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Analysis of Elevated Water Storage Structure Using Different Staging System

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Abstract: *Elevated tanks are structures of high importance which are considered as the main lifeline elements. i.e. operation during and after earthquakes. Many researchers have worked on the behavior, analysis, and seismic design of tanks, particularly ground tanks, while only a few of these researchers have concerned with the reinforced concrete elevated tanks. From the very upsetting experiences of few earthquakes, like Bhuj earthquake (2001) in India R.C.C elevated water tanks were heavily damaged or collapsed. This might be due to the lack of knowledge regarding the proper behavior of supporting system of the tank due to the dynamic effect and also due to improper geometrical selection of staging. The aim of this study is to understand the behavior of different staging, under different loading conditions and strengthening the conventional type of staging, to give better performance during earthquake. Equivalent Static Analysis, for eleven different types of bracing systems, applied to the staging of elevated circular water tank in all zones, is carried out using STAAD Pro. Comparison of base shear and nodal displacements of the container of circular water tank for empty, half-filled and full condition is done. Thirteen models are used for calculating base shear and nodal displacements for staging. After calculating base shear and nodal displacements of thirteen models for empty , half filled & full condition. Thirteen different type of bracing systems have been analyzed.*

Keywords: *elevated water tank, staging, bracing, earthquake effect, Base Shear, Nodal Displacement*

I. Introduction

Water is human's basic need for life. Sufficient water distribution depends on design of a water tank in certain area. An elevated water tank is a large water storage container constructed for the purpose of holding water supply at certain height to pressurize the water distribution system.. A large number of overhead water tanks damaged during past earthquake. Majority of them were shaft staging while a few were on frame staging type elevated water tanks consist of huge water mass at the top of a slender staging which are most critical consideration for the failure of the tank during earthquakes. Elevated water tanks are critical and strategic structures and damage of these structures during earthquakes may endanger drinking water supply, cause to fail in preventing large fires and substantial economic loss. Since, the elevated tanks are frequently used in seismic active regions also hence, seismic behavior of them has to be investigated in detail .Due to the lack of knowledge of supporting system some of the water tank were collapsed or heavily damaged. So there is need to focus on seismic safety of lifeline structure using with respect to alternate supporting system which are safe during earthquake and also take more design forces.Design of new tanks and safety evaluation of existing tanks should be carried out with a high level of accuracy because the failure of such structures, particularly during an earthquake, may be disastrous. Hydrodynamic pressures on tanks under earthquake forces play an important role in the design of the tank. Earthquake can induce large horizontal and overturning forces in elevated water tanks. Such tanks are quite vulnerable to damage in earthquakes due to their basic configuration involving large mass concentrated at top with relatively slender supporting system. When the tank is in full condition, earthquake forces almost govern the design of these structures in zones of high seismic activity. It is important to ensure that the essential requirement such as water supply is not damaged during earthquakes. In extreme cases, total collapse of tanks shall be avoided. However, some repairable damage may be acceptable during shaking not affecting the functionality of the tanks. Severe damages were observed in buildings, public utility structures like water tanks and hospitals during 26th January 2001 Bhuj earthquake.

Lots of research has been made in two mass model of elevated service reservoir and hydrodynamic analysis of the container. It has also been observed that a well-designed and well-constructed water tank**.** Elevated liquid tanks and particularly the elevated water tanks are considered as an important city services in the many flat areas, and accordingly, their serviceability performance during and after strong earthquakes is of crucial concern. The failure of these structures may cause some hazards for the health of the citizens due to the

shortage of water or difficulty in putting out fire during the earthquake time. Although many studies have been done on analysis and design of ground water tanks in the past decade, only a few studies have been conducted on the elevated water tanks. The performance of elevated water tanks during earthquakes is of much interest to engineers, not only because of the importance of these tanks in controlling fires, but also because the simple structure of an elevated tank is relatively easy to analyze and, hence, the study of tanks can be informative as to the behavior of structures during earthquakes.

II. Objective of the study

1. Calculate base shear of water tank using different type of bracing in staging.
2. Compare between base shear and nodal displacement between water tanks with different staging system.
3. Comparison of base shear and displacement for different tank condition.

III. Types of bracing system used

Models are used for calculating base shear and nodal displacements for staging without diagonal bracing, staging with cross bracing , staging with chevron bracing , staging with diagonal bracing , staging with k-type bracing , staging with v-type bracing and alternate cross bracing in staging , alternate chevron bracing in staging , alternate k-type bracing in staging , alternate v-type bracing in staging., alternate diagonal bracing in staging, alternate diagonal bracing in both direction, alternate cross bracing in both direction.

IV. STAAD pro.v8i

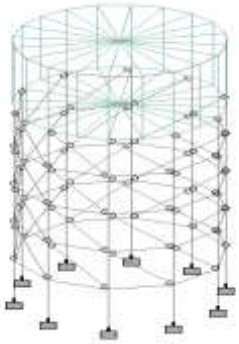
STAAD.Pro.v8i is the most popular structural engineering software product for 3D model generation, analysis and multi-material design. It has an intuitive, user-friendly GUI, visualization tools, powerful analysis and design facilities and seamless integration to several other modeling and design software products. For static or dynamic analysis of bridges, containment structures, embedded structures (tunnels and culverts), pipe racks, steel, concrete, aluminum or timber buildings, transmission towers, stadiums or any other simple or complex structure, STAAD.Pro has been the choice of design professionals around the world for their specific analysis needs.

