Study On Seismic Performance of Earth scraper Structure Under Zone-IV and Zone-V by Using Etabs

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Abstract - Earthscraper structures, also known as substructures or underground structures, are architectural marvels located partially or entirely beneath the ground level to facilitate future development. The specific structure in question was designed using Etabs software and comprises 15 stories, with 5 stories above ground level (GL) and 10 stories below ground level (GL). To ensure the overall stability of the building against seismic forces, a seismic analysis was conducted for Zone-IV and Zone-V, considering soil type-II medium soil conditions. The primary objective of the structural design was to withstand ground shaking during an earthquake and maintain its integrity. A central opening measuring 31mx31m was incorporated throughout the building for ventilation and natural light. Under seismic Zone-IV, the maximum story drift was observed in story-2 along the X-direction and story-2 along the Y-direction. For seismic Zone-V, the maximum drift occurred in story-1 along the X-direction and story-11 along the Y-direction. The maximum natural time period for the structure was found to be 0.358 seconds. Comparing the two seismic Zones, Zone-V exhibited a higher maximum story displacement, measuring 15.15mm, while the Zone-IV had a maximum displacement of 10.10mm. this indicates the Zone-V is more susceptible to displacement during seismic events.

Key words: Earthscraper, seismic analysis, story drift, etc.

1. INTRODUCTION

Earthscraper structure also appertained to as subsurface or underground structures, are architectural sensations that are partially or entirely located beneath the ground level. These unique constructions serve a wide range of purposes, including residential, commercial, industrial, or even governmental functions. Over the years, advancements in technology and engineering have significantly improved the feasibility and effectiveness of underground construction, making it an increasingly viable option for various applications. The construction of underground structure offers multitudinous advantages, contributing to their growing popularity and appeal and the advantages are: (1) Space Optimization (2) Aesthetics and Preservation (3) Environmental Considerations (4) Safety and Security.

Beyond these primary advantages, underground structures offer additional benefits. They can provide noise isolation, shielding inhabitants from external disturbances and creating a serene inner terrain. In recent years, notable exemplifications of underground structures have emerged worldwide. From subterranean residential complexes and commercial centers to underground exploration facilities and transportation systems, these structures showcase the remarkable possibility of underground construction. The expansion of underground spaces has brought innovative and visionary designs to life, inspiring architects, engineers, and urban planners to explore the untapped eventuality of erecting underneath the surface. The design of the structure has been completed by using Indian Standard code (1) IS 456:2000 - Code of practice for plain and reinforced concrete and (2) IS1893:2016 – Guidelines for designing earthquake-resistant structures.

Statement of the project

1. Building type	Underground Building
2. No. of story	15
3. Building shape	Square
4. Geometrical details:	
a. Floor to floor height	14ft
b. No, of story above GL	5
c. No. of story below GL	10
5. Material details:	
a. Concrete grade	M40
b. Steel grade	HYSD550
c. Type of soil	Type II
6. Type of construction	Concrete frame structure

2. Literature Review

(1) Faham Tahmasebinia (Tahmasebinia, 13 May 2020). This chapter discusses the "earthscraper" by BNKR Arquitectura, a unique underground building with comfortable temperatures. A 2D thermal analysis shows temperatures ranging from 20 to 38°C. a 3D analysis reveals 527mm and 19.8mm internal displacements on exterior and interior walls respectively. Earthquake analysis finds a maximum horizontal displacement of 19.2mm under designed loads.

(2) Carlos Arturo Morales Miranda (Miranda, 2017). This report explores the concept of "earthscrapers", which are underground skyscrapers, as an alternative to traditional aboveground skyscrapers for urban areas with limited surface space. It examines the advantages and disadvantages of earthscrapers compared to skyscrapers, focusing on space constraints, structure stability and energy efficiency. The report also evaluate safety, mechanical, electrical and lighting systems applicable to earthscrapers and discusses challenges and potential improvements. The document concludes by providing suggestions to implement this innovative design concept effectively.

