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Comparative Seismic Performance of a G+15 Reinforced Concrete Building on Plain and Sloping Ground

K. Prathip[1], G. suresh[2]
[1]M Tech Student, Avn Institute Of Engineering And Technology
[2]Assistant Professor, Avn Institute Of Engineering And Technology

Abstract- This study evaluates the seismic response of a G+15 reinforced-concrete framed building for three geometric configurations: a setback building on level ground, a step-back building on 30° sloping ground, and a step-setback building on 30° sloping ground. Three-dimensional models were analysed in STAAD.Pro using the equivalent static lateral-force method and linear time-history concepts in accordance with the source study's IS 1893:2002 framework. The comparative assessment covers storey drift, storey shear, time period, displacement, and column actions including shear force, bending moment, torsion and axial force under critical load combinations. The results demonstrate strong sensitivity of seismic response to vertical and plan irregularity and to the change in column geometry caused by sloping terrain. The setback configuration develops comparatively larger tensile moments in several critical cases, while short columns in the step-back and step-setback configurations require particular design attention. The complete numerical result tables, response curves, model views and comparative plots from the project study are retained in this manuscript to support transparent comparison among the three configurations.

Keywords- seismic analysis; G+15 RC building; sloping ground; setback building; step-back building; STAAD.Pro; storey drift; storey shear; time-history analysis.

I. INTRODUCTION

Problem Description

Earthquake response of reinforced-concrete buildings is strongly influenced by irregular distributions of mass, stiffness and geometry. Vertical and plan irregularities can alter dynamic characteristics, increase torsional response and concentrate seismic demand, particularly in buildings located on sloping ground.

Objectives of Work

- To conduct or assess the seismic analysis of structures with three distinct configurations: a setback building situated on level terrain a step-back building positioned on inclined terrain and a step-setback building located on sloped land.
- To evaluate various load combinations and time history functions in accordance with IS 1893:2002 during the examination of structures using the Staad Pro software.
- To examine the impact of torsional effects on the building's performance.
- To evaluate the outcomes regarding storey displacement time period base shear bending moment and torsion for the examined structures.

Need for the Present Investigation

Structures atop hills vary from those on flatlands; they exhibit significant irregularity and asymmetry in both horizontal and vertical dimensions and are torsionally related. They are vulnerable to significant harm when subjected to seismic ground movement. Historical seismic events such as those in Bihar-Nepal (1934 & 1980) Assam (1950) Tokachi-Oki-Japan (1968) and Uttarkashi-India (1991) have shown that structures situated at the periphery of hilly terrains or inclined surfaces experienced significant destruction. Structures of this kind exhibit mass and stiffness that fluctuate across both vertical and horizontal planes leading to a misalignment between the center of mass and the center of rigidity on different levels. This necessitates torsional evaluation including lateral pressures resulting from seismic activity. Limited literature exists about the examination of structures in inclined terrain. The study detailed in this article sought to forecast the seismic behaviour

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of reinforced concrete structures with varying configurations on both sloped and flat terrain.

Design Aspects

The structures are evaluated for gravity and seismic actions in accordance with the adopted Indian design provisions, with attention to strength, stiffness and deformation requirements.

Seismic regulations are specific to each individual area or nation. In India IS 1893(Part 1): 2002 serves as the primary code for determining seismic design forces. This force is contingent upon the mass and seismic coefficient of the structure which is influenced by factors such as the seismic zone the structure's significance its rigidity the underlying soil and its ductility. IS 1893 (Part 1):2002 pertains to the evaluation of seismic forces on diverse constructions and edifices. The whole algorithm focuses on the computation of base shear and its allocation across the height. The evaluation may be conducted based on external forces the performance of the structure or its materials and the chosen structural model. The sort of study conducted is contingent upon the structure's height and its designated zone. In all the techniques for evaluating multi-storey edifices prescribed in the code the structure is seen as a discrete system with concentrated masses at the floor levels including half the mass of the columns and walls situated above and below each floor. Moreover, a suitable quantity of live load on this level is also aggregated with it.

Scope of Work

The current research endeavours to examine the seismic response of a 15-story reinforced concrete framed structure situated on level terrain as well as step-back and step-setback buildings positioned on steeply sloped land. The incline of the terrain is a steep 30 degrees relative to the horizontal. The dimensions of the building follow a specific arrangement with the height and length measured in multiples of blocks (both vertically and horizontally) where the block dimensions are consistently 6 m x 5 m x 4 m and 4 m x 5 m x 4 m for the ground floor and 6 m x 5 m x 3.2 m and 4 m x 5 m x 3.2 m for the upper levels. The footing's depth under the ground surface is established at 2 m when a solid stratum is present. This research examines three structures with the first situated on level terrain and the other two positioned on a 30-degree incline all including an identical number of stories/bays and consistent floor space throughout the three designs. The characteristics of building frame components designated for examination The outcomes including lateral forces base shear story displacement story drift and torsional effects of the structures are analysed and contrasted for these edifices with sloped terrain. Three-dimensional dynamic analysis of these structures is conducted using the STAAD Pro software application. The examined parameters of columns include axial forces shear forces bending moments and torsional effects.

II. MODELLING AND ANALYSIS

Introduction

Constructing a building entails the design and assembly of its many structural components. An ideal model should comprehensively include the whole three-dimensional (3D) attributes of a structure including its mass distribution strength stiffness and deformability. This chapter addresses the modelling of material characteristics and structural components.

Material Properties

The characteristics of concrete encompass mass unit weight elasticity modulus Poisson's ratio shear modulus and thermal expansion coefficient. The modulus of elasticity for reinforced concrete according to IS 456:2000 is specified as follows:

$Ec = 5000\sqrt{fck}$

Where fck denotes the characteristic compressive strength of concrete at 28 days measured in MPa. The essential characteristics of steel rebar are yield strength and elastic modulus.

Building Configuration

In this investigation three structures are examined; the first one is situated on level terrain while the other two are positioned on a slope of 30 degrees.

(a) Set back buildings.
(b) Step back buildings.
(c) Setback -Step back buildings.

The incline of the terrain is at a 30-degree angle to the horizontal which is very severe. This research has examined three multi-storey structures that exhibit irregularities in both horizontal and vertical orientations with the first floor measuring 4 meters in height and subsequent levels typically at 3.2 meters with horizontal areas of proportions (6 * 5) m and (4 * 5) m. The footing's depth under ground level is considered to be 2 meters when a solid stratum is present.

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Table 1: "Geometrical Properties of Members."

Building configuration	Size of external column	Size of internal Column	Size of beam	Thickness of shear wall
Setback building	700* 700 mm	500 * 500 mm	350*600 mm	200mm
Step back buildings	700* 700 mm	500 * 500 mm	350*600 mm	200mm

Method of Analysis

The evaluation is predicated on the following premises.

- The material is uniform isotropic and stretchy. The modulus of elasticity and Poisson's ratio are quantified as 31622.77 N/mm² and 0.20 respectively.
- The secondary effects of P-Δ shrinkage and creep are excluded from consideration.
- Axial distortion in the column is considered. Every nodal point inside the framework has six degrees of freedom including three translational notations.
- The torsional impact is addressed in accordance with IS: 1893 (I) –2002. The characteristics of structural components of edifices that are considered for evaluation

About STAAD Pro.

STAAD.Pro was used for three-dimensional modelling and structural analysis of the building configurations, including equivalent static and dynamic seismic response evaluation.

Description of Building

The selected structure for examination is a 15-story reinforced concrete commercial complex. The structure is situated in seismic zone V on a location with medium soil. Three-dimensional mathematical representations for the aforementioned are created using STAAD Pro software. M40 grade concrete was used for all structural components. Seismic forces were evaluated as operating horizontally in either of the two primary orientations using a 15-storey reinforced concrete building with ground inclinations of 0° and 30° which were modelled and analysed.

The three-dimensional perspectives and elevations of a structure with a 30° incline are shown here.

Basic Data

Basic data was considered in analysis of building is given in Table 2.

Table 2: "Basic Data"

NO.	DATA	SPECIFICATION
1	Structure	Vertical and horizontal Irregular Building.
2	Plan Dimensions	30 M x 25 m
3	Height of Typical Floor	3.2 m
4	Ground Floor Height	4 m
5	Floors	15 floors with ground floor
6	Dimension of external Column	700 x700 mm
7	Dimension of internal Column	500 x 500 mm
8	Dimension of Beam	350 x 600 mm
9	Slab Thickness	200 mm
10	Shear wall	200 mm thick concrete wall
11	Support	Fixed
12	Type of Soil	Type II Medium Soil as Per IS:1893- 2002
13	Grade of concrete	M 40
14	Grade of steel	M 415
15	Density of concrete	25 kN/m2
16	Seismic Zone	V as Per IS:1893- 2002
17	Live Load on Typical Floor	4.0 kN/M^2
18	Live Load on Terrace	2 kN/M^2
19	Floor Finishes	1.0 kN/M^2

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Plan of Buildings

A schematic of three building designs each measuring (25 m x 30 m) and exhibiting uneven horizontal layouts is shown in Fig 1.

