of 600mm width and 200mm seating length Also slits having length 336mm and width 2mm used here. Slits are placed 186mm center to center. the plate thickness was optimized for deformation equal to that of fully reinforced concrete wall.

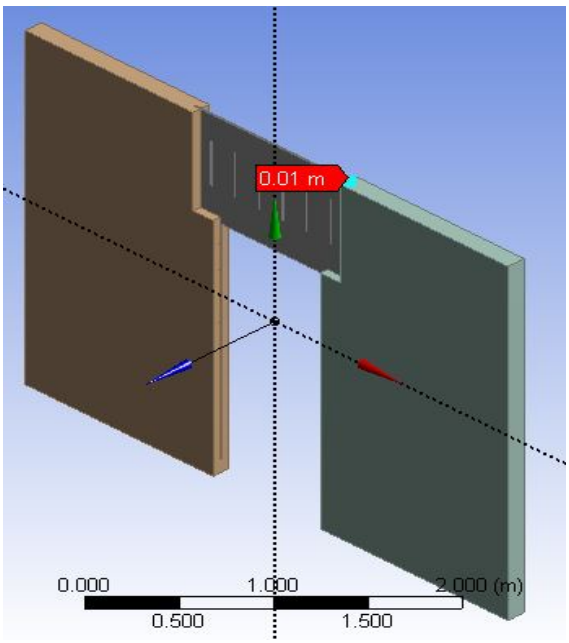
3.1 Design curve

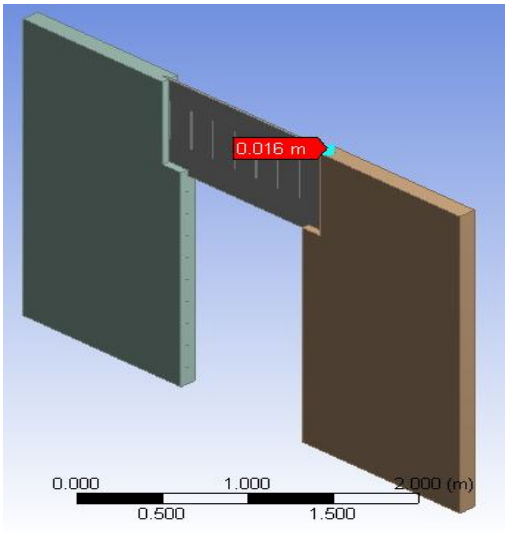
For different openings the thickness of coupled shear wall which actually behaves like a reinforced concrete shear wall was obtained. From the analysis results a curve was obtained. Table 2 below shows various conventional openings and thickness of plate in reinforced concrete shear wall.

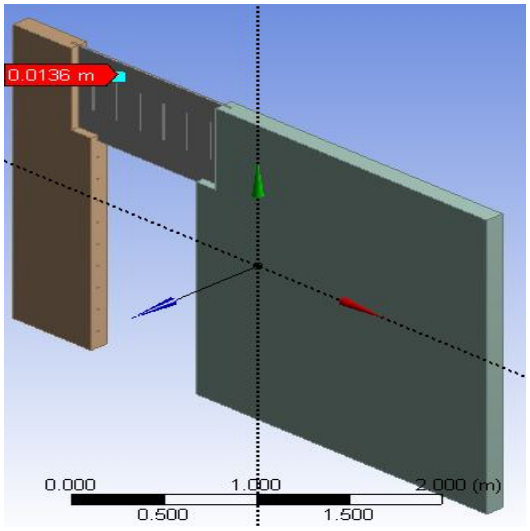
TABLE 2
THICKNESS OF STEEL PATE IN COUPLED SHEAR WALL

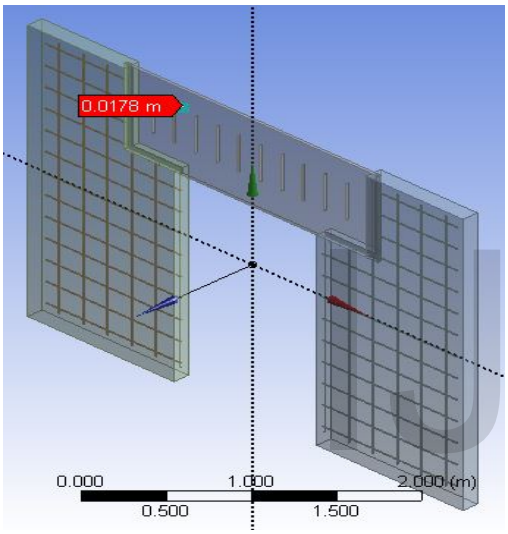
specimen	% opening	Thickness of plate (mm)
Centric opening		
D1(800x2100)	18	10
D2(1000x2100)	22	16
D3(1200x2100)	26	17.8
D4(1800x2100)	39	21.09
W1(500x1500)	8	7
W2(1000x1500)	15	14
W3(1500x1500)	23	16.4
W4(2000x1500)	31	18.1
Eccentric opening		
D5(800x2100)	18	13.6
D6(1000x2100)	22	18.8
D7(1200x2100)	26	20.8
D8(1800x2100)	39	23.1
W5(500x1500)	8	11.6
W6(1000x1500)	15	17.4
W7(1500x1500)	23	19.8
W8(2000x1500)	31	20.5

