www.ijemr.net ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

Volume-7, Issue-3, May-June 2017

International Journal of Engineering and Management Research

Page Number: 199-205

Seismic Behaviour of Elevated Water Tank under Different Staging Pattern

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ABSTRACT

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. This paper presents seismic analysis of elevated water tanks supported on different staging pattern with different tank storage capacities. Here two different supporting systems such as radial bracing and cross bracing are compared with basic supporting system for various fluid level conditions. Tank responses including base shear, overturning moment and roof displacement have been observed, and then the results have been compared and contrasted.

Keywords— Elevated water tanks, Seismic response; STADD pro; Tank Staging

I. INTRODUCTION

`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. 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 economical 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.

The draft code for liquid retaining structures is one of the outcomes of the project.

The present work is an effort to study the structural responses of circular elevated water tank considering different staging arrangements using STADD pro.

1. Damage Observed to Elevated Water Tanks in Bhuj Earthquake (2001) 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.

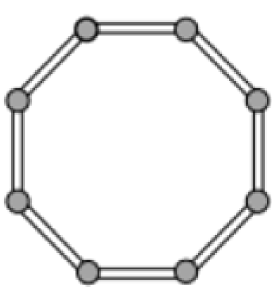
Bhuj earthquake (2001) [2] is the recent example, as shown in figure 1.1&1.2It is observed from the past earthquake; Most of the elevated water tanks undergo damage to their staging.

Figure 1: Collapse of water tank in Bhuj

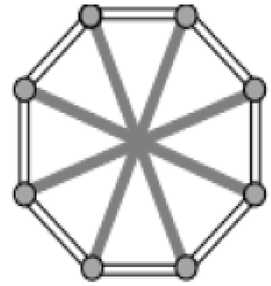
Figure 2: Flexure cracks in staging

II. TYPES OF STAGING SYSTEM USED

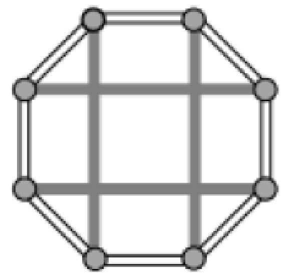
In the present study three types of arrangements have been considered i.e. normal, radial and cross as shown in Figure.



Normal



Radial



Cross

Figure 3: Different types of staging arrangements

III. METHODOLOGY

1 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.

2 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

Ah = Z/2 * I/R * Sa/g (3.2.1)

Where,

Z - Zone factor (Given In Table 2, Page No: 14 In IS: 1893-2002)

I - importance factor depending upon functional use of structure given by hazardous consequences of its failure post earthquake functional needs, historical value or economical importance (Table No 1, Page No 19 In IS: 1893-2002 part-II)

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 2, Page No : 20 In IS:1893-2002 part-II)

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

VB = Ah * W (3.2.2)

VB = design seismic base shear

W = seismic weight of container. (As per 7.4.2 in IS: 1893- 2002)

Table 1 – Importance factor, I

Type of liquid storage tank	I
Tanks used for storing drinking water, non- volatile material, low inflammable petrochemicals etc. and intended for emergency services such as fire fighting Services. Tanks of post earthquake importance	1.5
All other tanks with no risk to life and with negligible consequences to environment, society and economy	1

IV. PARAMETERS OF ELEVATED WATER TANK

Sr NO	PARAMETERS	VALUES
1	Volume of tank	500,800,1000m^3
2	size of top slab	100mm thick
3	size of bottom slab	450mm thick
4	size of top ring beam	300x300 mm
5	size of bottom ring beam	300 x600 mm
6	size of braces	300x300 mm
7	density of concrete	25 kN/sq.m
8	Diameter of tank	10.84,12.68,13.20m
9	Height of tank	5.7,6.6,7m
10	Height of staging	20m
11	Number of columns	10
12	Zone	III
13	Response reduction factor	1.8
15	Importance factor	1.5
16	Type of soil	Medium soil
17	Grade of Concrete & Steel	M25 & Fe415

