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Impact of Revised Code Provisions of Seismic and Wind Loads on RCC Elevated Water Tanks

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***Abstract:** Reinforced concrete elevated water tanks have been reckoned as importance structure for post-earthquake and Post cyclonic emergency service consideration.Certain additional guidelines have been recommended in IS 1893 (Part-2) 2014 Earthquake code and IS 875 (Part-3) 2015Wind load code in cyclonic prone areas of Indian peninsula. Three different capacities of RCC Elevated water tanks have been examined the effects of revised code provisions with the STAAD Pro (v8i) software to assess the internal parameters such as axial force at the ground level, Bending moment, Base Shear force and finally the quantity of steel required. The effect of Zonal classifications is illustrated and finally it can be concluded that the Earthquake design criteria governs when compared to Cyclonic load consideration.*

***Keywords:** IS 1893 (part2) 2014, IS875 (part3) 2015, impulsive and convective methods, k_4 factor,STAAD. Pro (V8i), RCC Elevated water tanks.*

I. INTRODUCTION

Elevated water tanks are the lifeline structures that must be designed to withstand. The life line structures are defined as the strictures should remain functional even during/ after the disaster viz., Earthquake or cyclone occurs. Elevated water tank is a storage facility structure supported by columns connected with horizontal bracings at regular interval. Water tanks have been classified as circular, rectangular or square type cross sections. The floors of tanks are either flat or conical shape. For small storage capacity tanks, square in plan is economical whereas for large capacities circular tanks are more economical. The tanks are constructed in the range of 10 m to 25 m height above the existing ground level. The terrain roughness and height of structure factor (k2 factor) for determining the wind loads of structures is varying when the height of structure is more than 10 m height .More over mass of tanks have considerable effect on seismic forces, hence elevated R.C.C water tanks have been designed for both wind and seismic loads. As the research works throw the some new importance factors for design of the structures The Indian standard code has constantly revising the Earthquake and Wind load codes. The IS 1893 code was revised in 2014 and wind code IS 875(Part 3) is revised in 2015. Hence this paper has made an attempt to communicate the effect of revised code recommendations on three specific storage capacities of R.C.C elevated water tanks.

II. LITERATURE REVIEW

In this section the literature of both earthquake and cyclonic regions are elucidated

P.L.N.Saroja et.al analysed the elevated water tanks in both impulsive and convective mode for IS 1893 (Part 1 & 2) 2002 code provisions for tank full and empty conditions . It was concluded that the IS 1893 (Part1)2002 renders the heavier section sizes when compared with Part 2 provisions of 2002 versions.

V. Sokolov studied the difference between Fourier-acceleration spectra, earthquake magnitude and distance that are used for different seismic regions ie., the Caucasus and Taiwan island on the basis of ground motion recordings of moderate earthquakes. It has been found that the acceleration spectra of most significant part of the records, starting from S-wave arrival, can be modeled accurately by the Brune;s “w-squared” point-source model. The calculations of peak ground acceleration and response spectra for rock site condition are done using stochastic simulation technique and obtained models of source spectra.

S.C. Dutta et.al investigated the torsional response of staging under seismic excitation and Closed-form expressions was proposed

M. Moslemi et.al studied to analyse elevated structures with Time history and modal analysed for the response of impulsive and convective components. and adjudged that performace of contemporary methiods configures better results. .

Kasim A. Korkmaz et.al studied storage tanks with time history, fragility analyses in Turkish code . The vulnerability of storage tanks were determined and also risk was identified .

R. Ghateh et.al designed forty eight model configurations with push over the author recommend the to use the differnt seismic response factors depending on the height to diameter ratio .

Sekhar Chandra Dutta et.al made some conclusions for not empahsisng the some parameters viz., , dynamic characteristics of elevated tanks since the parameter can effect the soil-structure interaction (SSI) Torsional vulnerability of shaft-supported elevated water tanks is also identified to be marginal as opposed to same for frame supported ones.

M.K. Shrimali and R.S. Jangid while studying the elevated steel water tanks the author opinioned that two-degrees-of-freedom model can give better results..

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M.R. Kianoush et.al investigated the impact of seismic frequency content on the behaviour of fluid rectangular tank system using different seismic motions. The liquid tank systems are considered under the response of both impulsive and convective methods. Six different types of soils are considered under well-recognized seismic zones. Comparison of base shear, base moment and sloshing responses are made using different ground motions by changing the soil properties and concluded that the dynamic behaviour of the fluid-tank-soil system is more y susceptible

EQ Code guide lines

As per IS 1893 (Part 1): 2002 it is clearly stated that for the liquid retaining structures the referred code shall be IS 1893 (Part 2), because of the remaining parts are in revision the code book that shall be used for the liquid retaining structures is IS : 1893 – 1984. In this code impulsive method is used for calculating natural time period and design seismic coefficient to get the base shear near ground and Bending moment. But as per the revised codal provisons of IS 1893 (Part 2): 2014 for the liquid retaining tanks it is mentioned clearly to use both impulsive and convective modes for calculating time period and design seismic coefficient to get the total base shear. With the impulsive and convective modes, base shaer increases

