Analysis of Vibration Control in Elevated Storage Reservoir Using Different types of Bracing Patterns

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CHAPTER 1s
INTRODUCTION

1.1: General

Water is human basic needs for daily 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 pressurization the water distribution system. Many new ideas and innovation has been made for the storage of water and other liquid materials in different forms and fashions. There are many different ways for the storage of liquid such as underground, ground supported, elevated etc. Liquid storage tanks are used extensively by municipalities and industries for storing water, inflammable liquids and other chemicals. Thus Water tanks are very important for public utility and for industrial structure. Water tanks are very important components of lifeline. They are critical elements in municipal water supply, firefighting systems and in many industrial facilities for storage of water. In general, there are three kinds of water tanks resting on ground, underground tanks and elevated tanks. The tanks resting on ground like clear water reservoirs, settling tanks, aeration tanks etc. are supported on the ground directly. The walls of these tanks are subjected to pressure and the base is subjected to weight of water and pressure of soil. The tanks may be covered on top. From design point of view, the tanks may be classified as per their shape rectangular tanks, Circular tanks, intze type tanks, spherical tanks conical bottom tanks and suspended bottom tanks. Rectangular tanks are provided when small capacity tanks are required. For small capacities circular tanks prove uneconomical as the formwork for circular tanks is very costly. The rectangular tanks should be preferably square in plan from point of view of economy. It is desirable that longer side should not be greater than twice the smaller side. The liquid storage tanks are particularly subjected to the risk of damage due to earthquake-induced vibrations. 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 behaviour 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 damages. 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 [2]. IS: 1893-1984 [17] does not count the convective hydrodynamic pressures in the analysis of tank wall and assumes the tank as a single degree of freedom idealization. The accurate approach for analysis of water tank is to model the tank with two masses representing the impulsive as well as convective components of liquid. Lots of research has been made in two mass model of ESR 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 golden time. Although many studies have been investigated 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 analyse and, hence, the study of tanks can be informative as to the behaviour of structures during earthquakes.

1.2: Damage Observed to Elevated Water Tanks in Bhuj Earthquake (2001)

Many elevated water tanks suffered damage to their staging (support structure) in the *Mw* 7.7Bhuj earthquake of January 26th, 2001[2] and at least three of them collapsed. These water tanks are located in the area of a radius of approximately 125km from the epicentre (USGS). The majority of these tanks are supported on cylindrical shaft type staging which developed circumferential flexural cracks near the base. These cracks pass through the thin section of the Staging and are clearly visible from inside too figure 1.1.RC framed staging's are not very common for elevated tanks in this part of the country. Most of the elevated water tanks undergo damage to their staging. Due to the lack of knowledge of supporting system some of the water tank were collapsed or heavily damages. 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. Hollow circular shaft is the most popular type of staging to support a tank container. Figure No.1.2. showing poor detailing of column-brace joints. The flexure cracks in staging's were observed from the level of the first lift to several lifts reaching one- third the height of the staging, as shown in figure 1.3.

These cracks are mostly in a circumferential direction and cover the entire perimeter of the shaft. They usually appear near the edges of the form used during casting of the shaft, which appear to form planes of weaknesses along the shaft's length. Hollow circular shaft is the most popular type of staging to support a tank container. The height of the shaft varied from a minimum of about 10m to a maximum of 20m whereas the shape and size of the tank container largely depended on the storage capacity and required head for the water supply. From 80 kL to 1000 kL. The diameter of the staging generally increases with increase in the capacity of the tank; however, the thickness of the staging section is usually kept between 150 and 200 mm. Frame type staging are generally regarded superior to shaft type staging for lateral resistance because of their large redundancy and greater capacity to absorb seismic energy through in elastic actions. Framed staging have many flexural members in the form of braces and columns to resist lateral loads and damage to a few will not result in the sudden collapse of the structure as inelastic deformations and damage is distributed to a large number of frame members. Furthermore, such RC frameworks can be designed to perform in a ductile fashion under lateral loads with greater reliability and confidence as opposed to thin shell sections of the shaft type staging. 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 Bhuj earthquake (2001) [2]is the recent example, as shown in figure 1.3,1.4,1.5&1.6 It is observed from the past earthquake; Most of the elevated water tanks undergo damage to their staging. 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. In order to make sure that the water tank design is capable to withstand any earthquake loads like overturning moment and base shear, therefore the needs of detailed investigation of fluid structure interaction must be taken into account. The movement and response of the water towards the wall structure may create an effect to the fundamental frequency of elevated tank.

Figure: 1.1. Cracks are `through' the shell thickness as seen from inside the shaft of 1000 kLAnjar Nagar Palika Tank.

Figure: 1.2. Poor detailing of column-brace joints for Manfera tank.

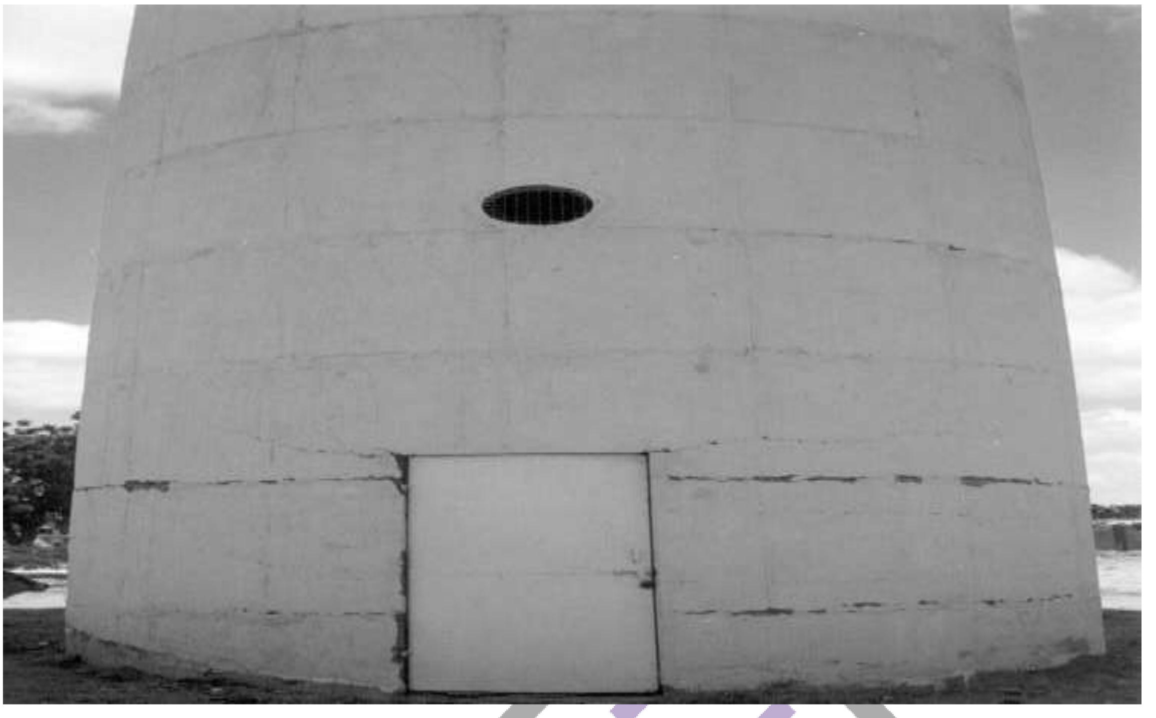


Figure: 1. 3. 200 kLBhachau water tank which developed circumferential cracks up to one-third height of the staging. Severe cracking at the junctions of the first two `lifts'.

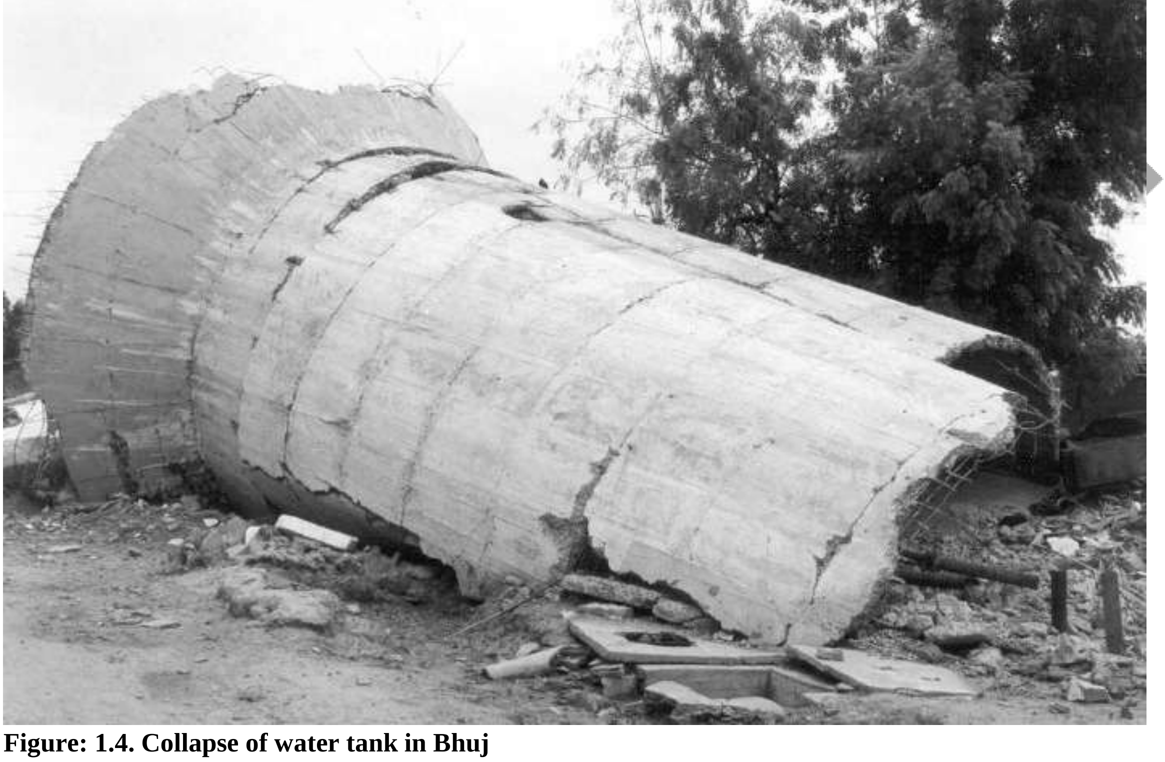


Figure: 1.4. Collapse of water tank in Bhuj

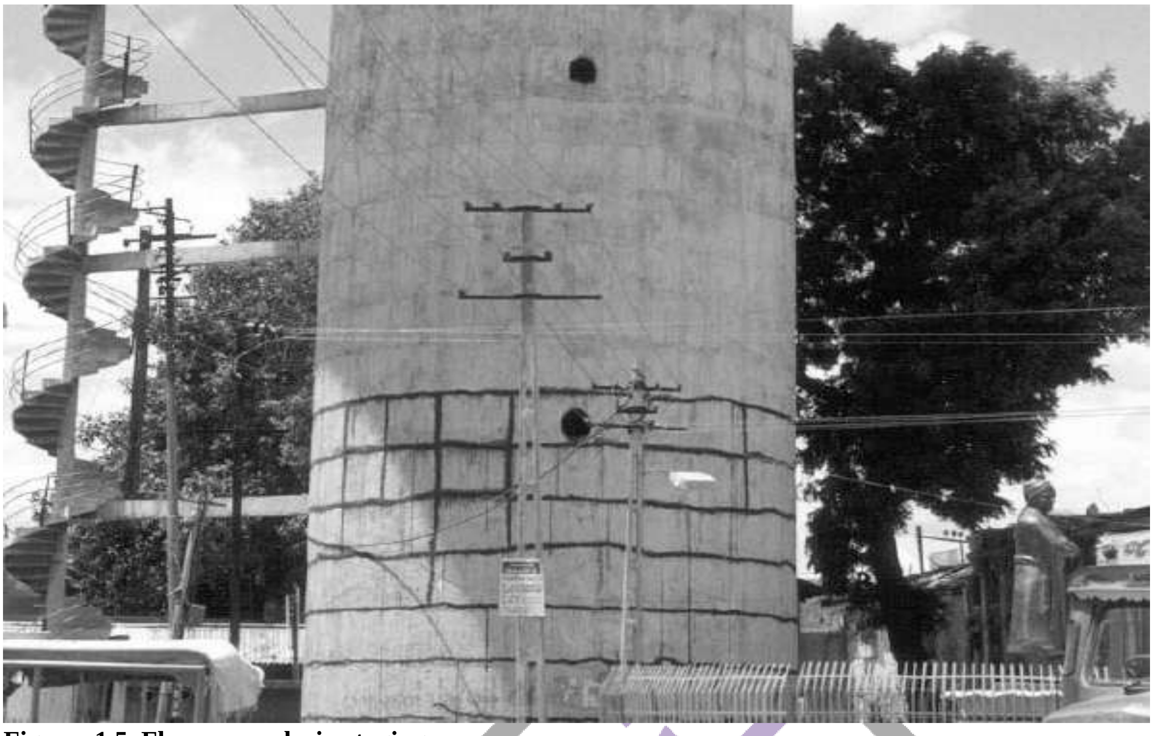


Figure: 1.5. Flexure cracks in staging

Figure: 1.6. Crack in soffit concrete under Side the staging beam of tank

Figure: 1.7. Crack in soffit concrete along the entire length of a staging

1.3: 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.