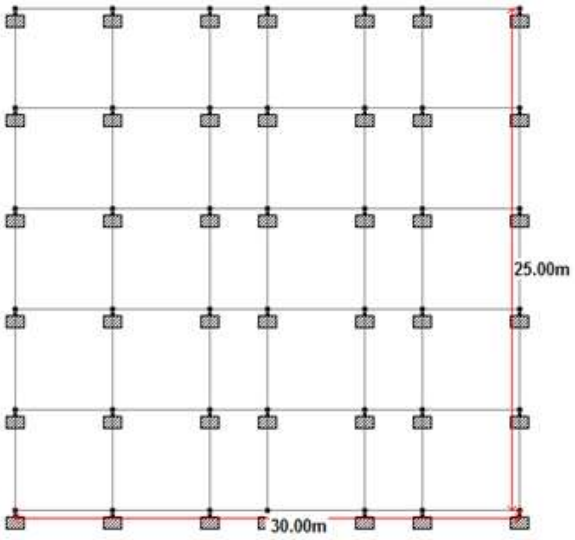

Figure 1: "Plan of Configuration of Building"

Set Back Building with 0° Slope

An isometric representation of setback structures standing on level terrain with 15 storeys and vertical irregularities is shown in Fig. 2.

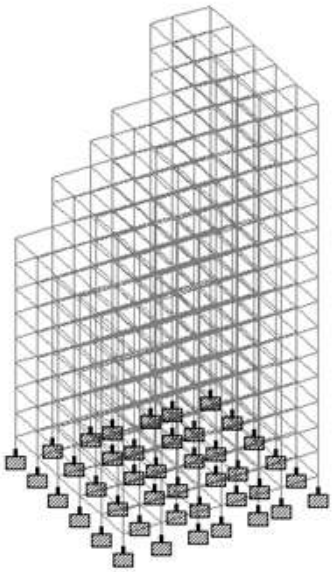

Figure 2: "Set Back Building Isometric view"

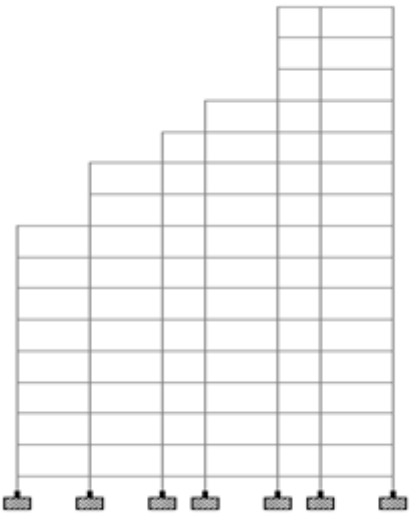

Figure 3: "Set Back Building Side View"

The lateral perspective of the Setback structures which stand on level terrain and include 15 storeys with vertical irregularities is seen in Fig. 3.

Step-set Back Building with 30° Slope

An isometric depiction of a 15-story Set set back structure situated on inclined terrain is seen in Fig..4..

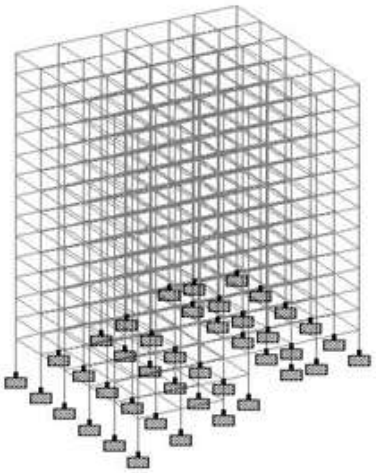

Figure 4: "Step-set Back Building Isometric view"

The lateral perspective of a 15-story structure positioned on inclined terrain is seen in Fig. 5.

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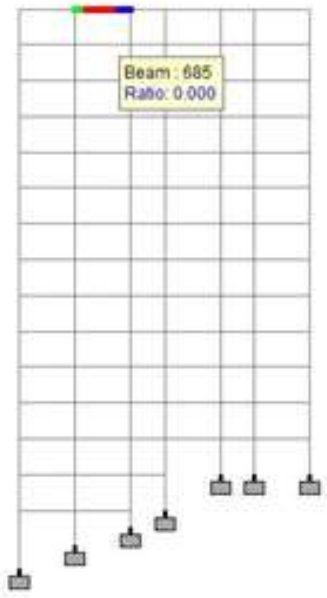

Figure 5: "Step-set Back Building Side View"

Step Back Building with 30° Slope

An isometric representation of a 15-story Setback structure situated on level terrain is seen in Fig. 6..

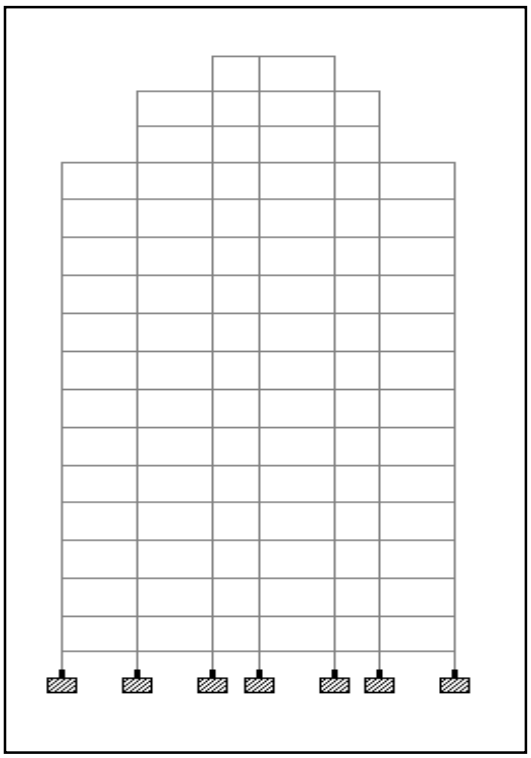

Figure 6: "Step Back Building Isometric view"

The lateral perspective of a 15-story setback structure situated on level terrain is seen in Fig. 7.

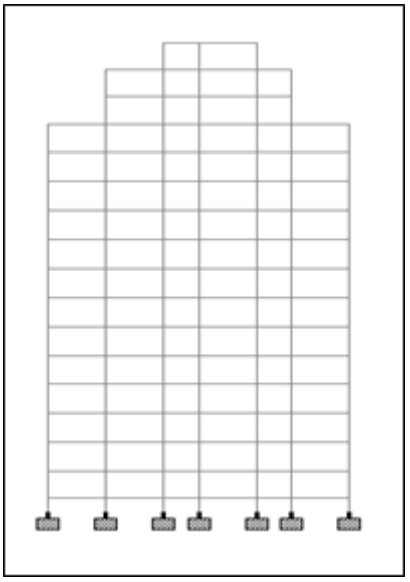

Figure 7: "Step Back Building Side View"

III. RESULTS AND DISCUSSION

Introduction

In this chapter dynamic analysis are performed STAAD Pro. the results and discussion are presented for setback building resting on plain ground the step back building and step – set back building for 15 storey RCC framed building resting on severe sloping (30º) with the horizon under high seismic effects by using equivalent static lateral force method and linear time history method .The parameters which are studied by equivalent static lateral force method under six serviceability combination of loads on three buildings diaphragm displacement storey drift time period storey shear and columns forces (including shear force bending moment torsion axial forces) for columns for the seventh floor of each building and discussion results of 10 columns only .

Results of Analysis using (equivalent static lateral force method)

3D dynamic analysis carried by STAAD Pro. Software programs under six serviceability combination loads on three buildings storey drift time period storey shear and columns forces (shear force bending moment torsion axial force) have been considered in this work. Study is done on many

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combinations of loads but the results are produced for the critical combinations of loads.

