International Journal of Technical Innovation in Modern Engineering & Science (IJTIMES)
Impact Factor: 5.22 (SJIF-2017), e-ISSN: 2455-2585
Volume 4, Issue 11, November-2018

COMPARISON OF FRAMED SHEAR WALL STRUCTURES WITH OPENING IN SHEAR WALL

Khushbu Tak[1], Mahendra Saini[2]

[1]*M. Tech Scholar, Department of Structural Engineering, Kautilya Institute of Technology & Engineering, Jaipur,*
[2]*Assistant Professor, Department of Civil Engineering, Kautilya Institute of Technology & Engineering, Jaipur,*

***Abstract*— In current scenario of our planet earth population is continuously increases and for this population we need more infrastructure for good life style. Among the all amenities requirement residential requirement is most essential. With the growth of population land for building construction is decreases. So to fulfil the adequate requirement of residence, construction of high rise building is essential. There are many structural systems for construction of high rise building. All structural system should safely transfer the all kind of loads include vertical loads and lateral loads. Gravity load includes various loads which act in vertical downward direction like that dead load, live load. Lateral load is due to wind, earthquake shaking and blast loading.**

***Keywords*— Include at least 5 keywords or phrases**

I. INTRODUCTION

As the population increases the need of infrastructure development is also increases. There are many structural systems for construction of high rise building. All structural system should safely transfer the all kind of loads include vertical loads and lateral loads. Shear walled framed structure is sufficient up to 30 story building. Shear wall structure consist of assembly of beams and columns and reinforced concrete wall which resist lateral loading by flexure action. Shear wall provided extra stiffness to framed structure to beam column frame and provide extra stiffness in case of earthquake loading. Shear wall make building deflection as cantilever action, which reduces the lateral story drift due to lateral loading. So shear wall is a very important component in framed shear wall structure for stability purpose.

Generally shear wall is provided in the core of the lift panel and outside of building. Generally opening is required in the shear wall which is provided outside building or in the core of lift panel for various types of services and architectural purposes. Opening is generally provided for electricity cables, various duct, windows, shaft, doors etc. Shear wall which is subjected to opening is generally called punctured shear wall.

The behaviour of shear wall with opening is different from the behaviour of solid shear wall. Solid shear wall resist the lateral load by the action of flexure i.e. a resistive moment will generated at the base of the shear wall which is responsible for cantilever action of solid shear wall. Shear wall with opening is generally called coupled i.e. two shear wall are connected by a beam which is called coupling beam and assembly is called coupled shear wall. Resistance against lateral loading is developing by resistive moment at the base of shear wall and shears action between couple beams and shear wall. So in case of coupled shear wall resistance action against lateral loading is provided by both flexure and shear action. But in case solid shear wall this resistance is provided by only flexure action.

Due to inelastic action of coupling beam sufficient ductility is provided by the coupling beam. So coupled shear wall provide adequate warning before failure in case of earthquake lateral loading.

II. STRUCTURAL ACTION OF COUPLED SHEAR WALL SYSTEM

The structure system in resisting lateral loading is compared between solid shear wall and coupled shear wall in fig. given below.

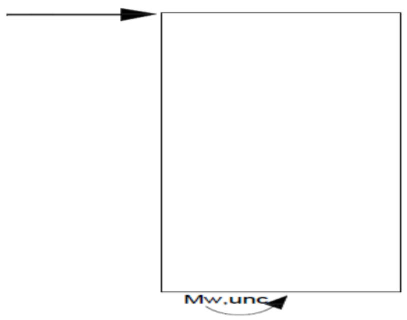

Fig.1 (a): Solid Shear wall

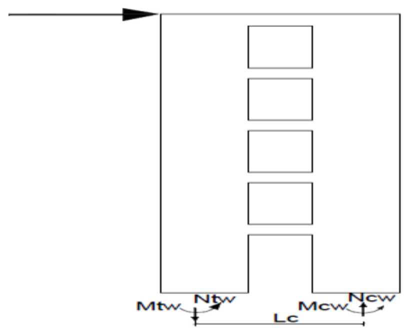

Fig.1 (b): Coupled Shear wall

In solid shear wall we can easily seen that the resisting action is provided by the moment develop at the base of the shear wall. In case of coupled shear wall when we subjected lateral loading left to right direction by the result of lateral loading left shear wall is subjected to tensile force and or right shear wall is subjected to compressive force. Magnitude of these tensile force and compressive is equal to the total shear force transfer between coupling beam and shear wall, so it is depend upon the stiffness and strength of coupling beam. These tensile force and compressive force have same magnitude and produce a couple which gives resisting moment against lateral loading, so in case of coupled shear wall resistance is provided by both shear action and flexure action.
As the result of action of both shear and flexure action of coupled shear wall. Coupled shear wall significantly provide more strength in comparison to solid shear wall. So the base moment is equal summation of both moments developed at base of shear wall and moment which is developed by couple form by tensile and compressive forces at the base level of wall.

