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Seismic Behavior of Structure with Cantilever Projections in Different Zones

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Abstract: In this research paper, the main focus is on understanding how structures with constant cantilever projections of 1m perform when subjected to seismic forces. To carry out the analysis, the researchers utilize ETABS software, which is commonly used in the field of structural engineering. The study investigates two types of buildings: a 5-storey building and a 10-storey building. By using the static method, the researchers evaluate various aspects of the structure's seismic behavior. This includes examining the story displacement, which refers to how much each floor moves during an earthquake. They also examine the overturning moment, which helps to assess the potential for the structure to rotate or tip over due to seismic forces. Additionally, the researchers analyze the base shear, which represents the total force experienced by the building's foundation due to seismic activity. By conducting these analyses, the researchers aim to gain insights into how the structures with 1m cantilever projections perform in different zones under seismic conditions. This information can be valuable for designing safer and more resilient buildings in earthquake-prone areas.
Keywords: Seismic behavior, Cantilever projections, ETABS software, Story displacement, Overturning moment, Base shear.

I. INTRODUCTION

The seismic behavior of buildings is a critical consideration in earthquake-prone regions. It refers to how buildings and structures react to ground motion during an earthquake. It encompasses a range of phenomena, including lateral and vertical movements, deformation, and potential damage. The goal of seismic design is to ensure that buildings can withstand these forces without collapsing or causing harm to people inside. Buildings are designed to exhibit ductile behavior, meaning they can undergo deformation and absorb energy without sudden failure. This is achieved through materials like reinforced concrete and steel. Cantilever projections refer to portions of a structure that extend horizontally from the main building mass without vertical supports beneath them. Examples include balconies, overhangs, or architectural features. The behavior of these projections during an earthquake depends on various factors, including their size, shape, and attachment to the main structure.

The seismic behavior of structures with cantilever projections can vary significantly depending on the seismic zone in which they are located. Seismic zones are defined based on the level of seismic activity in a region, and building codes and design requirements are established to ensure the safety and stability of structures in these zones.

Seismic zones are typically categorized into different levels, ranging from low to high seismicity. These zones are determined based on historical earthquake data and geological studies. The higher the seismicity, the more rigorous the design and construction requirements become. The height and mass distribution of a building also play a crucial role in seismic behavior. Taller structures with uneven mass distribution are more susceptible to torsional effects during earthquakes, which can impact cantilever projections. Proper mass distribution and seismic analysis are essential to prevent torsional effects and ensure the stability of cantilevered elements.

II. LITERATURE REVIEW

1) T. Jayakrishna, K. Murali, Powar Satish, J Seetunya (2018) studied G+5 multistorey domestic structure for earthquake and wall loads using STADD PRO and response diapason system, the geste of regular and irregular structures compared. For performing dynamic analysis, a material having direct static property as assumed. These analysis are carried out by considering different seismic zones, and for each zone, the geste assesses by taking the Soft Soil. A different response for deportations of base shear, story drift is colluded for different zones for different types of soils. Comparison of base shear, period, knot relegation and frequentness of different irregular structures are carried out. Compared to perpendicular irregular model side relegation is less in regular model. nearly the base shear is same in regular and irregular models.
2) D Sravya and Dr V B Reddy Sudha (2021) investigates the seismic performance of square and blockish RC framed structures of colorful heights when subordinated to combined loads.

Only square and blockish RC framed marketable structures with G+10, G+20, and G+30 stories that are located in seismic zone V are included for comparison in this study. The logical styles employed are original static and direct dynamic. For modelling RC framed structures, the lading computations were done according to codal regulations, videlicet IS 1893(Part I) – 2002, IS 875 (Part III) – 1987, and IS 456 – 2002. On the base of story drift, story shear, story stiffness story deportations, story drift, and capsizing moments, the results of seismic analysis in Zone V are compared with square and blockish structures using ETABS. When blockish model structures are compared to square model structures, seismic criteria similar as story shear, story deportations, story drift, and capsizing moments diminishments and story stiffness rises. It was discovered that when the story height increased, the values of seismic parameters dropped for all of the models studied. Because static analysis is inadequate for seismic zone areas with high- rise structures, and dynamic analysis is needed. When compared to square structures, cube structures are more effective.

