COMPARATIVE STUDY ON SEISMIC ANALYSIS OF REINFORCED CONCRETE BUILDING IN DIFFERENT EARTHQUAKE ZONES OF BANGLADESH

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An undergraduate thesis submitted to the Department of Civil & Environmental Engineering of Islamic University of Technology, Gazipur, Bangladesh in partial fulfilment of the requirements for the degree

Of

BACHELOR OF SCIENCE IN CIVIL ENGINEERING

APPROVAL

The thesis titled **"COMPARATIVE STUDY ON SEISMIC ANALYSIS OF REINFORCED CONCRETE BUILDING IN DIFFERENT EARTHQUAKE ZONES OF BANGLADESH"** submitted by Hameem Al Hussain, K.M. Jabir Hayam Ornub, Md. Mehedi Hasan and Ahmed Sabbir has been approved fulfilling the requirements for the Bachelor of Science Degree in Civil Engineering.

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DECLARATION

We hereby declare that the undergraduate research work reported in this thesis has been performed by us under the supervision of **Professor Dr. Md. Tarek Uddin, PEng.** and this work has not been submitted elsewhere for any purpose.

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DEDICATED TO

OUR BELOVED PARENTS

ACKNOWLEDGEMENTS

"In the name of Allah, Most Gracious, Most Merciful"

All praise belongs to Allah (SWT), the Lord of the ‘Alamin, for everything. We would like to express our sincere gratitude to our supervisor, Professor Dr. Md. Tarek Uddin, PEng. for his guidance throughout the work. Without his direction and support, it would never have been possible. We also express our gratitude towards all the faculty members of IUT, who have helped us in every way.

We are ever grateful to our parents, no words can ever be strong enough to express our gratitude towards them for their love, guidance and support from the beginning of our life. We dedicate this work to them for their unconditional love and care.

We are also grateful to those, who directly or indirectly helped and supported us throughout our work.

ABSTRACT

Due to emergence of earthquake prone areas, earthquake analysis is becoming one of the key aspects in the design of any structure. This study was undertaken with a view to determine the extent of possible changes in the seismic behavior of RC Building Models for different seismic zones. The study highlights the effect of seismic zone factor in six different zones, which is considered in the seismic performance evaluation of buildings. Adding to that, performance of RC building due to wind variation in similar seismic zones has been also evaluated.

The present study is aimed to find out the spatial changes of three major parameters– Story Drift, Story Shear and Story Displacement in different seismic areas as well as to figure out the consequences of same building when subjected to wind load of different speed in similar seismic zones.

From our findings, the seismic effects is higher whenever seismic coefficients gets higher and eventually the seismic intensification varies with respect to it's coefficients. And for wind load, the wind speed governs in similar seismic zones.

Table of Contents

ACKNOWLEDGEMENTS **6**
ABSTRACT **7**
INTRODUCTION **9**
1.1Background of the study **9**
1.2Significance of the study **9**
1.3Zonal properties of Bangladesh **10**
1.4Objective of the Study **12**
1.5Organization of the Thesis **12**
LITERATURE REVIEW **13**
EXPERIMENTAL METHOD **15**
3.1 General **15**
3.2 Work Sequence in ETABS **16**
3.3 Detail of Analysis **17**
RESULT AND DISCUSSION **18**
4.1 General **18**
4.1.1 Story Displacement (Due to Zonal Variation) **18**
4.1.2 Story Displacement (Due to Wind Variation) **25**
4.1.3 Story Drift (Due to Seismic Variation) **31**
4.1.4 Story Drift (Due to Wind Variation) **37**
4.1.5 Story Shear (Due to Seismic Variation) **43**
4.1.6 Story Shear (Due to Wind Variation) **49**
4.1.7 Comparison of Directional Story Shear **55**
4.2Discussion **57**
4.2.1Story Displacement **57**
4.2.2Story Shear **58**
4.2.3Story Drift **60**
CONCLUSIONS AND RECOMMENDATIONS **61**
5.1 Summary **61**
5.2 Recommendations **61**
REFERENCES **62**

Chapter 1

INTRODUCTION

1.1Background of the study

Bangladesh is surrounded by several juncture of active tectonic plates boundaries. Five geological fault lines run through Bangladesh, makes this country more vulnerable as it will cause human tragedy due to lack of awareness and faulty structure. From the historical information, Bangladesh has experienced several eight major seismic events (magnitude over 7.0); among them the epicentre of two earthquakes (Srimongal Earthquake of 1918 & Bengal Earthquake of 1885) were located within this country. So it is high time we should take measures to make our residencies earthquake resistant for the betterment of our future generations. (Islam, Islam, & Islam, 2016)

1.2Significance of the study

According to BNBC (Bangladesh National Building Code) 2015, Bangladesh has been divided into four zones in which every zone has got it' zonal seismic coefficient. Our study is to analysis the impact of seismic events of a same multi storied RC building at different seismic zones of Bangladesh. The study helps us to understand how the changes of structural parameters occurs with respect to it's seismic coefficients that is ground acceleration. It is also our interest to check the behavior of RC building in similar seismic zones but subjected to different wind loads. This study helps to understand whether it should require any precautions make similar RC structure in similar seismic zone or not.

1.3Zonal properties of Bangladesh

For Zonal Seismic Variation:

Zone	Seismic Co-efficient	Wind Speed
Sylhet	0.36	135 mph
Chittagong	0.28	179 mph
Dhaka	0.2	147 mph
Bagerhat	0.12	174 mph

Wind Variation in Similar Seismic Zone:

Zone	Seismic Co-efficient	Wind Speed
Chittagong	0.28	179 mph
Tangail		114 mph
Bagerhat	0.12	174 mph
Gopalgonj		167 mph

Figure: Different Seismic Zones of Bangladesh

1.4Objective of the Study

The specific objective of this study are as follows:

i. To perform seismic analysis of RC structure in different seismic zones of Bangladesh.
ii. To study the behavior of a multi storied RC building subjected to lateral load by adopting Static Linear Analysis using ETABS 2016.
iii. To evaluate corresponding effects of zonal seismic variation and wind variation in the similar seismic zones

1.5Organization of the Thesis

The rest of the thesis has been organized as follows:

Chapter 2 : Literature Review – this chapter discusses about the past works on similar type of study and will give idea on how the work plan should be done.

Chapter 3 : Study area and data collection - identifying the location of the study and collection of data from various locations of the study area.

Chapter 4 : Methodology – in this chapter the procedural steps of the study will be described thoroughly.

Chapter 5 : Results and Discussions - analysis of the data collected from field observation and through laboratory testing.

Chapter 6 : Conclusions and Recommendations - this chapter will discuss the effectiveness of the study, and recommendations of the future studies.

Chapter 2

LITERATURE REVIEW

With the help of seismic analysis, the structure can be designed and constructed to withstand the high lateral movement of earth's crust during an earthquake. Any type of basic or a highly advanced structure which maybe under static or dynamic conditions can be evaluated by using ETABS. ETABS is a coordinated and productive tool for analysis and designs, which range from a simple 2D frames to modern high-rises which makes it one of the best structural software for building systems (Rathod & Chandrashekar,2017)

Another study from Ali Kadhim Sallal (2018) present a building where designed and analyzed under effect of earthquake and wind pressure by using ETABS software. In this case, (18m x 18m) and eight stories structure are modelled using ETABS software. Ten story is taken as (3m) height and making the total height of the structure (31m).

Again, a case study in a paper of Abhay Guleria (2014) mainly emphasizes on structural behavior of multi-storey building for different plan configurations like rectangular, C, L and I-shape. Modelling of 15- storeys R.C.C. framed building is done on the ETABS software for analysis. Post analysis of the structure, maximum shear forces, bending moments, and maximum storey displacement are computed and then compared for all the analyzed cases.

In another proposed study of Kale and Rasal (2017), four different shapes of same area multistorey model is generated & tested by the ETABS under the guideline of IS-875-Part3 & IS1893-2002-Part1. The behavior of 15, 30 & 45 storey building has been studied. The Dynamic effects also find by Response spectrum method. All the parameters like Story displacement, Story drift, Base shear, Overturning moments, Acceleration and Time period are calculated. After

comparing all building shapes results concluded that which section is convenient & either seismic or wind effect is critical.

Another work from Kakpure and Mundhada (2016) presents a review of the previous work done on earthquake analysis for multi storied byuildings. It focuses on static and dynamic analysis of buildings. This paper presents a review of the comparison of static and dynamic analysis multistoried building. Design parameters such as Displacement, Bending moment, Base shear, Storey drift, Torsion, Axial Force were the focus of the study.

Again a residential of G+11 multi-story building is studied for earth quake and wind load using ETABS and STAAS PRO V8i .Assuming that material property is linear static and dynamic analysis are performed. These analysis are carried out by considering different seismic zones and for each zone the behaviour is assessed by taking three different types of soils namely Hard , Medium and Soft .Different response like story drift, displacements base shear are plotted for different zones and different types of soils (Mahesh & Rao ,2014)

Balaji and Selvarasan (2016) studied a residential building G+13 storied. The building was analyzed for earthquake loads using ETABS. Assuming that the material properties were linear, static and dynamic analysis was performed. Different response like displacement & base shear were calculated and it was observed that displacement increased with the building height.

Sultan and Peera (2015) studied behavior of the structure in high seismic zone and also evaluated Storey overturning moment, Storey Drift, Displacement, Design lateral forces etc. For this purpose, a 15 storey-high building of four totally different shapes like Rectangular, L-shape, H-shape, and C-shape were used for comparison. The complete models were analyzed with the assistance of ETABS 9.7.1 version.

Chapter 3

EXPERIMENTAL METHOD

3.1 General

This Chapter will discuss about the detailed procedure that has been followed to accomplish the work. The whole process is divided into four phases–

- Literature Review
- Seismic Analysis
- Data Study
- Result & Conclusion

In the previous chapter, Literature review has already been done. Seismic analysis has been performed in ETABS software (2016). There are several methods of seismic analysis in ETABS 2016. They are–

- Equivalent Lateral Force Method (Static, Linear)
- Response Spectrum Analysis (Dynamic, Linear)
- Time-History Analysis (Dynamic, Linear or Nonlinear)
- PBD-Performance Based Design (Static or Dynamic, Nonlinear)

We have used Equivalent Lateral Force method to analyze the seismic effects in different zone of Bangladesh and conclusion has been drawn according to this study.

3.2 Work Sequence in ETABS

A Flow chart is shown below to overview the total work which is accomplished using ETABS software.

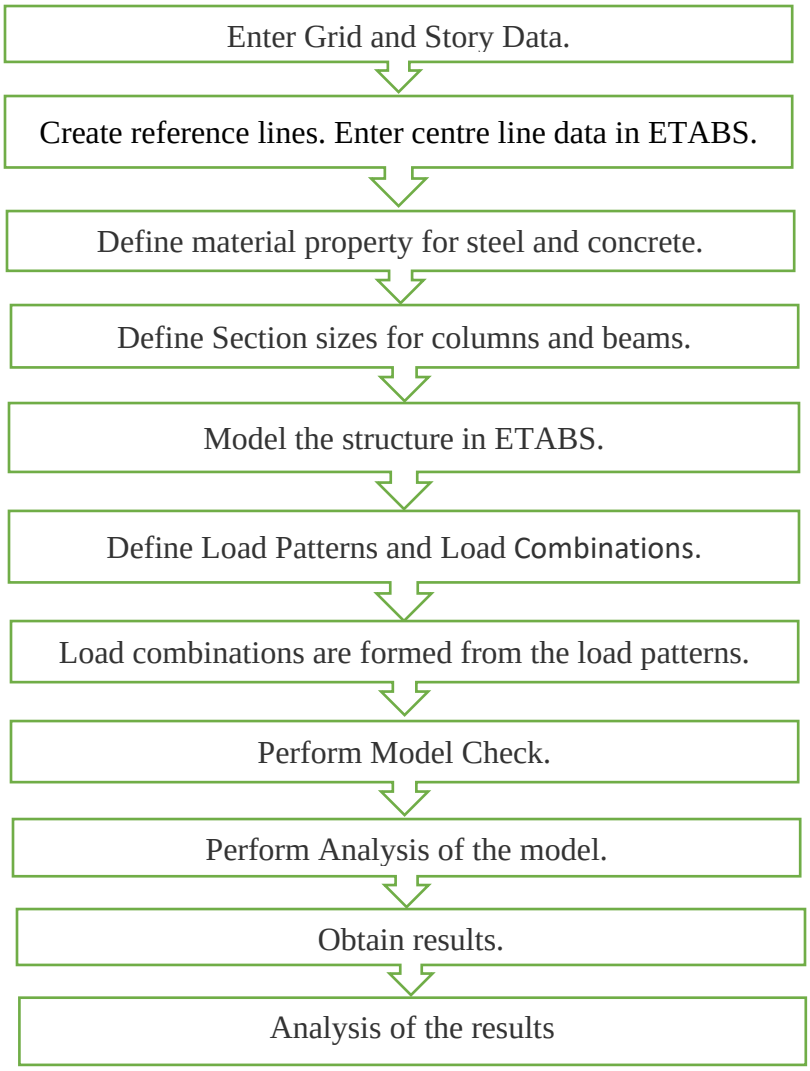


Figure: Flowchart of Work Sequence

3.3 Detail of Analysis

There are two types of variation in our analysis–

- Zonal seismic variation
- Wind variation in similar seismic zones.

With the help of different seismic coefficient that is zonal coefficient, analysis of several structural parameters has been performed. Then wind variation has been taken into account to distinguish the changes of effects on structural parameters due to wind load in similar seismic zones of Bangladesh. There are three structural parameters on which analysis has been performed–

1. Story Displacement
2. Story Shear
3. Story Drift

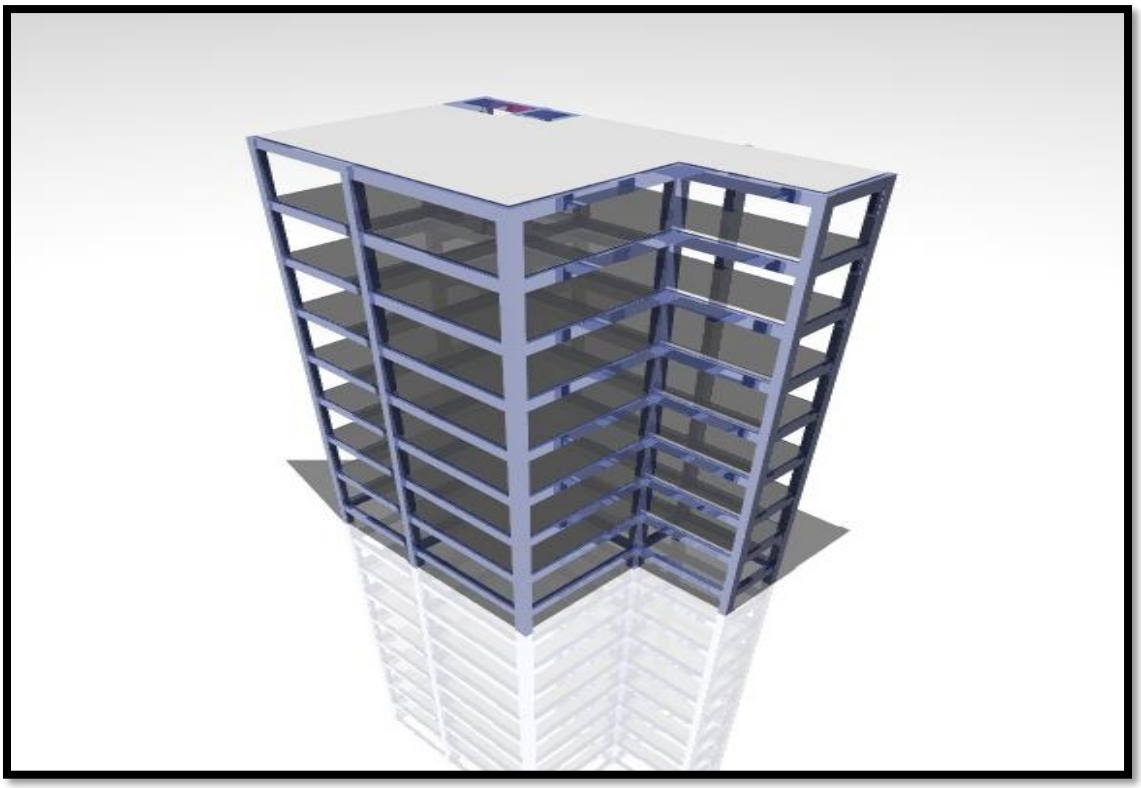


Figure: (G + 7) Story Building

Chapter 4

RESULT AND DISCUSSION

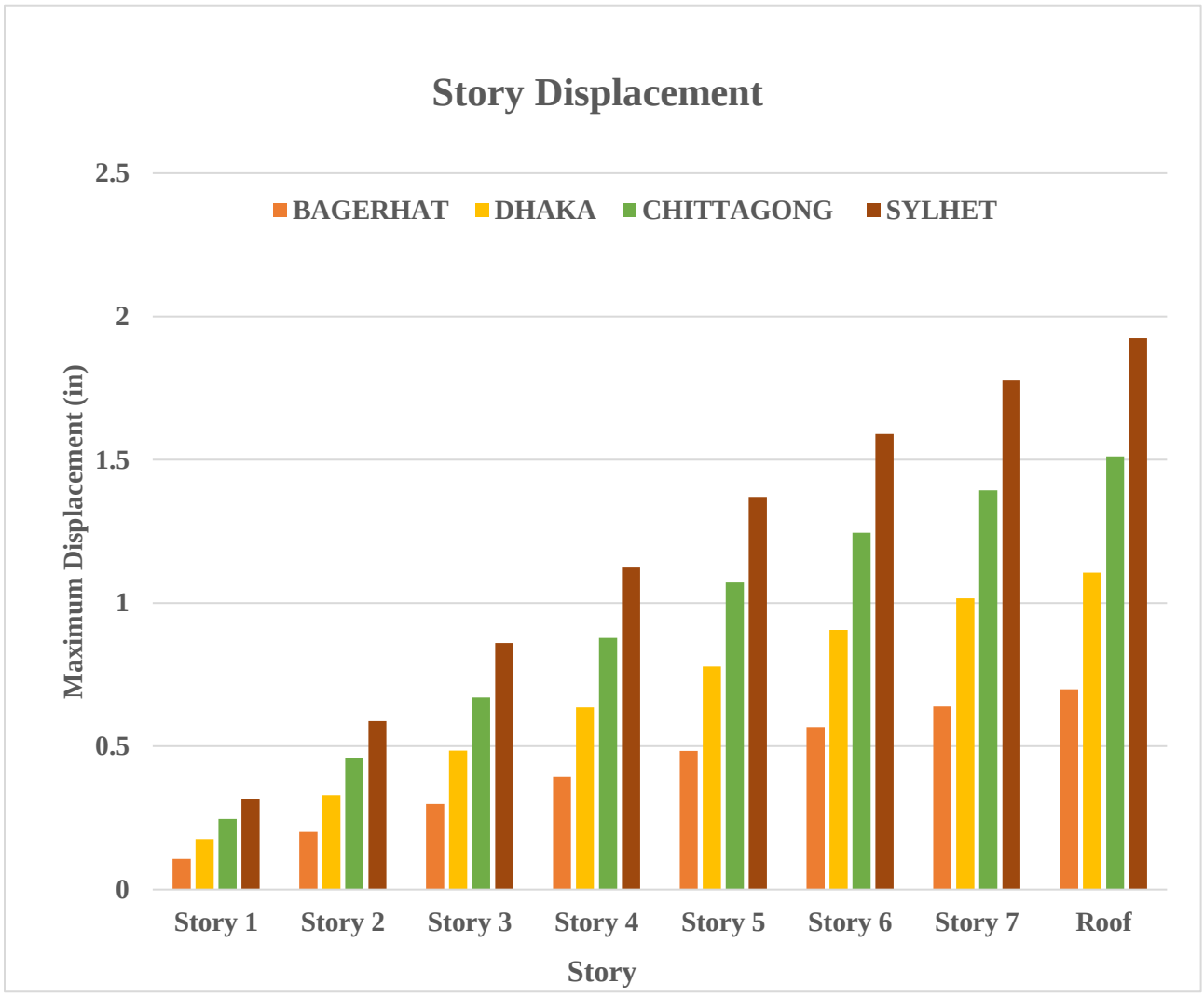
4.1 General

In this chapter, the results throughout the investigation are summarized and discussed. Zonal Seismic variation and wind Variation in similar seismic zone with respect to three different parameters i.e., Story Displacement, Story Drift and Story Shear has been discussed for different load combinations. Moreover, those parameters are discussed based on the result obtain from ETABS.