1.4: Seismic Coefficient Method

It is well known method for determining seismic forces. Purpose of finding seismic forces the country has been divided into 4 seismic zones. In earlier code of 1984, there were five zones, in revised code, zone 1&2 are merged and it called zone 2. Therefore, factor zones II, III, IV, and V for calculation forces due to Earthquake following coefficient quantities are required,

Ah = design horizontal seismic coefficient & given by (1.4.1)

$$Ah = \frac{Z}{2} x \frac{I}{R} x \frac{S_a}{g} \quad (1.4.1)$$

Where,

Z - Zone factor (given in table 2, page no: 14 in IS: 1893-2002) [16]

I - importance factor depending upon functional use of structure given by hazardous consequences of its failure post-earthquake functional needs, historical value or economic importance (table no 6, page no 18 in IS: 1893-2002) [16]

R- response reduction factor depending on perceived seismic damage performance of the structure characteristic by ductile or brittle deformation, however the ratio(I/R) shall not be greater than 1(given in table 7, page no: 23 in IS:1893-2002) [16]

Sa/g – average response acceleration coefficient.

The total design lateral forces or design seismic base shear (VB) along any principal direction shall be determine by the following formula (1.4.2).

$$\boldsymbol{V_B = Ah\ x\ W} \quad (1.4.2)$$

V_B = design seismic base shear

W = seismic weight of building. (As per 7.4.2 in IS: 1893-2002) [16]

CHAPTER 2
LITERATURE REVIEW

Ayazhussain M. Jabar and H. S. Patel (2012), has studied to understand the behavior of supporting system which is more effective under different earthquake time history is carried out with SAP 2000software. As known from very upsetting experiences, elevated water tanks were heavily damages or collapsed during earthquake. This was might be due to the lack of knowledge regarding the proper behavior of supporting system of the tank again dynamic effect and also due to improper geometrical selection of staging patterns. Due to the fluid-structure interactions, the seismic behavior of elevated tanks has the characteristics of complex phenomena. Here two different supporting systems such as radial bracing and cross bracing are compared with basic supporting system for various fluid level conditions. For later conditions water mass has been considered in two parts as impulsive and convective suggested by GSDMA guidelines. In addition to that impulsive mass of water has been added to the container wall using Westergaard's added mass approach. Tank responses including base shear, overturning moment and roof displacement have been observed, and then the results have been compared and contrasted. The result shows that the structure responses are exceedingly influenced by the presence of water and the earthquake characteristics.

Durgesh C Rai (2003), describes about the performance of elevated tanks in Bhuj earthquake of January 26th 2001. The current designs of supporting structures of elevated water tanks are extremely vulnerable under lateral forces due to an earthquake and the Bhuj earthquake provided another illustration when a great many water tank staging's suffered damage and a few collapsed. The more popular shaft type staging's suffer from poor ductility of thin shell sections besides low redundancy and toughness whereas framed staging's consist of weak members and poor brace-column joints. A strength analysis of a few damaged shaft type staging's clearly shows that all of them either met or exceeded the strength requirements of IS: 1893-1984, however, they were all found deficient when compared with requirements of the International Building Code. IS:1893-1984 is unjustifiablylow for these systems which do not have the advantage of ductility and redundancy and are currently being underestimated at least by a factor of 3 and need an upward revision of forces immediately.

AsariFalguni&Prof.M.G.Vanza (2012), has thrown light on the results of an analytical investigation of the seismic response of elevated water tanks using fiction damper. In This paper, the behaviour of RCC elevated water tank is studied with using friction damper (FD). For FD system, the main step is to determine the slip load. In nonlinear dynamic analysis, the response of structure for three earthquake time history has been carried out to obtain the values of tower drift base shear and acceleration Time Period. These values are compared with original structure. Results of the elevated tank with FD are compared to the corresponding fixed-base tank design and indicate that friction damper is effective in reducing the tower drift, base shear, time period, and roof acceleration for the full range of tank capacities. The obtained results show that performance of Elevated water tank with FD is better than without FD

Hasan Jasim Mohammed (2011), studied application of optimization method to the structural design of concrete rectangular and circular water tanks, considering the total cost of the tank as an objective function with the properties of the tank that are tank capacity, width and length of tank in rectangular, water depth in circular, unit weight of water and tank floor slab thickness, as design variables. A computer program has been developed to solve numerical examples using the Indian IS: 456-2000 Code equations. The results shown that the tank capacity taken up the minimum total cost of the rectangular tank and taken down for circular tank. The tank floor slab thickness taken up the minimum total cost for two types of tanks. The unit weight of water in tank taken up the minimum total cost of the circular tank and taken down for rectangular tank.

Arun Kumar (2006), has surveyed large capacity elevated intze tanks are used to store a variety of liquids, e.g. water for drinking and firefighting, petroleum, chemicals, and liquefied natural gas. The liquid storage tanks are particularly subjected to the risk of damage due to earthquake-induced vibrations. A large number of overhead water tanks damaged during past earthquake. Majority of them were shaft staging while a few were on frame staging. Recently the Muzaffarabad earthquake 2005 and Bhuj earthquake 2001 also represented similar damage. Most of the damage was caused because of the tanks were either designed without considering the earthquake forces or inadequate seismic design considerations. To cope with this, need the seismic design codes for overhead water tanks have been revised and upgraded. The objective of this dissertation is to shed light on the difference in the design parameters of (a) over head water tanks without having earthquake forces, (b) over head water tanks constructed with a consideration of earthquake forces following two approaches; firstly, based on Indian standard code 1893, (1984) i.e. adopting single mass method and second is based on draft code 1893-Part 2, (2005) considering two mass modal i.e. convective and impulsive mode method. Two types of elevated water tanks namely intze tank supported by frame staging and shaft staging have been considered in this study. These elevated water tanks are first conventionally designed and then seismic analysed and again redesigned considering earthquake forces. Their strength and ductility have also been evaluated and compared. It has been observed that time period in frame staging is higher than the shaft staging since the lateral stiffness of shaft staging is much larger. The tank supported on shaft staging has higher strength as compare to tank supported on frame staging but the ductility is low that may be the return of frequent failure of elevated water tank supported on shaft staging.

Durgesh C. Rai and Bhumika Singh (2004), studied Reinforced concrete pedestal (circular, hollow shaft type supports) are popular choice for elevated tanks for the ease of construction and the more solid form it provides compared to framed construction. In the recent past Indian earthquakes, Gujarat (2001) and Jabalpur (1997), thin shells (150 to 200 mm) of concrete pedestals have performed unsatisfactorily when great many developed circumferential tension flexural cracks in the pedestal near the base and a few collapsed. These observations partially fill the void that exists about the actual performance of such structures in earthquakes of significant magnitude. The shaft support of elevated tanks should have adequate strength to resist axial loads, and moment and shear forces due to lateral loads. The observed damage pattern shows that, for tanks of large aspect ratio and falling in long time period range, flexural behaviour is more critical than shear under seismic loads.

Therefore, the concrete pedestal should be adequately designed and detailed for flexural deformations and actions as well as for shear strength and deformations. However, for very large tanks designed as per ACI 371 provisions, shear strength frequently controls design of the cylindrical pedestal wall and it is partly due to the fact that Chapter 21 provisions of ACI 318 don't consider the beneficial effects of axial compression. Currently codes recognize that thin shaft shells of pedestal not only possess a very low flexural ductility but also lack redundancy of alternate load paths that are present in framed structures. As a result, for seismic design the response reduction factors for such structures are kept lower than those structures with higher capacity for ductility and energy dissipation, such as building frames, which results in about 3times large design forces. However, it is not adequate as the design and detailing of the support structure should conform to the expected behaviour and to the controlling failure mode. This paper will review the existing code design procedures in the light of actual performance data and will suggest modifications for safer designs.

Chirag N. Patel and H. S. Patel (2012),provides a literature review on behaviour and suitability of supporting system of reinforced concrete elevated/overhead tanks during vulnerable force events like earthquake with some unusual alteration. As from very offensive past records, many reinforced concrete elevated water tanks were collapsed or highly damaged during the earthquakes all over the world. General observations are pointing out the reasons towards the failure of supporting system which reveals that the supporting system of the elevated tanks has more critical importance than the other structural types of tanks. Most of the damages observed during the seismic events arise due to the causes like improper/unsuitable design of supporting system, mistakes during selection of supporting system, improper arrangement of supporting elements and/or underestimated demand or overestimated strength etc. Consequently, the aim of this study is to know the effectiveness of supporting systems of elevated tanks with different alteration. A reviewed literature demonstrates the considerable change in seismic behaviour of elevated tanks with consideration of responses like displacement, base shear, base moment, sloshing, and torsion vulnerabilityetc. Finally, study discloses the importance of suitable supporting configuration to remain withstands against heavy damage/failure of elevated water tanks during seismic events.

F. Omidinasab and H. Shakib(2012), have surveyed Liquid tanks and especially the elevated tanks are structures of high importance which are considered as the main lifeline elements that should be capable of keeping the expected performance. i.e. operation during and after earthquakes. Thus, researchers, in recent years, have focused on studying the seismic behaviour of these tanks. Many researchers have been done on the behaviour, analysis, and design of seismic tanks, particularly ground tanks, while only a few of these researches have concerned with the elevated tanks and even less with the reinforced Concrete elevated tanks. In this research, a sample of a reinforced concrete elevated water tank, with 900 cube meters under seven earthquake records have been studied and analysed in dynamic time history and the tank's responses including base shear, overturning moment, tank displacement, and sloshing displacement under these seven record have been calculated, and then the results have been compared and contrasted.

Gareane, I. algreane, A. Osman, Othman a. Karim, and anuar kasha (2004), presented analysis of hydrodynamic structure such as elevated concrete water tank is quite complicated when compared with other structures. As well as dynamic fluid-structure interaction (FSI) plays an important effect in this complexity for which research suggests solution by using different methods. This paper presents the dynamic behaviour of elevated concrete water tank with alternative impulsive masses configurations. Six models were simulated to determine the effects of impulsive mass mode. Simulation of the models was carried out in three-dimensional finite element method via LUSAS FEA 14.1. An artificial ground motion compatible with a target response spectrum that developed by other researchers has been generated according to Gasparini and Vanmarcke procedure.

CHAPTER 3
METHODOLOGY

In this thesis the seismic coefficient method used in STAAD Pro.V8i to calculate the base shear is explored. The results obtained from this direct method of the software are compared with manual calculation. Comparison of base shear of RCC elevated water tanks for different combinations of bracings patterns in staging (Table3.1) is carried out.Eleven models are used and earthquake analysis was carried out for all models for empty, half-filled and full conditions of circular water tank in STAAD pro. The displacement and base shear is calculated.

Table 3.1: Types of bracing patterns used for analysis

SN	Types of bracing patterns used for analysis
1	Staging with cross bracing
2	Staging with chevron bracing
3	Staging with diagonal bracing
4	Staging with k-type bracing
5	Staging with v-type bracing
6	Alternate cross bracing in staging
7	Alternate chevron bracing
8	Alternate v-type bracing in staging
9	Alternate k-type bracing in staging
10	Alternate diagonal bracing in staging

For validation of seismic coefficient method, base shear which is obtained from manual is calculation compare with base shear calculate by STAAD pro for same model.

CHAPTER 4
VALIDATION OF SEISMIC COEFFICIENT METHOD

4.1: Problem statement for water tank

Following problem is taken from IIT, Kanpur guidelines for seismic design of liquid storage tanks [3] having parameters shown Table4.2 & Figure 4.5 shows 3D-view of tank.

Table4.1: Parameters of elevated water tank.

SN	Parameters	Value
1	Thickness of roof slab	120 mm
2	Thickness of wall	200 mm
3	Thickness Bottom slab	200 mm
4	Top ring beam	200x100 mm
5	Bottom ring beam	250x600 mm
6	Size of braces	300x450 mm
7	Dia. of tank	5.0 m
8	Height of tank	3.0 m
9	Height of column from ground	12 m
10	Dia of column	450 mm
11	Zone	II
12	Importance factor	1.5
13	Type of soil	soft soil
14	Frame	SMRF (R=5)Special moment resisting frame
15	Depth of foundation	1.775m
16	No of columns	4
17	Concrete density	$25kN/m^3$

Table 4.2 Weight of various components

Component	**Calculations**	**Weight (kN)**
Roof Slab	$[\pi \times (5.05)^2 \times (0.12 \times 25)]/4$	60.1
Wall	$\pi \times 4.85 \times 0.20 \times 3.30 \times 25$	251.4
Floor slab	$[\pi \times (5.05)^2 \times 0.20 \times 25]/4$	100.2
Floor Beam	$\pi \times 4.85 \times 0.25 \times (0.60 - 0.20) \times 25$	38.1
Columns	$[\pi \times (0.45)^2 \times 11.7 \times 4 \times 25]/4$	186.1
Braces	$3.43 \times 0.30 \times 0.45 \times 4 \times 4 \times 25$	185.2
Water	$[\pi \times 4.652 \times 3.0 \times 9.81]/4$	499.8

4.1.1: Design Horizontal Seismic Coefficient
Design horizontal seismic coefficient for impulsive mode,
$(\boldsymbol{Ah})_i = \frac{\boldsymbol{ZI}}{\boldsymbol{2R}} \left(\frac{S_a}{g}\right)_i$(4.2.1)
Where,
Z = 0.1 (IS 1893(Part 1): Table 2; Zone II)
I = 1.5 (Table 1)
Since staging has special moment resisting frames (SMRF), R is taken as 2.5 (Table 2)
Here, Ti= 0.80 sec,
Site has soft soil, Damping = 5%, (Section 4.4)
Hence, $(Sa/g)i$= 2.09 (IS 1893(Part 1): Figure 2)

$$(Ah)_i = \frac{0.1\ X\ 1.5}{2\ X\ 2.5}\ X\ 2.09\ = 0.06$$

Design horizontal seismic coefficient for convective mode,

$$(Ah)_c = \frac{ZI}{2R} \left(\frac{S_a}{g}\right)_c (4.2.2)$$

Where,
Z = 0.1 (IS 1893(Part 1): Table 2; Zone II)
I = 1.5 (Table 1)
R = 2.5
For convective mode, value of R is taken same as that for impulsive mode as per Section 4.5.1.
Here, Tc = 2.26 sec,
Site has soft soil,
Damping = 0.5%, (Section 4.4)
Hence, $(Sa/g)\ c$ = 1.75 x 0.74 = 1.3 (IS 1893(Part 1): Figure 2)
Multiplying factor of 1.75 is used to obtain *Sa /g values* for 0.5% damping from that for 5% damping.

$$(Ah)_c = \frac{0.1\ X\ 1.5}{2\ X\ 2.5}\ X\ 1.3\ = 0.04$$

4.1.2: Base Shear
Base shear at the bottom of staging, in impulsive mode,

$$V_i = (Ah)_i(m_i + m_s)g(4.3.1)$$

= 0.06 x (33,116 + 63,799) x 9.81
= 59.9 kN.
Similarly, base shear in convective mode,
$V_c = (Ah)_c.m_c.g$(4.3.2)
= 0.04 x 17,832 x 9.81
= 7.0 kN.
Total base shear at the bottom of staging,

$$V = \sqrt{V_i^2 + V_c^2)}(4.3.3)$$

$$V = \sqrt{59.9^2 + 7^2)}$$

= 60 kN.
Total lateral base shear is about 5 % of total seismic weight (1,126 kN). It may be noted that this tank is located in seismic zone II.

