Earthquake response of Irregular Tall Building with Different Position of Shear Wall

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Abstract: Shear wall is a structural element which can be used to prevent the lateral loads in the high rise buildings. Shear wall is mostly used to resist the gravitational load. They are designed mainly for structural walls for resisting the horizontal forces which are caused in the plane wall because of the natural forces. How the building behaves whenever earthquake occurs is based on the shape, size and geometry of the structure. Earthquake forces can be resisted very effectively if shear walls are constructed in an efficient manner such that they have stiffness and strength to prevent it. Here, in the project, Response Spectrum method is used to analyze the irregular shaped RCC structure. The investigation is carried to know the contribution of different shapes and location of shear walls to lateral strength and lateral stiffness of the high rise irregular building. The comparison has been carried out between building with L SHAPE SW, C SHAPE SW and LINE SHAPE SW.

Keywords: Earthquake response, Position of Shear Wall, L shape, C shape and Line Shape Shear Wall.

1. INTRODUCTION

Irregular Buildings

Irregularities in construction buildings are not avoidable. So the behavior of structures with these irregularities during earthquake needs to be studied and adequate precautions can be taken.

Modern urban infrastructure mainly consists of irregular buildings. At present most of buildings are of irregular shaped in both plan and elevation. In coming days it may be affected to damage due to earthquakes. Hence it is required to notify the performance of the buildings to resist the damaging due to earthquake. The bunch of people engaged in construction of the buildings; such as architects, local authorities, structural engineer, contractor and including the owner of the building works for the selection of planning, structural system and overall configuration. This affects the structure of building with irregular allocations in their stiffness mass and strength onward the building height. If these types of buildings structures are placed in a high earthquake zone, then the role of structural engineers will be more difficult and time consuming. That's why; the structural engineer must to have a complete knowledge of realizing the seismic response of uneven building structures. Lot of studies has been done to find out the seismic response of irregular building structures. This paper tries to describe the work to the earthquake response of high rise irregular building structures.

Geometry or Shape of Shear Walls

Shear walls are a rectangular object or flat figure with unequal adjacent sides in cross sectional view. Single dimension of the cross-section is bigger than the other. Now a day's very common shape of shear wall is rectangular. In addition to that C shaped and L shaped sections are also used. Even very thin walled hollow shaped reinforced concrete (RC) shafts surrounding the elevator of buildings structures also acts like shear walls to resist earthquake forces.

For a safety measure and to lower the destruction level consideration a building structure is the main requirement of high rise buildings with shear wall to satisfy these requirements, against seismic motion. The irregular buildings must have enough lateral strength, lateral toughness. Shear wall concrete frame is the most helpful structural system for the engineer's choice among different other structural systems; hence, the aim of this project is to understand the effect of shear wall and position or location of shear wall. Also compare earthquake response of high rise tall building with different type of shear wall and finding of best design of seismic resistance performance level.

- To find the most favorable position of shear wall with same cross-sectional area on structural response under earthquake loading.

- To determine base shear, mode shapes, frequency, displacement, acceleration are obtained.
- To know mode shapes and its behavior.
- Equivalent static analysis is carried out to determine base shear and shear strength coefficient of models in zone II while earthquake response of spectrum analysis is used to identify the corresponding seismic responses of the irregular tall building.
- Earthquake response of high rise irregular building can be studied with shear wall by different position in response spectrum analysis in zone II.

2. SYSTEM MODEL

Present Work

In the present work, the as RCC building which is irregular in shape is analyzed by Response Spectrum Method further the investigation is carried to know the contribution of different shapes and location of shear walls to lateral strength and lateral stiffness of the high rise irregular building. Along with this the comparison has been carried out between building with L SHAPE SW, C SHAPE SW and LINE SHAPE SW RC multi storey buildings are sufficient for withstanding both the vertical and horizontal load. Hence Shear wall is very much required for lateral deflection control and also suitable in the economical point.

The project aims at recognizing seismic response of irregular tall building with different position of shear wall. Hence it will help to find-out exact optimum location along with shape of shear wall.

Multi-storey ICONIC structures are modelled with the help of ETABS, a software package. This study highlights shear wall's structural response. Dynamic response of high rise building structures with most accurate and exact comparison is done by considering response spectrum analysis and equivalent static analysis. ETABS use a design method called Limit State Design.

