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Seismic Behavior of Structures with Different Cantilever Projections in Different Zones

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Abstract: This research paper focuses on studying how structures with different cantilever projections (1m, 1.25m, and 1.5m) behave during seismic events in different seismic zones. The analysis is conducted for both 5-story and 10-story buildings, following the guidelines provided in IS 1893 (Part 1):2016. The static method is used to assess various parameters, including story drift, frequency and time period in ETABS software. By examining these factors, we can better understand how these structures perform under seismic forces.

Keywords: Seismic Zones, Cantilever Projection, IS 1893 (Part 1):2016, Static Method, Story Drift, Frequency, Time Period.

I. INTRODUCTION

Seismic behavior refers to the response of buildings and infrastructure to the ground motion generated by earthquakes. It encompasses a wide spectrum of phenomena, from structural integrity and stability to the safety of occupants and the preservation of property. Central to comprehending seismic behavior is the recognition that seismic hazards are not uniformly distributed across the globe; instead, they vary significantly from one geographic region to another. To address these regional variations in seismic risk, areas around the world are categorized into different seismic zones or seismic hazard zones. These zones are delineated based on the local geological, geophysical, and seismological conditions, which collectively govern the likelihood and intensity of seismic events. Each seismic zone is characterized by its unique seismic hazard level, specifying the ground motion acceleration that structures in that region may experience during an earthquake. The seismic behavior of structures is profoundly influenced by the seismic zone in which they are situated. Buildings and infrastructure in high seismic hazard zones must be engineered to withstand more severe ground motions, necessitating robust and innovative design approaches. In contrast, regions with lower seismic hazard levels may permit more relaxed design criteria.

II. LITERATURE REVIEW

- 1) Arunava Das, Priyabrata Guha (2016) finds response of regular and irregular structures by nonlinear static analysis and nonlinear dynamic analysis. The study includes the Pushover Analysis and Non-linear Time History Analysis of four legendary regular and irregular structures in SAP 2000 platform. Four legendary R.C. structures with Case I – regular plan and Case II – Irregular plan are considered for seismic analysis. It's observed that the deformation attained by static analysis is advanced than dynamic analysis for irregular Time History analysis should be performed as it predicts the structural response more directly in comparison with Pushover Analysis structure and deformation attained by dynamic analysis is advanced than stationary analysis for regular structure.
- 2) Sampath Nagod, Prof. A.J. Zende (2017) perform such an analysis, a representative earthquake time history is demanded for the structure being estimated. In this present work non-direct dynamic analysis of 12 legendary RC structure having mass irregularity considering Bhuj earthquake time history is carried out using ETABS software. Also, Lead Rubber Bearing is manually designed and hermit parcels are assigned to the structure. Various parameters like Base shear, Time period and Story deformation are determined for regular and mass irregular structures with fixed base and base insulated condition and compared with each other. In this study, 12 fabulous corroborated concrete structure with and without base sequestration are considered. In addition to that, mass irregularity is also taken into consideration by furnishing heavy mass at 11th bottom. Time history analysis is performed on structures using ETABS software.
- 3) Abhay Guleria (2014) the case study in this paper substantially emphasizes on structural gesture of multi-story structure for different plan configurations like blocky, C, L and I-shape. Modelling of 15-story R.C.C. framed structure is done on the ETABS software for analysis. Post analysis of the structure, maximum shear forces, bending moments, and maximum story expatriation are reckoned and also compared for all the anatomized cases. L-shape, I-shape type structures give nearly analogous response against the capsizing moment. It can be concluded that asymmetrical plans suffer further distortion than symmetrical plans.

- 4) Sanisha Santhosh, Linda Ann Mathew (2017), studied on the enhancement shape of shear walls in symmetrical high-rise structure. In symmetrical structures, the center of gravity and center of severity coincide, so that the shear walls are placed symmetrically. In this work a high-rise structure with different shapes of shear walls is considered for analysis. The multistory structure with G+14 and G+29 stories is analyzed for its story drift and base shear using ETABS software. For the analysis of the structure for seismic loading with two different Zones (Zone- III & Zone- V) is considered. The analysis of the structure is done by using dynamic system (Response spectrum analysis).
- 5) Shobha R, Vinod BR, Vivek Vedant, Jagdish Suthar B, Pawan Bhatia, Joell Binu P (2021) studied about the multi-story seismic analysis will proceed in two stages- Performance differentiation of a reinforced concrete structure for all present seismic regions in India i.e., II(Two), III(Three), IV(Four), and V(Five) and Analysis of factors like base shear, story drift and story displacement of designed structure for various seismic zones. Analysis of designed structure is done using ETABS and response spectrum analysis is considered for the different seismic regions, there's gradual increase in the base shear and lateral displacement in the structure. The drift is observed to be increasing with increase in story levels.
- 6) RAJU MUDDASANI, NAVJOT KAUR BHATIA (2023), the effect of seismic forces on structures with different vertical figure arrangements have been analyzed by exercising ETABS software. Analysis and design are done as per IS456- 2000. M30 grade of concrete and Fe- 500 brand is espoused. weight combinations are taken as per IS 875- part 5 (2015). There are several enterprises which affect the performance of structure from which story shear and story deformation play a vital part in changing the behavior of structure against the seismic loads. Story deformation increased with story height. The deformation decreases as the vertical irregularity increases.
- 7) Ravi Kumar Vishwakarma, Vipin Kumar Tiwari (2021), presents the literature review of colorful studies done before on the factors which affect the performance of shear walls similar as position of shear walls. It's studied that maximum drift and story drift value are set up to be advanced in seismic zone V as compared to other zones. Seismic zone II, III and VI which indicate the drift can be reduced by making structure with invariant stiffness. It was observed that drift with varying consistency in dwindling order throughout the height at middle external span achieves loftiest reduction in drift due to increased side stiffness and drop in seismic weight of the structure.
- 8) Asadullah Dost, Asst.Prof. Anil Kumar Chaudhary (2021) The primary thing of this exploration is to conduct an earthquake analysis of G+15, G+20, and G+25 domestic structures using Indian standard canons of practice IS 1893 (Part 1) 2002. The member forces are calculated using load combinations according to IS 456 2000's Limit State Method. According to IS 875 (Part 1, Part 2) 1987, the structure is subordinated to dead load, self-weight, and live load. With the help of the ETABS software, the structure was designed in agreement with seismic law IS- 18932002 under seismic zone IV. Response spectrum and seismic response of the structures are studied by ETABS 2018 using dynamic analysis.

III. METHODOLOGY

Seismic analysis is a critical aspect of structural engineering that involves evaluating the response of structures to earthquakes and ground motion. The analysis aims to ensure the safety and stability of buildings and other structures during seismic events. Seismic analysis methods can be broadly categorized into static and dynamic procedures.

A. Static Seismic Analysis

Static seismic analysis methods provide simplified but conservative approximations of the seismic forces that a structure might experience during an earthquake. These methods are often used for straightforward structures and include:

- 1) Equivalent Static Lateral Force Procedure
- 2) Pushover Analysis (Static Nonlinear Analysis)

B. Dynamic Seismic Analysis

Dynamic seismic analysis methods consider the time-varying characteristics of ground motion and a structure's response to them. These methods are typically employed for complex or tall structures and include:

- 1) Response Spectrum Analysis
- 2) Time History Analysis
- 3) Modal Response Spectrum Analysis

Out of these methods we are using only Equivalent Static Lateral Force Procedure. This method allows us to estimate the forces that an earthquake will exert on a structure. It simplifies the analysis by using a single, equivalent force that represents the overall effect of the earthquake. By applying this force to the structure, we can design it to withstand the seismic forces and ensure its safety. Another important aspect is following the IS:1893:(Part-1):2016 code, which provides guidelines for seismic design in India. This code, issued by the Bureau of Indian Standards (BIS), is a comprehensive document that covers various aspects of seismic design and construction, including:

- a) *Seismic Zoning:* The code classifies different regions of India into seismic zones based on their vulnerability to earthquakes. It provides guidelines for designing structures according to the seismic zone in which they are located.
- b) *Load Combinations:* IS: 1893 (Part-1):2016 outlines the load combinations and factors to consider when designing structures for earthquake loads, including dead loads, live loads, and seismic forces.
- c) *Structural Design:* The code provides design criteria for various types of structures, such as buildings, bridges, and industrial structures, to ensure they can withstand earthquake forces.
- d) *Material Specifications:* It includes specifications for materials commonly used in construction to ensure they meet seismic design requirements.
- e) *Foundation Design:* Guidelines for the design of foundations to withstand seismic forces are included in the code.
- f) *Retaining Structures:* The code also addresses the design of retaining structures and their stability during earthquakes.
- g) *Non-Structural Components:* IS: 1893 (Part-1):2016 provides recommendations for the earthquake-resistant design of non-structural components, such as cladding, partitions, and mechanical and electrical systems.

