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Effective Shape of RC Frame Building with their Optimum Location of Shear Wall

Gourav Mandniya, Savita Maru

Abstract*: As per the previous records of earthquakes, there is an increase in the demand of use of earthquake resisting structures. So it is necessary and prime concern of designer to design and analyses the structures by considering seismic effect to provide adequate safety to structure against lateral loads. Many existing RC frame buildings located in seismic zones are deficient to withstand earthquakes. Insufficient lateral resistances, improper shape and poor detailing of reinforcement are the main reasons for inadequate seismic performance of multi-storey building. Shear wall system is one of the most commonly used lateral-load resisting technique for high-rise buildings. Shear walls have very high in-plane strength and stiffness, which can be used simultaneously for resisting large horizontal and gravity loads. In tall buildings, it is very important to ensure adequate lateral stiffness to resist lateral load. The aim of this work is to determine the most effective shape of building with their optimum location of shear wall in multi-storey buildings. For this purpose five different shaped (i.e. square shape, rectangular shape, T-shape, U-shape and H-shape) fifteen storeyed building models each has been with their optimum location of shear wall. Building plan area and shear wall area are same for all different shaped fifteen storeyed building models. Models are analyzed in earthquake zone IV for comparing storey displacement, storey drift, storey shear and time period of buildings. Earthquake load is calculated as per IS: 1893-2016 (Part-1), the various parameters like response reduction factor, importance factor, zone factor are taken from IS: 1893-2016 (Part-1) and are applied to the buildings located in Zone IV. The buildings are modeled and analyzed using software ETAB 2017 and finally concluded that the square shaped building with their optimum location of shear wall is more effective other than different shaped buildings to control the lateral displacement in up to 15 stories buildings.

***Keywords*: ETABS, Optimized Shear Wall, Shape of Building, Storey Displacement, Time Period, Time History Analysis**

I. INTRODUCTION

The population in past few decades has been increased rapidly with a geometrically growth rate. This increase in population has increased the demand of land for both residential and industrials purpose. As the scarcity and high price of available land we have to move on multi-stored structures which come with lots of structural problems.

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As the height of structure increases then the consideration of lateral load and shape of building structures very much important. For that the lateral load resisting system becomes more important in rigid frame multi-storey building system that resists the lateral loads. The lateral load resisting systems that are widely used are rigid frame, shear wall, diagrid structural system, wall frame, braced tube system, outrigger system and tubular system. Recently rigid frame with shear wall systems is the most commonly used in lateral load resisting systems. Shear walls have very high in plan stiffness and strength, which can be used to simultaneously resist large horizontal loads. For the shape of building structure also become more important to resist the seismic and gravitational loads. The structure shapes like square shape, Rectangle shape, T shape, U shape, H shape with shear wall are widely used in rigid frame multi-storey building to resist the seismic loads.

The major criteria now-a-days in designing RCC structures in seismic zones is control of lateral displacement resulting from lateral forces. In this study, investigate and compare the lateral storey displacement, storey drift, Storey Shear and time period of different shaped i.e. square shape, rectangular shape, T-shape, U-shape and H-shape rigid frame multi-storey building with their optimum location of Shear Wall. The building plan area and provided shear wall area for all five shapes of building are same. This five different shaped RC frame G+14 storey structures with their optimum arrangement of shear wall are model and analyses on ETABS 2017 Software.

Non-linear Dynamic Analysis (Time History Analysis) is carried out for five type's different shaped multi-storey building frames and storey displacement, storey drift, storey Shear and time period is calculated from the curves and compared.