$$M_w=M_{tw}+M_{cw}+N_{cwb}L_C$$

Where M_{tw} and M_{cw} is the moment developed at the base of shear walls which is coupled by coupling beam. N_{cwb} = N_{twb} are the tensile force and compression forces which is developed at the base of walls and L_C is the distance between these forces which can also be say that lever arm for these forces and these forces develop moment of magnitude $N_{cwb}L_C$. So the contribution of coupling beam in resisting the lateral loading is called degree of coupling and the ratio of moment develop due to tension and compression forces to the total moment develop at the base of wall.

III. COUPLING BEAMS

Coupling are design as they intercept the deterioration of structure by dissipate the energy of lateral load by inelastic behaviour. Coupling beam also reduces the possibility of shear failure of soil by reduces the tensile and compressive force at wall or pier base. Due to transfer of high shear between beams and shear wall, coupling beam is design for colossal amount of shear reinforcement at the coupling of beam and wall to dissipate the high energy due earthquake loading. By high shear stresses diagonal tension and compression developed for this reason diagonal reinforcement are also provided instead of shear reinforcement.

1) Types of Reinforcement in Coupling Beams:-

Based upon the arrangement there are two types of reinforcement provided in case of coupling beam.

Fig. 2 Coupling Beams

- First type of reinforcement is type of conventional type reinforcement which has longitudinal reinforcement in both bottom and top of the beam and transverse reinforcement. The main difference in between conventional beam and coupling beam is of transverse reinforcement. Due to high shear transfer between wall and coupling colossal amount of transverse reinforcement is provided. Figure below show that the coupling beams with conventional reinforcement.

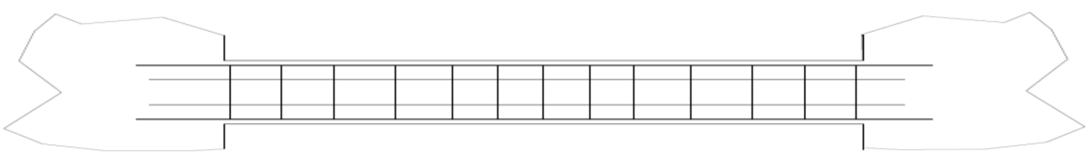

Fig.3 Typical Layout of Conventionally Reinforced Concrete Coupling Beam

- Second type of beam is diagonal reinforcement. This type of reinforcement is placed at an angle at mid span with symmetry about mid span. This type of reinforcement is provided for counteract diagonal tension and compression which is form by high shear which is developed at junction of shear wall and coupling beam.

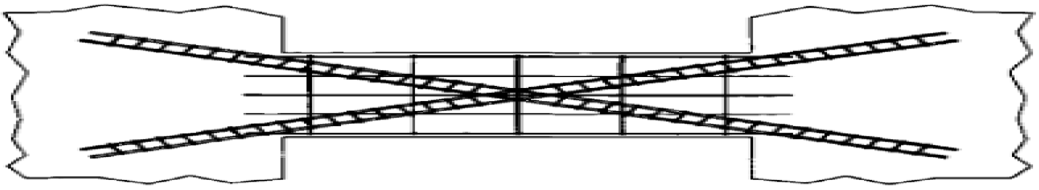

Fig. 4: Typical Layout of Diagonally Reinforced Coupling Beam

2) Degree of Coupling:-

Degree of coupling is defined percentage of overturning moment is resisted by tension and compression forces which is developed at the base of the shear walls. According to degree of coupling shear wall is divided into three categories.

- For low degree of coupling shear wall is define as isolated shear wall. i.e. both shear wall act as isolated member.
- For intermediate degree of coupling shear wall is defined as coupled shear wall and overturning moment is resisted by both shear and flexure action.
- For high degree of coupling wall with opening or pierced wall and behavior is same as solid shear wall.