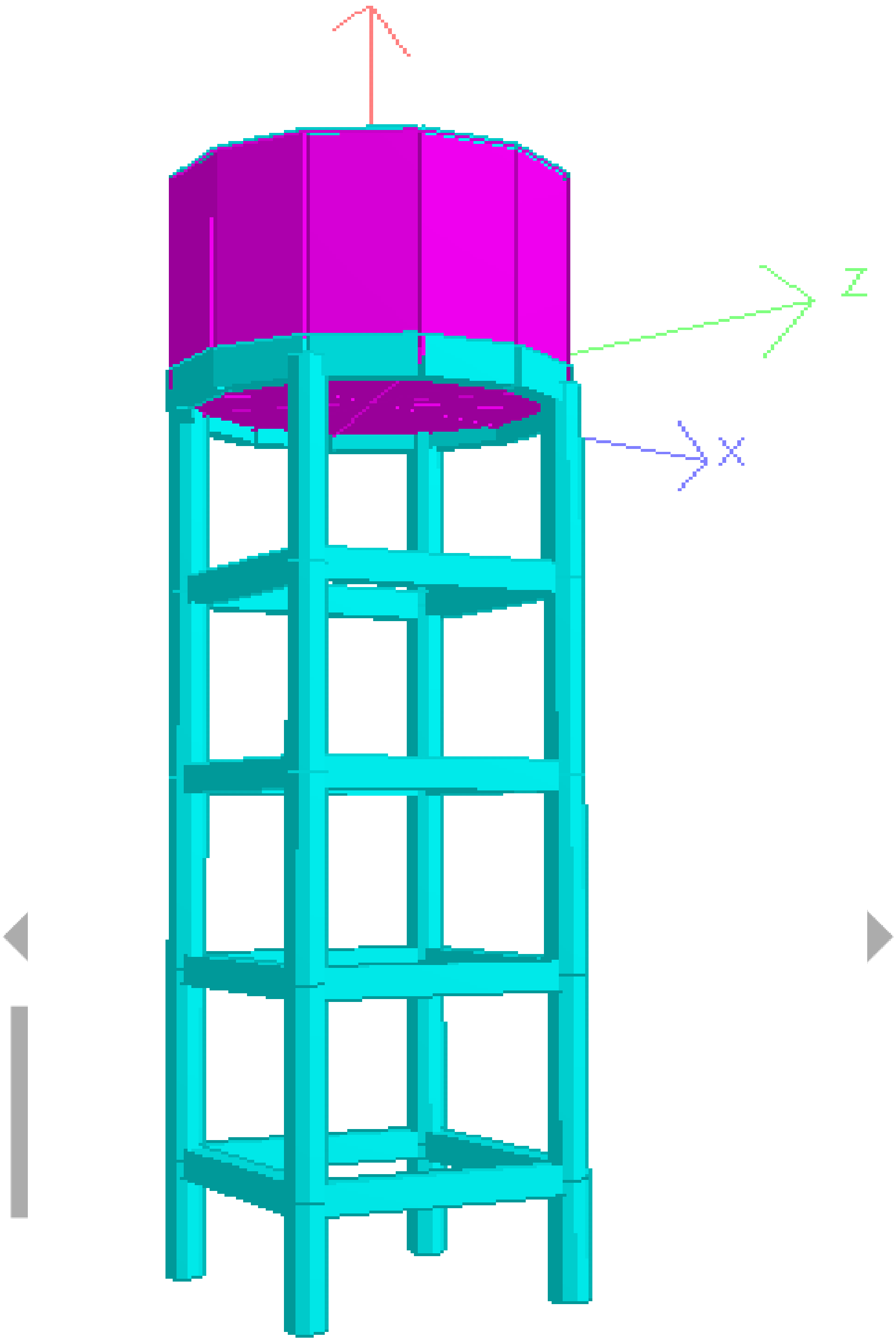


Figure 4.1: 3-D view of IITK Model.

The base shear calculated, for tank full condition, by IIT Kanpur guidelines is 60kN and for empty condition is 50 kN whereas, the base shear calculated by STAAD.Pro for same model is 61.88 kN and 50.50 kN

Table 4.2 Comparison of Base Shear by Manual method and STAAD.Pro. V8i

Sr.No.	Tank Condition	Base Shear (kN)	
		Manual	STAAD.Pro
1	Empty	50	51.50

2	Full	60	61.88

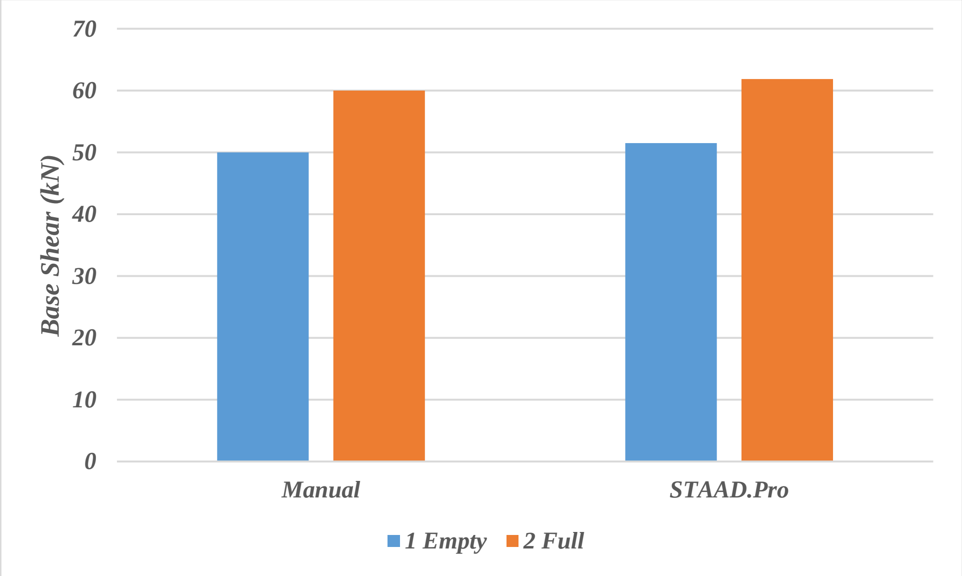


Figure 4.2: Comparison of Base Shear by Manual method and STAAD.Pro. V8i

From the section 4.1 and 4.2, it is verified that the results of simplified method, used by software are in fair agreement with the results of manual calculations. Based on this validation, following eleven models are analysed, in order to study the base shear and nodal displacement at the top and bottom of the container's wall.

CHAPTER 5

ANALYSIS OF ELEVATED WATER TANKS

5.1 General:

5.1: Stad.pro Modelling

Modelling and analysis of following eleven models was done in STAAD pro. For modelling purpose20 triangular plates shown in figure5.2 are used for bottom and top slab and 20 rectangular plates shown in figure5.1 were used for vertical cylindrical wall. Top ring beam having 300 x 400mm section where as bottom ring beam have 350 x 600 mm. analyses was done for zone IV.
Establishment of model was done by following procedure.

1. First geometry of bottom ring beam was created with the help of radial function Inserting values of radius of tank & no. bay in radial and circumferential direction. In geometry of bottom ring beam nodes are assigning.
2. By using transition repeat function top ring beam shown in figure5.6 was created after inserting height of tank
3. With help of triangular plates bottom and top slab was created by use of circular repeat function. Whereas rectangular plates are used for creating vertical cylindrical wall shown in Figure5.7.
4. After selecting nodes of bottom ring beam transition repeat function was used again to crating columns.
5. Then by using beam curser column and braces are connected.

After creating model of elevated water tank and applying earthquake loading from following parameters analysis was done. Figure5.3 shows container of elevated water tank and figure5.4 shows node geometry.