4.1.1 Story Displacement (Due to Zonal Variation)

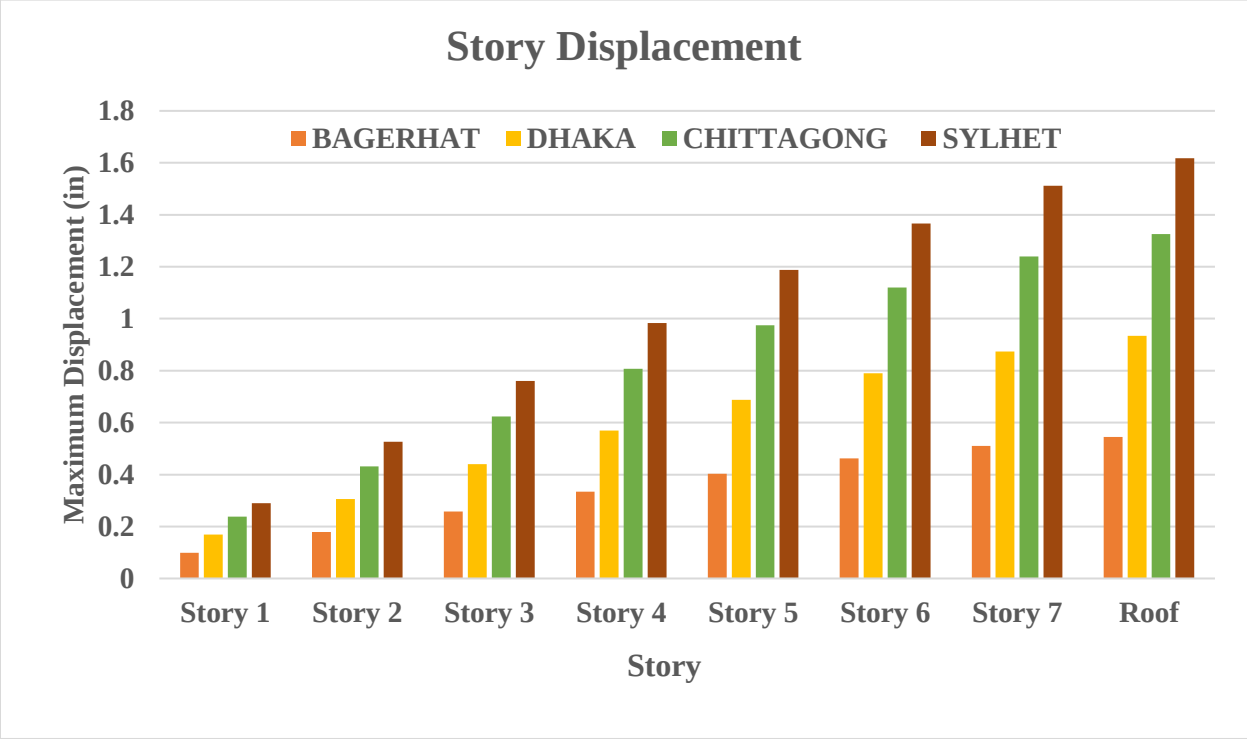
Load Combination: 1.05DL+1.275LL-1.4025Ex

Location	Story Displacement							
	1.05DL+1.275LL-1.4025Ex							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
BAGERHAT (0.12)	0.107	0.202	0.298	0.393	0.484	0.567	0.639	0.699
DHAKA (0.20)	0.177	0.330	0.485	0.636	0.778	0.906	1.017	1.106
CHITTAGONG (0.28)	0.246	0.458	0.671	0.878	1.071	1.245	1.393	1.511
SYLHET (0.36)	0.317	0.588	0.860	1.124	1.370	1.590	1.777	1.924


Story Displacement
BAGERHAT
DHAKA
CHITTAGONG
SYLHET
Maximum Displacement (in)
2.5
2
1.5
1
0.5
0
Story 1
Story 2
Story 3
Story 4
Story 5
Story 6
Story 7
Roof
Story

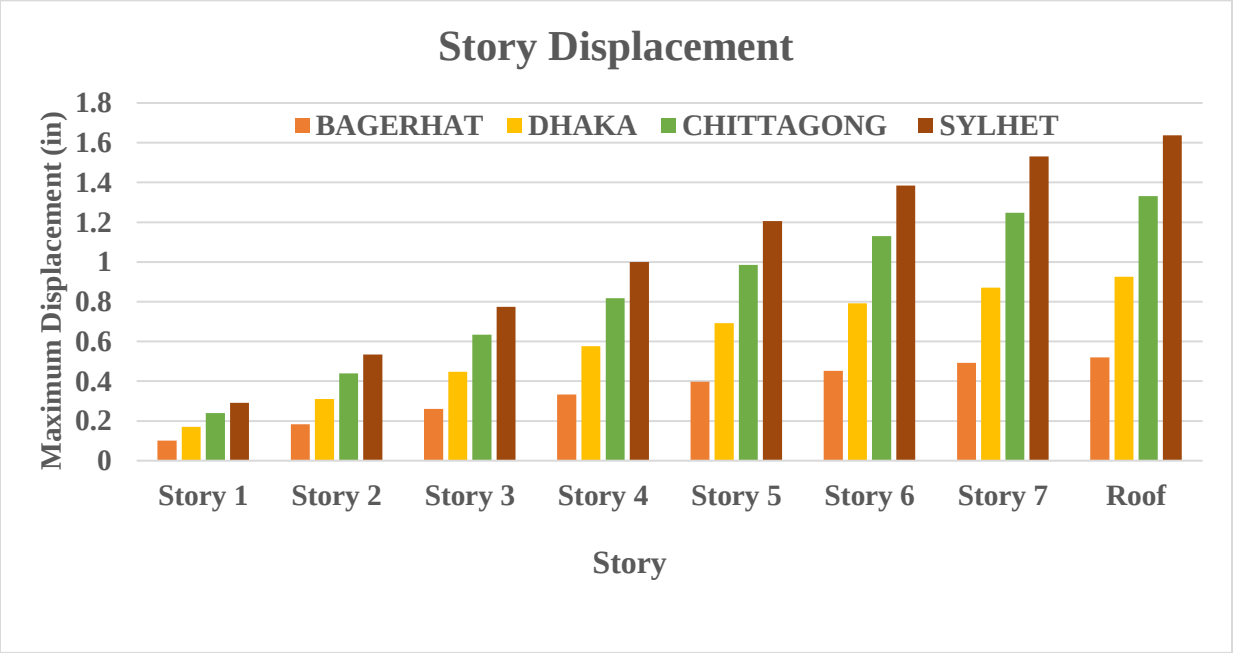
Load Combination: 1.05DL+1.275LL-1.4025Ey

Location	Story Displacement							
	1.05DL+1.275LL-1.4025Ey							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
BAGERHAT (0.12)	0.099	0.179	0.258	0.334	0.403	0.462	0.511	0.545
DHAKA (0.20)	0.169	0.305	0.440	0.569	0.687	0.790	0.874	0.934
CHITTAGONG (0.28)	0.238	0.432	0.624	0.807	0.974	1.121	1.240	1.326
SYLHET (0.36)	0.290	0.527	0.761	0.984	1.188	1.366	1.512	1.618



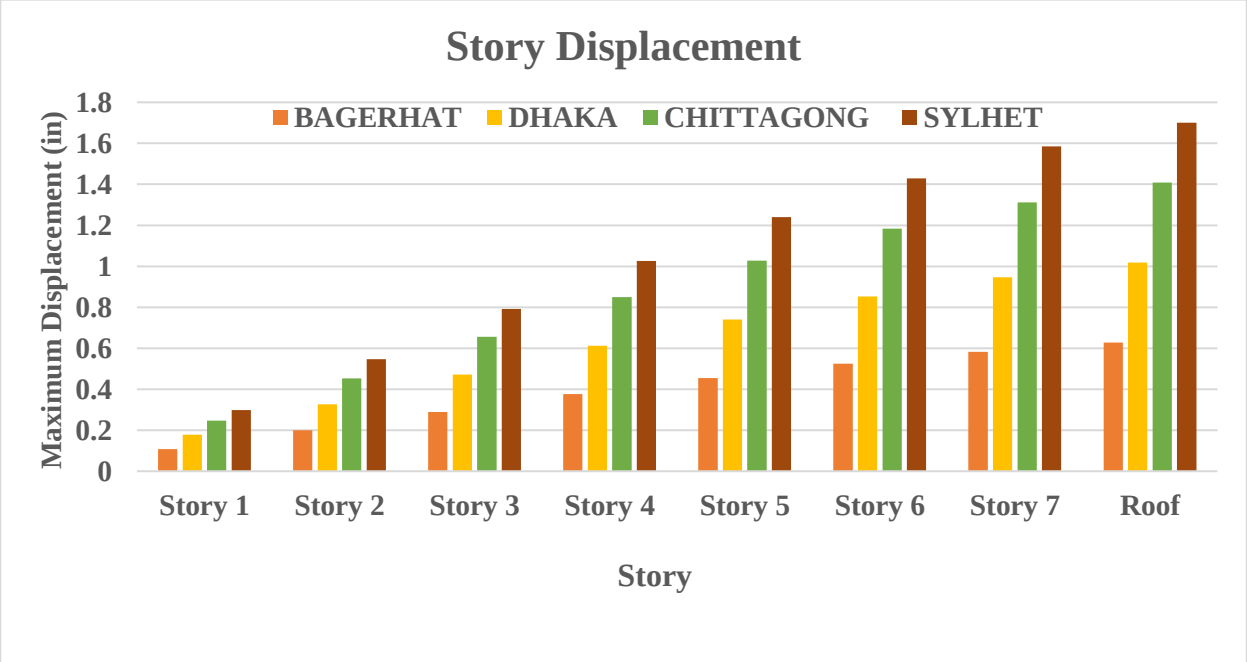
Load Combination: 1.05DL+1.275LL-1.4025Ex

Location	Story Displacement							
	1.05DL+1.275LL+1.4025Ex							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
BAGERHAT (0.12)	0.101	0.183	0.261	0.334	0.398	0.452	0.493	0.520
DHAKA (0.20)	0.170	0.311	0.448	0.576	0.692	0.791	0.871	0.926
CHITTAGONG (0.28)	0.239	0.439	0.634	0.818	0.986	1.130	1.247	1.332
SYLHET (0.36)	0.292	0.535	0.774	1.000	1.206	1.385	1.531	1.637



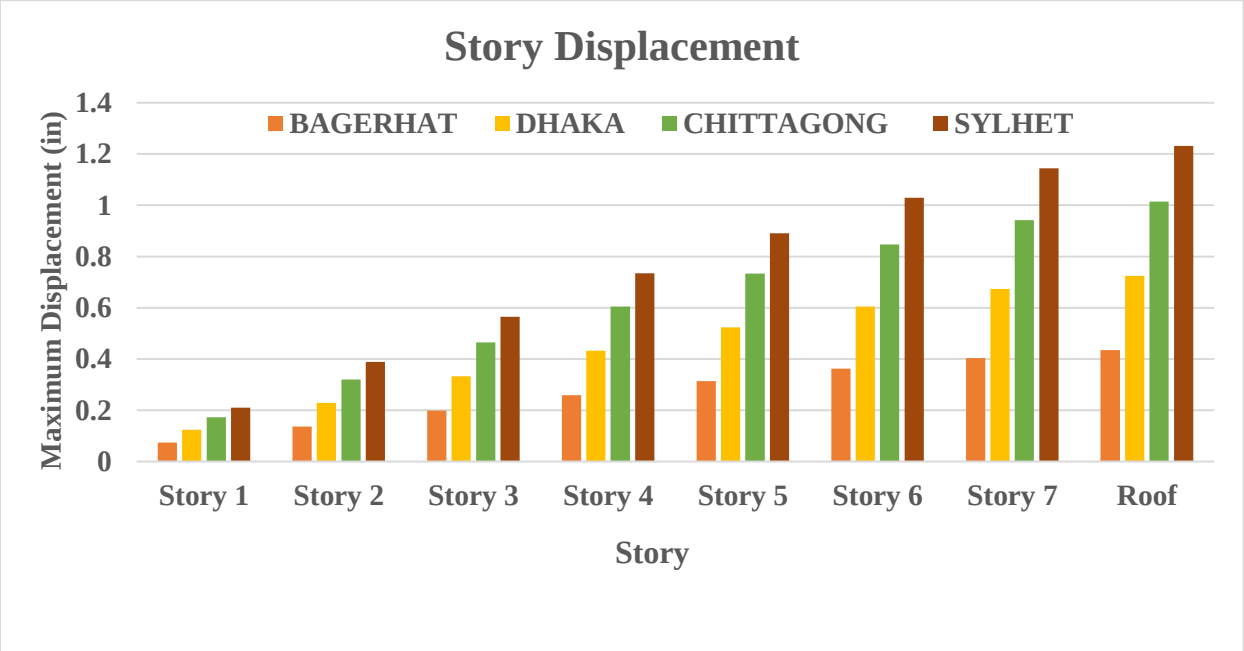
Load Combination: 1.05DL+1.275LL+1.4025Ey

Location	Story Displacement							
	1.05DL+1.275LL+1.4025Ey							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
BAGERHAT (0.12)	0.108	0.200	0.290	0.376	0.455	0.525	0.583	0.628
DHAKA (0.20)	0.178	0.326	0.472	0.612	0.740	0.853	0.947	1.017
CHITTAGONG (0.28)	0.247	0.452	0.655	0.849	1.027	1.183	1.312	1.409
SYLHET (0.36)	0.299	0.547	0.792	1.026	1.241	1.429	1.585	1.701



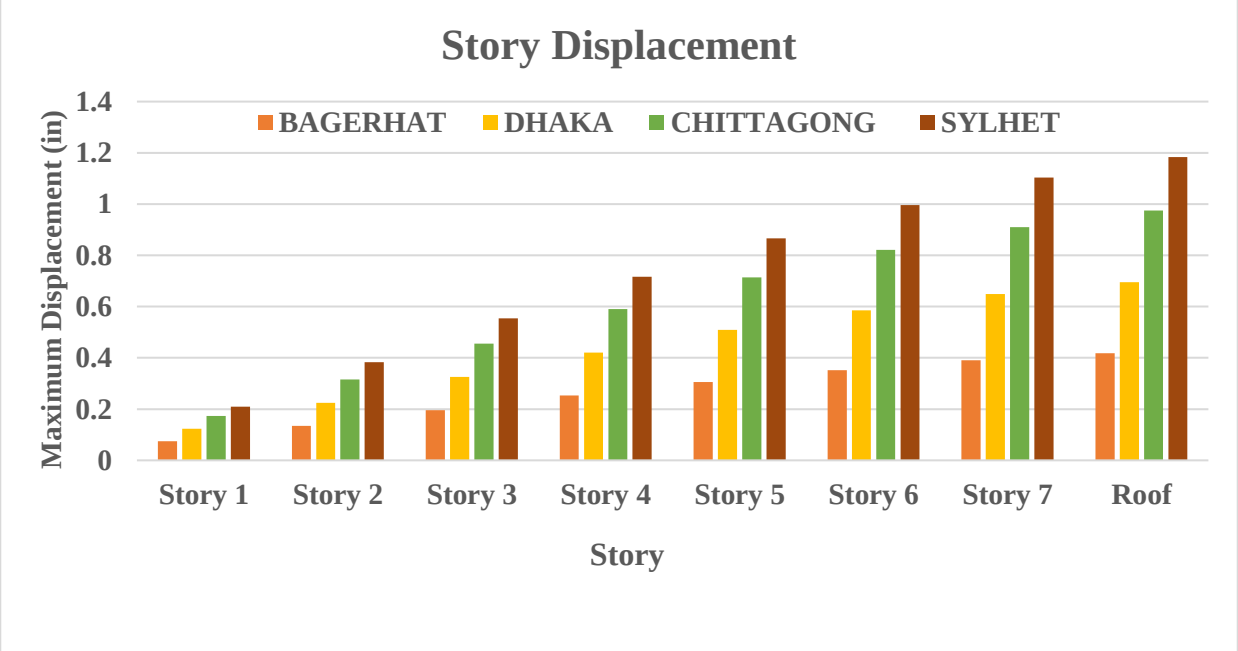
Load Combination: EQx

Location	Story Displacement							
	EQx							
	Story 1	**Story 2**	**Story 3**	**Story 4**	**Story 5**	**Story 6**	**Story 7**	**Roof**
BAGERHAT (0.12)	0.074	0.137	0.199	0.259	0.314	0.363	0.403	0.434
DHAKA (0.20)	0.124	0.228	0.332	0.432	0.524	0.605	0.673	0.724
CHITTAGONG (0.28)	0.173	0.319	0.465	0.605	0.733	0.847	0.941	1.014
SYLHET (0.36)	0.210	0.388	0.565	0.734	0.891	1.029	1.143	1.231



Load Combination: EQy

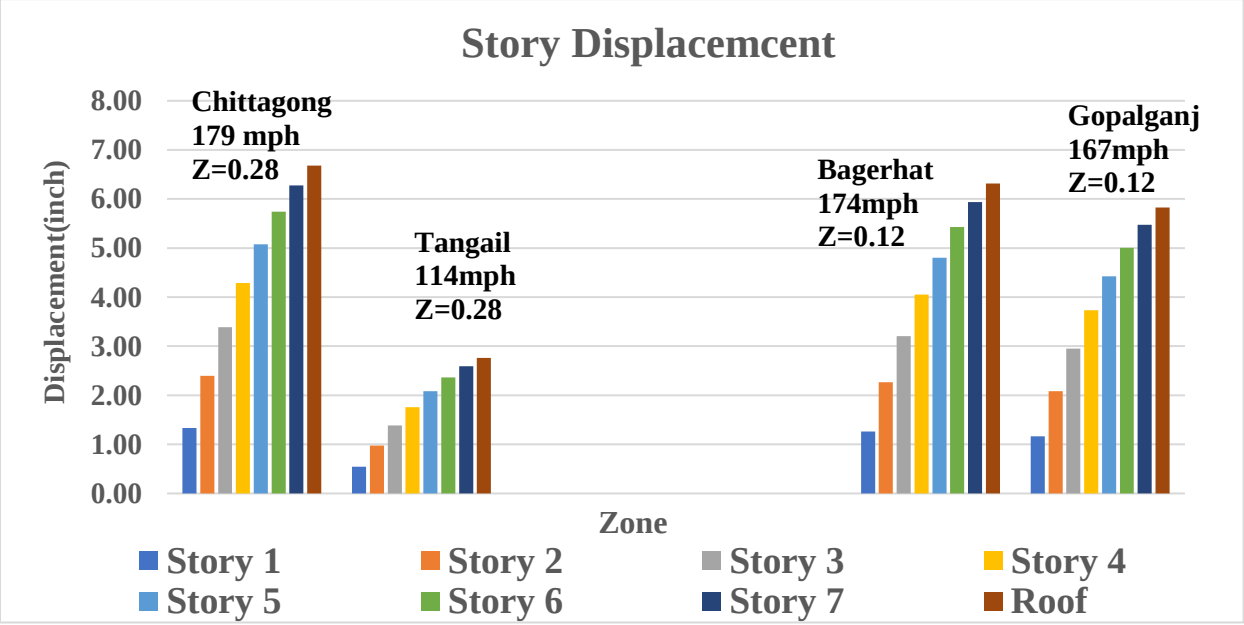
Location	Story Displacement							
	EQy							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
BAGERHAT (0.12)	0.074	0.135	0.195	0.253	0.306	0.352	0.390	0.418
DHAKA (0.20)	0.123	0.225	0.325	0.421	0.509	0.586	0.649	0.696
CHITTAGONG (0.28)	0.173	0.315	0.456	0.590	0.713	0.821	0.910	0.975
SYLHET (0.36)	0.210	0.383	0.554	0.716	0.866	0.997	1.104	1.183