(3) Koram Samuel Sakyi (Sakyi, may 2018). This paper focuses on the seismic impact of a real river-crossing subway tunnel. They use the pseudo-static method and FLAC3D to analyze the tunnel's behavior under seismic conditions, considering both static and dynamic effects. The study concludes that transverse shear waves cause significant tunnel displacement and considering groundwater affects the tunnel's behavior, affecting pore water pressure and effective stress.

(4) A.Salman (A.Salman, August 2022). This paper aims to explore the concept of earthscrapers, which are underground buildings, and understand their potential for housing and urban development. It discusses various case studies and provides conclusions with references. Underground construction addresses issues like city overpopulation, traffic and environmental concerns. However, living or working underground may trigger psychological challenges and the article explores ways to mitigate these issues through architectural and design considerations.

(5) Ankit Gupta (Gupta, June-2020). This paper applies a simplified seismic design methodology for tunnels to other types of structures. It focuses on a large reinforced concrete structure fully embedded in soil. The study considers dynamic pressures from body and surface waves acting on walls, roof and floor. Seismic load combinations are proposed to accommodate different polarization planes of seismic waves and the impact of neighboring buildings on soil stress states is also discussed.

3. OBJECTIVES

The objects of designing a 15-storey structure with 5-storey's above ground level (GL) and 10-storey's underground in seismic Zone-IV and Zone-V are:

- The primary idea is to ensuring the overall stability of the structure against seismic forces. The structural design should be robust enough to repel the implicit ground shaking and maintain its integrity during an earthquake.
- Another pivotal ideal is to guarantee the safety of inhabitants within the structure. The design should prioritize measure to help minimize the threat of structural damage during an earthquake.
- The structure should be designed to limit structural distortions and control accelerations caused by seismic loads. The ideal is to maintain the functionality of the structure indeed after a seismic event, allowing for safe evacuation and minimizing post-earthquake repairs.
- The design should cleave to the applicable structure canons and norms specific to seismic Zone-IV and Zone-V.
- The design must also consider practical aspects concerning construction styles, amenities and construction sequences.

4. METHODOLOGY

The study is about the seismic analysis of Earthscraper or underground structure of 15 story of which 5-story above GL and 10-story below GL is analysed using Etabs for seismic Zone-III moderate condition. The 3D model of Earthscraper structure is prepared by using Etabs.

4.1 Methods of analysis of structure

Seismic analysis begins with the description of he designs parameters, including the seismic zones point bracket and applicable structure canons. The coming step is the creation of the structural model in Etabs, where define the figure, accoutrements and structural factors of the structure. The software offers features to generate tools for creating the 3D models with shafts, column, walls, crossbeams and other rudiments. During the seismic analysis process, we can examine crucial parameters similar as deportations, inter-story drifts, base shear forces and member forces to estimate the structural performance.

4.2 Materials

Table-01 - Material Properties

Name	Type	E MPa	ν	Unit Weight kN/m^3	Design Strengths
A416Gr270	Tendon	196500.6	0	76.9729	Fy=1689.91 MPa, Fu=1861.58 MPa
A615Gr60	Rebar	199947.98	0.3	76.9729	Fy=413.69 MPa, Fu=620.53 MPa
HYSD550	Rebar	200000	0	76.9729	Fy=550 MPa, Fu=585 MPa
M40	Concrete	31622.78	0.2	24.9926	Fc=40 MPa

4.2 Properties

Frame Sections	Shell Sections
Beam = 1200x700mm Column-1 = 1200mm Column-2 = 1m	Slab-1 = 150mm Slab-2 = 300mm Wall-1 = 200mm Wall-2 = 600mm

4.3 Forces exerted on the structure

- Dead load
- Live load
- Earthquake load

4.4 Factors and Coefficients

Seismic Zone factor, Z (IS Table-3)	Z = 0.24 & Z-0.36
Response Reduction Factor, R (IS Table-9)	R = 3
Importance Factor, I (IS Table-8)	I = 1.5
Site type (IS Table-1)	II