3) Sonu Rani Nirmalkar, Aman Gautam, Vijay Kumar Shukla (2023) have considered an unsymmetrical plan under earthquake weight and wind weight. There are two models have taken to anatomize- 1. Bare frame structure and 2. Shear wall Structure. Shear walls are generally handed for full height of the frame. Shear wall systems are one of the most habituated side weight defying systems in high- rise structures. The earthquake and wind weight are applied in an unsymmetrical structure located at zone- III as per IS 456(Dead weight, Live weight) IS 1893:2002(Earthquake weight), IS875 1987(Wind weight). Side deportation, Time period and story drift are calculated in both the cases. This is a G+13 legendary structure. It was observed that Multistoried structures with shear wall is further suitable to repel side loads as compared to without shear wall. it's concluded that shear wall frame structure is more reliable against side displacements and story drift index. Shear wall structures are more safe compare with bare frame in the case of worst loading.
4) Vishal N, Ramesh Kannan M, Keerthika L (2020) studied the structural geste of a 20- story structure with perpendicular reversal irregularity has been modelled and analyzed by response diapason system considering with and without Construction Sequence Analysis (CSA) using different structural systems in CSI ETABS V16 as per BIS 1893: 2016 (Part 1). Eventually, results similar as axial force, shear force, bending moment are drawn for the structural members and response similar as story relegation, story shear and story drift are colluded and compared for each structural system.
5) Rajat Srivastava, Sitesh Kumar Singh (2018) the principle targets this exploration paper is to suppose about the seismic disquisition of structure for static and dynamic examination in standard nanosecond opposing covering. They've allowed about the private structure, a G+9 fabled structure for the seismic disquisition and it's positioned in Zone II quarter in India. The base musts relating to the introductory security of structures are being secured by the system for setting out the base plan loads which must be accepted for dead loads, forced burdens, and other outside ladings. In this work it's proposed to complete seismic disquisition of multi-story RCC structures exercising Response Diapason Analysis system considering mass irregularity with the help of STAAD PRO software. the design structure is located at Delhi (Zone 2) region, they've given further emphasis on earthquake cargo rather than others. In the paper, design and detailing of all bear element of structure were calculated manually and values were kept in required field in the software. The design work was only related with the practical operation of the studied courses in the field.
6) Abhishek Chanda & Shashank Gupta (2018) have taken two structures with same material specifications and are analyzed under two different seismic zones of India. The analysis brings out different shear force and bending moment values at different zones. The different story drifts are being colluded for different loads and cargo combinations. The main purpose of this software is to design multistoried structure in a methodical process. originally sword columns were being used but it failed the design check so the concrete columns were being introduced. There's a gradational increase in the value of side forces from bottom to top bottom in software analysis.
7) Sourabh Pandey, Anant Bhardwaj, Sidharth Pastariya (2021) studied the effect of curiosity between Centre of mass (CM) and Centre of stiffness (CR) on the performance of the structures. Two structures of story (G+12) are used in this paper, likes Symmetrical with stake section and Unsymmetrical with stake section. the study also focuses on, to identify an applicable fashion suitable for analysis of large span cantilevers with in unsymmetrical structure. compare the response parameters similar as story drift, story shear, relegation, of Symmetrical and conventional structure. To compare the torsional moment & capsizing moment of Symmetrical and unsymmetrical structure with stake section. it can be concluded that the seismic analysis of unsymmetrical structure with stake depends upon factors which are cargo distribution, common deportations, curiosity between the Centre of stiffness and the Centre of mass etc. Structural parameters similar as story drift, side relegation, stiffness is advanced into an unsymmetrical structure. Base shear and torsional moment of unsymmetrical structure is more as compared to a symmetrical structure.

8) RICHARD SAMUEL, GEETHAKUMARI D, GOKULRAM H (2022) deals with analysis and design of multistoried (G+9) erecting with IS law and EURO law by using ETABS 2019 software considering zone II and medium soil condition. The BIS recommended IS 456:2000 and IS 1893(Part- 1) 2002 likewise European standard recommended EC2 and EC8 for Design of concrete structures and Design of earthquake resistant structures independently. The main purpose of this study is to bring out a detailed seismic analysis and structural design on simulation tool of ETABS 2019 using a blockish plan of multistorey structure. This study is concentrated to carry out the advantages of seismic design of multistorey structure using Indian standard (IS) law and Euro law with ETABS software. done the static and dynamic analysis on a 30-story structure, using Indian and Euro law of norms. To give comparison with the parameters like Displacement, Base shear, Story relegation, Story drift, Time period, Shear force, bending moments needed.

III. METHODOLOGY

To study the seismic behavior of structures with cantilever projections in different zones using ETABS, we will follow a systematic methodology. Here's an overview of the steps we will take:

1) *Model Creation:* We will create a detailed 3D model of the structure in ETABS, incorporating all the necessary geometric and material properties. This will include defining the building's dimensions, floor plans, column and beam layouts, and assigning appropriate material properties.
2) *Load Assignments:* We will apply seismic loads to the structure based on the specific design codes and regulations of the target zones. These loads will be representative of the seismic forces that the structure may experience during an earthquake event.
3) *Analysis Setup:* We will configure the analysis settings in ETABS, selecting the appropriate analysis type (such as linear or nonlinear) and defining the necessary parameters for the seismic analysis. This will include specifying the appropriate analysis method, damping values, and convergence criteria.
4) *Cantilever Projection Modeling:* We will accurately model the cantilever projections in the structure, ensuring that their dimensions, locations, and connections to the main structure are properly represented in the model.
5) *Seismic Analysis:* Using the defined model and load assignments, we will perform a seismic analysis in ETABS. This analysis will simulate the response of the structure to seismic forces, considering the presence of the cantilever projections. We will analyze the structural response in terms of displacements, stresses, and deformations.
6) *Results Evaluation:* We will analyze and evaluate the results obtained from the seismic analysis. This will involve examining the behavior of the structure with different types and arrangements of cantilever projections. We will compare the response of structures with and without cantilevers to identify any significant differences and draw conclusions regarding their seismic performance.
7) *Interpretation and Conclusion:* Based on the analysis results, we will interpret the findings and draw conclusions regarding the seismic behavior of structures with cantilever projections in different zones. We will discuss the implications of the results and provide recommendations for the design and construction of such structures.