Parameters of elevated water tank

SN	Parameters	values
(1)	(2)	(3)
1	Size of top slab	100 mm thick
2	Size of bottom slab	150 mm
3	Size of top ring beam	250mm x350 mm
4	Size of bottom ring beam	250mm x500 mm
5	Size of column	500mm x250 mm
6	Size of braces	500mm x250 mm
7	Density of concrete	25 KN/m^3
8	Diameter of tank	10 m
9	Height of tank	5 m
10	Height of staging	15 m
11	Number of columns	10
12	Earthquake Zone (Z)	IV(0.24)
13	Response reduction factor(R)	5 (SMRF)
14	Importance factor	1.5 (for water tank)
15	Type of soil	hard soil

Sample Model

Staging with diagonal bracing



STAAD pro model of bracing with diagonal bracing

V. Results

Base shear of different bracing system

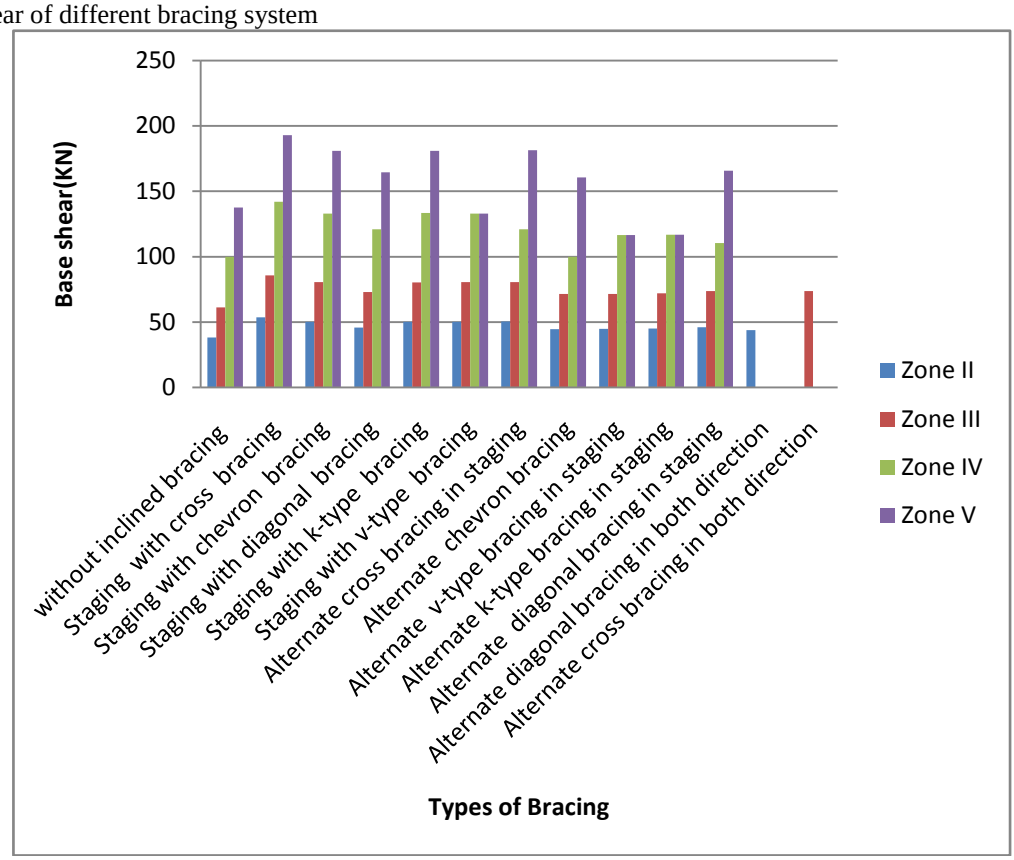


Figure5.1:Bar chart of base shear for different bracing system for empty condition of tank.

Table no 5.1: Base shear of different bracing system for empty tank condition

SN	Types of Bracing	Base shear (KN)			
		Zone II	Zone III	Zone IV	Zone V
1	without inclined bracing	38.239	61.183	99.994	137.668
2	Staging with cross bracing	53.602	85.767	141.922	192.976
3	Staging with chevron bracing	50.287	80.458	132.934	181.033
4	Staging with diagonal bracing	45.677	73.084	120.96	164.436
5	Staging with k-type bracing	50.235	80.378	133.436	180.848
6	Staging with v-type bracing	50.301	80.477	132.934	132.934
7	Alternate cross bracing in staging	50.4	80.64	120.96	181.438
8	Alternate chevron bracing	44.629	71.406	99.994	160.665
9	Alternate v-type bracing in staging	44.715	71.544	116.464	116.464
10	Alternate k-type bracing in staging	45.014	72.018	116.716	116.716
11	Alternate diagonal bracing in staging	46.031	73.651	110.476	165.714
12	Alternate diagonal bracing in both direction	43.847			
13	Alternate cross bracing in both direction		73.651		

