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Comparison between RCC and Encased Composite Column Elevated Water Tank

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Abstract : *This paper present the comparative equivalent static and time history analysis of elevated encased composite column water tank is during earthquake. The RCC column staging of elevated water tank can be replace by a encases composite column staging water tank, because the RCC water tank developed the cracks during earthquake, result in loss of their of strength and stiffness, so increase performance of elevated water tank during earthquake to study the behavior of composite elevated water tank. Therefore the parametric studies on mathematical model of six water tank are creating in ETABS software. These are both tank has been create models in an ETABS for a different height from ground level. The Indian draft code part II of IS 1893:2002 which has provision of elevated water tank. The equivalent analysis with regards time periods, base shear, storey stiffness, displacement against height and storey drift.*

Keywords: *Elevated encased composite column water tank, Static analysis, time history analysis, ETABS software. Draft code part II IS 1893:2002.*

I. INTRODUCTION

The significant social and economic impacts of recent earthquakes affecting urban areas have resulted in an increased awareness of the potential seismic hazard and the corresponding vulnerability of the existing elevated storage water tank required for estimating seismic risk. Greater effort has been made to estimate and mitigate the risks associated with these potential losses. In order to successfully mitigate potential losses and to aid in post-disaster decision-making processes, the expected damage and the associated loss in urban areas caused by earthquakes should be estimated with an acceptable degree of certainty. Seismic loss assessment depends on the comprehensive nature of estimating vulnerability. The determination of vulnerability measure requires the assessment of the seismic performances of elevated water tank typically constructed in an urban region when subjected to a series of earthquakes, taking into account the particular response characteristics of each structural type. The fragility study generally focuses on the generic types of construction because of the enormity of the problem. Hence, simplified structural models with random properties to account for the uncertainties in the structural parameters are used for all representative structure types.

II. OBJECTIVES

The objectives of paper to design had been attempted getting optimum section of water tank for comparative equivalent static and non linear dynamic analysis elevated RCC and Encased Composite column water tank has been analyze for full water filled condition. Both tank has been analyze for equivalent static analysis with parameter storey stiffness, bas shear and maximum displacement at top each storey and for non linear dynamic analysis for Bhuj and Kobe earthquake time history records.

III. PROBLEMS STATEMENT

For the study, the twelve water tanks For 250 cum capacity but different staging heights are considered; each water tank is modeled as Reinforced cement concrete and Encased Composite Column water tank. The models which are used in this report are 250 cum capacity with 30m, 40m and 50m staging height from the ground level. The above models are analyzed for static and Time History records of earthquake such as Kobe, Bhuj. The comparative static analysis of both tank for hard soil and seismic zone V. An elevated water tank has Staging height 30m, 40m and 50m from the ground level. The above water tank has been analyzed by static and time history analysis.

Table 1. Designation of water tank model

Model No.	Types of Elevated water tank	Designation
1	Elevated RCC water tank at 30m staging height	RCC 30
2	Elevated composite water tank at 30m staging height	COMP 30
3	Elevated RCC water tank at 40m staging height	RCC 40
4	Elevated composite water tank at 40m staging height	COMP 40
5	Elevated RCC water tank at 50m staging height	RCC 50
6	Elevated composite water tank at 50m staging height	COMP 50

Above the data and models are used for analysis of structure with different such as time periods, storey displacement, storey stiffness, storey drift, storey displacement and base shear for static analysis and time history analysis for maximum displacement and velocity was considered. The general characteristics of structure are as per Table 2. This was given below