V. BASE SHEAR ANALYSIS

For radial staging, (500 m^3)

Δ=1.944mm = 1.944*10^{-3}

Stiffness, k=1000/Δ

=1000/1.944*10^{-3}= 5.14*10^6

$A_h = Z/2 * I/R * S_a/g$

Where, I=1.5

Z=0.16

R=1.8 (from IS 1893-partII)

a) For tank empty condition

W=2203.986 KN

$T_e=2\pi\ (m/k)^{1/2}$

$=2\pi\ ((2203.986*10^3)/ (5.14*10^6*9.81))$

= 1.314 sec

From IS 1893-2002

1.36/Te=1.035

Sa/g=1.035

$A_h = Z/2 * I/R * S_a/g$

= 0.16/2*1.5/1.8*1.035

= 0.069

Base Shear,

$V_B= A_h*W$

= 0.069*2203.986*10^3

= 152.12 KN

b) For tank full condition

W=8798.895 KN

$T_e=2\pi\ (m/k)^{1/2}$

$=2\pi\ ((8798.895*10^3)/ (5.14*10^6*9.81))$

= 2.62 sec

From IS 1893-2002

$1.36/T_e$=0.52

S_a/g=0.52

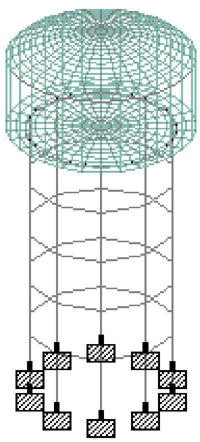
ISSN (ONLINE): 2250-0758, ISSN (PRINT): 2394-6962

$A_h = Z/2 * I/R * S_a/g$
$= 0.16/2*1.5/1.8*0.52$
$= 0.0345$

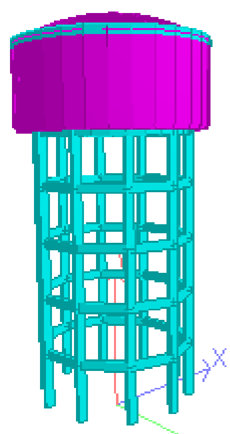
Base Shear,

$V_B = A_h*W$
$= 0.0345*8798.895*10^3$
$= 303.94KN$

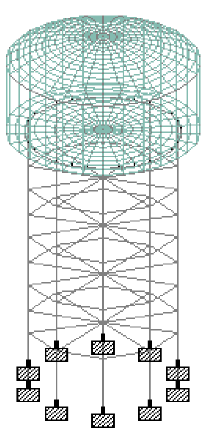
VI. 3D MODELS (FEW SYSTEMS)