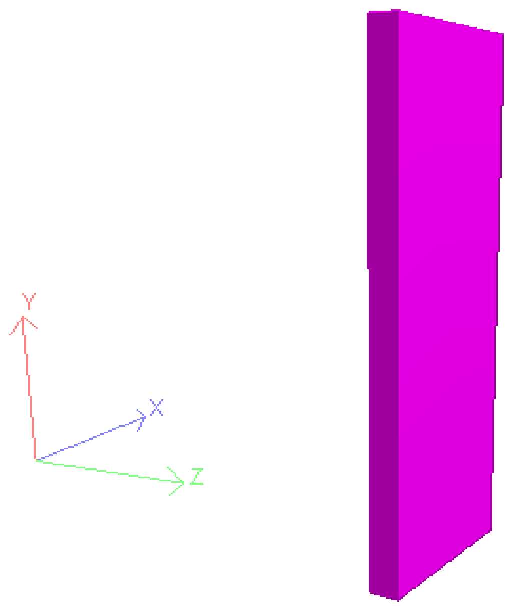


Figure5.1: Rectangular plate with local axis

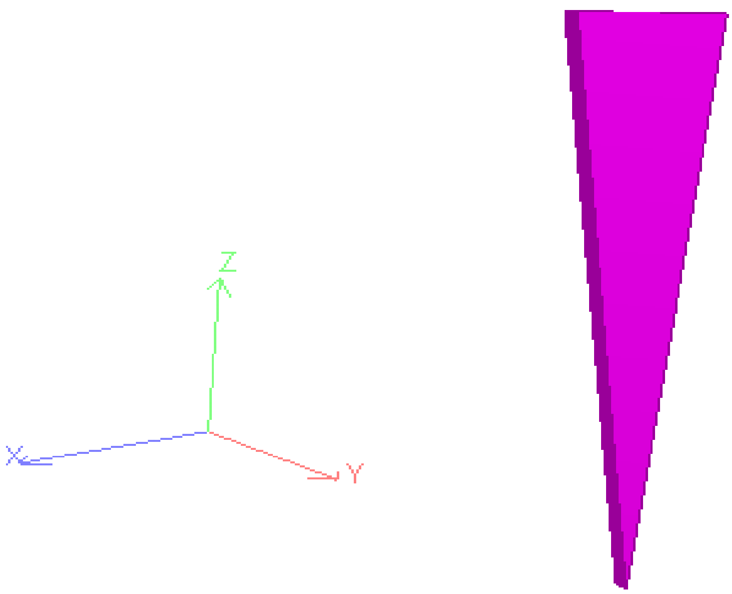


Figure5.2: Triangular plate with local axis

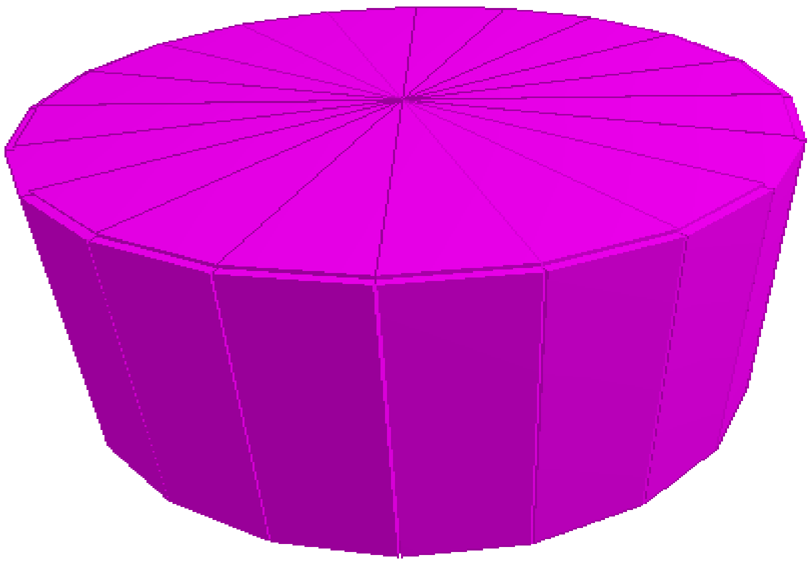


Figure5.3: Container view

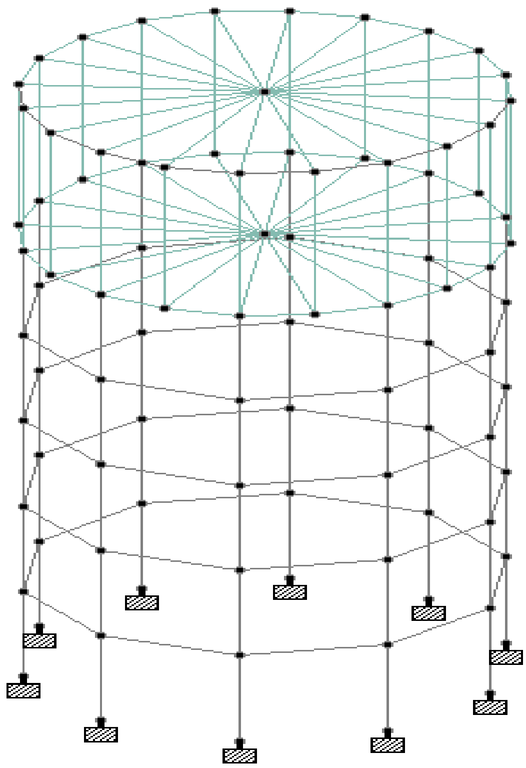


Figure5.4: Node geometry

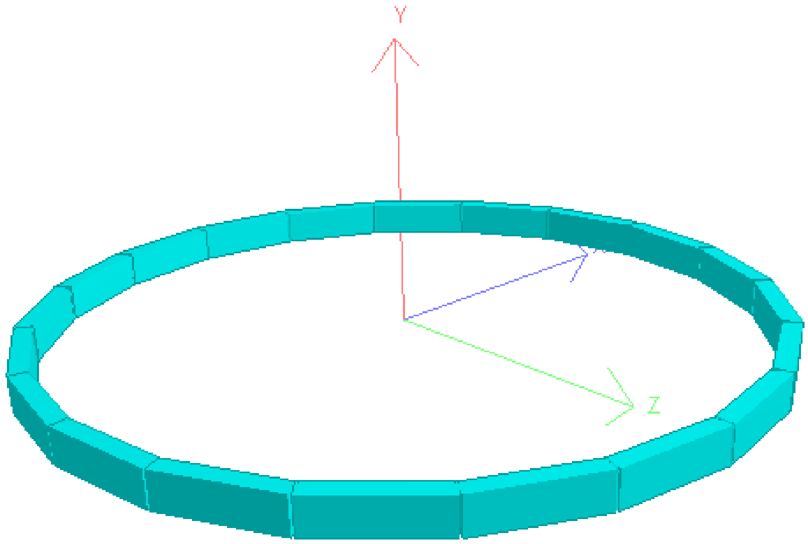


Figure5.5: View of bottom ring beam with local axis

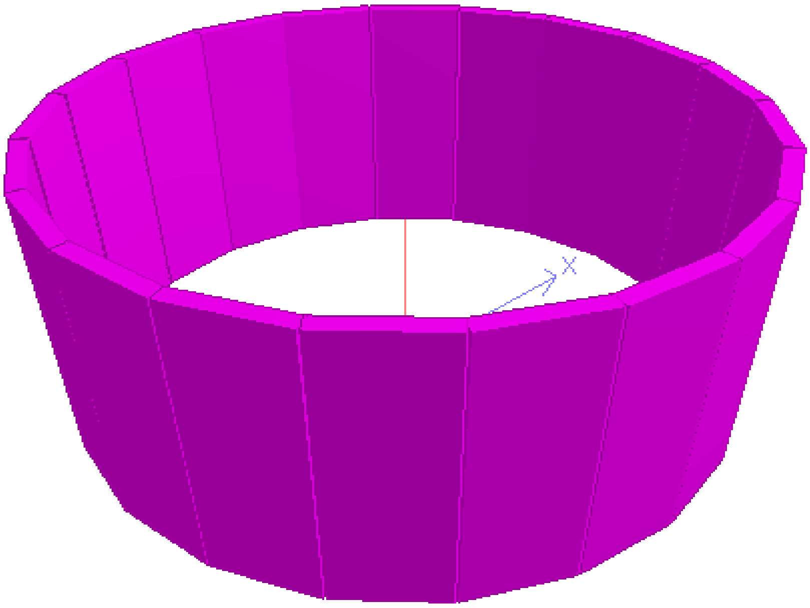


Figure5.6: View of cylindrical wall

Structural data:

Table 5.1: Parameters of elevated water tank

Sr.No.	Parameters	Values
1	Size Of Top Slab	150 mm thick
2	Size of bottom slab	400 mm
3	Thickness of side wall	400 mm

4	Size of top ring beam	300 x 400 mm
5	Size of bottom ring beam	350 x 600 mm
6	Size of column	600 x 350 mm
7	Size of braces	500 x 300 mm
8	Density of concrete	25 kN/m^3
9	Diameter of tank	10 m
10	Height of tank	5 m
11	Height of column	15 m
12	Number of columns	10
13	Zone	IV(0.24)
14	Response reduction factor (R)	5 (SMRF)
15	Importance factor	1.5 (for water tank)
16	Type of soil	hard soil

5.1.1: Loading of tank in STAAD pro.

Figure 5.7 shows the triangular distribution of hydrostatic force. Figure5.8 shows uniform distributed pressure on bottom slab. After the analysis of complete model, the lateral loads act in X-direction as shown in figure5.9, while figure5.10 shows self-weight of structure and figure5.11shows defected shape of tank.

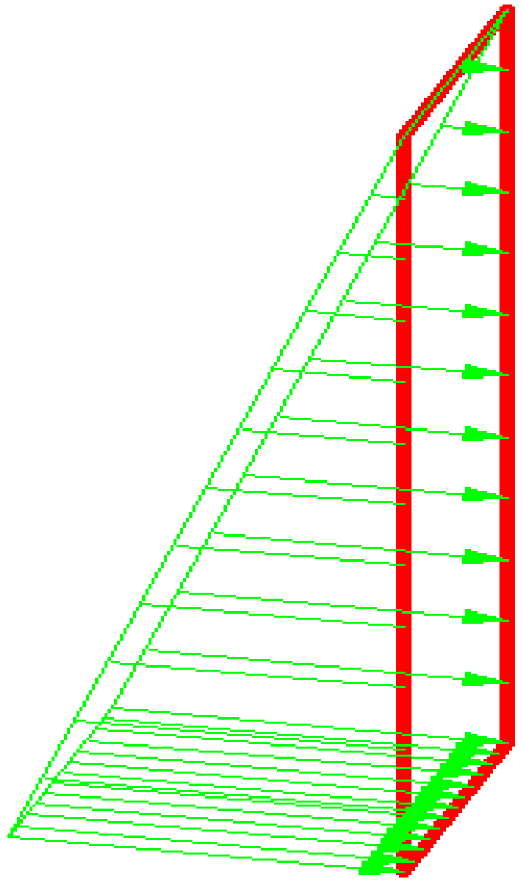


Figure5.7: Hydrostatic pressure on vertical plate

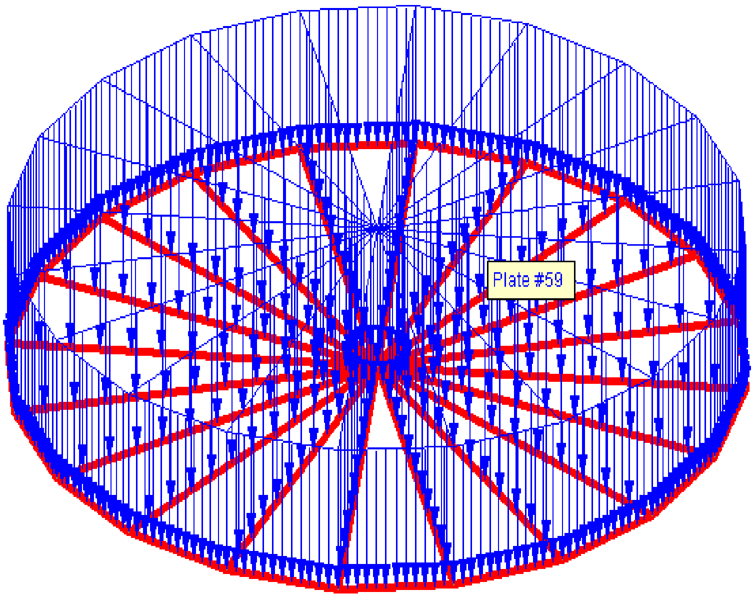


Figure5.8: Water pressure on bottom slab

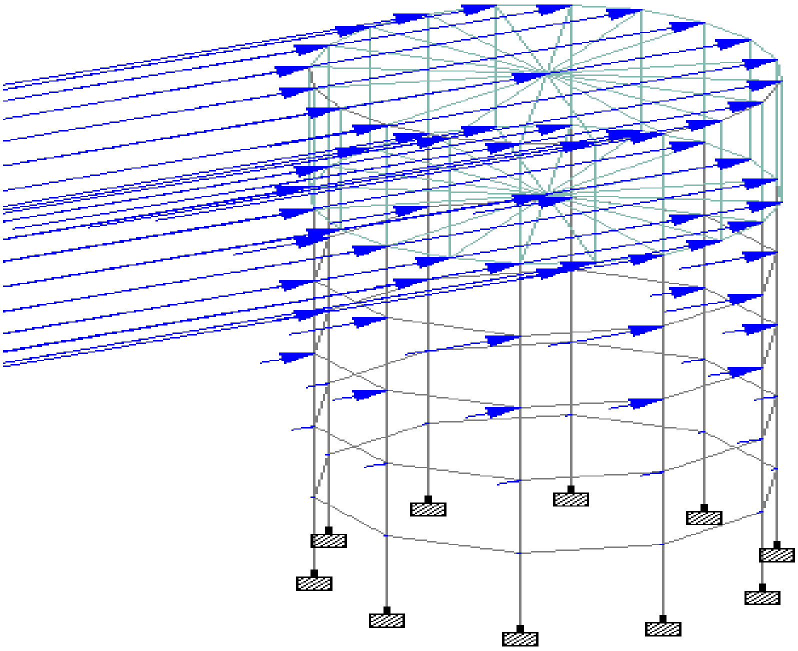


Figure5.9: Lateral forces

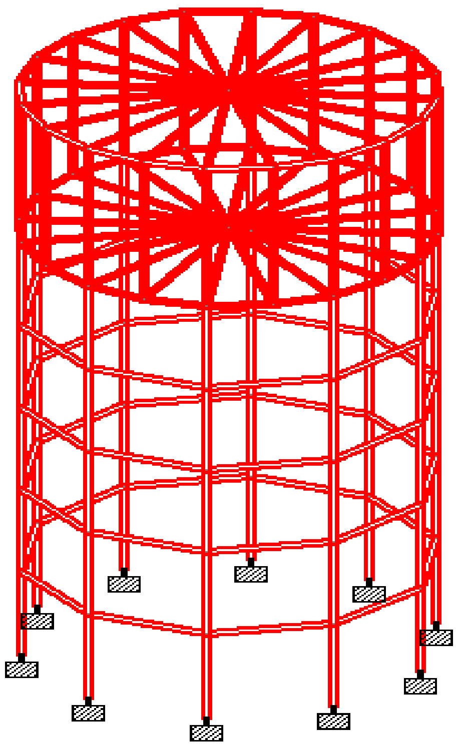


Figure5.10: Self weight of tank

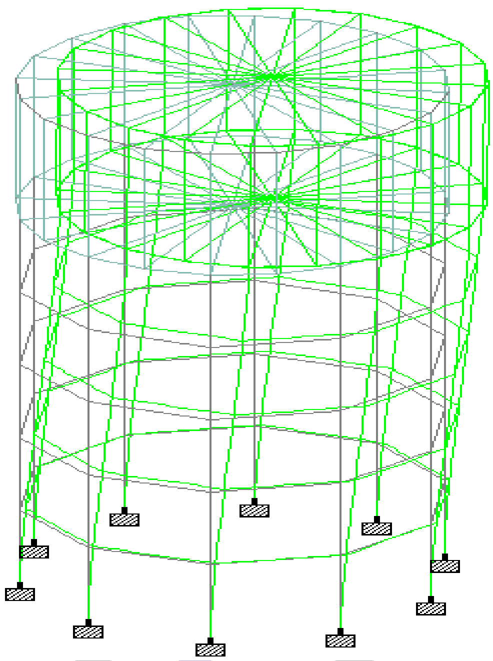


Figure5.11: Deflected shape of tank

5.1.2: 3D views of models

Following are 3D and STAAD pro. models of circular water tank for empty, half, full filled, full condition of container with different types of bracing pattern in staging.