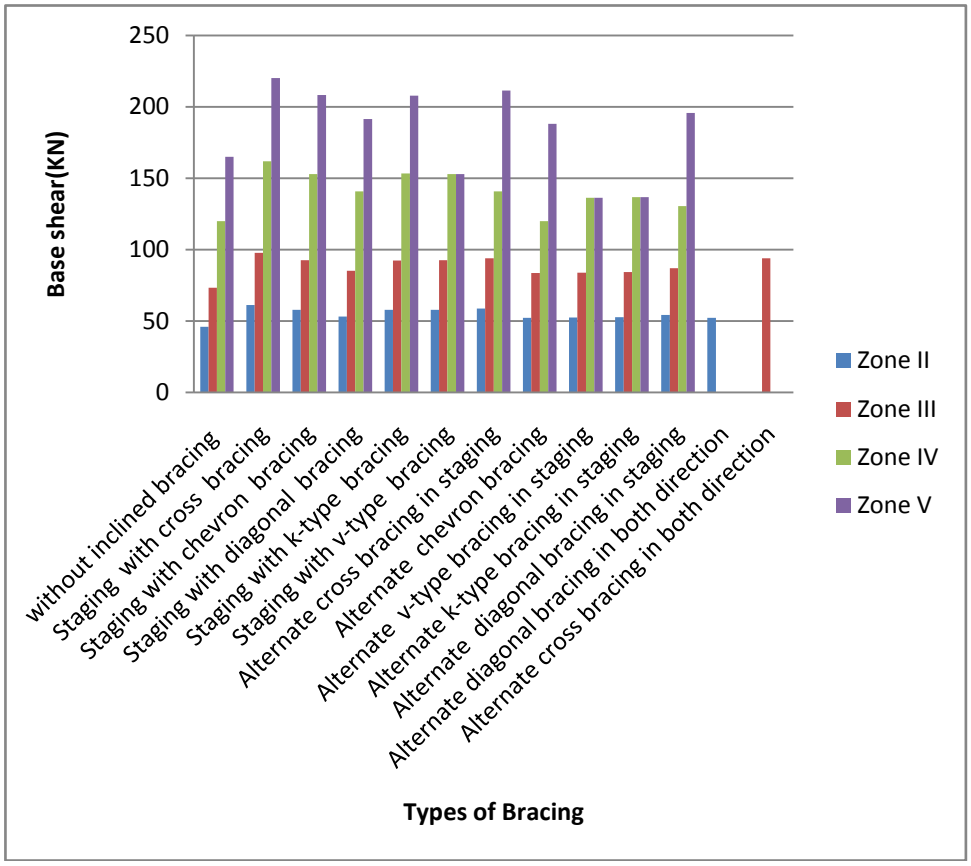


Figure5.2:Bar chart of base shear for different bracing system for half condition of tank.

Table no 5.2:Base shear of different bracing system for half tank condition

SN	Types of Bracing	Base shear (KN)			
		Zone II	Zone III	Zone IV	Zone V
1	without inclined bracing	45.872	73.392	119.942	165.134
2	Staging with cross bracing	61.141	97.823	161.878	220.107
3	Staging with chevron bracing	57.833	92.537	152.882	208.205
4	Staging with diagonal bracing	53.208	85.137	140.91	191.557
5	Staging with k-type bracing	57.748	92.395	153.386	207.887
6	Staging with v-type bracing	57.848	92.554	152.88	152.88
7	Alternate cross bracing in staging	58.712	93.94	140.91	211.365
8	Alternate chevron bracing	52.272	83.638	119.942	188.182
9	Alternate v-type bracing in staging	52.373	83.797	136.416	136.416
10	Alternate k-type bracing in staging	52.705	84.327	136.665	136.665
11	Alternate diagonal bracing in staging	54.345	86.95	130.426	195.642
12	Alternate diagonal bracing in both direction	52.158			
13	Alternate cross bracing in both direction		93.94		