4.1.2 Story Displacement (Due to Wind Variation)

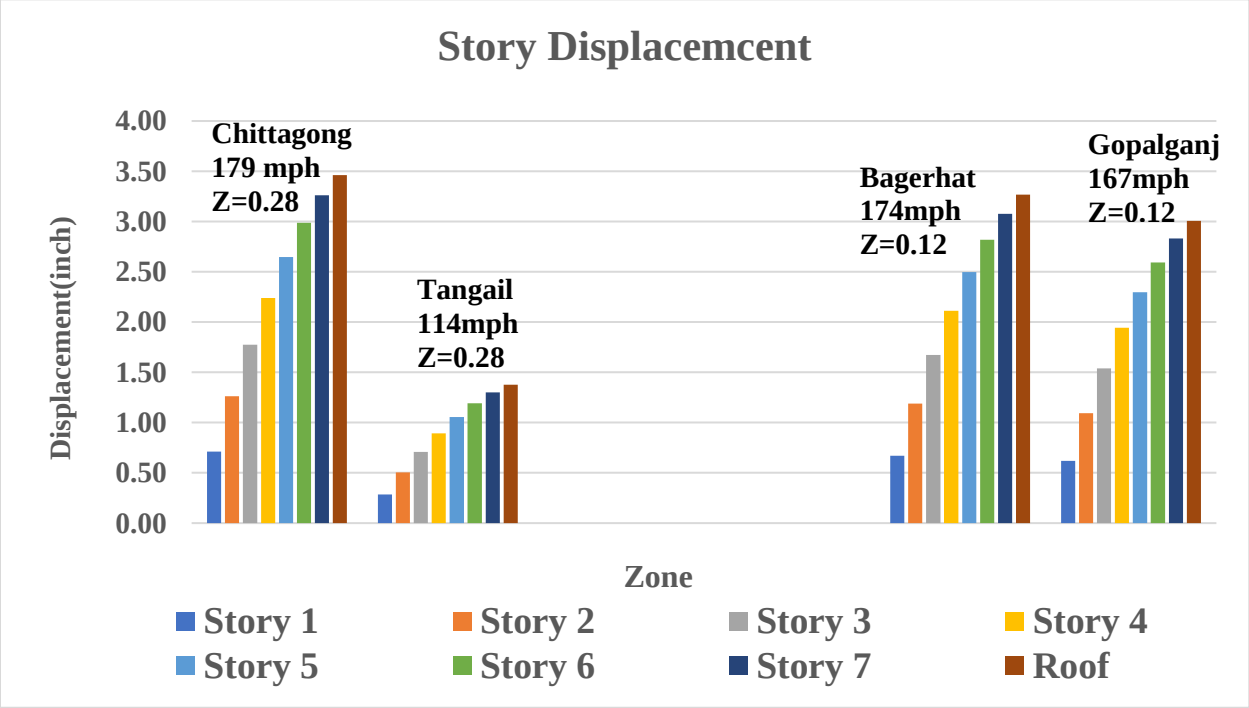
Load Combination: 1.05DL+1.275LL-1.275Wx

Location	Story Displacement							
	1.05DL+1.275LL-1.275Wx							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	1.34	2.40	3.39	4.29	5.08	5.74	6.28	6.68
TANGAIL (0.28)	0.54	0.98	1.39	1.76	2.08	2.36	2.59	2.76
BAGERHAT (0.12)	1.26	2.26	3.20	4.05	4.80	5.43	5.93	6.32
GOPALGANJ (0.12)	1.16	2.09	2.95	3.74	4.42	5.01	5.47	5.82



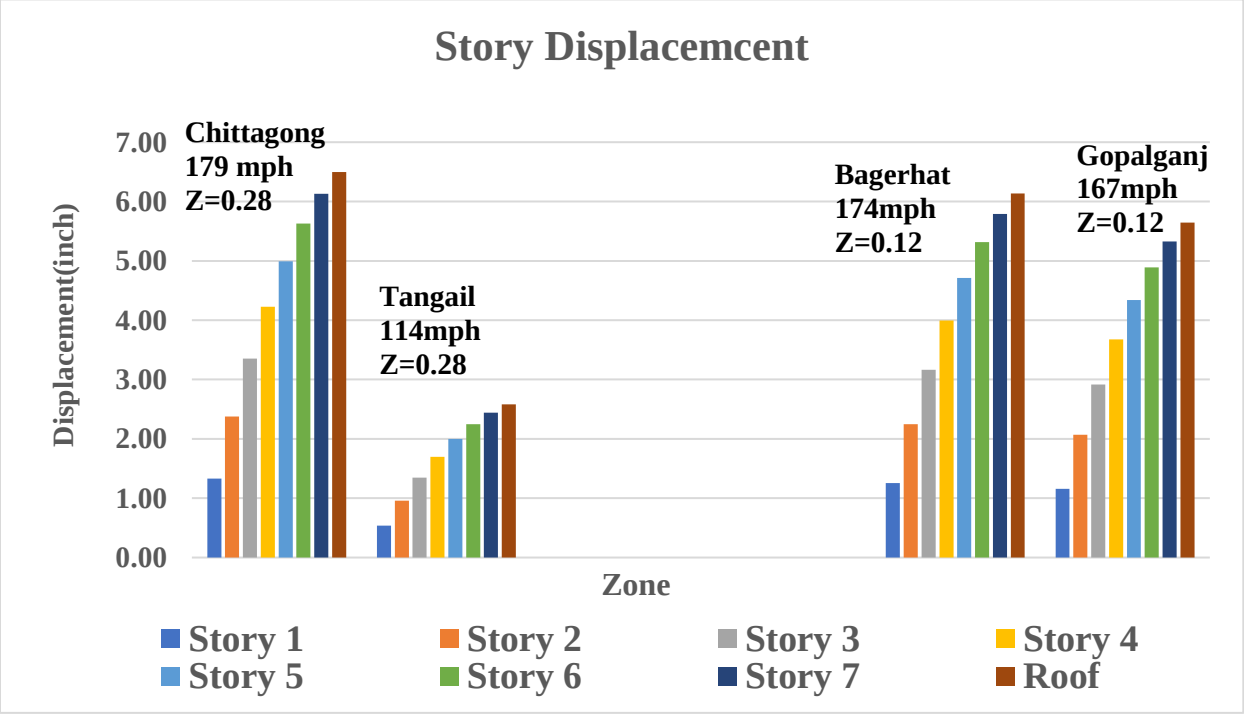
Load Combination: 1.05DL+1.275LL-1.275Wy

Location	Story Displacement							
	1.05DL+1.275LL-1.275Wy							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	0.71	1.26	1.77	2.24	2.65	2.99	3.26	3.46
TANGAIL (0.28)	0.29	0.50	0.71	0.89	1.06	1.19	1.30	1.38
BAGERHAT (0.12)	0.67	1.19	1.67	2.11	2.50	2.82	3.08	3.27
GOPALGANJ (0.12)	0.62	1.10	1.54	1.94	2.30	2.59	2.83	3.01



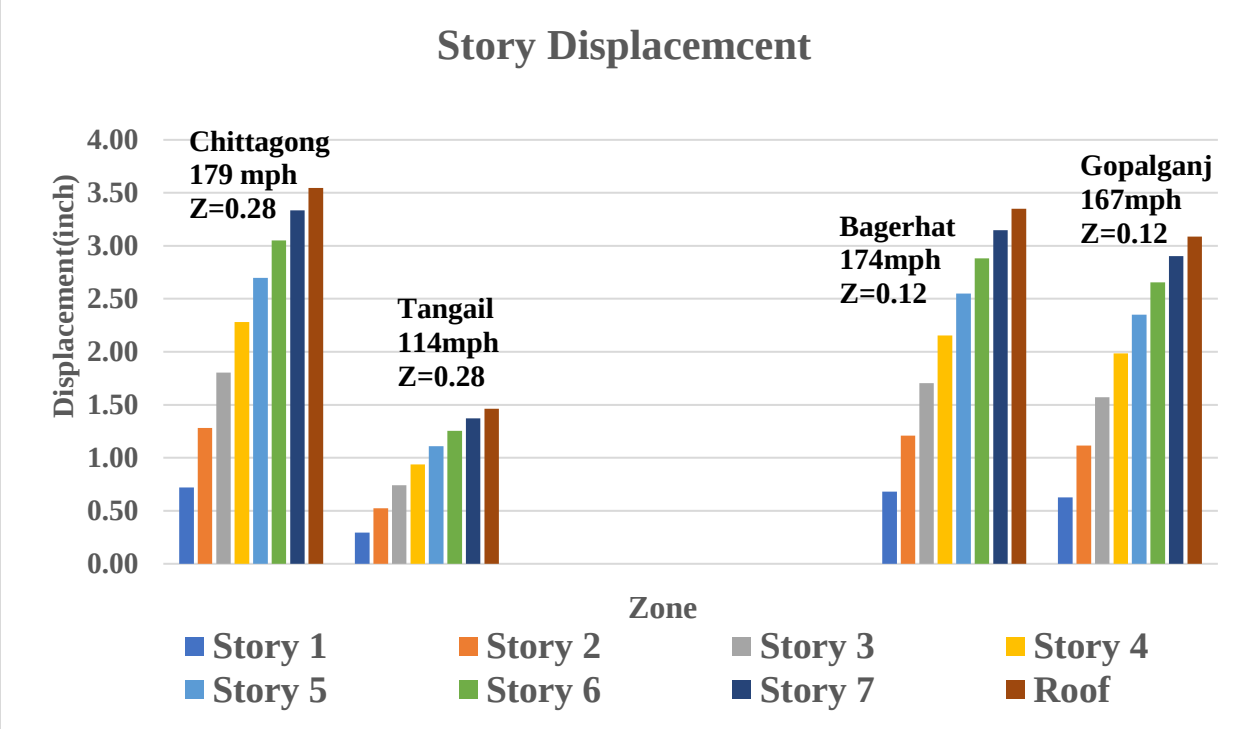
Load Combination: 1.05DL+1.275LL+1.275Wx

Location	Story Displacement							
	1.05DL+1.275LL+1.275Wx							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	1.33	2.38	3.35	4.23	4.99	5.63	6.13	6.50
TANGAIL (0.28)	0.54	0.96	1.35	1.70	2.00	2.25	2.44	2.58
BAGERHAT (0.12)	1.26	2.24	3.17	3.99	4.71	5.31	5.79	6.14
GOPALGANJ (0.12)	1.16	2.07	2.91	3.68	4.34	4.89	5.33	5.65



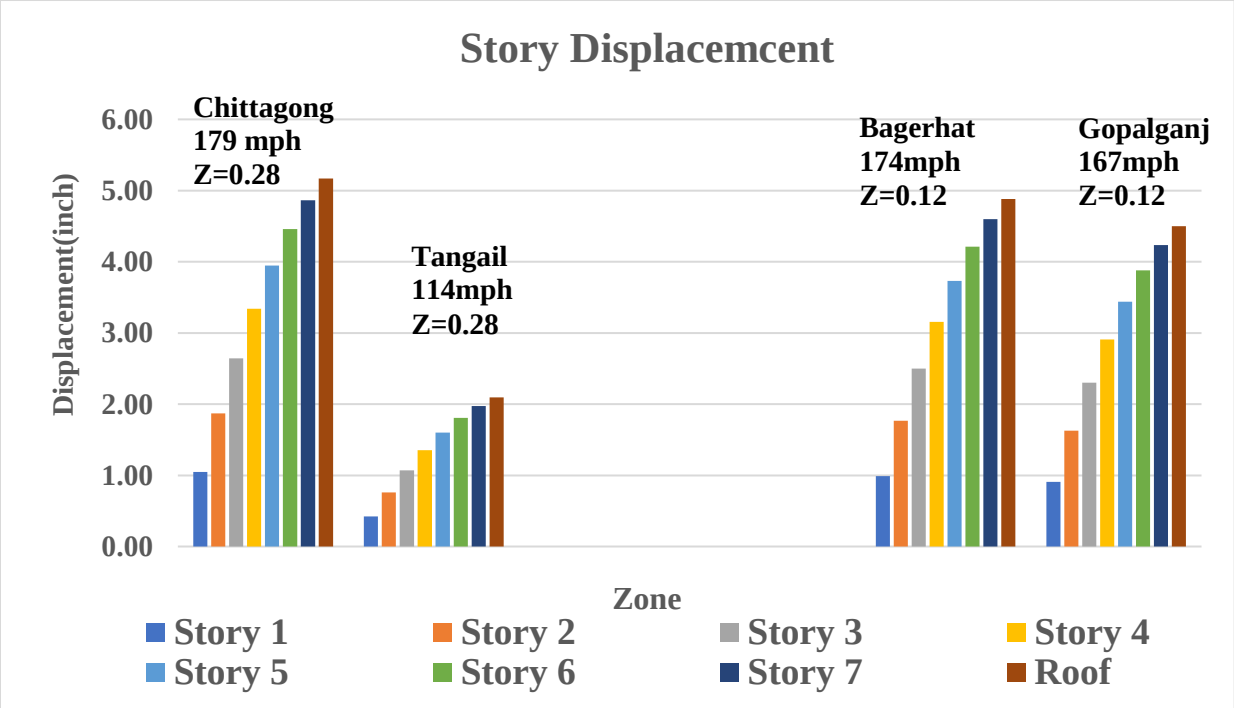
Load Combination: 1.05DL+1.275LL+1.275Wy

Location	Story Displacement							
	1.05DL+1.275LL+1.275Wy							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	0.72	1.28	1.81	2.28	2.70	3.05	3.33	3.55
TANGAIL (0.28)	0.29	0.53	0.74	0.94	1.11	1.25	1.37	1.46
BAGERHAT (0.12)	0.68	1.21	1.70	2.15	2.55	2.88	3.15	3.35
GOPALGANJ (0.12)	0.63	1.12	1.57	1.99	2.35	2.66	2.90	3.09



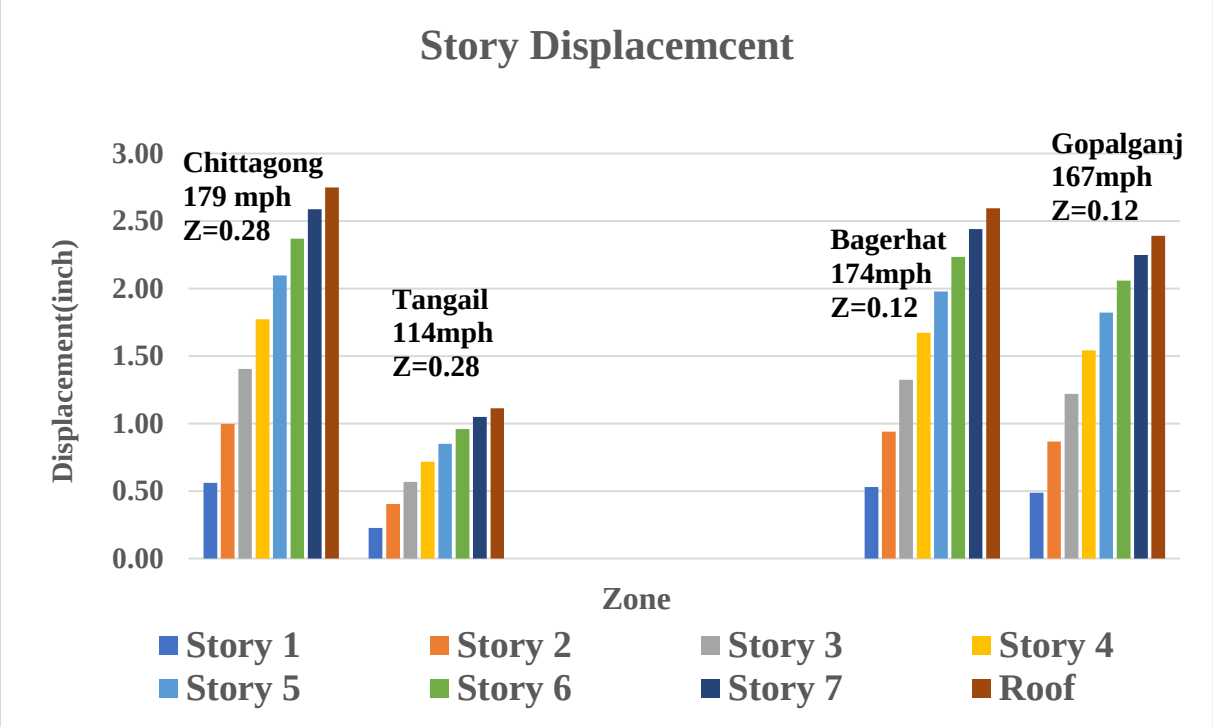
Load Combination: Wind X

Location	Story Displacement							
	Wind X							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	1.05	1.87	2.64	3.34	3.95	4.46	4.87	5.17
TANGAIL (0.28)	0.42	0.76	1.07	1.35	1.60	1.81	1.97	2.10
BAGERHAT (0.12)	0.99	1.77	2.50	3.16	3.73	4.21	4.60	4.88
GOPALGANJ (0.12)	0.91	1.63	2.30	2.91	3.44	3.88	4.23	4.50



Load Combination: Wind Y

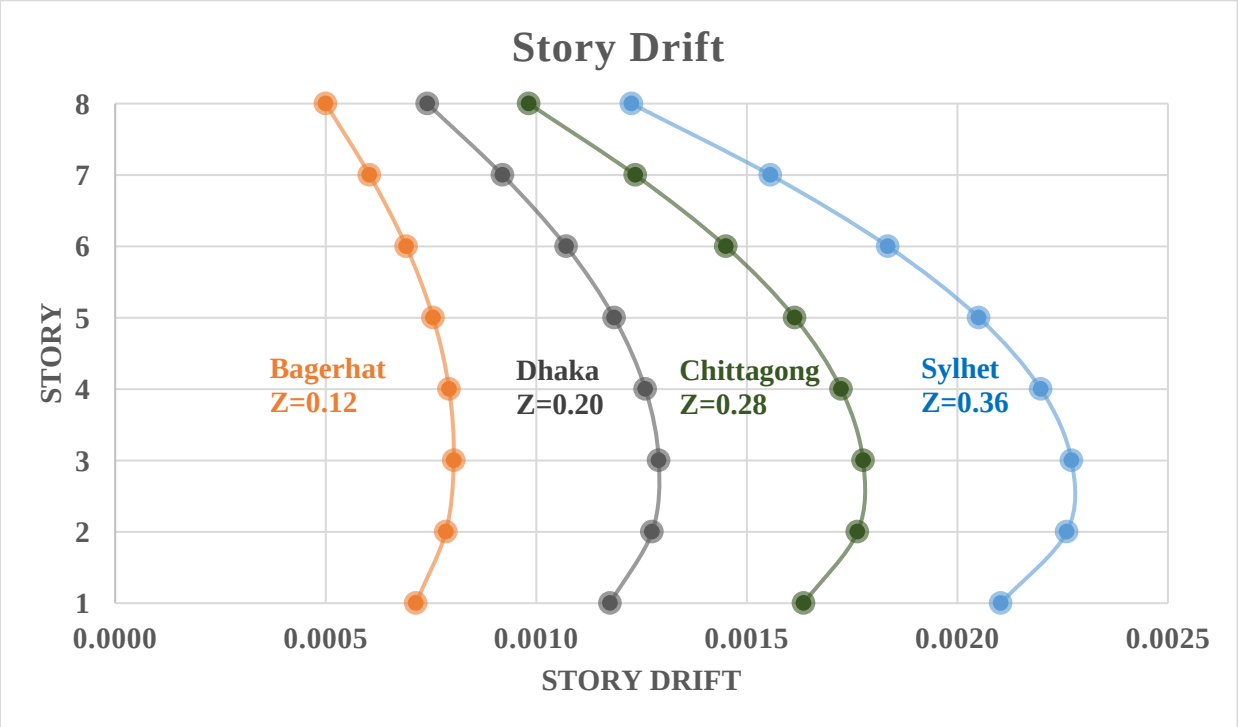
Location	Story Displacement							
	Wind Y							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	0.56	1.00	1.40	1.77	2.10	2.37	2.59	2.75
TANGAIL (0.28)	0.23	0.40	0.57	0.72	0.85	0.96	1.05	1.11
BAGERHAT (0.12)	0.53	0.94	1.32	1.67	1.98	2.24	2.44	2.59
GOPALGANJ (0.12)	0.49	0.87	1.22	1.54	1.82	2.06	2.25	2.39