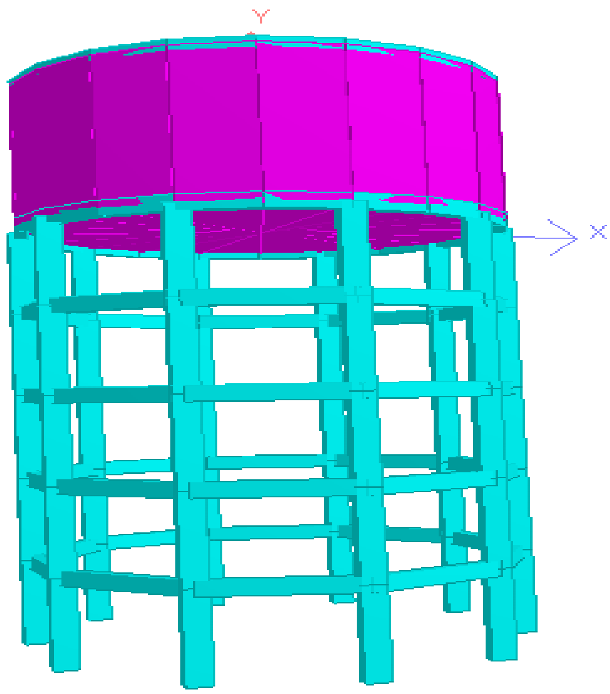


Figure5.12: Staging without inclined bracing

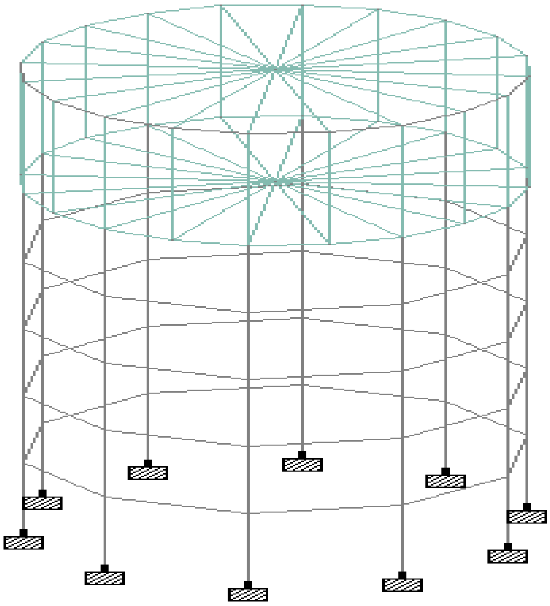


Figure5.13: STAAD pro model of staging without inclined bracing

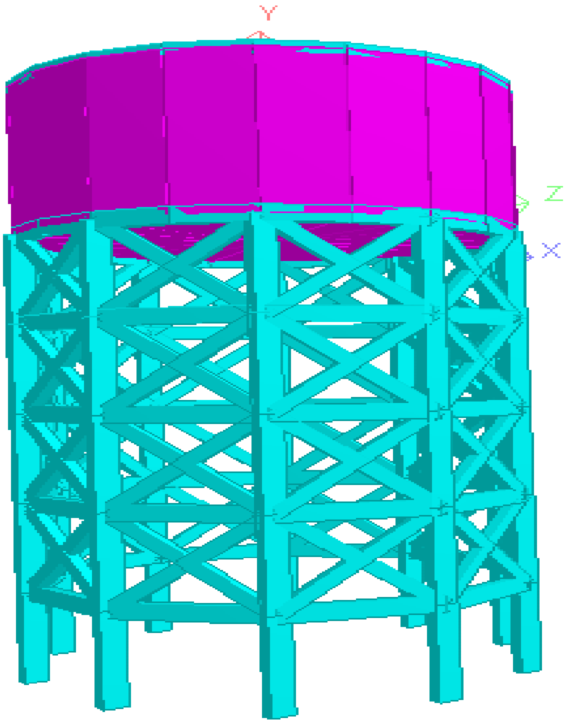


Figure5.14: Staging with cross bracing

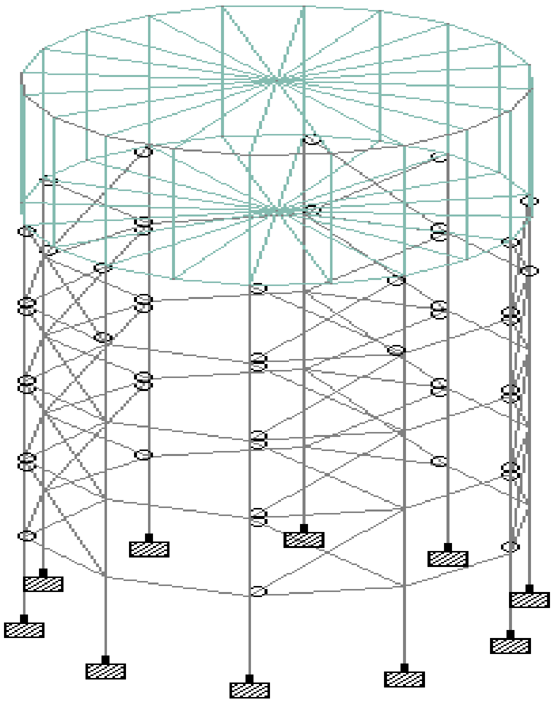


Figure5.15: STAAD pro model of staging with cross bracing

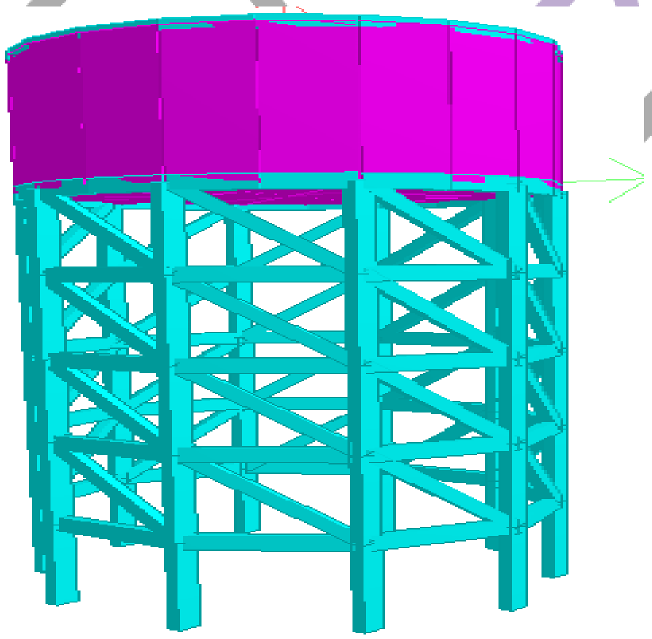


Figure5.16: Staging with diagonal bracing

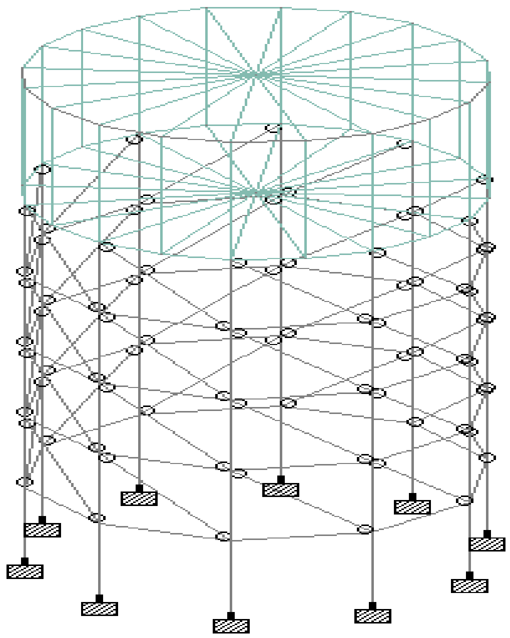
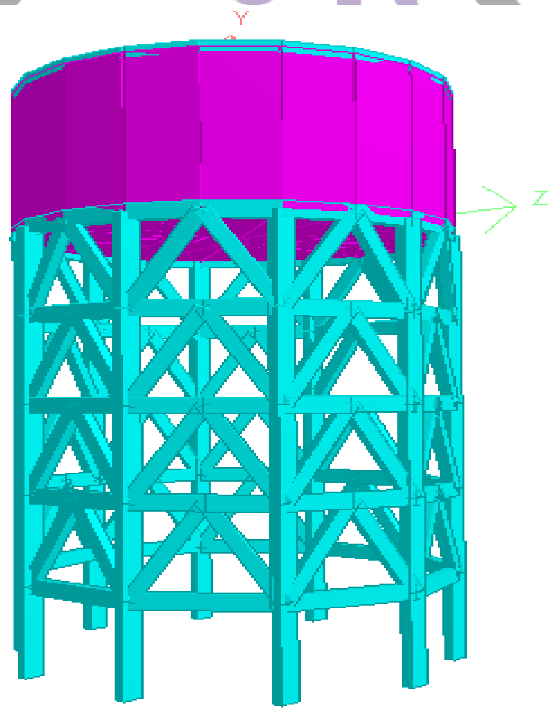