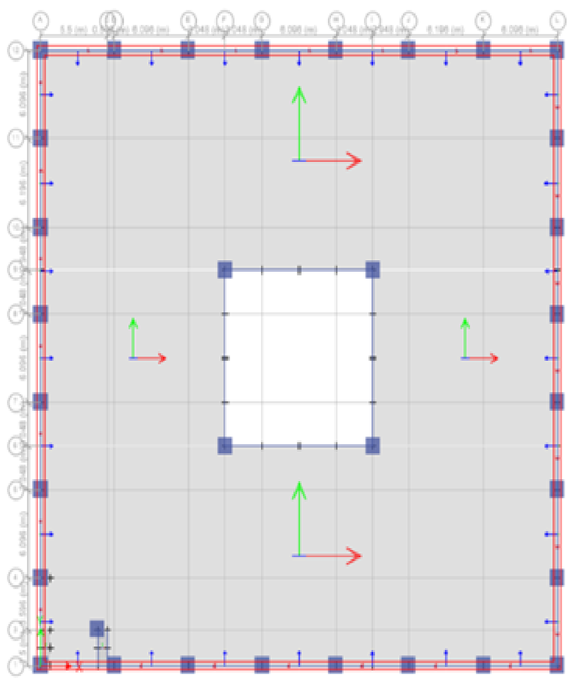

Fig-01 – Plan of the Structure

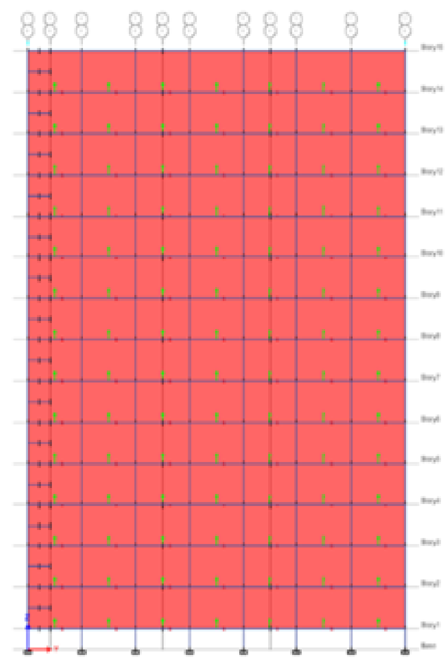

Fig.2 – Outer Elevation of Structure

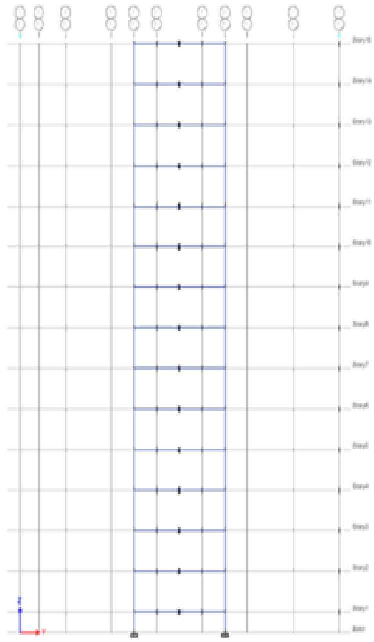

Fig.3 – inner elevation of the structure

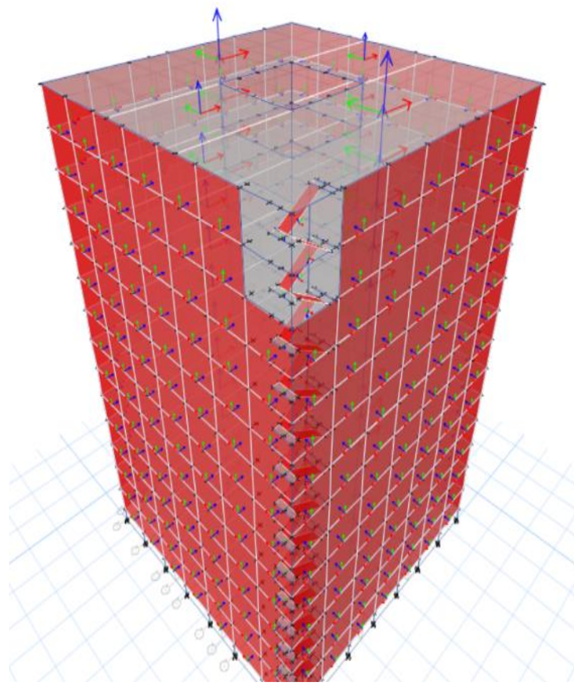

Fig.4 – 3D view of the Structure

5. RESULTS

Table-02 - Base Reactions for Z-IV

Load Case	FX	FY	FZ	MX	MY	MZ
	kN	kN	kN	kN-m	kN-m	kN-m
Dead	0	0	550250.49	11595408	-11669178	0
Live	0	0	65323.74	1395354.2	-1427745	0
EQ 1	-60546.725	0	0	0	-2718505	1269850.9
EQ 2	0	-60546.725	0	2718505.1	0	-1275011
EQ 3	-60546.725	0	0	0	-2718505	1269850.9
EQ 4	0	-60546.725	0	2718505.1	0	-1275011
EQ 5	-60546.725	0	0	0	-2718505	1269850.9
EQ 6	0	-60546.725	0	2718505.1	0	-1275011
U F L Max	0	0	615574.23	15709267	-13096923	1269850.9
U F L Min	-60546.725	-60546.725	615574.23	12990762	-15815428	-1275011
FL Max	0	0	923361.34	23563901	-19645384	1904776.3
FL Min	-90820.087	-90820.087	923361.34	19486143	-23723142	-1912517

Table-03- Base Reactions for Z-V

Load Case	FX	FY	FZ	MX	MY	MZ
	kN	kN	kN	kN-m	kN-m	kN-m
Dead	0	0	550250.49	11595408	-11669178	0
Live	0	0	65323.74	1395354.2	-1427745	0
EQ 1	-90820.0867	0	0	0	-4077758	1904776.3