Overall, IS: 1893 (Part-1):2016 is a crucial document for engineers and architects in India, providing standards and practices to enhance the earthquake resistance of structures and improve public safety during seismic events.

IV. MODELING AND ANALYSIS

A. General Statement Of The Building

No. of stories = 5 story	No. of stories = 10 story
Plan dimension = 16m X 16m	Plan dimension = 16m X 16m
Total height of building = 15m	Total height of building = 30m
Height of each story = 3m	Height of each story = 3m

B. Building Dimensions

MEMBERS	5 STORY	10 STORY
Column	600 X 600mm	600 X 600mm
Beam	600 X 350mm	500 X 450mm
Slab	150mm	180mm

C. Grade Of Material Used

MATERIALS	5 STORY	10 STORY
Concrete	M30	M40
Steel	Fe415	Fe550

D. Seismic Parameter

as per IS: 1893 (Part-1):2016

Response reduction factor: 5

Importance factor: 1

Soil type: II

Damping ratio: 0.05

E. 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

F. Loads Considered

Sr No	LOAD	MEMBERS	5 Story	10 Story
1	Dead	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		2.5 kN/m ²	2.5 kN/m ²
3	Floor		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 kN/m ²

G. 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)

H. Structural Analysis

- 1) 5 Story Building: One side cantilever

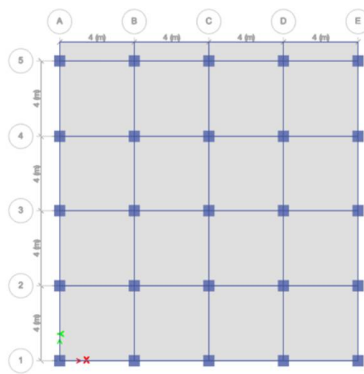


Fig 1: Plan view

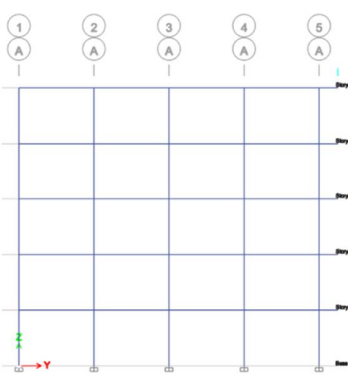


Fig 2: Elevation view

