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Pushover analysis of setback frame & step frame building with and without shear wall by using ETABS

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Abstract - *This study focuses on the pushover analysis (Non-linear Static Analysis) of structure. The current building codes and design standards only offer a small amount of performance-based or prescriptive advice on the study and design of structures. And give overviews on the pushover analysis of setback frame & step frame buildings. And also analyze and design of setback frame & step frame building with G+5 story. The durability and economy of the structure are the focus of this article. For the current study, basic parameter including story drift, base shear and story displacement were examined. Along with guidelines of IS 875, analysis of building is done considering dead load, live load depending upon the requirement and function of the structure.*

Key Words: *Seismic analysis, Pushover analysis, Setback & Step Building, Vertical geometric Irregularities, Basement Wall, Shear Wall, ETABS, Response Spectrum Analysis, Story drift, Story Displacement, Base Shear*.

1.INTRODUCTION

General

It is quite challenging to plan with irregular shapes in today's world because the great majority of development is set up with structural importance. Because of their functional and fashionable design, irregular shaped constructions are in demand.in the design plan, sidelong forces have a fundamental impact. Because of its irregular behavior and great eradication power, tremor is quite perhaps the most terrible horizontal forces. Building setbacks fall in during extreme ground shaking and cause direct scattering of individual lives. Over the past few years, various investigation has been carried out internationally to determine the cause of the failure of various types of designs under extreme significant stress. Its discontinuity in the arrangement is one of the crucial probabilities for the failure labor of the RC multi story construction. It is quite challenging to plan with irregular shapes in today's world because the great majority of development is set up with structural importance.

Because of their functional and fashionable design, irregular shaped constructions are in demand.in the design plan, sidelong forces have a fundamental impact. Because of its irregular behavior and great eradication power, tremor is quite perhaps the most terrible horizontal forces. Building setbacks fall in during extreme ground shaking and cause direct scattering of individual lives. Over the past few years, various investigation has been carried out internationally to determine the cause of the failure of various types of designs under extreme significant stress. Its discontinuity in the arrangement is one of the crucial probabilities for the failure labor of the RC multi story construction.

1.1 What are Vertical Geometric Irregularities?

In IS 1893(part 1): 2016, three types of mathematical constructions are shown, including the step frame, set back frame and floating column. The earthquake impacts of designs with vertically geometrical irregularity and located in seismic zine III, IV, and V will be evaluated using the investigation strategy.

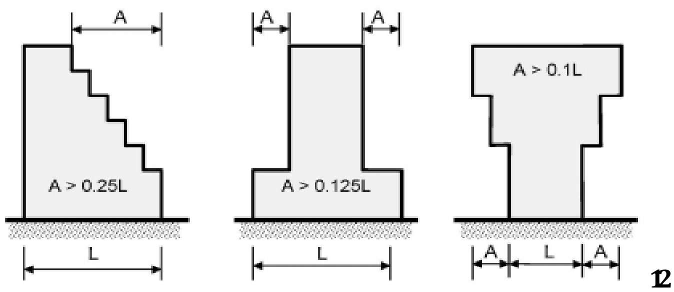


Fig 1.1: Vertical Geometric Irregularity as per IS 1893(Part 1) – 2016

Pushover Analysis

To determine the estimated seismic requirements for building structures of non-linear static analysis or pushover analysis is used more and more. Since buildings display nonlinear behavior during earthquakes, nonlinear analysis must be used to determine whether or not the structure is performing as desired. One of the most significant study areas in seismic engineering over the past ten years has been the performance-based design (PBD) technique.

Determining the desired deformation for every resisting element until its failures allows the nonlinear static evaluation of the asymmetric buildings to take the torsion effects into account. Once the target displacement is obtained, the base shear is applied in increasing amounts.

Knowing the maximum base shear, the structure can withstand for the member within the permitted displacement is made possible by this.

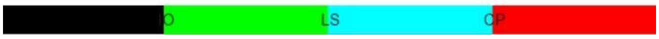
There are two steps in the pushover methods. A desired displacement for the building is first determined. When exposed to the design earthquake excitation, the target displacement is an estimation for the top displacement of the building. Following a pushover analysis in which the buildings top displacement is equal to the desired displacement, a force-controlled type analysis is performed in which the total amount of acting force is estimated, applied to the structure, and the study is completed.