EQ 2	0	-90820.087	0	4077757.7	0	-1912517
EQ 3	-90820.0867	0	0	0	-4077758	1904776.3
EQ 4	0	-90820.087	0	4077757.7	0	-1912517
EQ 5	-90820.0867	0	0	0	-4077758	1904776.3
EQ 6	0	-90820.087	0	4077757.7	0	-1912517
U F L Max	0	0	615574.23	17068520	-13096923	1904776.3
U F L Min	-90820.0867	-90820.087	615574.23	12990762	-17174680	-1912517
FL Max	0	0	923361.34	25602779	-19645384	2857164.5
FL Min	-136230.13	-136230.13	923361.34	19486143	-25762020	-2868776

Table-04 – story drift seismic in X-direction for Z-IV and Z-V

Story	Load Case	Direction	Drift Z-IV	Drift Z-V
Story15	**seismic**	X	0.000128	0.000192
Story14	**seismic**	X	0.000158	0.000237
Story13	**seismic**	X	0.000186	0.000278
Story12	**seismic**	X	0.000207	0.000311
Story11	**seismic**	X	0.000206	0.000309
Story10	**seismic**	X	0.000157	0.000236
Story9	**seismic**	X	0.000144	0.000216
Story8	**seismic**	X	0.000144	0.000215
Story7	**seismic**	X	0.000144	0.000215
Story6	**seismic**	X	0.000142	0.000213
Story5	**seismic**	X	0.000137	0.000206
Story4	**seismic**	X	0.000132	0.000197
Story3	**seismic**	X	0.00015	0.000225
Story2	**seismic**	X	0.000232	0.000349
Story1	**seismic**	X	0.00049	0.000735