Table 2. Description of water tank models

Member size	RCC 30	COMP 30	RCC 40	COMP 40	RCC 50	COMP 50
Distance from ground (m)	30	30	40	40	50	50
Shape of tank	Square	Square	Square	Square	Square	Square
Size (m)	10 x 10	10 x10	10 x 10	10 x 10	10 x10	10 x10
Container height(m)	3	3	3	3	3	3
Roof slab (mm)	120	120	120	120	120	120
Floor slab (mm)	250	250	250	250	250	250
Wall (mm)	200	200	200	200	200	200
Floor beam (mm)	300x 500	ISMB 400	300x 500	ISMB 400	300x 500	ISMB 400
Bracing (mm)	300x 500	ISMB 400	300x 500	ISMB 400	300x 500	ISMB 400
Column size (mm)	300 x 300	250 x 250 Encased with ISMB 200	500 x 500	400 x 400 Encased with ISMB 150	500 x 500	400 x 400 Encased with ISMB 250
Importance factor	1.5	1.5	1.5	1.5	1.5	1.5
Zone factor	V	V	V	V	V	V
Response reduction factor (R)	5	5	5	5	5	5
Soil condition	Hard soil	Hard soil	Hard soil	Hard soil	Hard soil	Hard soil
Materials	M25 and steel Fe 415	M25 and steel Fe 250	M25 and steel Fe 415	M25 and steel Fe 250	M25 and steel Fe 415	M25 and steel Fe 250

Table 3. Earthquake characteristic (Time history records)

Records	Bhuj	Kobe
Magnitude	7.1	6.9
PGA (g)	0.39 g	0.49 g

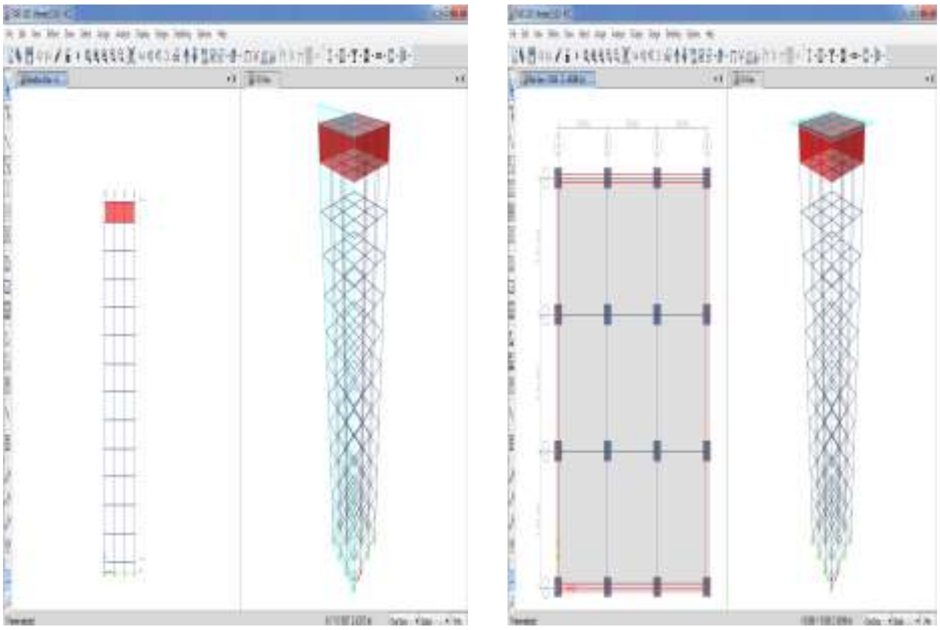


Figure 1: Elevation and plan of Model of RCC and encased column composite water tank in ETABS

A) Effective elastic flexural stiffness

Composite columns may fail in buckling and one important parameter for the buckling design of composite columns is its elastic critical buckling load (Euler Load), P_{cr}, which is defined as follows:

$$P_{cr} = \frac{\pi^2 (EI)_e}{\ell^2}$$

Where,

$(EI)_e$ is the effective elastic flexural stiffness of the composite column.

l is the effective length of the column, which may be conservatively taken as system is length L for an isolated non-sway composite column. However, the value of the flexural stiffness may decrease with time due to creep and shrinkage of concrete. Two design rules for the evaluation of the effective elastic flexural stiffness of composite columns are given below.

The effective elastic flexural stiffness, $(EI)_e$, is obtained by adding up the flexural stiffness of the individual components of the cross-section:

$(EI)_{ex} = E_a I_a + 0.8 E_{cd} I_c + E_s I_s$

where, I_a , I_c and I_s are the second moments of area of the steel section, the concrete (assumed uncracked) and the reinforcement about the axis of bending considered respectively. E_a and E_s are the modulus of elasticity of the steel section and the reinforcement 0.8 $E_{cd} I_c$ is the effective stiffness of the concrete; the factor *0.8* is an empirical multiplier (determined by a calibration exercise to give good agreement with test results).