2.1) Degree of Coupling Evaluation:-

a) Standard method
b) Proposed Method

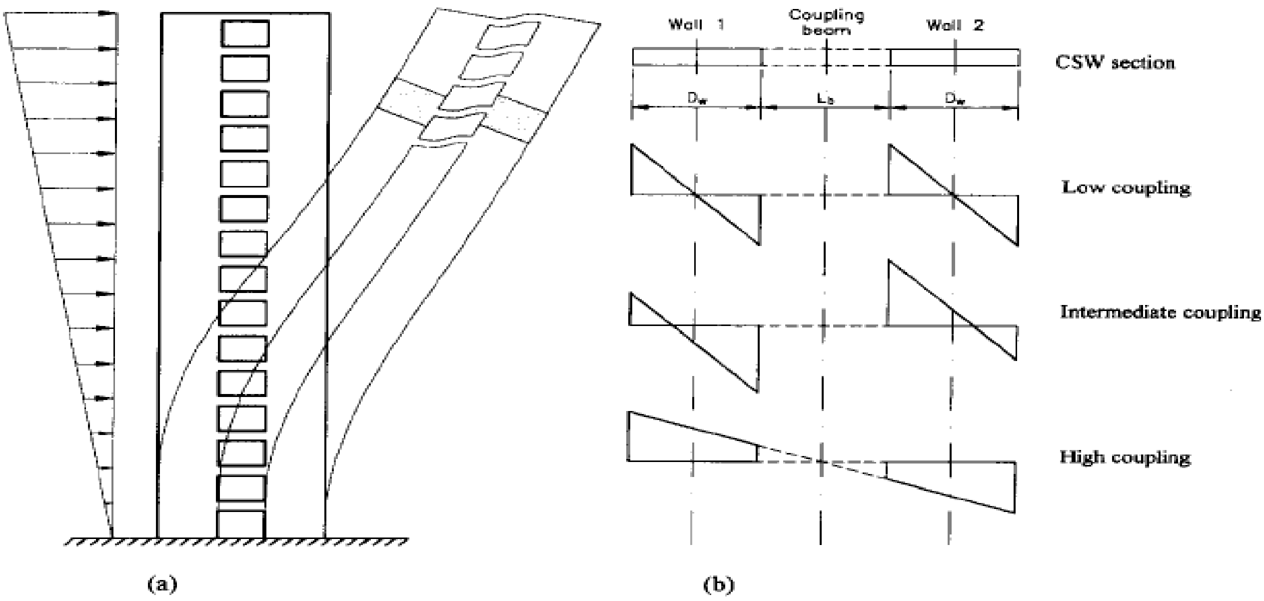

Fig. 5: Behaviour of Coupled Shear wall with Different Degree of Coupling

IV. Assumptions

There are basically three types of assumption:

1. Assumption for Material behavior
2. Assumption for element behavior
3. Assumption for structural behavior

In the analysis of all kind of structure various type of basic assumption will considered for simplify the analysis and reduces the calculation size.

1) Assumption for material behaviour:-

The study of material behaviour is assumed to be considered as linear elastic. It is the most common type of analysis. There are following assumption:

1. The material is homogenous and continuous.
2. The strain increases in a linear portion as stress increases.
3. As stress decreases, the strain decreases in the same linear portion.
4. The strain induced at right angles to an applied strain is linearly proportional to the applied strain, which is called Poisson's ratio effect.

2) Assumption of element behaviour:-

There is two type of material elements are defined. First one is beam and column which are defined as two nodded frame elements. Second is shear wall which is defined as four nodded shell element. In addition to this there are some element behavior assumptions which are as follows:

1. Shear deformations of all type of structural elements are neglected.
2. All defined frame section and shell section have uniform cross section throughout the length.

3) Assumption of structural behaviour :-

The behaviour of structure is linear elastic i.e. deformation is proportional to load through the analysis. This widely use assumption to simplify the calculations, the main application of this assumption is that superposition theorem. According if a linear elastic structure is subjected to a number of simultaneously applied loads, the overall response can be determined by summing the responses of the structure to the loads applied at one time . Based on this assumption, the behaviour of the structural system under eccentric lateral loads can be determined by superposing. The behaviour under the considered lateral loads, which are applied as symmetrically, and the behaviour under the pure torsion produced by these eccentric lateral loads.

V. MODELLING OF STRUCTURE IN STAAD.PRO

Modelling of beam and column is done by two nodded frame elements wall is modelled by four nodded plate element.

