Seismic Analysis of Vertically Irregular Buildings Subjected to Seismic Forces as Per IS-1893 (Part-1)-2016 using ETABS

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Abstract - *Most of the multi storey building in the modern era are asymmetrical in shape due to architectural and aesthetic requirements. But the performance of such building during earthquake ground motion generally enlightened at locations of structural deficiency present in the lateral load resisting frames. Due to Rapid drop of the height common type of discontinuity occurs is vertical geometrical irregularity. Two types of vertical geometric irregular frame are taken in this project such as Set back frame and Step Frame. Also vertical geometric irregular frames are analyzed with having one storey basement. Total 32 model are considered in this project such as 8 types (One Regular type RC Frame, four type of Set Back Irregular frame and three type of Step Irregular frame) of frame are having modeled as one irregular frame, second Shear Wall at core, third is shear wall at Periphery and fourth is irregular frame with Basement. Linear Static Dynamic Analysis such as Response Spectrum Analysis has been carried out for seismic zone V specified in IS 1893 (Part I): 2016 to understand the performance characteristics of the irregular frame in comparison with regular RC frame. All building frames are modeled & analyzed in software ETABS 2018. Regular frame with shear wall shows maximum value of base shear. Also regular frame with basement shows the maximum time period among all models. Step frame with basement shows maximum value of storey drift while step frame without shear wall gives maximum value of top storey displacement. The entire frame with basement gives higher value of storey stiffness.*

Key Words: Vertical geometric Irregularities, Basement, Shear Wall, ETABS, Response spectrum analysis, Seismic response parameters.

1. INTRODUCTION

In these recent days, most of the construction is established with architectural significance and it is extremely impossible to program with regular shapes. Lateral loads play a major role in the design of multi storey buildings, choosing a suitable structural system can mitigate the unfavorable dynamic effects on the design of multi storey buildings. One of the major reasons for the failure of RC multi-storey building is its discontinuity in plan. These discontinuities are responsible for structural damage of buildings under the action of dynamic loads. In the latest version of IS 1893 (part-1): 2016, shows different category of vertical geometric irregularities. Setback can be arranged either in one side or in two sides. Setback Ratio is known as the horizontal dimension of the lateral load resisting system in extreme end of setback (A) to the maximum horizontal plan dimension of structure (L). Vertical geometric discontinuity exist, when the lateral dimension of lateral load resisting system in any adjacent storey is more than 150% of that in an adjacent storey. The non-uniform arrangement of mass, stiffness and strength induce structural weaknesses in buildings which are different from the uniform building and damages from the ground shaking. Therefore, a remarkable amount of examination has been received to evaluate the performance of vertical and horizontal irregular buildings.

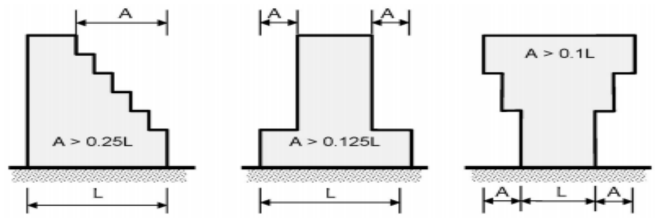


Fig -1: Vertical Geometric Irregularity as per IS 1893-2016

2. LITERATURE REVIEW

Sumit Gurjar and Lovish Pamecha [2017] [1]: In this study they considered the four different types of 20th storey building frame with and without shear wall. Also Study the seismic behavior of regular building frame with vertically irregular building frame using STAAD.PRO software.

Ravikumar C M, Babu Narayan, Sujith B V and Venkat Reddy D [2012] [2]: In this study they considered diaphragm discontinuity, re-entrant corners, geometrical irregularity & buildings resting on sloping ground. The performance was studied in terms of time period, base shear, lateral displacements, storey drift, eccentricity, and performance point as per ATC40 using ETABS software.

Shashiknath H, Sanjith J and N Darshan [2017] [3]: In this study they considered mass irregularity, stiffness irregularity and vertical geometry irregularity. Wind load analysis was done using ETABS software.

Malavika Manilal and S.V Rajeeva [2017] [4]: In this study they considered behavior of re-entrant corner buildings under dynamic loading using ETABS software. They compare the behavior of RC regular and re-entrant frames in zone V.

Mohd Abdul Aqib Farhan [2019] [5]: In this research paper they study the RC building of height G+6, G+9 & G+14 having re-entrant corners are selected for analysis by using ETABS software. Response spectrum Analysis is carried out for varies seismic zones with soil types II (Medium Stiff).