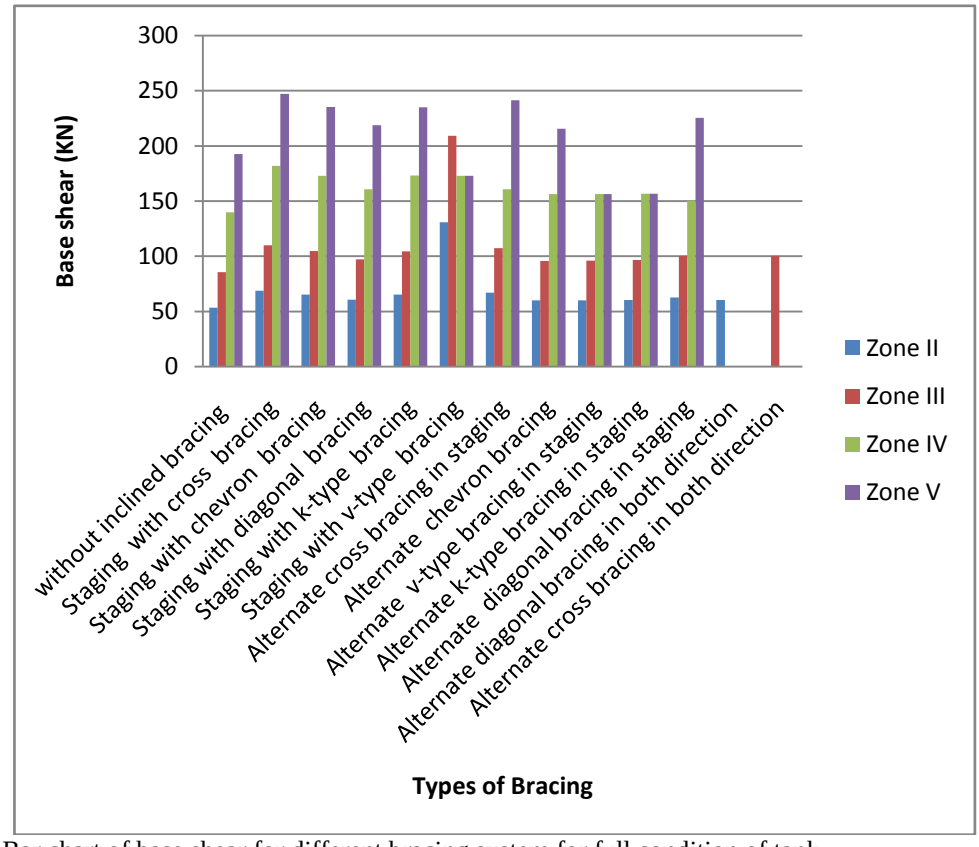


Figure5.3:Bar chart of base shear for different bracing system for full condition of tank.

Table no 5.3:Base shear of different bracing system for full tank condition

SN	Types of Bracing	Base shear (KN)			
		Zone II	Zone III	Zone IV	Zone V
1	without inclined bracing	53.503	85.602	139.894	192.603
2	Staging with cross bracing	68.675	109.883	181.826	247.238
3	Staging with chevron bracing	65.382	104.609	172.834	235.378
4	Staging with diagonal bracing	60.743	97.19	160.86	218.676
5	Staging with k-type bracing	65.256	104.411	173.338	234.927
6	Staging with v-type bracing	130.792	209.273	172.832	172.832
7	Alternate cross bracing in staging	67.026	107.24	160.86	241.288
8	Alternate chevron bracing	59.915	95.866	156.364	215.699
9	Alternate v-type bracing in staging	60.032	96.052	156.367	156.367
10	Alternate k-type bracing in staging	60.398	96.639	156.615	156.615
11	Alternate diagonal bracing in staging	62.659	100.252	150.375	225.567
12	Alternate diagonal bracing in both direction	60.474			
13	Alternate cross bracing in both direction		100.252		

Displacement of different bracing system

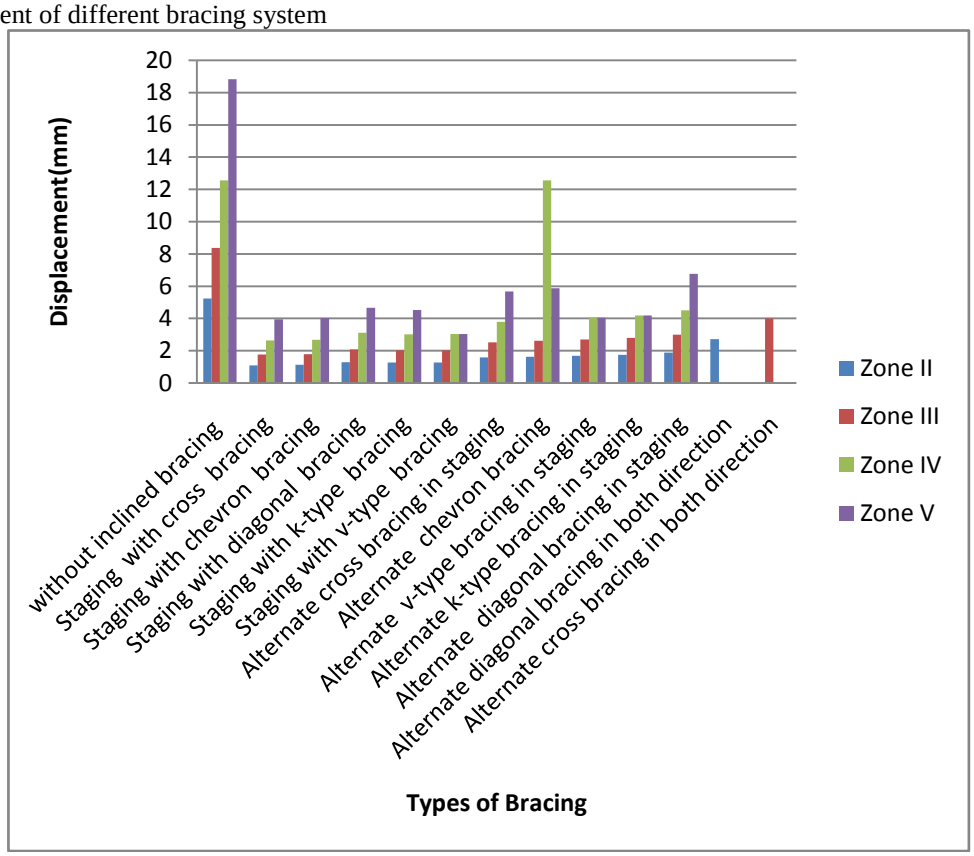


Figure5.4: Bar chart of displacement of node 71 for different bracing system for empty condition of tank in X direction.

Table no 5.4.: Displacement of node 71 for different bracing system for empty tank condition in X direction.