1) Description of building plan:-

A 10 stories building of 3 meter story height is modelled by use of STAAD.PRO. Building has 5 spans of 6 meters in X-direction and 3 spans of 5 meters in Z -direction. A shear wall is modelled along Global X-Direction at 3rd span outer side of the building plan and another shear wall is modelled at second span along Global Z -Direction. Materials and section properties are:

- Type of frame: Special RC moment resisting frame fixed at the base.
- Steel of grade Fe 415
- Seismic zone: III (i.e. Z = 0.16)
- Number of storey: 10
- Floor height : 3 meters
- Live load on floor : 3 kN/m2
- Damping of structure : 5 %
- Response spectra : As per IS1893(Part-1):2002
- Beams of size 300 mm width and 500 mm width
- columns of size 500 mm width and 500 mm width
- Shear wall of thin shell type thickness of 300 mm.
- Concrete floor of membrane type and thickness 150 mm.
- Structure is restrained for rotation and translation at the base i.e. supports are fixed.

For the analysis and comparison purpose five modal were prepared

- MODEL – 1: shear wall framed structure with opening in shear wall at central, size of opening: width 3000 mm and depth 2000 mm
- MODEL – 2: shear wall framed structure with opening in shear wall at central, size of opening: width 2000 mm and depth 2000 mm.
- MODEL – 3: shear wall framed structure with solid shear wall.
- MODEL – 4shear wall framed structure with opening in shear wall in X direction, size of opening: width 2000 mm and depth 2000 mm.
- MODEL – 5shear wall framed structure with opening in shear wall in Z direction , size of opening: width 2000 mm and depth 2000 mm.

So comparison is done in between two parts in first one we compare the analysis results between solid shear walls and shear wall with opening at centre. In second part we compare the results for changing the direction of opening in shear wall.

2) Description of analysis: - As we discussed earlier that the main purpose of structure is that to support various kind of loading. The loading is either gravity loading or lateral loading. Gravity loading consists of all the loading which is subjected in the direction of gravity. Lateral load which act in lateral direction of building either Global – X or Global – Z direction. Lateral loads are applied due to earthquake loading, wind loading and blast loading.

1. Equivalent static analysis
2. Response spectrum analysis.

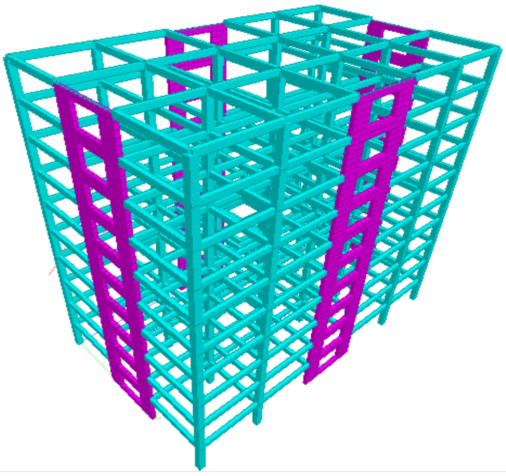

Fig. 6:- MODEL – 1 shear wall framed structure With opening in shear wall at central, size of Opening: width 3000 mm and depth 2000 mm

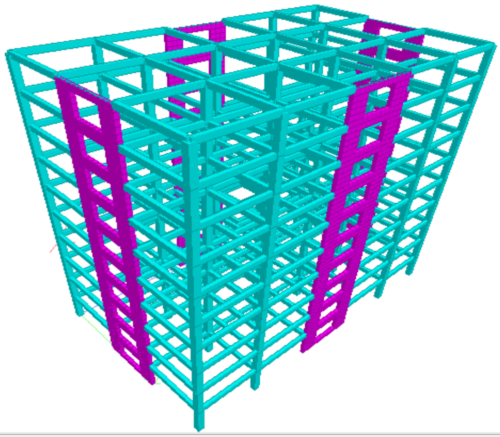

Fig. 7:- MODEL – 2 shear wall with rectangular opening in centre of size is depth 2000mm and width 2000mm

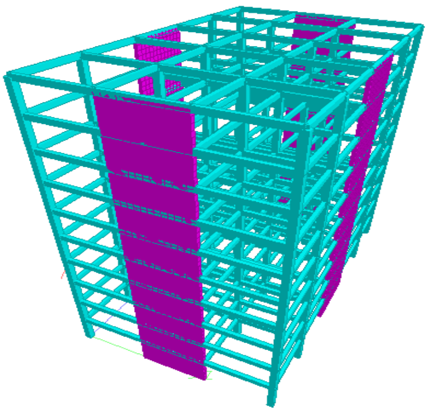

Fig. 8:- MODEL – 3 Building with solid shear wall.