Note I_c is the moment of inertia about the centroid of the uncracked column section.

$$E_{cd} = E_{cm} / \gamma^*_c$$

E_{cm} is the secant modulus of the concrete, see Table *2* of the text.

γ^*_c is reduced to *1.35* for the determination of the effective stiffness of concrete according to Eurocode *2*.

by this above reference evaluate effective flexural stiffness, $(EI)_{ex}$ and $(EI)_{ey}$ of the cross- section for short term loading from equations

$(EI)_{ex} = E_a I_{ax} + 0.8\ E_{cd} I_{cx} + E_s I_{sx}$

$(EI)_{ex} = E_a I_{ay} + 0.8\ E_{cd} I_{cy} + E_s I_{sy}$

B) Lateral staging Stiffness by using finite element software ETABS:

Lateral stiffness of staging is defined as the force required to be applied at the centre of gravity of tank some so as to get a corresponding unit deflection from the deflection of centre of gravity of the tank due to an arbitrary lateral force one can get the stiffness of staging in elevated composite water tank. ETABS software is used to model the staging.

C) Analysis of Elevated RCC and composite water tank:

Seismic codes are unique to a particular region or country in India, Indian Standard Criteria for Earthquake Resistant Design of Structures IS 1893 (Part-II): 2002 is the main code that provides outline for calculating seismic design force. This force depends on the mass and seismic coefficient of the structure and the latter in turn depends on properties like seismic zone in which structure lies, importance of the structure, its stiffness, the soil on which it rests, and its ductility. The code recommends following methods of analysis.

D) Equivalent static analysis

Here explained 3D building models are analyzed using equivalent static method (linear static method). These methods are briefly described in this section. The lateral forces are determine and then distributed along the height of the elevated water tank as per the empirical equations given in the code. The elevated water tank both ten models of RCC and composite are create and then analyzed by the finite element software ETABS for different parameters such as modal time period, stiffness, drift, base shear and displacement against are studied for all the models. Displacements are found out and inter storey drift and the stiffness is calculated for each storey. Equivalent static analysis is performed on all the models as shown in Figure . Brief description of which is given below.

The weight of the floor slab, roof slab, staging beam, tank bottom beam, wall, column and water is calculated and total seismic weight of the water tank is found out.

$$W = \sum W_i \qquad M_s = \sum m_i + m_s$$

where, M_s = mass of empty container of elevated tank plus one-third mass of staging.

2) The approximate time period (T) **,** in seconds, is estimated by the empirical expression

$$T = 2\pi \sqrt{\frac{m_s}{k_s}}$$

where, k_s = Lateral staging stiffness of elevated tank

3) The design horizontal seismic coefficient A_h for a structure is determined by the following expression

$$A_h = \frac{Z}{2}\frac{I}{R}\frac{S_a}{g}$$

where, Z = Zone factor given in Table 2 of IS 1893 (Part 1): 2002, I = Importance factor given in Table 1 of this standard,
R = Response reduction factor given in Table 2 of this standard, and
Sa/g = Average response acceleration coefficient as given by Fig. 2 and Table 3 of IS 1893(Part 1): 2002 and subject to Clauses 4.5.1 to 4.5.4 of this standard.
4) The total design lateral force or design seismic base shear is determined by the following expression.