II. STRUCTURAL MODELING

A. Geometrical Properties of Buildings

Table- I Geometrical Properties

S. No.	Particular	Dimensions
1	Building Plan Area	900.00 Square meters
2	Ground Storey Height	3.50 meters
3	Typically Storey Height	3.00 meters
4	Column Cross Section size	450 X 450 mm
5	Beam Cross Section Size	300 X 450 mm
6	Shear Wall Thickness	225 mm
7	Shear wall plan area	9.00 Square meters

8	Slab Thickness	150 mm
9	Beam-Column Joint	Rigid
10	Foundation	Fixed at Ground Level

B. Material Properties of Buildings

Table- II Material Properties

S. No.	Material	Grade
1	Concrete (Beam Column)	M30
2	Concrete (Shear Wall)	M30
3	Concrete (Slab)	M30
4	Reinforcement (Rebar)	HYSD-500

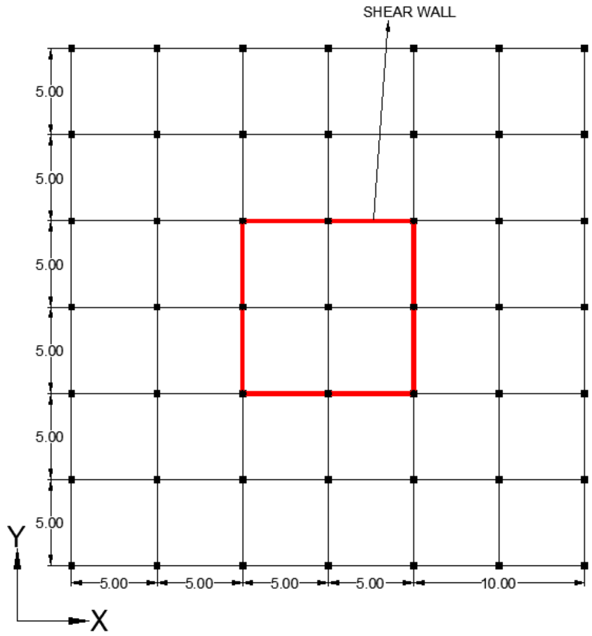

Fig.1. Square shape building plan with their optimum location of shear wall

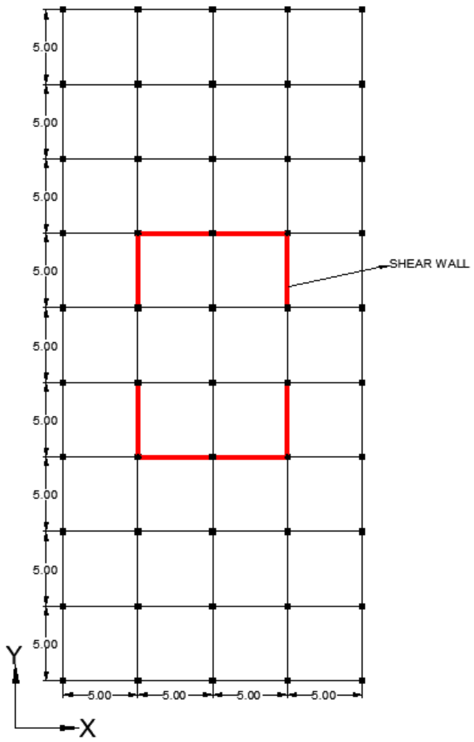

Fig.2. Rectangular shape building plan with their optimum location of shear wall

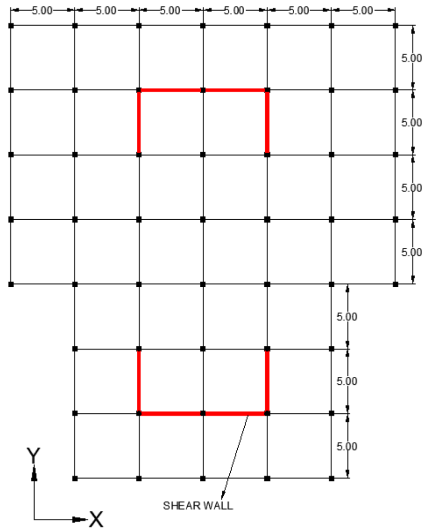

Fig.3. T shape building plan with their optimum location of shear wall

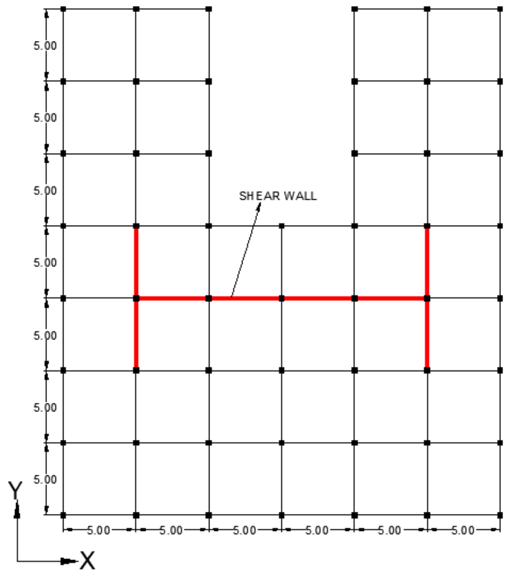

Fig.4. U shape building plan with their optimum location of shear wall

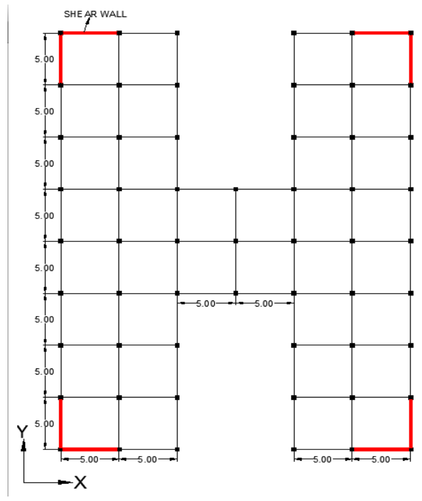

Fig.5. H shape building plan with their optimum location of shear wall

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III. TIME HISTORY ANALYSIS ETABS

A. Time History Analysis: It is an analysis of dynamic response of the structure at each instant of time, when its base is subjected to a specific ground motion time history.

B. Loads: All loads acting on the building except wind load were considered. These are