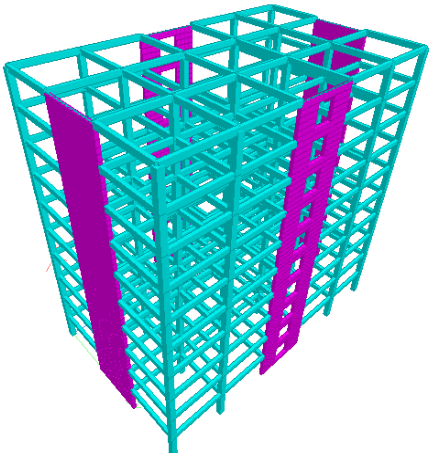

Fig. 9:- MODEL – 4shear wall framed structure with opening in shear wall in X direction, size of opening: width 2000 mm and depth 2000 mm

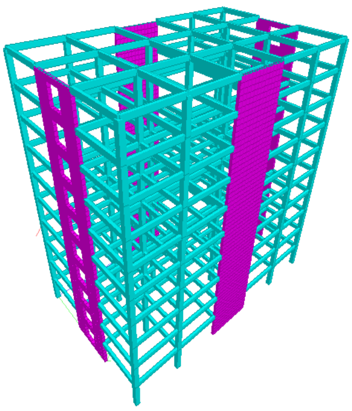

Fig. 10:- MODEL – 5shear wall framed structure with Opening in shear wall in Z direction, size of opening: Width 2000 mm and depth 2000 mm and solid shear Wall in x direction.

3) Description of loading:-

This is the description of various loads which is to be considered in the analysis of building.

- Live Loads on floor : 3 kN/m2
- Load of outer walls on beams : 13 kN/m2
- Load of inner walls on beam : 6.6 kN/m2
- Load of parapet wall : 4.6 kN/m2

After applied these loading model will analyze for equivalent static analysis and response spectrum analysis. The comparison is done for these parameters.

- Lateral displacement for each floor
- Maximum roof displacement
- Maximum story drift
- Axial force in column
- Time period of building

VI. RESULTS

1) Displacement plots of building in X and Z direction:-

TABLE – 1
DISPLACEMENT IN SEISMIC X DIRECTION DUE TO EQUIVALENT STATIC ANALYSIS

	DISPLACEMENT IN STATIC ANALYSIS				
STOREY	**MODEL 1**	**MODEL 2**	**MODEL 3**	**MODEL 4**	**MODEL 5**
0	0	0	0	0	0
1	1.425	0.982	0.613	0.912	0.638
2	4.18	2.95	1.905	2.74	2.009
3	7.55	5.495	3.724	5.1	3.961
4	11.268	8.434	5.962	7.822	6.384
5	15.154	11.617	8.492	10.784	9.145
6	19.063	15.395	11.205	13.809	12.14
7	22.864	18.867	14.006	16.855	15.257
8	26.554	21.464	16.835	19.826	18.432
9	29.957	24.57	19.651	22.669	21.662
10	32.0508	27.66	22.117	25.114	24.747