3. PREVIOUS WORK

Raul Gonzalez Herrera1 and Consuelo Gomezsoberon [2012]

Different irregular plan during earthquake disaster with varying magnitude results in damages which are analytical in nature. Their study regarding earthquake response explains the geometric forms which are repeated mostly in urban region of Mexico which includes square shaped, rectangular shaped and sections such as U & L and T and also it explains how it varies with respect to plants and Google Earth aerial photography. These architecture plans are modeled in SAP-2000 by recognizing several levels to understand the impact of the geometric form in the earthquake response of building with elastic analyses. Along with these studies, what would be the impact of the extension in rectangular plants along with the effect of projections in cross sections with architectural design plans U, T, and L sections were studied. Results of these studies proves that impact of several irregularity buildings are studied and analyzed by considering the variation of displacements occurred with respect to regular systems.

Bhattacharya S.P and Chakra Borty S Etal [2005]

Had given in there article that, two important things are necessary for the analysis of dynamic response of buildings with structural design under vibratory motion are mass and the stiffness. Mass, distribution of stiffness, condition of soil and types of foundation are responsible for different behavior of tall structural buildings. In 2001 Buhl earthquake in Gujarat, India clearly explains how the earthquake can damage and collapse the tall buildings; we must note that the reason for such damage is due to the irregular design in the stiffness structure and mass of floor. Studies on this is base to investigate and makes us understand the regular distribution of lateral forces are evolved through earthquake action in each and every level of storey because of the changes in stiffness of structures and mass of tall buildings. The result concludes that tall buildings which have very high mass and toughness ration will cause instability and is a reason for attraction by huge storey shear. Mass and distribution of stiffness of buildings is an advantage such that it provides a control over multiple storey and base shear.

K. Galal1 and H. El-Sokkary (2008)

In this paper different modeling techniques that have been used by researchers in modeling of RC shear walls were discussed. These ranged from macro-models such as lumped plasticity, truss models, multi-axial spring models, and combined models, up to micro-models such as finite element models and fiber models. The efficiency of each model in representing both the global and local behavior of RC shear walls was summarized. This paper discussed different factors that affect the response of RC shear walls and should be taken into account when a numerical model is developed. Different important models used to simulate the behavior of RC shear walls were also discussed and it provides a state-of-the-art on the recent advancements and challenges in the area of modeling of RC shear walls.

Seong-Hoon Jeong and Amr S. Elnashai (2011)

Earthquake effect investigations regularly prove that irregularly designed tall building structures are suffered with more damage than the regular building structures. This difference is identified in earthquake design codes and limitations on brief changes in the mass and toughness are recognized. Due to irregularity in the design of building structures' dimension stiffness distribution and capacity is affected. Irregularities due to mass impact the imposed demand. Because of the non uniform distribution of the demand and supply ratio along height, storey failure will be caused by the irregularity structure in the elevation. Non uniform distribution of demand and capacity ratios of the columns of a single floor in plane irregularities causes failure of multi storey buildings. From so many years, we are following an earthquake assessment by considering floor by floor as a basis. If we consider the type of storey drift ratios which give a unique number and shows the demand and supply image along height of a building which is available easily and can be measured.

4. PROPOSED METHODOLOGY

Proposed methodology is based on response spectrum analysis. A spectrum is an idea of a building which has a vast range in terms of period of response which is explained in a graph. For a specific seismic motion and with a given critical damping, we can obtain a graph of responses which are related to seismic motion.

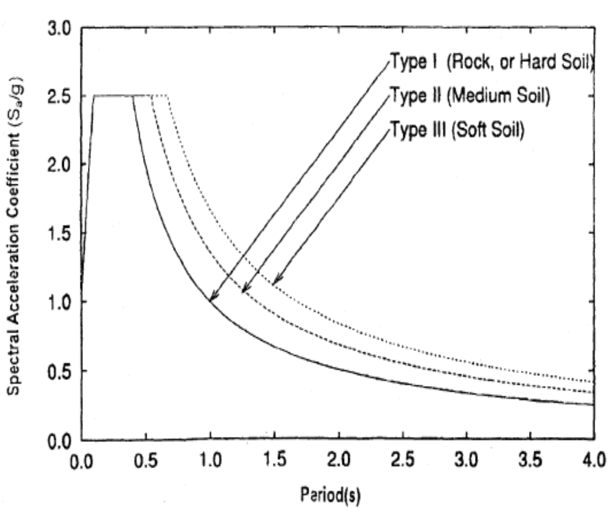

Fig 1: Design Response spectrum

If we can able to find the peak response of a building whenever an earthquake occurs by using the earthquake response spectrum and without using time history analysis, then that method of analysis is called as response spectrum analysis. It is as shown in the graph below.