Zabihullah, Priyanka Singh and Mohammad Zamir Aryan [2020] [6]: In this research paper they analyzed G+7 storey one regular frame & six number of irregular frame. All building frames are analyzed and compared by the response spectrum method using ETABS software.

Rahul Ghosh and Rama Debbarma [2017] [7]: In this research paper they analyze seismic performance of setback structures resting on plain ground & slope of a hill, with soft storey. The equivalent static force method, response spectrum method and time history method has been performed.

Kevin Shah and Prutha Vyas [2017] [8]: In this study they considered building with infill masonry walls, mass irregularity and vertical irregularity. This study shows the calculations of storey shear, storey drift and storey displacement of G+14 building which is situated in zone-V with different irregularities.

Patil M. Sadhana and D.N.Shinde [2016] [9]: In this paper five (one regular and four different vertical geometric irregular) RC building frames of G+7 floor are selected. All building frames are analyzed by using ETABS software.

H.M.S.C. Rathnasiri, J.A.S.C. Jayasinghe and C.S. Bandara [2020] [10]: The total 78 stepped frames with varying irregularity and height were analyze by Modal analysis method using SAP2000 software. The proposed index specified in paper can easily quantify the degree of irregularity in vertically irregular RC moment-resisting frames.

Prakash Sangamnerkar and Dr. S. K. Dubey [2013] [11]: In this study they analyze static and dynamic behavior of a six storey building using ETABS Software. It has analyzed structures on all four seismic zones II, III, IV, and V.

Saraswathy B, Udaya K L and Rahul Leslie [2014] [12]: A twelve storey RC framed building with masonry infill wall is considered in the this paper. Building models with and without setbacks generated using SAP 2000.

Dileshwar Rana and Prof. Juned Raheem [2015] [13]: In this study they change in different seismic response parameters along the increasing height and increasing bays. Also compare between regular and vertical irregular frame on the basis of shear force, bending moment, storey drift, & node displacement etc.

Pradeep Pujar and Amaresh [2017] [14]: In this work they considered three types of structures such as I-shape, L-shape, C-shape having ten stories, where three model of bare frame and three model with shear walls. The analysis is done by Equivalent static method with help of ETABS 2015.

3. RESEARCH GAP

All the past research studies is based on vertical geometric irregular structures with having different functionality criteria which is based on different structure frame, seismic zone, random setback ratio, Irregularities Index, countries code, height etc. But none of them are discussing the performance of the Vertical Geometric Irregular structures such as Stepped Frame & Set Back Frame having various Set Back Ratios with Shear Wall at core & periphery of building. Irregular building having basement is also taken.

4. OBJECTIVE

The objective of this work is as follows:

1. To obtain the Seismic performances of different irregular buildings located in severe earthquake zone (V) of India and also identify the most vulnerable building among them.
2. To investigate the behavior of vertical geometric irregular buildings such as Setback frame and Stepped frame under dynamic loading.
3. To study the performance of Vertical Irregular Frames with having Shear Wall at Core & Periphery.
4. To carry out Linear Dynamic Analysis method such as Response Spectrum Analysis method for both regular and irregular models using software ETABS 2018.
5. To study the behavior of irregular building having one storey Basement.
6. To perform a comparative study of the various seismic parameters such as Maximum Lateral Displacement, Story Drift, Story Stiffness, Base Shear & Time Period of different types of reinforced concrete moment resisting frames (MRF) having Vertical Geometric Irregularities.

5. METHODOLOGY

Two type of vertical geometric irregular frame is taken in this project such as Set back frame and Step Frame. Also vertical geometric irregular frames are analyzed with having one storey basement. Total 32 model are considered in this project such as 8 type (One Regular type RC Frame, four type of setback Irregular frame and three type of Step Irregular frame) of frames are modeled as one Irregular Frame, second is Shear Wall at Core, third is Shear Wall at Periphery and fourth is Irregular Frame with Basement. Linear Static Dynamic Analysis such as Response Spectrum Analysis has been carried out for seismic zone V specified in IS 1893 (Part I): 2016 to understand the performance characteristics of the irregular frame in comparison with regular RC frame using software ETABS 2018.

