

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Seismic Investigation of RC Elevated Water Tank for different Types of Staging Systems

Sonali M. Pole¹, Amey R. Khedikar²

P.G. Student, Department of Civil Engineering, Tulsiramji Gaikwad-Patil College of Engineering & Technology,
Maharashtra, India¹

Asst. Professor, Department of Civil Engineering, Tulsiramji Gaikwad-Patil College of Engineering & Technology,
Maharashtra, India²

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 behaviour, 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 behaviour 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 behaviour of different staging, under different loading conditions and strengthening the conventional type of staging, to give better performance during earthquake. 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. Eleven models are used for calculating base shear and nodal displacements for staging using STAAD pro. After calculating base shear and nodal displacements of eleven models for empty & full condition. Three different type of staging systems have been analyzed.

KEYWORDS: Elevated water tank, Staging, bracing, Earthquake effect, Base Shear, Nodal Displacement.

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.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

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.



Fig. 1 Collapse of water tank in Bhuj



Fig. 2 Flexure cracks in staging

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&2. It is observed from the past earthquake; Most of the elevated water tanks undergo damage to their staging.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

II. RELATED WORK

This chapter presents the background to the need for the development of alternative staging with different bracing in elevated water tanks. The available published literature on analysis of elevated water tanks is also briefly reviewed.

[1] 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 2000 software. As known from very upsetting experiences, elevated water tanks were heavily damaged or collapsed during earthquake. This might be due to the lack of knowledge regarding the proper behavior of supporting system of the tank against dynamic effect and also due to improper geometrical selection of staging patterns.

[2] 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 stagings suffered damage and a few collapsed.

[3] Asari Falguni & Prof. M.G.Vanza (2012) has thrown light on the results of an International Journal of Research in Advent Technology, Vol.2, No.2, February 2014 E-ISSN: 2321-96373 analytical investigation of the seismic response of elevated water tanks using friction damper. In this paper, the behavior of RCC elevated water tank is studied with using friction damper (FD). For FD system, the main step is to determine the slip load.

[4] 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.

[5] 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.

III. METHODOLOGY

2.1 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.

2.2 Seismic Coefficient Method

It is a 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 is called zone 2. Therefore factor zones II, III, IV, and V

For calculation of forces due to earthquake following coefficient quantities are required,

A_h = design horizontal seismic coefficient & given by

$$A_h = Z/2 * I/R * S_a/g \quad (2.2.1)$$

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)

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

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

$$VB = Ah * W \quad (2.2.2)$$

VB = design seismic base shear

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

IV. PROBLEM DESCRIPTION

The frame type is the most commonly used staging in practice. The main components of frame type of staging are columns and braces. In frame staging, columns are arranged on the periphery and it is connected internally by bracing at various levels. The staging is acting like a bridge between container and foundation for the transfer of loads acting on the tank. In elevated water tanks, head requirement for distribution of water is satisfied by adjusting the height of the staging portion. A reinforced elevated circular water tank having different staging arrangements has been considered for the present study. Total nine combinations were studied for tank full and empty condition. The storage capacity of water tank is 500,800 and 1000 m³ considering ten number of columns. Finite element model of tank is modeled in STAAD-pro. In the present study three types of arrangements have been considered i.e. normal, radial and cross as shown in Figure 3.