- Dead Load (member self-weight).
- Super Imposed Dead Load (masonry wall loads and floor finish load).
- Live Loads (as per IS 875 part 2- 1987).
- Lateral Load due to Earthquake (as per IS 1893 part 1-2016).

It was assumed that the wind force is not governing the structure efficiency.

C. Member Loading:

- Self-Weight (software calculated).
- Masonry Wall Load = 10.80 KN/meter.
- Floor Finish Load = 1.75 KN/meter^2.
- Live Load = 3.0 KN/meter^2.
- Earthquake Load in X and Y Direction: Table III shows the seismic data.

Table-III Seismic Data

1	Earthquake Zone	IV
2	Importance Factor	1.20
3	Type of Soil	Medium Soil
4	Response Reduction factor	5
5	Time Period	Program Calculated
6	Damping Ratio	5%

IV. ANALYSIS RESULTS

The analysis of all models has been done and results are shown below. The parameters which were studied are on the behavior of building during seismic excitation are time period, storey displacement, storey drift and storey shear.

A. Time Period: The taken (in second) by structure to compete one cycle of oscillation in its natural mode of oscillation.

Table- IV Time period for structures

Modes	Time Period (sec)				
	Square Shape	Rectangular Shape	T Shape	U Shape	H Shape
Mode 1	1.078	1.853	1.892	2.009	1.955
Mode 2	1.078	1.499	1.087	1.608	1.897
Mode 3	0.856	1.072	0.945	0.702	1.125
Mode 4	0.286	0.401	0.404	0.46	0.409
Mode 5	0.257	0.382	0.263	0.342	0.406
Mode 6	0.257	0.258	0.23	0.207	0.223
Mode 7	0.172	0.186	0.171	0.204	0.173
Mode 8	0.124	0.171	0.126	0.149	0.173
Mode 9	0.122	0.124	0.11	0.126	0.104
Mode 10	0.122	0.123	0.102	0.108	0.103
Mode 11	0.097	0.102	0.083	0.092	0.096
Mode 12	0.08	0.094	0.073	0.091	0.072