2. Response Spectrum Method

A response spectrum is a powerful tool in the linear dynamic evaluation and building design. It offers a useful method for examining the most extreme response of all potential direct SDOF structures to an indescribable components of ground motion. Additionally, it provides a practical way to apply the ability of underlying components to the design of primary edges and the development of parallel burden requirements in building legislation. The most influential aspects of a reaction sum are divided into the response spectrum, which serves as explanation for the plan's typical swaying duration.

Hinge formation

The result of the pushover analysis shows how the plastic hinges develop and how they are doing at different degrees of building performance. This provides details on the structure's weakest link. Thus, it is possible to identify the member that needs to be strengthened in the event that a building needs to be retrofitted. In order to obtain the desired pattern of failure of members in the event of powerful earthquakes, the members details can be done appropriately. To show the state of the hinge at various phases, the acceptance criteria IO (Immediate occupancy), LS (life safety), and CP (collapse prevention) are each represented by a different color.



Literature Review

N. Lingeshwaran, Sartasala koushi [2020] [1]: In this present study they have modelled asymmetric & symmetric buildings like, L-shape, T-shape, H-shape and rectangle shape building for G+9 story by using ETABS. the structures have been constructed with seismic forces considered according to IS 1893 (PART 1):2016. This paper main goal is comparison the variations in story displacement and story drift in different buildings. They have seen during earthquakes; symmetrical buildings perform better than asymmetrical structures.

Dona mary daniel, Shemin T. John [2016] [2]: In this present paper examines the seismic response of a 10-story reinforced concrete structure by using displacement-controlled pushover analysis. It is located in seismic zone III. The frame building analysed and designed by using SAP2000 software. Moment curvature relationships are utilized in nonlinear static analysis to model the behavior of plastic hinges. In order to represent user defined hinges for column and beam section, this software was created. The end of the column and beam sections were given moment (M) and interactive P-M hinges, respectively.

Singisala Satyanarayana, T Sai Keertan [2019] [3]: In this study pushover analysis of RCC frames using ETABS was performed with and without vertical irregularity under the loading in order to compare and examine the relative weights of various parameters in the nonlinear analysis of RCC frames. Included in this is the variance in the load displacement graph, such as the pushover curve, story shear, inter story drifts, lateral displacement, hinges properties, and performance point.

Prof. Milind V. Mohod [2015] [4]: The purpose of this research is to investigate and comprehend the critical behavior of irregular plan structure under seismic excitation. The main variables used to determine the performance point of each of the nine models created in the ETABS 9.6.2 modelling programmed were lateral displacement, story drift, base shear and story displacement. Pushover curve and hinge formation data from all 9 models are shown in software output, which raises awareness of the need to design straightforward buildings to lessen the impact of earthquakes.

Nuthan L pathani, Guruprasad T N. [2015] [5]: In this study focuses on the seismic performance of reinforced concrete (RC) buildings with G+6 story that are both regular and irregular. This has been accomplished using the finite element computer program ETABS (v. 9.7.1). in terms of static linear equivalent static lateral force method (ESLM) and non-linear analysis (Pushover), the study as a whole aim to access the effect of vertical irregularity on RC buildings. The structures performance is measured using the response parameters base shear, lateral displacement, story drift and performance point. The analysis has been done for soil type III (soft soil) conditions in India's ZONE II and V.

Pradip Sarkar, A. Meher Prasad. [2022] [6]: This research suggested a new approach to evaluate irregularity in such building frames while taking dynamic properties (mass and stiffness) into account. The 'regularity index' that has been proposed gives a framework for evaluating the severity of irregularities in stepped building frames. In order to estimate the fundamental time period of the stepped building frame, this study also suggests modifying the empirical formula stated by the code for estimating fundamental period for regular frames. The regularity index is represented as a function in the suggested equation for basic time intervals. It has been tested with numerous stepped irregular frame types.

