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Seismic Analysis of Elevated Water Tank

Nishigandha R.Patil[1], Dr. R. S. Talikoti[2]

[1.]PG Student, [2]Head Of Department, [1,2]Late G.N. Sapkal College Of Engineering Nashik,
Savitribai Phule Pune University, Maharastra, India

Abstract: **The tank is considered to be a single degree of freedom system with large mass concentrated at the top of tank. The behavior of tank under seismic loading is largely dependent on staging height. Seismic forces are dependent on staging height. In the present work effect of staging height on seismic behavior of water tank is studied. The tank with various staging height was modeled in finite element software ETABS. The spring mass model as suggested in IS 1893:2002 consisting of convective and impulsive masses was used for analysis. The parameters such as displacement, maximum forces in columns and base shear are compared for different staging height and presented.**

***Keywords*: Staging height, spring mass model, ETABS.**

1. INTRODUCTION

Water tank is considered to be an important structure and they should remain functional during earthquakes to overcome the water demand due to fire etc. Water tanks are different from buildings, in the sense that a huge mass of water is concentrated at top supported on slender staging. This can be treated as an inverted pendulum representing a single degree of freedom system. The fair understanding of the behavior of tank during seismic activity is necessary in order to evaluate the forces exerted due to earthquake. In case of elevated tank the resistance against lateral forces exerted by earthquake is largely dependent of supporting system. Staging is considered to be a critical element as far as lateral resistance is concern. Satisfactory performance of staging during strong ground shaking is crucial.

When partially filled with water, the tank is subjected to horizontal seismic acceleration and sloshing waves generates which exerts hydrodynamic forces on walls and base of tank. To calculate these hydrodynamic forces spring mass model suggested by IS 1893:2002 can be used. In case of elevated tank behavior of tank under hydrostatic and hydrodynamic forces is largely dependent on the staging configuration its height and stiffness.

2. METHODOLOGY

In the present study different staging height was adopted for the same water tank. The tank selected for study will be rectangular type. Tank is analyzed by using ETABS analysis package and performance with respect to displacement, base shear and maximum forces are presented. Seven different staging heights are selected for the study they are 6m, 9m, 12m, 18m, 21m and 24m. In all the seven models depth of foundation is kept same to keep our main focus on staging height.