Storey Drift

A fundamental measure that provides an assessment of a building's lateral stiffness is the drift index which is defined as the ratio of the highest deflection at the building's apex to its overall height. The relevant measurement of the single-storey height the inter-storey height and the inter-storey drift provides an indication of potential localised excessive deformation. The regulation of lateral deflection is crucial for contemporary structures since conventional stiffness reserves from substantial interior walls and external cladding have significantly diminished. The determination of drift index thresholds is a significant design choice; yet regrettably there exist neither clear or universally recognised values nor any definitive guidelines in many relevant national regulations. The design must subsequently determine an estimated value which will be influenced by the building's function the specific design criteria utilised the construction method and the materials used including significant infills or cladding the type of lateral loads considered and notably prior experiences with similar buildings that have demonstrated satisfactory performance. Establish design drift index thresholds that have been used across various index coefficients ranging from 0.001 to 0.005. As the elevation of the structure rises drift index coefficients have to be reduced toward the lower spectrum to maintain the storey deflection at an acceptable minimum.

IS: 1893-2002(clause 4.2.3) limits the inter-storey drift (ISD) caused by seismic pressures to 0.004 times the height of the storey. This research aims to quantitatively examine the process of drift. Monitoring for drift is essential for all structures. The outcome of storey drift is seen in Tables 5.1 through 5.4.

Table 3: "Storey Drift in X Direction under Combination Load 1.2(dl+ll+elx)"

Storey	Storey level	storey drift X / m		
		SET BACK	STEP BACK	STEP –SET
1	Storey14	0.000613	0.000417	0.000445
2	Storey13	0.000649	0.000449	0.000475
3	Storey12	0.00063	0.000474	0.0005
4	Storey11	0.000705	0.000495	0.000515
5	Storey10	0.000721	0.000505	0.000518
6	Storey9	0.000728	0.000502	0.000507
7	Storey 8	0.000718	0.000484	0.000473
8	Storey 7	0.000697	0.00044	0.000418
9	Storey 6	0.00061	0.000386	0.000294
10	Storey5	0.000583	0.00045	0.00018
11	Storey4	0.000537	0.00014	0.000108
12	Storey 3	0.000477	0.000069	0.000046
13	Storey 2	0.000379	0.000023	0.000018
14	Storey 1	0.000302	0.000037	0.000011
15	storey ground	0.00016	0.000007	0.000008

The fluctuation of storey drift for three structures subjected to Load combination 1.2 (dl + LL + elx) is shown in Fig. 5.1.

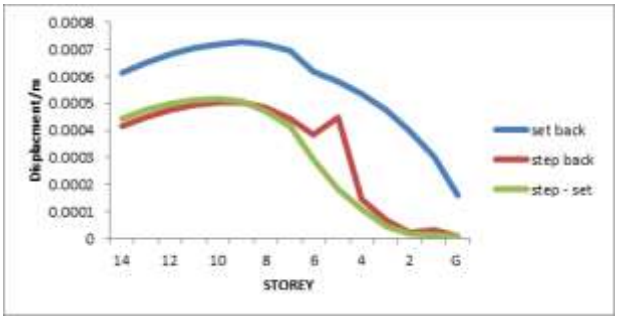

Figure 8: "Storey Drift under Load of combination 1.2 (dl + ll + elx)"

Table 4: "Storey Drift in X Direction under Load of combination (0.9dl+1.5 elx)"

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Storey	Storey level	Storey drift X / m		
		SET BACK	STEP BACK	STEP –SET
1	storey14	0.000842	0.000566	0.000657
2	storey13	0.000883	0.000604	0.000694
3	storey12	0.000915	0.000636	0.000721
4	storey11	0.000939	0.000662	0.000733
5	storey10	0.000944	0.000675	0.000725
6	storey9	0.000944	0.000652	0.000705
7	storey 8	0.000917	0.00065	0.000654
8	storey 7	0.000883	0.000602	0.000579
9	storey 6	0.000766	0.00053	0.000406
10	storey5	0.00072	0.000661	0.000254
11	storey4	0.000663	0.000213	0.000157
12	storey 3	0.000589	0.0001	0.000069
13	storey 2	0.000493	0.000037	0.000029
14	storey 1	0.000374	0.000021	0.000005
15	ground	0.000199	0.000009	0.000009

The fluctuation of storey drift under the combined load of (0.9dl + 1.5elx) is seen in Figure 5.2.

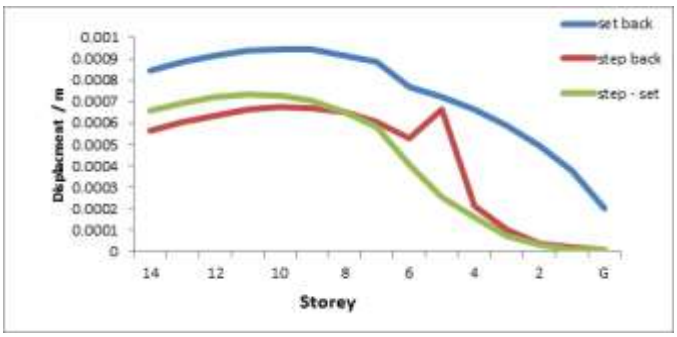

Figure 9: "Variation of Storey Drift for Load of combination (0.9dl+1.5 elx)"

Table 5: "Storey Drift in Y Direction under Load of combination 1.2 (dl+ll+ely)"

Storey	Storey level	Storey Drift Y / m		
		SET BACK	STEP BACK	STEP –SET
1	Storey14	0.000735	0.000598	0.000788
2	Storey13	0.000806	0.000639	0.000869
3	Storey12	0.000869	0.000672	0.000934
4	Storey11	0.000918	0.000699	0.000973
5	Storey10	0.000933	0.000714	0.001011
6	Storey9	0.000947	0.000713	0.000992
7	Storey 8	0.000902	0.000692	0.000935
8	Storey 7	0.000876	0.000648	0.000784
9	Storey 6	0.000798	0.000572	0.000361
10	Storey5	0.000761	0.000397	0.000201

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11	Storey4	0.000709	0.00029	0.000146
12	Storey 3	0.000636	0.000195	0.000101
13	Storey 2	0.000538	0.000124	0.000067
14	Storey 1	0.000735	0.000598	0.000788
15	Ground	0.000806	0.000639	0.000869

The fluctuation of storey drift in the Y direction under combination 1.2 (dl + ll + Ely) is seen in Fig. 5.3.

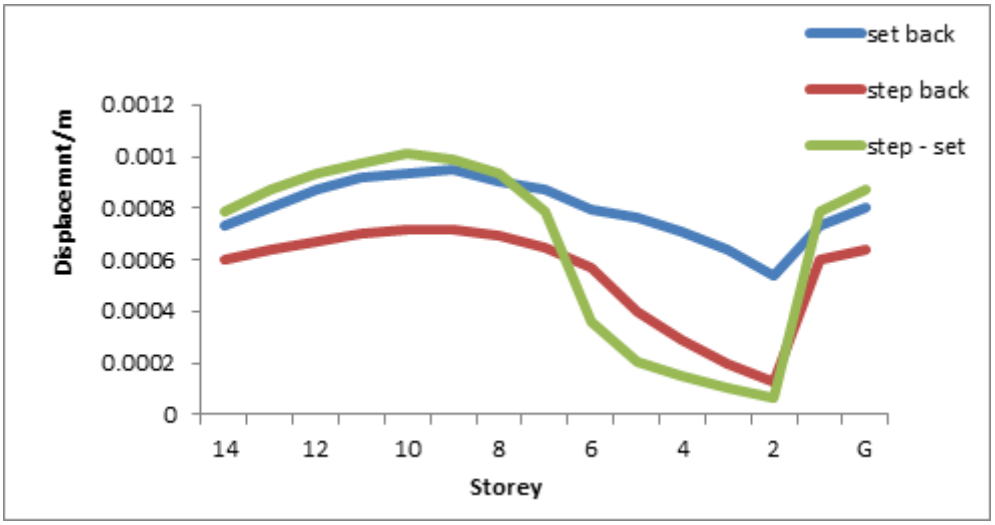

Figure 10: "Storey Drift in Y Direction under Load of combination 1.2 (dl + ll +ely)"

Table 6: "Storey Drift in Y Direction under Load of combination

Storey	Storey level	DRIFT Y / m		
		SET BACK	STEP BACK	STEP –SET
1	Storey14	0.000918	0.000746	0.000984
2	Storey13	0.001007	0.000798	0.001085
3	Store 12	0.001087	0.000839	0.001167
4	Storey11	0.001148	0.000873	0.001215
5	Storey10	0.001166	0.000892	0.001263
6	Storey9	0.001184	0.000891	0.00124
7	Storey 8	0.001127	0.000866	0.00117
8	Storey 7	0.001095	0.00081	0.000982
9	Storey 6	0.000998	0.000716	0.000453
10	Storey5	0.000952	0.000497	0.000253
11	Storey4	0.000887	0.000363	0.000184
12	Storey 3	0.000795	0.000245	0.000127
13	Storey 2	0.000673	0.000156	0.000085