IV. MODELING AND ANALYSIS

A. *Building Parameters*

Number of stories	5 Story	Number of stories	10 Story
Plan dimensions	16m X 16m	Plan dimensions	16m X 16m
Total height of building	15m	Total height of building	30m
Height of each story	3m	Height of each story	3m
Size of beam	600 X 350mm	Size of beam	500 X 450mm
Size of column	600 X 600mm	Size of column	600 X 600mm
Thickness of slab	150mm	Thickness of slab	180mm
Seismic zone	II, III, IV & V	Seismic zone	II, III, IV & V
Soil condition	Medium	Soil condition	Medium
Concrete grade	M30	Concrete grade	M40
Grade of steel	Fe 415	Grade of steel	Fe 550

B. Loads Considered

Sr.No.	LOAD	MEMBERS	5 Story	10 Story
1	Dead Load	Column	0.60 X 0.60 X 25 = 9 kN/m	0.60 X 0.60 X 25 = 9 kN/m
		Beam	0.60 X 0.35 X 25 = 5.25 kN/m	0.50 X 0.45 X 25 = 5.625 kN/m
		Slab	0.150 X 25 = 3.75 kN/m^2	0.180 X 25 = 4.5 kN/m^2
2	Live Load		2.5 kN/m^2	2.5 kN/m^2
3	Floor Load		1 kN/m^2	1 kN/m^2
4	Seismic- EQX		50% of 2.5 = 1.25 kN/m^2	1.25 kN/m^2
5	EQY		1.25 kN/m^2	1.25 N/m^2

C. Load Combination

1) 1.5 DL
2) 1.5 (DL + LL)
3) 1.5 (DL + EQX)
4) 1.5 (DL - EQX)
5) 1.5 (DL + EQY)
6) 1.5 (DL - EQY)
7) 1.2 (DL + LL + EQX)
8) 1.2 (DL + LL – EQX)
9) 1.2 (DL + LL + EQY)
10) 1.2 (DL + LL – EQY)
11) 0.9 (DL) + 1.5 (EQX)
12) 0.9 (DL) – 1.5 (EQX)
13) 0.9 (DL) + 1.5 (EQY)
14) 0.9 (DL) – 1.5 (EQY)

D. Seismic Zone Factor: as per, IS 1893 (Part 1): 2016

Seismic zone	ZONE 2	ZONE 3	ZONE 4	ZONE 5
Seismic zone factor	0.10	0.16	0.24	0.36

E. Structural Analysis

1) 5 Story building: Without cantilever

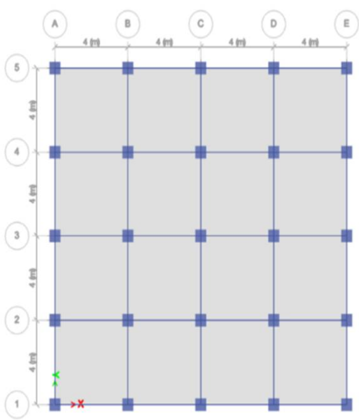

Fig 1: Plan view

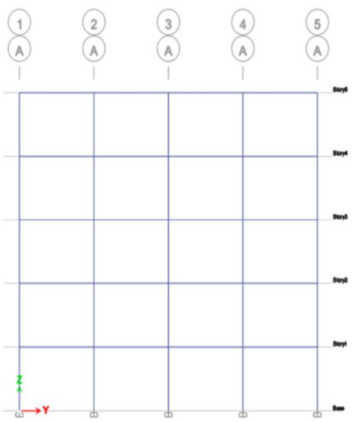

Fig 2: Elevation view

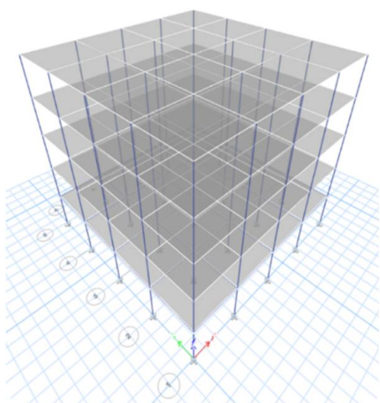

Fig 3: 3-d view

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2) 10 Story building: Without cantilever