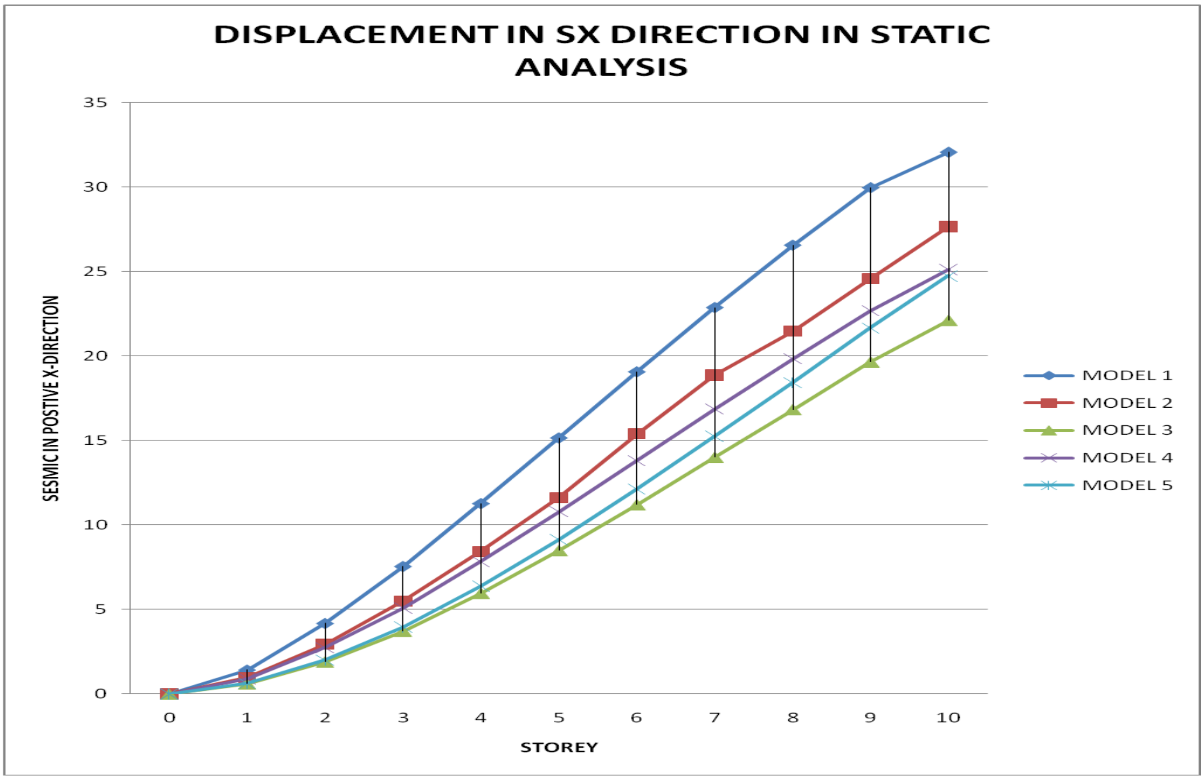

Fig. 11:- storey wise displacement in X direction

TABLE -2
Displacement in seismic z direction due to Equivalent static analysis

	DISPLACEMENT IN SZ DIRECTION IN STATIC ANALYSIS				
STOREY	**MODEL NO 1**	**MODEL NO 2**	**MODEL NO 3**	**MODEL NO 4**	**MODEL NO 5**
0	0	0	0	0	0
1	1.224	0.827	0.513	0.475	0.858
2	3.649	2.524	1.615	1.518	2.619
3	6.677	4.767	3.202	3.036	4.947
4	10.065	7.39	5.169	4.939	7.668
5	13.647	10.263	7.41	7.126	10.646
6	17.291	13.268	9.829	9.509	13.765
7	20.88	16.328	12.347	12.012	16.925
8	24.316	19.328	14.899	14.572	20.044
9	27.553	22.267	17.466	17.161	23.089
10	30.5	25.018	19.871	19.639	25.933