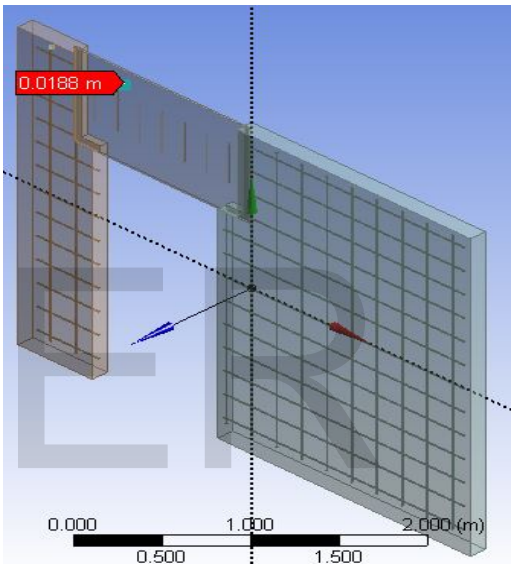
The optimized modal of RC coupled shear wall is given below in fig 3

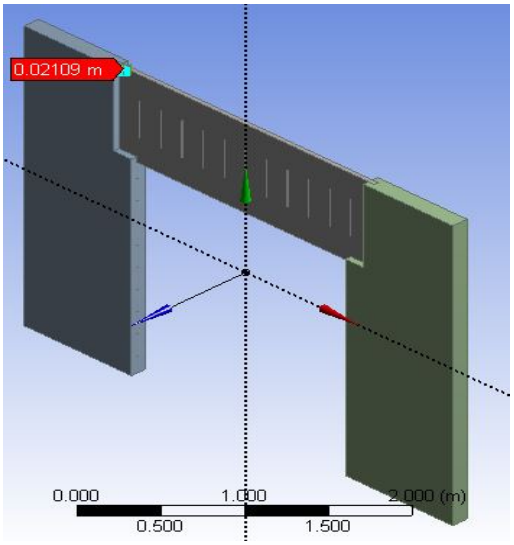


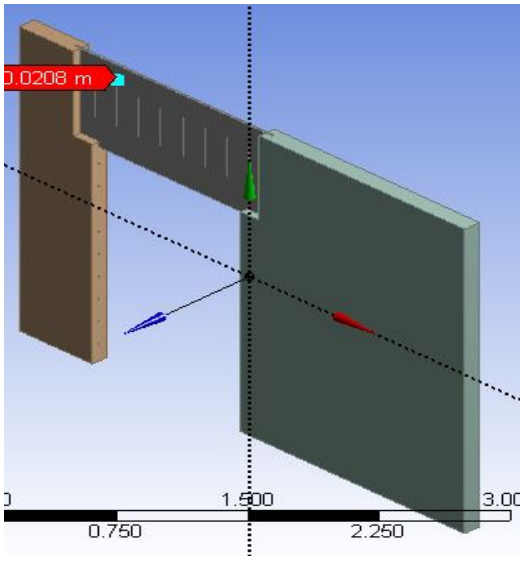

0.016 m
0.000
1.000
2.000 (m)
0.500
1.500

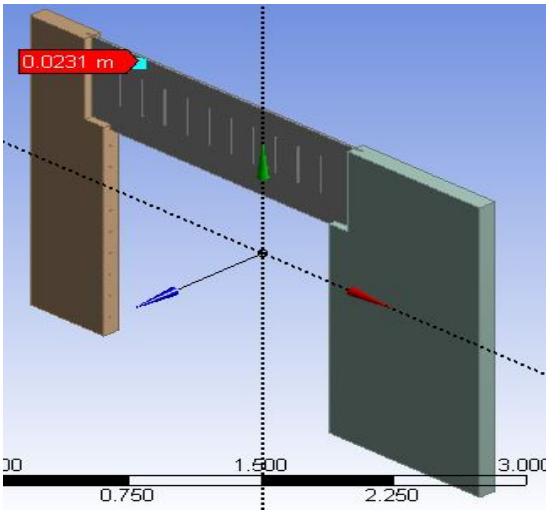

0.0136 m
0.000
1.000
2.000 (m)
0.500
1.500

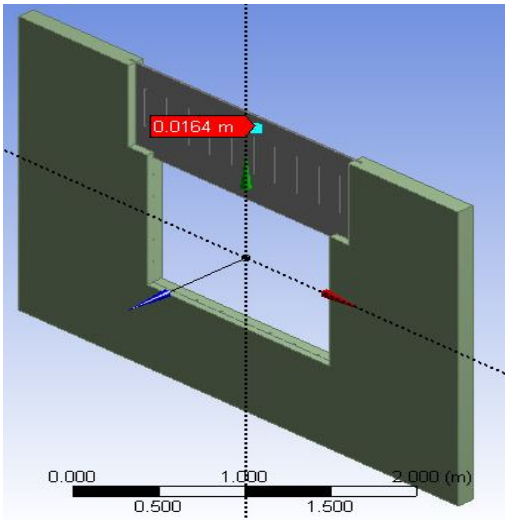

0.0178 m
0.000
1.000
2.000 (m)
0.500
1.500

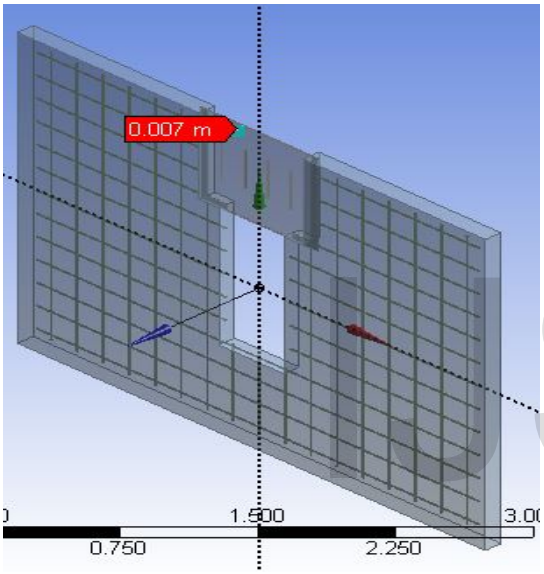

0.0188 m
0.000
1.000
2.000 (m)
0.500
1.500

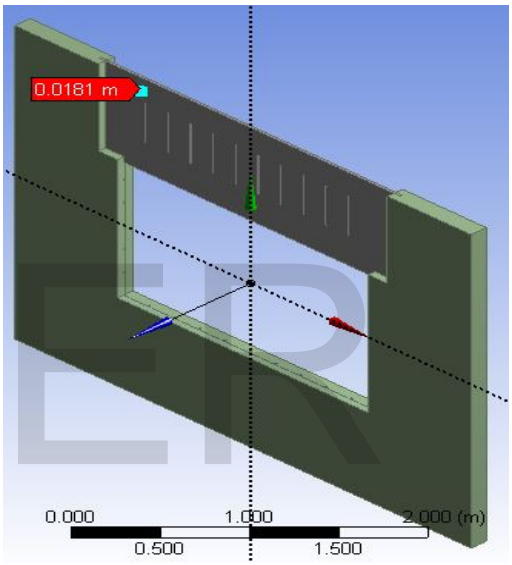