Rahul Ghosh, Rama Debbarma. [2017] [7]: In this paper they dissect seismic execution of irregular structures resting on flat ground and sloping ground, with delicate story. The investigation has been performed with three strategies, the same static force method, response spectrum technique and time history technique. The limit reactions recorded for open ground story difficulty building.

Md. Abdul Alim, Md. Nazrul Islam [2017] [8]: In this present study due to the absence of walls with comparable properties to those found in the other levels, the soft story is the one in which stiffness is lower than that of the others. If the partitioning wall and the vertical load bearing structural components extend through all floors, the construction is not a soft story. Typically, the soft story is found at a building's entry level (below). Because the entrances to the building are also utilized as a bank branch, store, restaurant, office and parking spaces above stores.

Patil Sadhana M., D.N. Shinde. [2016] [9]: In this study, 5 RC building frames one regular and four different vertical geometric irregulars are chosen. To get performance points, the RC building frame with G+ 7 stores is taken into account. According to IS 456:2000 and IS 1893:2002, all building frames are examined using the ETABS software.

Pradeep Pujar, Amaresh. [2016] [10]: In this work, they take consideration of three different types of constructions, such as I, L, and C shapes with ten stores, and created three models of uncovered buildings as well as three models with shear walls. With the help of ETABS 2015, a comparable static procedure is used to complete the test. Without shear wall structures, seismic boundaries such as story displacement, story float, and base shear of design are contrasted. They also took into account how the earthquake impact may affect the arrangement anomaly in certain participant corner structures.

Research Gap

All of the earlier exploratory studies were based on vertical irregularities construction with unique usefulness metrics that were based on different design elements, seismic zones, arbitrary setback ratio, irregularity indices, nations codes, stature, and so on. However, none of them are examining the exhibition of the pushover analysis like setback frames and step frames having different set back ratio with shear wall at center and periphery and basement wall provide at base of building.

Objectves

1. Comparison the result of regular & irregular buildings.
2. The Seismic earthquake of various irregular structures situated in earthquake zone (III) of India.
3. To examine the conduct of Set Back frame and step frame with different ratio.
4. To examination indicates of Vertical irregular building with having Shear wall at Center and periphery.
5. To complete Non-Linear static Analysis technique, for example, Response Spectrum method.
6. Generation of building models using by ETABS 17
7. To investigation the conduct of basement wall at one story cellar.
8. To find out the different seismic parameters such as Horizontal displacement, Story drift, Story shear, Base Shear.
9. Study various drawings and design of RC frame building.

Methodology

Two types of irregular frames are taken in this study such as step frame and set back frames. Also, irregular frames are analyzed with having one story basement. Total 32 models are considered in this study such as eight types (one regular type RC frame, three type of step frame and four type of setback frame) of frames are modeled as one irregular frame, second is shear wall at periphery, third is shear wall at core and fourth is basement wall with irregular frame. Nonlinear static analysis such as response spectrum analysis has been carried out for

seismic zone III specified IS 1893(part 1):2016 to understand the performance characteristics of the irregular frame in comparison with regular frame using ETABS 2017.

Model Data

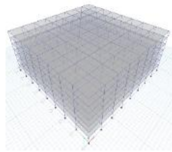
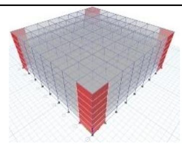
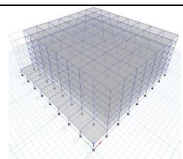
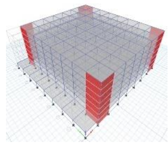
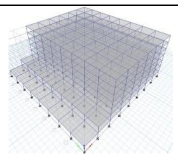
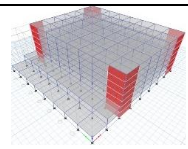
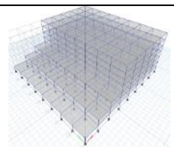
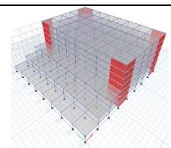
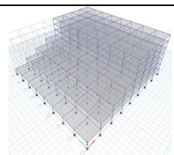
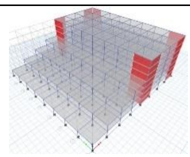
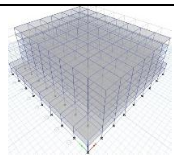
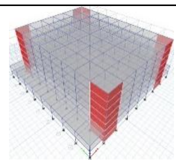
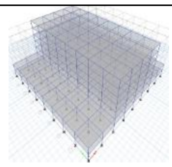
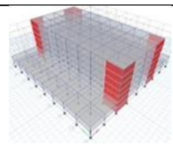
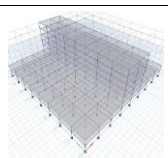
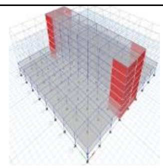
Table1: Preliminary data