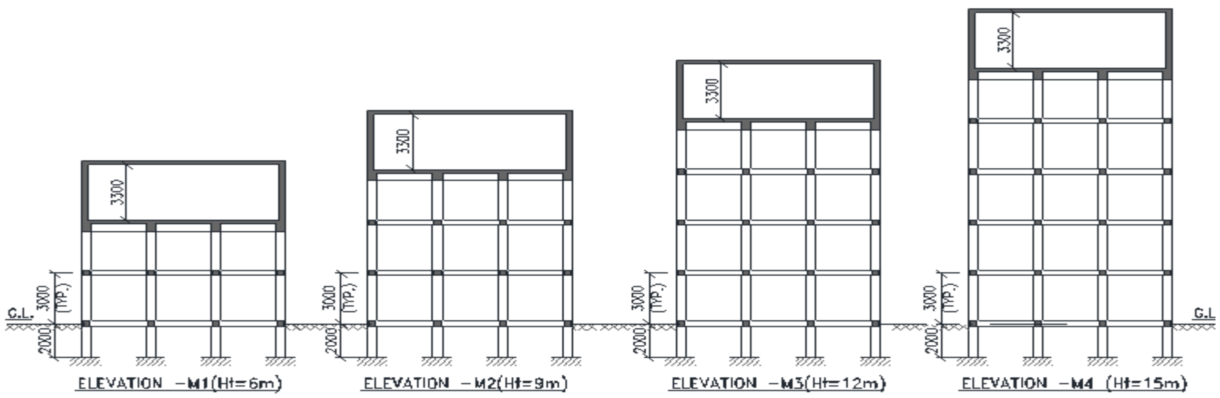

Figure 1: Elevation of Model M1 to M4

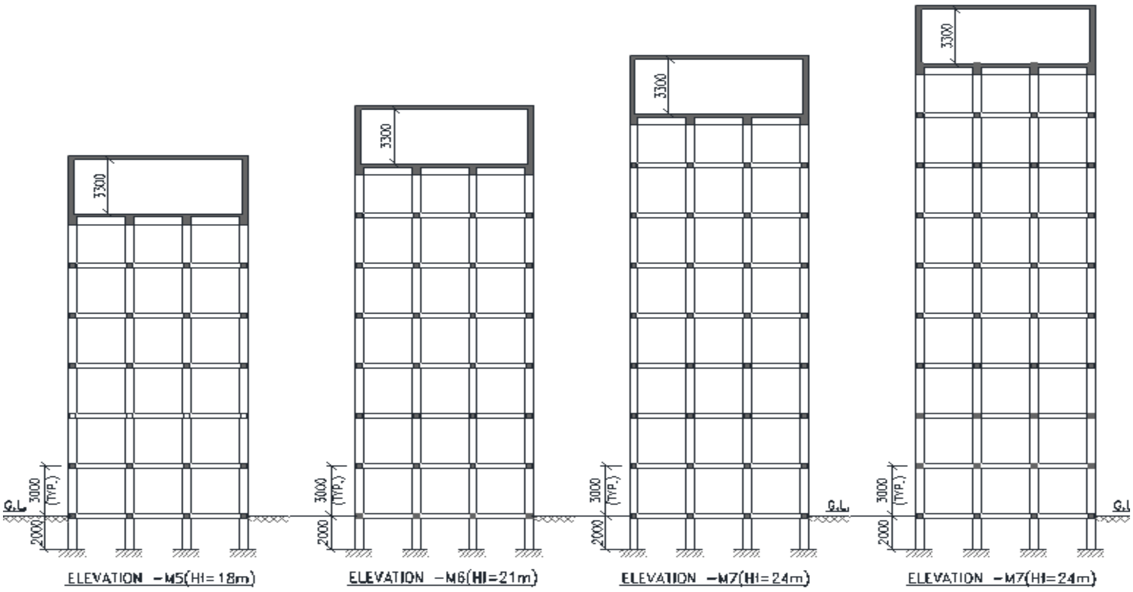

Figure 2: Elevation of Model M5 to M8

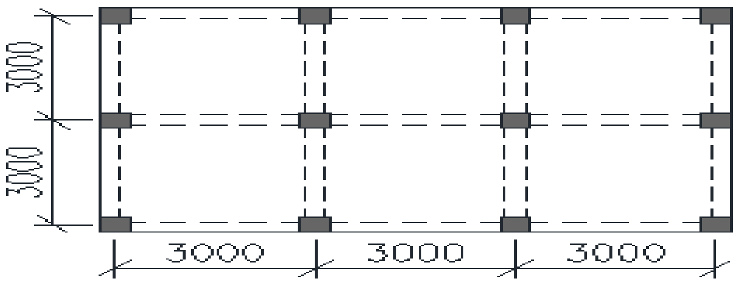

Figure 3: Plan of water tank (M1 to M8)

Table 1: Analysis data

Water Capacity (Approx.)	170m^3
Size of water tank	6m x9m
Clear height of container	3.3m
Zone	IV
Soil Type	Medium
Importance factor	1.5
Response reduction factor for SMRF	2.25
Response reduction factor for SMRF with bracing	3.0
Sizes of columns	450mm x 450mm
Sizes of beams at tank base	300 mm x 450mm
Size of tie beam	300mm x 300mm
Height of staging	12m
Ties provided at	3m c/c along height
Depth of foundation	2.0m
Thickness of wall	300 mm
Thickness of cover slab	300 mm
Thickness of base slab	200mm
Thickness of shear wall	200mm

3. ANALYSIS

Equivalent static analysis considering hydrodynamic effect and response spectra analysis was carried out on the above selected models. For static analysis seismic force calculation, lumping of masses and rigid link modeling procedure is exactly same as that described in case I of this chapter. Parameters of spring mass model are as per case I and lateral earthquake forces are summarized below the models as per IS 1893:2002 (Part I).Comparison between each of the following model is made based on analysis results and are presented in graphical format.

Table 2: Weight of different components of water tank

Sr. No	Component	Weight (KN)							
		Model I	Model II	Model III	Model IV	Model V	ModelVI	ModelVII	ModelVIII
1	Cover slab	405	405	405	405	405	405	405	405
2	Tank Walls	798.75	798.75	798.75	798.75	798.75	798.75	798.75	798.75
4	Floor Slab	270	270	270	270	270	270	270	270
5	Floor Beams	146.3	146.3	146.3	146.3	146.3	146.3	146.3	146.3
6	Columns	486	668.25	850.5	1032.75	1215	1397.2	1579.5	1761.7
7	Tie Beams	195.05	292.61	390.15	487.68	585.22	682.72	780.3	877.83
9	Water	1523.6	1523.6	1523.6	1523.6	1523.6	1523.6	1523.6	1523.6
10	Wt. of staging	681.05	960.86	1240.6	1520.43	1800.2	2079.9	2359.8	2639.5
11	Wt. of Empty container	1620	1620	1620	1620	1620	1620	1620	1620
12	Wt. of Container +1/3 staging	1847.0	1940.2	2033.5	2126.81	2220.0	2313.3	2406.6	2499.8