Response spectrum is a graph of high response of a single degree of freedom for different value of the period for a given input. Seismic resistance design is mainly based on IS-1893 and it gives an average Response spectrum.

This method allows the different modes of response of a structure to be taken into account. This method is necessary for most of the buildings codes except the buildings which are most simple and more irregular. The response of a structure can be defined as a combination of many special modes that in a vibrating string correspond to the "arrangements". The different modes of structures can be determined by computer analysis. Response is read from the design spectrum for each of the mode depending on the modal mass and the modal frequency and later these are then combined to give a result of the total response of the building. In this we need to find out the magnitude of all forces in X, Y & Z so that we are able to find the effect of the building.

STRUCURAL MODEL

In this project, ten storey building are taken into to account. Here we consider the dimensions 24m X 36m in plan. Each storey is having three meter in these structural models. It also has a uniform mass distribution over building height. For both of the direction we provide grid spacing of 6m.

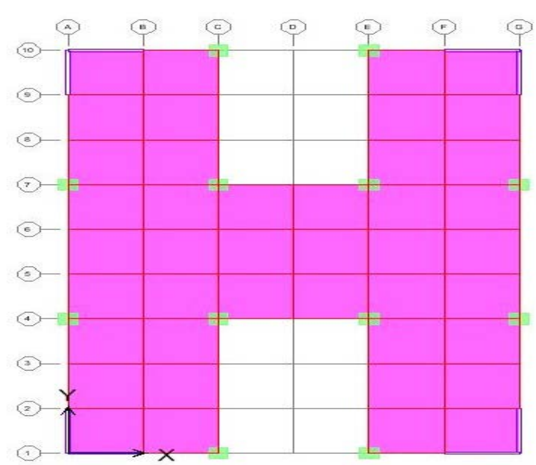

Fig 2: Building Plan (L shape SW at corner)

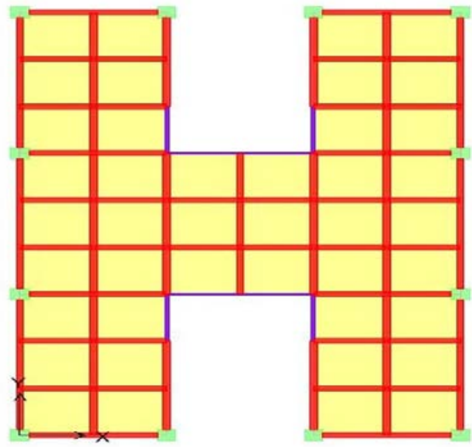

Fig 3: Building Plan (C shape SW at center)

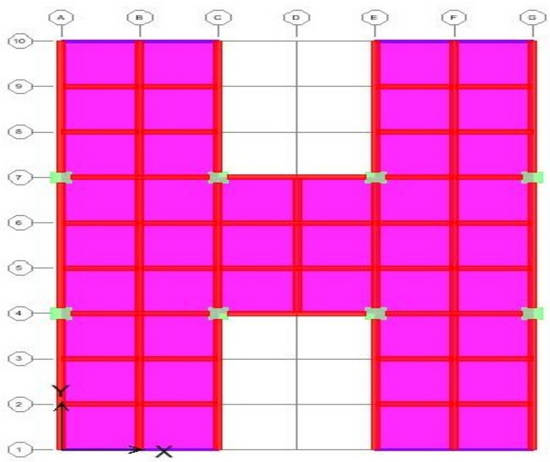

Fig 4: Building Plan (Line shape at middle)

In this thesis, there are three types of models namely,

- L shape Shear Wall at Corners
- C shape Shear Wall at inside
- Line shape Shear Wall at middle.