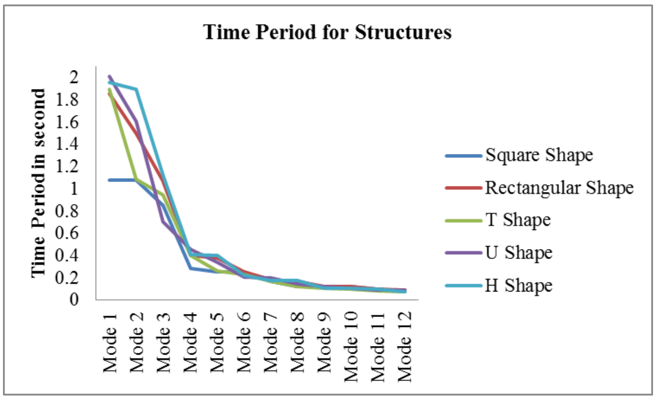

Fig.6. Time Period for Structures

B. Storey Displacement: Storey displacement can be define as "it is the displacement of storey with respect to base of the structure. As per IS 1893 part 1-2016, the storey displacement in both X and Y directions should not be more than H/250, where H is the height of storey from base/ground. Here permissible displacement is 182 mm.

Table- V (a) Storey Displacement

Storey	Storey Displacement in X- Direction (mm)				
	Square Shape	Rectangular Shape	T Shape	U Shape	H Shape
Story15	15.10	13.60	15.30	15.50	23.10
Story14	14.00	12.60	14.20	14.60	21.30
Story13	12.90	11.70	13.10	13.70	19.50
Story12	11.80	10.70	12.00	12.70	17.70
Story11	10.60	9.70	10.90	11.60	15.80
Story10	9.40	8.70	9.80	10.60	14.00
Story9	8.30	7.70	8.60	9.50	12.10
Story8	7.10	6.70	7.50	8.40	10.30
Story7	6.00	5.60	6.30	7.20	8.60
Story6	4.90	4.60	5.20	6.10	6.80
Story5	3.80	3.60	4.00	4.90	5.20
Story4	2.80	2.60	2.90	3.70	3.70
Story3	1.90	1.80	2.00	2.60	2.40
Story2	1.10	1.10	1.20	1.70	1.30
Story1	0.50	0.50	0.60	0.80	0.50
Base	0.00	0.00	0.00	0.00	0.00

Table- V (b) Storey Displacement

Storey	Storey Displacement in Y- Direction (mm)				
	Square Shape	Rectangular Shape	T Shape	U Shape	H Shape
Story15	15.10	21.50	21.80	18.30	22.30
Story14	14.00	19.90	20.20	16.90	20.60
Story13	12.90	18.20	18.50	15.60	18.90
Story12	11.80	16.60	16.80	14.20	17.20
Story11	10.60	14.90	15.10	12.80	15.40
Story10	9.40	13.20	13.30	11.40	13.70
Story9	8.30	11.50	11.60	9.90	11.90
Story8	7.10	9.80	9.90	8.40	10.10
Story7	6.00	8.20	8.20	6.90	8.40

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Story6	4.90	6.50	6.60	5.40	6.70
Story5	3.80	5.00	5.00	4.10	5.10
Story4	2.80	3.60	3.60	3.00	3.70
Story3	1.90	2.40	2.40	2.00	2.40
Story2	1.10	1.30	1.30	1.10	1.30
Story1	0.50	0.50	0.50	0.50	0.50
Base	0.00	0.00	0.00	0.00	0.00