Fig-012 Comparison of Drift in Z-IV and Z-V in X-Direction

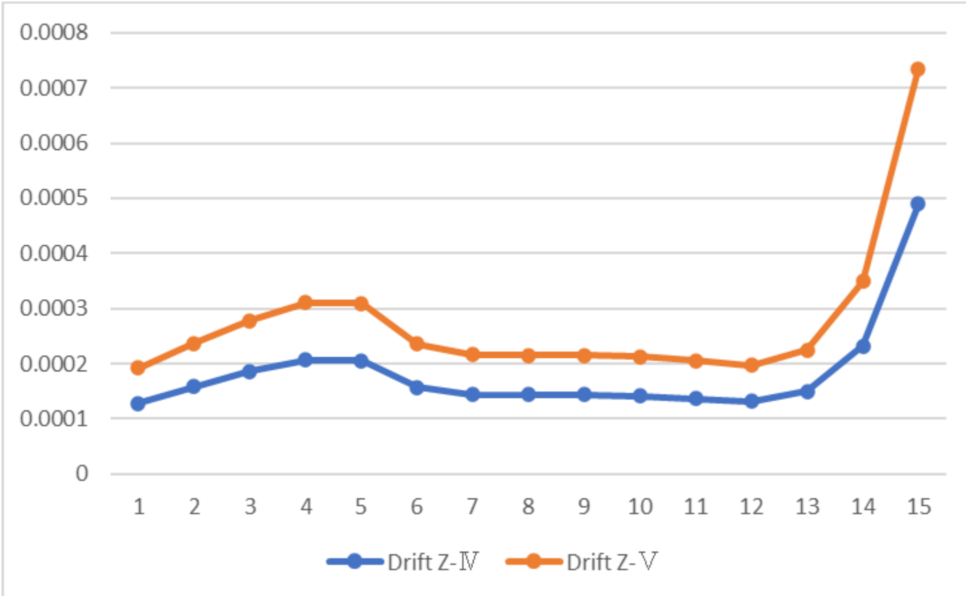

Table-05 – story drift seismic in Y-direction for Z-IV and Z-V

Story	Load Case	Direction	Drift Z-IV	Drift Z-V
Story15	**seismic**	Y	0.000316	0.000474
Story14	**seismic**	Y	0.000404	0.000606
Story13	**seismic**	Y	0.000507	0.00076
Story12	**seismic**	Y	0.000571	0.000857
Story11	**seismic**	Y	0.000562	0.000843
Story10	**seismic**	Y	0.00048	0.000719
Story9	**seismic**	Y	0.000409	0.000613
Story8	**seismic**	Y	0.000355	0.000533
Story7	**seismic**	Y	0.000319	0.000479
Story6	**seismic**	Y	0.000298	0.000446
Story5	**seismic**	Y	0.000287	0.00043
Story4	**seismic**	Y	0.000277	0.000416
Story3	**seismic**	Y	0.000249	0.000374
Story2	**seismic**	Y	0.000219	0.000329
Story1	EQ 2	Y	0.000492	0.000738

Fig-013 Comparison of EQ Drift in Z-IV and Z-V in Y-Direction

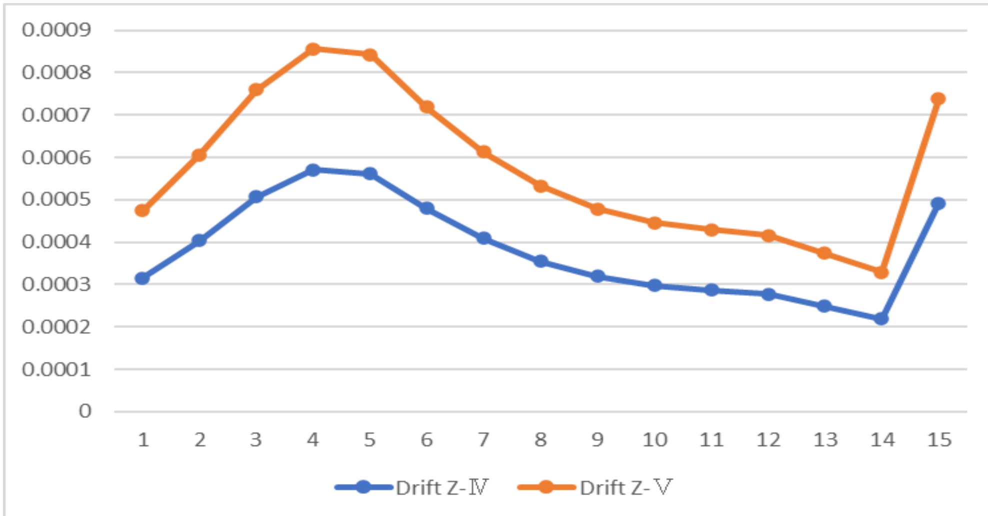

Table-06 story drift UFL min in X-direction for Z-IV and Z-V

story	load cases	Direction	Drift Z-4	Drift Z-5
Story15	U F L Min	X	5.50E-05	0
Story14	U F L Min	X	2.80E-05	3.10E-05
Story9	U F L Min	X	0	2.70E-05
Story8	U F L Min	X	0	2.10E-05
Story2	U F L Min	X	4.60E-05	5.80E-05
Story1	U F L Min	X	9.20E-05	0.000122