$$V = A_h x\ M_s x\ g$$

5) The design base shear computed as above is distributed along the height of water tank as per the following expression

$$Q_i = V_B X \frac{W_i h_i^2}{\sum W_i h_i^2}$$

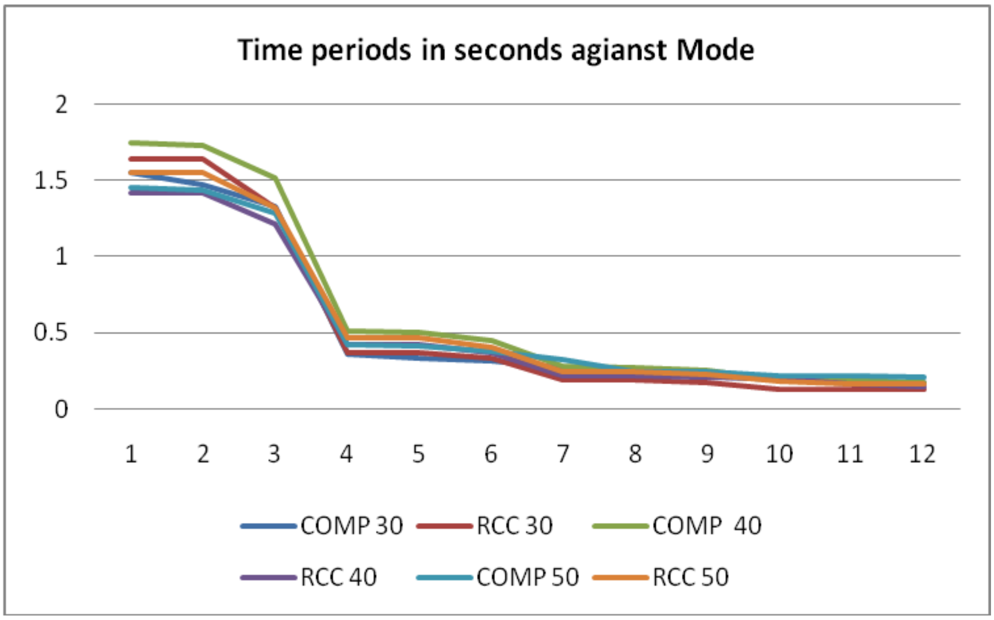
E) Non linear dynamic analysis

It is known as Time history analysis. It is an important technique for structural seismic analysis especially when the evaluated structural response is nonlinear. To perform such an analysis, a representative earthquake time history is required for a structure being evaluated. Time history analysis is a step-by-step analysis of the dynamic response of a structure to a specified loading that may vary with time. Time history analysis is used to determine the seismic response of a structure under dynamic loading of representative earthquake ground acceleration. For this analysis refers two earthquake time history records.

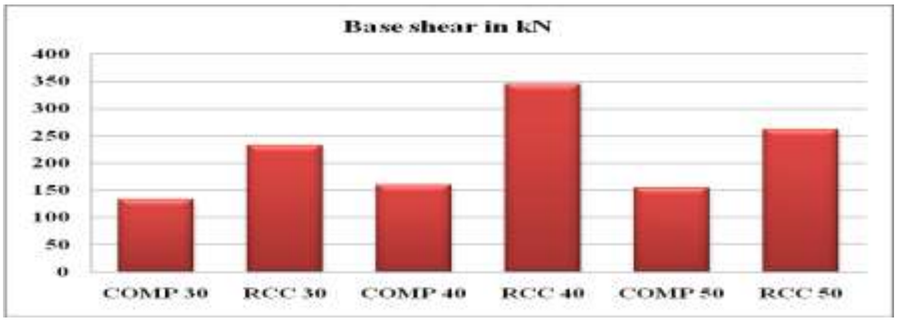
V. Results and Discussion

A) Linear equivalent static analysis

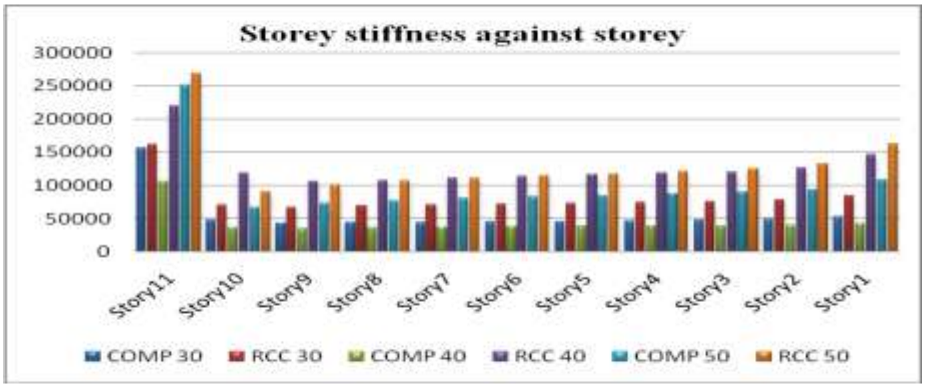
Linear equivalent static analysis is performed is for modal analysis. The significant time period and frequency, base shear, storey stiffness, storey drift and storey displacement for each mode and storey extracted. These are RCC and encased composite column water tank can be compare the systematic ways for comparison between them in the graphical from as shown in Graph 1 to Graph 5 with above said parameters.