0.02109 m
0.000
1.000
2.000 (m)
0.500
1.500

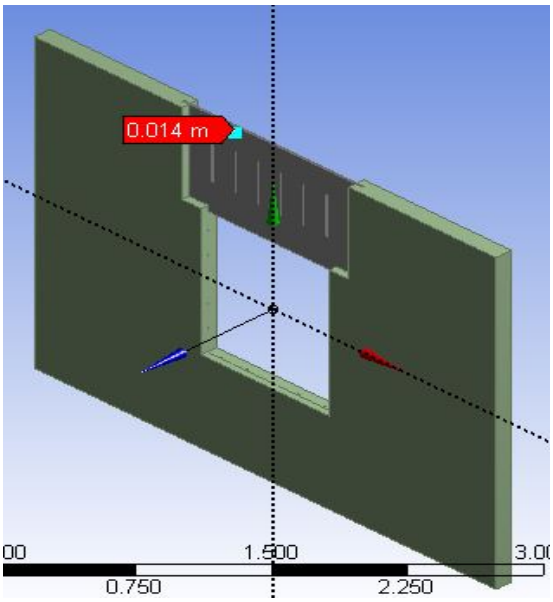

0.0208 m
1.500
3.00
0.750
2.250

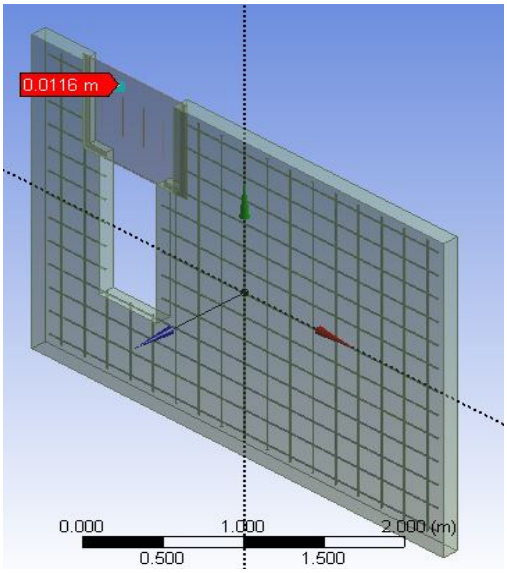

0.0231 m
1.500
3.000
0.750
2.250


0.0164 m
0.000
1.000
2.000 (m)
0.500
1.500


0.007 m
1.500
0.750
2.250


0.0181 m
0.000
1.000
2.000 (m)
0.500
1.500


0.014 m
1.500
0.750
2.250


0.0116 m
0.000
1.000
2.000 (m)
0.500
1.500

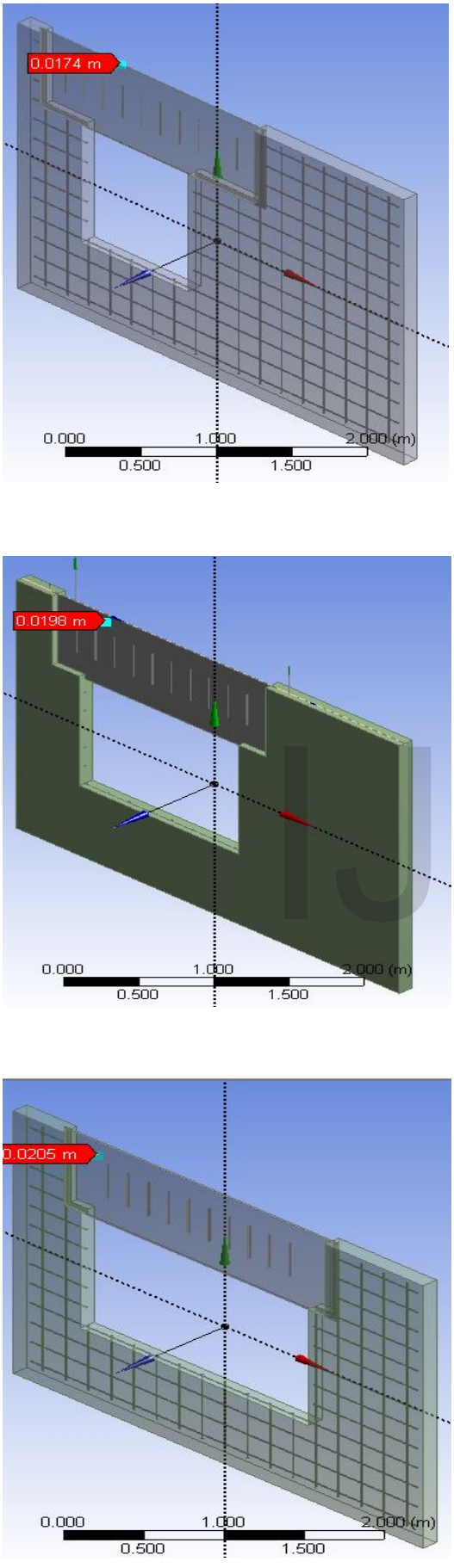


Fig 3 Thickness values of coupled shear wall