Fig-14 Comparison of UFL min drift in Z-IV and Z-V in X-direction

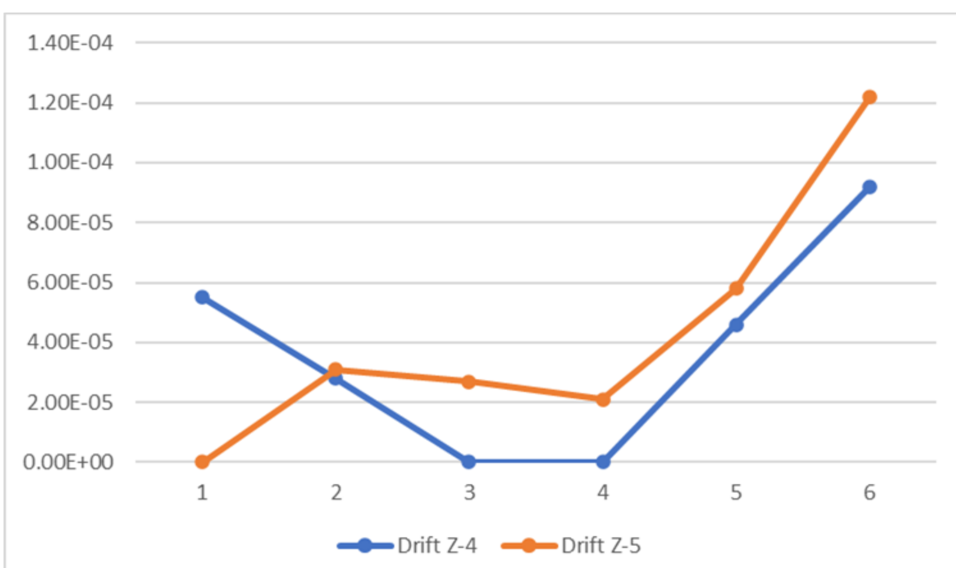

Table-07 story drift UFL min in Y-direction for Z-IV and Z-V

Story	Load Case	Direction	Drift Z-4	Drift Z-5
Story15	U F L Min	Y	0.000124	0.000135
Story14	U F L Min	Y	3.40E-05	3.40E-05
Story13	U F L Min	Y	7.40E-05	7.50E-05
Story12	U F L Min	Y	0.000175	0.000176
Story11	U F L Min	Y	0.000219	0.00022
Story10	U F L Min	Y	0.000166	0.000167
Story9	U F L Min	Y	9.90E-05	0.0001
Story8	U F L Min	Y	5.00E-05	5.20E-05
Story7	U F L Min	Y	2.90E-05	3.10E-05
Story6	U F L Min	Y	3.50E-05	3.70E-05
Story5	U F L Min	Y	6.90E-05	7.00E-05
Story4	U F L Min	Y	0.000128	0.000127
Story3	U F L Min	Y	0.000195	0.000193
Story2	U F L Min	Y	0.00021	0.000208
Story1	U F L Min	Y	0.000105	0