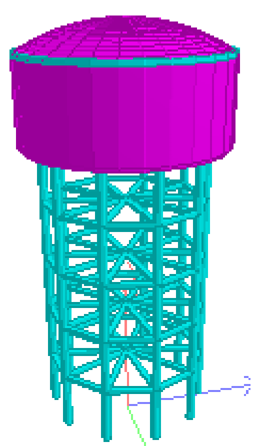
Normal Staging model



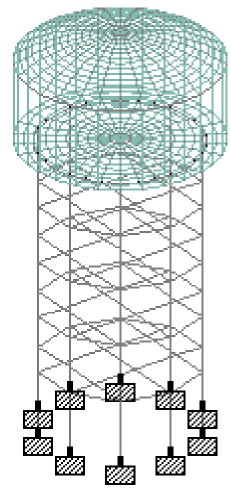
STAAD pro model with Normal staging



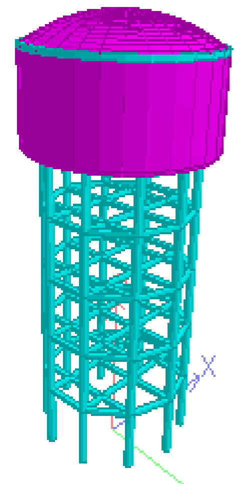
Radial staging model



STAAD pro model With radial staging



Cross staging model



STAAD pro model With cross staging

VII. DATA INTERPRETATION THROUGH GRAPHS

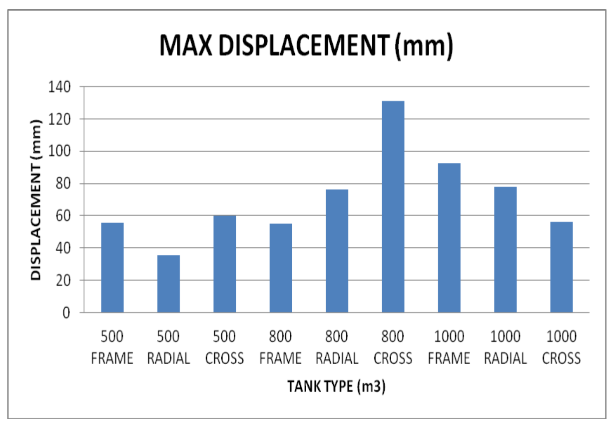


Figure4: maximum displacement variation

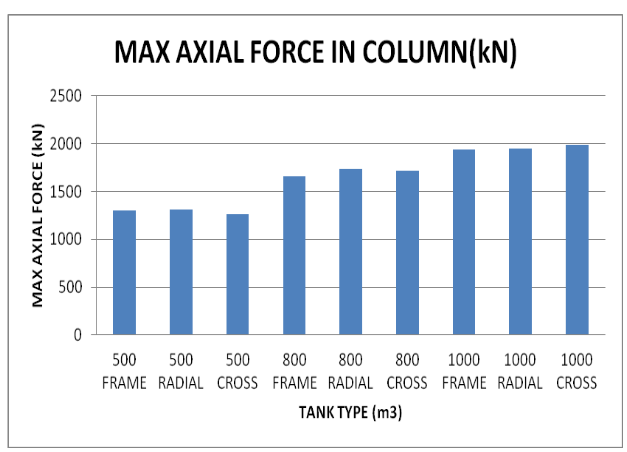


Figure5: maximum axial force in column

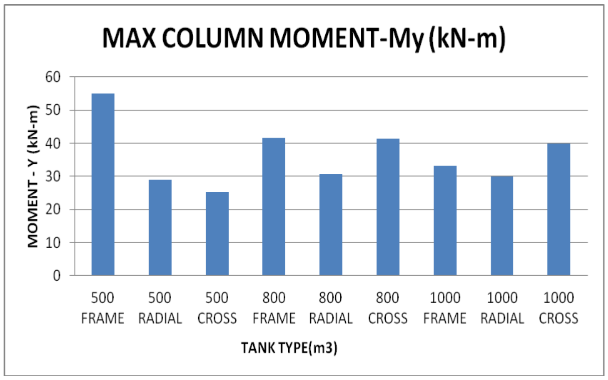


Figure6: maximum column moment

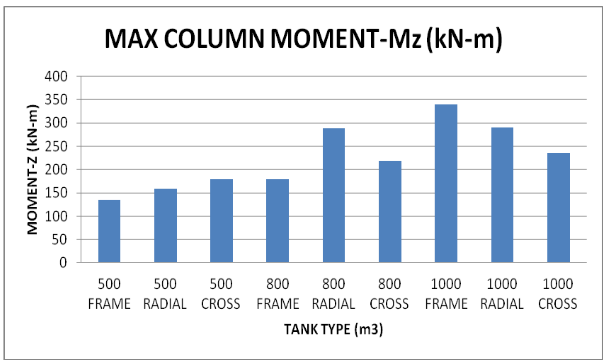
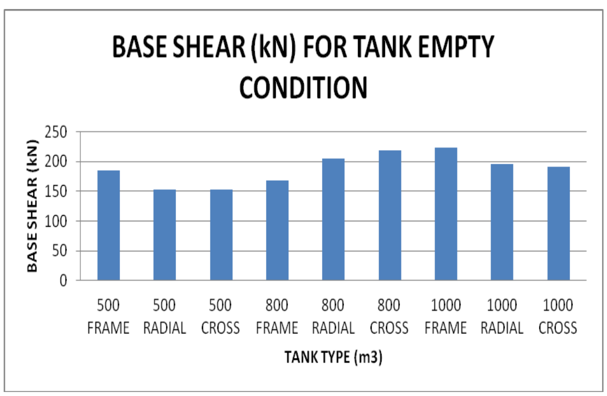