SN	Types of Bracing	Displacement (mm)			
		Zone II	Zone III	Zone IV	Zone V
1	without inclined bracing	5.234	8.372	12.557	18.833
2	Staging with cross bracing	1.101	1.758	2.635	3.95
3	Staging with chevron bracing	1.123	1.794	2.688	4.03
4	Staging with diagonal bracing	1.298	2.074	3.109	4.662
5	Staging with k-type bracing	1.26	2.014	3.019	4.526
6	Staging with v-type bracing	1.263	2.019	3.026	3.026
7	Alternate cross bracing in staging	1.581	2.526	3.788	5.679
8	Alternate chevron bracing	1.633	2.61	12.557	5.867
9	Alternate v-type bracing in staging	1.688	2.698	4.045	4.045
10	Alternate k-type bracing in staging	1.744	2.789	4.182	4.182
11	Alternate diagonal bracing in staging	1.878	3.005	4.507	6.761
12	Alternate diagonal bracing in both direction	2.72			
13	Alternate cross bracing in both direction		4.008		

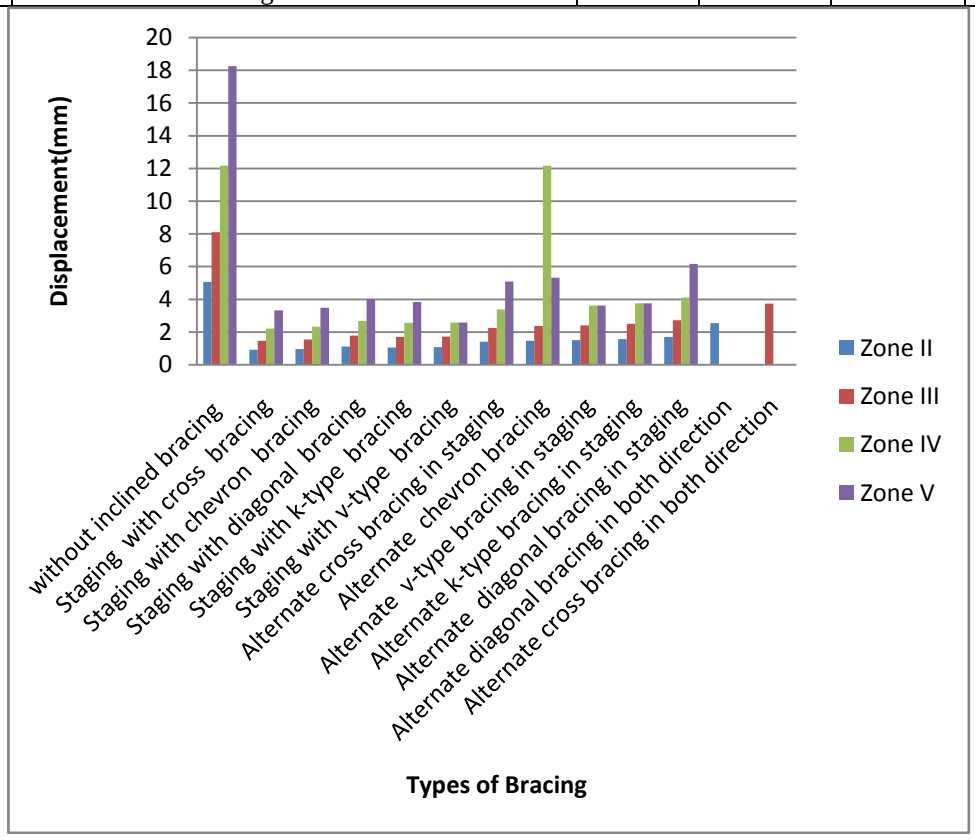


Figure5.5: Bar chart of displacement of node 51 for different bracing system for empty condition of tank in X direction.

Table no 5.5: Displacement of node 51 for different bracing system for empty tank condition for node no 51 in X direction.

SN	Types of Bracing	Displacement (mm)			
		Zone II	Zone III	Zone IV	Zone V
1	without inclined bracing	5.065	8.11	12.17	18.26
2	Staging with cross bracing	0.912	1.469	2.212	3.327
3	Staging with chevron bracing	0.96	1.542	2.32	3.485
4	Staging with diagonal bracing	1.11	1.781	2.677	4.02
5	Staging with k-type bracing	1.059	1.7	2.555	3.837
6	Staging with v-type bracing	1.067	1.714	2.576	2.576
7	Alternate cross bracing in staging	1.401	2.25	3.381	5.079
8	Alternate chevron bracing	1.472	2.362	12.17	5.327
9	Alternate v-type bracing in staging	1.501	2.408	3.617	3.617
10	Alternate k-type bracing in staging	1.56	2.502	3.759	3.759
11	Alternate diagonal bracing in staging	1.701	2.729	4.101	6.158
12	Alternate diagonal bracing in both direction	2.545			
13	Alternate cross bracing in both direction		3.737		