Figure5.17: STAAD pro model of staging with diagonal bracing



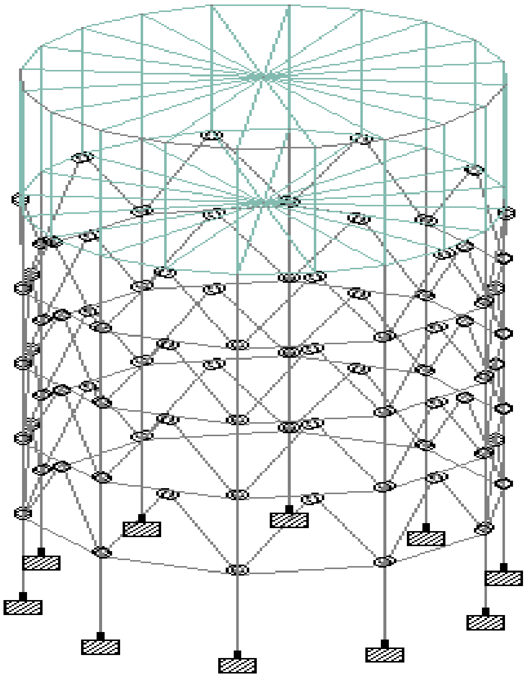


Figure5.18: Staging with chevraon bracing

Figure5.19: STAAD pro model of staging with chevraon bracing

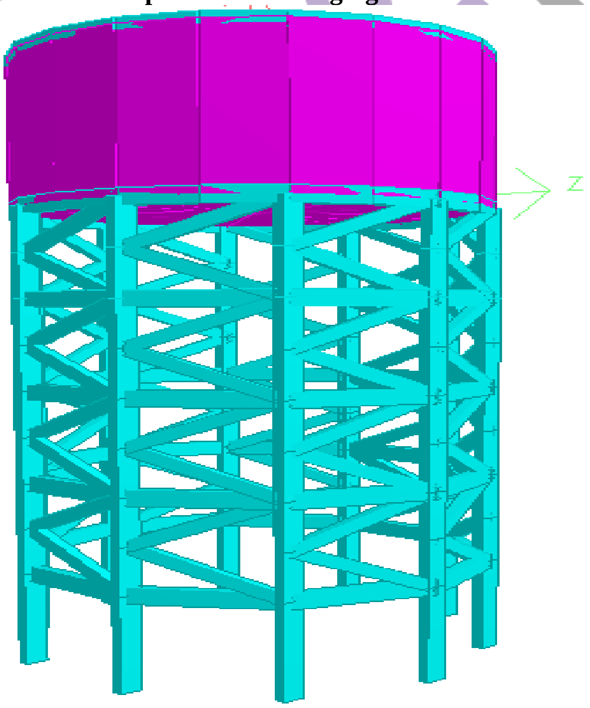


Figure5.20: Staging with k-type bracing

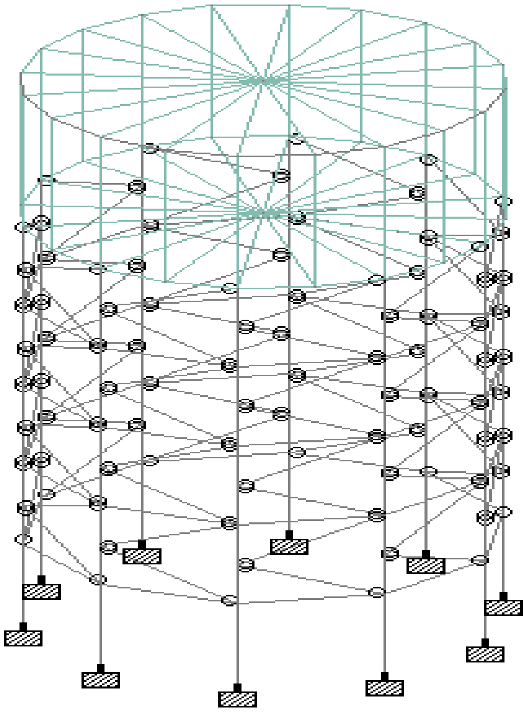


Figure5.21: STAAD pro model of staging with k-type bracing

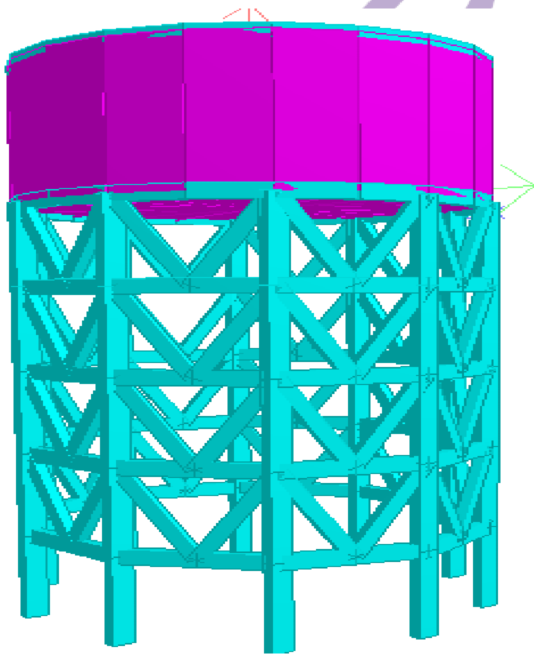


Figure5.22: Staging with v-type bracing

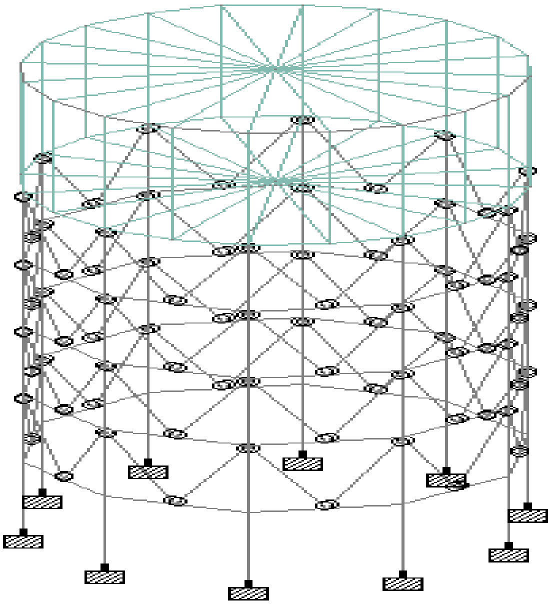


Figure5.23: STAAD pro model of staging with v-type bracing

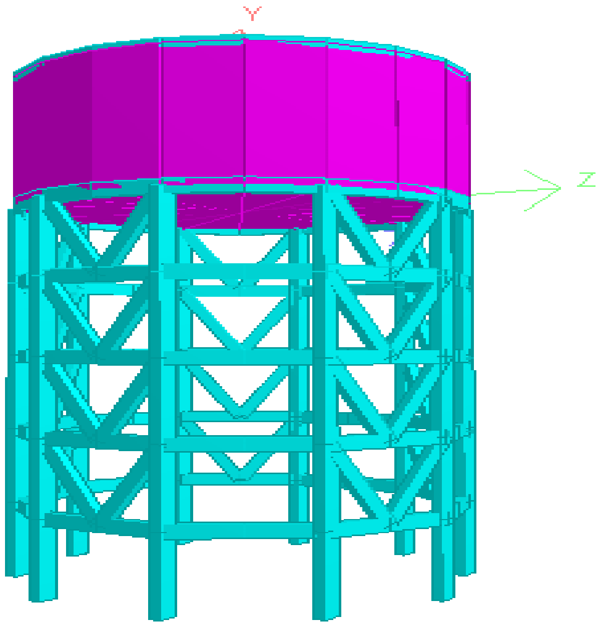


Figure5.24: Alternate v-type bracing in staging

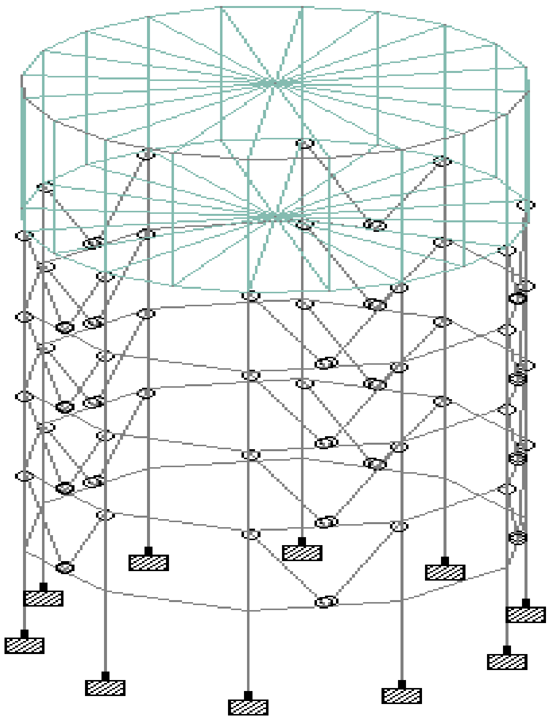


Figure5.25: STAAD pro model of alternate v-type bracing in staging

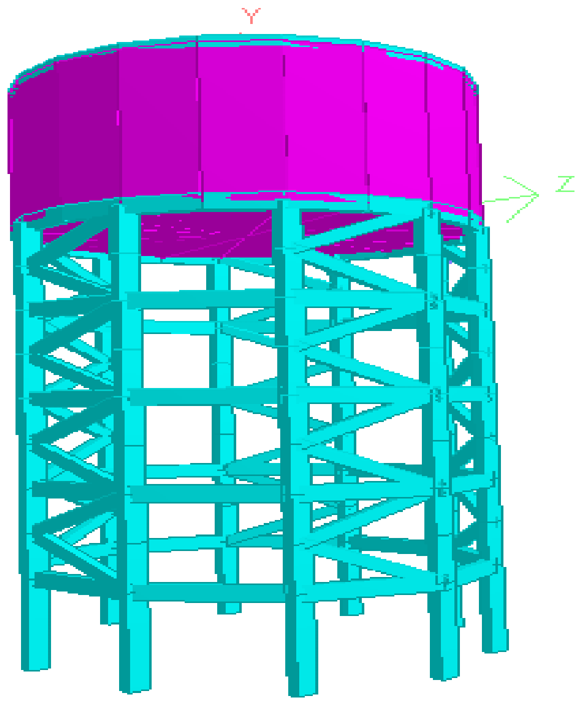


Figure5.26: Alternate k-type bracing in staging

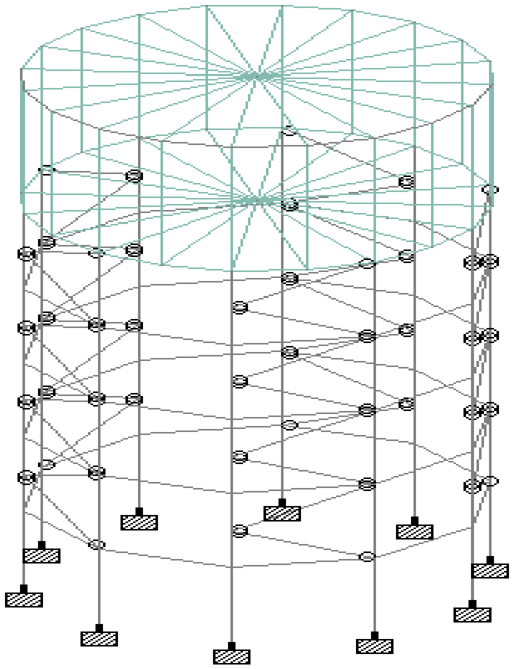


Figure5.27: STAAD pro model of alternate k-type bracing in staging

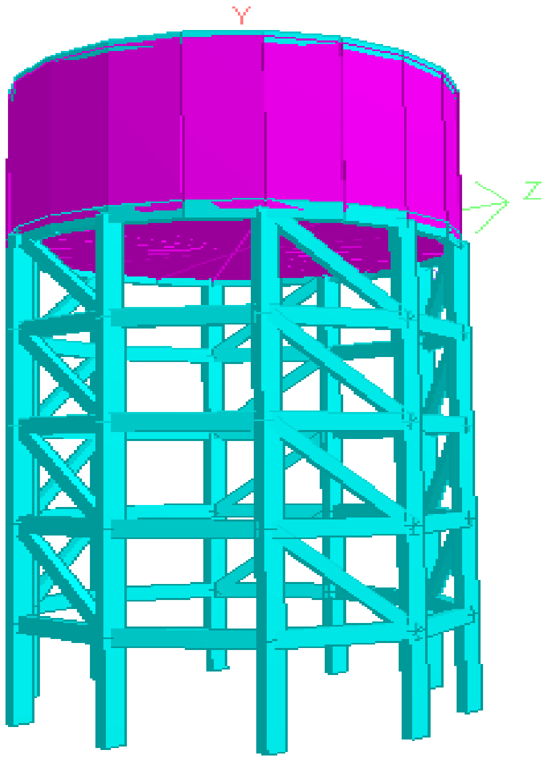


Figure5.28: Alternate diagonal bracing in staging

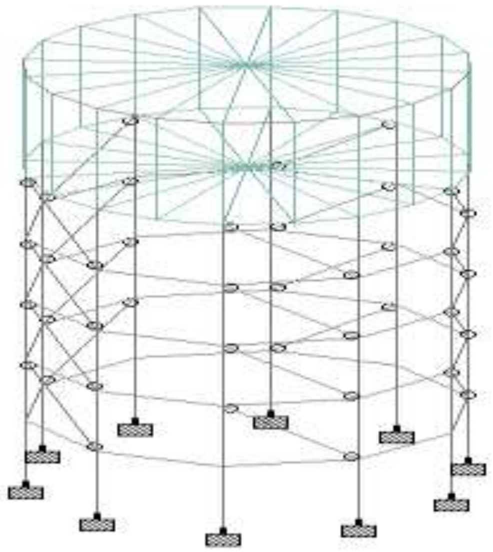


Figure5.29: STAAD pro model of alternate diagonal bracing in staging

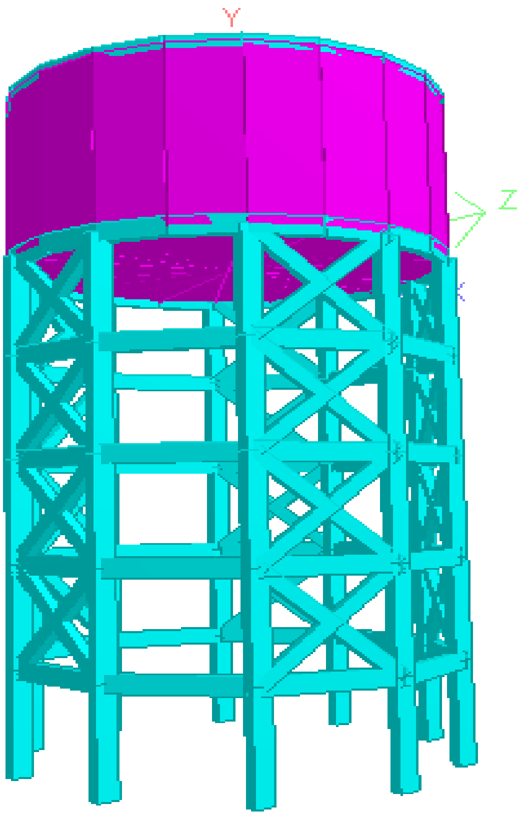


Figure5.30: Alternate cross bracing in staging

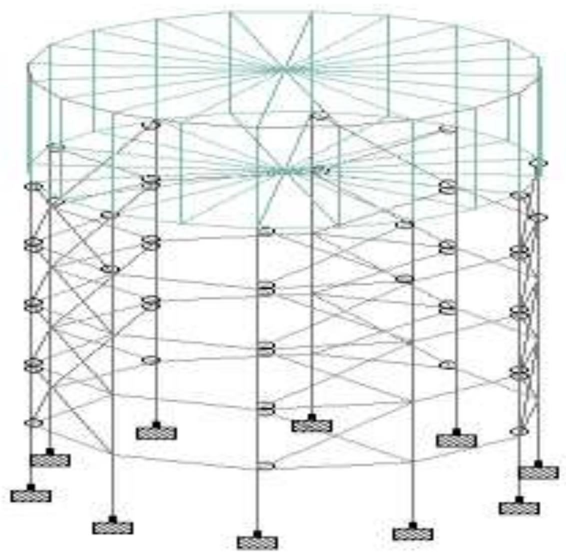


Figure5.31: STAAD pro model of alternate cross bracing in staging

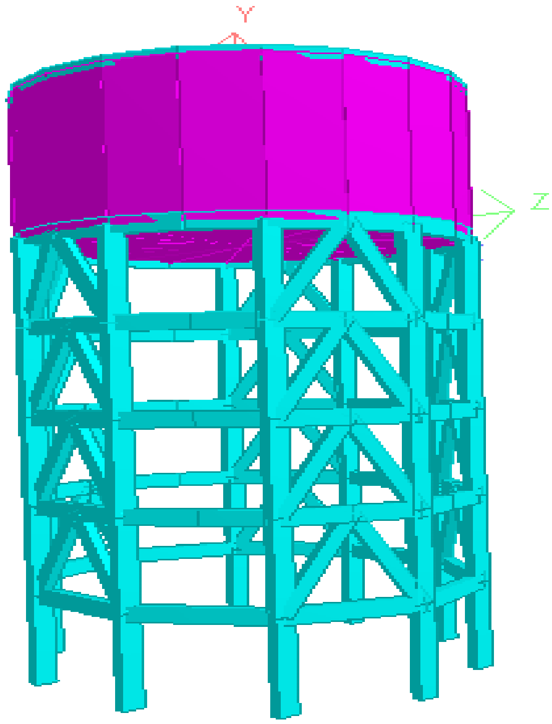


Figure5.32: Alternate chevron bracing in staging

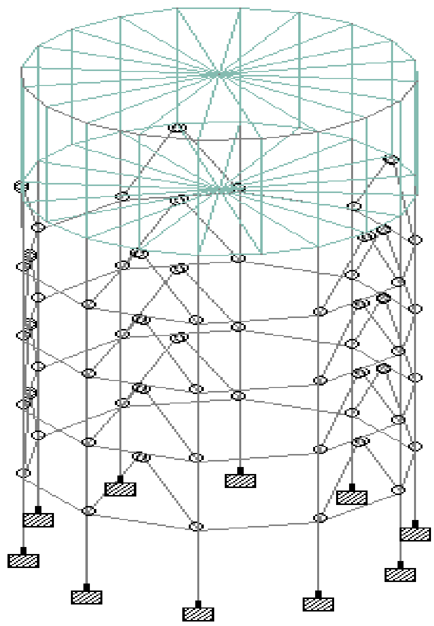


Figure5.33: STAAD pro model of alternate chevron bracing in staging

CHAPTER 6

RESULT AND DISCUSSION

6.1 GENERAL

Following are results of base shear and nodal displacement for circular water tank for empty, 25%, 50%, 75, and full conditions with staging without inclined bracing , staging with cross bracing , staging with chevron bracing , staging with diagonal bracing , staging with k-type bracing , staging with v-type bracing, 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. It is observed that maximum displacement achived for 1.5(DL+EQX) loading combination for all types of bracing system. For this loading comination of 1.5(DL+EQX), displacement values are noted for node No.78 and 14 as shown in figure 6.1&6.2in x-direction for circular water tank for empty,half and full condition.