4.1.3 Story Drift (Due to Seismic Variation)

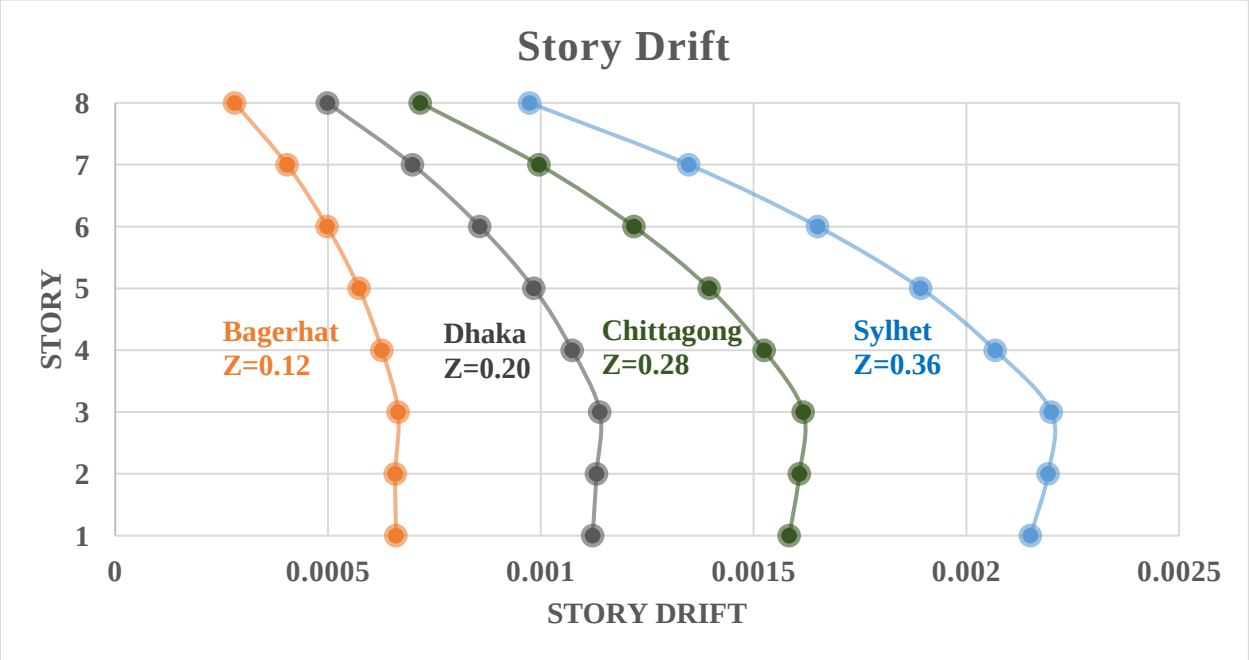
Load Combination: 1.05DL+1.275LL-1.4025Ex

Location	Story Drift							
	1.05DL+1.275LL-1.4025Ex							
	Roof	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1
BAGERHAT (0.12)	0.0005	0.0006	0.0007	0.0008	0.0008	0.0008	0.0008	0.0007
DHAKA (0.2)	0.0007	0.0009	0.0011	0.0012	0.0013	0.0013	0.0013	0.0012
CHITTAGONG (0.28)	0.0010	0.0012	0.0015	0.0016	0.0017	0.0018	0.0018	0.0016
SYLHET (0.36)	0.0012	0.0016	0.0018	0.0021	0.0022	0.0023	0.0023	0.0021



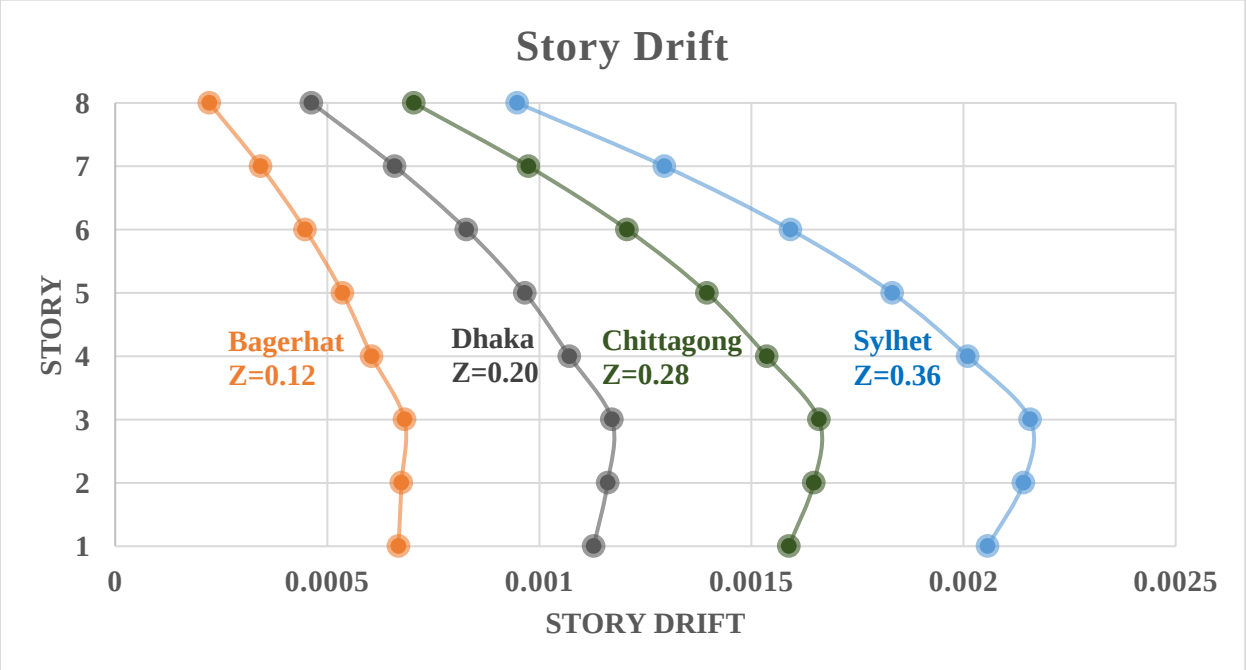
Load Combination: 1.05DL+1.275LL-1.4025Ey

Location	Story Drift							
	1.05DL+1.275LL-1.4025Ey							
	Roof	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1
BAGERHAT (0.12)	0.00028	0.0004	0.0005	0.00057	0.00063	0.00067	0.00066	0.00066
DHAKA (0.2)	0.0005	0.0007	0.00086	0.00098	0.00107	0.00114	0.00113	0.00112
CHITTAGONG (0.28)	0.00072	0.001	0.00122	0.0014	0.00153	0.00162	0.00161	0.00158
SYLHET (0.36)	0.00097	0.00135	0.00165	0.00189	0.00207	0.0022	0.00219	0.00215



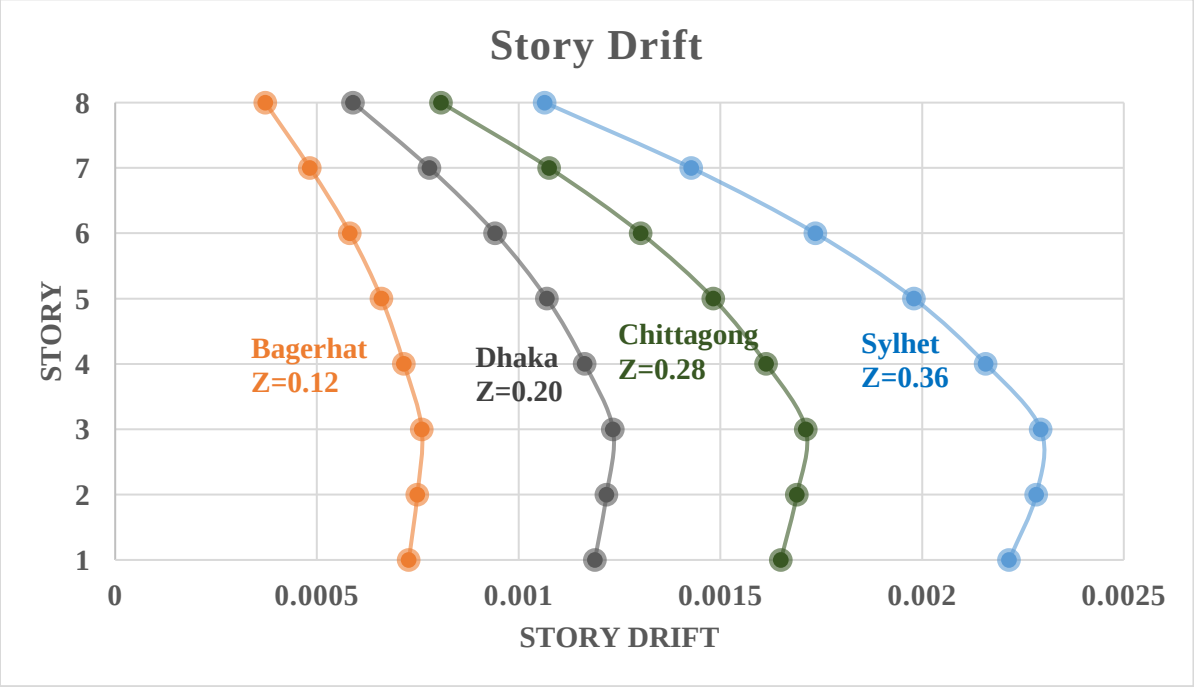
Load Combination: 1.05DL+1.275LL+1.4025Ex

Location	Story Drift							
	1.05DL+1.275LL+1.4025Ex							
	Roof	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1
BAGERHAT (0.12)	0.00022	0.00034	0.00045	0.00054	0.00061	0.00068	0.00068	0.00067
DHAKA (0.2)	0.00046	0.00066	0.00083	0.00097	0.00107	0.00117	0.00116	0.00113
CHITTAGONG (0.28)	0.0007	0.00097	0.00121	0.0014	0.00154	0.00166	0.00165	0.00159
SYLHET (0.36)	0.00095	0.0013	0.00159	0.00183	0.00201	0.00216	0.00214	0.00206



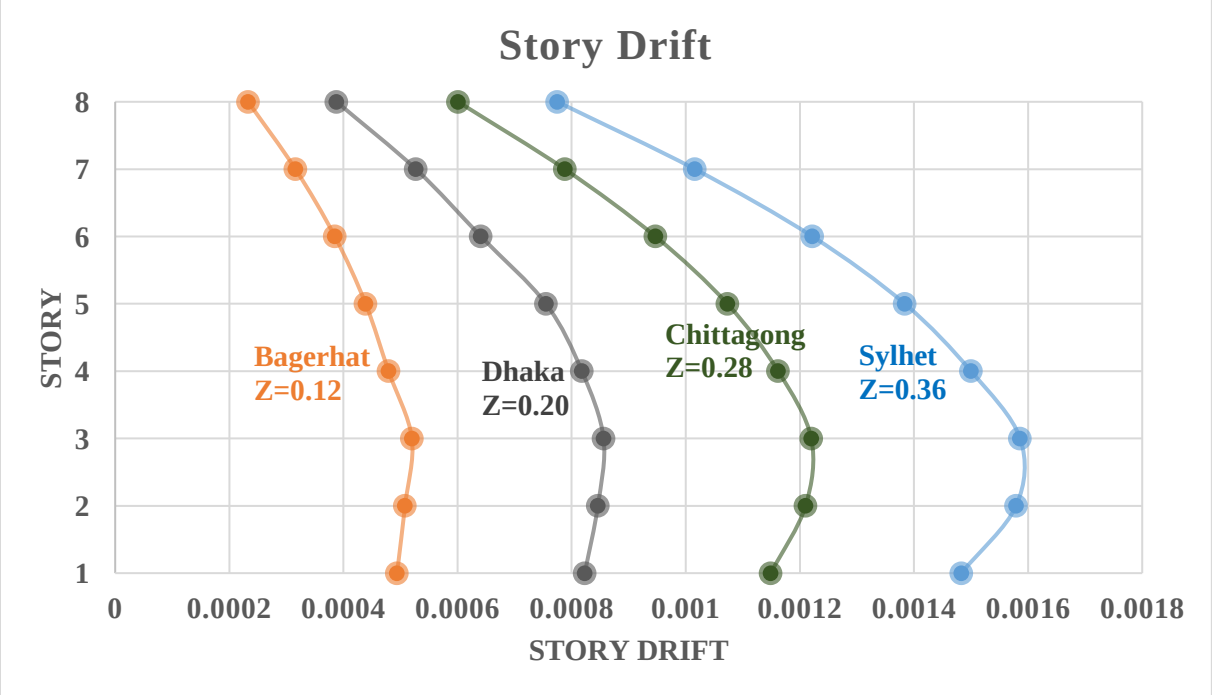
Load Combination: 1.05DL+1.275LL+1.4025Ey

Location	Story Drift							
	1.05DL+1.275LL+1.4025Ey							
	Roof	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1
BAGERHAT (0.12)	0.00037	0.00048	0.00058	0.00066	0.00072	0.00076	0.00075	0.00073
DHAKA (0.2)	0.00059	0.00078	0.00094	0.00107	0.00116	0.00123	0.00122	0.00119
CHITTAGONG (0.28)	0.00081	0.00108	0.0013	0.00148	0.00161	0.00171	0.00169	0.00165
SYLHET (0.36)	0.00107	0.00143	0.00174	0.00198	0.00216	0.00229	0.00228	0.00222



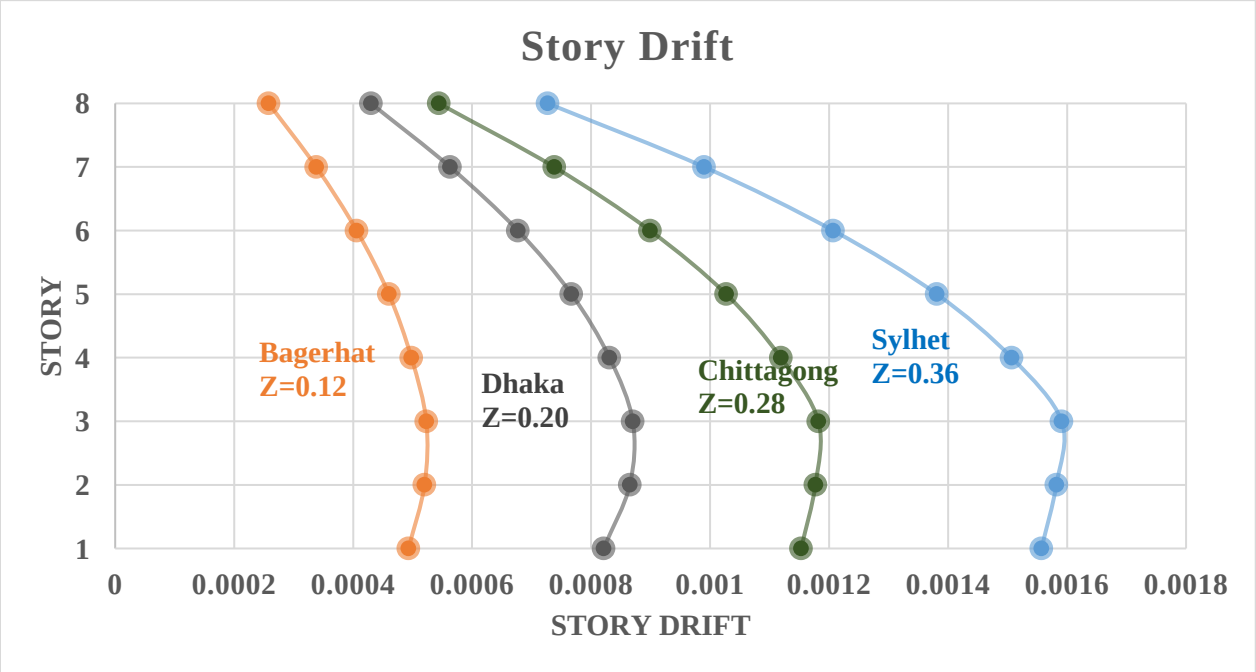
Load Combination: EQx

Location	Story Drift							
	EQx							
	Roof	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1
BAGERHAT (0.12)	0.00026	0.00034	0.00041	0.00046	0.0005	0.00052	0.00052	0.00049
DHAKA (0.2)	0.00043	0.00056	0.00068	0.00077	0.00083	0.00087	0.00087	0.00082
CHITTAGONG (0.28)	0.0006	0.00079	0.00095	0.00107	0.00116	0.00122	0.00121	0.00115
SYLHET (0.36)	0.00078	0.00102	0.00122	0.00138	0.0015	0.00159	0.00158	0.00148



Load Combination: EQy

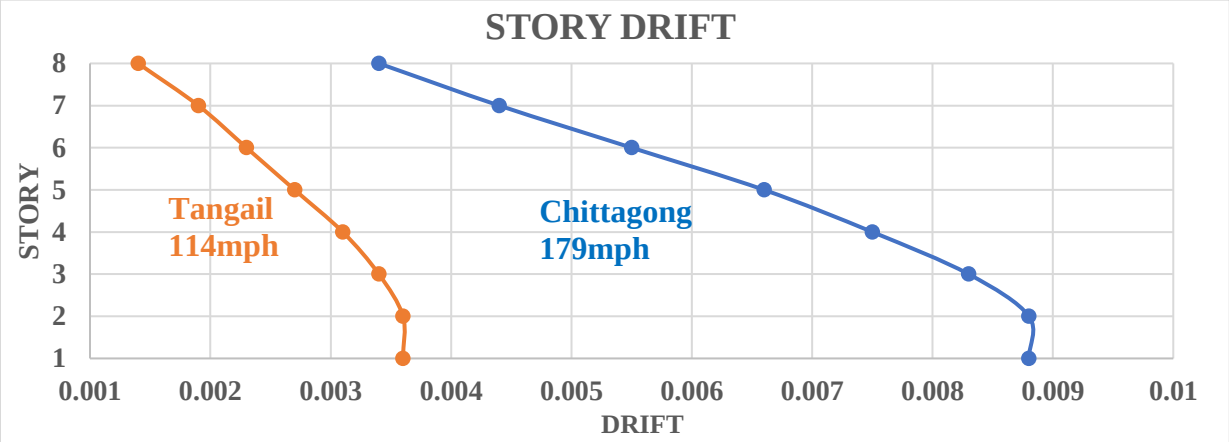
Location	Story Drift							
	EQy							
	Roof	Story 7	Story 6	Story 5	Story 4	Story 3	Story 2	Story 1
BAGERHAT (0.12)	0.00023	0.00032	0.00039	0.00044	0.00048	0.00052	0.00051	0.00049
DHAKA (0.2)	0.00039	0.00053	0.00064	0.00076	0.00082	0.00086	0.00085	0.00082
CHITTAGONG (0.28)	0.00054	0.00074	0.0009	0.00103	0.00112	0.00118	0.00118	0.00115
SYLHET (0.36)	0.00073	0.00099	0.00121	0.00138	0.00151	0.00159	0.00158	0.00156