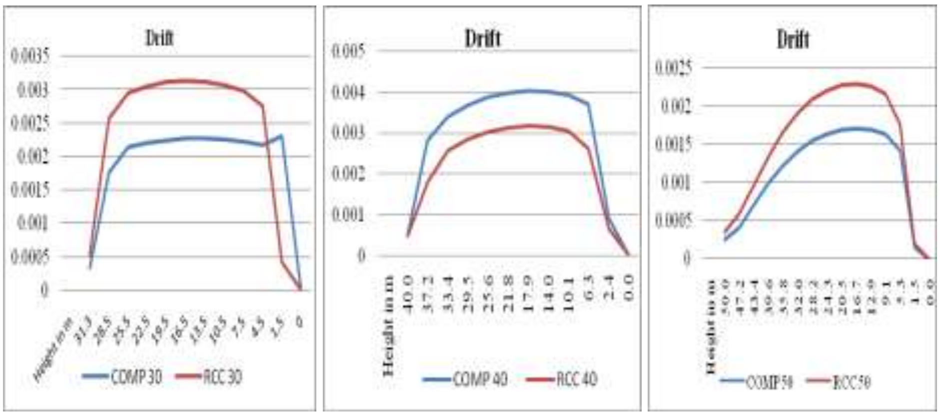
Graph 1. Modal time periods reponse at the top of tank



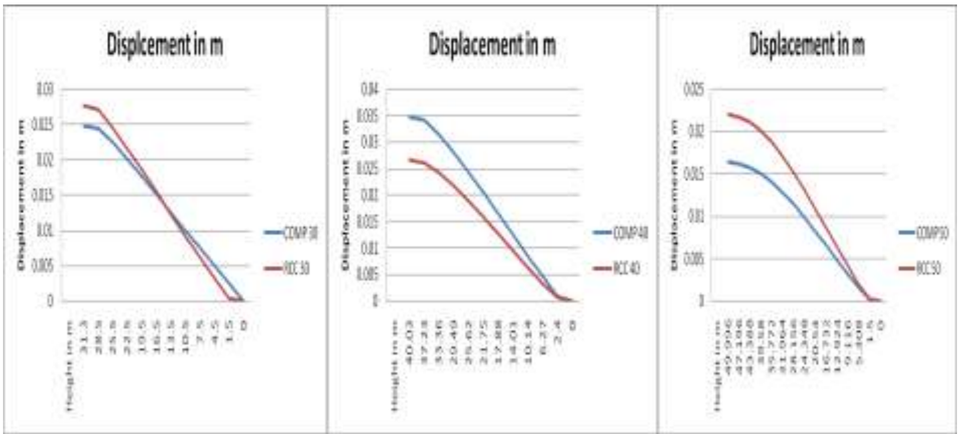
Graph 2. Base shear at the bottom of tank



Graph 3. Storey stiffness between each storey



Graph 4. Storey drift between each storey

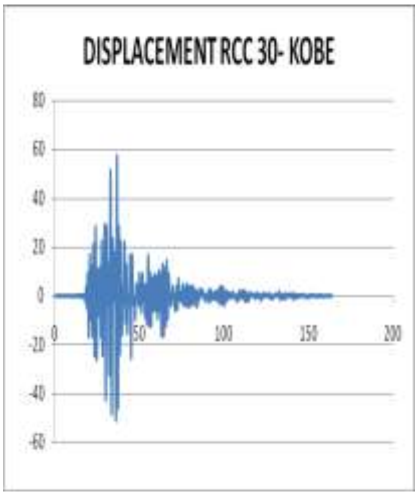


Graph 5. Storey displaecement against height

B) Non liear dynamic analysis (Time History analysis)