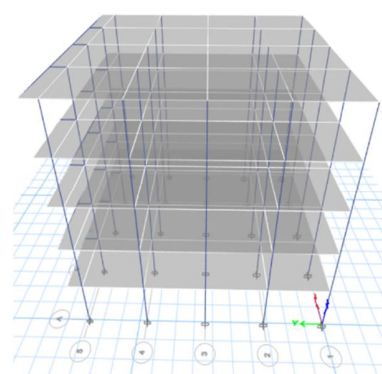


Fig 3: 3-d view

2) 10 Story Building: One side cantilever

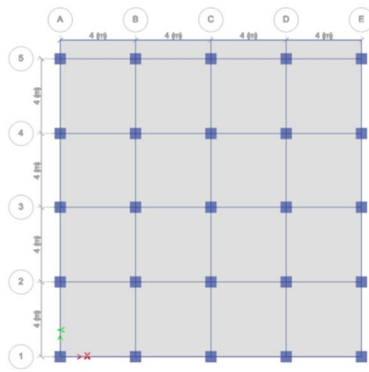


Fig 4: Plan view

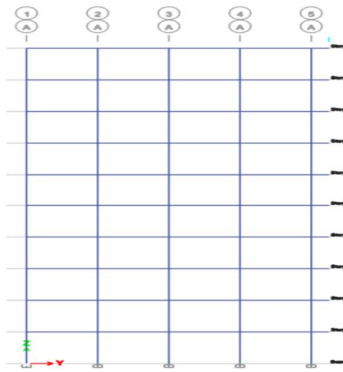


Fig 5: Elevation view

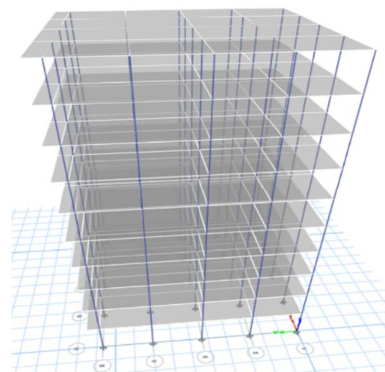


Fig 6: 3-d view

3) Plan View

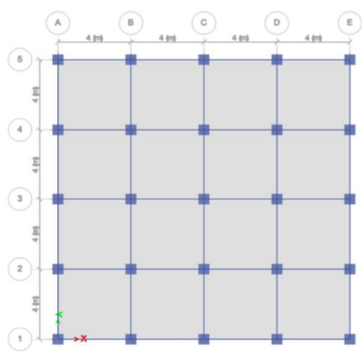


Fig 7: Without cantilever

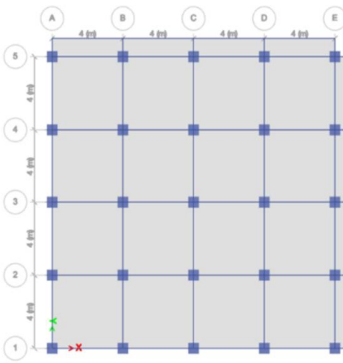


Fig 8: Two side cantilever

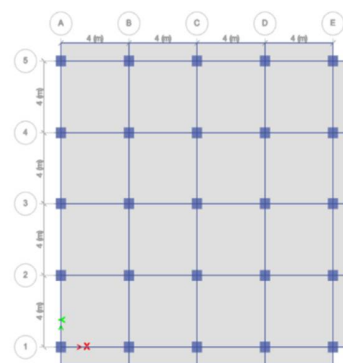


Fig 9: Three side cantilever

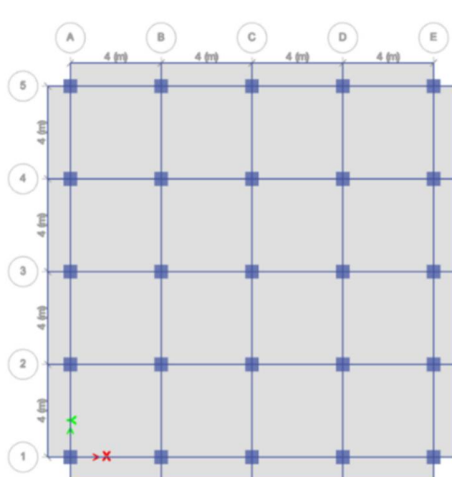


Fig 10: Four side cantilever

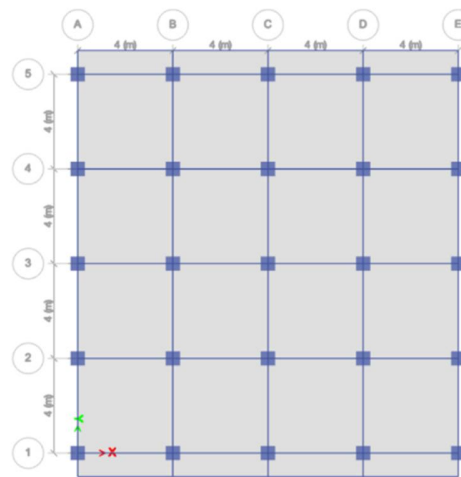


Fig 11: Opposite side cantilever

V. RESULTS AND DISCUSSION

A. Story Drift

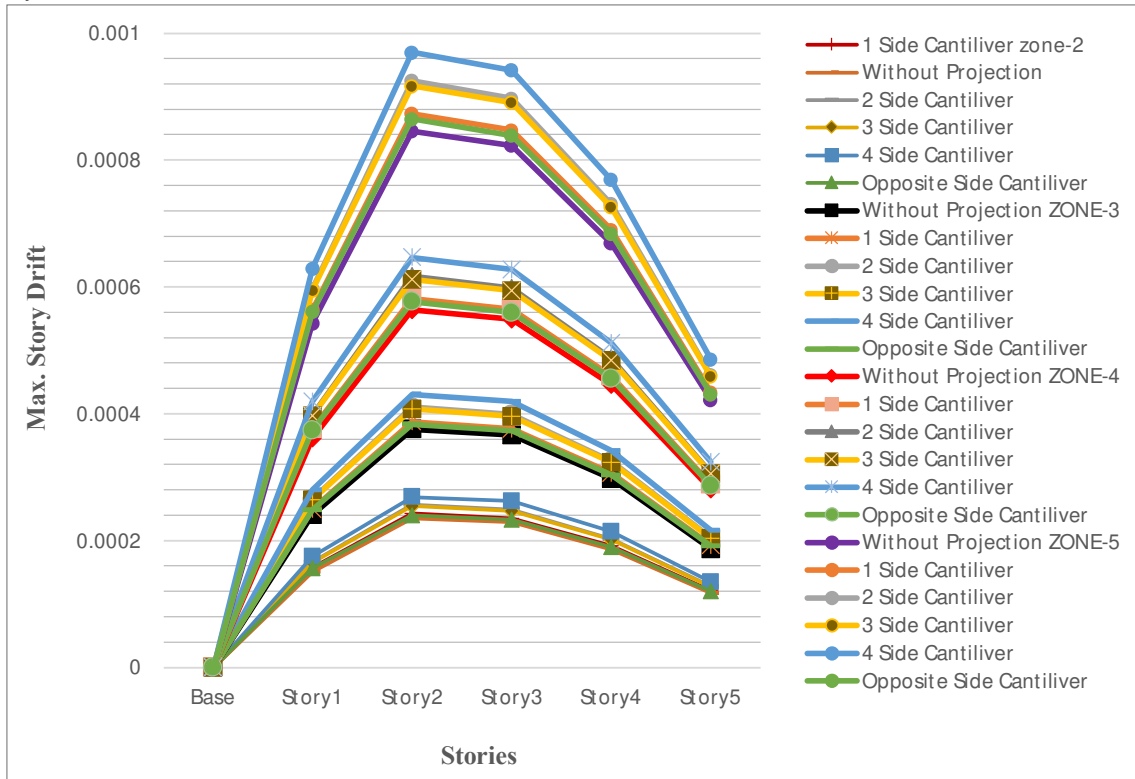


Fig 12: Story-5 of 1m cantilever projection in all zones

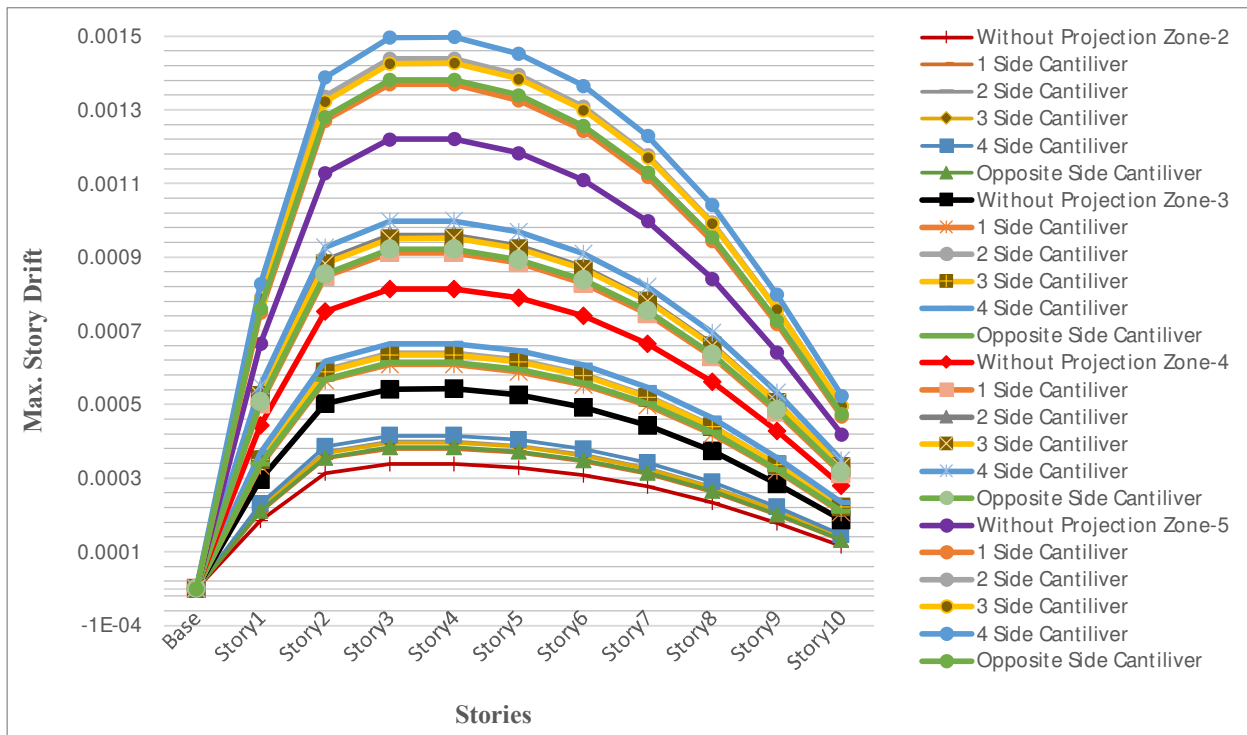


Fig 13: Story-10 of 1m cantilever projection in all zones

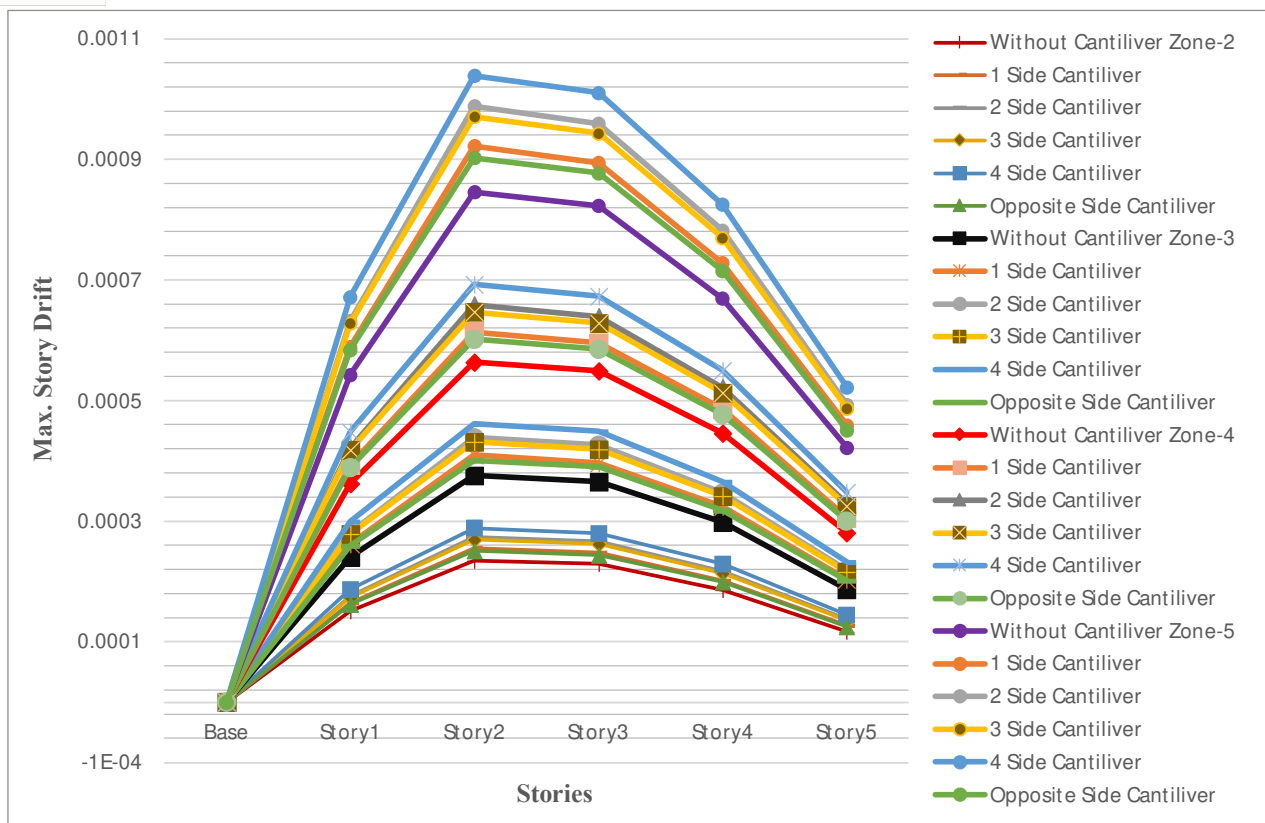


Fig 16: Story-5 of 1.5m cantilever projection in all zones

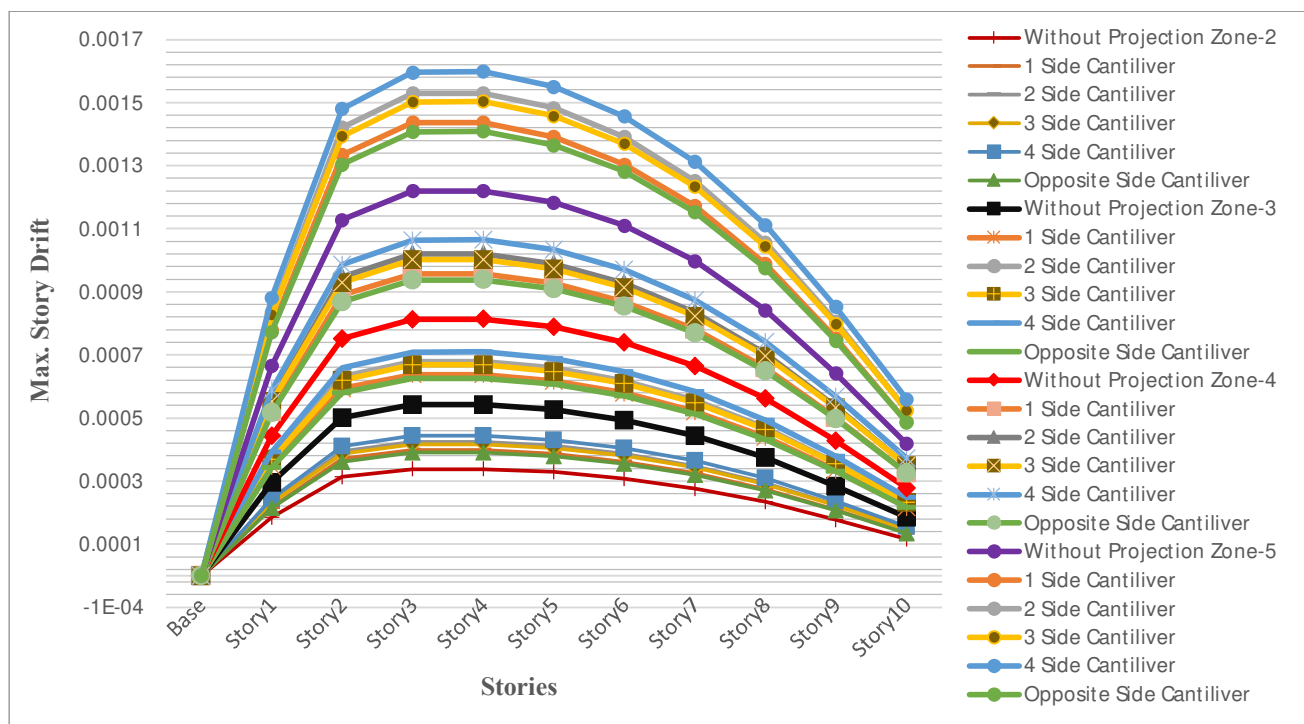


Fig 17: Story-10 of 1.5m cantilever projection in all zones

B. Time Period

TABLE 1: Story-5 of 1m cantilever projection {The time period for 5-story remains same in all the zones (2,3,4&5)}

Mode	without projection	1 side cant.	2 side cant.	3 side cant.	4 side cant.	opposite side
	sec	sec	sec	sec	sec	sec
1	0.511	0.511	0.529	0.542	0.549	0.527