Table 3: Lateral seismic forces

Total Force	M1	M2	M3	M4	M5	M6	M7	M8
FX (KN)	503.31	454.28	414.94	359.88	326.85	303.72	285.03	279.1
FY (KN)	563.73	477.69	385.79	355.71	326.45	305.31	286.3	267.06

4. RESULTS AND DISCUSSION

Displacements and Base shear:

Displacement and base shear for static analysis is presented in figure It is observed that base shear decreases as height of staging increases this means that the earthquake force is inversely proportional to height of staging. The displacement profile for both the direction is show in figure The displacement increases with the increase in staging height this effect is seen up to certain height (Model M7 height = 24m) after that displacement remains roughly constant.

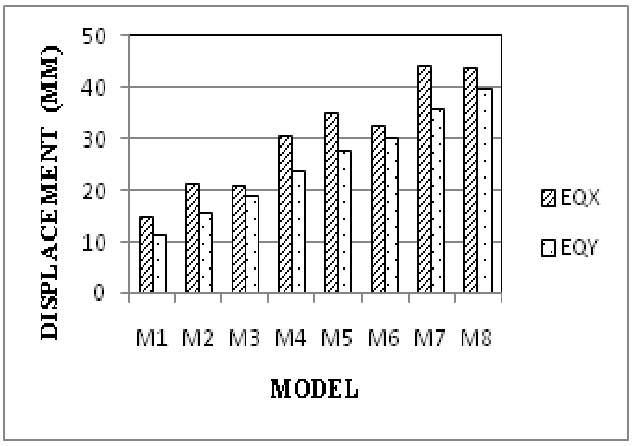

Figure 4: Lateral displacement

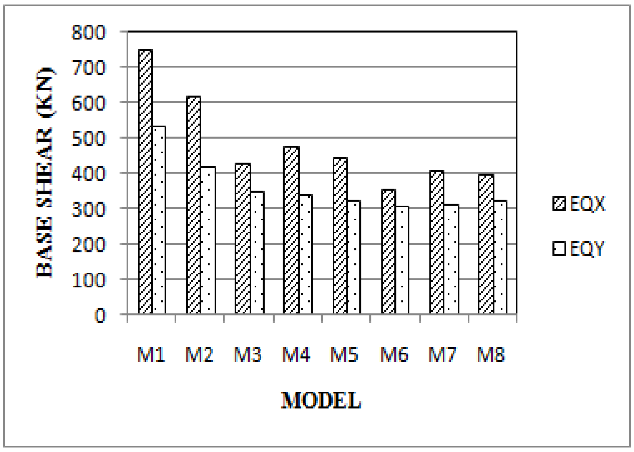

Figure 5: Base shear

Maximum Column forces:

Maximum forces for column are calculated and presented in figure . It is observed that the maximum bending moment in column C1 and C2 in both the principal direction decreases as height of staging increases. This decrease in moments was observed up to the height of 21m and thereafter these forces will remain same. This study was performed by increasing the height of staging in the equal steps of 3m each so the height of 21m reflect ratio of height to width of around 21/9= 2.333. Hence it is observed that up to the ratio of 2 to 2.5 the forces in columns reduces and then it become constant. This may be because as the height increases the columns become slender and their share in resisting lateral forces will be less due to reduced lateral stiffness. However it should be noted that this is only for the lateral load case and will not include any gravity load.