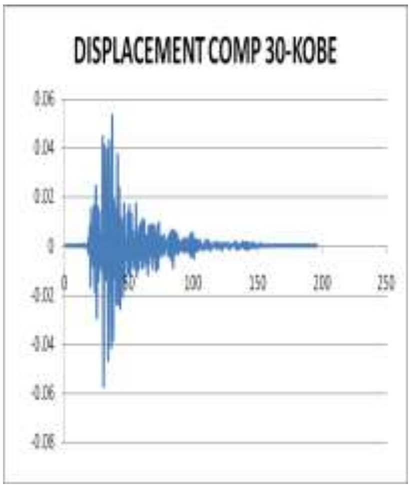
Time history analysis was carried out to study the behaviour of the water tank unde Bhuj, Kobe earthquake s accekeration -time records. Time history analysis was carried out in ETABS software. the peak ground acceration values for Bhuj is 0.39g and Kobe 0.49g. The tme history analysis under maximum displaement and maximum velocity. The results are shown graphically as shown in Graph 6 to Graph 17.

Graph 6. RCC 30 Displacements-Bhuj

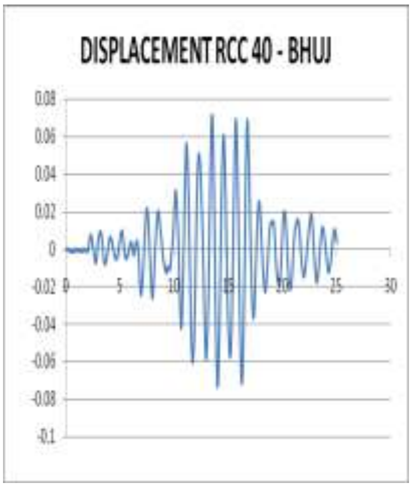


Graph 7. RCC 30 Displacements-Kobe

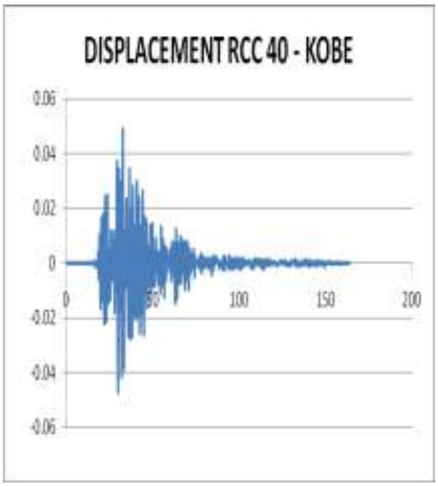
Graph 8. COMP 30 Displacements -bhuj



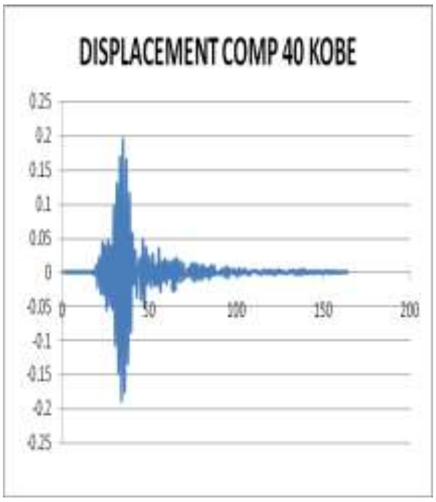
Graph 9. COMP 30 Displacement -Kobe



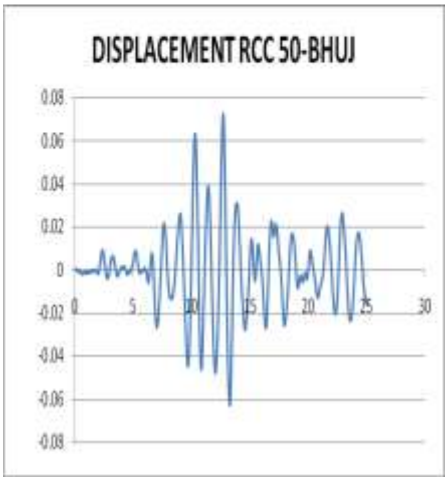
Graph 10. RCC 40 Displacements - Bhuj

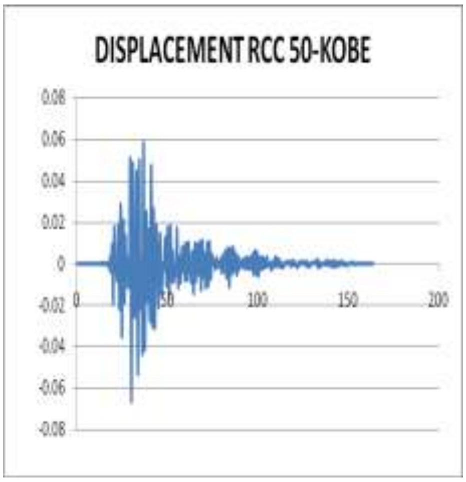


Graph 11. RCC 40 Displacements- Kobe

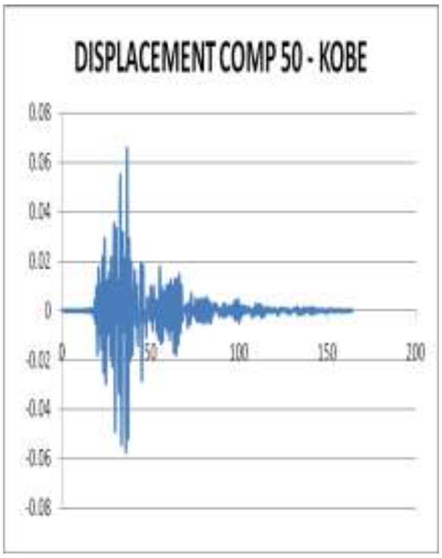


Graph 12. COMP 40 Displacements - Bhuj **Graph 13. COMP 40** Displacements – Kobe





Graph 14. RCC 50 Displacements - Bhuj **Graph 15. RCC 50** Displacements – Kobe



Graph 16. COMP 50 Displacements - Bhuj **Graph 17. COMP 50** Displacements – Kobe

VI. CONCLUSION

In this study, a elevate reinforced cement concrete water tank and elevated encased composite column water tank with 30 m, 40m and 50m supporting height from the ground level has been considered. With considering IS 1893:2002 code provisions for static analysis including modal time periods, storey stiffness, storey drift, base shear and storey displacement for earthquake zone IV and soft soil condition With also considered time history analysis including displacement of tank for comparative analysis obtained result shown in Graph 6 to 15.