A curve can be plotted with percentage opening in the X axis and thickness of plate in the Y axis. The seismic behaviour of doors and windows are different so they should be analysed separately. Also effect of opening location in the shear wall should be taken in to consideration. The design curves obtained is shown in fig 4 and fig 5

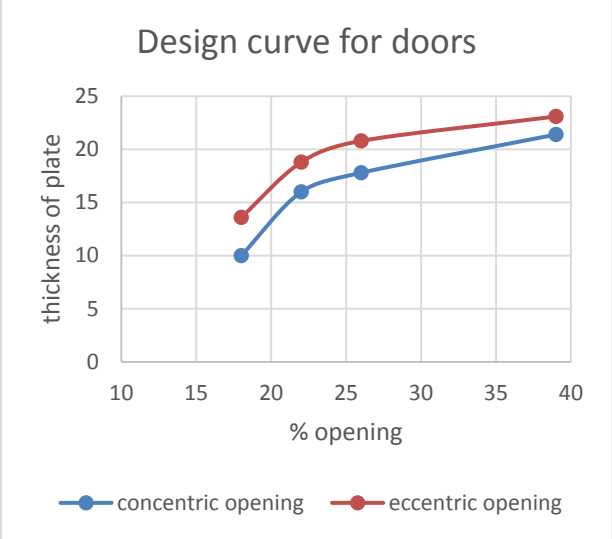


Fig 4 Design curve for doors

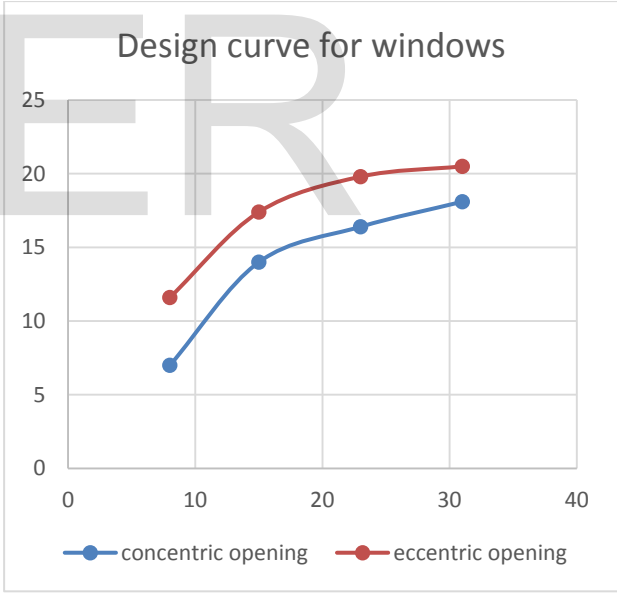
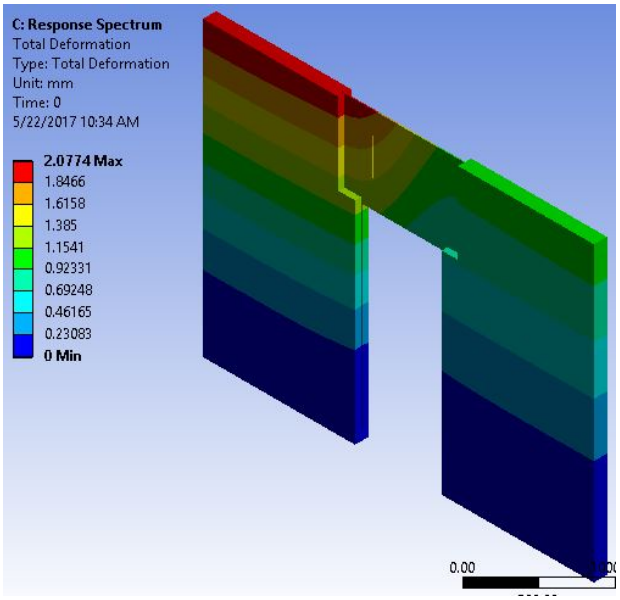
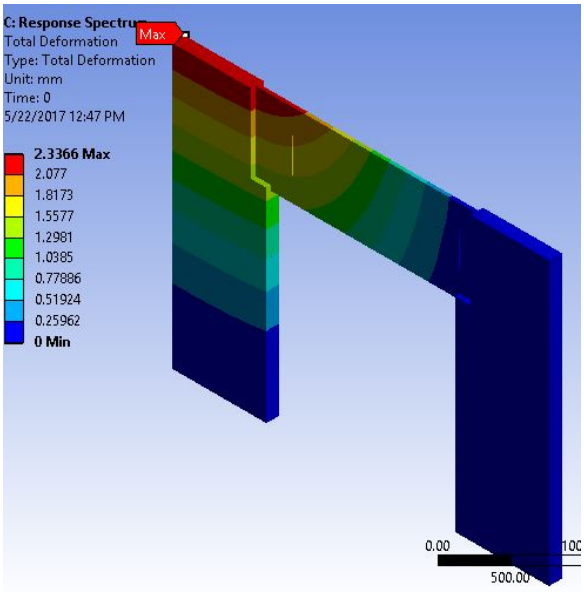
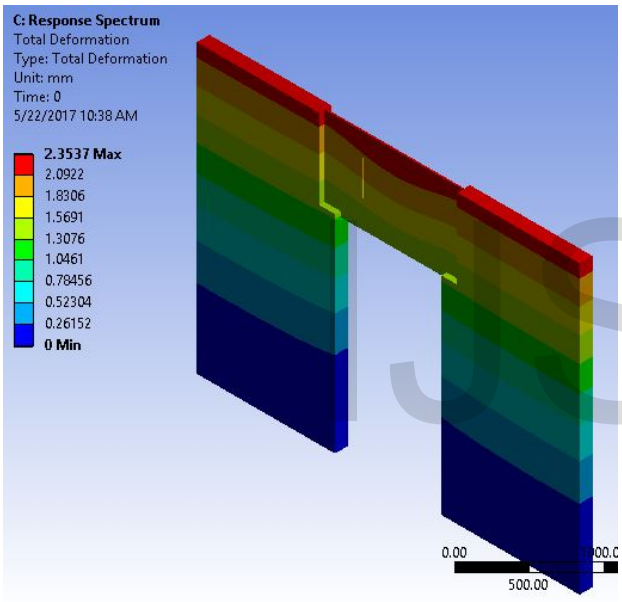