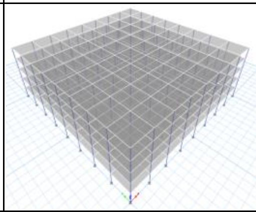
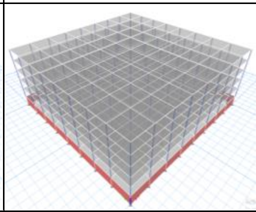
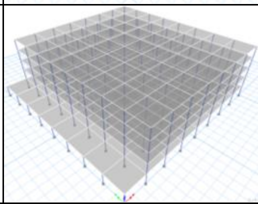
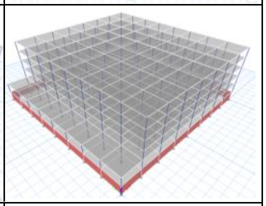
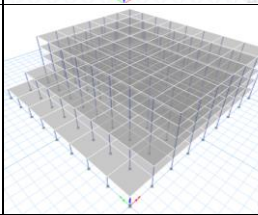
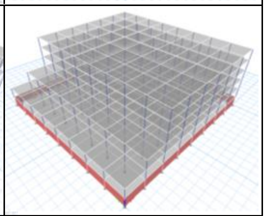
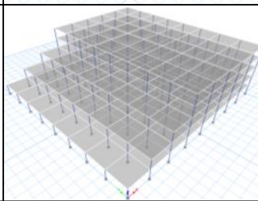
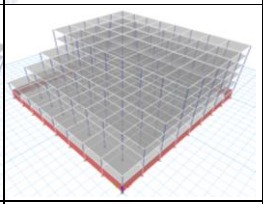
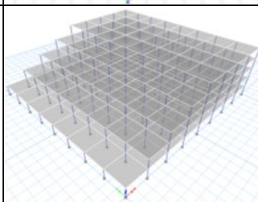
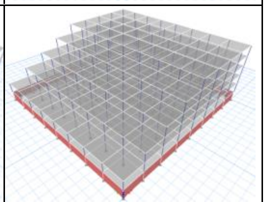
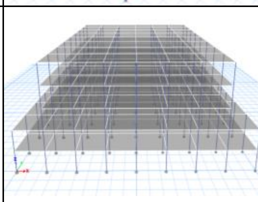
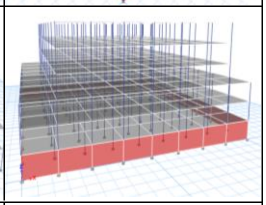
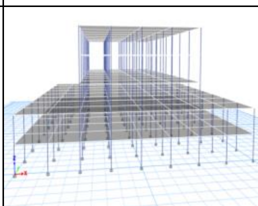
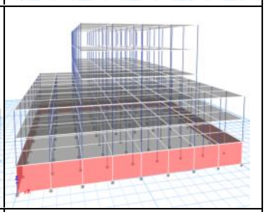
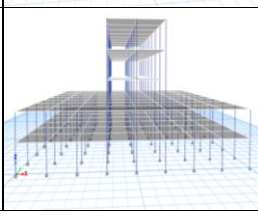
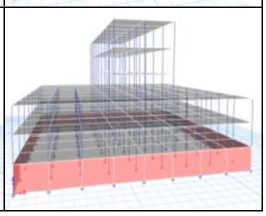
6. MODEL DATA

Table -1: Model data

Geometric Parameters	
Typical Storey Height	3m
Storey Height	3m
Number of Floors	5
Height of Basement	3m
Total dimension of plan in X-direction	8 bays @ 5m = 40m
Total dimension of plan in Y-direction	8 bays @ 5m = 40m
Dimension of Members	
Column Size	600mm x 600mm
Beam Size	300mm x 530mm
Slab Thickness	150mm
Thickness of Wall	225mm
Thickness of Shear Wall	150mm
Thickness of Basement Wall	150mm
Material Properties	
Grade of Concrete	M25
Grade of Steel	Fe 500
Loads Taken	
Unit weight of RCC	25 kn/m3
Unit weight of Masonry	19 kn/m3
Floor Finish Load	1 kn/m3
Live Load	3 kn/m3
Seismic Parameters	
Seismic Zone Factor	0.36 (V)
Response Reduction Factor	5
Importance Factor	1
Type of Soil	Medium (II)
Damping Ratio	5%
Support Condition	Fixed
Frame Type	MRF

Table -2: 3D view of structure models

[**Note:** RG= Regular, SB= Set Back, ST= Step]

Frame Type	SB Ratio	Regular [1]	Basement [4]
RG	0 [A]		
SB	0.125 [B]		
	0.25 [C]		
	0.375 [D]		
	0.5 [E]		
ST	0.125 [F]		
	0.25 [G]		
	0.375 [H]		