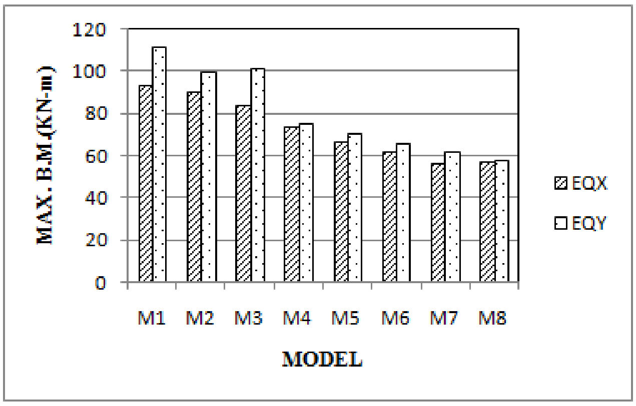

Figure 5: Maximum bending moment in C1

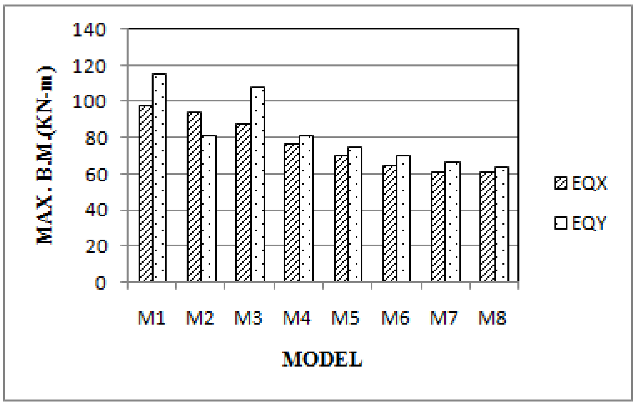

Figure 6: Maximum bending moment in C2

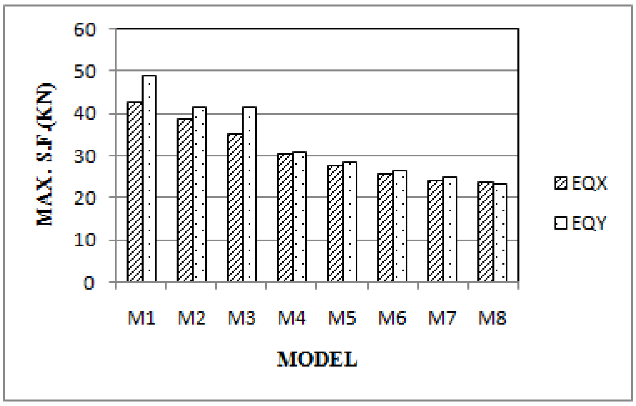

Figure 5: Maximum Shear force in C1

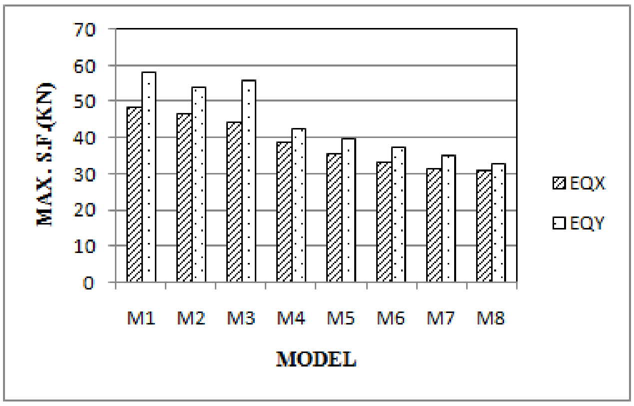

Figure 6: Maximum shear force in C2

Table 4: Time period of vibration

Mode	M1	M2	M3	M4	M5	M6	M7	M8
1	0.772	1.043	1.349	1.494	1.705	1.995	2.08	2.278
2	0.539	0.729	0.966	1.055	1.201	1.417	1.48	1.616
3	0.383	0.518	0.625	0.75	0.855	0.948	1.055	1.152
4	0.065	0.103	0.149	0.197	0.249	0.302	0.351	0.406
5	0.062	0.099	0.14	0.187	0.233	0.275	0.326	0.372
6	0.058	0.088	0.125	0.163	0.201	0.239	0.276	0.311
7	0.054	0.079	0.1	0.114	0.123	0.136	0.161	0.188
8	0.052	0.073	0.088	0.099	0.111	0.129	0.155	0.179
9	0.05	0.072	0.075	0.097	0.107	0.128	0.139	0.159
10	0.047	0.063	0.072	0.086	0.103	0.118	0.133	0.135
11	0.046	0.059	0.066	0.083	0.096	0.106	0.119	0.116
12	0.032	0.045	0.064	0.076	0.094	0.095	0.109	0.113

5. CONCLUSION

Earthquake forces decreases with increase in staging height because as staging height increases the structure become more flexible. Therefore time period increases due to which structural response factor decreases from lower to higher staging height. Maximum column forces will reduces as staging height increases up to a width to height ratio of 2 to 2.5 after that the forces are stable.

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