V. 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.

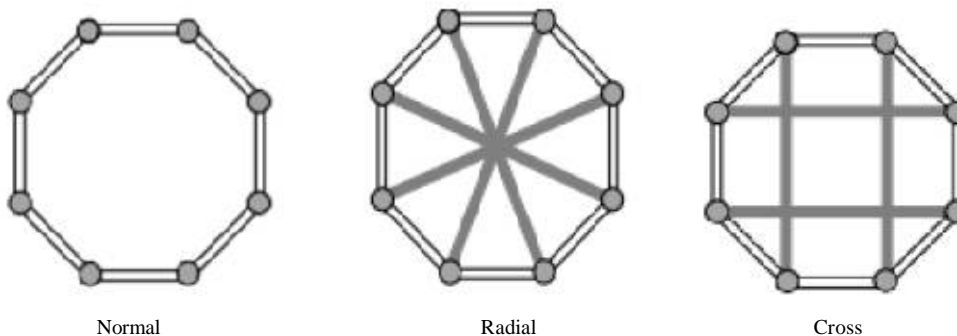


Fig. 3 Different Types of Staging Arrangement

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

VI. PARAMETERS OF ELEVATED WATER TANK

Table 1: Parameters

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

VII. 3D MODELS (FEW SYSTEMS)

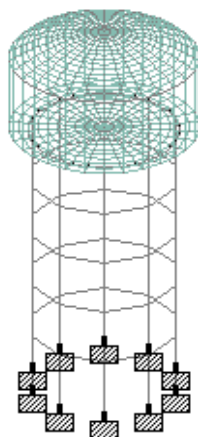
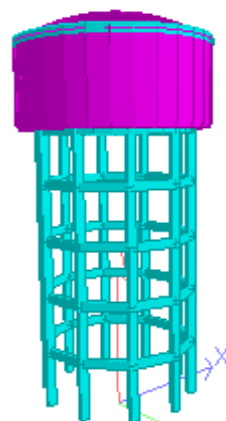


Fig. 4 Normal Staging Model



STAAD Pro Model With Normal Staging

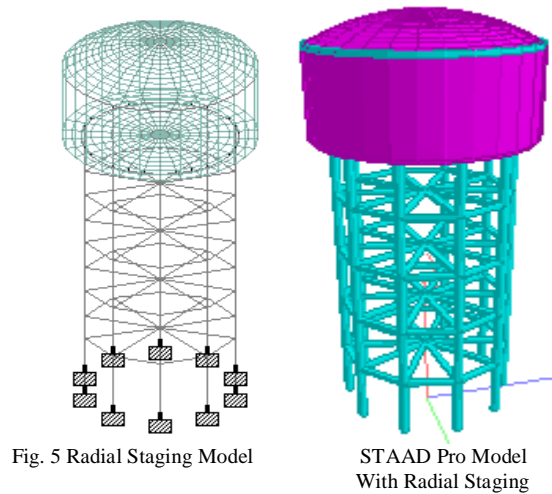
Above figure shows that model of elevated water tank with frame staging having staging height of 20 m and each staging height is 4 m. The support condition is considered as fully fixed and 10 numbers of columns are taken for analysis.

International Journal of Innovative Research in Science, Engineering and Technology

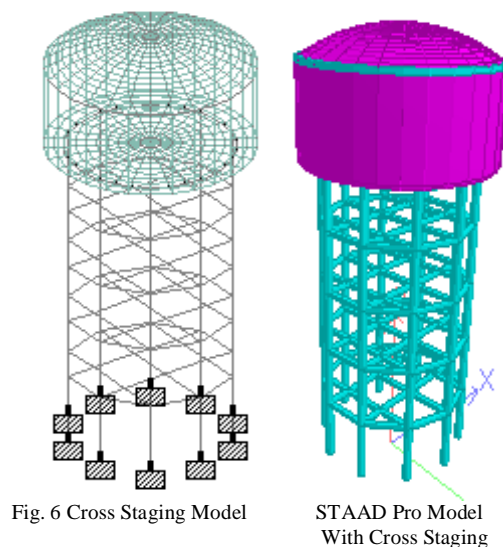
(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017



Above figure shows that model of elevated water tank with radial staging having staging height of 20 m and each staging height is 4 m. The support condition is considered as fully fixed and 10 numbers of columns are taken for analysis.



Above figure shows that model of elevated water tank with cross staging having staging height of 20 m and each staging height is 4 m. The support condition is considered as fully fixed and 10 numbers of columns are taken for analysis.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

VIII. DATA INTERPRETATION THROUGH TABLES & GRAPHS

Table 2: Stiffness variation

Series of models	Tank type (m ³)	Stiffness (kN-mm)
Model I	500 frame	7770000
Model II	500 radial	5140000
Model III	500 cross	5140000
Model IV	800 frame	4400000
Model V	800 radial	6900000
Model VI	800 cross	7490000
Model VII	1000 frame	6710000
Model VIII	1000 radial	5280000
Model IX	1000 cross	5370000

Above table shows that stiffness variation for different tank capacities with different staging pattern. Total nine combinations are observed and analysis is carried out by seismic coefficient method.