2	0.511	0.51	0.523	0.534	0.549	0.518
3	0.451	0.455	0.473	0.497	0.519	0.481
4	0.161	0.161	0.167	0.171	0.174	0.166
5	0.161	0.161	0.165	0.169	0.174	0.164
6	0.143	0.144	0.15	0.158	0.166	0.153
7	0.089	0.09	0.093	0.095	0.096	0.092
8	0.089	0.089	0.092	0.094	0.096	0.091
9	0.08	0.081	0.084	0.088	0.093	0.086
10	0.06	0.061	0.063	0.065	0.065	0.062
11	0.06	0.06	0.062	0.064	0.065	0.062
12	0.054	0.055	0.057	0.06	0.064	0.058

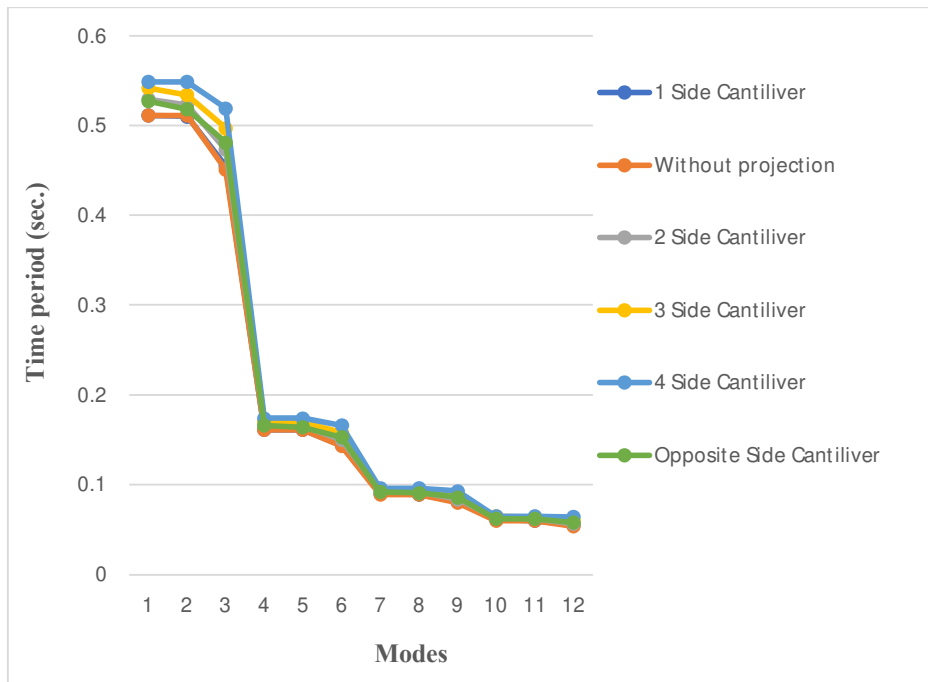


Fig 18: Story-5 of 1m cantilever projection

TABLE 2: Story-10 of 1m cantilever projection {The time period for 10-story remains same in all the zones (2,3,4&5)}

Mode	without projection	1 side cant.	2 side cant.	3 side cant.	4 side cant.	opposite side
	sec	sec	sec	sec	sec	sec
1	1.094	1.134	1.173	1.197	1.215	1.167
2	1.094	1.127	1.157	1.185	1.215	1.165
3	0.949	0.994	1.036	1.093	1.148	1.068
4	0.353	0.366	0.379	0.387	0.392	0.377
5	0.353	0.364	0.374	0.383	0.392	0.376
6	0.308	0.323	0.336	0.355	0.374	0.347
7	0.199	0.207	0.215	0.219	0.221	0.213
8	0.199	0.205	0.211	0.216	0.221	0.212
9	0.176	0.185	0.192	0.203	0.214	0.199
10	0.134	0.139	0.145	0.148	0.149	0.143
11	0.134	0.138	0.142	0.146	0.149	0.143
12	0.119	0.125	0.13	0.137	0.145	0.135

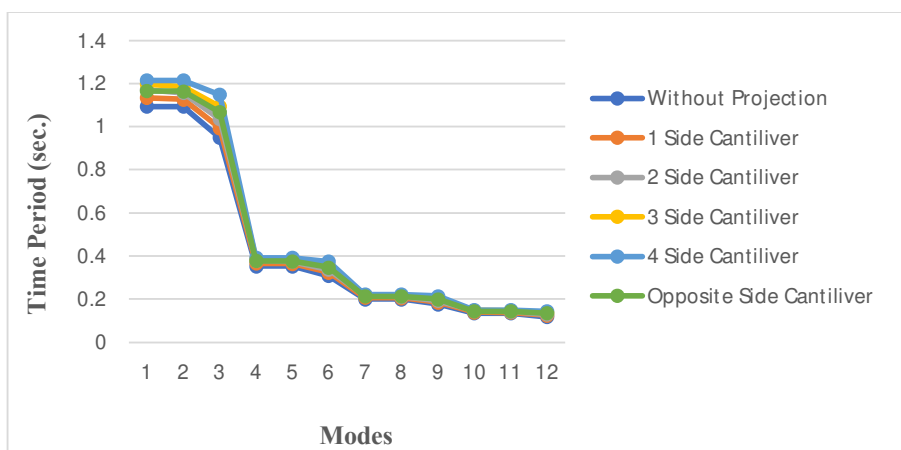


Fig 19: Story-10 of 1m cantilever projection

TABLE 3: Story-5 of 1.25m cantilever projection {The time period for 5-story remains same in all the zones (2,3,4&5)}