L shape shear walls at corners are considered for resisting lateral forces. The L shape Shear Wall at Corners is selected TYPE 1 Model. C shaped Shear Wall at Centre is one of models such that, C shape shear walls at inside are taken into account for resisting lateral forces. The C shape Shear Wall at Centre is selected as TYPE 2 Model. Line shape Shear Wall at middle is one of model such that, line shape shear walls at middle are taken into account for resisting lateral forces. Line shape Shear Wall at Middle is called as TYPE 3 Model.

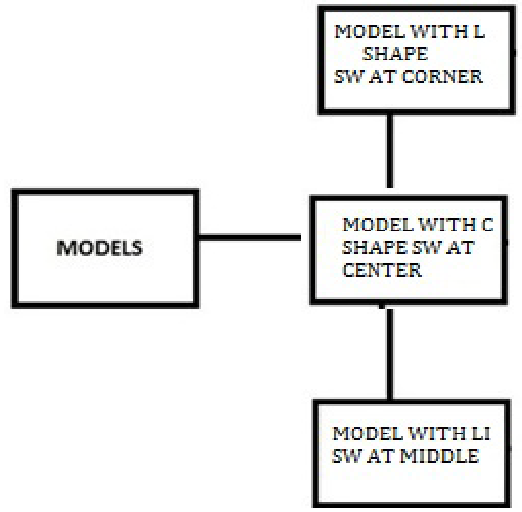

Fig 5: Types of models

SECTIONS & E.QUAKE FORCE DETAIL

Table-1: Sections & Earthquake Force Detail

	COLUMN SIZES(mm)	BEAM SIZES(mm)
STORY		
S-7 TO S-10	1000X1000	400X600
STORY6	1000X1000	400X600
STORY5	1000X1000	400X600
STORY4	1000X1000	400X600
STORY3	1000X1000	400X600
STORY2	1000X1000	400X600
STORY1	1000X1000	400X600
GF	1000X1000	400X600
BASE	1000X1000	400X600

SEISMIC LOADING ZONE AS PER IS:1893

Table-2: Seismic Loading Zone

Details	All Models
R	**3**
I	**1**
R	**2**
Sa/G	**Type 2**

Z=Zone,
Sa/g=Soil type II,
R= response reduction factor,
I = Importance factor

MATERIAL PROPERTIES

Table 3: Material Property

MODEL TYPE MATERIAL PROPERTIES	All Models
Column	M45
Beam	M25
Slab	M25

Density of concrete is 25 KN/m3
Density of brick masonry is 20 KN/m3
Thickness of slab is 150mm
Thickness is 200 mm

STATIC LOAD ASSIGNMENT

All the models consists of Live load, dead load, floor finish, and earth quake Loads.

Dead Load: IS 875 parts 1 1987 given the structure of a dead load. The acceptable value for unit weight of reinforced concrete ranges from 24.80kN/m^3 to 26.50 kN/m^3. That's why we are taking as 25kN/m^3 of unit weight of concrete. Already the software has inbuilt dead load calculator. Self weight of the structural components Floor finish is 1.5 kN/m˙ and 9.4 kN/m of wall load or all beams.

Imposed Load: The IS 875 part 2 1987 given the imposed load on the floor. The assumed uniformly distributed load on the floor is 4.0 kN/m^2 including the passages, corridors, assembly areas etc. above the roof 1.5 kN/m^2 and 4.0 kN/m^2 above the floor.

Earth Quake Load: As per IS 1893 to 2002 code the structure is in Zone II. So that zone factor is obtained from IS 1893 – 2002 (table 2). The damping is assumed to be 5% as per IS 1893 to 2002 for concrete.

We took 1 as importance factor. R=3 (Reduction factor) Soil type II.

Load combinations: All the load combinations are obtained from clause 6.3.1.2

DLEQX=1.2 (DL+LL+FF+SPECX)

DLEQY=1.2(DL+LL+FF+SPECY)

ANALYSIS INPUT

Response spectra analysis for different types of models,

Table 4: Response spectra analysis

TYPES OF MODELS	ALL MODELS
R VALUE	R=3
Function input	0.1
spectrum case name	Spec x
structural and function damping	0.05
model combination	CQC
directional combination	SRSS
input response spectra	9.81/2*3
eccentricity ratio	0.05

5. SIMULATION/EXPERIMENTAL RESULTS

FREQUENCY AND TIME PERIOD

Time period value is mainly based on both mass and flexibility. As the flexibility increases period increases.