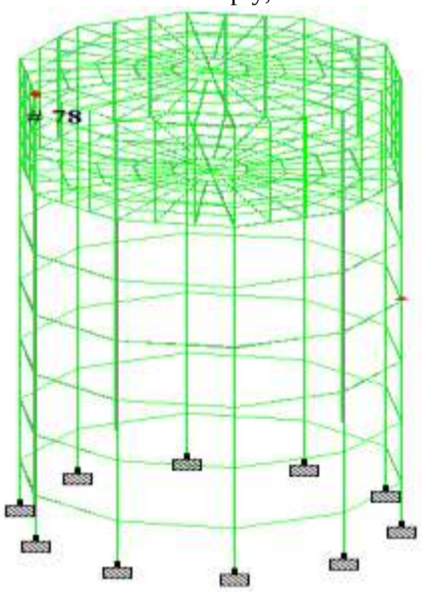


Figure6.1: Position of node no.78

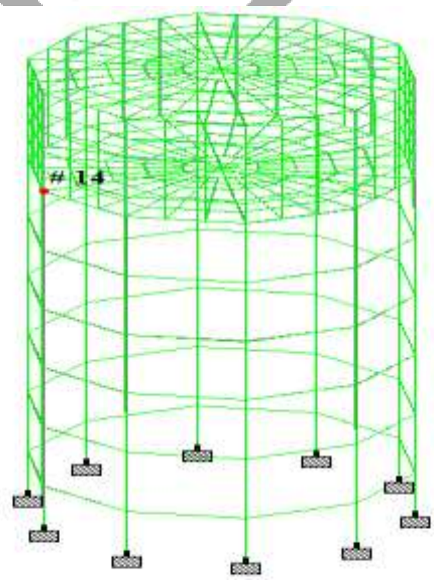


Figure6.2: Position of node no.14

6.1: Results of different Bracing Systems in Staging

Following are the characterized results of base shear and nodal displacement for circular water tank with different types of bracing pattern in staging for empty,half filled and full condition of container

Table6.1: Results of base shear and nodal displacement of without inclined bracing in staging

SR.NO.	Tank condition	Displcement (mm)		Base shear (kN)
		Node No:78	Node No:14	
1	Empty (0%)	12.98	12.56	228.41
2	25% Filled	15.46	14.97	271.81
3	50% Filled	18.1	17.54	317.91
4	75% filled	20.41	19.79	358.6
5	Full (100%)	22.88	22.2	402

Table6.2: Results of base shear and nodal displacement of cross bracing in staging

SR.NO.	Tank condition	Displcement (mm)		Base shear (kN)
		Node No:78	Node No:14	
1	Empty (0%)	1.89	1.51	289.79
2	25% Filled	2.15	1.73	333.19
3	50% Filled	2.37	1.9	395.76
4	75% filled	2.68	2.17	419.98
5	Full (100%)	2.94	2.38	463.38

Table 6.3: Results of base shear and nodal displacement of chevron bracing in staging

SR.NO.	Tank condition	Displcement (mm)		Base shear (kN)
		Node No:78	Node No:14	
1	Empty (0%)	2.32	1.9	210.61
2	25% Filled	2.43	2.03	343.76
3	50% Filled	2.72	2.27	387.16
4	75% filled	2.14	1.77	430.55
5	Full (100%)	3.3	2.77	473.95

Table6.4: Results of base shear and nodal displacement of diagonal bracing in staging

SR.NO.	Tank condition	Displcement (mm)		Base shear (kN)
		Node No:78	Node No:14	
1	Empty (0%)	2.59	2.15	290.24
2	25% Filled	2.96	2.46	333.64
3	50% Filled	3.32	2.77	377.04

4	75% filled	3.68	3.08	420.43
5	Full (100%)	4.04	3.39	463.83

Table6.5: Results of base shear and nodal displacement of k-type bracing in staging

SR.NO.	Tank condition	Displcement (mm)		Base shear (kN)
		Node No:78	Node No:14	
1	Empty (0%)	2.03	2.49	301.38
2	25% Filled	2.83	2.31	344.77
3	50% Filled	3.16	2.59	388.17
4	75% filled	3.49	2.87	431.57
5	Full (100%)	3.82	3.16	474.96

Table6.6: Results of base shear and nodal displacement of v-type bracing in Staging

SR.NO.	Tank condition	Displcement (mm)		Base shear (kN)
		Node No:78	Node No:14	
1	Empty (0%)	2.52	2.07	300.36
2	25% Filled	2.87	2.36	343.76
3	50% Filled	3.2	2.64	387.16
4	75% filled	3.55	2.93	430.55
5	Full (100%)	3.89	3.22	473.95

Table6.7: Results of base shear and nodal displacement of alternate cross bracing in staging

SR.NO.	Tank condition	Displcement (mm)		Base shear (kN)
		Node No:78	Node No:14	
1	Empty (0%)	3.54	3.14	279.92
2	25% Filled	4.07	3.63	323.32
3	50% Filled	4.6	4.11	366.72
4	75% filled	5.15	4.59	410.12
5	Full (100%)	5.66	5.08	453.51

Table6.8: Results of base shear and nodal displacement of alternate chevron bracing in staging

SR.NO.	Tank condition	Displcement (mm)		Base shear (kN)
		Node No:78	Node No:14	
1	Empty (0%)	3.86	3.49	272.12

2	25% Filled	4.45	4.05	315.52
3	50% Filled	5.06	4.16	358.92
4	75% filled	5.66	5.16	402.31
5	Full (100%)	6.27	5.72	445.71

Table6.9: Results of base shear and nodal displacement of alternate diagonal bracing in staging

SR.NO.	**Tank condition**	**Displcement (mm)**		**Base shear (kN)**
		Node No:78	Node No:14	
1	Empty (0%)	4.27	3.85	261.9
2	25% Filled	4.96	4.49	305.3
3	50% Filled	5.64	5.12	348.7
4	75% filled	6.33	5.75	392.09
5	Full (100%)	7.02	6.39	435.49

Table6.10: Results of base shear and nodal displacement of alternate k-type bracing in staging

SR.NO.	**Tank condition**	**Displcement (mm)**		**Base shear (kN)**
		Node No:78	Node No:14	
1	Empty (0%)	4.09	3.67	272.63
2	25% Filled	4.73	4.25	316.02
3	50% Filled	5.36	4.82	359.42
4	75% filled	5.99	5.41	402.82
5	Full (100%)	6.63	5.98	446.22

Table6.11: Results of base shear and nodal displacement of alternate v-type bracing in staging

SR.NO.	**Tank condition**	**Displcement (mm)**		**Base shear (kN)**
		Node No:78	Node No:14	
1	Empty (0%)	4.1	3.66	272.12
2	25% Filled	4.73	4.24	315.52
3	50% Filled	5.36	4.81	358.92
4	75% filled	5.99	5.39	402.31
5	Full (100%)	6.63	5.97	445.71

Following are the summerised results and graphs for base shear and nodal displacement of circular water tank with different types of bracing systems in staging for empty, 25%, 50%, 75, and full condition of container.

6.2: Base Shear of Different Bracing System

Following are results of base shear shown figure6.3 and table6.12 of circular water tank for empty, 25%, 50%, 75, and full with staging without inclined bracing, staging with cross bracing, staging with chevron bracing, staging with diagonal bracing, staging with k-type bracing, staging with v-type bracing.

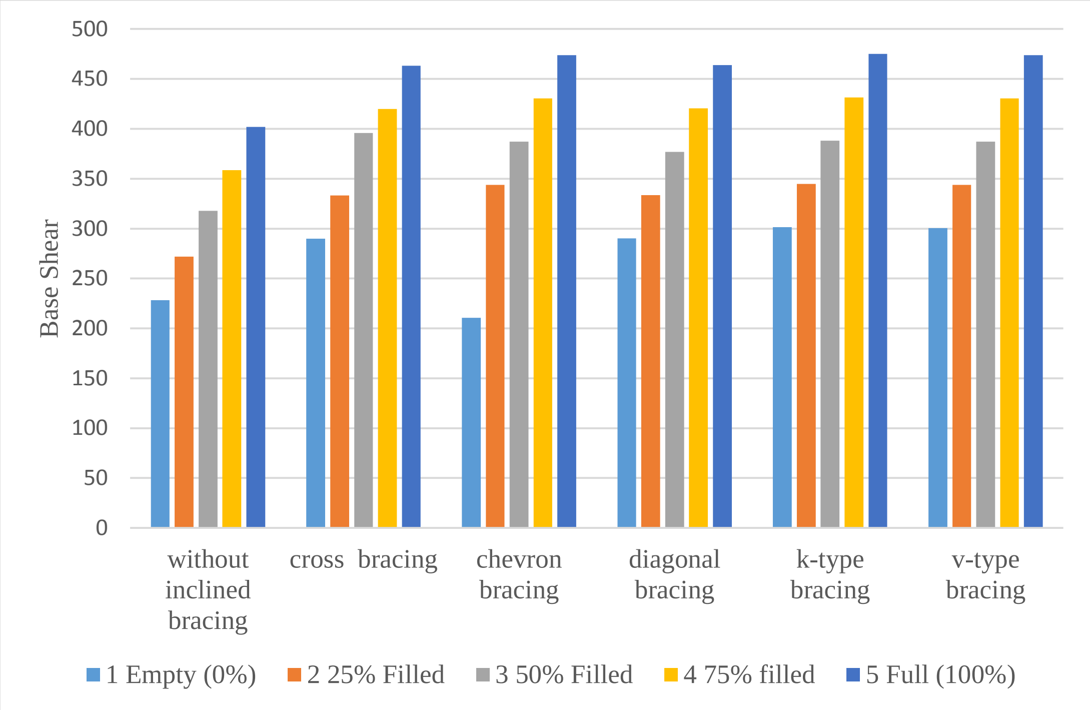


Figure6.3:Bar chart of base shear for different bracing system for empty, 25%, 50%, 75, and full of tank.

Table6.12:Base shear of different bracing system for empty, 25%, 50%, 75, and full condition of tank.

SR.NO.	Tank condition	Base shear in kN for					
		Without inclined bracing	**Cross bracing**	**Chevron bracing**	**Diagonal bracing**	**K-type bracing**	**V-type bracing**
1	Empty (0%)	228.41	289.79	210.61	290.24	301.38	300.36
2	25% Filled	271.81	333.19	343.76	333.64	344.77	343.76
3	50% Filled	317.91	395.76	387.16	377.04	388.17	387.16
4	75% filled	358.6	419.98	430.55	420.43	431.57	430.55
5	Full (100%)	402	463.38	473.95	463.83	474.96	473.95

6.3 :Displacement of Different Bracing System .

It is scrutinize that maximum displacement is occures in 1.5(DL+EQX) loading combination for all types of bracing system. Critical loading combination is 1.5(DL+EQX) and displacement values are detect at node No. 78 and 14.

Following are results of displacement of node No.78 & 14 in x-direction of circular water tank shows figure.6.4, 6.5 & table6.13 for empty, 25%, 50%, 75, andfull with staging without inclined bracing, staging with cross bracing, staging with chevron bracing, staging with diagonal bracing, staging with k-type bracing, staging with v-type bracing.

Figure6.4:Bar chart of displacement for different bracing system for empty, 25%, 50%, 75, and full condition of tank for node 78.

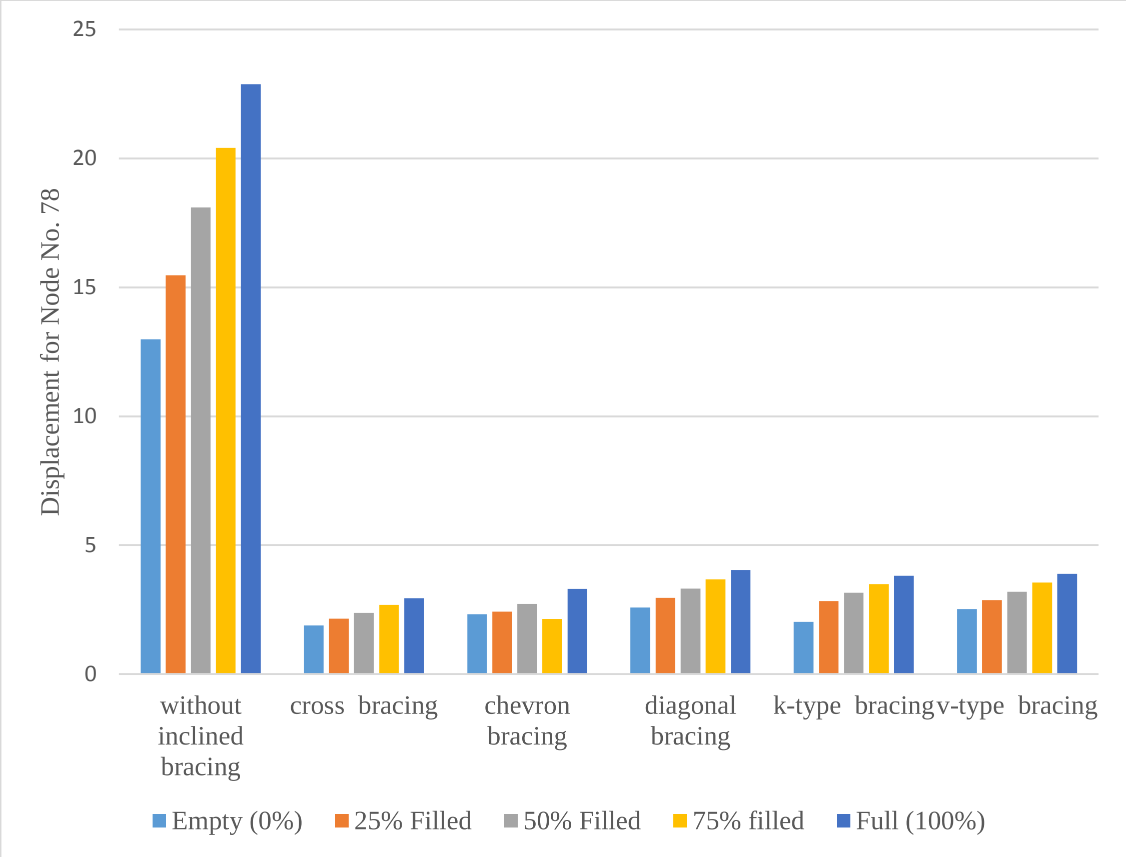


Figure6.5:Bar chart of displacement for different bracing system for empty, 25%, 50%, 75, and full condition of tank for node 14

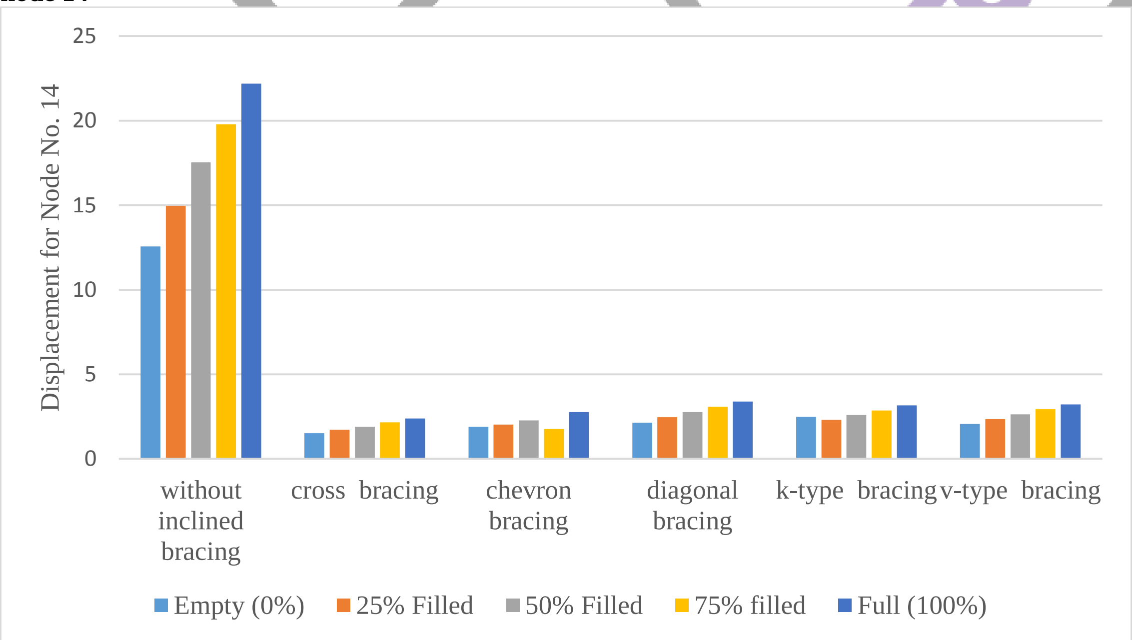


Table6.13: Displacement for different bracing system for empty, 25%, 50%, 75, and full condition of tank.