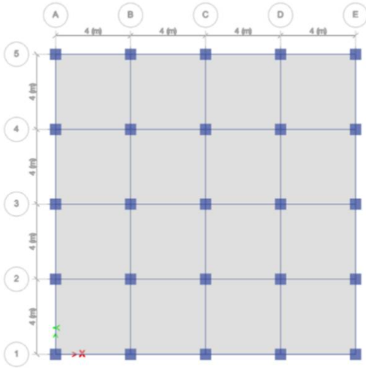
Fig 4: Plan view

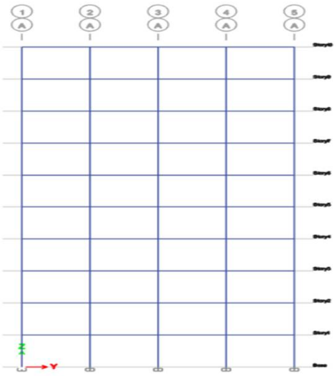
Fig 5: Elevation view

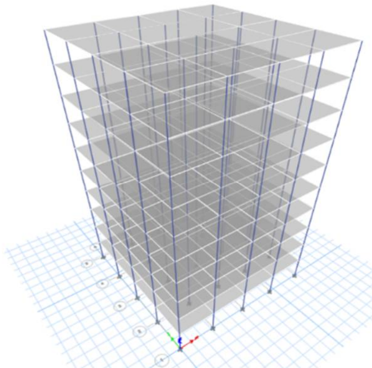
Fig 6: 3-d view

PLAN VIEW

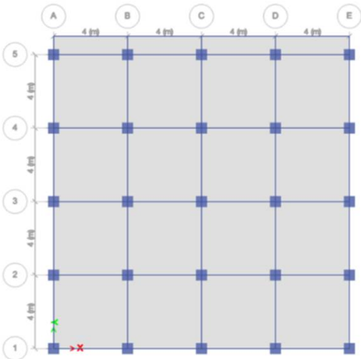
Fig 7: One side cantilever

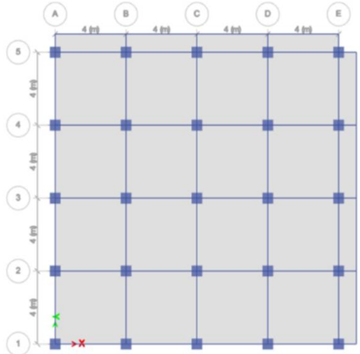
Fig 8: Two side cantilever

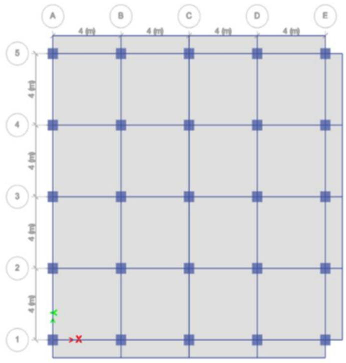