The conclude discussion as of elevated encased composite column water tank as compared with Elevated reinforced cement concrete column water tank in percentage shown in tabular form below

Table 4. Obtained result of equivalent static analysis

Method of analysis	**Equivalent static analysis**				
Parameter & staging height from Ground level	**Time periods**	**Storey Stiffness**	**Storey Drift**	**Base shear**	**Storey displacement**
30m	Increased by 18.51%	Decreased by 38%	Decreased by 38%	Decreased by 42.96%	Decreased by 10%
40m	Increased by 5.97%	Decreased by 66%	Decreased by 66%	Decreased by 53.55%	Increased by 30%
50m	Increased by 22.71%	Decreased by 27%	Decreased by 25%	Decreased by 40.84%	Decreased by 25%

Time history Analysis obtained result for maximum displacement of Elevated encased composite water tank as compare with elevated reinforced cement concrete column water tank shown in tabular form in percentage in Table 4.

Table 5. Obtained result maximum displacement for time history records

Method of analysis	**Time history analysis**		
Staging height from G.L.	**30m**	**40m**	**50m**
Bhuj time history records	Decreased by 15.55 %	Decreased by 1.69 %	Increased by 7.05 %
Kobe time history records	Decreased by 7.66 %	Increased by 29.5 %	Increased by 12.70 %

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