Mode	without projection	1 side cant.	2 side cant.	3 side cant.	4 side cant.	opposite side
	sec	sec	sec	sec	sec	sec
1	0.511	0.515	0.538	0.552	0.559	0.532
2	0.511	0.513	0.528	0.542	0.559	0.524
3	0.451	0.458	0.479	0.509	0.537	0.491
4	0.161	0.163	0.17	0.175	0.177	0.168
5	0.161	0.162	0.167	0.171	0.177	0.166
6	0.143	0.145	0.152	0.162	0.171	0.156
7	0.089	0.09	0.095	0.097	0.098	0.093
8	0.089	0.09	0.092	0.095	0.098	0.092
9	0.08	0.081	0.085	0.09	0.096	0.087
10	0.06	0.061	0.064	0.066	0.066	0.063
11	0.06	0.061	0.063	0.064	0.066	0.062
12	0.054	0.055	0.057	0.061	0.066	0.059

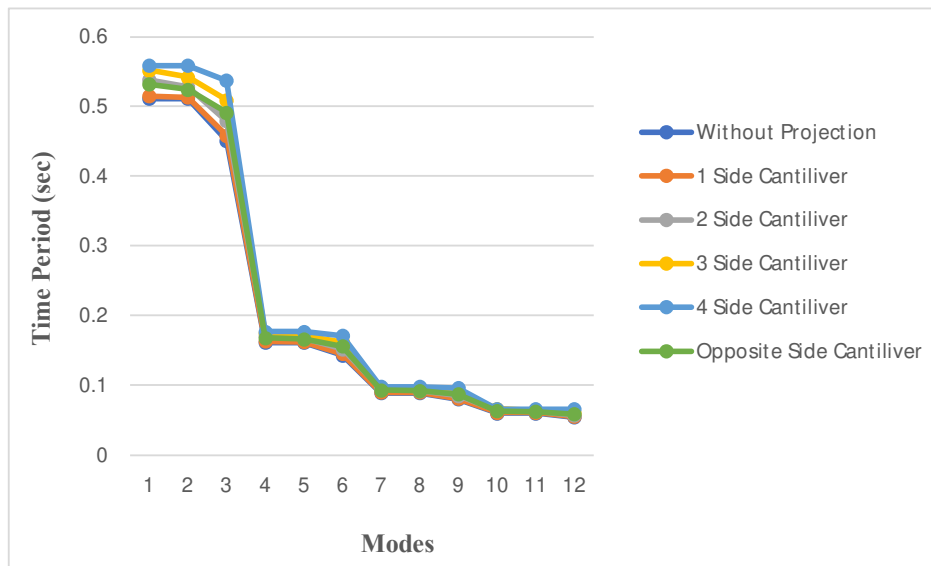


Fig 20: Story-5 of 1.25m cantilever projection

TABLE 4: Story-10 of 1.25m cantilever projection {The time period for 10-story remains same in all the zones (2,3,4&5)}

Mode	without projection	1 side cant.	2 side cant.	3 side cant.	4 side cant.	opposite side
	sec	sec	sec	sec	sec	sec
1	1.094	1.143	1.191	1.217	1.235	1.17
2	1.094	1.133	1.168	1.201	1.235	1.165
3	0.949	1.001	1.048	1.115	1.183	1.076
4	0.353	0.369	0.385	0.394	0.399	0.378
5	0.353	0.366	0.377	0.388	0.399	0.376
6	0.308	0.325	0.34	0.362	0.385	0.35
7	0.199	0.209	0.218	0.223	0.225	0.213
8	0.199	0.206	0.213	0.219	0.225	0.212
9	0.176	0.186	0.194	0.207	0.221	0.201
10	0.134	0.141	0.147	0.151	0.152	0.143
11	0.134	0.139	0.143	0.148	0.152	0.143
12	0.119	0.125	0.131	0.14	0.15	0.136

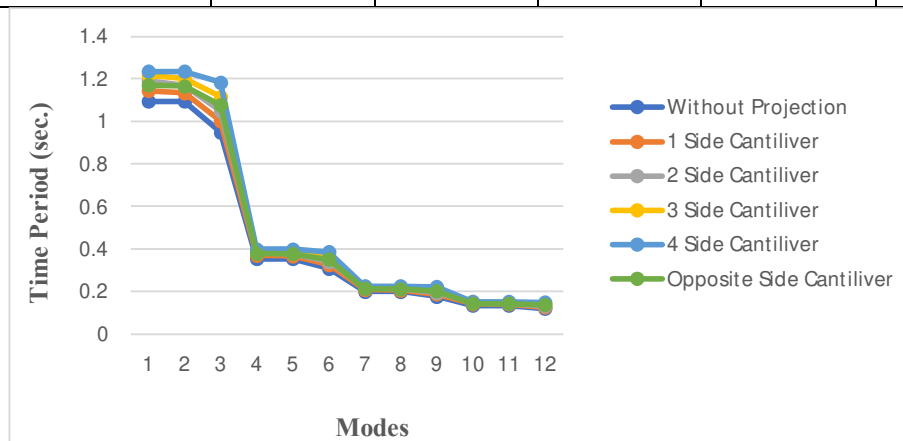


Fig 21: Story-10 of 1.25m cantilever projection

TABLE 5: Story-5 of 1.5m cantilever projection {The time period for 5-story remains same in all the zones (2,3,4&5)}

Mode	without projection sec	1 side cant. sec	2 side cant. sec	3 side cant. sec	4 side cant. sec	opposite side sec
1	0.511	0.52	0.547	0.562	0.569	0.537
2	0.511	0.516	0.533	0.549	0.569	0.529
3	0.451	0.461	0.484	0.519	0.555	0.501
4	0.161	0.164	0.173	0.178	0.18	0.169
5	0.161	0.163	0.168	0.174	0.18	0.167
6	0.143	0.146	0.153	0.165	0.177	0.159
7	0.089	0.091	0.096	0.099	0.1	0.094
8	0.089	0.09	0.093	0.096	0.1	0.093
9	0.08	0.081	0.085	0.092	0.099	0.089
10	0.06	0.062	0.065	0.067	0.068	0.063
11	0.06	0.061	0.063	0.065	0.067	0.063
12	0.054	0.055	0.058	0.062	0.067	0.061

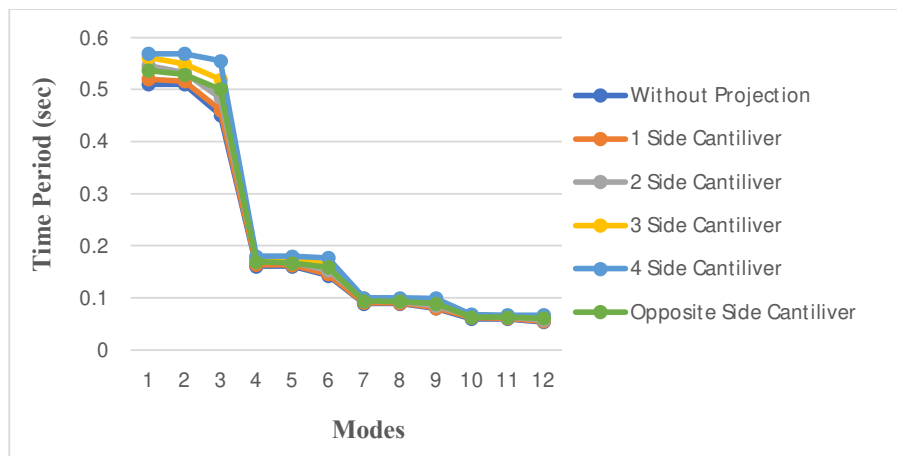


Fig 22: Story-5 of 1.5m cantilever projection

TABLE 6: Story-10 of 1.5m cantilever projection {The time period for 10-story remains same in all the zones (2,3,4&5)}

Mode	without projection sec	1 side cant. sec	2 side cant. sec	3 side cant. sec	4 side cant. sec	opposite side sec
1	1.094	1.153	1.211	1.24	1.255	1.18
2	1.094	1.138	1.179	1.217	1.255	1.177
3	0.949	1.007	1.059	1.138	1.221	1.097
4	0.353	0.373	0.392	0.401	0.405	0.381
5	0.353	0.367	0.38	0.393	0.405	0.38
6	0.308	0.327	0.344	0.369	0.397	0.357
7	0.199	0.211	0.222	0.227	0.229	0.215
8	0.199	0.207	0.215	0.222	0.229	0.214
9	0.176	0.187	0.196	0.211	0.228	0.204
10	0.134	0.142	0.15	0.154	0.154	0.145
11	0.134	0.139	0.145	0.149	0.154	0.144
12	0.119	0.126	0.132	0.142	0.154	0.138