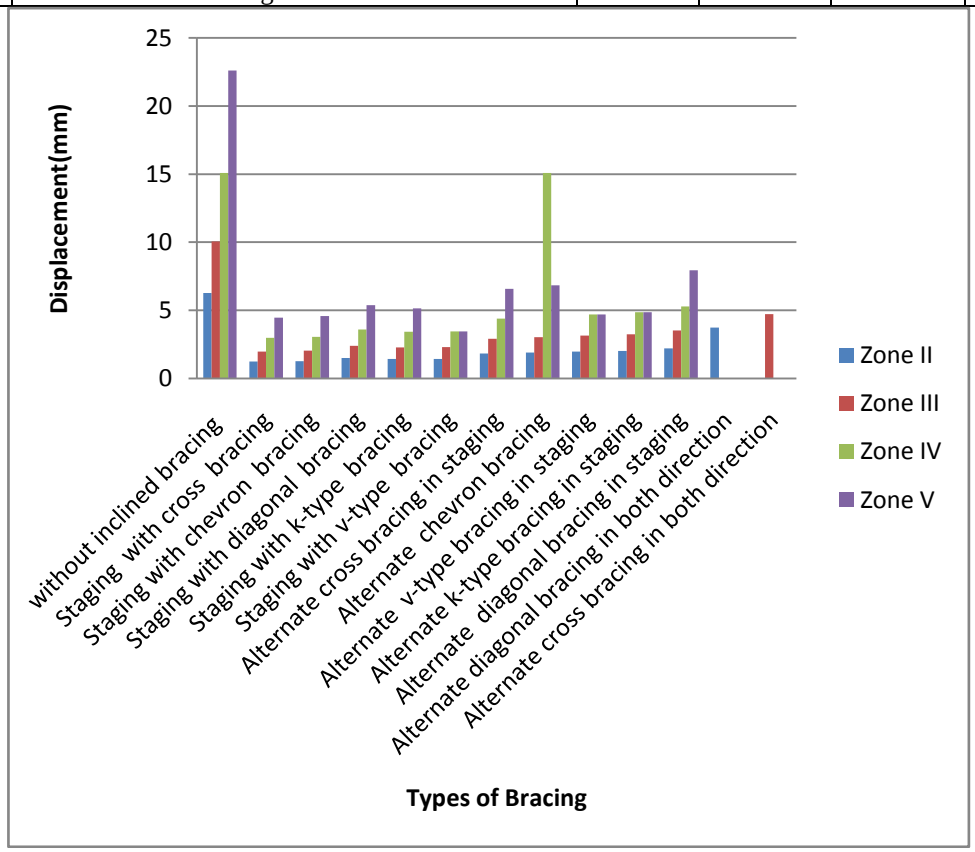


Figure5.6: Bar chart of displacement of node 71 for different bracing system for half condition of tank in X direction.

Table no 5.6: Displacement of node 71 for different bracing system for half tank condition for node no 71 in X direction.

SN	Types of Bracing	Base shear (KN)			
		Zone II	Zone III	Zone IV	Zone V
1	without inclined bracing	6.284	10.051	15.075	22.611
2	Staging with cross bracing	1.241	1.983	2.973	4.457
3	Staging with chevron bracing	1.279	2.043	3.063	4.592
4	Staging with diagonal bracing	1.496	2.391	3.585	5.375
5	Staging with k-type bracing	1.433	2.29	3.433	5.148
6	Staging with v-type bracing	1.438	2.298	3.445	3.445
7	Alternate cross bracing in staging	1.828	2.923	4.383	6.572
8	Alternate chevron bracing	1.902	3.041	15.075	6.836
9	Alternate v-type bracing in staging	1.962	3.138	4.705	4.705
10	Alternate k-type bracing in staging	2.029	3.245	4.866	4.866
11	Alternate diagonal bracing in staging	2.205	3.528	5.291	7.937
12	Alternate diagonal bracing in both direction	3.746			
13	Alternate cross bracing in both direction		4.727		