Figure7: maximum column moment



Figur8: Base shear variation for tank empty condition

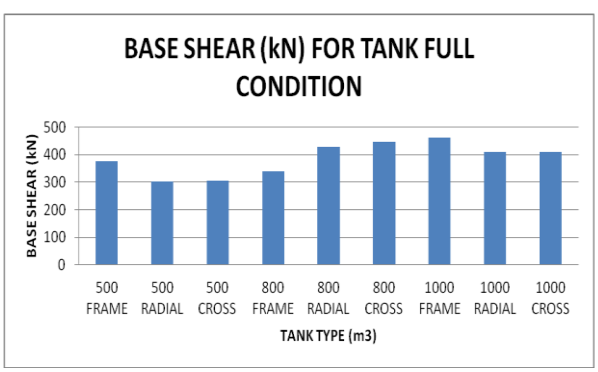


Figure9: Base shear variation for tank full condition

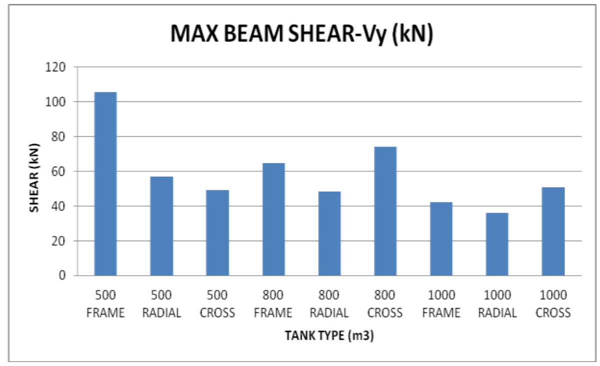


Figure10: maximum base shear

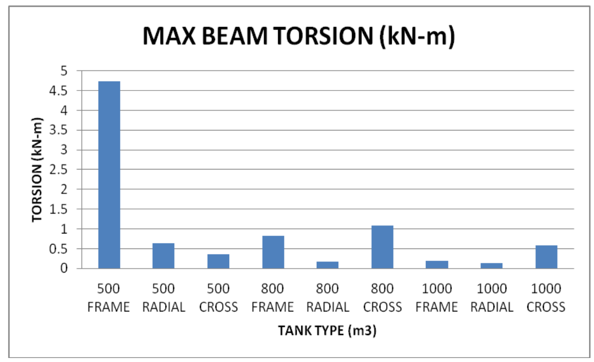


Figure11: Maximum beam torsion

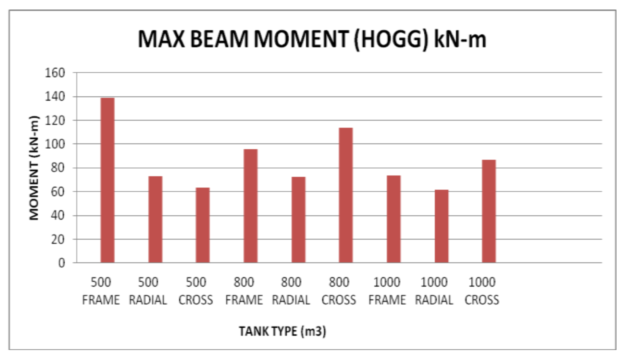


Figure12: maximum beam moment

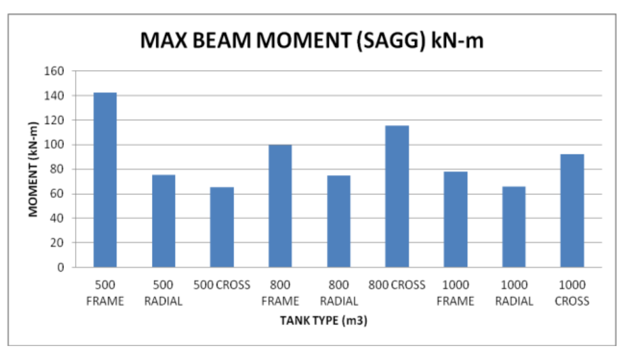


Figure13: Maximum beam moment

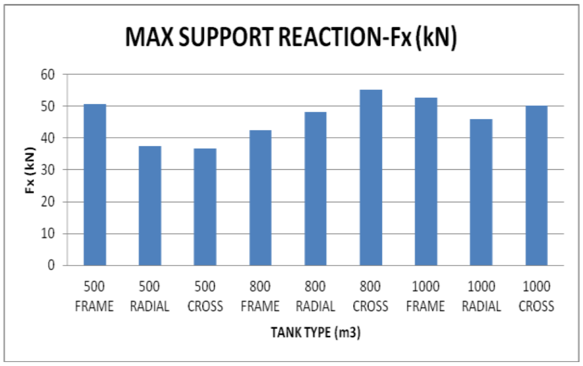


Figure14: Maximum support reaction

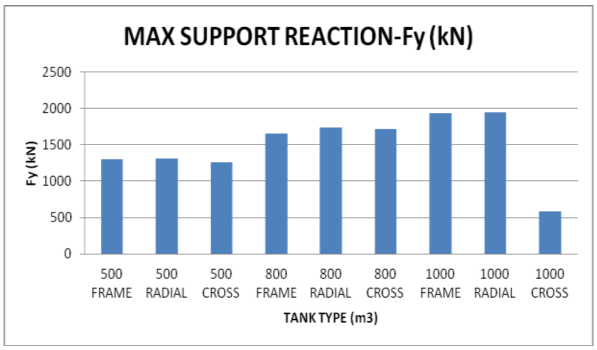


Figure15: Maximum support reaction

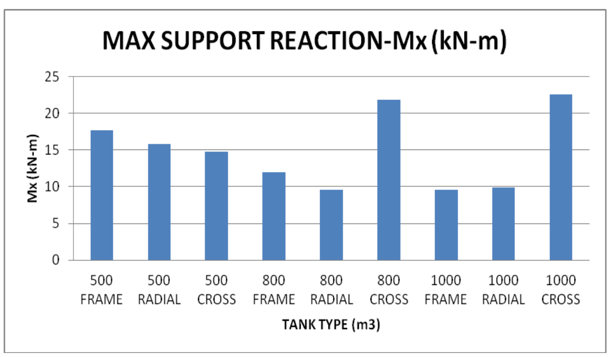


Figure16: Maximum support reaction

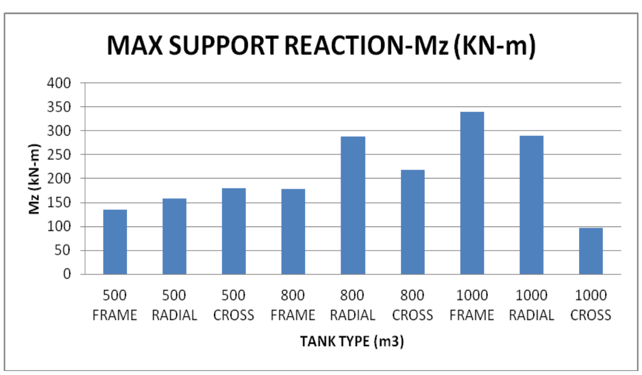