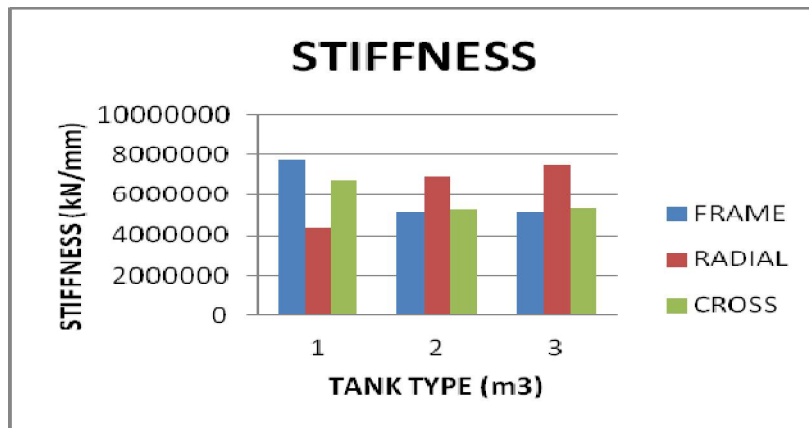


Fig.7 Stiffness variation for different staging arrangements

In above graph, stiffness (kN/mm) is given on y-axis and tank type (m³) i.e. tank having different capacities with different staging pattern. Variation of stiffness along various types of tank is shown in graph. From graph, it is concluded that 500 m³ tank with frame staging having maximum stiffness and least in 800 m³ tank with frame staging. Tank with radial and cross staging is having nearest same values for all tank capacities.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Table 3: maximum displacement variation

Series of models	Tank type (m ³)	Maximum displacement (mm)
Model I	500 frame	55.416
Model II	500 radial	35.676
Model III	500 cross	60.096
Model IV	800 frame	54.82
Model V	800 radial	76.477
Model VI	800 cross	131.055
Model VII	1000 frame	92.58
Model VIII	1000 radial	78.162
Model IX	1000 cross	56.074

Above table shows that maximum displacement variation for different tank capacities with different staging pattern. Total nine combinations are observed and analysis is carried out by seismic coefficient method.

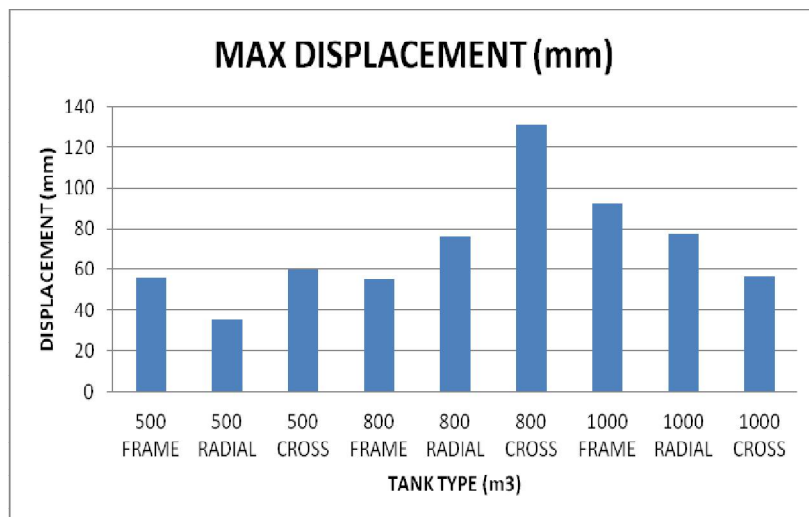


Fig.8 maximum displacement variation

In above graph, tank type (m³) i.e. tank having different capacities with different staging pattern on x-axis and maximum displacement (kN/mm) is given on y-axis. Variation of maximum displacement in various types of tank is shown in graph. From graph, it is concluded that 800 m³ tank with cross staging having maximum displacement and least in 500 m³ tank with radial staging.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Table 4: Base shear variation for tank empty condition

Series of models	Tank type (m ³)	Maximum base shear for tank empty condition (kN)
Model I	500 frame	185.62
Model II	500 radial	152.12
Model III	500 cross	152.12
Model IV	800 frame	168.32
Model V	800 radial	204.52
Model VI	800 cross	219.16
Model VII	1000 frame	223.44
Model VIII	1000 radial	195.71
Model IX	1000 cross	191.67

Above table shows that maximum base shear variation for different tank capacities with different staging pattern for tank empty condition. Total nine combinations are observed and analysis is carried out by seismic coefficient method.