Fig 9: Three side cantilever

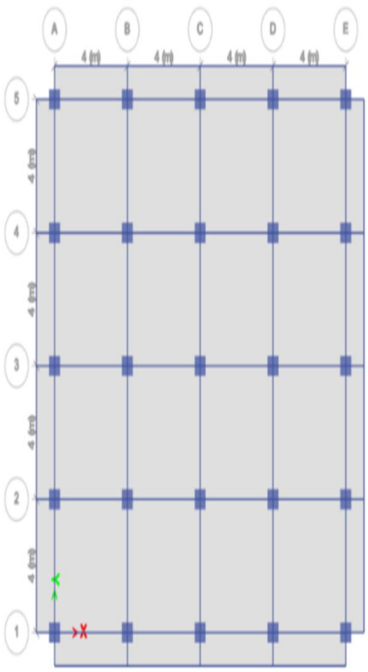
Fig 10: Four side cantilever

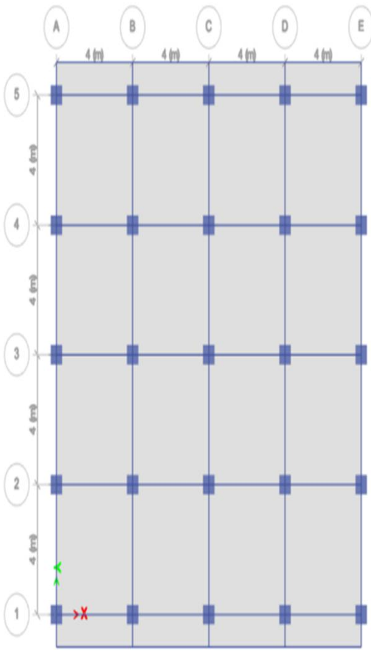
Fig 11: Opposite side cantilever

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V. RESULT AND DISCUSSION

A. Story Displacement

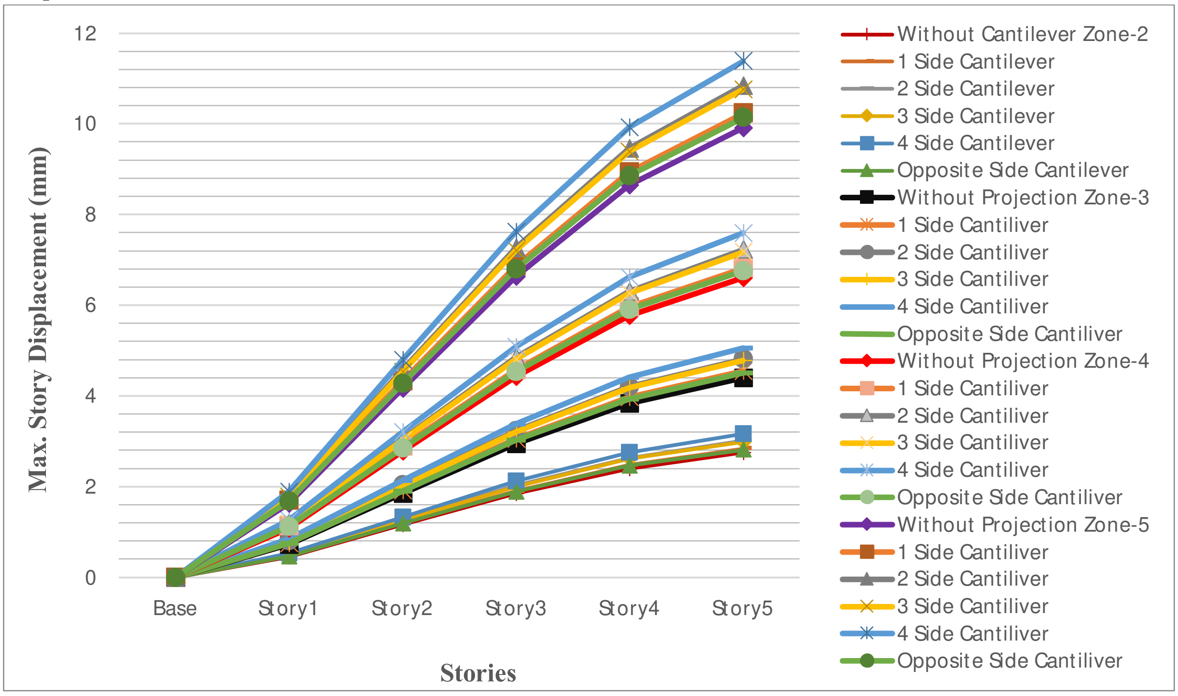

Fig 12: Story-5 of 1m cantilever projection in all zones