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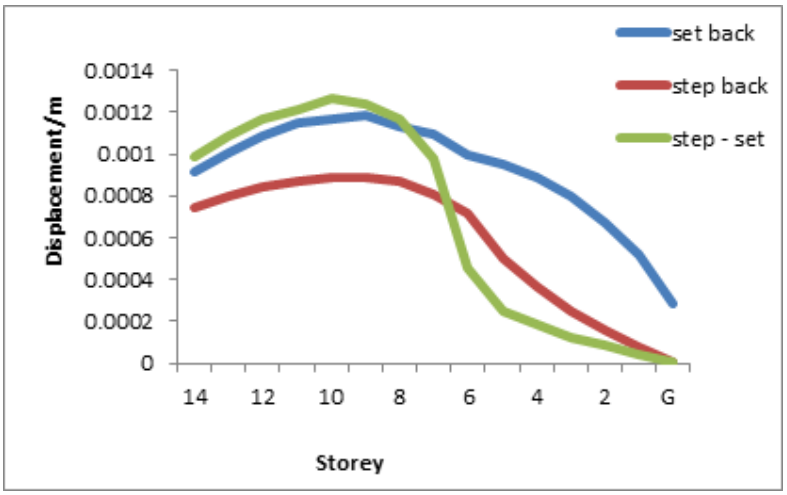
14	Storey 1	0.000517	0.000075	0.000044
15	Ground	0.000282	0.000005	0.000005

The fluctuation of storey drift in the Y direction is seen in Fig. 11.



Storey Shear

Storey shear for setback and step-back structures is computed with software through the comparable static lateral force methodology.

Table 7: "Storey Shear in Direction under Load of combination 1.5(DL+ ELX)"

Storey

Storey	Storey level	Storey Shear / kN		
		SET BACK	STEP BACK	STEP –SET
1	Storey 14	-1190.55	-1906.79	-1236.91
2	Storey 13	-2406.48	-3842.36	-2500.19
3	Storey 12	-3457.74	-5515.8	-3592.39
4	Storey 11	-4356.31	-6946.18	-4525.95
5	Storey10	-5262.74	-8152.56	-5467.69
6	Storey9	-6027.34	-9154	-6262.06
7	Storey 8	-6750.48	-9969.57	-7013.36
8	Storey 7	-7333.59	-10618.33	-7619.17
9	Storey 6	-7885.58	-11119.35	-8192.66
10	Storey5	-8312.55	-2619.72	-1976.96
11	Storey4	-8613.81	-1813.4	-1416.34
12	Storey 3	-8811.24	549.26	561.57
13	Storey 2	-8926.69	463.7	500.7
14	Storey 1	-8982.02	224.15	397.7
15	Ground	-8999.7	-34.64	12.71

The fluctuation of storey shear due to the load combination 1.5(DL + ELX) is seen in Fig. 12.

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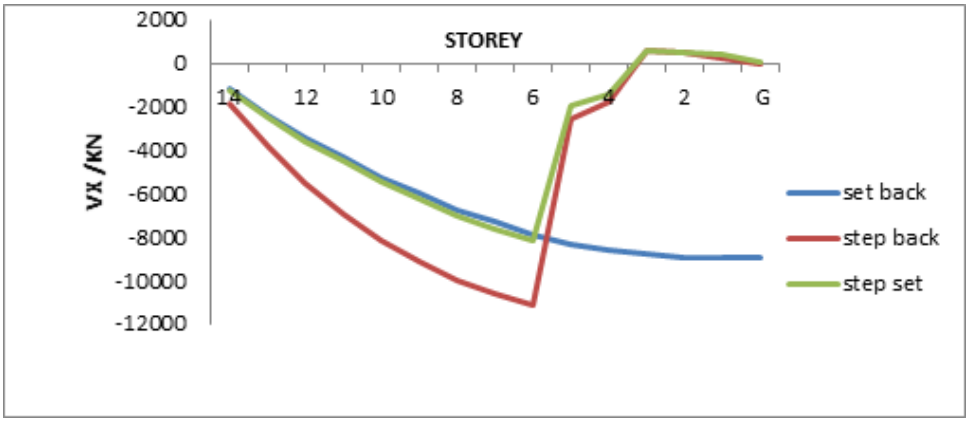

Figure 12: "Variation of Storey Shear under Load of combination 1.5 (DL+ ELX)"

Table 8: "Storey Shear in X Direction under Load of combination (0.9 DL + 1.5 ELX)"

Storey	Storey Level	STOREY SHEAR / kN		
		SET BACK	STEP BACK	STEP –SET
1	Storey14	-1190.55	-1906.79	-1236.91
2	Storey13	-2406.48	-3842.36	-2500.19
3	Storey12	-3457.74	-5515.8	-3592.39
4	Storey11	-4356.31	-6946.18	-4525.95
5	Storey10	-5262.74	-8152.56	-5467.69
6	Storey9	-6027.34	-9154	-6262.06
7	Storey 8	-6750.48	-9969.57	-7013.36
8	Storey 7	-7333.59	-10618.33	-7619.17
9	Storey 6	-7885.58	-11119.35	-8192.66
10	Storey5	-8312.55	-1898.41	-1542.39
11	Storey4	-8613.81	-955.27	-883.96
12	Storey 3	-8811.24	1091.66	710.73
13	Storey 2	-8926.69	1041.68	679.62
14	Storey 1	-8982.02	842.11	597.89
15	Ground	-8999.7	4.52	23.9

The fluctuation of Storey Shear for three structures subjected to the load combination (0.9 DL + 1.5 ELX) is shown in Fig. 13.

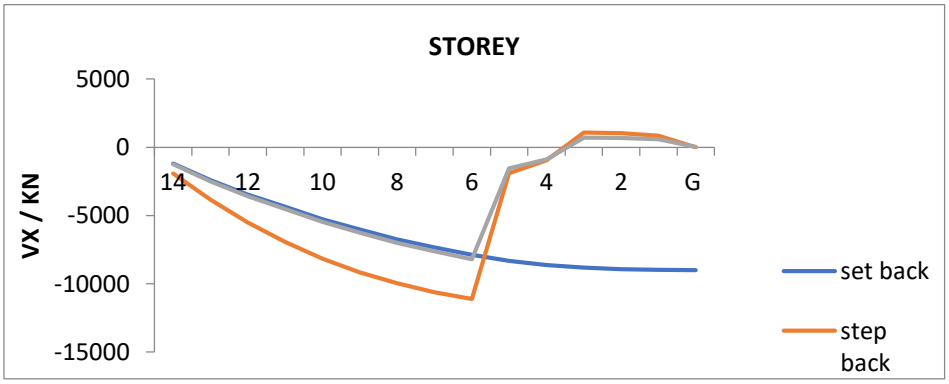

Figure 13: "Variation of Storey Shear under Load of combination (0.9 DL + 1.5 ELX)"

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Table 9: "Storey Shear in X Direction under Combination Load 1.2 (DL+LL+ELX)"

Storey	Storey Level	STOREY SHEAR –X- /kN		
		SET BACK	STEP BACK	STEP –SET
1	Storey 14	-952.44	-1525.43	-989.53
2	Storey 13	-1925.18	-3073.89	-2000.15
3	Storey 12	-2766.19	-4412.64	-2873.91
4	Storey 11	-3485.05	-5556.94	-3620.76
5	Storey10	-4210.2	-6522.04	-4374.15
6	Storey9	-4821.88	-7323.2	-5009.65
7	Storey 8	-5400.39	-7975.66	-5610.69
8	Storey 7	-5866.87	-8494.67	-6095.34
9	Storey 6	-6308.47	-8895.48	-6554.13
10	Storey5	-6650.04	-2310.36	-1711.51
11	Storey4	-6891.05	-1705.25	-1291.59
12	Storey 3	-7048.99	294.08	416.86
13	Storey 2	-7141.35	216.19	359.36
14	Storey 1	-7185.62	16.89	273.66
15	Ground	-7199.76	-40.73	5.41

The alteration of Storey Shear for three structures subjected to Load combination 1.2 (DL+LL+ELX) is shown in Fig. 14.