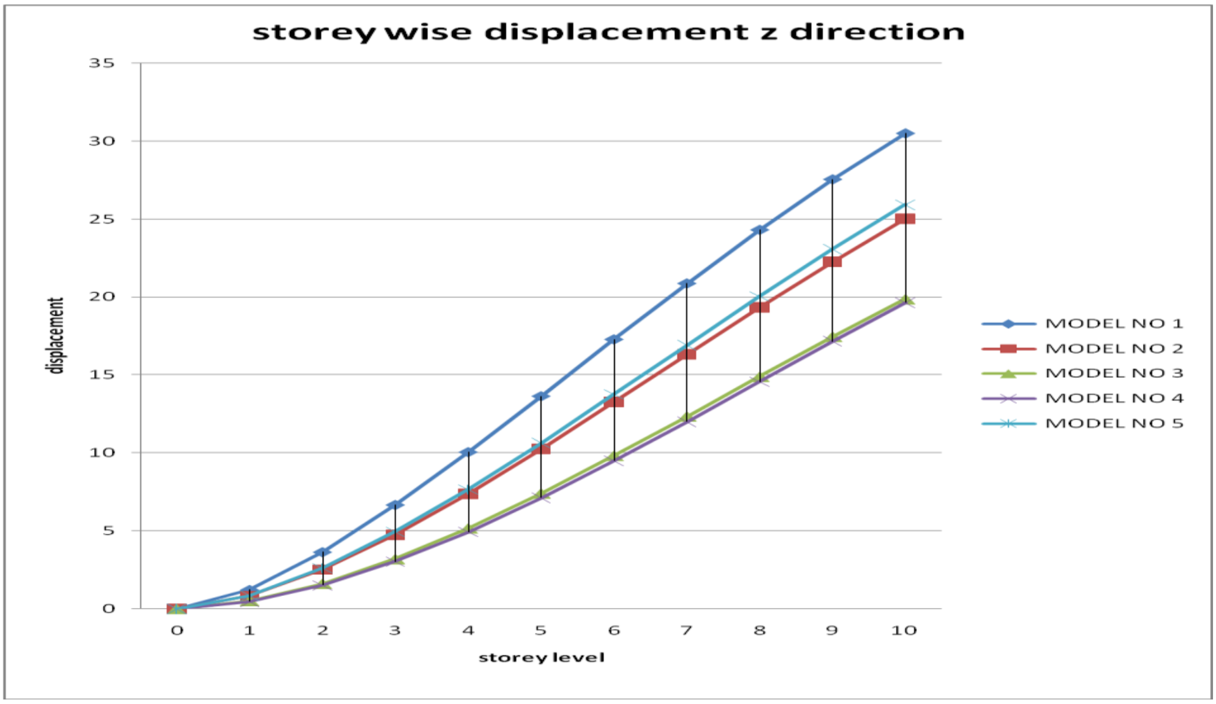

Fig. 12: story-wise displacement in Z-direction

2) Lateral Story drift of the building frame:-

Lateral story drift is defined as the relative movement of story relative to another adjacent story. Generally story drift increase as story height increases and again decreases for higher stories. Story drift for equivalent static analysis in X and Z direction are shown in table below:

TABLE -3
Drift in seismic X direction due to Equivalent static analysis

	DRIFT				
STOREY NO.	**MODEL 1**	**MODEL 2**	**MODEL 3**	**MODEL 4**	**MODEL 5**
0	0	0	0	0	0
1	0.000698	0.000327	0.000204	0.000304	0.000212667
2	0.001134	0.000656	0.000431	0.000913333	0.000457
3	0.00123	0.000848	0.000606	0.001396	0.000650667
4	0.001267	0.00098	0.000746	0.001694	0.000807667
5	0.001303	0.001061	0.000843	0.001894667	0.000920333
6	0.001295	0.001259	0.000904	0.001995667	0.000998333
7	0.001239	0.001157	0.000943	0.002023667	0.0010309
8	0.001123	0.000866	0.000943	0.002005667	0.001058333
9	0.000918	0.001035	0.000939	0.001938	0.001076667
10	0.000475	0.00103	0.000822	0.001762667	0.001028333

3) Maximum Lateral Displacement at Roof Level:-

TABLE –4
Maximum Displacement at Roof Level due to Response Spectrum Analysis

MODEL NO.	MAX. DEFLECTION IN X-DIRECTION (MM)	MAX. DEFLECTION IN Z-DIRECTION (MM)
Model - 1	28.457	25.165
Model - 2	23.91	20.875
Model - 3	20.789	16.637
Model -4	22.287	16.813
Model -5	22.099	21.92

In analyse for X -direction maximum deflection is 28.457 mm for MODEL – 1, for MODEL – 2 maximum lateral deflection is 23.91 mm which is also about 15.9 % less than MODEL – 1, for MODEL – 3 maximum deflection is 20.789 mm which is also about 26.9 % less than MODEL – 1,for MODEL-4 maximum deflection is is 22.287 mm which is also about 21.6% less than MODEL –1, for MODEL-5maximum deflection is is 22.099 mm which is also about 22.3% less than MODEL –1.As analyze given table maximum lateral deflections is occurs for MODEL -1. Maximum lateral deflection in Z-direction for MODEL – 1 is 25.165mm, for MODEL – 2 is 20.875mm which is 17 % less than the MODEL – 1, For MODEL – 3 maximum lateral deflection in Z-direction is16.637mm as it is about 33.88 % less than the MODEL – 1,For MODEL –4 maximum lateral deflection in Z-direction is 16.813mm as it is about 33.15 % less than the MODEL – 1.For MODEL – 5 maximum lateral deflection in Z -direction is 21.92mm as it is about 12.8 % less than the MODEL – 1. Minimum lateral displacement in model 3 which is consists of solid shear wall.
So it is concluded that the lateral displacement is minimum in solid shear wall. Opening in shear wall increases it lateral deflection in both X and Z direction. Further Deflection is also increase when direction and size of opening is changes.