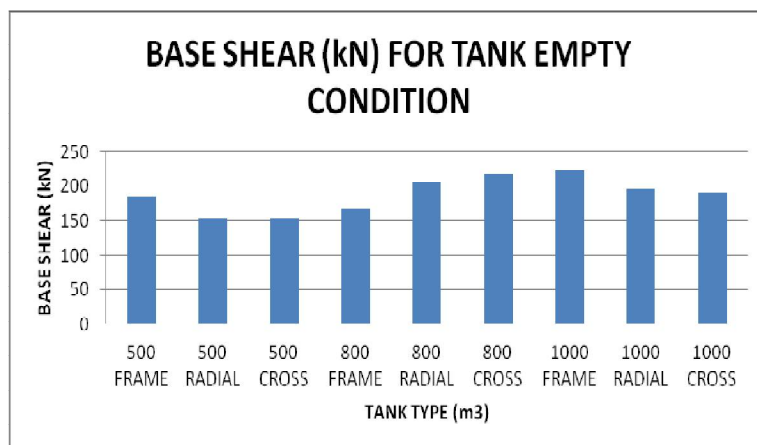


Fig.9 Base shear variation for tank empty condition

In above graph, tank type (m³) i.e. tank having different capacities with different staging pattern on x-axis and maximum base shear (kN) is given on y-axis. Variation of maximum base shear for tank empty condition in various types of tank is shown in graph. From graph, it is concluded that 1000 m³ tank with frame staging having maximum base shear and least in 500 m³ tank with radial and cross staging for tank empty condition.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Table 5: Base shear variation for tank full condition

Series of models	Tank type (m ³)	Maximum base shear for tank full condition (kN)
Model I	500 frame	376.06
Model II	500 radial	303.94
Model III	500 cross	305.44
Model IV	800 frame	339.68
Model V	800 radial	428.39
Model VI	800 cross	446.21
Model VII	1000 frame	461.06
Model VIII	1000 radial	410.43
Model IX	1000 cross	410.53

Above table shows that maximum base shear variation for different tank capacities with different staging pattern for tank full condition. Total nine combinations are observed and analysis is carried out by seismic coefficient method.

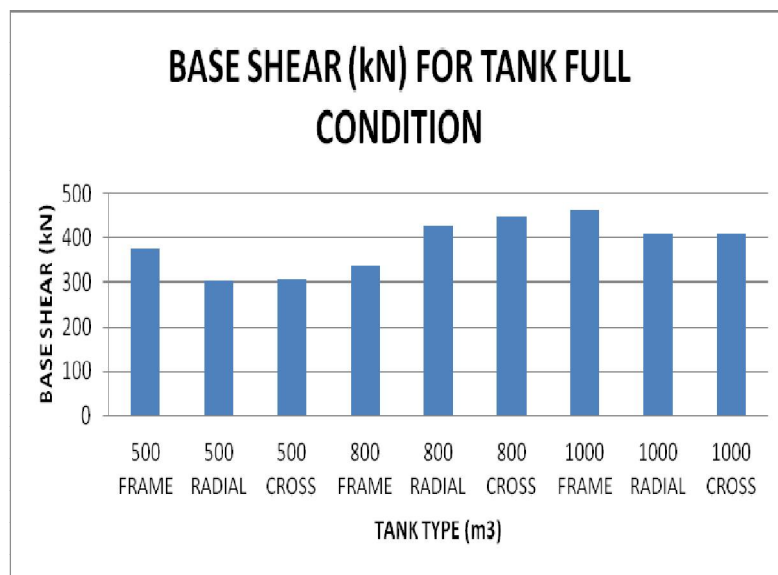


Fig.10 Base shear variation for tank full condition

In above graph, tank type (m³) i.e. tank having different capacities with different staging pattern on x-axis and maximum base shear (kN) is given on y-axis. Variation of maximum base shear for tank full condition in various types of tank is shown in graph. From graph, it is concluded that 1000 m³ tank with frame staging having maximum base shear and least in 500 m³ tank with radial staging for tank empty condition.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Table 6: Abs max displacement