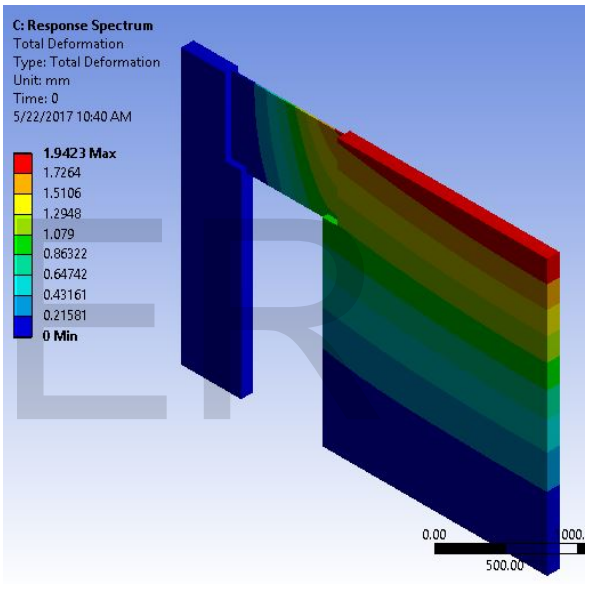
Fig 5 Design curve for doors

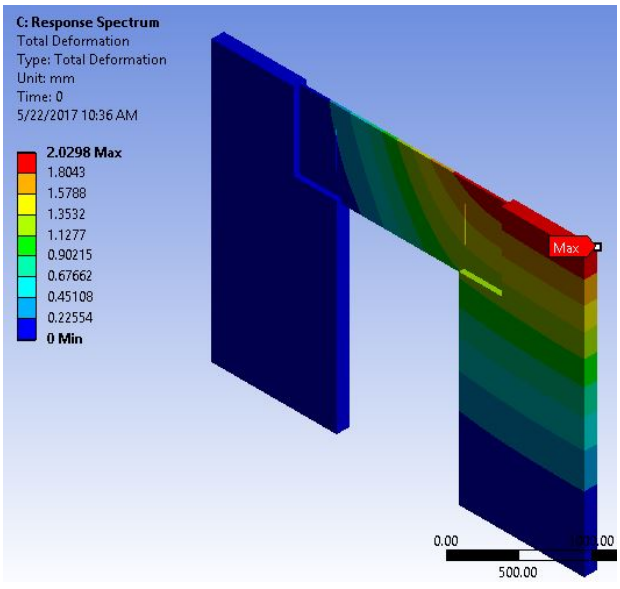
A curve can be plotted with percentage opening in the X axis and thickness of plate in the Y axis. The seismic behaviour of doors and windows are different so they should be analysed separately. Also effect of opening location in the shear wall should be taken in to consideration.

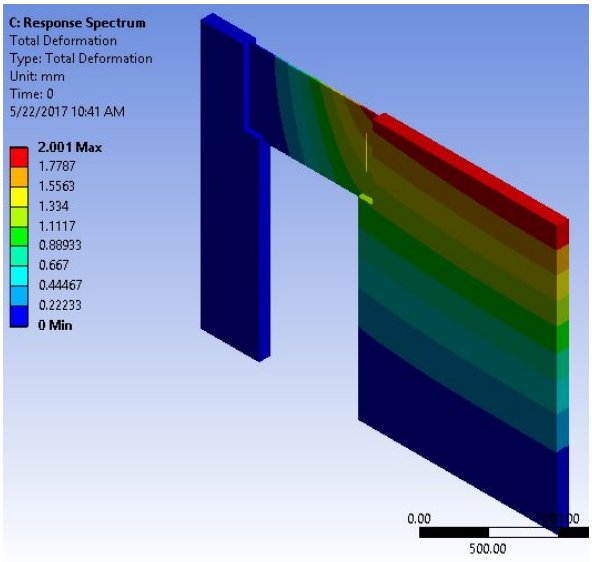

C: Response Spectrum
Total Deformation
Type: Total Deformation
Unit: mm
Time: 0
5/22/2017 10:34 AM
2.0774 Max
1.8466
1.6158
1.385
1.1541
0.92331
0.69248
0.46165
0.23083
0 Min
0.00