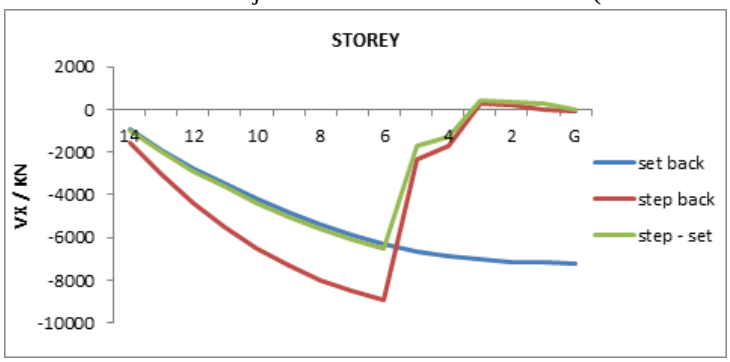

Figure 14: "Variation of Storey Shear under Combination Load 1.2 (DL+LL+ELX)"

Table 10: "Storey Shear in Y Direction under Load of combination 1.5 (DL+ELY)"

Storey	Storey level	Storey Shear in –Y- / kN		
		SET BACK	STEP BACK	STEP –SET
1	Storey 14	-989.39	-1658.51	-1209.68
2	Storey 13	-1999.88	-3342.04	-2445.14
3	Storey 12	-2873.52	-4797.57	-3513.29
4	Storey 11	-3620.26	-6041.7	-4426.29
5	Storey10	-4373.54	-7090.99	-5347.29
6	Storey9	-5008.95	-7962.03	-6124.18

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7	Storey 8	-5609.91	-8671.41	-6858.93
8	Storey 7	-6094.49	-9235.69	-7451.4
9	Storey 6	-6553.22	-9671.47	-8012.27
10	Storey5	-6908.05	-986.5	-792.87
11	Storey4	-7158.41	-313.97	-361.57
12	Storey 3	-7322.48	293.8	-31.6
13	Storey 2	-7418.42	505.39	59.01
14	Storey 1	-7464.41	840.83	244.47
15	Ground	-7479.1	965.3	405.77

The fluctuation of Storey Shear in the Y direction under the loading of combination 1.5 (DL + ELY) is seen in Fig. 15.

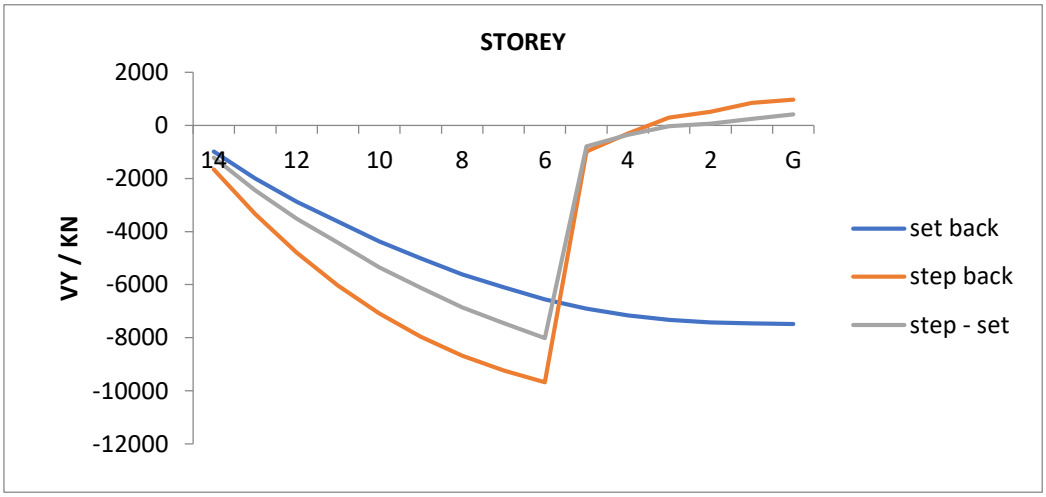

Figure 15: "Variation of Storey Shear under Load of combination 1.5 (DL +ELY)"

Table 11: "Storey Shear in Y direction under Load of combination (0.9 DL + 1.5 ELY)"

Storey	Storey level	Storey Shear in Y / kN		
		SET BACK	STEP BACK	STEP –SET
1	Storey 14	-989.39	-1658.51	-1209.68
2	Storey 13	-1999.88	-3342.04	-2445.14
3	Storey 12	-2873.52	-4797.57	-3513.29
4	Storey 11	-3620.26	-6041.7	-4426.29
5	Storey10	-4373.54	-7090.99	-5347.29
6	Storey9	-5008.95	-7962.03	-6124.18
7	Storey 8	-5609.91	-8671.41	-6858.93
8	Storey 7	-6094.49	-9235.69	-7451.4
9	Storey 6	-6553.22	-9671.47	-8012.27

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10	Storey5	-6908.05	-1002.01	-807.53
11	Storey4	-7158.41	-332.03	-378.14
12	Storey 3	-7322.48	277.9	-45.46
13	Storey 2	-7418.42	493.74	49.85
14	Storey 1	-7464.41	833.02	240.13
15	Ground	-7479.1	963.64	404.13

The fluctuation of Storey Shear in the Y direction for three structures subjected to the load combination (0.9 DL + 1.5 ELY) is shown in Fig. 16.

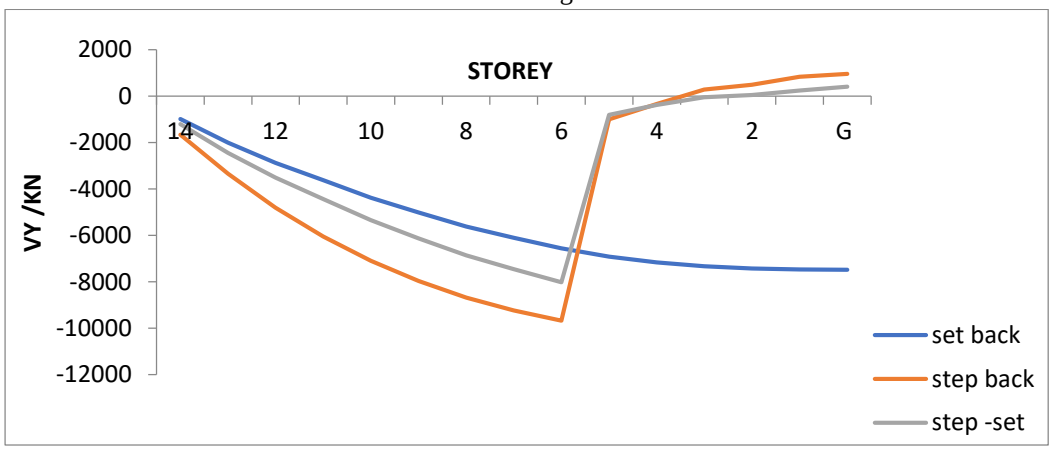

Figure 16: "Variation of Storey Shear for Three Buildings under Load combination (0.9 DL + 1.5 ELY)"

Column Forces

Columns forces (axial force shear force bending moment and torsion) considered for 3 configurations of buildings under same Load of combinations for 3D dynamic analysis using (equivalent static lateral force method) carried by ETABS software program using results of 7th floor to investigation the behaviour of croup columns in sloping and plan ground in each configuration. That the columns are studied and discussed to investigate the behaviour of columns for three configurations of buildings.

Table 12: "Variation of Shear Force under Load of combination 1.5 (DL + ELX)"

S.No.	column	Shear Force / kN		
		Set back	Step back	Step – set
1	C3	34.96	34.99	18.8
2	C8	35.89	27.88	18.39
3	C11	24.4	64.77	17.84
4	C15	51.66	72.91	29.88
5	C19	25.03	62.82	21.46
6	C23	35.87	62.2	25.24
7	C25	82.6	77.32	56.31
8	C36	82.06	71.45	52.19
9	C39	142.78	107.09	89.79
10	C40	142.85	102.23	84.62

Variation of shear force under Load of combination 1.5 (dl + elx) can be shown in table 12.

Table 13: "Variation of Bending Moment under Load of combination 1.5 (DL + ELX)"

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S.No.	column	Bending Moment / kN.m		
		Set back	Step back	Step – set
1	C3	10.979	17.292	5.442
2	C8	66.012	66.271	46.247
3	C11	23.945	13.546	10.426
4	C15	24.639	8.104	7.515
5	C19	23.699	2.58	2.84
6	C23	83.926	38.766	44.423
7	C25	74.827	75.251	58.066
8	C36	36.816	35.131	19.557
9	C39	166.358	2.188	15.022
10	C40	187.249	22.643	28.253

Variation of bending moment under Load of combination 1.5 (DL + ELX) can be shown in table 13.