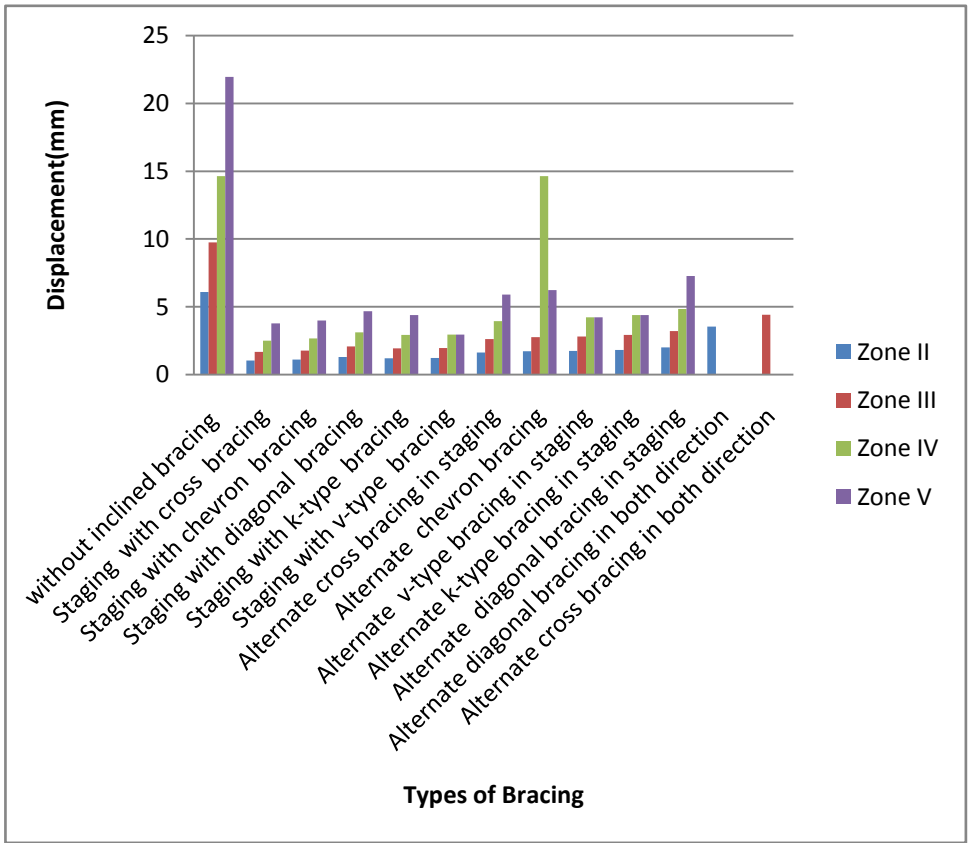


Figure5.7: Bar chart of displacement of node 51 for different bracing system for half condition of tank in X direction.

Table no 5.7: Displacement of node 51 for different bracing system for half tank condition in X direction.

SN	Types of Bracing	Base shear (KN)			
		Zone II	Zone III	Zone IV	Zone V

1	without inclined bracing	6.094	9.756	14.638	21.962
2	Staging with cross bracing	1.037	1.669	2.513	3.778
3	Staging with chevron bracing	1.101	1.769	2.659	3.995
4	Staging with diagonal bracing	1.288	2.067	3.106	4.664
5	Staging with k-type bracing	1.213	1.946	2.924	4.391
6	Staging with v-type bracing	1.223	1.962	2.949	2.949
7	Alternate cross bracing in staging	1.631	2.618	3.933	5.907
8	Alternate chevron bracing	1.725	2.766	14.638	6.237
9	Alternate v-type bracing in staging	1.756	2.815	4.228	4.228
10	Alternate k-type bracing in staging	1.825	2.927	4.396	4.396
11	Alternate diagonal bracing in staging	2.008	3.22	4.837	7.263
12	Alternate diagonal bracing in both direction	3.53			
13	Alternate cross bracing in both direction		4.426		

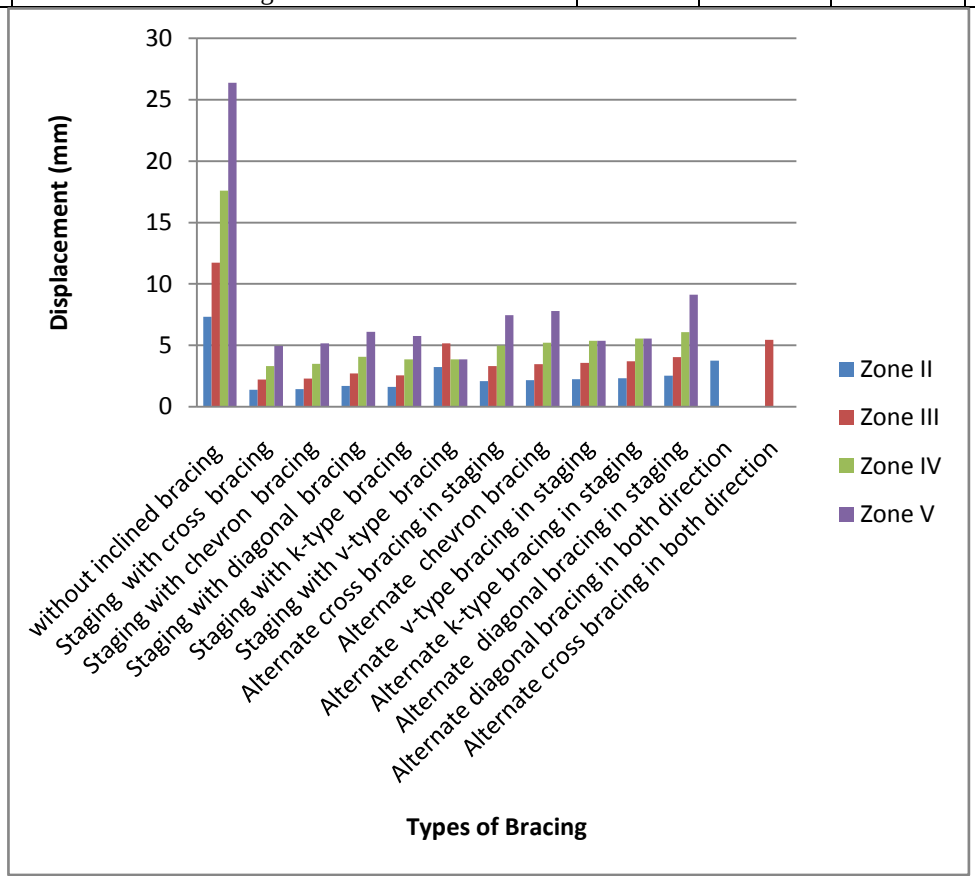


Figure5.8: Bar chart of displacement of node 71 for different bracing system for full condition of tank in X direction.

Table no 5.8: Displacement of node 71 for different bracing system for full tank condition in X direction.