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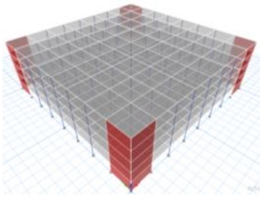
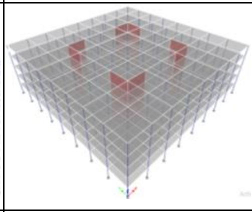
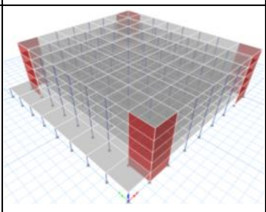
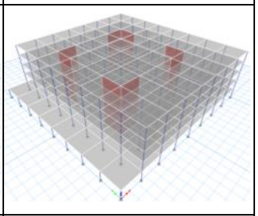
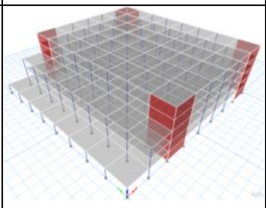
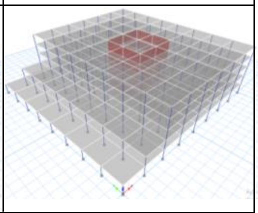
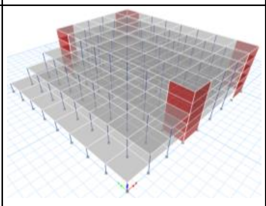
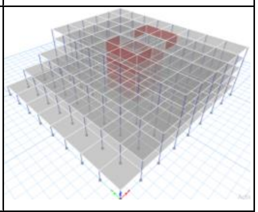
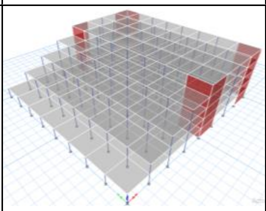
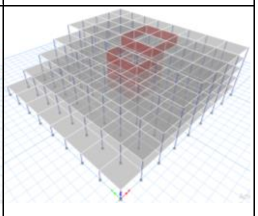
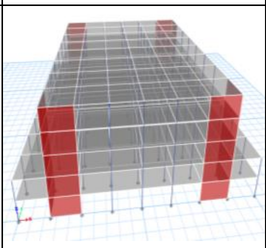
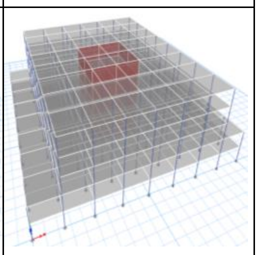
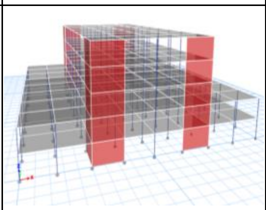
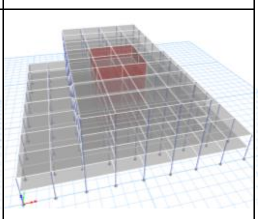
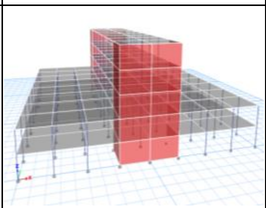
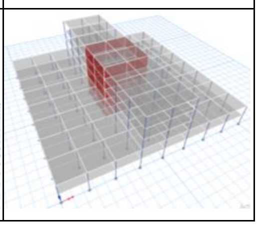
Frame Type	SB Ratio	Shear Wall @ Periphery [2]	Shear Wall @ Core [3]
RG	0 [A]		
SB	0.125 [B]		
	0.25 [C]		
	0.375 [D]		
	0.5 [E]		
ST	0.125 [F]		
	0.25 [G]		
	0.375 [H]		

7. RESULT

Maximum value of base shear, storey displacement, storey stiffness, storey drift and time period are taken from the software. The comparison of regular, set back and step frame for the parameters mentioned above presented in tables and charts below.