Fig-15 Comparison of UFL min drift in Z-IV and Z-V in Y-direction

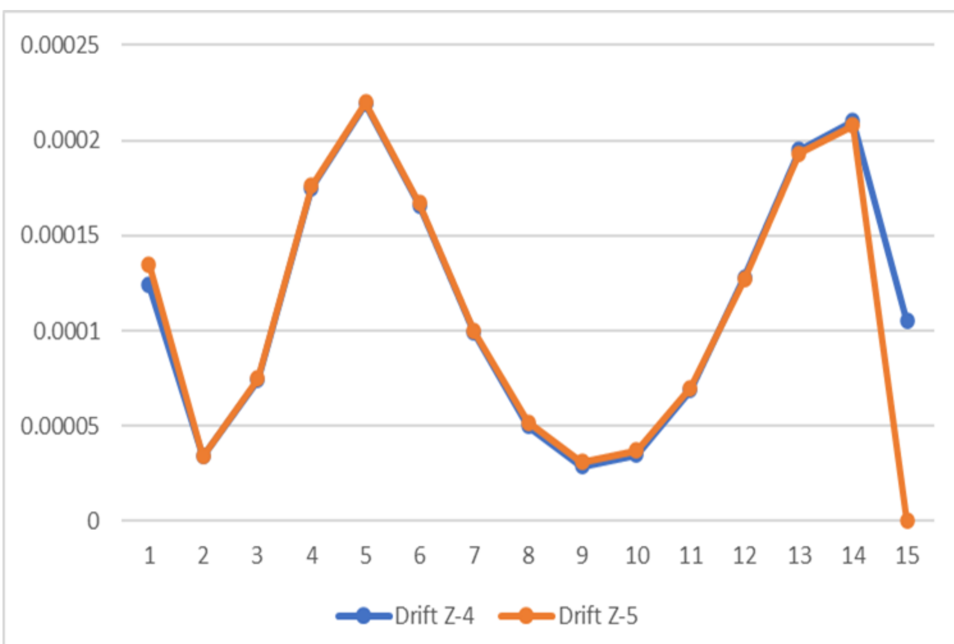

Fig-16 Maximum story displacement in Z-IV

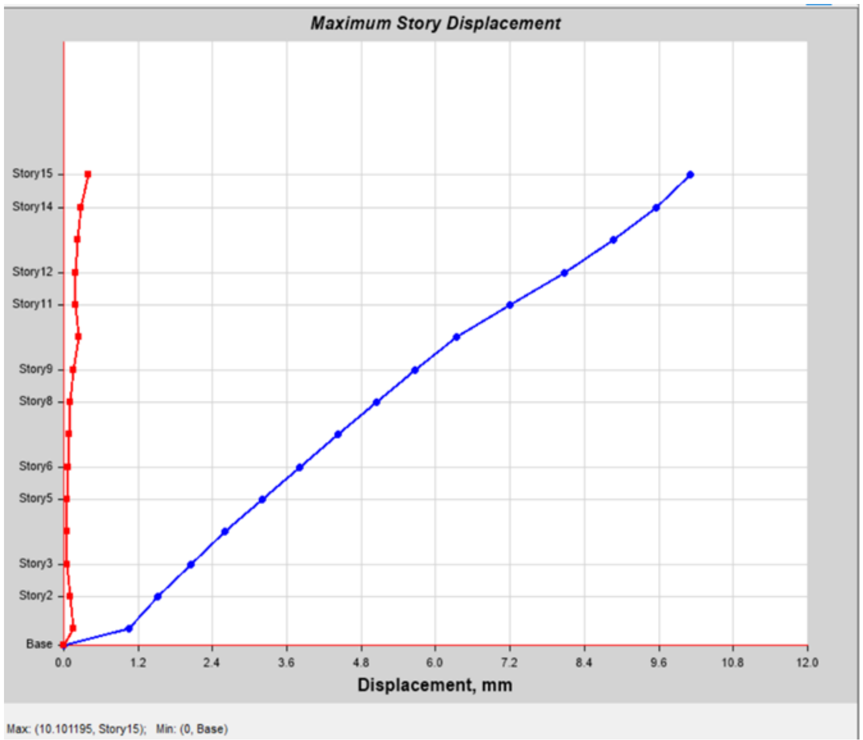

Fig-17 Maximum story displacement in Z-V

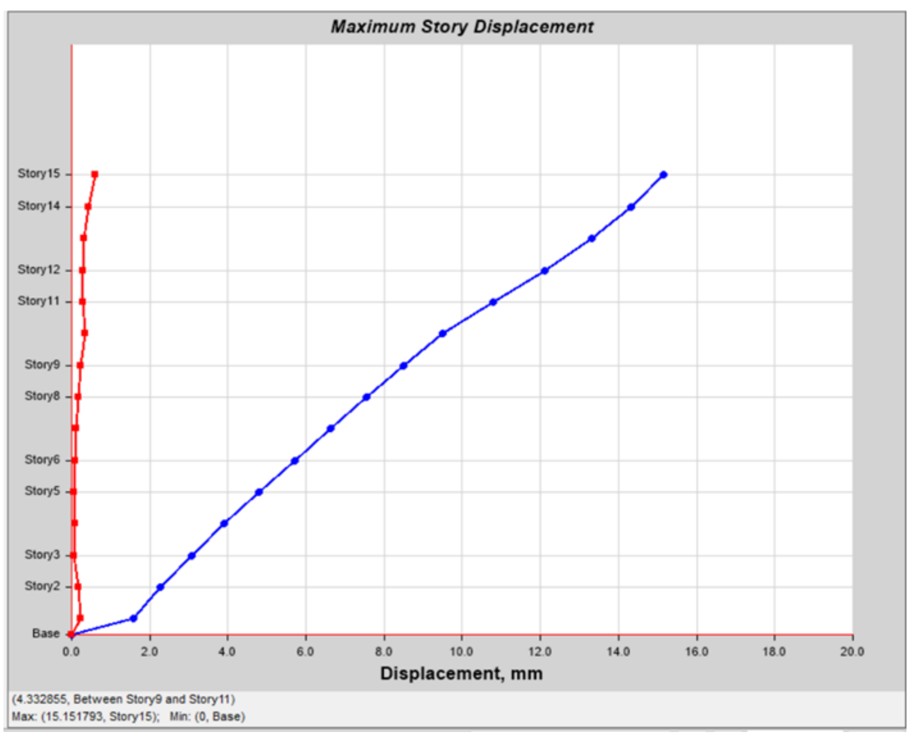

Table-10 Modal periods and frequencies

Case	Mode	Period sec	Frequency cyc/sec	Circular Frequency rad/sec	Eigenvalue rad^2/sec^2
Modal	1	0.358	2.791	17.5393	307.6278
Modal	2	0.328	3.048	19.1541	366.8777
Modal	3	0.273	3.663	23.017	529.783
Modal	4	0.248	4.026	25.2972	639.9469
Modal	5	0.23	4.357	27.3772	749.5091
Modal	6	0.222	4.509	28.3294	802.5562
Modal	7	0.182	5.493	34.5144	1191.242
Modal	8	0.156	6.398	40.2006	1616.088
Modal	9	0.149	6.69	42.0314	1766.6381
Modal	10	0.14	7.153	44.9411	2019.7067
Modal	11	0.136	7.365	46.2739	2141.2776
Modal	12	0.136	7.37	46.3042	2144.0791

6. CONCLUSION

A study on seismic analysis of Earthscraper structure which has total no. of 15-story of which 5-story is above ground level (GL) and 10-storey below ground level (GL). The seismic analysis is conducted for Zone-IV and Zone-V in Etabs software.

- The centre square opening of 9.492m (approximately 31ft) throughout the 15 story of which the walls are glazed for the light and ventilation purpose.
- The load combinations are utilized for the analysis of a structure in both cases X-direction and Y-direction. The demeanor of the Earthscraper is shown clearly in drift table and graph.
- It found that the maximum drift is in story-12 in Y-direction and in X-direction the maximum drift is in story-2 in Zone-IV.
- It found that the maximum drift is in story-11 in Y-direction and in X-direction the maximum drift is in story-1 in Zone-V.
- The maximum story forces are applied on 1st floor which is 42ft beneath the ground.
- The maximum natural time period is 0.358sec.
- The maximum story displacement is 10.10 in Zone-IV and 15.15 in Zone-V. Hence, the Zone-V has a maximum displacement.
- Based on the study analysis the Earthscraper or underground structure can be constructed with appropriate seismic deign within Zone-V.
- This earthscraper or underground structure can be utilized for commercial purpose or for any governmental functions purpose within Zone-V through the well-planned structural design.

7. REFERENCES

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