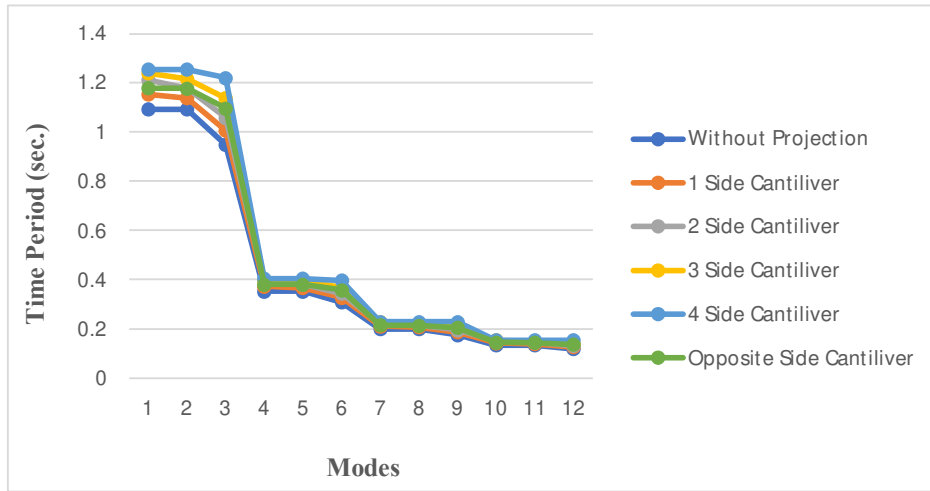


Fig 23: Story-10 of 1.5m cantilever projection

C. Frequency

TABLE 7: Story-5 of 1m cantilever projection {The frequency for 5-story remains same in all the zones (2,3,4&5)}

Mode	without projection	1 side cant.	2 side cant.	3 side cant.	4 side cant.	opposite side
	cyc/sec	cyc/sec	cyc/sec	cyc/sec	cyc/sec	cyc/sec
1	1.956	1.958	1.891	1.845	1.821	1.896
2	1.956	1.962	1.913	1.873	1.821	1.93
3	2.215	2.197	2.113	2.012	1.926	2.078
4	6.196	6.202	5.971	5.833	5.755	6.011
5	6.196	6.205	6.056	5.92	5.755	6.1
6	6.988	6.929	6.66	6.328	6.038	6.536
7	11.193	11.162	10.729	10.495	10.367	10.868
8	11.193	11.215	10.924	10.66	10.367	10.979
9	12.522	12.416	11.935	11.304	10.729	11.666
10	16.555	16.449	15.788	15.458	15.286	16.094
11	16.555	16.598	16.135	15.712	15.286	16.175
12	18.462	18.3	17.589	16.616	15.684	17.132

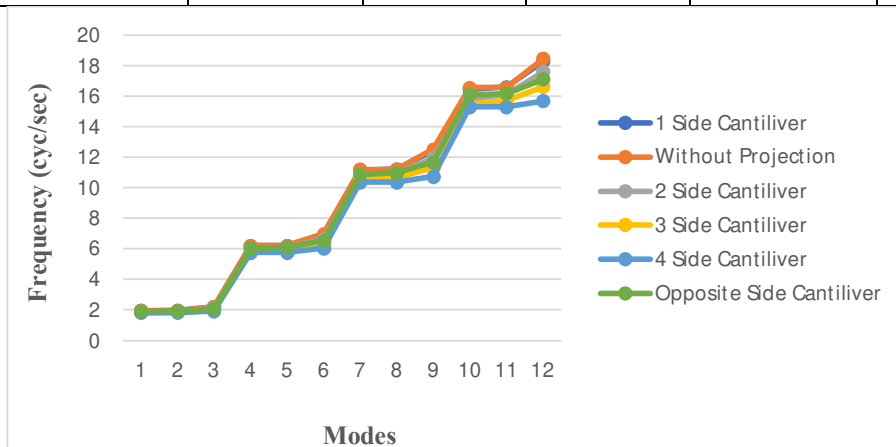


Fig 24: Story-5 of 1m cantilever projection

TABLE 8: Story-10 of 1m cantilever projection {The frequency for 10-story remains same in all the zones (2,3,4&5)}

Mode	without projection cyc/sec	1 side cant. cyc/sec	2 side cant. cyc/sec	3 side cant. cyc/sec	4 side cant. cyc/sec	opposite side cyc/sec
1	0.914	0.882	0.852	0.835	0.823	0.857
2	0.914	0.887	0.864	0.844	0.823	0.859
3	1.054	1.006	0.965	0.915	0.871	0.937
4	2.833	2.731	2.636	2.585	2.549	2.654
5	2.833	2.749	2.677	2.613	2.549	2.659
6	3.245	3.097	2.973	2.816	2.677	2.88
7	5.027	4.835	4.659	4.57	4.518	4.704
8	5.027	4.877	4.747	4.631	4.518	4.712
9	5.669	5.417	5.204	4.923	4.662	5.022
10	7.465	7.171	6.902	6.769	6.694	6.972
11	7.465	7.24	7.043	6.865	6.694	6.984
12	8.397	8.023	7.707	7.284	6.884	7.42

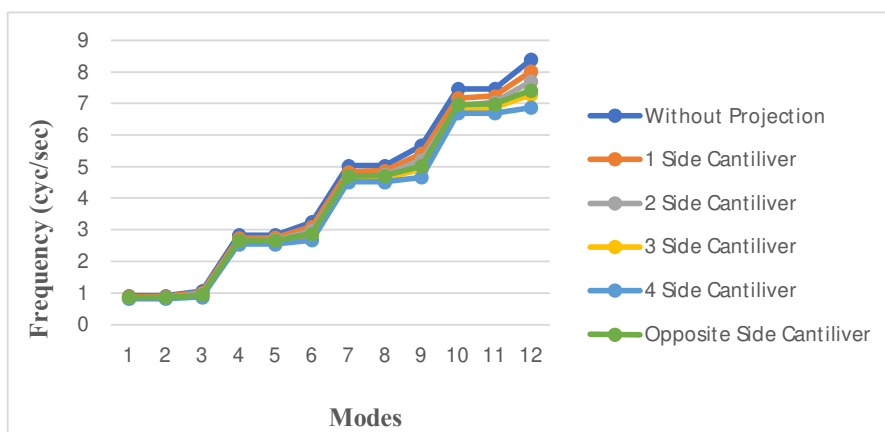


Fig 25: Story-10 of 1m cantilever projection

TABLE 9: Story-5 of 1.25m cantilever projection {The frequency for 5-story remains same in all the zones (2,3,4&5)}

Mode	without projection cyc/sec	1 side cant. cyc/sec	2 side cant. cyc/sec	3 side cant. cyc/sec	4 side cant. cyc/sec	opposite side cyc/sec
1	1.956	1.943	1.859	1.812	1.788	1.88
2	1.956	1.949	1.894	1.845	1.788	1.909
3	2.215	2.183	2.087	1.966	1.861	2.036
4	6.196	6.142	5.87	5.727	5.656	5.959
5	6.196	6.177	5.997	5.836	5.656	6.035
6	6.988	6.886	6.585	6.192	5.84	6.406
7	11.193	11.055	10.548	10.3	10.197	10.776
8	11.193	11.164	10.824	10.517	10.197	10.87
9	12.522	12.348	11.815	11.085	10.394	11.444
10	16.555	16.3	15.531	15.173	15.05	15.959
11	16.555	16.524	15.995	15.517	15.05	16.029
12	18.462	18.208	17.428	16.324	15.22	16.823