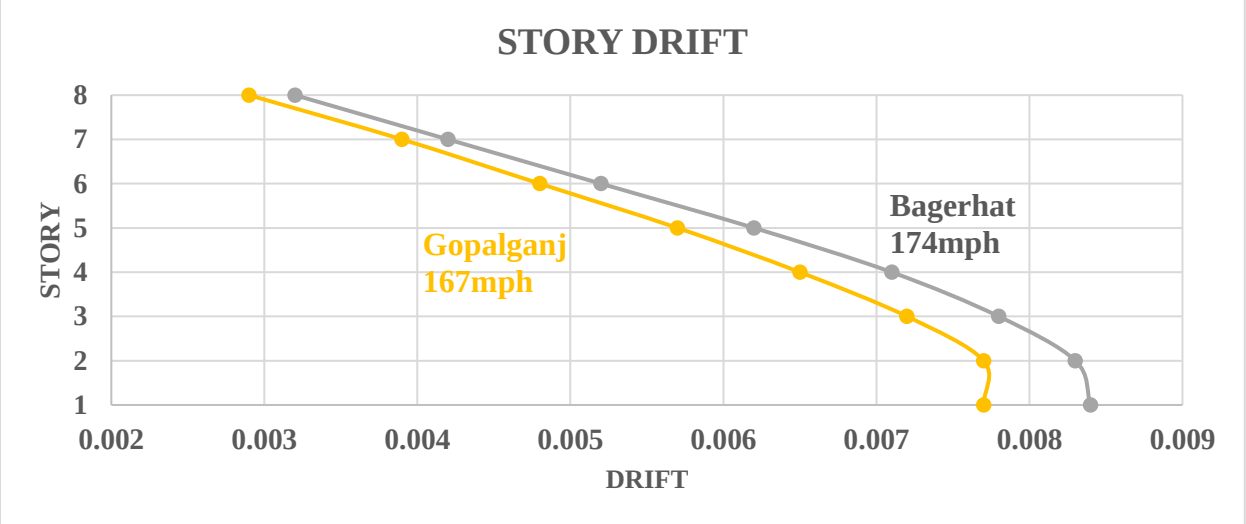


4.1.4 Story Drift (Due to Wind Variation)

Load Combination: 1.05DL+1.275LL-1.275Wx

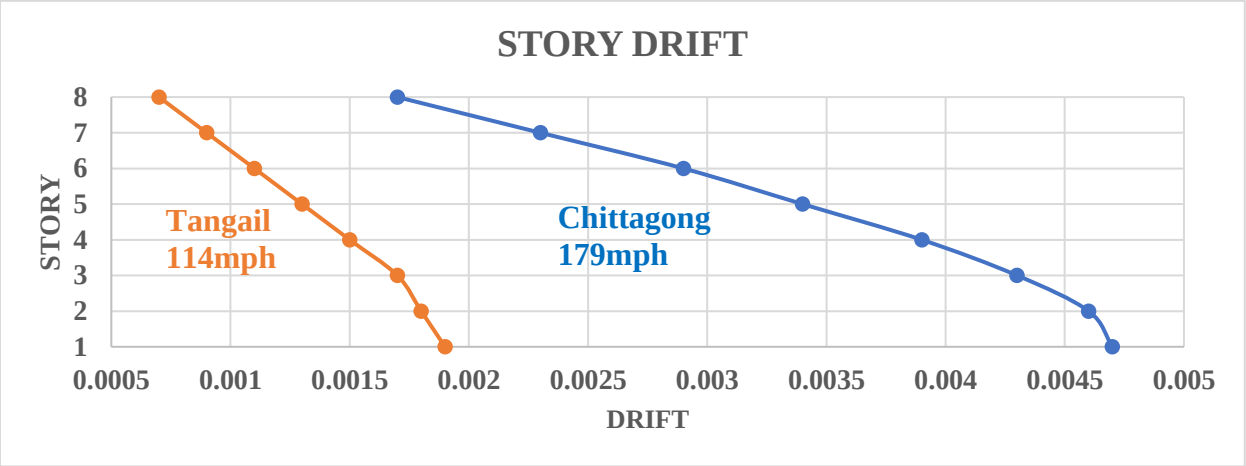
Location	Story Drift							
	1.05DL+1.275LL-1.275Wx							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	0.0088	0.0088	0.0083	0.0075	0.0066	0.0055	0.0044	0.0034
TANGAIL (0.28)	0.0036	0.0036	0.0034	0.0031	0.0027	0.0023	0.0019	0.0014
BAGERHAT (0.12)	0.0084	0.0083	0.0078	0.0071	0.0062	0.0052	0.0042	0.0032
GOPALGANJ (0.12)	0.0077	0.0077	0.0072	0.0065	0.0057	0.0048	0.0039	0.0029

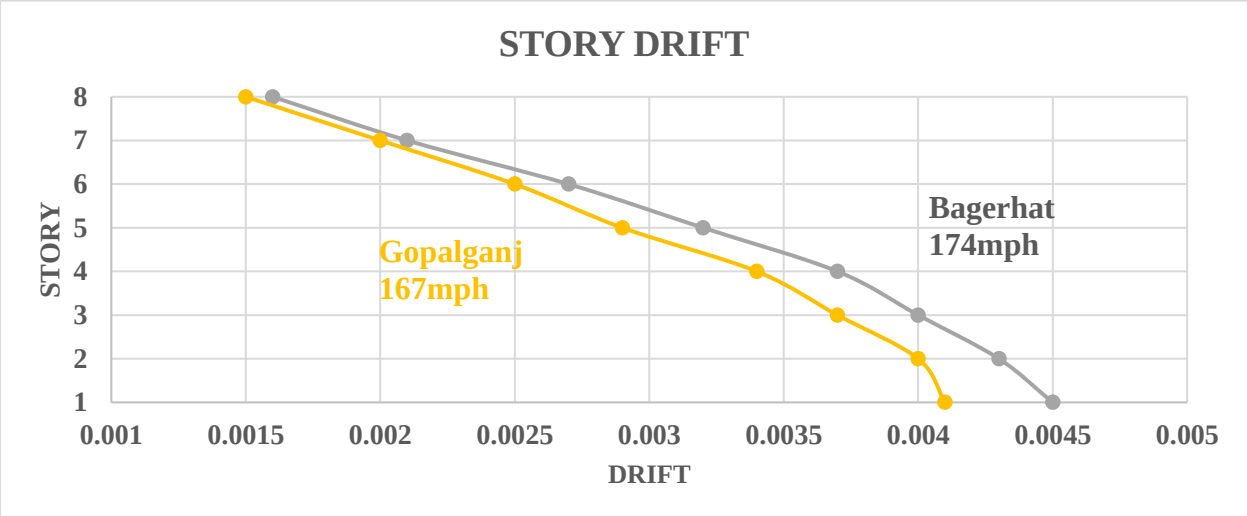




Load Combination: 1.05DL+1.275LL-1.275Wy

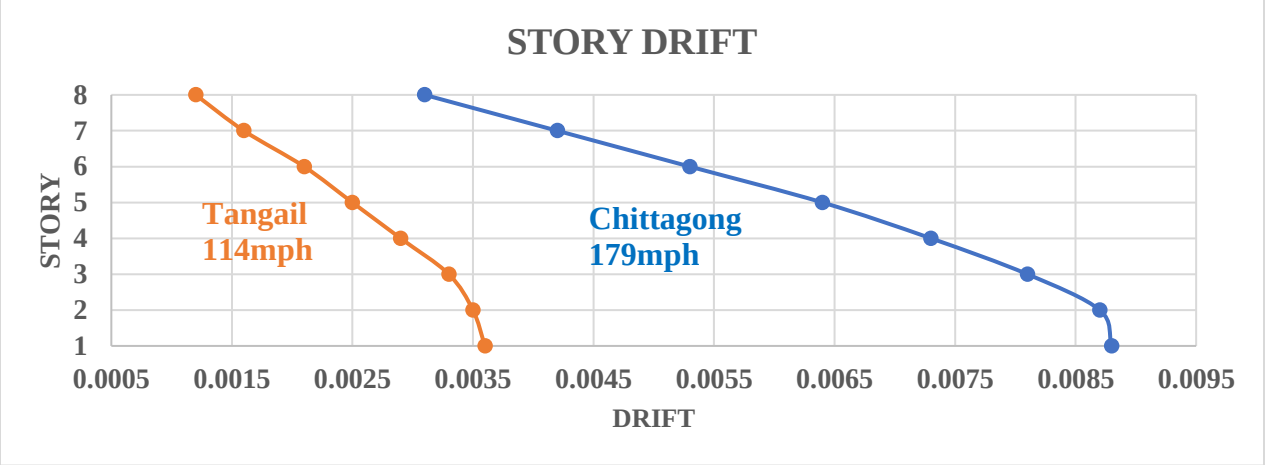
Location	Story Drift							
	1.05DL+1.275LL-1.275Wy							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	0.0047	0.0046	0.0043	0.0039	0.0034	0.0029	0.0023	0.0017
TANGAIL (0.28)	0.0019	0.0018	0.0017	0.0015	0.0013	0.0011	0.0009	0.0007
BAGERHAT (0.12)	0.0045	0.0043	0.004	0.0037	0.0032	0.0027	0.0021	0.0016
GOPALGANJ (0.12)	0.0041	0.004	0.0037	0.0034	0.0029	0.0025	0.002	0.0015

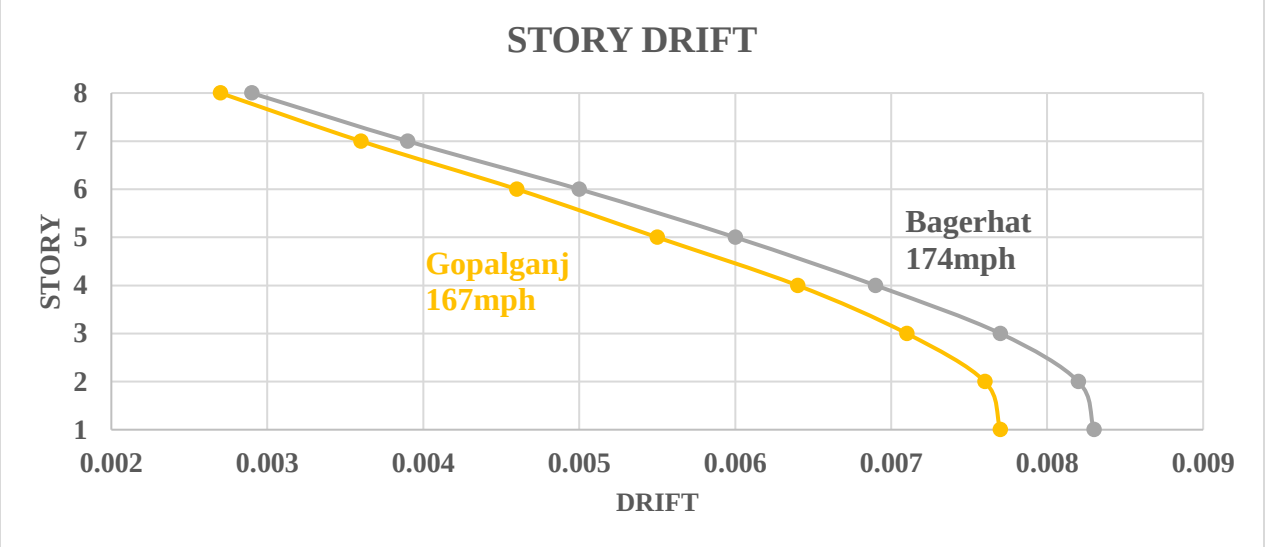




Load Combination: 1.05DL+1.275LL+1.275Wx

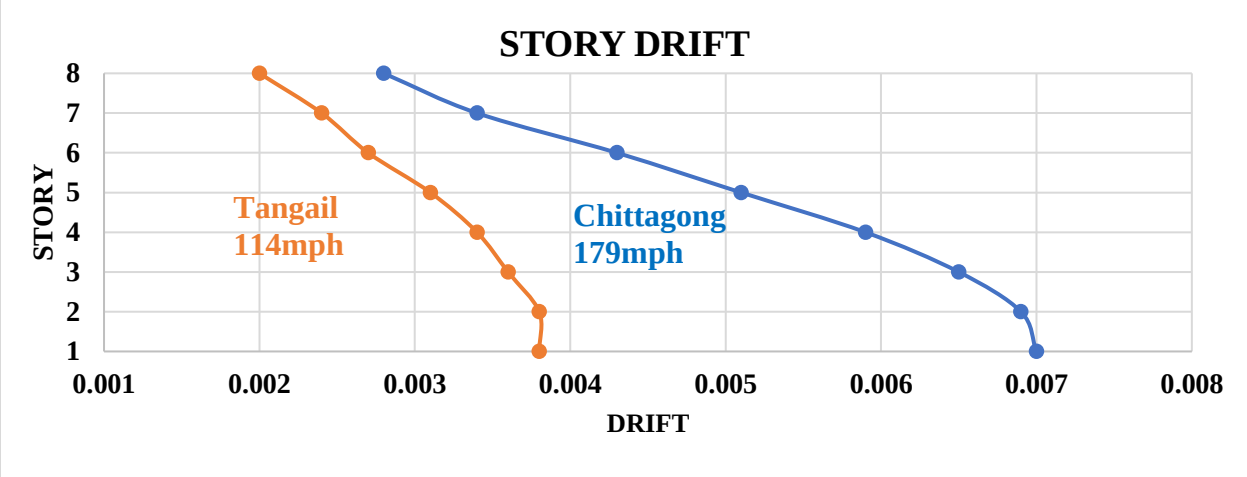
Location	Story Drift							
	1.05DL+1.275LL+1.275Wx							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	0.0088	0.0087	0.0081	0.0073	0.0064	0.0053	0.0042	0.0031
TANGAIL (0.28)	0.0036	0.0035	0.0033	0.0029	0.0025	0.0021	0.0016	0.0012
BAGERHAT (0.12)	0.0083	0.0082	0.0077	0.0069	0.006	0.005	0.0039	0.0029
GOPALGANJ (0.12)	0.0077	0.0076	0.0071	0.0064	0.0055	0.0046	0.0036	0.0027

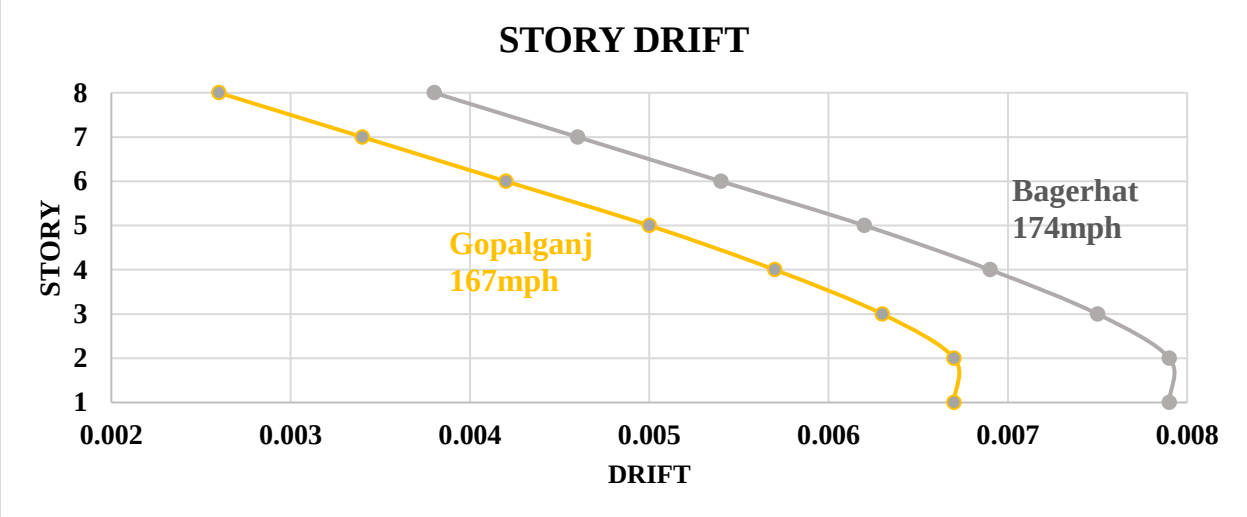




Load Combination: 1.05DL+1.275LL+1.275Wy

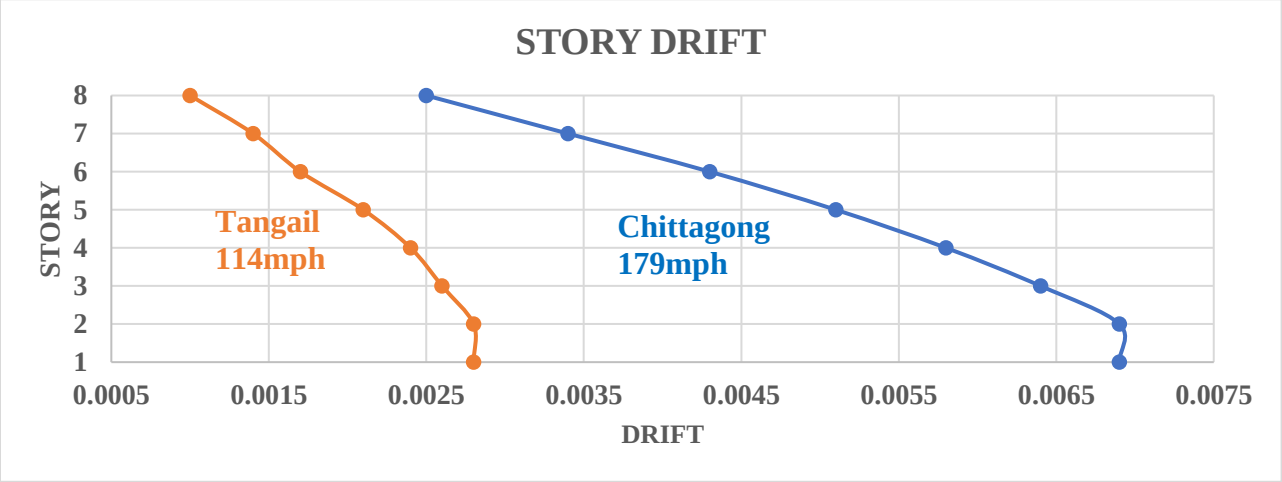
Location	Story Drift							
	1.05DL+1.275LL+1.275Wy							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	0.007	0.0069	0.0065	0.0059	0.0051	0.0043	0.0034	0.0028
TANGAIL (0.28)	0.0038	0.0038	0.0036	0.0034	0.0031	0.0027	0.0024	0.002
BAGERHAT (0.12)	0.0079	0.0079	0.0075	0.0069	0.0062	0.0054	0.0046	0.0038
GOPALGANJ (0.12)	0.0067	0.0067	0.0063	0.0057	0.005	0.0042	0.0034	0.0026

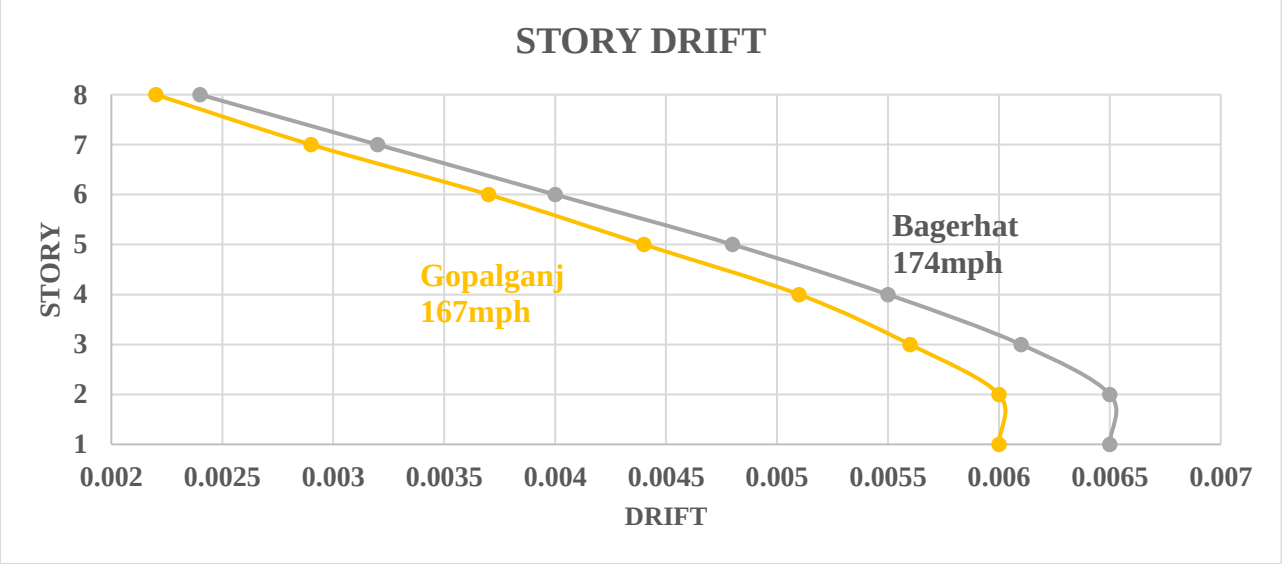




Load Combination: Wind X

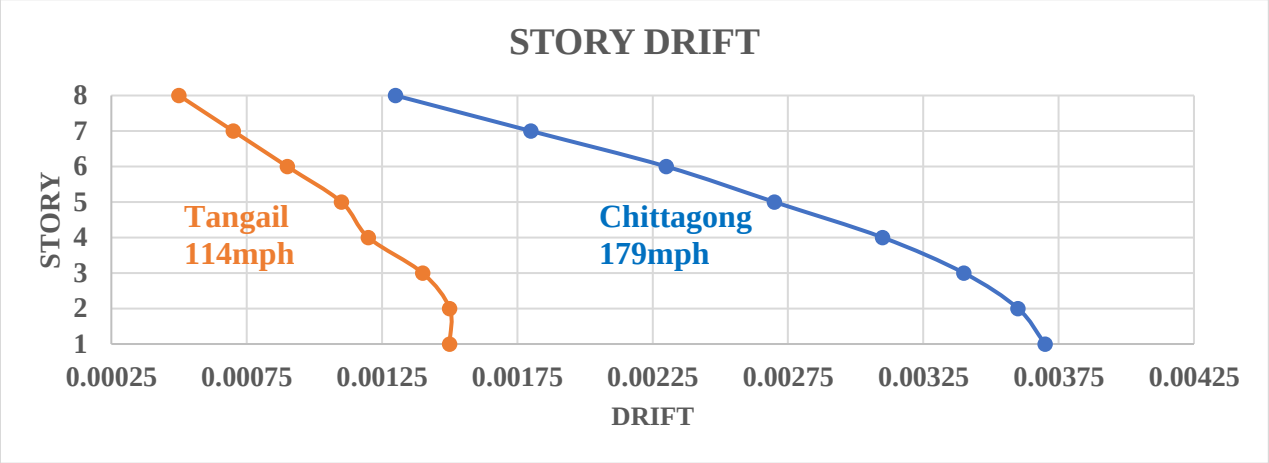
Location	Story Drift							
	Wind X							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	0.0069	0.0069	0.0064	0.0058	0.0051	0.0043	0.0034	0.0025
TANGAIL (0.28)	0.0028	0.0028	0.0026	0.0024	0.0021	0.0017	0.0014	0.001
BAGERHAT (0.12)	0.0065	0.0065	0.0061	0.0055	0.0048	0.004	0.0032	0.0024
GOPALGANJ (0.12)	0.006	0.006	0.0056	0.0051	0.0044	0.0037	0.0029	0.0022