Table 14: “Variation of Torsion Moment under Load of combination 1.5 (DL +ELX)”

S.No.	column	Torsion Moment/ kN.m		
		Set back	Step back	Step – set
1	C3	0.066	0.012	0.012
2	C8	0.066	0.012	0.012
3	C11	0.066	0.012	0.012
4	C15	0.066	0.012	0.012
5	C19	0.066	0.045	0.045
6	C23	0.253	0.045	0.045
7	C25	0.253	0.045	0.045
8	C36	0.253	0.045	0.045
9	C39	0.253	0.045	0.045
10	C40	0.253	0.045	0.045

Variation of torsion under Load of combination 1.5 (DL + ELX) can be shown in table 14 .

Table 15: “Variation in Shear Force under Load of combination 1.5 (DL + ELY)”

S.NO.	Column	Shear force / kN		
		Set back	Step back	Step – set
1	C3	52.65	34.99	18.8
2	C8	52.99	72.91	29.88
3	C11	49.29	62.82	21.46
4	C15	8.78	77.32	56.31
5	C19	80.88	107.09	89.79
6	C23	22.92	51.69	18.63
7	C25	95.87	162.56	87.75
8	C36	210.81	2.93	2.85
9	C39	58.93	19.5	21.64
10	C40	200.41	34.88	20.37

Variation of shear force under Load of combination 1.5 (DL + ELY) can be shown in table 15.

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Table 16: "Variation in Bending Moment under Load of combination 1.5 (DL + ELY)"

S.No.	Column	Bending Moment /kN.m		
		Set back	Step back	Step – set
1	C3	82.407	60.433	34.714
2	C8	82.718	119.657	52.848
3	C11	76.935	104.602	40.57
4	C15	13.609	125.216	93.181
5	C19	126.975	177.038	148.684
6	C23	30.283	163.77	55.644
7	C25	144.885	275.835	164.035
8	C36	347.006	3.782	3.673
9	C39	88.175	29.741	31.963
10	C40	276.447	54.632	26.903

Variation of bending moment under Load of combination 1.5 (DL + ELY) can be shown in table 16.

Table 17: "Variation in Torsion Moment under Load of combination 1.5 (DL + ELY)"

S.No.	column	Torsion moment /kN.m		
		Set back	Step back	Step – set
1	C3	1.3	0.012	0.012
2	C8	1.3	0.012	0.012
3	C11	1.3	0.012	0.012
4	C15	1.3	0.012	0.012
5	C19	1.3	0.012	0.012
6	C23	4.9993	0.045	0.045
7	C25	4.9993	0.045	0.045
8	C36	4.9993	0.045	0.045
9	C39	4.9993	0.045	0.045
10	C40	4.9993	0.045	0.045

Variation of torsion under Load of combination 1.5 (DL+ ELY) can be shown in table 17.

.

Table 18: "Variation of Shear Force under Load of combination (0.9 DL+1.5 ELX)"

S.No.	column	Shear force /kN		
		Set back	Step back	Step – set
1	C3	53.49	43.93	30.82
2	C8	67.98	72.32	39.21
3	C11	43.22	61.64	29.5
4	C15	78.21	69.24	49.72

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S.No.	column	Shear force /kN		
		Set back	Step back	Step – set
5	C19	111.22	92.83	74.29
6	C23	17.87	51.69	15.56
7	C25	194.92	169.63	102.91
8	C36	12.46	1.25	1.13
9	C39	27.13	15.66	19.55
10	C40	30.47	23.63	14.64

Variation of shear force under Load of combination (0.9 DL +1.5 ELX) can be shown in table 18.

Table 19: "Variation of Bending Moment under Load of combination (0.9 DL+1.5 ELX)"

S.No.	column	Bending moment /kN.m		
		Set back	Step back	Step – set
1	C3	87.833	74.225	53.476
2	C8	111.507	118.504	67.136
3	C11	72.283	102.512	52.729
4	C15	126.938	112.348	82.73
5	C19	178.764	156.353	125.916
6	C23	42.53	104.325	51.795
7	C25	324.441	287.76	189.292
8	C36	19.625	1.505	1.341
9	C39	41.263	23.611	29.171
10	C40	40.418	36.995	19.369

Variation of bending moment under Load of combination (0.9 DL +1.5 ELX) can be shown in table 19.

Table 20: "Variation of Torsion Moment under Load of combination (0.9 DL +1.5 +ELX)"

S.No.	column	Torsion moment /kN.m		
		Set back	Step back	Step – set
1	C3	0.08	0.013	0.013
2	C8	0.08	0.013	0.013
3	C11	0.08	0.013	0.013
4	C15	0.08	0.013	0.013
5	C19	0.08	0.013	0.013
6	C23	0.305	0.05	0.051
7	C25	0.305	0.05	0.051
8	C36	0.305	0.05	0.051
9	C39	0.08	0.013	0.013
10	C40	0.08	0.013	0.013

Variation of torsion under Load of combination (0.9 DL +1.5 ELX) can be shown in table 20.

Table 21: "Variation of Shear Force under Load of combination (0.9 DL +1.5 ELY)"

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S.No.	column	Shear Force /kN		
		Set back	Step back	Step – set
1	C3	34.12	16.03	20.2
2	C8	36.67	8.85	15.83
3	C11	31.1	3.3	13.56
4	C15	4.39	13.6	8.64
5	C19	49.32	25.38	23.3
6	C23	26.27	1.45	38.62
7	C25	77.03	32.12	40.55
8	C36	198.79	64.44	50.51
9	C39	55.78	65.27	73.11
10	C40	192.97	172.17	130.02

Variation of shear force under Load of combination (0.9 DL +1.5 ELY).can be shown in table 21.

Table 22: "Variation of Bending Moment under Load of combination (0.9 DL +1.5 ELY)"

S.No.	column	Bending Moment /kN.m		
		Set back	Step back	Step – set
1	C3	53.363	24.788	31.307
2	C8	57.238	14.19	23.867
3	C11	48.496	5.574	20.352
4	C15	6.864	21.293	13.842
5	C19	77.475	38.144	34.628
6	C23	34.804	2.616	54.741
7	C25	114.555	47.138	56.585
8	C36	347.006	3.782	3.673
9	C39	88.175	29.741	31.963
10	C40	276.447	54.632	26.903

Variation of bending moment under Load of combination (0.9 DL +1.5 ELY) can be shown in table 22.

Table 23: "Variation of Torsion Moment under Load of combination (0.9 DL +1.5 ELY)"

S.No.	column	Torsion Moment /kN.m		
		Set back	Step back	Step – set
1	C3	1.286	0.874	0.134
2	C8	1.286	0.874	0.134
3	C11	1.286	0.874	0.134
4	C15	1.286	0.874	0.134
5	C19	1.286	0.874	0.134
6	C23	4.94	3.358	0.516
7	C25	4.94	3.358	0.516
8	C36	4.94	3.358	0.516
9	C39	4.94	3.358	0.516
10	C40	4.94	3.358	0.516

Variation of torsion under Load of combination (0.9 DL +1.5 ELY) can be shown in table 23.

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Table 24: "Variation of Shear Force under Load of combination 1.2 (DL + LL + ELX)"

S.No.	column	Shear force / kN		
		Set back	Step back	Step – set
1	C3	19.53	23.15	9.49
2	C8	34.97	58.76	20.2
3	C11	12.6	51.18	13.73
4	C15	68.53	65.96	48.12
5	C19	128.06	92.94	79.33
6	C23	18.33	41.45	16.07
7	C25	134.27	127.39	65.06
8	C36	24.3	3.15	3.12
9	C39	25.69	17.51	18.49
10	C40	33.65	33.24	19.08

Variation of shear force under Load of combination 1.2 (DL+ LL + ELX) can be shown in table 24.

.

Table25: "Variation of Bending Moment under Load of combination 1.2 (DL+ LL + ELX)"

S.No.	column	Bending moment /kN.m		
		Set back	Step back	Step – set
1	C3	33.83	40.87	19.146
2	C8	58.901	96.529	36.612
3	C11	23.521	85.304	27.306
4	C15	110.754	106.676	79.4
5	C19	204.175	152.385	130.087
6	C23	39.335	83.536	45.855
7	C25	224.512	216.242	122.546
8	C36	38.166	4.125	4.069
9	C39	38.473	26.821	27.172

Variation of bending moment under Load of combination 1.2 (DL + LL + ELX) can be shown in table 25.