SN	Displacement in mm for						
	Tank condition	**Without inclined bracing**	**Cross bracing**	**Chevron bracing**	**Diagonal bracing**	**K-type bracing**	**V-type bracing**

	Node no	78	14	78	14	78	14	78	14	78	14	78	14
1	Empty (0%)	12.98	12.56	1.89	1.51	2.32	1.9	2.59	2.15	2.03	2.49	2.52	2.07
2	25% Filled	15.46	14.97	2.15	1.73	2.43	2.03	2.96	2.46	2.83	2.31	2.87	2.36
3	50% Filled	18.1	17.54	2.37	1.9	2.72	2.27	3.32	2.77	3.16	2.59	3.2	2.64
4	75% filled	20.41	19.79	2.68	2.17	2.14	1.77	3.68	3.08	3.49	2.87	3.55	2.93
5	Full (100%)	22.88	22.2	2.94	2.38	3.3	2.77	4.04	3.39	3.82	3.16	3.89	3.22

6.4:Base Shear of Different Alternate Bracing System.

Following are results of base shear of circular water tank shown figure6.6 and table6.14 for empty, 25%, 50%, 75, and full conditions with staging without inclined bracing, 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.

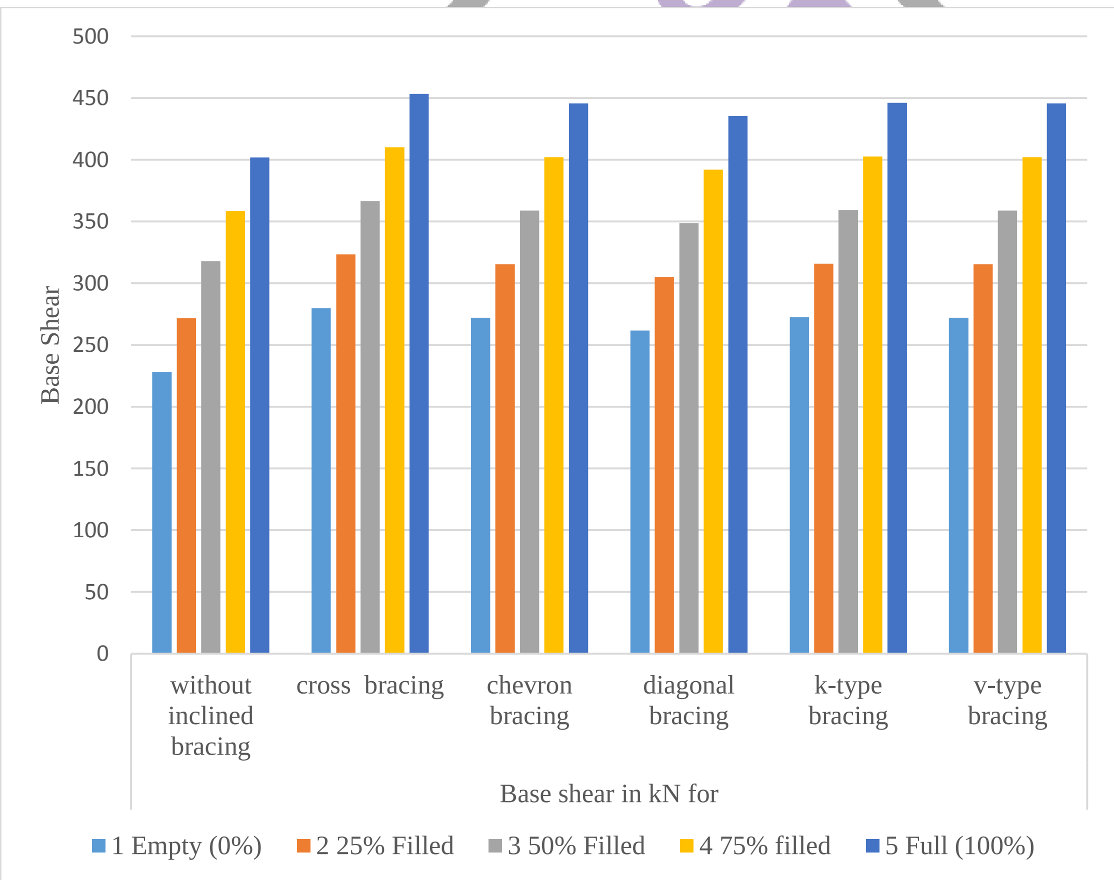


Figure6.6:Bar chart of base shear for different alternate bracing system for empty, 25%, 50%, 75, and full condition of tank

Table6.14:Base shear for different alternate bracing system for empty, 25%, 50%, 75, and full condition of tank

SR.NO.	Tank condition	Base shear in kN for					
		Without inclined bracing	Cross bracing	Chevron bracing	Diagonal bracing	K-type bracing	V-type bracing
1	Empty (0%)	228.41	279.92	272.12	261.9	272.63	272.12
2	25% Filled	271.81	323.32	315.52	305.3	316.02	315.52
3	50% Filled	317.91	366.72	358.92	348.7	359.42	358.92
4	75% filled	358.6	410.12	402.31	392.09	402.82	402.31
5	Full (100%)	402	453.51	445.71	435.49	446.22	445.71

6.5:Displacement of Different Alternate Bracing System

Following are results of displacement shown figure6.7,6.8 and table6.15.for empty, 25%, 50%, 75, and full conditions with staging without inclined bracing, 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.

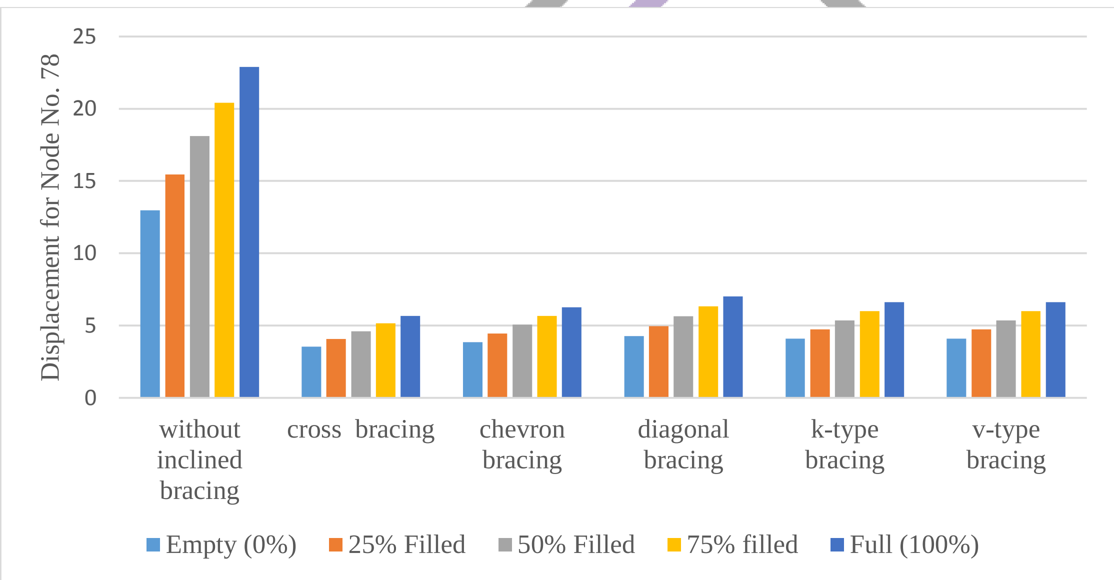


Figure6.7:Bar chart of displacement for different altrnate bracing system for empty, 25%, 50%, 75, and full condition of tank for node 78

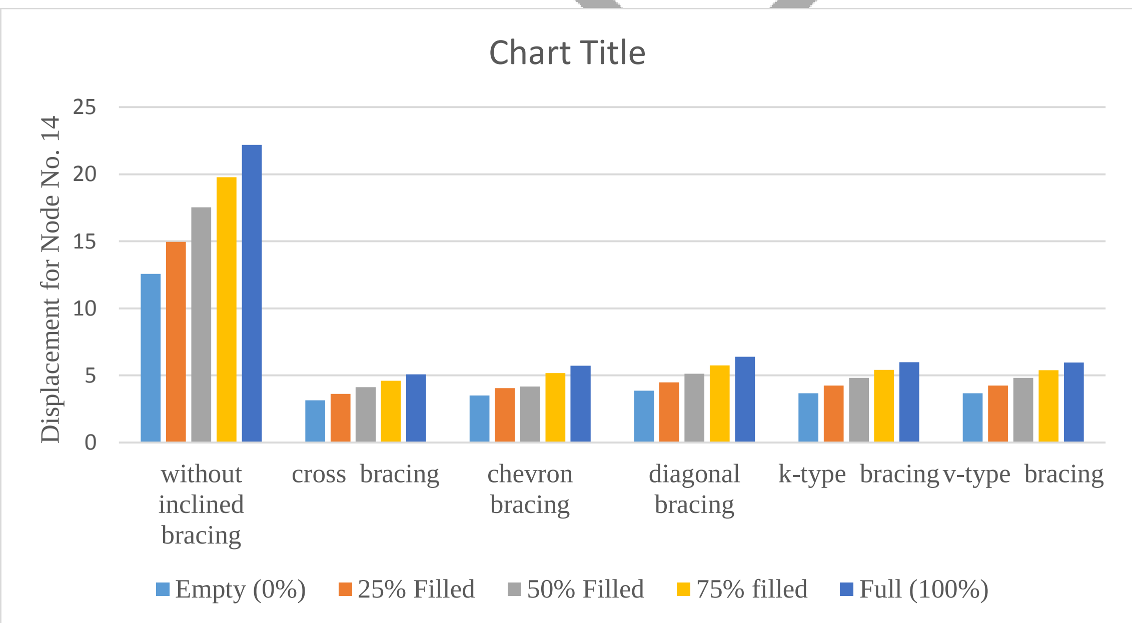


Figure6.8:Bar chart of displacement for different altrnate bracing system for empty, 25%, 50%, 75, and full condition of tank for node 14.

Table6.15: Displacement for different alternate bracing system for empty, 25%, 50%, 75, and full conditions of tank.

SN	Displacement in mm for Alternate												
	Tank condition	**without inclined bracing**		**cross bracing**		**chevron bracing**		**diagonal bracing**		**k-type bracing**		**v-type bracing**	
	Node no	78	14	78	14	78	14	78	14	78	14	78	14
1	Empty (0%)	12.98	12.56	3.54	3.14	3.86	3.49	4.27	3.85	4.09	3.67	4.1	3.66
2	25% Filled	15.46	14.97	4.07	3.63	4.45	4.05	4.96	4.49	4.73	4.25	4.73	4.24
3	50% Filled	18.1	17.54	4.6	4.11	5.06	4.16	5.64	5.12	5.36	4.82	5.36	4.81
4	75% filled	20.41	19.79	5.15	4.59	5.66	5.16	6.33	5.75	5.99	5.41	5.99	5.39
5	Full (100%)	22.88	22.2	5.66	5.08	6.27	5.72	7.02	6.39	6.63	5.98	6.63	5.97

CHAPTER 7

CONCLUSIONS

7.1 CONCLUSIONS:

In this project, emphasis is given on the study of the in-built feature of solving seismic coefficient method in STAAD.pro V8i. This method provide the values of Displacement and base shear, which are very much in agreement with the values of the manually calculated results (section 4.1 and section 4.2).

[1] Parametric study is carried out by using different patterns of bracings in staging of an elevated water tank. From the figure 6.7 and table 6.14, it is clear that the base shear value, reduces for alternate bracing pattern in staging. This is apparent because of the reduction of overall stiffness of the structure.
[2] The figure 6.7 and table 6.15 reveals displacement values of top node(78) of container of tank,where as The figure6.8 and table 6.15 reveals displacement values of bottom node(14) of container of tank .
[3] Though it is evident that alternate cross bracing pattern gives the minimum value of displacement, but from the construction point of view and economy of overall construction, the alternate diagonal bracing pattern can be suggested.

7.2 FUTURE SCOPE:

Critical anaysis of water tank container considering hydrodynamic effect ,finite element analysis can be carried out Bending moment of wall of container using aforesaid methods can be studied comparison of bending moments with IS:3370 (part-IV) can be thought of dynamic analysis of water tank using different types of bracing pattern in staging. Non linear analysis of complete water tank structure can be carried out**.**

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