Tank type (m ³)	Staging height	Abs maximum displacement (mm)
500 frame	0	0
	4	7.205
	8	19.747
	12	33.286
	16	46.15
	20	53.968
500 radial	0	0
	4	4.039
	8	12.452
	12	22.09
	16	30.657
	20	34.983
500 cross	0	0
	4	6.644
	8	21.036
	12	37.701
	16	52.275
	20	59.263

Above table shows that absolute maximum displacement variation for various tank staging height. Total nine combinations are observed and analysis is carried out by seismic coefficient method. As the height of staging increases absolute maximum displacement increases.

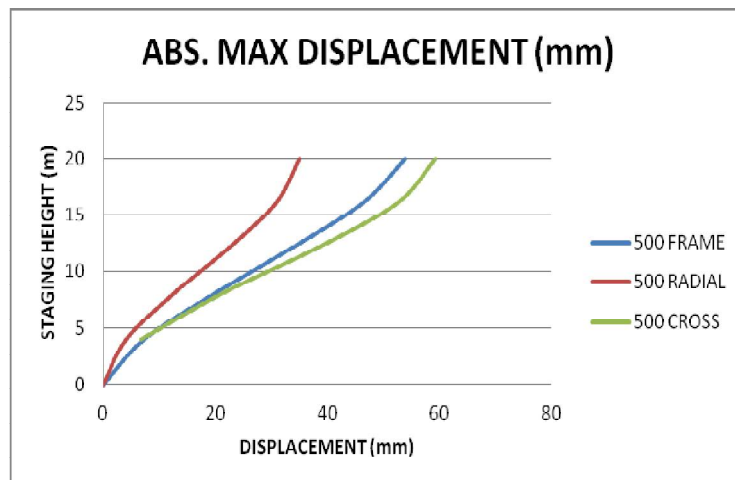


Fig.11 maximum displacement variation

In above graph, displacement (mm) is given on x-axis and staging height (m) on y-axis. Variation of displacement verses staging height is shown in graph. From graph, it is concluded that as height of staging increases absolute

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

maximum displacement increases. The maximum displacement occurs at staging height of 20 m in 500 m³ cross type of model and minimum displacement is in 500 m³ radial type of model at staging height of 4 m.

Table 7: Abs max displacement

Tank type (m ³)	Staging height	Abs maximum displacement (mm)
800 frame	0	0
	4	6.27
	8	19.334
	12	34.303
	16	47.546
	20	54.079
800 radial	0	0
	4	8.283
	8	26.765
	12	48.418
	16	67.084
	20	75.662
800 cross	0	0
	4	15.245
	8	46.603
	12	82.191
	16	113.841
	20	129.622

Above table shows that absolute maximum displacement variation for various tank staging height. Total nine combinations are observed and analysis is carried out by seismic coefficient method. As the height of staging increases absolute maximum displacement increases.

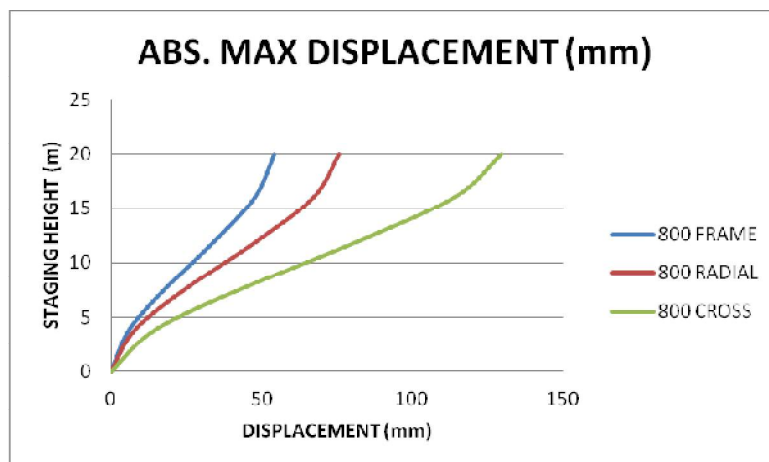


Fig.12 maximum displacement variation

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

In above graph, displacement (mm) is given on x-axis and staging height (m) on y-axis. Variation of displacement verses staging height is shown in graph. From graph, it is concluded that as height of staging increases absolute maximum displacement increases. The maximum displacement occurs at staging height of 20 m in 800 m³ cross type of model and minimum displacement is in 800 m³ frame type of model at staging height of 4 m.