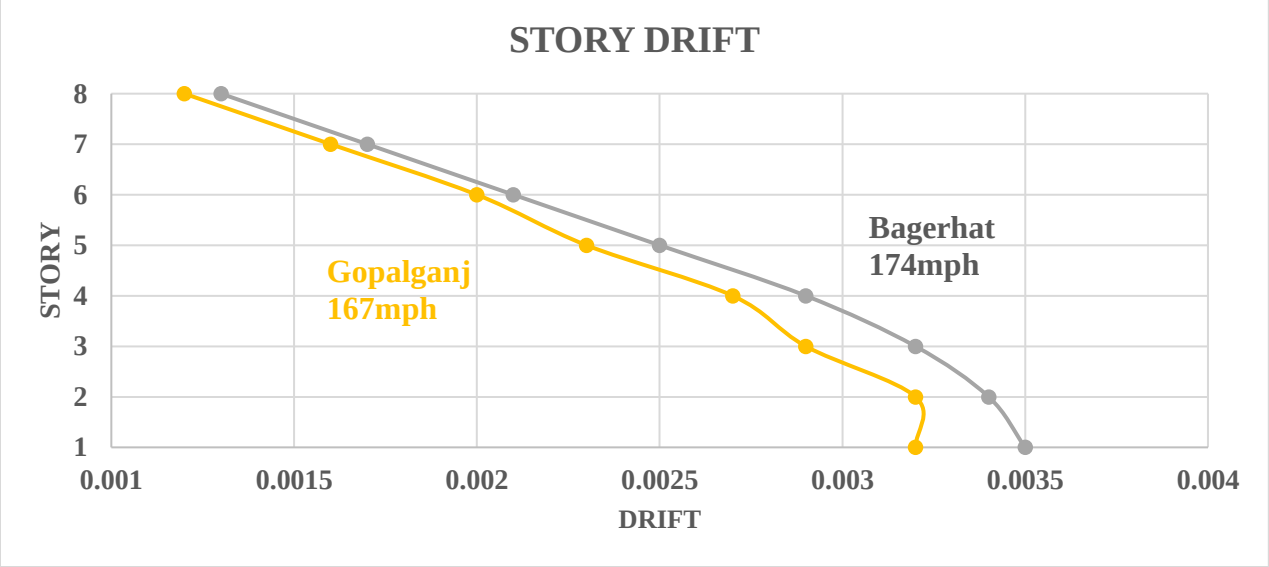




Load Combination: Wind Y

Location	Story Drift							
	Wind Y							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	0.0037	0.0036	0.0034	0.0031	0.0027	0.0023	0.0018	0.0013
TANGAIL (0.28)	0.0015	0.0015	0.0014	0.0012	0.0011	0.0009	0.0007	0.0005
BAGERHAT (0.12)	0.0035	0.0034	0.0032	0.0029	0.0025	0.0021	0.0017	0.0013
GOPALGANJ (0.12)	0.0032	0.0032	0.0029	0.0027	0.0023	0.002	0.0016	0.0012

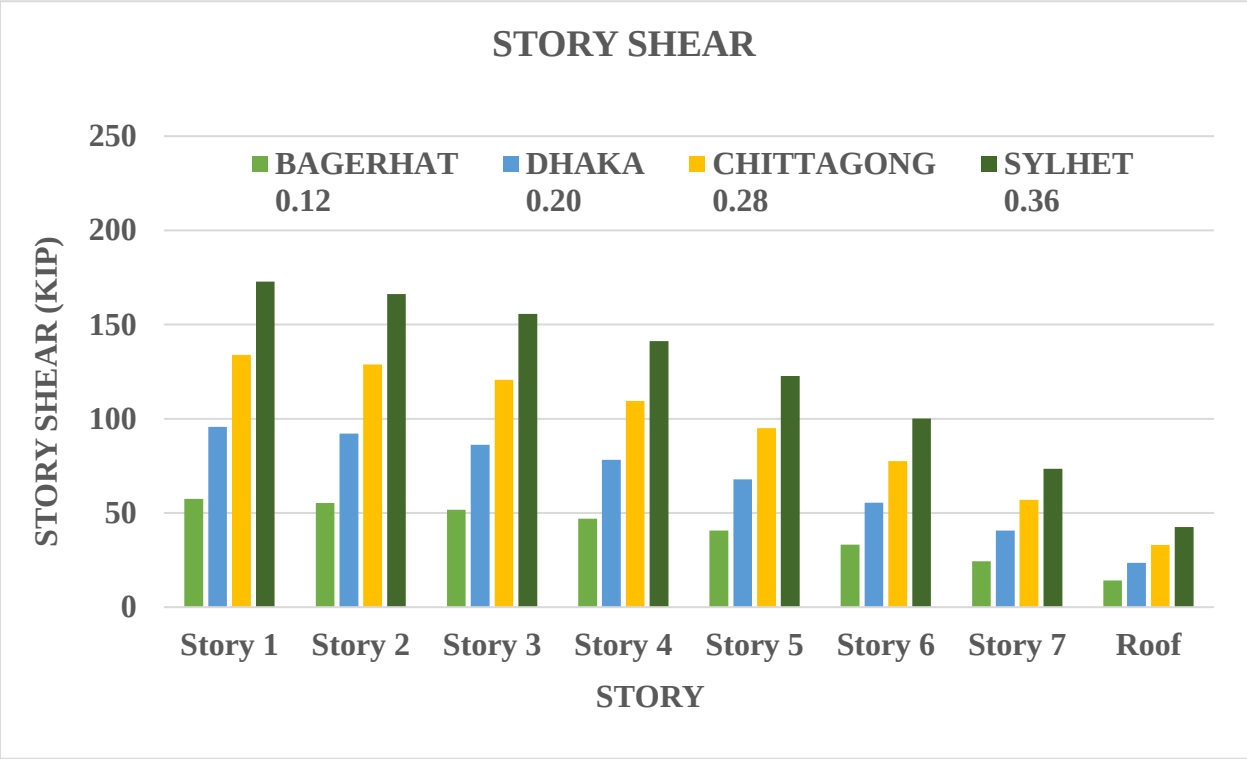




4.1.5 Story Shear (Due to Seismic Variation)

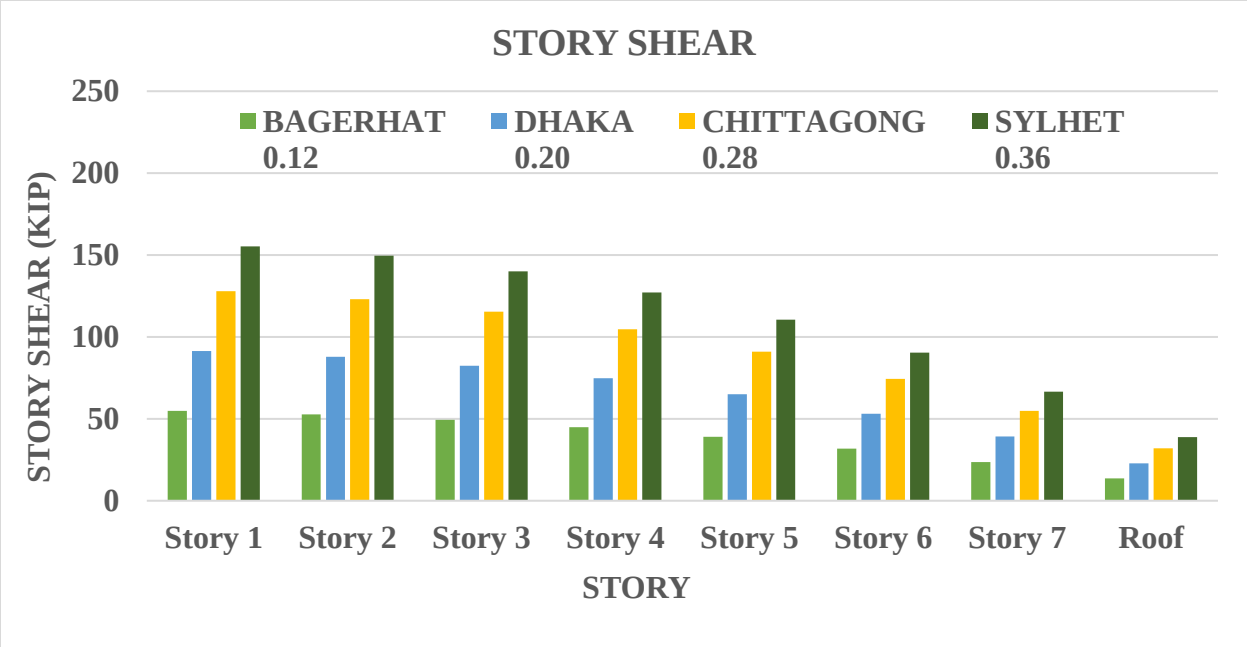
Load Combination: 1.05DL+1.275LL-1.4025Ex

Location	Story Shear							
	1.05DL+1.275LL-1.4025Ex							
	Story 1	**Story 2**	**Story 3**	**Story 4**	**Story 5**	**Story 6**	**Story 7**	**Roof**
BAGERHAT (0.12)	57.41	55.24	51.74	46.91	40.75	33.25	24.43	14.13
DHAKA (0.20)	95.68	92.07	86.23	78.18	67.91	55.42	40.72	23.54
CHITTAGONG (0.28)	133.89	128.83	120.67	109.40	95.03	77.56	56.98	32.95
SYLHET (0.36)	172.80	166.27	155.73	141.19	122.63	100.07	73.50	42.47



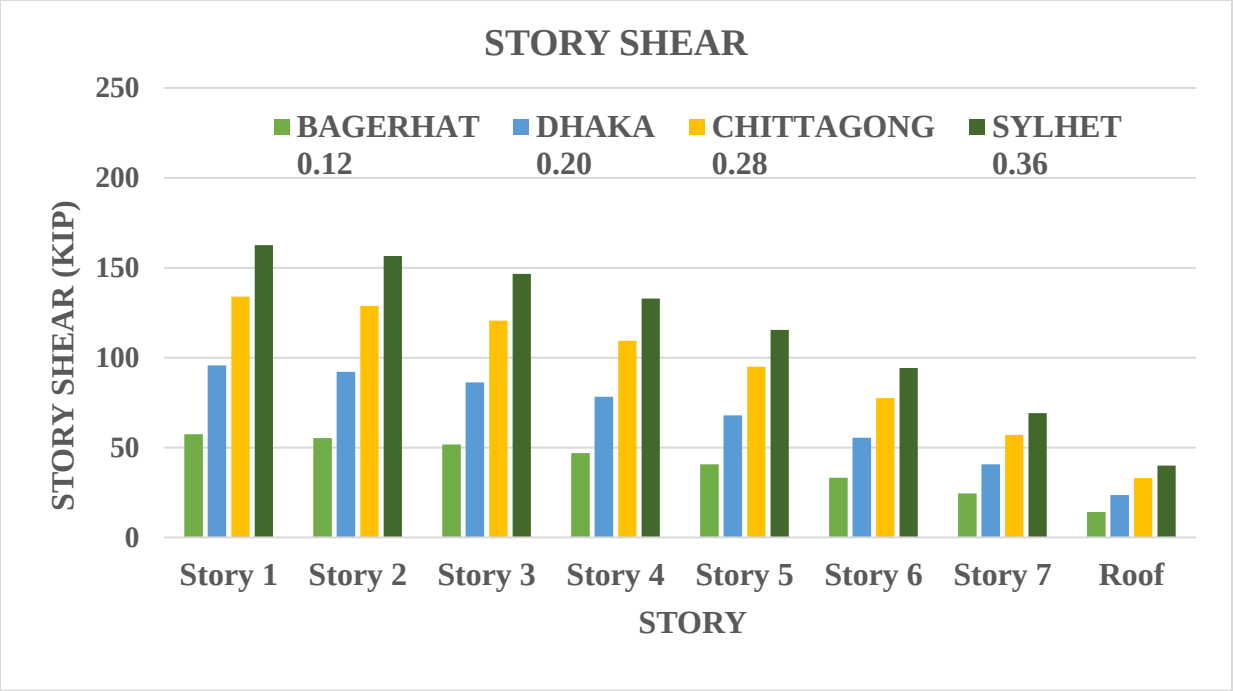
Load Combination: 1.05DL+1.275LL-1.4025Ey

Location	Story Shear							
	1.05DL+1.275LL-1.4025Ey							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
BAGERHAT (0.12)	54.83	52.77	49.45	44.86	39.01	31.90	23.52	13.73
DHAKA (0.20)	91.38	87.95	82.41	74.77	65.02	53.16	39.20	22.88
CHITTAGONG (0.28)	127.93	123.13	115.37	104.67	91.03	74.43	54.89	32.04
SYLHET (0.36)	155.34	149.51	140.10	127.10	110.53	90.38	66.65	38.90



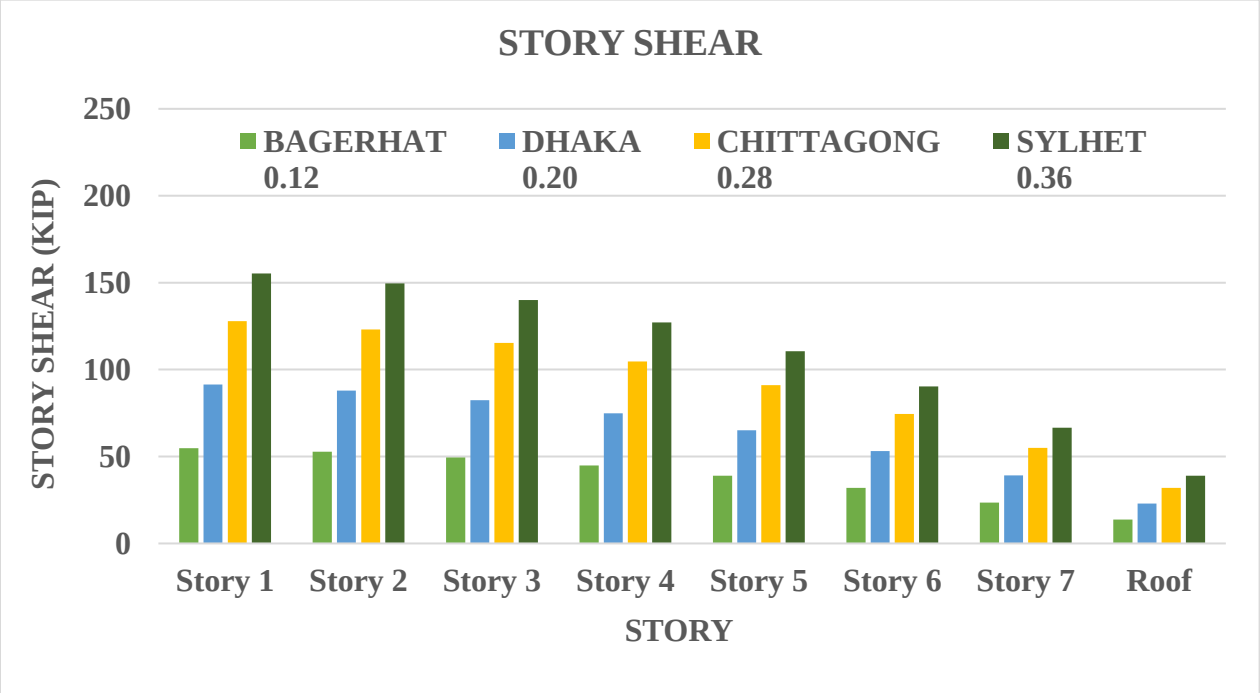
Load Combination: 1.05DL+1.275LL+1.4025Ex

Location	Story Shear							
	1.05DL+1.275LL+1.4025Ex							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
BAGERHAT (0.12)	57.38	55.21	51.71	46.89	40.73	33.24	24.42	14.12
DHAKA (0.20)	95.68	92.07	86.23	78.18	67.91	55.42	40.72	23.54
CHITTAGONG (0.28)	133.89	128.83	120.67	109.40	95.03	77.56	56.98	32.95
SYLHET (0.36)	162.61	156.47	146.56	132.87	115.42	94.20	69.20	40.02



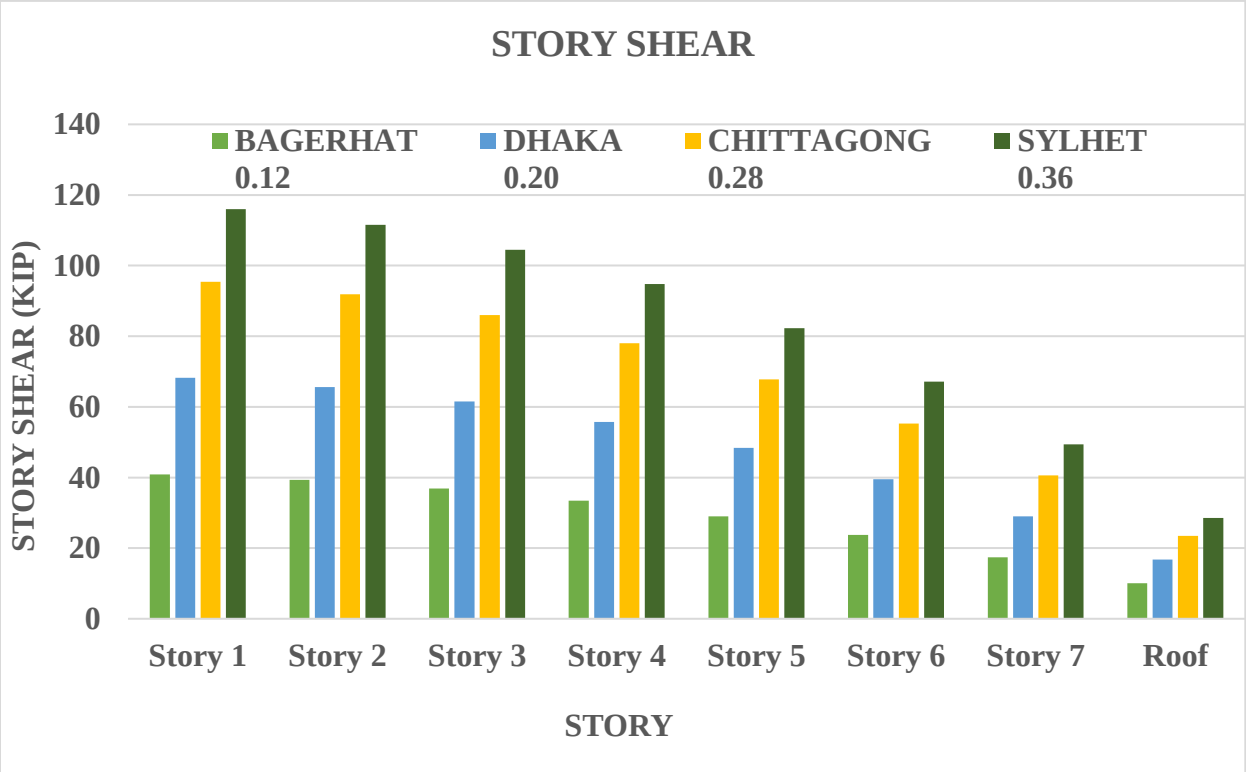
Load Combination: 1.05DL+1.275LL+1.4025Ey