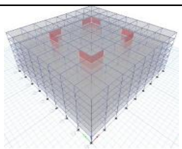
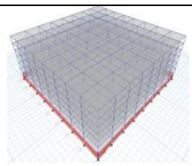
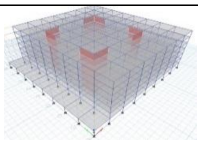
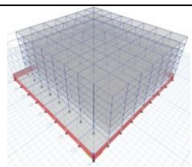
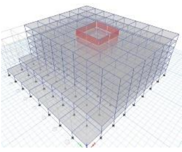
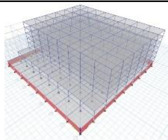
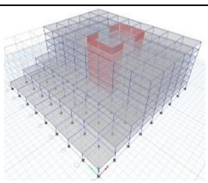
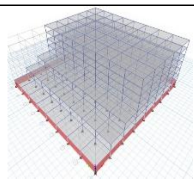
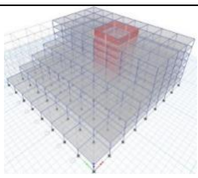
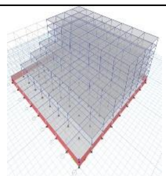
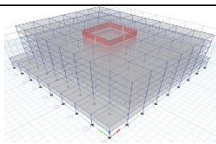
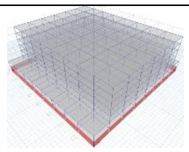
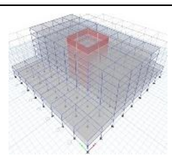
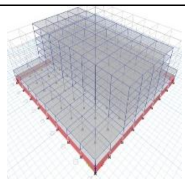
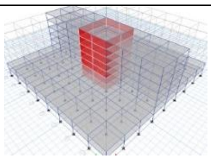
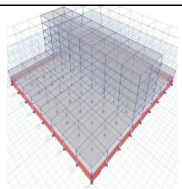
Mathematical Parameters	
Average Story Tallness	3m
Story Tallness	3m
Number of Floors	7
Tallness of Cellar	3m
Total dimension of plan in X-direction	8 bays @ 6m = 48m
Total dimension of plan in Y-direction	8 bays @ 6m = 48m
Dimension of Members	
Column Size	600mm x 600mm
Beam Size	530mm x 600mm
Slab Thickness	150mm
Thickness of Wall	230mm
Thickness of Shear Wall	150mm
Thickness of Basement Wall	250mm

Material Properties	
Grade of Concrete	M30
Grade of Steel	Fe 550
Loads Taken	
Unit weight of RCC	25 KN/m^3
Unit weight of Masonry	19 KN/m^3
Floor Finish Load	1 KN/m^3
Live Load	3 KN/m^3
Dead Load	2 KN/m^3
Seismic Parameters	
Seismic Zone Factor	0.16 (III)
Response Reduction Factor	5
Importance Factor	1
Type of Soil	Medium (II)
Damping Ratio	5%
Support Condition	Fixed
Frame Type	MRF

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

Table: 3D view of building models

frame	SB ratio	Regular	Shear wall @ periphery
RG	0 [P]		
ST	0.125[Q]		
	0.25[R]		
	0.375[s]		
SB	0.5[T]		
	0.125[U]		
	0.25[V]		
	0.375[W]		

frame	SB ratio	Shear wall @ core	Basement wall
RG	0 [P]		
ST	0.125[Q]		
	0.25[R]		
	0.375[s]		
SB	0.5[T]		
	0.125[U]		
	0.25[V]		
	0.375[W]		

Result

Max. value of base shear, Displacement, story drift and story shear are taken from the software. The comparison of regular, set back and step frame for the parameters mentioned above presented in tables and chart below.