Figure17: Maximum support reaction

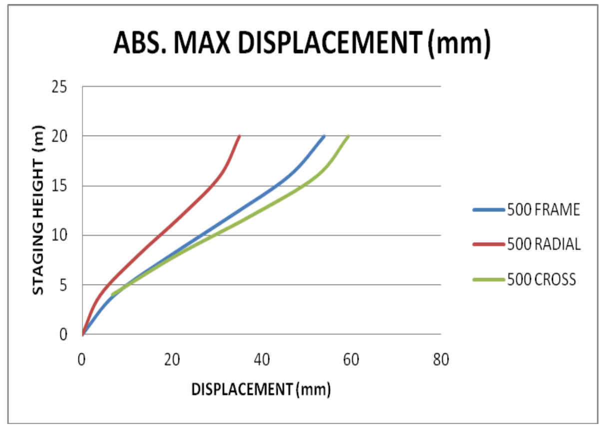


Figure18: maximum displacement variation

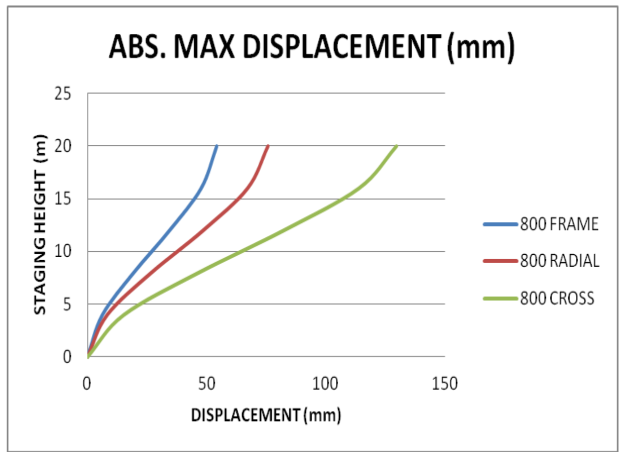


Figure19: maximum displacement variation

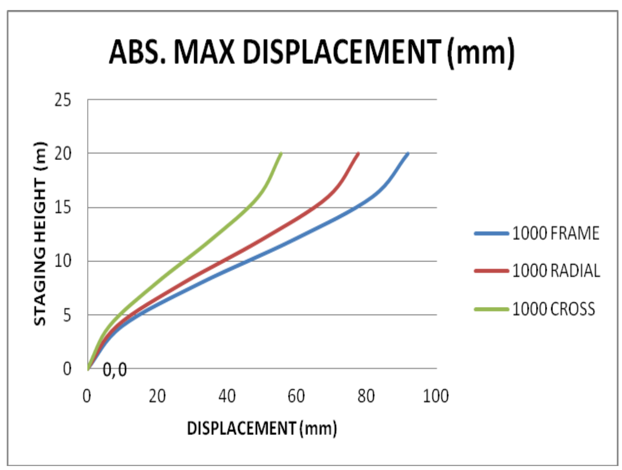


Figure20: maximum displacement variation

VIII. CONCLUSION

From the data revealed by the manual as well as software analysis for an elevated water tank having different staging pattern using seismic coefficient method tried following conclusions are drawn:

1. 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 provides the values of time period and base shear, which are very much in agreement with the values of the manually calculated results.
2. Parametric study is carried out by using different patterns of staging of an elevated water tank.
3. Tank Empty condition has less Base shear and Base moment compared to Full tank condition.
4. Full tank condition shows critical response than empty tank conditions. But we can't neglect empty tank condition.
5. Design of water tank is a very tedious method. Particularly design of elevated cylindrical water tank involves lots of mathematical formulae and calculation. It is also time consuming. Hence Staad – pro gives all results such as base shear, nodal displacement etc. from the analysis immediately.
6. Tank Empty condition has less Base shear and Base moment compared to Full tank condition. Vice versa for the Roof displacement.

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