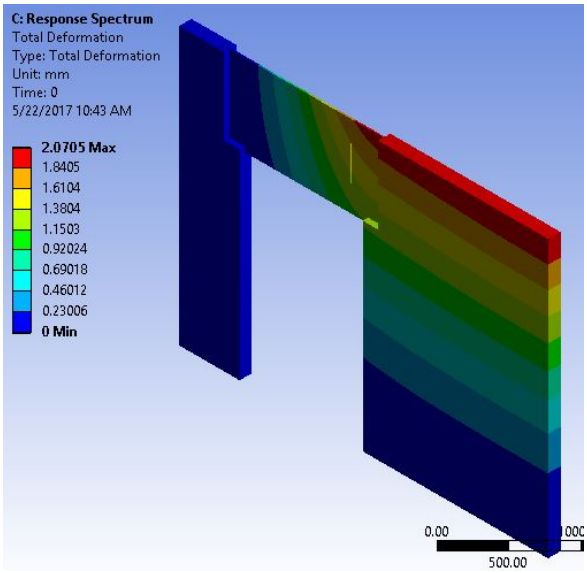

C: Response Spectrum
Total Deformation
Type: Total Deformation
Unit: mm
Time: 0
5/22/2017 12:47 PM
Max
2.3366 Max
2.077
1.8173
1.5577
1.2981
1.0385
0.77886
0.51924
0.25962
0 Min
0.00
500.00

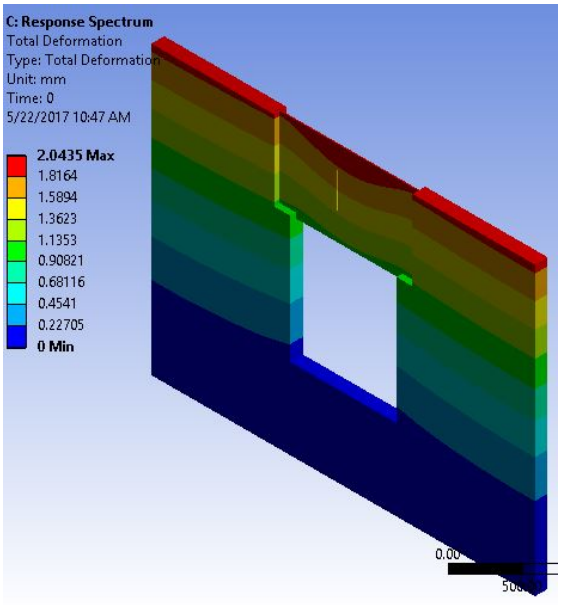

C: Response Spectrum
Total Deformation
Type: Total Deformation
Unit: mm
Time: 0
5/22/2017 10:38 AM
2.3537 Max
2.0922
1.8306
1.5691
1.3076
1.0461
0.78456
0.52304
0.26152
0 Min
0.00
500.00

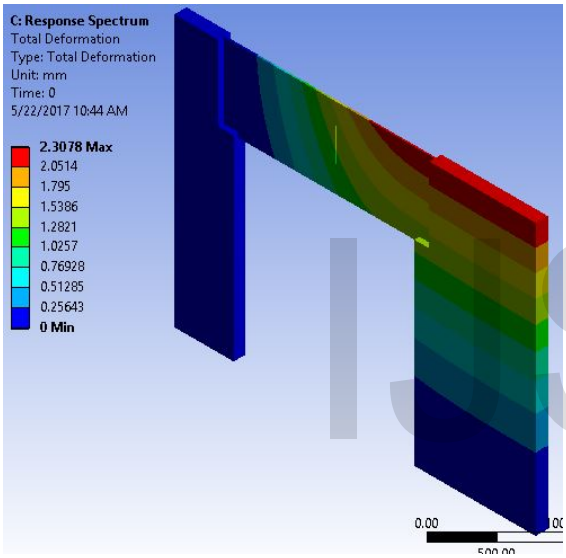

C: Response Spectrum
Total Deformation
Type: Total Deformation
Unit: mm
Time: 0
5/22/2017 10:40 AM
1.9423 Max
1.7264
1.5106
1.2948
1.079
0.86322
0.64742
0.43161
0.21581
0 Min
0.00
500.00

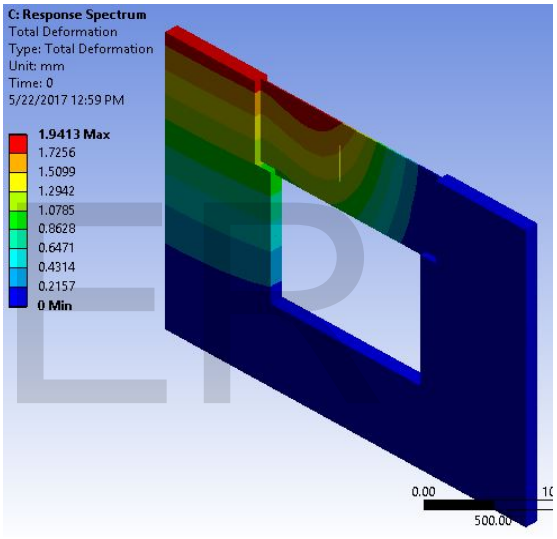

C: Response Spectrum
Total Deformation
Type: Total Deformation
Unit: mm
Time: 0
5/22/2017 10:36 AM
2.0298 Max
1.8043
1.5788
1.3532
1.1277
0.90215
0.67662
0.45108
0.22554
0 Min
Max
0.00
500.00