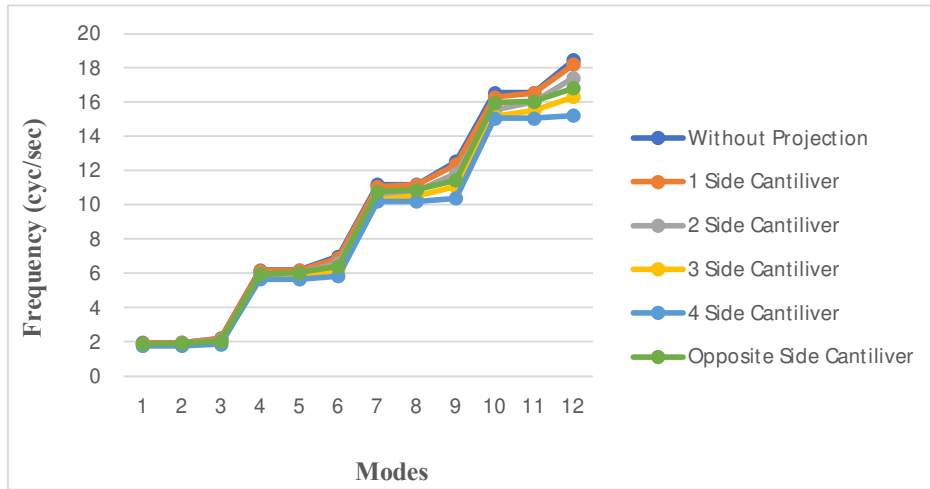


Fig 26: Story-5 of 1.25m cantilever projection

TABLE 10: Story-10 of 1.25m cantilever projection {The frequency for 10-story remains same in all the zones (2,3,4&5)}

Mode	without projection	1 side cant.	2 side cant.	3 side cant.	4 side cant.	opposite side
	cyc/sec	cyc/sec	cyc/sec	cyc/sec	cyc/sec	cyc/sec
1	0.914	0.875	0.84	0.821	0.81	0.855
2	0.914	0.883	0.856	0.833	0.81	0.858
3	1.054	0.999	0.954	0.897	0.845	0.929
4	2.833	2.709	2.596	2.541	2.508	2.648
5	2.833	2.735	2.653	2.579	2.508	2.658
6	3.245	3.078	2.94	2.76	2.597	2.859
7	5.027	4.793	4.585	4.487	4.446	4.698
8	5.027	4.853	4.705	4.572	4.446	4.712
9	5.669	5.387	5.152	4.832	4.524	4.987
10	7.465	7.108	6.791	6.644	6.588	6.972
11	7.465	7.205	6.979	6.778	6.588	6.988
12	8.397	7.98	7.632	7.151	6.68	7.377

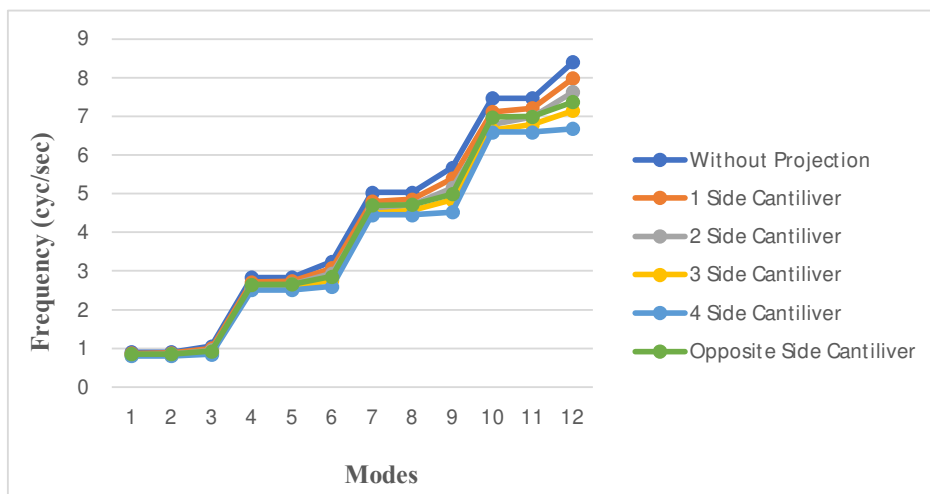


Fig 27: Story-10 of 1.25m cantilever projection

TABLE 11: Story-5 of 1.5m cantilever projection {The frequency for 5-story remains same in all the zones (2,3,4&5)}

Mode	without projection	1 side cant.	2 side cant.	3 side cant.	4 side cant.	opposite side
	cyc/sec	cyc/sec	cyc/sec	cyc/sec	cyc/sec	cyc/sec
1	1.956	1.923	1.827	1.779	1.759	1.864
2	1.956	1.94	1.876	1.82	1.759	1.889
3	2.215	2.17	2.066	1.927	1.802	1.996
4	6.196	6.081	5.769	5.62	5.565	5.908
5	6.196	6.148	5.942	5.759	5.565	5.975
6	6.988	6.849	6.521	6.074	5.66	6.283
7	11.193	10.946	10.368	10.102	10.038	10.686
8	11.193	11.114	10.728	10.384	10.038	10.769
9	12.522	12.289	11.71	10.895	10.085	11.232
10	16.555	16.145	15.272	14.882	14.785	15.828
11	16.555	16.45	15.859	15.331	14.827	15.89
12	18.462	18.128	17.284	16.065	14.827	16.522

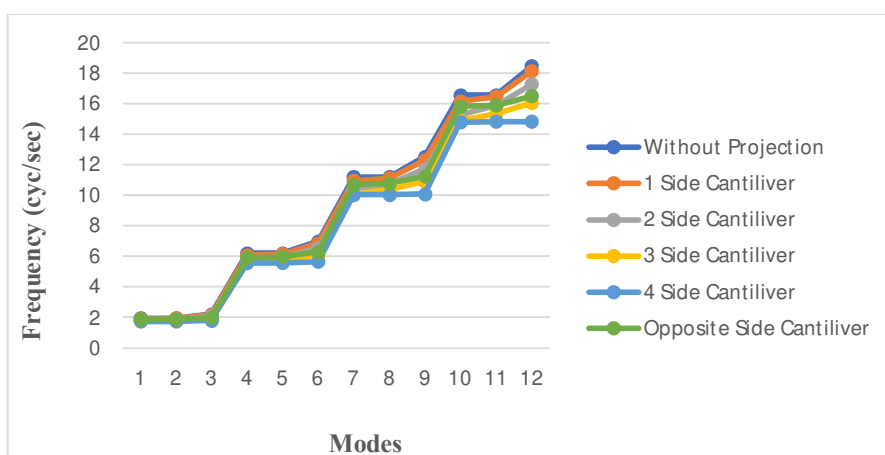


Fig 28: Story-5 of 1.5m cantilever projection

TABLE 12: Story-10 of 1.5m cantilever projection {The frequency for 10-story remains same in all the zones (2,3,4&5)}

Mode	without projection	1 side cant.	2 side cant.	3 side cant.	4 side cant.	opposite side
	cyc/sec	cyc/sec	cyc/sec	cyc/sec	cyc/sec	cyc/sec
1	0.914	0.867	0.826	0.807	0.797	0.847
2	0.914	0.879	0.848	0.822	0.797	0.85
3	1.054	0.993	0.944	0.879	0.819	0.911
4	2.833	2.683	2.553	2.493	2.468	2.626
5	2.833	2.723	2.628	2.546	2.468	2.632
6	3.245	3.061	2.91	2.707	2.517	2.803
7	5.027	4.745	4.504	4.398	4.375	4.659
8	5.027	4.831	4.662	4.513	4.375	4.667
9	5.669	5.359	5.105	4.747	4.385	4.892
10	7.465	7.037	6.672	6.511	6.478	6.913
11	7.465	7.172	6.917	6.691	6.485	6.922
12	8.397	7.94	7.564	7.03	6.485	7.236

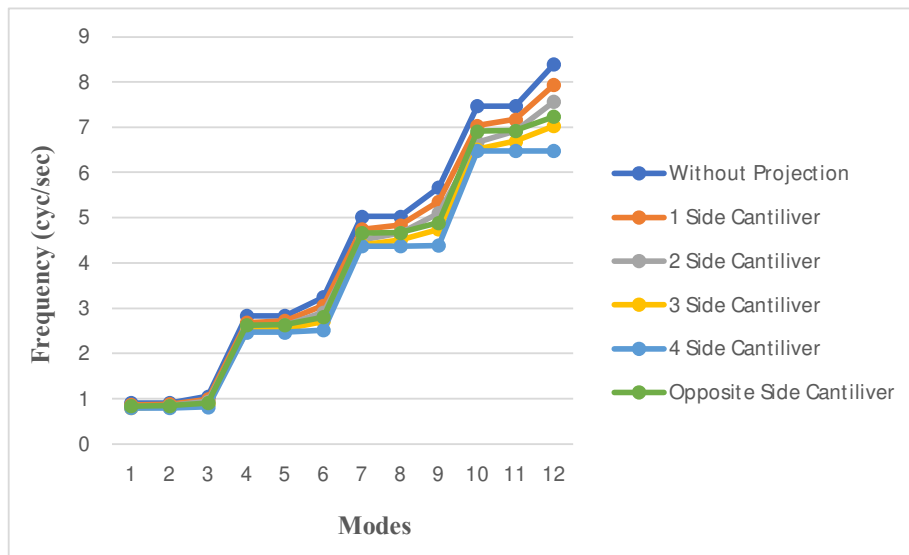


Fig 29: Story-10 of 1.5m cantilever projection

VI. CONCLUSION

A. Story Drift

1) 1m Cantilever Projection

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

- When cantilever is on one side story drift at top increases by 3% for 5-storied building whereas it increases by 12% for 10-storied building. The top floor story drift increases with cantilever projection on one side.
- When cantilever is on two side story drift at top increases by 9% for 5-storied building whereas it increases by 17% for 10-storied building. The top floor story drift increases with cantilever projection on two side.
- When cantilever is on three side story drift at top increases by 8% for 5-storied building whereas it increases by 17% for 10-storied building. The top floor story drift increases with cantilever projection on three side.
- When cantilever is on four side story drift at top increases by 14% for 5-storied building whereas it increases by 22% for 10-storied building. The top floor story drift increases with cantilever projection on four side.
- When cantilever is on opposite side story drift at top increases by 2% for 5 storied building whereas it increases by 13% for 10-storied building. The top floor story drift increases with cantilever projection on opposite side.