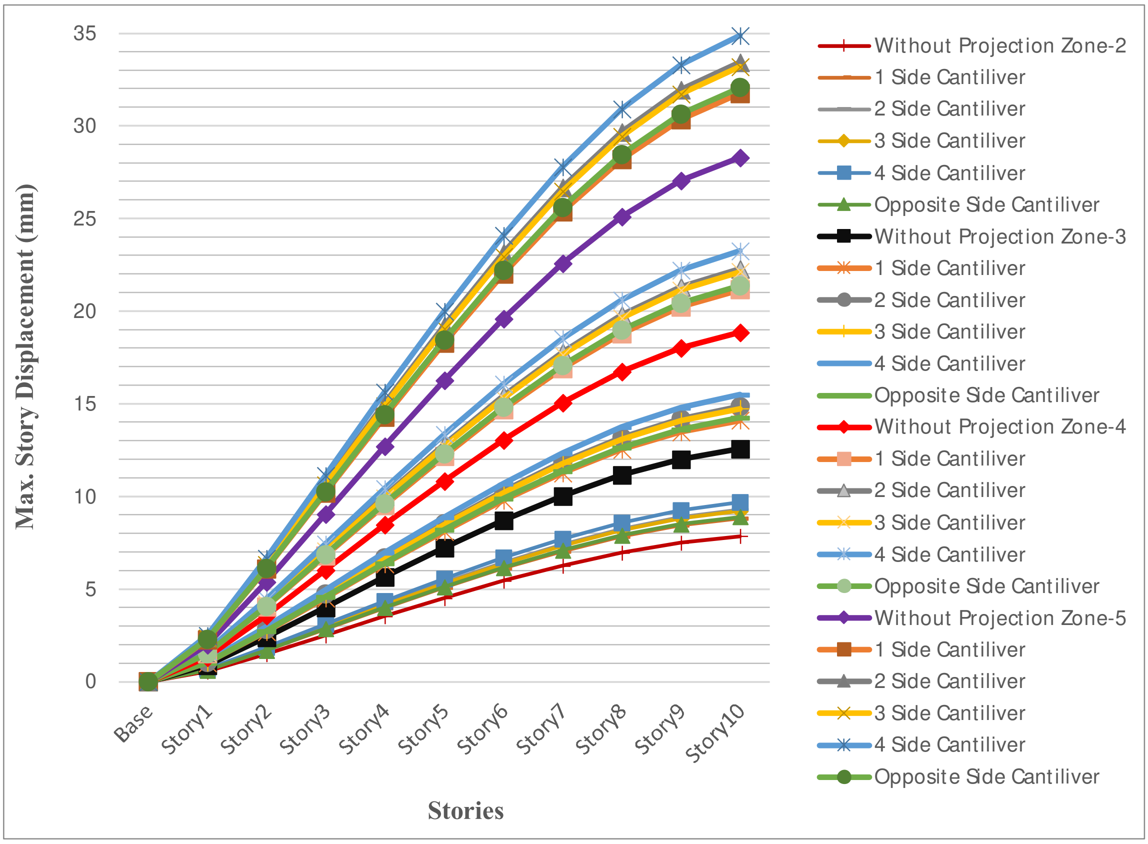

Fig 13: Story-10 of 1m cantilever projection in all zones

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B. Overturning Moment

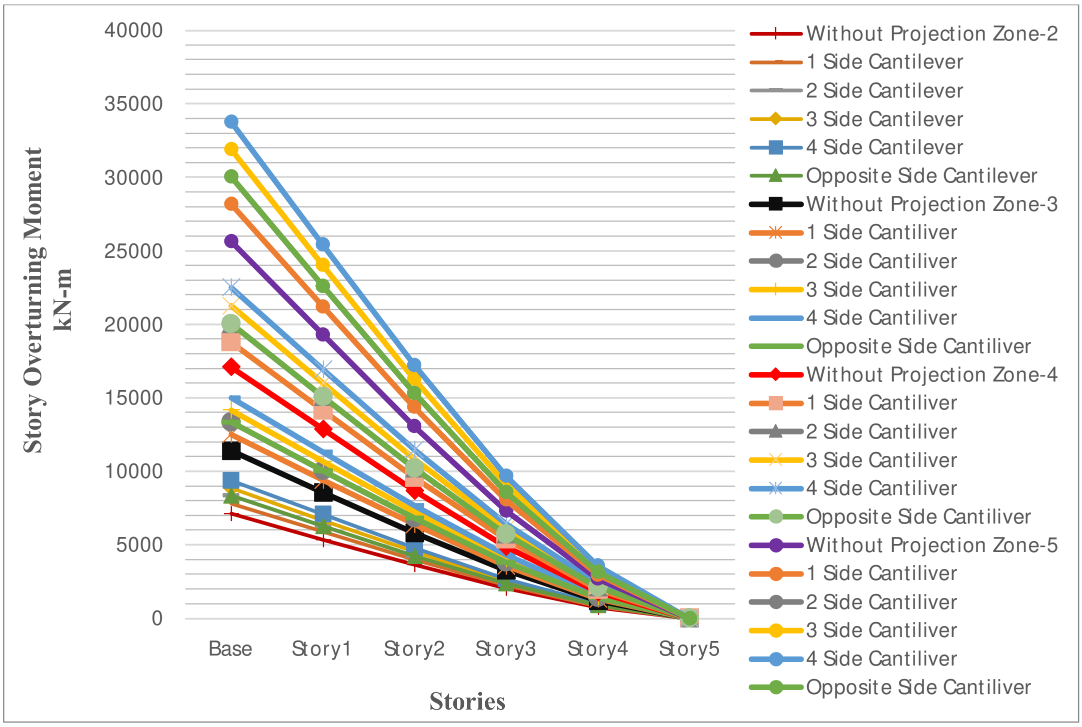


Fig 14: Story-5 of 1m cantilever projection in all zones

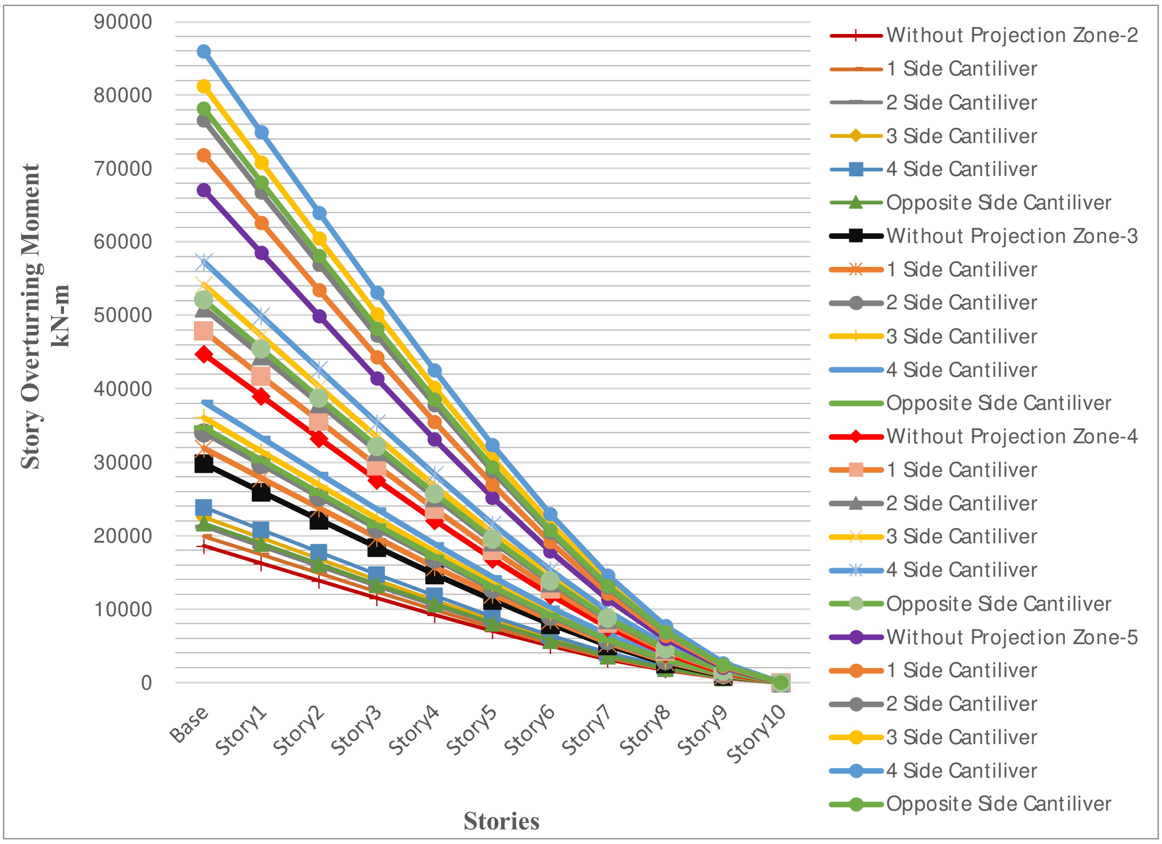
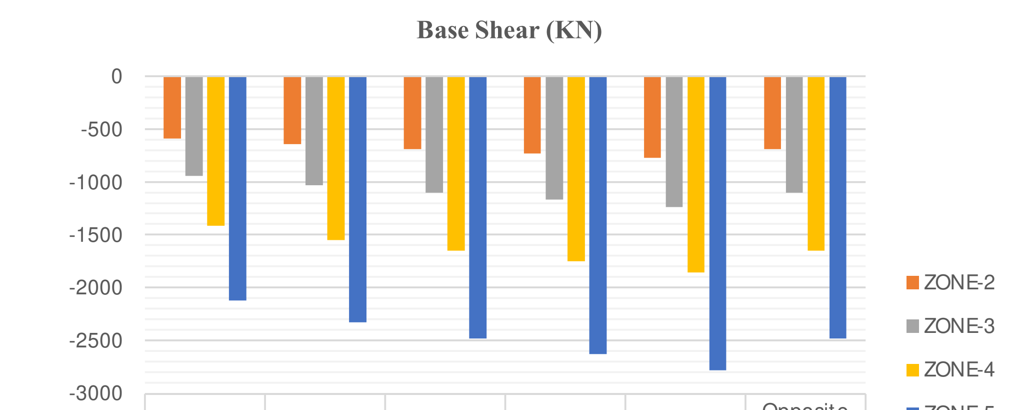