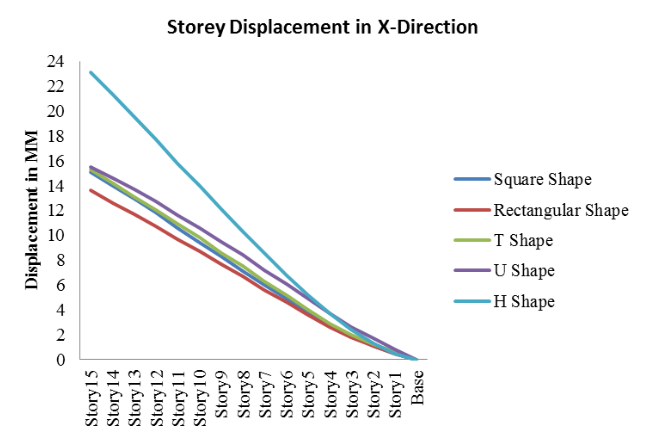

Fig.7(a). Storey Displacement in X- Direction

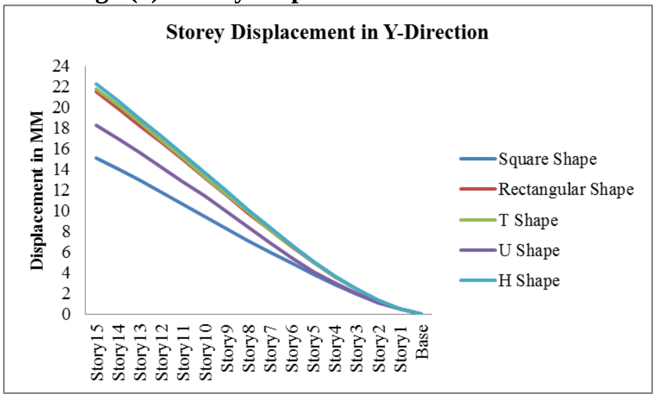

Fig.7(b). Storey Displacement in Y- Direction

C. *Storey Drift:* It is the relative displacement between the floors above and/ or below the storey under consideration. Or Storey drift is the drift of one level of multi-storey building relative to the level below. Or relative displacement between two consecutive storey of multi-storey building. As per IS 1893 part 1-2016 clause 7.11.1, the storey drift in both X and Y direction should not be more than 0.004H, where H is the difference of height between two consecutive storey.

Table- VI (a) Storey Drift

Storey	Storey Drift in X- Direction				
	Square Shape	Rectangular Shape	T Shape	U Shape	H Shape
Story15	0.000367	0.000326	0.000367	0.000322	0.000618
Story14	0.000375	0.000337	0.000384	0.000345	0.000628
Story13	0.00038	0.000349	0.000393	0.000364	0.000632
Story12	0.000386	0.000356	0.000397	0.000375	0.000633
Story11	0.000392	0.000355	0.000399	0.000379	0.00063
Story10	0.000395	0.00035	0.000394	0.000382	0.000623
Story9	0.000391	0.000341	0.000385	0.000383	0.000622
Story8	0.000382	0.000339	0.000384	0.000382	0.000607
Story7	0.000371	0.000345	0.000388	0.000391	0.000578
Story6	0.000358	0.000343	0.000384	0.000395	0.000544
Story5	0.000337	0.000324	0.000362	0.000389	0.000503
Story4	0.000304	0.00029	0.000323	0.000368	0.000446
Story3	0.000264	0.000245	0.000275	0.000335	0.000369
Story2	0.000217	0.000204	0.000227	0.000294	0.000279
Story1	0.000142	0.000144	0.000159	0.000228	0.000142
Base	0	0	0	0	0

Table- VI (b) Storey Drift

Storey	Storey Drift in Y- Direction				
	Square Shape	Rectangular Shape	T Shape	U Shape	H Shape
Story15	0.000367	0.000565	0.00058	0.000499	0.00059
Story14	0.000375	0.000576	0.000591	0.000509	0.000601
Story13	0.00038	0.000581	0.000595	0.000512	0.000606
Story12	0.000386	0.000583	0.000596	0.000509	0.000608
Story11	0.000392	0.000581	0.000593	0.0005	0.000606
Story10	0.000395	0.000575	0.000586	0.000497	0.0006
Story9	0.000391	0.000577	0.000586	0.000499	0.0006
Story8	0.000382	0.000566	0.000574	0.000495	0.000587
Story7	0.000371	0.000542	0.000549	0.000481	0.000561
Story6	0.000358	0.000515	0.00052	0.000454	0.000531
Story5	0.000337	0.000478	0.000482	0.00041	0.000493
Story4	0.000304	0.000426	0.000428	0.000352	0.000439
Story3	0.000264	0.000354	0.000355	0.000291	0.000365
Story2	0.000217	0.000271	0.000271	0.000225	0.000277
Story1	0.000142	0.000141	0.000139	0.000129	0.000142
Base	0	0	0	0	0