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

2) 1.25m Cantilever Projection

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

- When cantilever is on one side story drift at top increases by 6% for 5-storied building whereas it increases by 14% for 10-storied building. The top floor story drift increases with cantilever projection on one side.
- When cantilever is on two side story drift at top increases by 13% for 5-storied building whereas it increases by 21% for 10-storied building. The top floor story drift increases with cantilever projection on two side.
- When cantilever is on three side story drift at top increases by 11% for 5-storied building whereas it increases by 19%-20% for 10-storied building. The top floor story drift increases with cantilever projection on three side.
- When cantilever is on four side story drift at top increases by 18% for 5-storied building whereas it increases by 26% for 10-storied building. The top floor story drift increases with cantilever projection on four side.
- When cantilever is on opposite side story drift at top increases by 4% for 5 storied building whereas it increases by 13% for 10-storied building. The top floor story drift increases with cantilever projection on opposite side.

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

3) 1.5m Cantilever Projection

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

- When cantilever is on one side story drift at top increases by 8% for 5-storied building whereas it increases by 17% for 10-storied building. The top floor story drift increases with cantilever projection on one side.
- When cantilever is on two side story drift at top increases by 16% for 5-storied building whereas it increases by 25% for 10-storied building. The top floor story drift increases with cantilever projection on two side.
- When cantilever is on three side story drift at top increases by 14% for 5-storied building whereas it increases by 23% for 10-storied building. The top floor story drift increases with cantilever projection on three side.
- When cantilever is on four side story drift at top increases by 22% for 5-storied building whereas it increases by 30% for 10-storied building. The top floor story drift increases with cantilever projection on four side.
- When cantilever is on opposite side story drift at top increases by 6% for 5 storied building whereas it increases by 15% for 10-storied building. The top floor story drift increases with cantilever projection on opposite side.

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

B. Time Period

1) 1m Cantilever Projection

With increase in height of the building the time period increases-

- When cantilever is on one side time period increases by 0% for 5-storied building whereas it increases by 3% for 10-storied building. The time period increases with cantilever projection on one side.
- When cantilever is on two side time period increases by 3% for 5-storied building whereas it increases by 7% for 10-storied building. The time period increases with cantilever projection on two side.
- When cantilever is on three side time period increases by 6% for 5-storied building whereas it increases by 9% for 10-storied building. The time period increases with cantilever projection on three side.
- When cantilever is on four side time period increases by 7% for 5-storied building whereas it increases by 11% for 10-storied building. The time period increases with cantilever projection on four side.
- When cantilever is on opposite side time period increases by 3% for 5 storied building whereas it increases by 6% for 10-storied building. The time period increases with cantilever projection on opposite side.

The time period increases with cantilever projections on all sides and in all zones.

2) 1.25m Cantilever Projection

With increase in height of the building the time period increases-

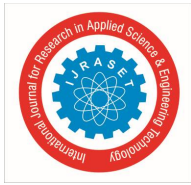
- When cantilever is on one side time period increases by 0.78% for 5-storied building whereas it increases by 4% for 10-storied building. The time period increases with cantilever projection on one side.
- When cantilever is on two side time period increases by 5% for 5-storied building whereas it increases by 8% for 10-storied building. The time period increases with cantilever projection on two side.
- When cantilever is on three side time period increases by 8% for 5-storied building whereas it increases by 11% for 10-storied building. The time period increases with cantilever projection on three side.
- When cantilever is on four side time period increases by 9% for 5-storied building whereas it increases by 12% for 10-storied building. The time period increases with cantilever projection on four side.
- When cantilever is on opposite side time period increases by 4% for 5 storied building whereas it increases by 6% for 10-storied building. The time period increases with cantilever projection on opposite side.

The time period increases with cantilever projections on all sides and in all zones.

3) 1.5m Cantilever Projection

With increase in height of the building the time period increases-

- When cantilever is on one side time period increases by 1% for 5-storied building whereas it increases by 5% for 10-storied building. The time period increases with cantilever projection on one side.
- When cantilever is on two side time period increases by 7% for 5-storied building whereas it increases by 10% for 10-storied building. The time period increases with cantilever projection on two side.



- When cantilever is on three side time period increases by 9% for 5-storied building whereas it increases by 13% for 10-storied building. The time period increases with cantilever projection on three side.
- When cantilever is on four side time period increases by 11% for 5-storied building whereas it increases by 14% for 10-storied building. The time period increases with cantilever projection on four side.
- When cantilever is on opposite side time period increases by 5% for 5 storied building whereas it increases by 7% for 10-storied building. The time period increases with cantilever projection on opposite side.

The time period increases with cantilever projections on all sides and in all zones.

C. Frequency

1) 1m cantilever projection

With increase in height of the building the frequency increases-

- When cantilever is on one side frequency increases by 0.87% for 5-storied building whereas it increases by 4% for 10-storied building. The frequency increases with cantilever projection on one side.
- When cantilever is on two side frequency increases by 4% for 5-storied building whereas it increases by 8% for 10-storied building. The frequency increases with cantilever projection on two side.
- When cantilever is on three side frequency increases by 9% for 5-storied building whereas it increases by 13% for 10-storied building. The frequency increases with cantilever projection on three side.
- When cantilever is on four side frequency increases by 15% for 5-storied building whereas it increases by 18% for 10-storied building. The frequency increases with cantilever projection on four side.
- When cantilever is on opposite side frequency increases by 7% for 5 storied building whereas it increases by 11% for 10-storied building. The frequency increases with cantilever projection on opposite side.

The frequency increases with cantilever projections on all sides and in all zones.

2) 1.25m Cantilever Projection

With increase in height of the building the frequency increases-

- When cantilever is on one side frequency increases by 1% for 5-storied building whereas it increases by 4% for 10-storied building. The frequency increases with cantilever projection on one side.
- When cantilever is on two side frequency increases by 5% for 5-storied building whereas it increases by 9% for 10-storied building. The frequency increases with cantilever projection on two side.
- When cantilever is on three side frequency increases by 11% for 5-storied building whereas it increases by 14% for 10-storied building. The frequency increases with cantilever projection on three side.
- When cantilever is on four side frequency increases by 17% for 5-storied building whereas it increases by 20% for 10-storied building. The frequency increases with cantilever projection on four side.
- When cantilever is on opposite side frequency increases by 8% for 5 storied building whereas it increases by 12% for 10-storied building. The frequency increases with cantilever projection on opposite side.

The frequency increases with cantilever projections on all sides and in all zones.

3) 1.5m Cantilever Projection

With increase in height of the building the frequency increases-

- When cantilever is on one side frequency increases by 1% for 5-storied building whereas it increases by 5% for 10-storied building. The frequency increases with cantilever projection on one side.
- When cantilever is on two side frequency increases by 6% for 5-storied building whereas it increases by 9% for 10-storied building. The frequency increases with cantilever projection on two side.
- When cantilever is on three side frequency increases by 12% for 5-storied building whereas it increases by 16% for 10-storied building. The frequency increases with cantilever projection on three side.
- When cantilever is on four side frequency increases by 19% for 5-storied building whereas it increases by 22% for 10-storied building. The frequency increases with cantilever projection on four side.
- When cantilever is on opposite side frequency increases by 10% for 5 storied building whereas it increases by 13% for 10-storied building. The frequency increases with cantilever projection on opposite side.

The frequency increases with cantilever projections on all sides and in all zones.



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