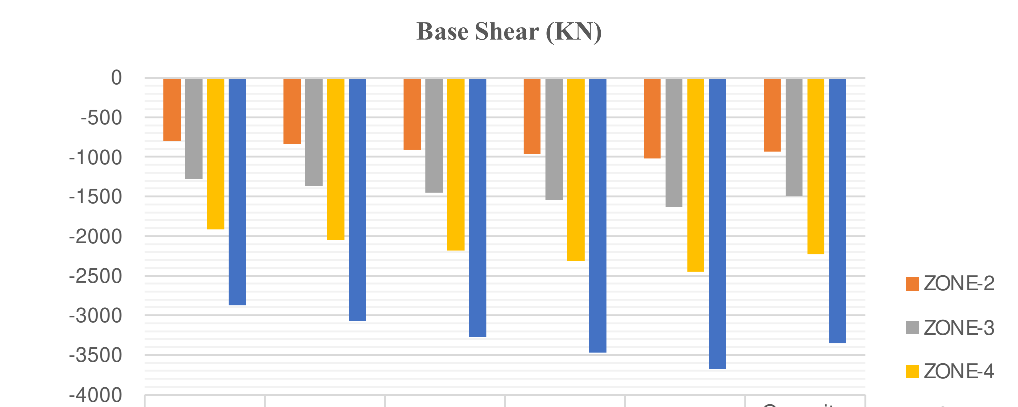
Fig 15: Story-10 of 1m cantilever projection in all zones

C. Base Shear



	Without projection	1 Side Cantilever	2 Side Cantilever	3 Side Cantilever	4 Side Cantilever	Opposite Side Cantilever
ZONE-2	-588.6881	-646.2658	-688.3252	-730.3847	-772.4441	-688.3252
ZONE-3	-941.901	-1034.0253	-1101.3204	-1168.6154	-1235.9105	-1101.3204
ZONE-4	-1412.8516	-1551.038	-1651.9806	-1752.9232	-1853.8658	-1651.9806
ZONE-5	-2119.2773	-2326.5569	-2477.9708	-2629.3848	-2780.7987	-2477.9708

Fig 16: Story-5 of 1m cantilever projection in all zones



	Without projection	1 Side Cantilever	2 Side Cantilever	3 Side Cantilever	4 Side Cantilever	Opposite Side Cantilever
ZONE-2	-798.0868	-835.6468	-909.2069	-964.767	-1020.327	-930.2112
ZONE-3	-1276.9389	-1365.835	-1454.731	-1543.6271	-1632.5232	-1488.3378
ZONE-4	-1915.4083	-2048.7524	-2182.0966	-2315.4407	-2448.7848	-2232.5068
ZONE-5	-2873.1124	-3073.1287	-3273.1449	-3473.1611	-3673.1773	-3348.7602

Fig 17: Story-10 of 1m cantilever projection in all zones

VI. CONCLUSION

A. Story Displacement

With increase in height of the building with top floor story displacement increases-

1) When cantilever is on one side story displacement at top increases by 3% for 5-storied building whereas it increases by 12% for 10-storied building. The top floor story displacement increases with cantilever projection on one side.

2) When cantilever is on two side story displacement at top increases by 9% for 5-storied building whereas it increases by 18% for 10-storied building. The top floor story displacement increases with cantilever projection on two side.

3) When cantilever is on three side story displacement at top increases by 8% for 5-storied building whereas it increases by 17% for 10-storied building. The top floor story displacement increases with cantilever projection on three side.
4) When cantilever is on four side story displacement at top increases by 14% for 5-storied building whereas it increases by 23% for 10-storied building. The top floor story displacement increases with cantilever projection on four side.
5) When cantilever is on opposite side story displacement at top increases by 2% for 5 storied building whereas it increases by 13% for 10-storied building. The top floor story displacement increases with cantilever projection on opposite side.

The top floor story displacement increases with cantilever projections on all sides and in all zones.

B. Overturning Moment

With increase in height of the building with top floor overturning moment decreases-

1) When cantilever is on one side overturning moment at top increases by 9% for 5-storied building whereas it decreases by 7% for 10-storied building. The top floor overturning moment decreases with cantilever projection on one side.
2) When cantilever is on two side overturning moment at top increases by 17% for 5-storied building whereas it decreases by 14% for 10-storied building. The top floor overturning moment decreases with cantilever projection on two side.
3) When cantilever is on three side overturning moment at top increases by 24% for 5-storied building whereas it decreases by 21% for 10-storied building. The top floor overturning moment decreases with cantilever projection on three side.
4) When cantilever is on four side overturning moment at top increases by 31% for 5-storied building whereas it decreases by 28% for 10-storied building. The top floor overturning moment decreases with cantilever projection on four side.
5) When cantilever is on opposite side overturning moment at top increases by 17% for 5-storied building whereas it decreases by 16% for 10-storied building. The top floor overturning moment decreases with cantilever projection on opposite side.