Table 26: "Variation of Torsion Moment under Load of combination 1.2 (DL + LL + ELX)"

S.No.	**column**	**Torsion moment /kN.m**		
		Set back	**Step back**	**Step – set**
1	C3	0.049	0.009	0.009
2	C8	0.049	0.009	0.009
3	C11	0.049	0.009	0.009
4	C15	0.049	0.009	0.009
5	C19	0.049	0.009	0.009
6	C23	0.189	0.034	0.033

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7	C25	0.189	0.034	0.033
8	C36	0.189	0.034	0.033
9	C39	0.189	0.034	0.033
10	C40	0.189	0.034	0.033

Table 27: "Variation of Shear Force under Load of combination 1.2 (DL + LL + ELY)"

S.No.	column	Shear force /kN		
		Set back	Step back	Step – set
1	C3	50.56	24.82	31.32
2	C8	48.75	7.98	23.83
3	C11	46.85	4.5	20.72
4	C15	9.48	21.45	15.26
5	C19	78.54	38.98	38.54
6	C23	16.98	1.25	27.28
7	C25	83.29	17.38	49.71
8	C36	2735.95	2673.69	2681.47
9	C39	55.28	601.29	103.63
10	C40	206.32	1842.54	224.83

Variation of shear force under Load of combination 1.2 (DL + LL + ELY) can be shown in table 27.

.

Table 28: "Variation of Bending Moment under Load of combination 1.2 (DL + LL + ELY)"

S.No.	column	Bending moment /kN.m		
		Set back	Step back	Step – set
1	C3	79.127	38.34	48.68
2	C8	76.095	13.078	36.19
3	C11	73.102	7.753	31.159
4	C15	14.695	33.832	24.29
5	C19	123.144	57.817	57.057
6	C23	22.532	2.017	39.375
7	C25	126.685	23.745	74.156
8	C36	284.991	84.686	76.858
9	C39	72.552	112.492	102.799
10	C40	225.57	261.368	165.652

Variation of bending moments under Load of combination 1.2 (DL+ LL + ELY) can be shown in table 28.

Discussion results of Equivalent Static lateral method

Storey drift base shear columns forces are considered in discussion for results of equivalent static lateral method

Table29: "Maximum Storey Drift in X Direction"

S.No.	Load of combination	Set back mm	Step back mm	Step – set Mm
1	1.5 (dl + elx)	0. 926	0. 643	0. 673
2	1.5 (dl + ely)	0. 131	0. 436	0. 392

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S.No.	Load of combination	Set back mm	Step back mm	Step – set Mm
3	(0.9 dl + 1.5 elx)	0. 944	0. 675	0. 733
4	(0.9 dl + 1.5 ely)	0. 137	0. 364	0. 333
5	1.2 (dl + ll + elx)	0. 728	0. 505	0. 517
6	1.2 (dl + ll + ely)	0. 127	0. 157	0. 335

It is observed that the maximum storey drift in setback building under loads combinations show in Table 29 is more by 30.5 % 28.5% 30.6 % when compared corresponding with storey drift in step back building. In addition, the maximum storey drift in setback building under loads combinations show in Table 5.27 is more by 27.3 % 22.3% 28.9% when compared corresponding to storey drift in step-set building.

Furthermore, the maximum storey drift in setback building under loads combinations at Sl.No. 2 4 6 show in Table 5.1 is less by 69.9 % 62.3 % 19.1 % when compared corresponding to storey drift in step back building. The maximum storey drift in setback building under loads combinations at Sl.No. 1 3 5 show in is in less by 27.3 % 58.8 % 62% corresponding with storey drift in step-set building.

The cause of the results above is the irregular distribution of mass in the three configurations of building under the load of combinations.

Table 30: “Maximum Storey Drift in Y Direction”

S.No.	Load of combination	Set back Mm	Step back mm	Step – set mm
1	1.5 (dl + elx)	0	0. 007	0. 006
2	1.5 (dl + ely)	1.184	0. 865	1.264
3	(0.9 dl + 1.5 elx)	0	0. 006	0. 005
4	(0.9 dl + 1.5 ely)	1.184	0. 892	1.263
5	1.2 (dl + ll + elx)	0	0. 005	0. 005
6	1.2 (dl + ll + ely)	0. 947	0. 713	1.011

According to the results above the maximum storey drift in setback building under loads combinations at Sl.No. 2 4 6 show in Table 5.2 is more by 26.9 % 24.6 % 24.7 % when compared corresponding with storey drift in step back building. In addition the maximum storey drift in setback building under loads combinations at Sl.No. 1 2 3 4 5 6 show in Table 5.28 is less by 100% 6.3%100%6.2% 100 % 6.4 % when compared corresponding with storey drift in step-set building.

The maximum storey drift in setback building under loads combinations at Sl.No. 1 3 5 show in Table 5.28 is more by 100% when compared corresponding with storey drift in step back building.

Table31: “Maximum Storey Shear in X Direction”

S.No.	Combination load	Set back kN	Step back kN	Step – set kN
1	1.5 (dl + elx)	8999.7	11119.35	8192.66
2	1.5 (dl + ely)	0	2006.57	1277.43
3	(0.9 dl + 1.5 elx)	8999.7	11119.35	8192.66
4	(0.9 dl + 1.5 ely)	0	1148.43	745.06
5	1.2 (dl + ll + elx)	7199.76	8895.48	6554.13
6	1.2 (dl + ll + ely)	0	1859.78	1180.47

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The maximum storey shear in setback building under loads combinations at Sl.No. 1 2 3 4 5 6 show in Table 5.3 is less by 19 % 100 % 19 % 100% 19.6% 100% when compared corresponding with storey shear in step back building. In addition the maximum storey shear in setback building under loads combinations at Sl.No. 1 3 5 show in Table 5.29 is more by 8.96 % when compared corresponding with storey shear in step-set building.

The maximum storey shear in setback building under loads of combinations at Sl.No. 2 4 6 show in Table 31 is less by 100 % when compared corresponding with storey shear in step-set building

.

Table32: "Maximum Storey Shear in Y Direction"

S.No.	Load of combination	Set back kN	Step back kN	Step – set kN
1	1.5 (dl + elx)	0	43.09	34.06
2	1.5 (dl + ely)	7497.1	9671.47	8012.27
3	(0.9 dl + 1.5 elx)	5983.28	7737.18	6409.82
4	(0.9 dl + 1.5 ely)	7479.1	9671.47	8012.27
5	1.2 (dl + ll + elx)	0	39.47	31.78
6	1.2 (dl + ll + ely)	5983.28	7737.18	6409.32

It is observed that the maximum storey shear in setback building under loads combinations at Sl.No. 1 2 3 4 5 6 show in Table 5.30 is less by 100 % 22.4 % 22.6 % 22.6 % 100% 22.6 % when compared corresponding with storey shear in step back building. In addition the maximum of storey shear in setback building under loads combinations at Sl.No. 1 2 3 4 5 6 show in Table 5.30 is more by 100 % 6.4 % 6.6 % 6.4 % 100% 6.6 % when compared corresponding with storey shear in step-set building.

Method Discussions of Columns forces Results of equivalent static Lateral force

This step of work discusses results of columns forces (shear forces bending moment torsion and axial forces) for the columns considering the Maximum value of forces using result of equivalent static Lateral force method for three configurations of buildings.

Table 33: "Maximum Shear Force for Column C 3"

S.No.	Load of combination	Set back kN	Step back kN	Step – set kN
1	1.5 (dl + elx)	34.96	34.99	18.8
2	1.5 (dl + ely)	52.65	24.97	32.22
3	(0.9 dl + 1.5 elx)	53.49	43.93	30.82
4	(0.9 dl + 1.5 ely)	34.12	16.03	20.2
5	1.2 (dl + ll + elx)	19.53	23.15	9.49
6	1.2 (dl + ll + ely)	50.56	24.82	31.32

It is observed that the maximum shear force for C3 in setback building under loads combinations at Sl.No. 2 3 4 6 show in Table 5.31 is more by 52.5 % 17.8 % 53 % 50.9 % when compared corresponding with C3 in step back building. Furthermore the maximum shear force for C3 in setback building under loads combinations at Sl.No. 1 2 3 4 5 6 show in Table 5.31 is more by 42.1 % 38.8 % 41% 40 % 51.3% 38% when compared corresponding with C3 in step-set building.

The maximum of shear force for C3 in setback building under loads combinations at Sl.No.15 shows in Table 33 is less by 0.0008 % 15.6 % when compared corresponding with C3 in step back building.