Table 8: Abs max displacement

Tank type (m ³)	Staging height	Abs maximum displacement (mm)
1000 frame	0	0
	4	9.958
	8	32.504
	12	59.046
	16	81.752
	20	91.904
1000 radial	0	0
	4	8.456
	8	27.463
	12	49.786
	16	68.924
	20	77.564
1000 cross	0	0
	4	6.309
	8	19.805
	12	35.378
	16	48.989
	20	55.488

Above table shows that absolute maximum displacement variation for various tank staging height. Total nine combinations are observed and analysis is carried out by seismic coefficient method. As the height of staging increases absolute maximum displacement increases.

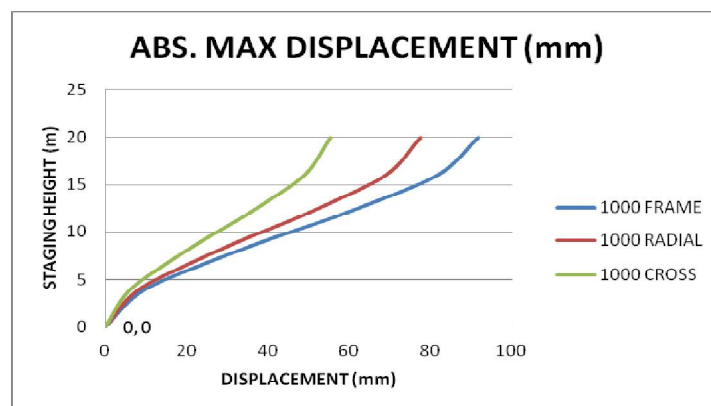


Fig.13 maximum displacement variation

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

In above graph, displacement (mm) is given on x-axis and staging height (m) on y-axis. Variation of displacement verses staging height is shown in graph. From graph, it is concluded that as height of staging increases absolute maximum displacement increases. The maximum displacement occurs at staging height of 20 m in 1000 m³ frame type of model and minimum displacement is in 1000 m³ cross type of model at staging height of 4 m.

IX. 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. Design of water tank is a very tedious method. Particularly design of elevated 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.
4. Tank Empty condition has less Base shear compared to Full tank condition. Vice versa for the displacement.
5. Cross type of arrangement has more deflection than frame and least in radial, and vice versa is the stiffness.
6. For tank full and empty conditions, Base shear is more for frame arrangement then cross and followed by radial type of arrangement.

REFERENCES

- [1] Ayazhussain M. Jabar and H. S. Patel, "Seismic Behavior of RC Elevated Water Tank under Different Staging Pattern and Earthquake Characteristics", International journal of advanced engineering research and studies, IJAERS/Vol. I/ Issue III/April-June, pp.293- 296, 2012.
- [2] Durgesh C Rai, "Performance of Elevated Tanks in Mw 7.7 Bhuj Earthquake of January 26th, 2001", International journal of advanced engineering research Proc. Indian Acad. Sci. (Earth Planet. Sci.), 112, No. 3, pp. 421-429, 2003.
- [3] Asari Falguni, Prof. M.G.Vanza, "Structural Control System for Elevated Water Tank", International journal of advanced engineering research and studies, IJAERS/Vol. I/ Issue III/April-June, 325-328, 2012.
- [4] Hasan Jasim Mohammed, "Economical Design of Water Concrete Tanks", European journal of scientific research, vol.49 no.4 pp. 510-520, 2011.
- [5] IITK-GSDMA "Guidelines for seismic design of liquid storage tanks", National Information Centre for Earthquake Engineering, IIT Kanpur, 2007.
- [6] IS: 1893-2002 (Part I) "Criteria for Earthquake Resistant Design of Structure", Bureau of Indian Standards, New Delhi.
- [7] IS: 1893-2002 (Part II) "Criteria for Earthquake Resistant Design of Structure (Liquid Retaining Tanks)", Bureau of Indian Standards, New Delhi.