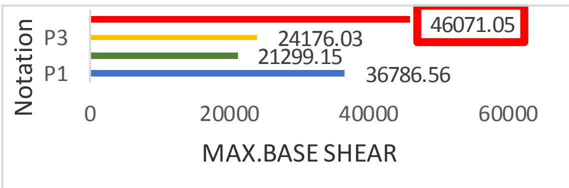
Notation	Max. Base Shear	Max. Displacement	Max. Story Drift	Max. Story Shear
P1	36786.56	69.09	0.0047	45469.94
P2	21299.15	49.23	0.00276	68658.78
P3	24176.03	48.076	0.00270	69832.39
P4	46071.05	61.267	0.0046	46303.72
Q1	34532.49	73.29	0.00501	40732.72
Q2	17424.78	47.48	0.00267	62719.34
Q3	22028.914	47.48	0.00266	55557.28
Q4	41415.05	61.88	0.00475	41059.29
R1	33491.82	77.25	0.00523	37240.97
R2	24607.81	45.568	0.00256	57623.96
R3	42890.74	29.95	0.0017	62633.15
R4	39509.28	64.07	0.00494	36330.34
S1	33552.2	77.10	0.00512	34936.46
S2	21980.94	43.265	0.00242	53524.96
S3	24742.92	40.68	0.0023	56191.67
S4	39234.18	65.99	0.005	33102.88
T1	34166.96	80.10	0.0048	33629.36
T2	22383.47	39.07	0.0022	49070.07
T3	46225.23	23.36	0.00139	52101.87
T4	40471.44	69.43	0.005	31808.91
U1	34787.5	67.76	0.0046	38739.95
U2	21418.49	45.33	0.0025	58838.10
U3	44041.58	28.87	0.0016	63911.85
U4	42271.24	59.59	0.0045	37419.61
Notation	Max. Base Shear	Max. Displacement	Max. Story Drift	Max. Story Shear
V1	33047.34	66.45	0.0046	31233.59
V2	25738.03	37.89	0.0021	45882.00
V3	44799.94	22.03	0.012	48624.44
V4	33148.58	61.30	0.00	27939.07
W1	24731.41	65.43	0.0050	24515.64

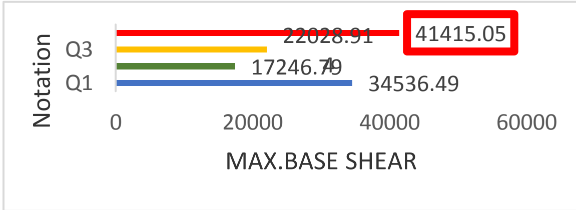
W2	45603.18	25.28	0.0014	34236.33
W3	50905.54	14.89	0.00083	34429.71
W4	25440.45	58.02	0.0048	20209.85