Period and mass are directly proportional. That is with increase in period mass also increases.

TIME PERIOD (Sec)

Table 5: Time Period (sec)

	TP-T1	TP-T2	TP-T3
1	1.257889	1.790531	2.97319
2	1.078213	1.643384	1.360685
3	0.662312	1.009761	1.056483
4	0.295425	0.470797	0.890517
5	0.27333	0.392673	0.449807
6	0.158022	0.23412	0.267317
7	0.126887	0.216618	0.259219
8	0.122535	0.166793	0.196255
9	0.074259	0.128913	0.175391
10	0.072914	0.108543	0.123816
11	0.070249	0.095628	0.104624

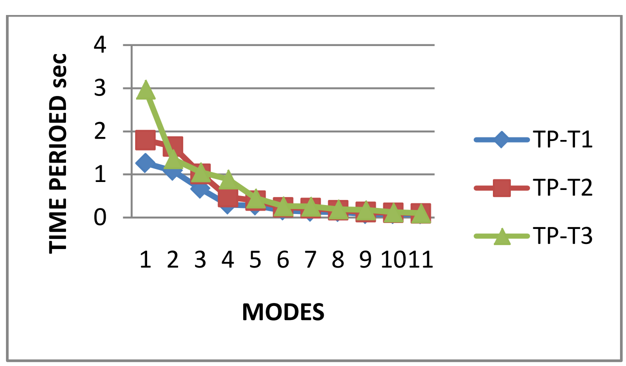

Fig 5: Time period vs Modes

FREQUENCY (cyc/sec)

Table 6: Frequency (cycles/second)

	FR-T1	FR-T2	FR-T3
1	0.794983	0.558494	0.336339
2	0.927461	0.608501	0.734924
3	1.509862	0.990333	0.946537
4	3.384954	2.124058	1.122943
5	3.658581	2.546648	2.223176
6	6.328233	4.271314	3.740877
7	7.881028	4.616422	3.857742
8	8.160934	5.995455	5.095412
9	13.46638	7.75717	5.701547
10	13.71479	9.212939	8.076501
11	14.23508	10.45719	9.558036

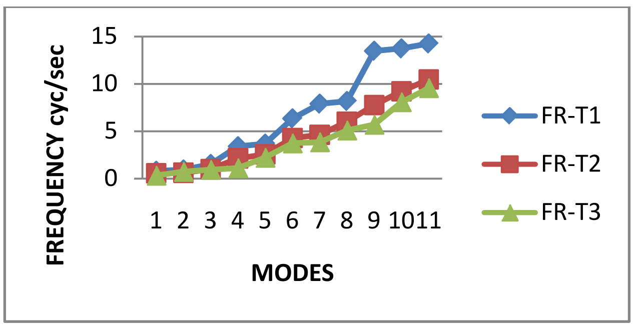

Fig 6: Frequency vs Modes

As the plan of a building is same in all the models, the time period and frequency won't change for various models or zones etc. because the time period and frequency depends on the building flexibility and mass.

DISPLACEMENT (mm)

The displacement is based on with respect to
Structural balance
Structural Strength
User convenience

EARTH QUAKE IN X-DIRECTION

From below figures, the type 2 model helps to minimize the displacement of the stories of buildings in x direction and in type 3 model displacements is maximum out of all the models. According to my project, minimization of displacement of stories is directly related to stiffness, velocity and acceleration. This is because reduction in displacement increases the stiffness of buildings and reduces the velocity and acceleration. Hence by providing the type 2 model the velocity and acceleration can be minimized and it can reduce the displacement in x direction. In compared to all types of models the displacement of type 2 model is less. So that the type 2 structure is more stable and reduction of structural strength is less and is user convenient.