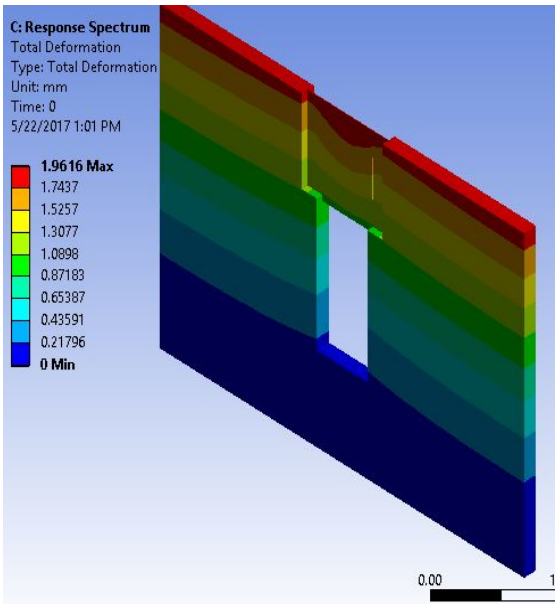

C: Response Spectrum
Total Deformation
Type: Total Deformation
Unit: mm
Time: 0
5/22/2017 10:41 AM
2.001 Max
1.7787
1.5563
1.334
1.1117
0.88933
0.667
0.44467
0.22233
0 Min
0.00
500.00

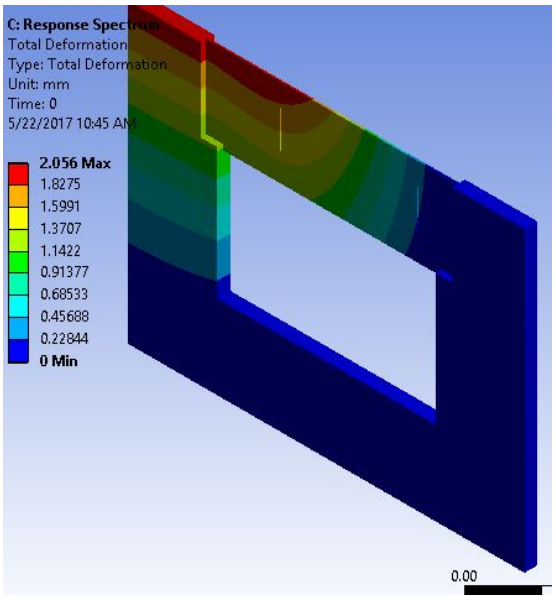

C: Response Spectrum
Total Deformation
Type: Total Deformation
Unit: mm
Time: 0
5/22/2017 10:43 AM
2.0705 Max
1.8405
1.6104
1.3804
1.1503
0.92024
0.69018
0.46012
0.23006
0 Min
0.00
500.00

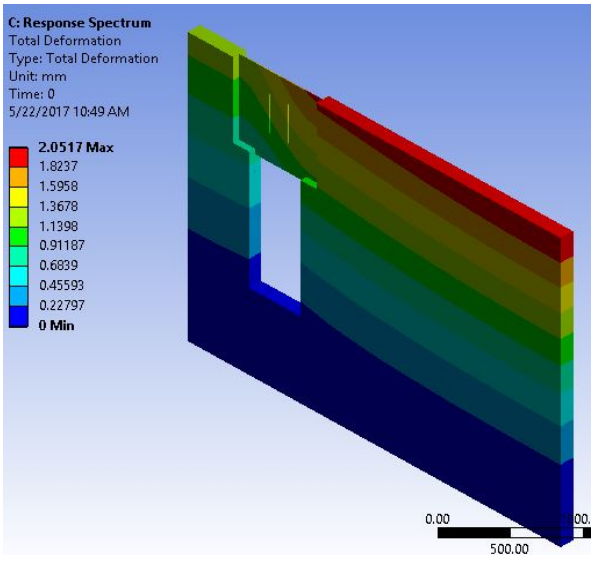

C: Response Spectrum
Total Deformation
Type: Total Deformation
Unit: mm
Time: 0
5/22/2017 10:47 AM
2.0435 Max
1.8164
1.5894
1.3623
1.1353
0.90821
0.68116
0.4541
0.22705
0 Min
0.00

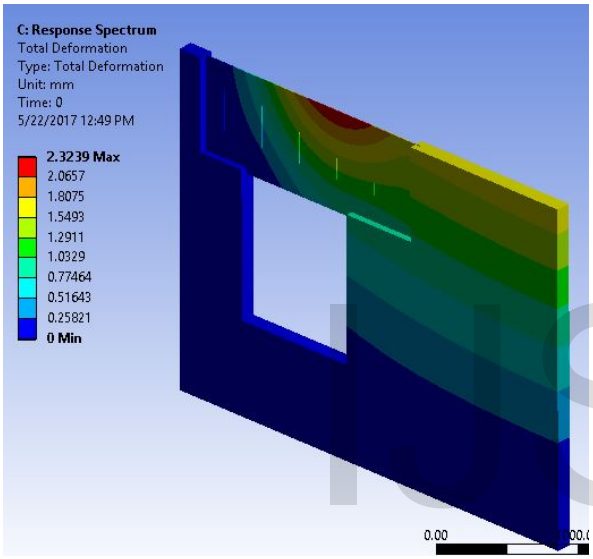

C: Response Spectrum
Total Deformation
Type: Total Deformation
Unit: mm
Time: 0
5/22/2017 10:44 AM
2.3078 Max
2.0514
1.795
1.5386
1.2821
1.0257
0.76928
0.51285
0.25643
0 Min
0.00