Table -3: Maximum value of base shear and top storey displacement in X & Y direction

	Max. Base Shear (KN)		Max. storey Displacement (mm)	
	X direction	Y direction	X direction	Y direction
A1	11777.97	11777.97	23.614	23.614
A2	16034.68	16034.68	11.202	11.202
A3	16034.68	16034.68	11.373	11.373
A4	13546.33	13546.33	27.55	27.55
B1	10846.04	10796.77	27.034	26.882
B2	14520.28	14520.28	10.552	10.729
B3	14520.28	14520.28	10.619	11.599
B4	12765.47	12727.9	31.623	31.693
C1	10380.79	10115.45	27.814	27.872
C2	13763.08	13763.08	10.009	9.794
C3	13384.48	13384.48	7.02	6.189
C4	12446.95	12172.57	32.666	33.09
D1	10269.23	9724.385	28.309	28.878
D2	12627.28	12627.28	9.542	9.645
D3	12615.67	12615.67	6.727	6.939
D4	12459.12	11876.84	33.217	34.264
E1	10318.93	9592.189	29.195	30.49
E2	12248.68	12248.68	9.138	8.451
E3	12212.67	12212.67	6.653	6.926
E4	12582.14	11802.91	32.969	34.697
F1	10853.24	10844.69	27.858	26.371
F2	13763.08	13763.08	10.165	9.818
F3	13763.08	13763.08	7.118	6.153
F4	12902.06	12894.79	32.516	30.887
G1	9804.18	9877.103	31.242	27.605
G2	11491.47	11491.47	9.433	8.281
G3	11491.47	11491.47	6.364	4.669
G4	12202.98	12291.09	36.537	32.499
H1	8693.062	8809.929	39.839	31.048
H2	9219.871	9219.871	8.03	6.384
H3	9219.871	9219.871	6.426	3.484
H4	11575.62	11992.37	45.797	36.954

[**Note:** Yellow colored cell shows the maximum value of properties]

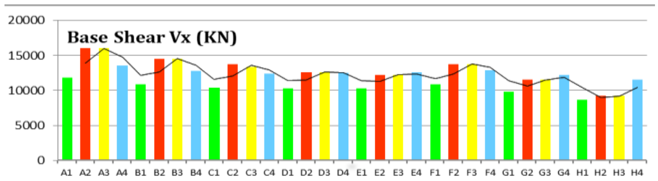


Chart -1: Maximum Base Shear in X direction

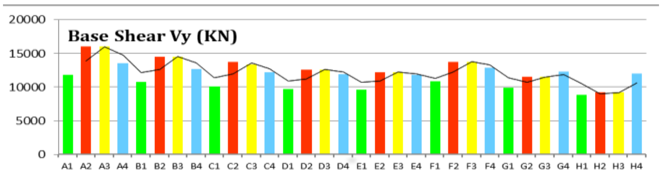


Chart -2: Maximum Base Shear in Y direction

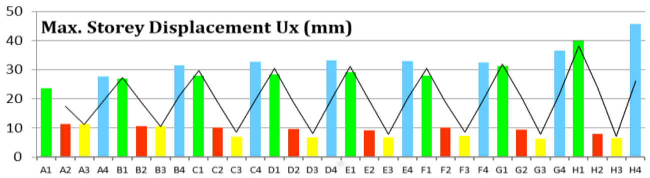


Chart -3: Maximum Storey Displacement in X direction

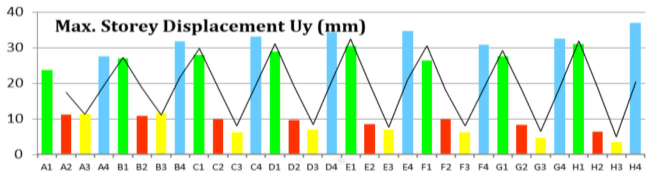


Chart -4: Maximum Storey Displacement in Y direction

Table -4: Maximum value of storey stiffness in X & Y direction, storey drifts and time period

	Storey Stiffness (KN/m)		Max. Storey Drift	Max. Time Period (Sec)
	X direction	Y direction		
A1	3504478	3504478	0.002	0.722
A2	13637484	13637484	0.000909	0.406
A3	14248609	14248609	0.000903	0.392
A4	20578419	20578419	0.002356	0.764
B1	3462365	3557089	0.002353	0.711
B2	13750907	14019859	0.000871	0.388
B3	13982357	14454763	0.000917	0.386
B4	20066321	21158808	0.00273	0.748
C1	3442375	3500101	0.002475	0.698
C2	13815365	14358244	0.000872	0.369
C3	18727038	20500146	0.000588	0.389
C4	20015034	21332691	0.002838	0.732
D1	3448365	3485076	0.002433	0.683
D2	13833352	14383898	0.000854	0.348
D3	19041945	21087026	0.00056	0.365
D4	20026349	21257650	0.002928	0.715
E1	3456273	3483080	0.00273	0.671
E2	13566757	14479832	0.000788	0.334
E3	18911624	21401261	0.000572	0.357
E4	20094534	21330718	0.002973	0.702
F1	3510503	3508169	0.002426	0.67
F2	13606231	13929991	0.000859	0.367
F3	18464948	18395719	0.000585	0.389
F4	20726609	20704386	0.002651	0.707
G1	3550339	3551502	0.002838	0.615
G2	13576546	14109453	0.000835	0.325
G3	18303040	18296650	0.000539	0.315
G4	20769249	20865630	0.003139	0.645
H1	3683578	3686481	0.004014	0.551
H2	17319269	14226857	0.000796	0.247
H3	18001967	18003884	0.000577	0.254
H4	20967496	21075358	0.004293	0.574