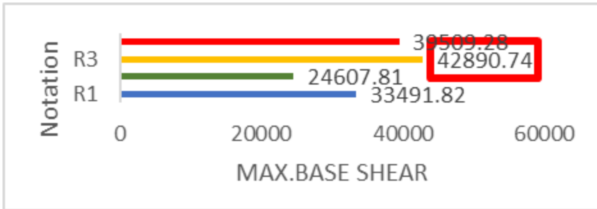
Hinge Formation

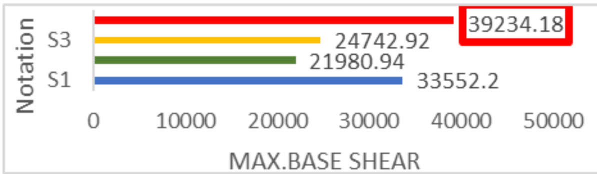
B to IO		IO to LS		LS to CP		C to D	
X	Y	X	Y	X	Y	X	Y
0	0	21	18	7	15	59	148
0	0	0	34	0	34	0	78
0	0	0	8	0	4	6	182
0	0	32	30	0	15	81	83
0	0	92	74	27	0	0	0
0	0	0	0	0	0	0	0
0	0	4	4	0	0	0	0
0	0	125	0	63	0	0	0
0	0	132	38	0	0	47	2
0	0	0	0	0	0	0	2
0	0	0	0	0	0	2	2
0	0	19	35	49	0	0	4
0	0	0	0	0	4	0	79
0	0	0	52	0	0	0	65
0	0	119	80	12	0	4	46
0	0	0	0	0	6	0	2
0	0	0	8	0	0	0	0
0	0	82	46	0	4	0	85
0	0	0	0	7	36	0	26
0	0	0	34	0	18	2	0
0	0	125	8	0	0	0	0
0	0	0	30	0	0	0	49
0	0	89	74	0	6	4	148
0	0	132	0	23	0	0	89
0	0	0	0	0	0	0	0
0	0	0	18	0	4	0	0
0	0	125	38	0	2	0	79
0	0	112	0	0	15	2	4
0	0	0	28	69	34	2	2
0	0	89	0	0	0	0	2
0	0	0	0	0	0	0	78
0	0	0	8	49	4	71	173
Total		1294	665	306	118	280	1426

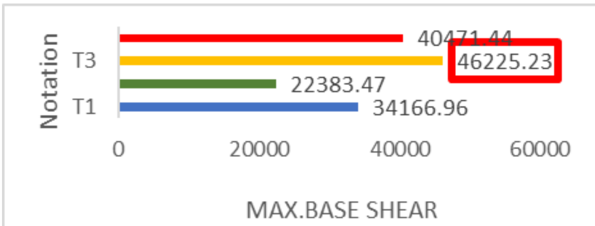
Table: Maximum Value of Base shear

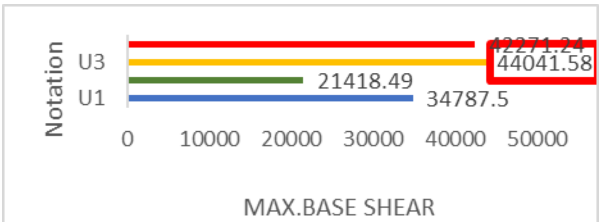


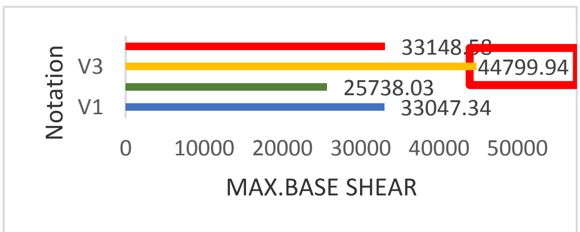












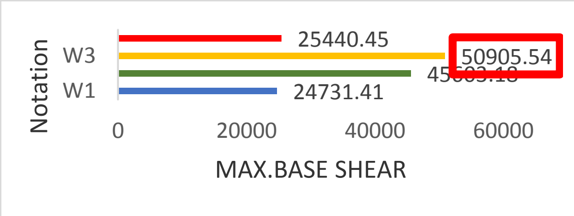
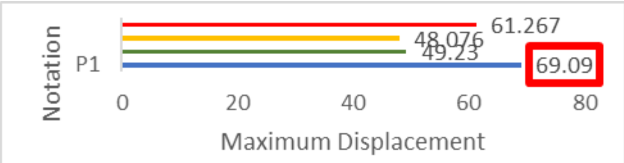
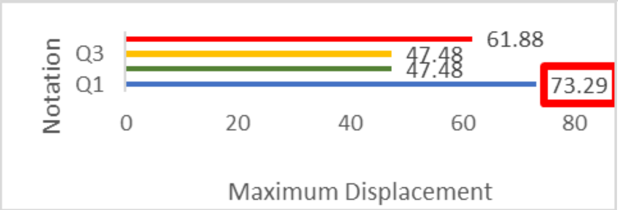
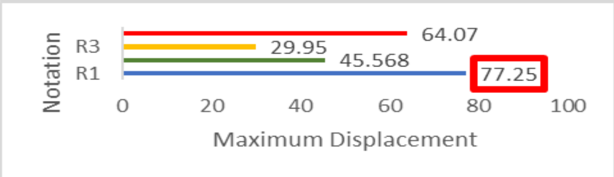
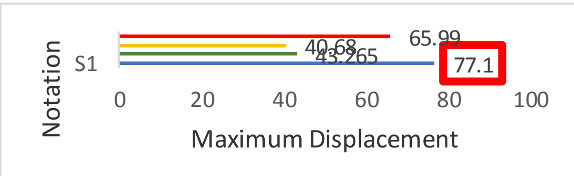