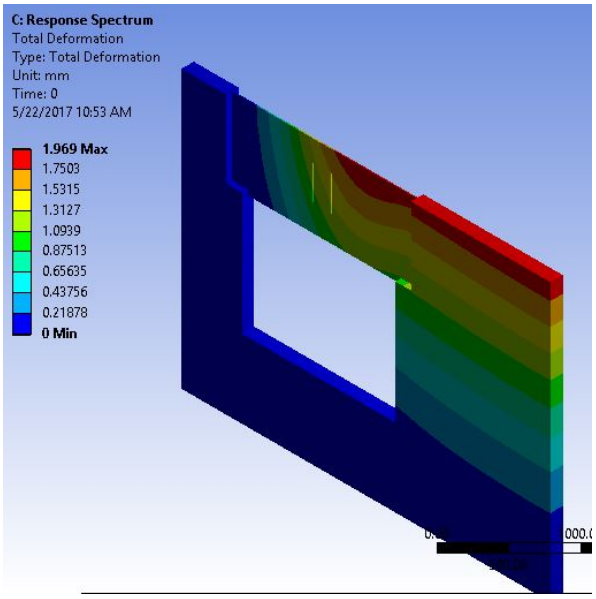

C: Response Spectrum
Total Deformation
Type: Total Deformation
Unit: mm
Time: 0
5/22/2017 12:59 PM
1.9413 Max
1.7256
1.5099
1.2942
1.0785
0.8628
0.6471
0.4314
0.2157
0 Min
0.00
500.00


C: Response Spectrum
Total Deformation
Type: Total Deformation
Unit: mm
Time: 0
5/22/2017 1:01 PM
1.9616 Max
1.7437
1.5257
1.3077
1.0898
0.87183
0.65387
0.43591
0.21796
0 Min
0.00


C: Response Spectrum
Total Deformation
Type: Total Deformation
Unit: mm
Time: 0
5/22/2017 10:45 AM
2.056 Max
1.8275
1.5991
1.3707
1.1422
0.91377
0.68533
0.45688
0.22844
0 Min
0.00







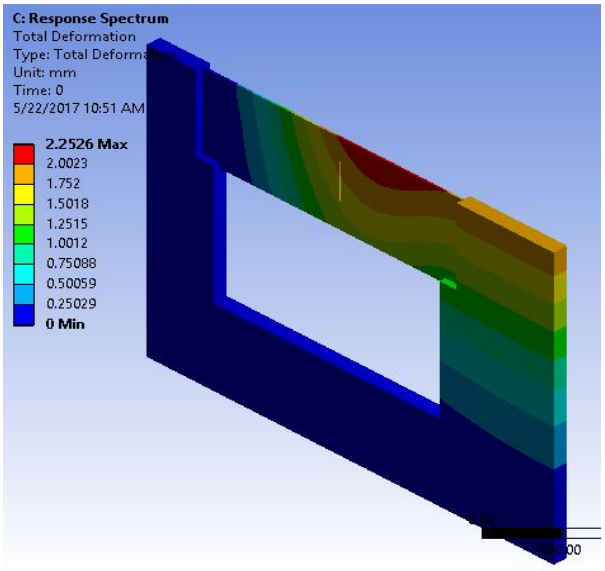


Fig 4 Response spectrum results

4. CONCLUSIONS

The conclusions drawn from this study were,

1. The effect of opening in the shear wall was found to be insignificant, when the opening area is less than 20 %
2. A nonlinear variation is observed with different openings with increase in opening percentage.
3. Dramatic increase in deformation is observed from 15 to 25 percentage in case of door opening.
4. For window opening the increase was somewhat linear, and the thickness is found to be increasing considerably from 8 to 18 % after that the no such considerable increase was found. For the same percentage opening of doors and windows, windows proves to be more safer opening
5. Introducing eccentricity in shear wall increases the responses because reinforced concrete region in the shear wall will be vulnerable to fail. The effect of eccentricity became insignificant when door opening increase more than 35 % and window opening increase more than 30 %
6. Major failure of RC coupled shear wall was found to be failure of reinforced concrete region. In all the specimen the steel plate yielding of steel plate was observed as one of the reason for failure.

4.1 Scope of the work

Although introducing a coupling plate improved the seismic response, the load bearing capacity of the wall get reduced considerably so measures should be taken to improve load carrying capacity during service condition. The method of coupling is found to be useful for improving existing design models. The effect of coupling will be very effective when the steel plate is provided as an infill wall and thereby it can be reduce the thickness of the shear wall. Also the wrapping with FRP can also could improve the response of the coupled shear wall.

REFERENCES

[1] A. Astaneh-ASL, *Steelplate shear wall*, U.S.-Japan Workshop on Seismic Fracture issues in Steel Structures}, Proceedings, U.S.-Japan Partnership for Advanced Steel Structures 2000

[2] A. Neuenhofer, 2006 Lateral stiffness of shear wall with opening, J. Struct. Eng.,ASCE} , 132(11): 1846-1851

[3] Behbahanifard,M.R.,Grondin,G.Y., and Elwi,A.E. 2003. *Experimental and numerical investigation of steel plate shear wall*, Structural Engineering , Dept. of Civil and Environmental Engineering, Univ. of Alberta, Edmonton, AB, Canada, Rep. No. 254

[4] Berman, J., and Bruneau, M. *2003 Plastic analysis and design of steel plate shear walls* J. Struct. Eng},10.1061/(ASCE)0733-9445, 129:11(1448), 1448–1456.

[5] Cosmin Popescu, Gabriel Sas; Cristian Sabău; and Thomas Blanksvärd 2003) Effect *of Cut-Out Openings on the Axial Strength of Concrete waJls.*

[6] Development of probablistic seismic hazard maps of India, Appendix II, PSHA results

[7] Earthquake tips, Learning earthquake design and construction, IITK, building materials and technology promotion council

[8] Toko Hitaka, Andres Jacobsen 2008 *Cyclic test on RC-steel shear plate composite wall system applicable in beam spans with large openings,* International Conference on Composite Construction in Steel and Concrete VI