Location	Story Shear							
	1.05DL+1.275LL+1.4025Ey							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story7	Roof
BAGERHAT (0.12)	54.83	52.77	49.45	44.86	39.01	31.90	23.52	13.73
DHAKA (0.20)	91.38	87.95	82.41	74.77	65.02	53.16	39.20	22.88
CHITTAGONG (0.28)	127.93	123.13	115.37	104.67	91.03	74.43	54.89	32.04
SYLHET (0.36)	155.34	149.51	140.10	127.10	110.53	90.38	66.65	38.90



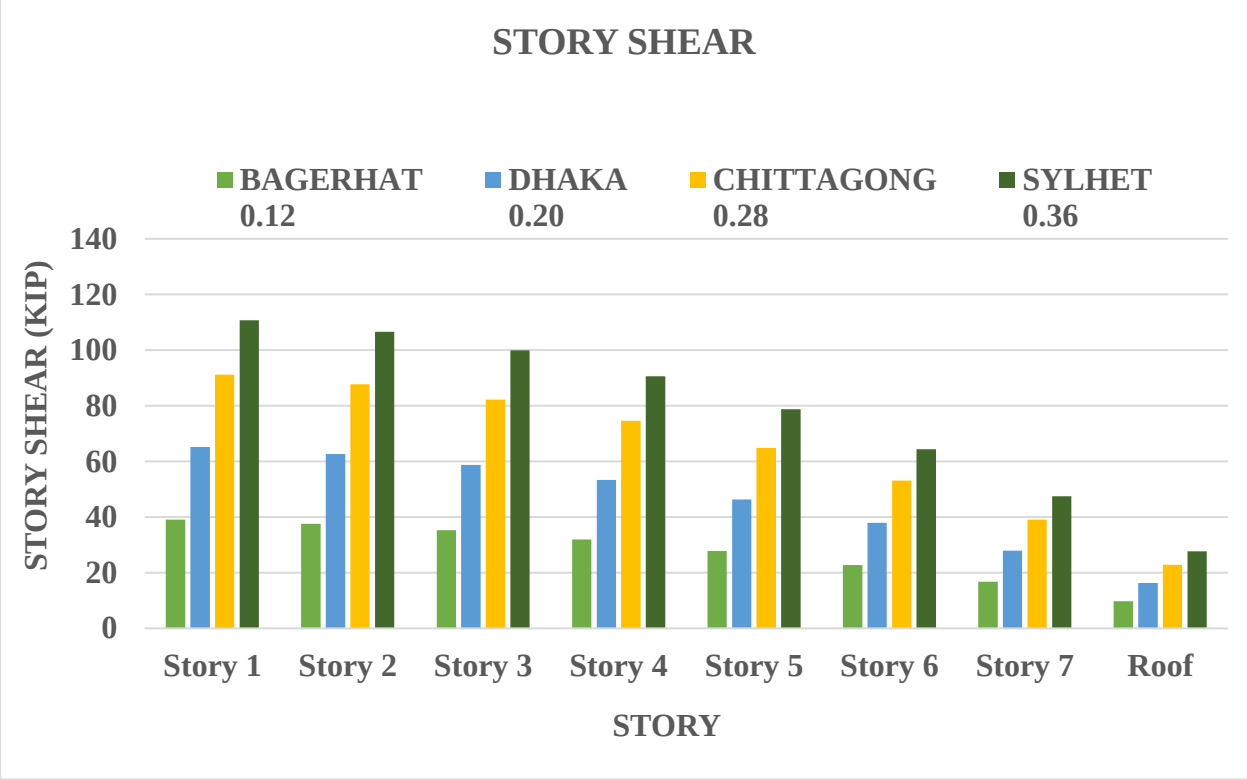
Load Combination: EQx

Location	Story Shear							
	EQx							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
BAGERHAT (0.12)	40.91	39.37	36.87	33.43	29.04	23.70	17.41	10.07
DHAKA (0.20)	68.22	65.64	61.49	55.74	48.42	39.52	29.03	16.79
CHITTAGONG (0.28)	95.46	91.86	86.04	78.00	67.76	55.30	40.63	23.50
SYLHET (0.36)	115.95	111.57	104.50	94.74	82.30	67.16	49.34	28.53



Load Combination: EQy

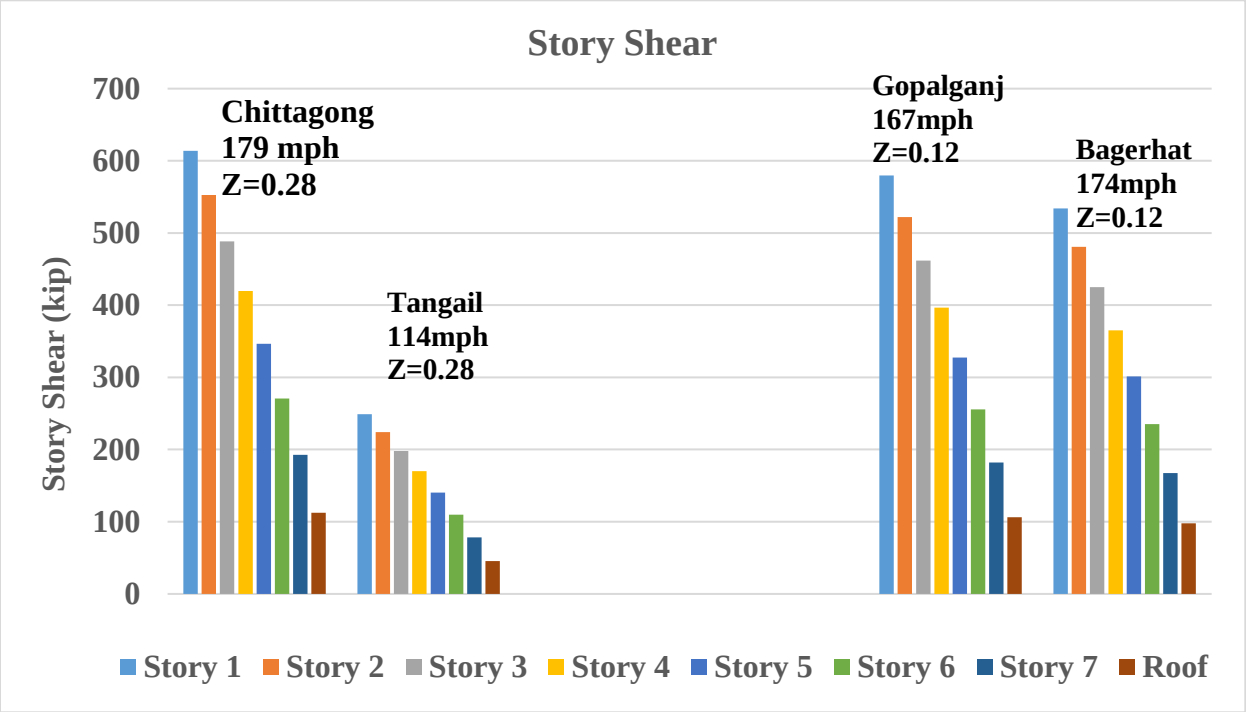
Location	Story Shear							
	EQy							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
BAGERHAT (0.12)	39.09	37.62	35.26	31.99	27.82	22.74	16.77	9.79
DHAKA (0.20)	65.15	62.71	58.76	53.31	46.36	37.91	27.95	16.32
CHITTAGONG (0.28)	91.22	87.79	82.26	74.63	64.90	53.07	39.13	22.84
SYLHET (0.36)	110.76	106.60	99.89	90.63	78.81	64.44	47.52	27.74



4.1.6 Story Shear (Due to Wind Variation)

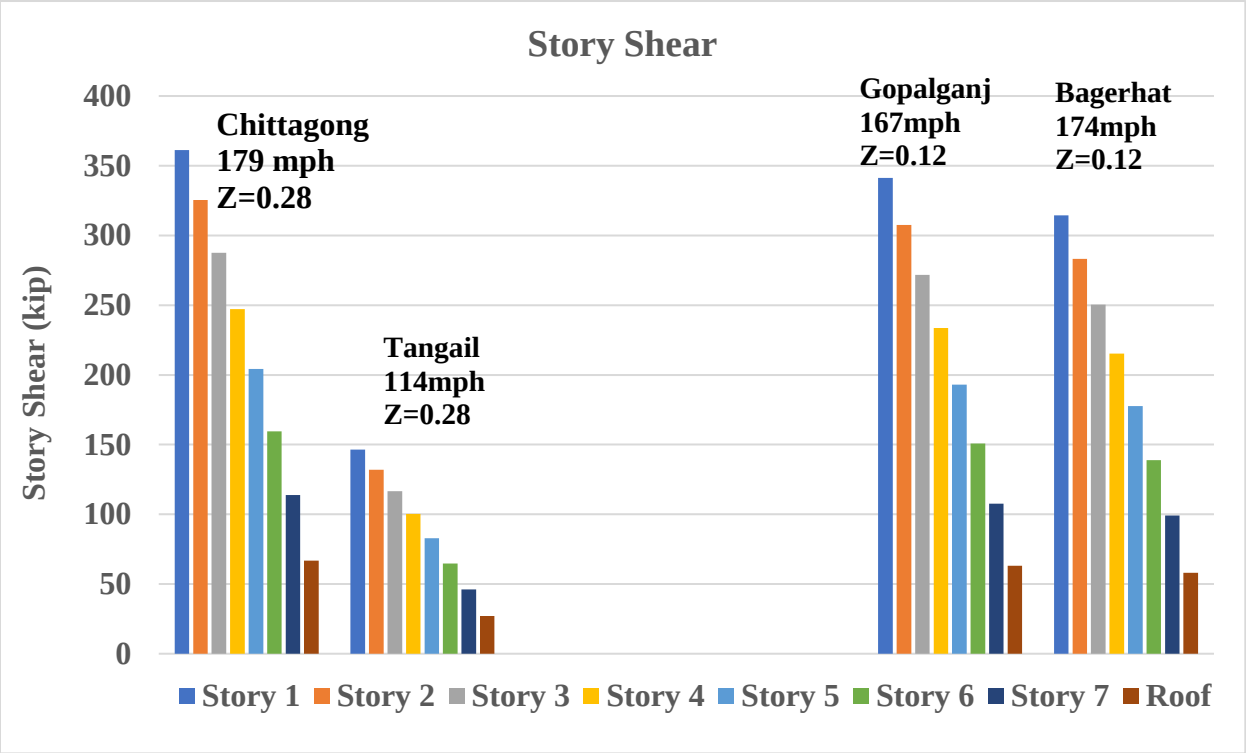
Load Combination: 1.05DL+1.275LL-1.275Wx

Location	Story Shear							
	1.05DL+1.275LL-1.275Wx							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	613.66	552.62	488.49	419.72	346.37	270.50	192.58	112.59
TANGAIL (0.28)	248.90	224.14	198.13	170.24	140.49	109.72	78.11	45.67
BAGERHAT (0.12)	579.85	522.18	461.58	396.60	327.29	255.60	181.97	106.38
GOPALGANJ (0.12)	534.14	481.01	425.19	365.33	301.49	235.45	167.62	98.00



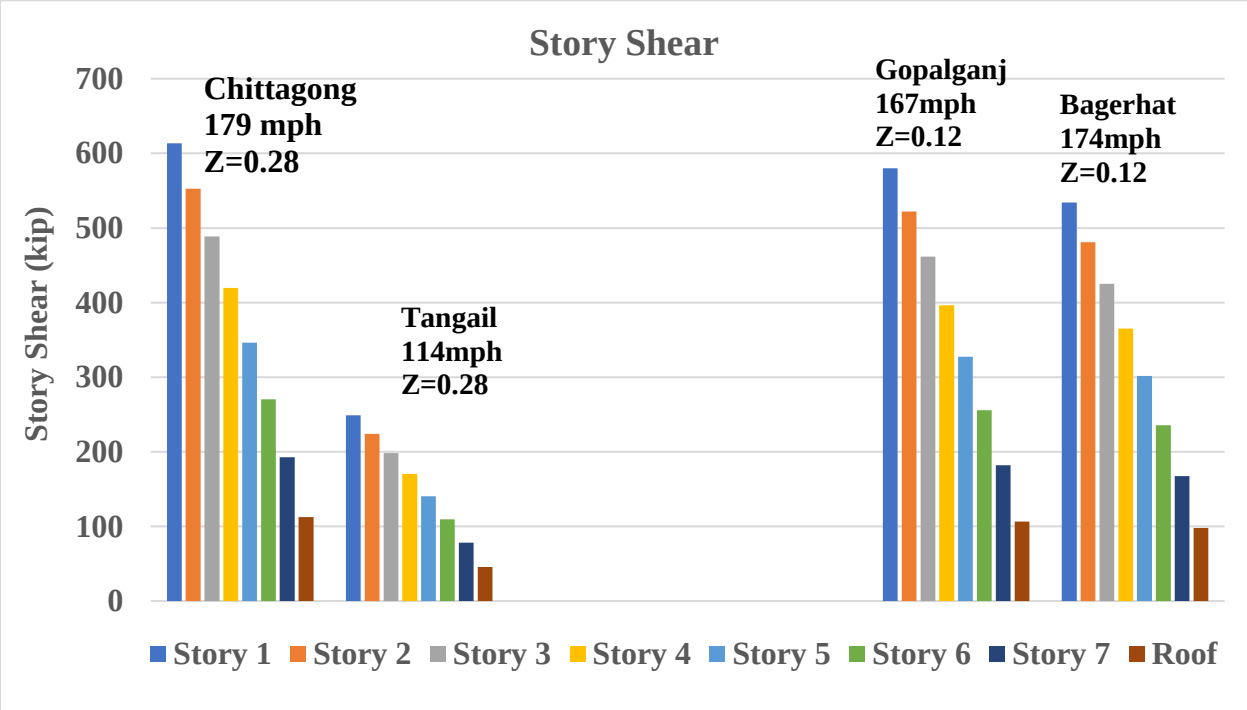
Load Combination: 1.05DL+1.275LL-1.275Wy

Location	Story Shear							
	1.05DL+1.275LL-1.275Wy							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	361.21	325.35	287.67	247.27	204.18	159.60	113.82	66.82
TANGAIL (0.28)	146.51	131.96	116.68	100.29	82.82	64.74	46.17	27.10
BAGERHAT (0.12)	341.31	307.43	271.83	233.65	192.93	150.81	107.55	63.14
GOPALGANJ (0.12)	314.40	283.19	250.39	215.23	177.72	138.92	99.07	58.16



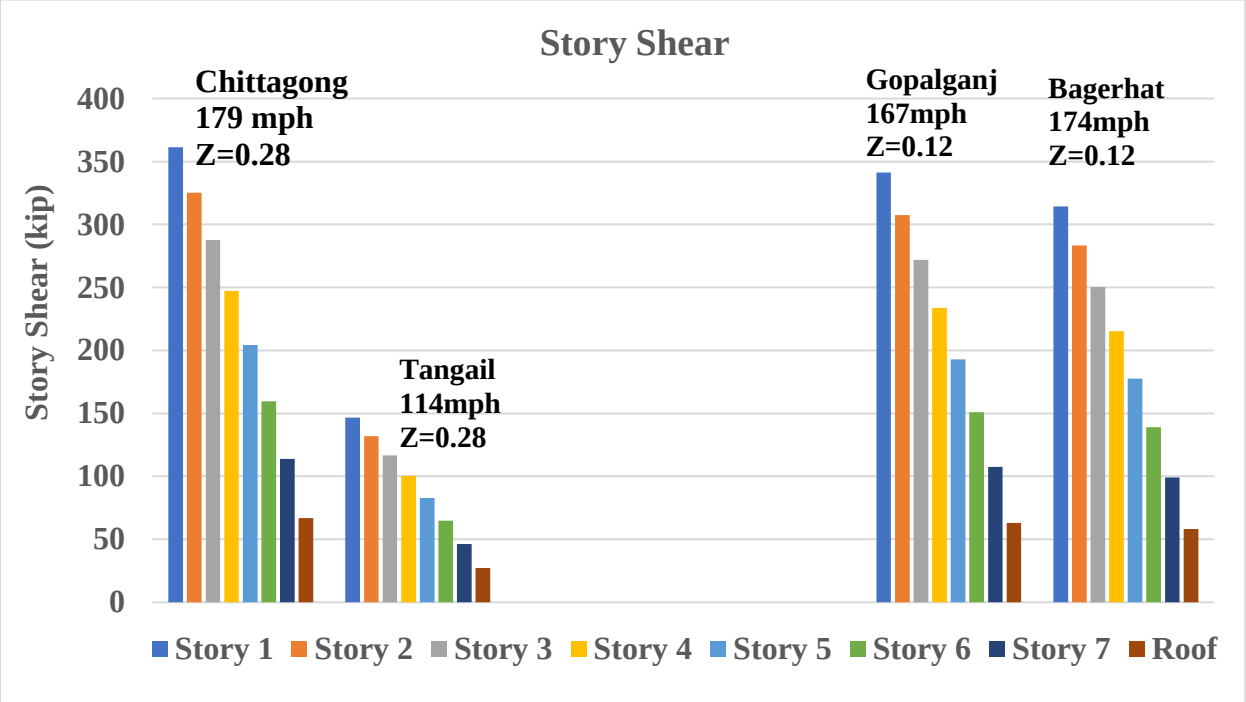
Load Combination: 1.05DL+1.275LL+1.275Wx

Location	Story Shear							
	1.05DL+1.275LL+1.275Wx							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	613.66	552.62	488.49	419.72	346.37	270.50	192.58	112.59
TANGAIL (0.28)	248.90	224.14	198.13	170.24	140.49	109.72	78.11	45.67
BAGERHAT (0.12)	579.85	522.18	461.58	396.60	327.29	255.60	181.97	106.38
GOPALGANJ (0.12)	534.14	481.01	425.19	365.33	301.49	235.45	167.62	98.00



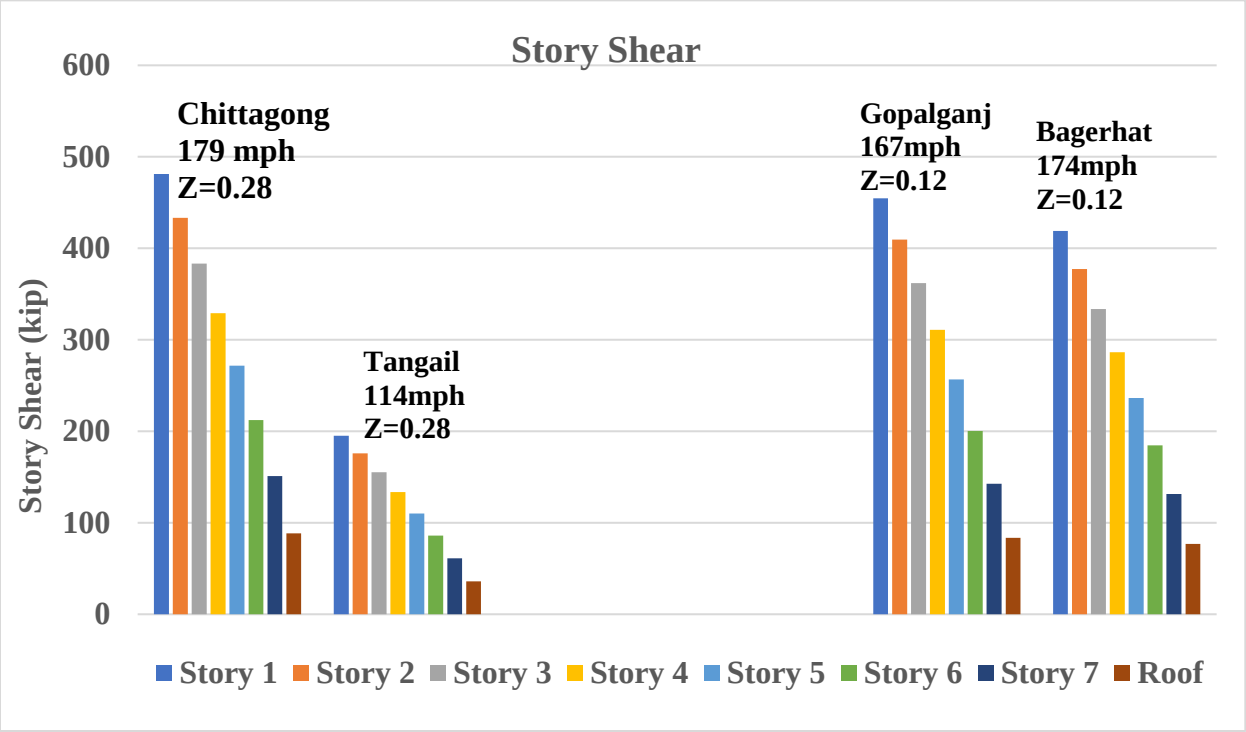
Load Combination: 1.05DL+1.275LL+1.275Wy