The top floor overturning moment decreases with cantilever projections on all sides and in all zones.

C. Base Shear

With increase in height of the building with Base Shear decreases-

1) When cantilever is on one side base shear increases by 9% for 5-storied building whereas it decreases by 6% for 10-storied building. Base shear decreases with cantilever projection on one side.
2) When cantilever is on two side base shear increases by 16% for 5-storied building whereas it decreases by 13% for 10-storied building. Base shear decreases with cantilever projection on two side.
3) When cantilever is on three side base shear increases by 24% for 5-storied building whereas it decreases by 20% for 10-storied building. Base shear decreases with cantilever projection on three side.
4) When cantilever is on four side base shear increases by 31% for 5-storied building whereas it decreases by 27% for 10-storied building. Base shear decreases with cantilever projection on four side.
5) When cantilever is on opposite side base shear increases by 16% for 5-storied building whereas it remains constant by 16% for 10-storied building. Base shear remains constant with cantilever projection on opposite side.

Base shear decreases with cantilever projections on all sides and in all zones.

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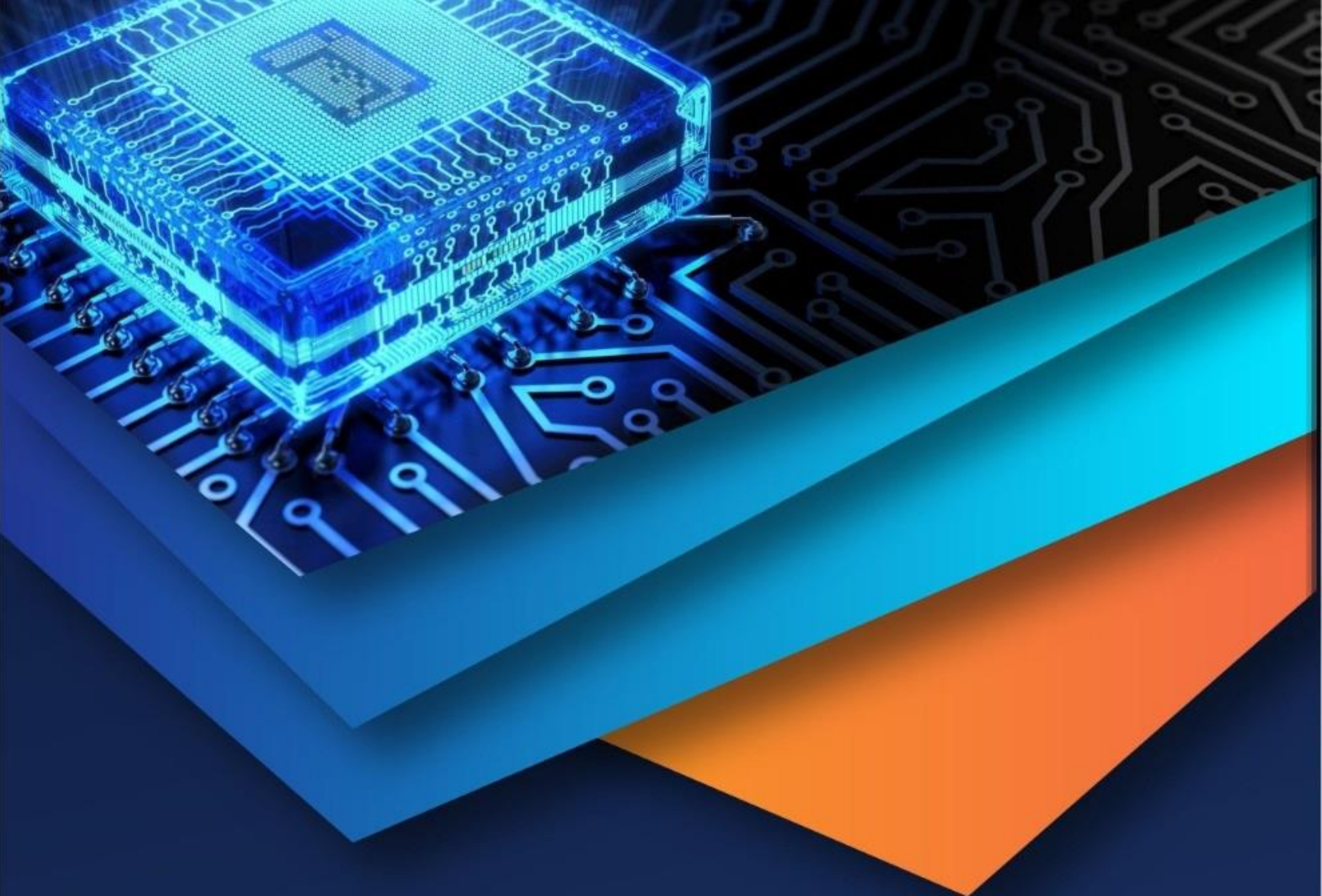

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