Table34: "Shear Force for Column C 15"

S.No.	**Load of combination**	**Set back kN**	**Step back kN**	**Step – set kN**

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1	1.5 (dl + elx)	82.6	77.32	56.31
2	1.5 (dl + ely)	8.78	21.68	15.23
3	(0.9 dl + 1.5 elx)	78.21	69.24	49.72
4	(0.9 dl + 1.5 ely)	4.39	13.6	8.64
5	1.2 (dl + ll + elx)	68.53	65.96	48.12
6	1.2 (dl + ll + ely)	9.48	21.45	15.26

According to the aforementioned data the peak shear force for C15 in a setback structure under load combinations at Sl.No. 1 3 and 5 as shown in Table 34 exceeds that of C15 in a step-back building by 6.3% 11.4% and 3.7% respectively. Moreover the peak shear force for C15 in setback structures under load combinations at Sl.No. 1 3 and 5 as seen in Table 5.32 exceeds that of C15 in step-set buildings by 31.8% 36.4% and 29.7% respectively.

The peak shear force for C15 in setback structures under load combinations at Sl.No. 2 4 6 as seen in Table 5.32 is reduced by 59% 67.7% and 55% when contrasted with C15 in step back buildings. Furthermore the peak shear force for C15 in setback structures under load combinations at Sl.No. 2 4 and 6 as shown in Table 5.32 is decreased by 41.7% 49.1% and 35.5% when juxtaposed with C15 in step-set buildings.

Table 35: "Bending Moment for Column C 3"

S.No.	Load of combination	Set back kN.m	Step back kN.m	Step – set kN.m
1	1.5 (dl + elx)	58.789	60.433	34.714
2	1.5 (dl + ely)	82.407	38.58	50.068
3	(0.9 dl + 1.5 elx)	87.833	74.225	53.476
4	(0.9 dl + 1.5 ely)	53.363	24.788	31.307
5	1.2 (dl + ll + elx)	33.83	40.87	19.146
6	1.2 (dl + ll + ely)	79.127	38.34	48.68

The maximum bending moment for C3 in the setback building under load combinations at Sl.No. 2 3 4 and 6 as shown in Table 35 is greater by 53.5% 15.4% 53.1% and 51.5% respectively in comparison to the bending moment for C3 in the step back building. Furthermore the peak bending moment for C3 in the setback structure under load combinations at Sl.No. 1 2 3 4 5 6 as seen in Table 5.33 is greater by 40.94% 39.24% 39.11% 41.33% 38.47% and 38.47% when contrasted with C3 in the step-set building.

The peak bending moment for C3 in the setback structure under load combinations at Sl.No.1 and 5 as seen in Table 35 is reduced by 2.7% and 17.2% in comparison to C3 in the step-back building.

Table 36: "Bending Moment for column C 15"

S.No.	Load of combination	Set back kN.m	Step back kN.m	Step – set kN.m
1	1.5 (dl + elx)	133.684	125.216	93.181
2	1.5 (dl + ely)	13.609	34.161	24.293
3	(0.9 dl + 1.5 elx)	126.938	112.348	82.73
4	(0.9 dl + 1.5 ely)	6.864	21.293	13.842
5	1.2 (dl + ll + elx)	110.754	106.676	79.4
6	1.2 (dl + ll + ely)	14.695	33.832	24.29

The maximum bending moment for C15 in setback buildings under load combinations at Sl.No. 1 3 and 5 as shown in Table 36 is greater by 6.3% 11.4% and 3.6% when compared to C15 in step back buildings. Furthermore the peak bending moment for C15 in setback structures under load combinations at Sl.No.

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1 3 and 5 as seen in Table 36 is elevated by 30.2% 34.8% and 28.3% in comparison to C15 in step-set buildings.

It is noted that the peak bending moment for C15 in setback structures under load combinations at Sl.No. 2 4 6 as shown in Table36 is reduced by 60.1% 67.7% and 56.5% when contrasted with C15 in step back buildings. The peak bending moment for C15 in setback structures under load combinations at Sl.No. 2 4 and 6 as shown in Table36 is reduced by 43.9% 50.4% and 39.5% respectively in comparison to the bending moment for C15 in step-set buildings.

Table37: "Torsion Moment for column C3 C8 C11 C15 C19"

S.No.	Load of combination	Set back kN.m	Step back kN.m	Step – set kN.m
1	1.5 (dl + elx)	0.066	0.012	0.012
2	1.5 (dl + ely)	1.3	0.873	0.136
3	(0.9 dl + 1.5 elx)	0.08	0.013	0.013
4	(0.9 dl + 1.5 ely)	1.286	0.874	0.134
5	1.2 (dl + ll + elx)	0.049	0.009	0.009
6	1.2 (dl + ll + ely)	1.043	0.698	0.109

It is observed that the maximum torsion moment for setback building under loads combinations at Sl.No. 1 2 3 4 5 6 show in Table 37 is more by 81.8% 32.8% 83.7% 32%81.6% 33% when compared corresponding with step back building. In addition the maximum torsion moment for setback building under loads combinations at Sl.No. 12 3 4 5 6 show in Table 37 is more by 81.8% 89.5% 89.5% 89.5% 81.6% 89.5% when compared corresponding with step-set building.

The variation of torsion moment for the columns occurs if the mass for the buildings is more on one side than the other in case of setback building and also if the building constructed on a sloping ground in case of step back building and step set back building.

Table 38: "Torsion Moment for Columns"

S.No.	Load of combination	Set back kN.m	Step back kN.m	Step – set kN.m
1	1.5 (dl + elx)	0.253	0.045	0.045
2	1.5 (dl + ely)	4.993	3.353	0.522
3	(0.9 dl + 1.5 elx)	0.305	0.05	0.051
4	(0.9 dl + 1.5 ely)	4.94	3.358	0.516
5	1.2 (dl + ll + elx)	0.189	0.034	0.033
6	1.2 (dl + ll + ely)	4.007	2.68	0.42

According to the above it is observed that the maximum of torsion moment for in setback building under loads combinations at 1 2 3 4 5 6show in Table 38 is more by 82.2% 32.8% 83.6% 25.2 % 82% 33% when compared corresponding with in step back building. In addition the maximum torsion moment in setback building under loads combinations at 12 3 4 5 6 show in Table 38 is more by 82.21 % 89.5% 83.2 % 88.5 % 82.5% 89.5% respectively when compared with torsion moment in step-set building.

Table39: "Axial force for Column C 3C8 C11"

S.NO	Load of combination	Set back kN	Step back kN	Step – set kN
1	1.5 (dl + elx)	575.27	2137.76	579.46
2	1.5 (dl + ely)	759.48	2198.76	717.11
3	(0.9 dl + 1.5 elx)	269.08	1240.32	288.1
4	(0.9 dl + 1.5 ely)	453.28	1301.32	425.75
5	1.2 (dl + ll + elx)	580.45	2092.48	578.18
6	1.2 (dl + ll + ely)	727.82	2141.28	688.3

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It is observed that the maximum axial force for setback building under loads combinations at Sl.No. 1 2 3 4 5 6 show in Table 39 is less by 73%65.4% 78.3 % 65.1% 72.2% 66 % when compared corresponding with in step back building. Also the maximum axial force for in setback building under loads combinations at Sl.No. 2 3 4 5 6 show in Table 39 is more by 5.5% 6.6 % 6% 0.4% 5.5% when compared corresponding with in step-set building.

IV. CONCLUSIONS

Summary

This research examined analytical methodologies and evaluated step back building set back building and step-set back building structures for analogous static analysis scenarios to ascertain Base shear Time period and Displacement of buildings under various seismic data. The subsequent results are derived from the aforementioned procedure and enumerated below.

Conclusions

The Following conclusions are made from the present study:

- The setback building has experienced much more tensile moments compared to both the step-back and step-setback buildings due to the uneven mass distribution and vertical geometric irregularities influenced by load combinations and time history functions.
- The shear force for the column of the setback structure exceeds 51.4% in comparison to the step set structure under Load Combination 1.2 (dl + ll + elx) with column c11 of the setback building exhibiting a greater shear force.
- The bending moment for column C3 in the setback building exceeds that of the step back building by 53.53%. The bending moment for C8 in a setback building exceeds that of a step back building by 89.39%.
- The axial force percentage in columns is shown to be 73.09% 57.02% and 25.41% lower in setback buildings compared to step back buildings.
- Given that the mass remains constant despite the increasing ground slope it may be inferred that the building's stiffness diminishes as the column length increases in comparison to the other end.
- In Step back and Step back-Set back structures it is noted that the extreme left column at ground level which is shorter is the most adversely impacted. Particular emphasis must be placed on these columns in terms of design and details.
- The essential horizontal stresses and bending moment in the foundation markedly escalate with an increase in ground inclination. Nonetheless the essential values of vertical response in the foundation remain mostly unchanged across various ground inclinations.
- The essential bending moment in the column markedly escalates for a 15-degree inclined terrain in contrast to level ground. The essential critical value of axial force in a column stays relatively constant across many substrates.

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