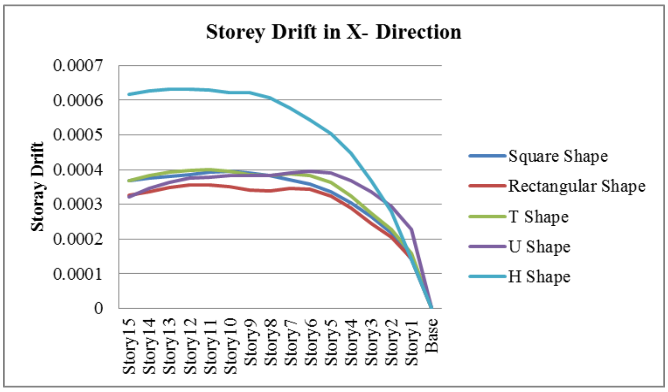

Fig.8(a). Storey Drift in X- Direction

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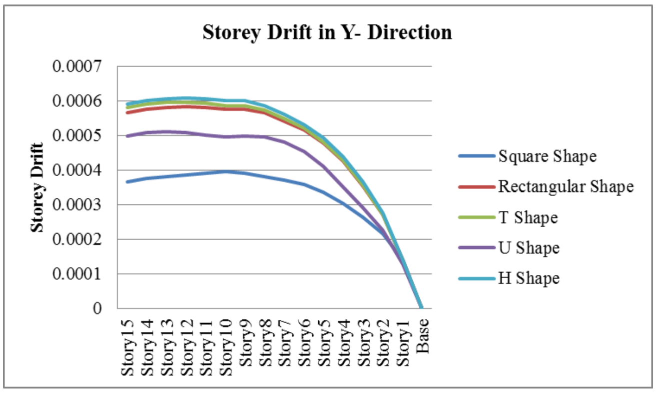

Fig.8(b). Storey Drift in Y- Direction

D. Storey Shear: The design seismic force to be applied at each floor is called storey shear.

Table- VII (a) Storey Shear

Storey	Storey Shear in X- Direction				
	Square Shape	Rectangular Shape	T Shape	U Shape	H Shape
Story15	748.50	846.58	700.12	982.83	432.60
Story14	1410.51	1333.80	1351.91	1914.78	653.26
Story13	1869.24	1903.65	1854.27	2774.11	815.53
Story12	2102.43	2200.41	2134.46	3217.37	968.66
Story11	2193.21	2233.49	2247.73	3294.46	1167.14
Story10	2404.75	2565.56	2337.96	3723.50	1396.28
Story9	2704.91	2709.51	2626.22	4263.43	1672.39
Story8	3113.06	3053.74	3001.67	4727.58	1802.74
Story7	3468.54	3602.50	3598.35	5223.78	1969.68
Story6	3967.97	4460.33	4281.16	6361.07	1975.28
Story5	4449.06	4828.03	4601.59	7058.68	2126.00
Story4	4679.40	4801.62	4696.82	7715.00	2464.65
Story3	5055.28	4884.71	4867.13	8184.97	2756.66
Story2	5375.67	5329.53	5246.74	8486.26	3080.85
Story1	5624.46	5875.95	5660.10	9114.41	3281.03
Base	0.00	0.00	0.00	0.00	0.00