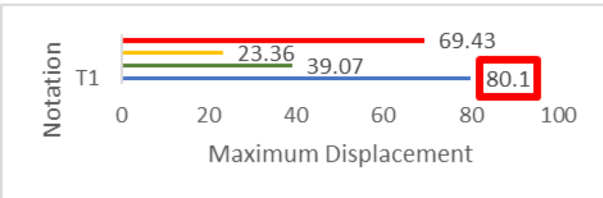
Table: Maximum Value of Displacement

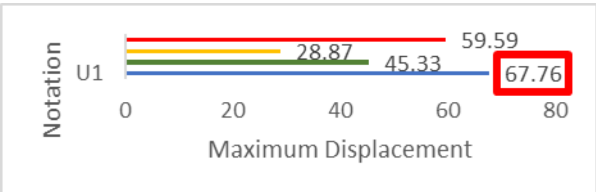


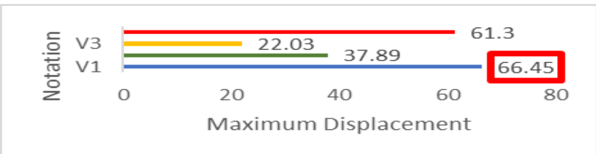












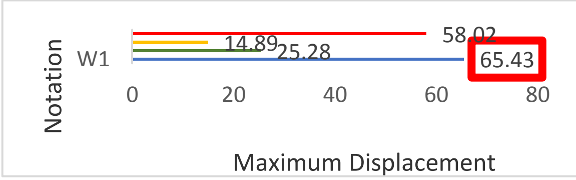
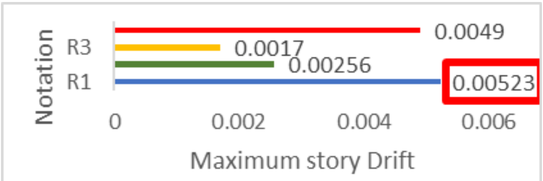
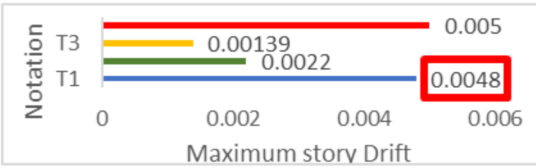


Table: Maximum Value of story drift





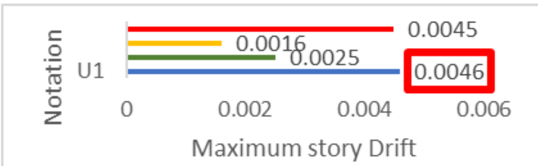
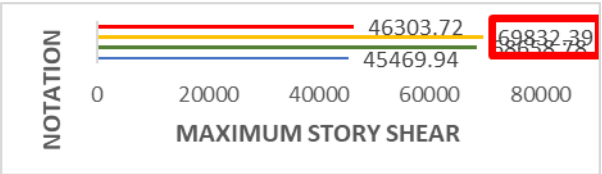
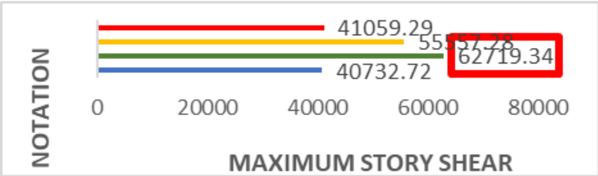
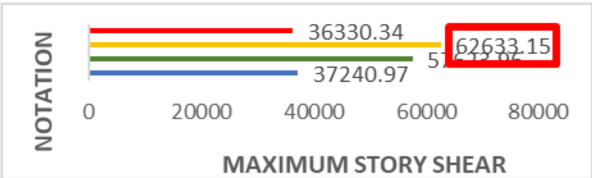
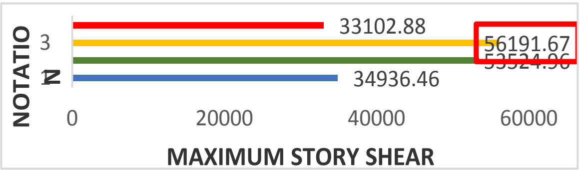