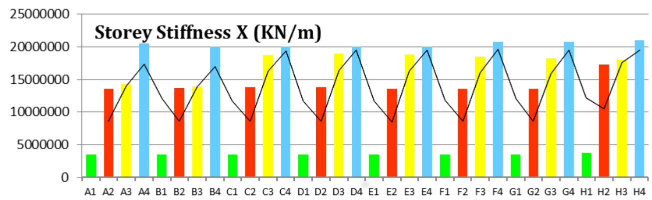


Chart -5: Maximum Storey Stiffness in X direction

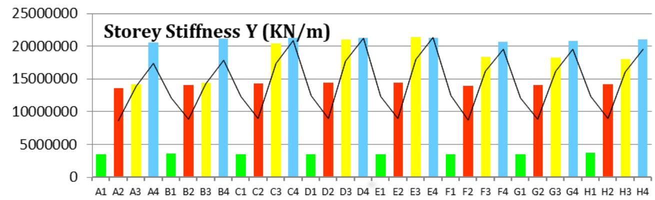


Chart -6: Maximum Storey Stiffness in Y direction

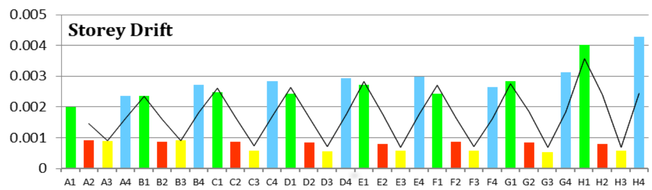


Chart -7: Maximum Storey Drift

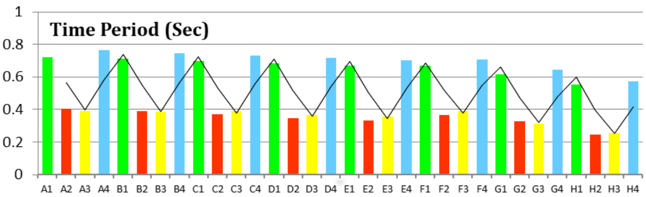


Chart -8: Maximum Time Period

8. OBSERVATION

1. The value of base shear show maximum in shear wall type of frames in both directions. Shear Wall at periphery and at core shows very close value of base shear. Due to setback of irregular frame the weight of structure decrease, for that irregular frame show lower value of base shear compare to regular frame. Hence, regular frame with shear wall shows maximum value of base shear in both directions.
2. The basement and regular type of frames show the maximum top storey displacement in both directions. Also the Step frames with higher set back ratio show the maximum top storey displacement. Hence, Step Frame without shear wall shows the maximum top storey displacement in both directions.
3. The regular frame and irregular frame show the close value of storey stiffness. Also frame with basement increase the value of stiffness. Hence all frames with basement shows higher value of storey stiffness.
4. The shear wall decreases the value of storey drift. Also Step frame with higher setback ratio shows higher value of storey drift. Hence step frame with basement show maximum value of storey drift among all models.
5. Height of structure is directly proportional to the time period of structural frames. Also regular frame shows higher value of time period rather than irregular frames. Hence regular frame with basement shows the maximum value of time period among all models. Hence regular frame with basement shows the maximum value of time period among all models.

9. RESULT

The main observations and conclusions are summarized below.

1. Regular frame with having shear wall shows maximum value of base shear in both directions.
2. Step Frame without shear wall identifies the most vulnerable building among them in case of maximum top storey displacement in both directions.
3. All frame with basement show the higher value of storey stiffness.
4. Step frame with basement is most vulnerable among all in case of storey drift.
5. Regular frame with basement shows the maximum value of time period among all models.

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