Table 7: Earthquake in X direction

	UX-T1	UX-T2	UX-T3
10TH	10.5153	10.0501	13.6951
9TH	9.5688	8.9758	12.0636
8TH	8.5575	7.8656	10.4225
7TH	7.4842	6.7374	8.7913
6TH	6.3577	5.6084	7.1916
5TH	5.1976	4.5004	5.6522
4TH	4.0331	3.4389	4.2074
3RD	2.903	2.4526	2.8966
2ND	1.8579	1.5736	1.7653
1ST	0.9625	0.8383	0.8652
GF	0.2995	0.2854	0.2539
BASE	0	0	0

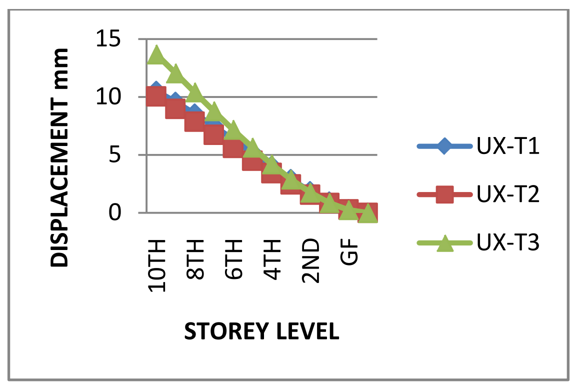

Fig 7: Displacement vs Storey Level (X- direction)

EARTH QUAKE IN Y-DIRECTION

From respective fig below, by providing type 1 model in Y direction the displacement of storey of structure is reduced. Type 3 model has maximum displacement out of all the models in both direction and in Y direction type 1 model has minimum displacement. Based to this project, reduction in displacement increases the stiffness of buildings and reduces the velocity and acceleration. In other words by providing the type 1 model the velocity and acceleration can be minimized and it can reduce the displacement in y direction. In compared to all types of models the displacement of type 1 model is less. So that the type 1 structure is more stable and reduction of structural strength is less and is user convenient.

Table 8: Earthquake in Y direction

	UY-T1	UY-T2	UY-T3
10TH	12.4011	16.119	26.9001
9TH	11.1545	14.5393	25.6148
8TH	9.8563	12.8927	24.0199
7TH	8.5149	11.1858	22.0459
6TH	7.1437	9.432	19.6839
5TH	5.7661	7.657	16.9549
4TH	4.4148	5.8987	13.9047
3RD	3.1323	4.21	10.6089
2ND	1.9721	2.6629	7.1968
1ST	1.0014	1.3536	3.9113
GF	0.3028	0.406	1.2207
BASE	0	0	0

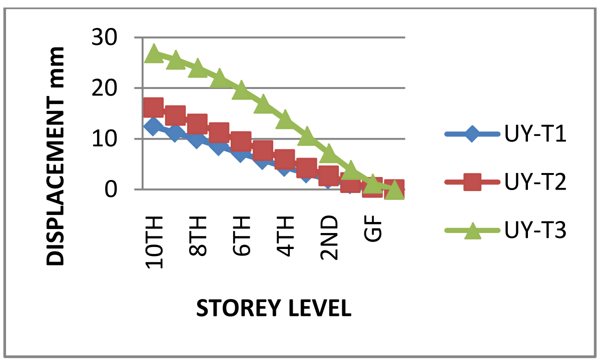

Fig 8: Displacement vs Storey Level (Y-direction)

STOREY DRIFT RATIO

It is nothing but the displacement of one storey level corresponding to the storey level, it can up or down. Collapse of building structure is directly proportional to several response quantities. Each storey may display additional horizontal displacement. That's why this could be concluded that by minimising the story drifts of buildings, the chance of building being failure can be minimised. For that reason, type 2 model play an important role to reduce the response of the building in X direction and type 1 model in Y direction. By seeing, storey drift ratios are less in Type 2 model compared with the other models in x direction and y direction. Here we can observe the storey drift ratio is very low in below stories, very high storey drift ratio at the centre part of stories and at last storey drift ratio decreases towards the upper stories.

EARTH QUAKE IN X-DIRECTION

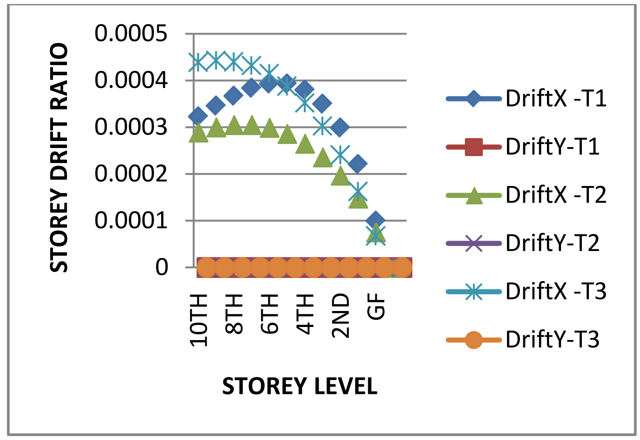

Fig 9: Storey Drift Ration vs Storey Level (X-direction)