4) Seismic Base Shear for the Models:-

TABLE –5
Maximum Displacement at Roof Level due to Response Spectrum Analysis

MODEL NO.	BASE SHEAR (KN)X DIRECTION	BASE SHEAR (KN)Z DIRECTION
Model 1	1809.58	1807.70
Model 2	1761	1761
Model 3	1989.2	1886.1
Model 4	1623	1631.02
Model 5	1833.50	1833.50

As observed that the time period for model – 1 is more in comparison to the any other four models. So frequency of model – 1 is less than other four models.

VII. CONCLUSIONS

The response of 10 story building for equivalent static analysis and response spectrum analysis were investigated with shear wall (without opening) and couple shear wall with opening. Response according to change in size and direction of opening in shear wall was also studied i.e. five models were analysed one with an opening of 3000mm at centre and second with an opening of 2000mm at centre, third had shear wall (without opening)and fourth had an opening of shear wall in X direction and the fifth model had an opening of shear wall in Z direction. Following are the conclusions of this thesis:

- While building model-2 which was modeled with shear wall (with opening of 2000mm at center) was more stable in comparison to the building model -1 with shear wall (with opening of 3000 mm) because lateral displacement and story drift in both X and Z directions were more for model-1. So it was concluded that if the size of an opening in shear wall is varied, it impacts the lateral displacement of building.
- Building model-4 which was modeled with shear wall (with an opening of 2000 mm in X direction) lateral displacement was more in X direction as compared to Z direction. It means this model was more stable in Z direction as compared to X direction because of the opening in shear wall in X direction and shear wall (without opening) in Z direction.
- Building model-5 which was modeled with shear wall (with opening of 2000 mm in Z direction) lateral displacement is more in Z direction as compared to X direction. It means this model more stable in X direction as compared to Z direction because opening of the shear wall in Z direction and shear wall (without opening) in X direction.
- Base shear is maximum for model – 3which consists of shear wall (without opening).
- Time period was maximum for model-1(with opening of 3000mm). It increases as opening is increased in shear wall; it was minimum for model 3 which consisted of shear wall (without opening).

REFERENCES

[1] Seyed M. Khatami, AlirezaMortezaei, Rui C. Barros (2012) “Comparing Effects of Openings in Concrete Shear Walls Under Near-Fault Ground Motions” 15 WCEE Lisboa 2012 .

[2] Mulyo Harris PradonoandSugengWijanto (2000) “Some Differences Between Coupled Wall and Cantilever Wall Structures” 12 WCEE 2000.

[3] MotamarriSarat Chandra, B. Sowmya (2014) “Behavior of Coupled Shear Walls in Multi-Storey Buildings” International Journal of Engineering Research & Technology (IJERT) Vol. 3 Issue12, December-2014

[4] ReshmaChandran , UnniKartha , Preetha Prabhakaran (2014) “Comparative Study on Solid And Coupled Shear Wall” International journal of civil Engineering and technology (IJCIET) Volume 5, Issue 12, December (2014).

[5] Mulyo Harris PRADONO1 and SugengWijanto (2000) “Some Differences between Coupled Wall and Cantilever Wallstructures” 12 WCEE 2000.

[6] R J Folicand D J Z Ladjinovic (2000) “Energy Aspect of Coupled Shear Walls Behavior in an Earthquake” 12 WCEE 2000.

[7] S. A. Meftah, F. Mohri, and E. M. Daya (2012) “Seismic Behavior of RC Coupled Shear Walls with Strengthened Coupling Beams by Bonded Thin Composite Plates” KSCE Journal of Civil Engineering (2013) 17(2).

[8] Barjari, S.H. (2012). Investigation of nonlinear behavior of openings in shear walls. MSc Thesis in Civil Engineering (Structures)supervised by Prof. A. Kheyroddin, Islamic Azad University (Turkestan Branch), Iran.

[9] Dawn E. Lehman, M.ASCE; Jacob A. Turgeon; Anna C. Birely, M.ASCE; Christopher R. Hart, M.ASCE; Kenneth P. Marley; Daniel A. Kuchma; And Laura N. Lowes (2013), Seismic Behavior Of A Modern Concrete Coupled Wall.

[10] Caughey, T.K. (1960), "Classical Normal Modes in Damped Linear Systems", Journal of Applied Mechanics, Vol. 27, pp. 269-271