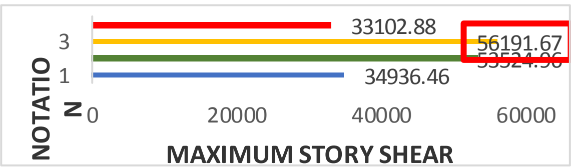
Table: Maximum Value of story shear

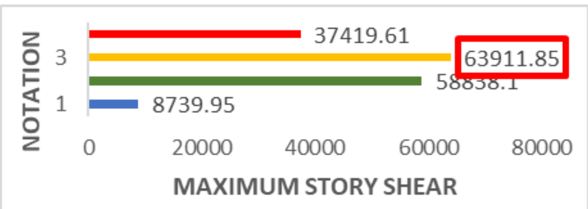


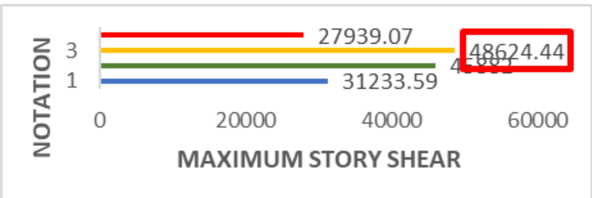


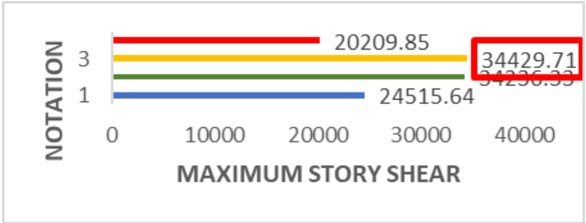












Observation

1. The worth of base shear shows higher in shear wall at periphery type of frames. In step frame the worth of base shear shows higher in standard type of frames. Shear wall at core show lower worth of base shear contrast with ordinary edge. As a result, the regular frame without shear wall shows higher value of base shear.

2. The basement wall and standard frames show the maximum top story displacement. As a result, the step frame with higher set back ratios shows the maximum story displacement. Thus, step frame with shear wall at periphery shows minimum story displacement. In step frame with setback ratio (0.125) shows same value of story displacement. After that step frames with basement wall show higher value of story displacement.

3. The value of story drift is reduced by the shear wall. The higher value of story drift shows in basement wall. Similarly, in step frame with higher irregular ratio shows higher worth of story drift. After that step frames with basement wall show higher value of story displacement.

4. The worth of story shear shows higher value in shear wall at periphery. Similarly, the shear wall at periphery and shear wall at core shows close value of story shear. In the standard frame shows minimum value of story shear.

3. CONCLUSIONS

The fundamental perceptions and ends are summed up underneath.

1. The most extreme value of base shear is shown in periphery with shear wall.

2. Step frame with basement wall and without shear wall distinguish the weakest structure among them in the event of top story displacement.

3. All buildings with basement wall (cellar) show the higher worth of story drift.

4. If there should be a case of the story drift, step frame and setback frame with basement wall is typically the most vulnerable of all.

5. All buildings with shear wall at periphery shows the higher worth of story shear.

6. If there should be a case of the story shear, step frame with shear wall at periphery typically the most vulnerable of all.

7. Localized collapse occurs in beams before columns, according to the sequence of hinge formation. For both X axis and Y axis loading, 77% and 85% of hinges, respectively, were created within the life safety standard.

8. Exploring the nonlinear behavior of a structure using pushover analysis is ideal.

9. Based on its base shear capability, the building is suitable and secure against the earthquake at the estimated level.

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