EARTH QUAKE IN Y-DIRECTION

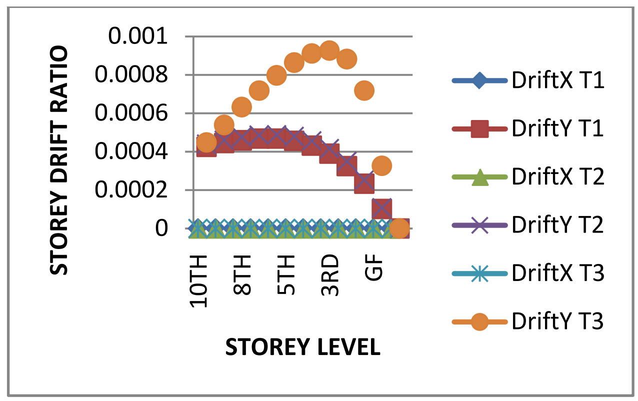

Fig 10: Storey Drift Ration vs Storey Level (Y-direction)

STOREY SHEAR (kN)

It is the total amount of design horizontal forces at every level above the storey.

EARTH QUAKE IN X-DIRECTION: In Type 2 model, maximum story shear is found and in Type 3 model minimum story shear is found.

In the graph it has been constantly minimising in the quantity of story shear above the building's height. In every model, in the base of the building story shear is maximum and at the top of the model story shear is less. Now in this we observed that type 3 models has minimum storey shear and type 2 model has maximum storey shear.

Table 9: Earthquake in X-direction

	VX-T1	VX-T2	VX-T3
10TH	451.09	480.1	428.68
9TH	811.99	887.18	733.79
8TH	1066.31	1169.81	902.49
7TH	1263.9	1374.8	1006.63
6TH	1431.85	1547.93	1106.4
5TH	1585.2	1711.8	1223.16
4TH	1731.99	1871.66	1356.77
3RD	1869.15	2028.39	1503.65
2ND	1989.72	2174.24	1646.51
1ST	2079.35	2285.99	1751.93
GF	2117.88	2337.78	1796.25

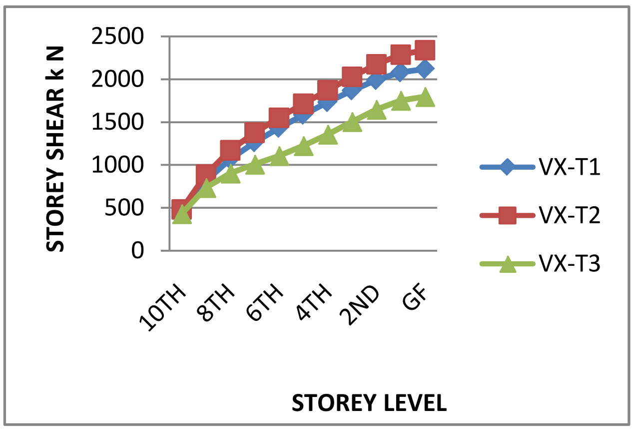

Fig 11: Storey Drift Ration vs Storey Level (X-direction)

EARTH QUAKE IN Y-DIRECTION

In Type 1 model, maximum story shear is found and in Type 3 model minimum story shear is found. In the graph it has been constantly minimising in the quantity of story shear above the building's height. In every model, in the base of the building story shear is maximum and at the top of the model story shear is less. Now in this we observed that type 3 models has minimum storey shear and type 1 model has maximum storey shear.