Location	Story Shear							
	1.05DL+1.275LL+1.275Wy							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	361.21	325.35	287.67	247.27	204.18	159.60	113.82	66.82
TANGAIL (0.28)	146.51	131.96	116.68	100.29	82.82	64.74	46.17	27.10
BAGERHAT (0.12)	341.31	307.43	271.83	233.65	192.93	150.81	107.55	63.14
GOPALGANJ (0.12)	314.40	283.19	250.39	215.23	177.72	138.92	99.07	58.16



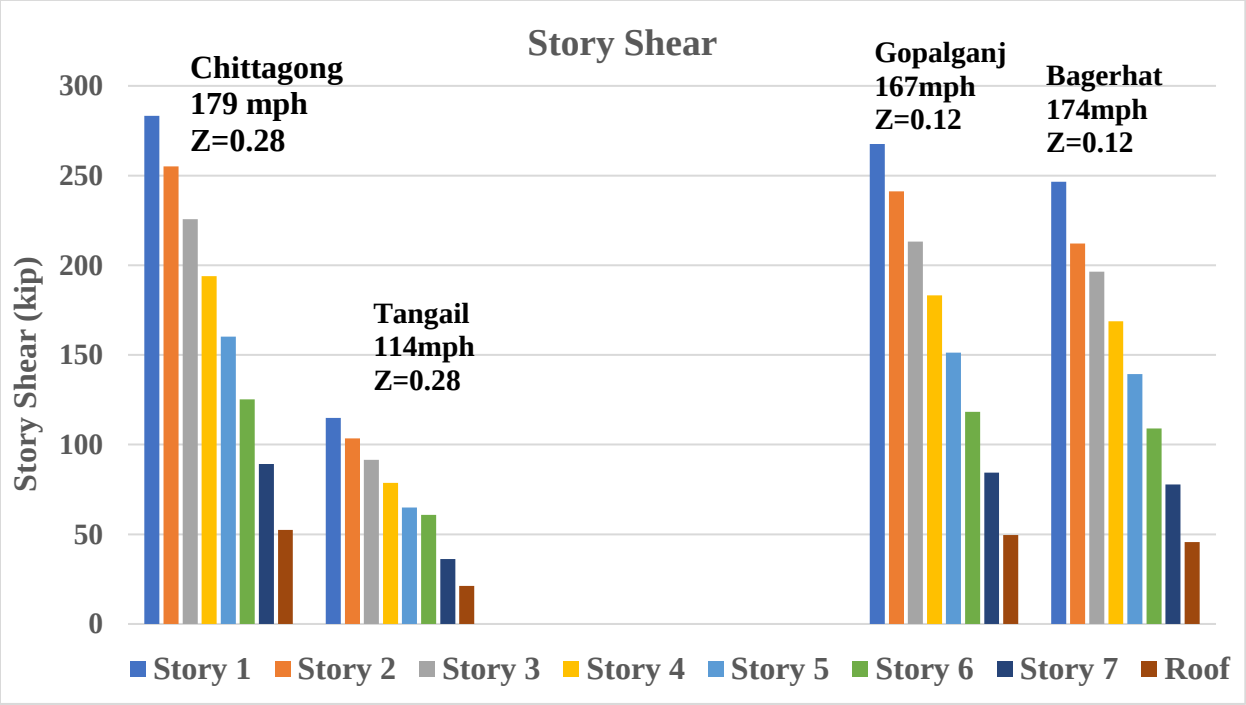
Load Combination: Wind X

Location	Story Shear							
	Wind X							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	481.30	433.43	383.13	329.19	271.66	212.16	151.04	88.30
TANGAIL (0.28)	195.22	175.80	155.40	133.52	110.19	86.05	61.26	35.82
BAGERHAT (0.12)	454.79	409.55	362.02	311.06	256.70	200.47	142.72	83.44
GOPALGANJ (0.12)	418.93	377.26	333.48	286.53	236.46	184.67	131.47	76.86

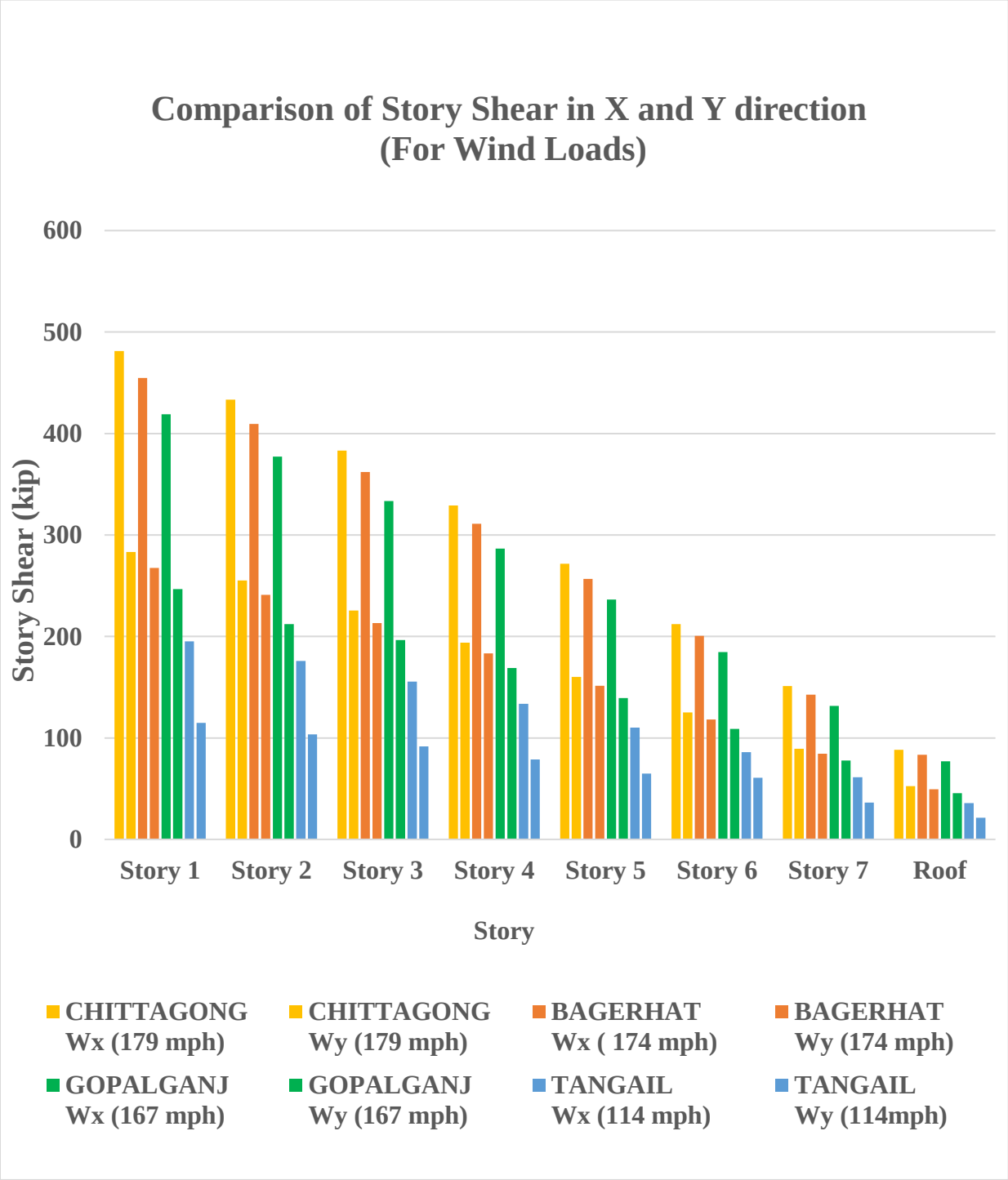


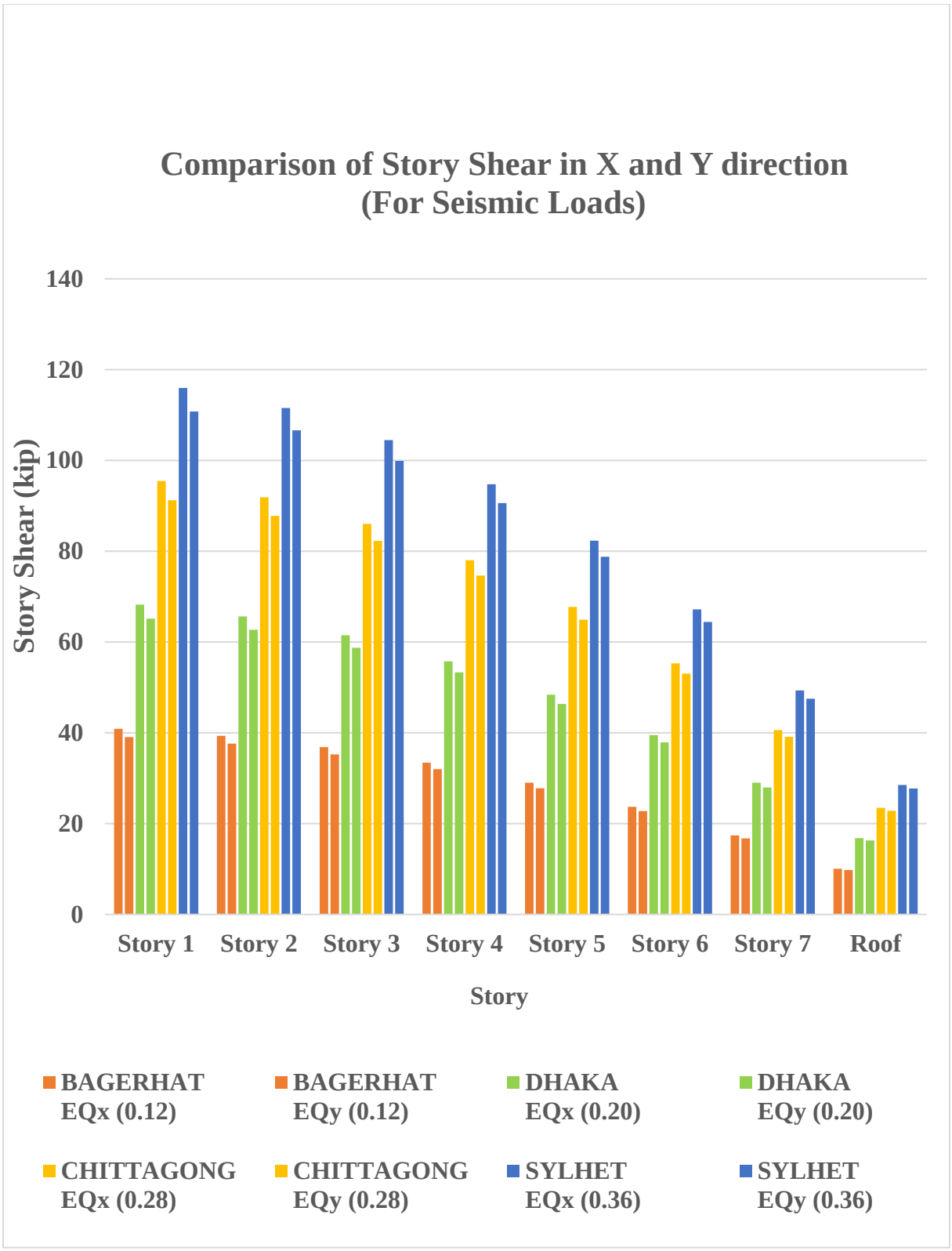
Load Combination: Wind Y

Location	Story Shear							
	Wind Y							
	Story 1	Story 2	Story 3	Story 4	Story 5	Story 6	Story 7	Roof
CHITTAGONG (0.28)	283.30	255.18	225.63	193.94	160.14	125.18	89.27	52.41
TANGAIL (0.28)	114.91	103.50	91.52	78.66	64.95	60.77	36.21	21.26
BAGERHAT (0.12)	267.66	241.12	213.20	183.25	151.32	118.28	84.35	49.52
GOPALGANJ (0.12)	246.59	212.11	196.39	168.81	139.39	108.96	77.70	45.62



4.1.7 Comparison of Directional Story Shear




Comparison of Story Shear in X and Y direction
(For Seismic Loads)
Story Shear (kip)
140
120
100
80
60
40
20
0
Story 1
Story 2
Story 3
Story 4
Story 5
Story 6
Story 7
Roof
Story
BAGERHAT EQx (0.12)
BAGERHAT EQy (0.12)
DHAKA EQx (0.20)
DHAKA EQy (0.20)
CHITTAGONG EQx (0.28)
CHITTAGONG EQy (0.28)
SYLHET EQx (0.36)
SYLHET EQy (0.36)

4.2Discussion

4.2.1Story Displacement

a) Due to zonal seismic variation :

From the analysis of the Story Displacement of the building model we can come into a conclusion that the displacement of the building is minimum at the base level and as we move upwards the value increases. Thus the maximum displacement is observed in the rooftop level. Moreover, if we consider the seismic variations for different combinations, we see that the displacement significantly increases with the increasing of seismic Zone factor. Displacement is minimum in the zone having the minimum seismic coefficient and vise versa.

The story displacement (maximum) value for the model in Bagerhat (Z=0.12) is 0.70 inch and in Sylhet (Z=0.36) is 1.92 inch. This means the story displacement increases by more than 174% in Sylhet as compared to that of Bagerhat.

b) Due to wind variation in similar seismic zone :

If we consider wind variation for similar seismic zone like Chittagong and Tangail (Z=0.28) or Bagerhat and Gopalgonj (Z=0.12) we can see that story displacement value is more in the zone where wind speed is more.

For example– Maximum story displacement value for the model in Tangail (Wind speed=114 mph) is 2.76 inch and in Chittagong (Wind speed=179 mph) is 6.68 inch.This means the story displacement increases by more than 142% in Chittagong as compared to that of Tangail (Though both have same seismic coefficient Z=0.28).

In case for Bagerhat and Gopalgonj, story displacement value for Bagerhat (Wind speed=174 mph) is 6.32 and for Gopalgonj (Wind speed=167 mph) it is 5.82. So, the story displacement value increases by more than 8.5% in Bagerhat as compared to that of Gopalgonj (Though both have the same seismic coefficient Z=0.12).

4.2.2Story Shear

a) Due to zonal seismic variation :

For a particular seismic zone, it is observed that the Story Shear has decreased as the height from the ground increased and reduced to minimum at topmost floor when seismic load was considered. The story shear is maximum at the base. And if we consider the seismic variations for different combinations it is seen that the story shear increases with the increase of seismic Zone factor.

And the story shear value for the model in Bagerhat (Z=0.12) is 57.38 kip and in Sylhet (Z=0.36) is 162.61 kip. This means the story shear increases by more than 183% in Sylhet as compared to that of Bagerhat**.**

b) Due to wind variation in similar seismic zone:

When we consider wind variation for similar seismic zone like Chittagong and Tangail (Z=0.28) or Bagerhat and Gopalgonj (Z=0.12) we can see that story shear value is more in the zone where wind speed is more. For example– story shear value for the model in Tangail (Wind speed=114 mph) is 45.67 kip and in Chittagong (Wind speed=179 mph) is 112.59 kip .This means the story shear increases by more than 146% in Chittagong as compared to that of Tangail (Though both have same seismic coefficient Z=0.28).

In case for Bagerhat and Gopalgonj, story shear value for Bagerhat (Wind speed=174 mph) is 106.38 kip and in Gopalgonj (Wind speed=167 mph) it is 98 kip. As a result, the story shear value increases by more than 8.5% in Bagerhat as compared to that of Gopalgonj (Though both have the same seismic coefficient Z=0.12).

c) Due to directional (X & Y) variation for Seismic Loads:

In the ETABS 2016 building modelling, seismic loads comes from both in X and Y direction. From the analysis, it is found that seismic loads are almost same in both X & Y directions. Seismic loads are high in higher seismic zones and it begins to decrease as zonal seismic coefficients decreases. For a particular seismic zone, at every story seismic load acting in X direction is slightly higher than the load acts in Y direction. In general, these differences is negligible and loads are quite equal.

d) Due to directional (X & Y) variation for Wind Loads:

In the ETABS 2016 building modelling, Wind loads comes from both in X and Y direction. From the analysis, it is found that wind loads are different in X and Y directions. Wind loads are higher in zones which have higher wind speed. Wind loads also depend on the surface area on which the wind hits. The larger the surface area the higher the loads generate. From the Building model, the length of the building is nearly twice the width of the building. As the other parameters are quite similar, wind loads depend on the surface area of the building. As a result, wind loads of X direction is twice the wind loads of Y direction.

4.2.3Story Drift

a) Due to zonal seismic variation :

According to the analysis it is observed that relative lateral displacement or Story Drift is maximum at around the one-third height of the building (3rd Story) structure from the ground. Adding to that, when seismic variations for different load combinations are taken into consideration, it is observed that story drift increases with the increasing of seismic zone factor.

For a similar building, maximum Story Drift value for the model in Bagerhat (Z=0.12) is 0.0008 and in Sylhet (Z=0.36) is 0.0023. This means the story drift increases by more than 187% in Sylhet as compared to that of Bagerhat**.**

b) Due to wind variation in similar seismic zone:

When we consider wind variation for similar seismic zone like Chittagong and Tangail (Z=0.28) or Bagerhat and Gopalgonj (Z=0.12) we can see that story drift value is more in the zone where wind speed is more.

For example– maximum story drift value for the model in Tangail (Wind speed=114 mph) is 0.0036 and in Chittagong (Wind speed=179 mph) is 0.0088. This means the story drift increases by more than 144% in Chittagong as compared to that of Tangail (though both have same seismic coefficient Z=0.28). In case for Bagerhat and Gopalgonj, maximum story drift value is 0.0084 in Bagerhat (Wind speed=174 mph) compared to Gopalgonj (Wind speed=167 mph) 0.0077. As a result, story drift increases by more than 9% in Bagerhat as compared to that of Gopalgonj (Though both have the same seismic coefficient Z=0.12).

Chapter 5

CONCLUSIONS AND RECOMMENDATIONS

In this chapter, the outcomes of the study has been summarized obtained from ETABS software (2016). How the study data results may benefit people also discuss here shortly. Furthermore, possible improvement of effectiveness of the study and how the study presents more realistic outcomes has also been discussed here.

5.1 Summary

After analyzing all the parameters (Story Displacement, Story Shear, Story Drift) for different load combination as well as different seismic zones with corresponding wind load ; we can summarize the behavior of data of this study within two conclusions–

I. For zonal seismic variation story displacement, story shear, story drift values significantly increases in higher seismic zone as compared to the lower one.
II. For similar seismic zone story displacement, story shear, story drift values are substantially more in the zone having higher wind speed.

5.2 Recommendations

Based on result obtained from the study and limitation observed, some further study can be conducted on the following topic :

- At what extent reinforcement requirement is changed in RC structure when moving to higher seismic zone as compared to lower one.
- Effects of soil properties on RC structure in similar seismic zones or impacts of soil properties in different seismic zones of Bangladesh.
- Changes in cost of RC structure in different seismic zones of Bangladesh.

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