SN	Types of Bracing	Base shear (KN)			
		Zone II	Zone III	Zone IV	Zone V

1	without inclined bracing	7.333	11.73	17.594	26.389
2	Staging with cross bracing	1.382	2.209	3.311	4.965
3	Staging with chevron bracing	1.435	2.293	3.48	5.154
4	Staging with diagonal bracing	1.694	2.708	4.06	6.088
5	Staging with k-type bracing	1.606	2.567	3.848	5.771
6	Staging with v-type bracing	3.222	5.152	3.865	3.865
7	Alternate cross bracing in staging	2.077	3.32	4.978	7.465
8	Alternate chevron bracing	2.171	3.471	5.205	7.805
9	Alternate v-type bracing in staging	2.238	3.578	5.365	5.365
10	Alternate k-type bracing in staging	2.314	3.701	5.551	5.551
11	Alternate diagonal bracing in staging	2.532	4.05	6.075	9.113
12	Alternate diagonal bracing in both direction	3.746			
13	Alternate cross bracing in both direction		5.447		

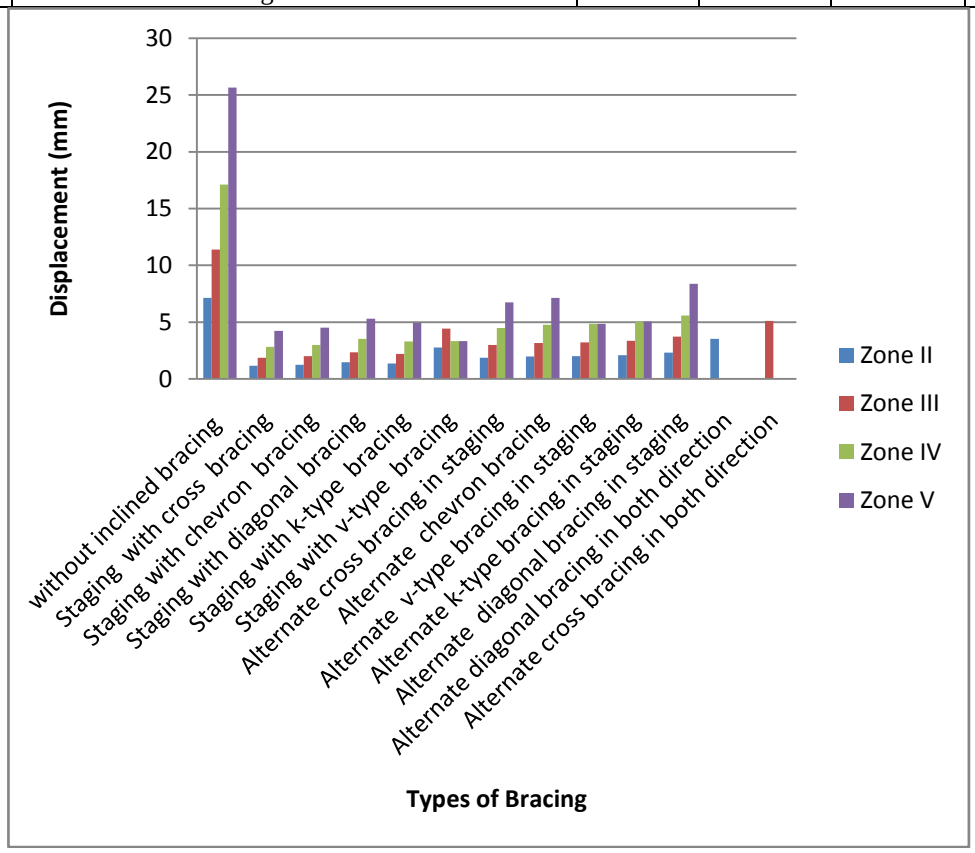


Figure5.9: Bar chart of displacement of node 51 for different bracing system for full condition of tank in X direction.

Table no 5.9: Displacement of node 51 for different bracing system for full tank condition for node no 51 in X direction.

SN	Types of Bracing	Base shear (KN)			
		Zone II	Zone III	Zone IV	Zone V

1	without inclined bracing	7.122	11.401	17.107	25.665
2	Staging with cross bracing	1.162	1.87	2.814	4.229
3	Staging with chevron bracing	1.243	1.996	2.999	4.505
4	Staging with diagonal bracing	1.467	2.353	3.535	5.307
5	Staging with k-type bracing	1.367	2.193	3.294	4.946
6	Staging with v-type bracing	2.767	4.434	3.323	3.323
7	Alternate cross bracing in staging	1.861	2.986	4.486	6.736
8	Alternate chevron bracing	1.977	3.17	4.761	7.147
9	Alternate v-type bracing in staging	2.01	3.223	4.839	4.839
10	Alternate k-type bracing in staging	2.091	3.352	5.033	5.033
11	Alternate diagonal bracing in staging	2.315	3.711	5.574	8.368
12	Alternate diagonal bracing in both direction	3.53			
13	Alternate cross bracing in both direction		5.114		

VI. Conclusion

In this paper, base shear and nodal displacement of elevated water tank calculated by using STAAD Pro V8i. This gives more accurate values of base shear and nodal displacement as compare to manual method. The table shows displacement values of top node(71) and bottom node(51) of container of tank, Though Hence we conclude that the permissible value is observed for alternate diagonal bracing in both direction in zone II. Similarly for zone III, zone IV and zone V are alternate cross bracing in both direction , alternate cross bracing and alternate v type bracing in staging respectively.

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