Table 10: Earthquake in Y direction

	VY-T1	VY-T2	VY-T3
10TH	433.31	406.7	257.46
9TH	751.16	682.17	390.23
8TH	954.51	830.02	467.27
7TH	1099.5	921.51	526.06
6TH	1223.08	995.02	581.76
5TH	1346.98	1080.75	633.58
4TH	1477.52	1195.86	678.63
3RD	1611.95	1327.22	724.44
2ND	1736.33	1457.53	782.35
1ST	1831.54	1563.23	846.73
GF	1874.6	1610.25	891.32

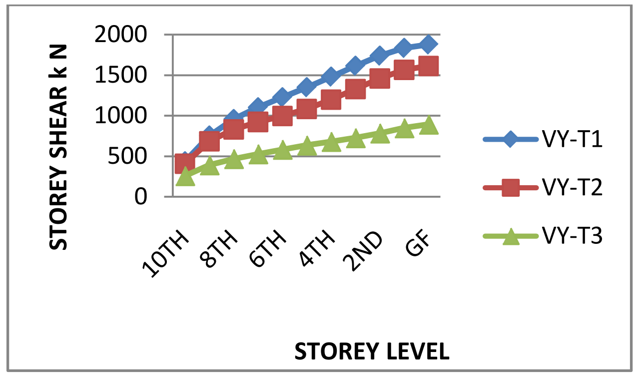

Fig 12: Storey Drift Ration vs Storey Level (Y-direction)

6. CONCLUSION

Here we are mainly dealing with the study of tall irregular buildings with the use of different types of shear wall. The main aim of this study is to find out if in case the different location of shear wall model provide sufficient energy to structure or not.

The results evidenced that the Displacement analysis C-SHAPE model is less earthquake response compare to other shapes in X-direction. L-SHAPE model is in Y-direction

The results evidenced that in the Drift ratio analysis C-SHAPE model is less storey drift compare to other shapes in X-direction. L-SHAPE model is in Y-direction

The results evidenced that in the Drift ratio analysis C-SHAPE model is more storey shear compares to other shapes in X-direction. L-SHAPE model is in Y-direction

The eccentricities between center of mass and center of resistance are more significant to the torsion behavior of structures during an earthquake.

It was found that the shear wall location, shape, size and total number of shear wall in a building acts as an important factor for the building to displace or drift during earthquake.

By this study,

- Displacement can reduce by providing a L-shape shear walls at corners.
- C-shape shear walls perform well but as this shape shear walls are kept at centre, there will be torsion effect in building. Hence using L-shape at corners is good in irregular building.

7. FUTURE SCOPES

- Identifying the seismic response of high rise buildings by doing non linear dynamic analysis to assess the exact response of different location of shear wall.
- Determining the earthquake response of tall irregular building structures by considering different shapes and sizes of shear wall at different locations.
- To check the structural stability by using response spectrum analysis method by using mivan wall.
- Study of various elements dimension of shear wall.

REFERENCES

[1]. Chopra, A.K. and E.F. Cruz, 1986. "Elastic Earthquake Response of Building." Journal of Structural Engineering, 112(3).

[2]. Agrawal, Pankaj and Manish Shrikhande, 2010. Earthquake Resistant Design of Structures: PHL Learning Private Limited, 234-238.

[3]. Banginwar, Rucha S., M.R. Vyawahare and P. . Modani, 2012. "Effect of Plans Configurations on the Seismic Behavior of the Structure by Response Spectrum Method." International Journal of Engineering Research and Applications (IJERA), 2 (3): 1439-1443.

[4]. Costa, Anibal G., Carlos S. Oliveira and Ricardo T. Duarte, 1988. "Influence of Vertical Irregularities on Seismic Response of Buildings." proceedings of ninth world conference on earthquake engineering 5.

[5]. Dubey, S.K. and Sangamnerkar, 2011. "Seismic Behaviour of Assymetric Rc Buildings." international journal of advanced engineering tecknology, 2(4): 296-301.

[6]. Duggal, S.K., 2011. Earthquake Resistant Design of Structures. Sixth Ed. New Delhi: oxford university press.

[7]. FEMA, 2006. "Risk Management Series Designing for Earthquakes Fema 454." In PROVIDING PROTECTION TO PEOPLE AND BUILDINGS.

[8]. Giordano, A., M. Guadagnuolo and G. Faella, 2008. "Pushover Analysis of Plan Irregular Masonry Buildings." In the 14th worl conference on earthquake engineering. Beijing, Chaina, October 12-17.

[9]. Herrera, Raul Gonzalez and Consuelo Gomez Soberon, 2008. "Influence of Plan Irregularity of Buildings." In the 14th worl conference on earthquake engineering. Beijing, Chaina, October 12-17.

[10]. Jaiswal, Dr. O.R., 2000. Seismic Response of Building Frame with Irregular Profile.

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