Table- VII (b) Storey Shear

Storey	Storey Shear in Y- Direction				
	Square Shape	Rectangular Shape	T Shape	U Shape	H Shape
Story15	748.50	449.05	428.91	524.23	448.26
Story14	1410.51	690.84	657.32	874.81	677.65
Story13	1869.24	829.94	797.45	1152.55	833.96
Story12	2102.43	935.52	894.90	1269.43	979.24
Story11	2193.21	1153.76	1107.26	1304.80	1190.23
Story10	2404.75	1415.87	1352.44	1504.32	1433.06
Story9	2704.91	1712.69	1635.87	1891.66	1720.39
Story8	3113.06	1841.41	1772.15	2153.32	1846.34
Story7	3468.54	1999.40	1916.32	2489.42	2015.81
Story6	3967.97	2028.54	1945.57	2712.81	2025.63
Story5	4449.06	2158.54	2059.44	2674.04	2186.72
Story4	4679.40	2464.91	2374.30	2655.52	2513.06
Story3	5055.28	2776.17	2671.40	3110.02	2816.52
Story2	5375.67	3178.95	3039.65	3601.05	3171.18
Story1	5624.46	3396.79	3252.45	3978.25	3379.61
Base	0.00	0.00	0.00	0.00	0.00

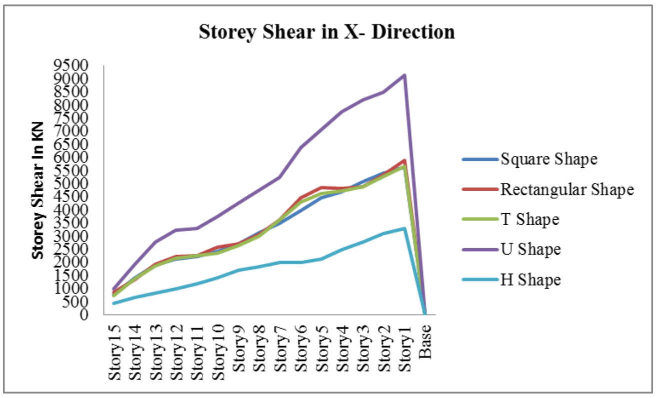

Fig.9(a). Storey Shear in X- Direction

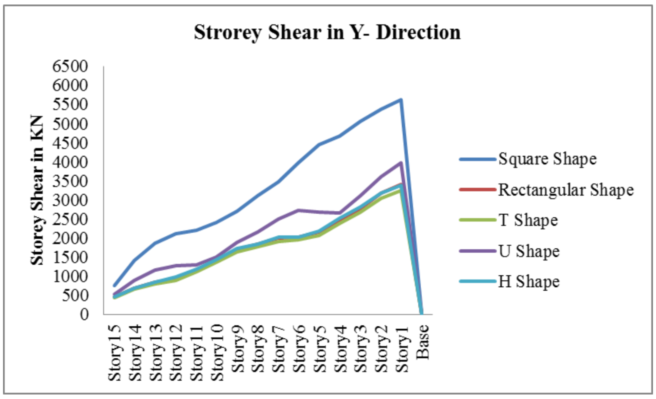

Fig.9(b). Storey Shear in Y- Direction

V. CONCLUSIONS

A Non-linear time history was performed and results were found in terms of time period, storey displacement, storey drift and storey shear. From the results of analysis of the models following conclusions can be down.

1) The shape of structure and their optimum position of shear wall have a significant influenced on the time period. The square shape structure with optimum location of shear wall is better performed because it has low time period.
2) From the comparative study of storey displacement in X and Y direction the storey displacement value of square shape model is smaller than other shape models in Y direction and the value of rectangular shape model is smaller than other shape models in X direction. But the rectangular shape model storey displacement value is two times more than from square shape model. Thus, the square shape model is more effective form other shapes models.
3) From the comparative study of storey drift in X and Y direction the storey drift value of square shape model is smaller than other shape models in Y direction and the value of rectangular shape model is smaller than other shape models in X direction. But the rectangular shape model storey drift value is two times more than from square shape model in Y direction. Thus, the square shape model is more effective form other shapes models.
4) The analysis gives that the value of storey shear is inversely proportional to the width and length of the structure. If the width and length of structure is increase then the storey shear value is decreases.

From the above study concluded that the square shaped building structure with their optimum location of shear wall is more effective other than different shaped buildings to control the lateral displacement in up to 15 stories buildings.

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