Cyclones and East Coast of India

a) Cyclonic Importance factor

B.Santhosh Kumar, Balaji KVGD, Chandan Kumar Patnaikuni specifically reported the historic developmentof introduction of Cyclonic importance factors in India. To account for cyclonic wind speeds, cyclonic importance factor with 1.0, 1.15 and 1.30 for dwellings, industrial buildings and post-cyclone importance structures respectively were specified by IS 875(PARR3)205 version., The Government of India organization- National Disaster Management Authority (NDMA,2008)- while circulating the management of cyclones guidelines in 2008 suggested the basic wind speed in the cyclonic region shall be increased by a factor 1.30 for designing buildings, cyclone shelters, schools, and other life line structures, thus the wind speed shall be 50m/s x1.30 is 65 m/s, this design wind speed is same as tsunami guidelines.

b) Statement of problem and Research Objectives for EQ consideration and Cyclone prone considerations

From the above literature, it was observed that there have been no studies for the recommended guide lines of revised Earthquake codes water tanks that are elevated or ground supported with capacity more than or equal to 1000KL then it is necessary to perform the impulsive and convective methods and secondly for cyclonic region basic wind speed shall not be more than 50m/s. The IS875-Part3:2015 code has very clearly stated that the wind speed for cyclonic region is to be modified by the K4 factor. Hence this paper presents the analysis for both the methods of considerations.

III. METHODOLOGY

a) Water tanks, Model

Reinforced concrete elevated circular water tanks of capacities 1000kL, 1500kL and 2000kL are modelled in STAAD Pro V8i software for analysis. The elevated water tanks of height from ground level to the bottom of the tank is taken as 18m and were subjected to both the seismic and wind loads. The geometric properties of the tanks are shown in the Table1.

Table 1 Geometric properties Elevated Water tanks

Capacity of the tank	1000kL	1500kL	2000kL
Height of tank wall	4.6m	4.4m	4.4m
Inner diameter of the staging	5.7m	6.4m	6.2m
Middle diameter of the staging	12m	14.4m	12.4m
Middle diameter of the staging	-	-	18.6m
Outer diameter of the staging	18m	22m	24.8m
Height of the tank from ground level up to floor slab	18m	18m	18m
Total height of the tank G.L	22.6m	22.4m	22.4m
Height of the footing upto basement	2m	2m	2m
Columns below water tank	450x450mm	450x450mm	450x450mm
Columns in water tank	230x230mm	300x300mm	300x300mm
Floor Beams	450x650mm	450x750mm	450x750mm
Roof Beams	450x300mm	450x300mm	450x300mm

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Staging Braces	450x350mm	450x450mm	450x450mm
Floor slab	380mm	380mm	420mm
Roof slab	120mm	120mm	120mm
Tank side wall	200mm	200mm	200mm
Grade of concrete	M30	M30	M30
Grade of steel	Fe 415	Fe 415	Fe 415

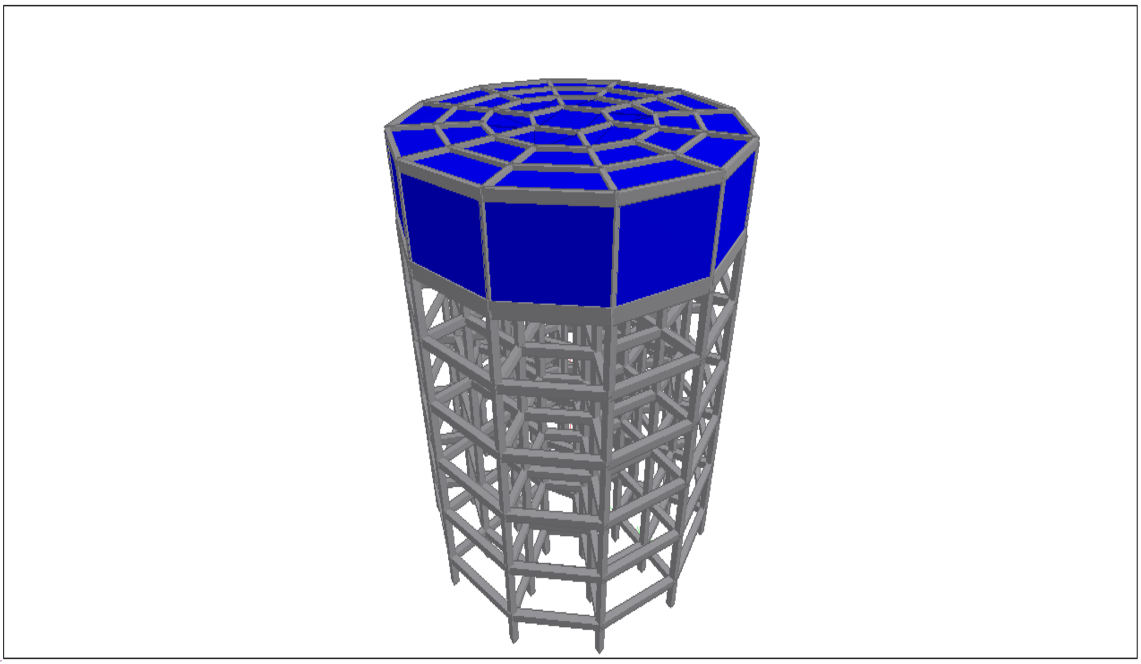

Figure 1 STAAD model of RCC Elevated water tank

Load consideration and design procedure

b) Design Seismic coefficient considered (as per IS 1893 (Part-1):2002 and IS 1893 (Part-2):2014)

As per IS 1893 (part-2) 2002 and 2014 illustrated that total base shear “V” acting on Water tank is computed from Eq (1 to 6).

$$T_i=\frac{2\pi\sqrt{m_i+m_c}}{K_s} \qquad (1)$$

Where,

m_s = mass of empty container and one – third mass of staging and K_s = lateral stiffness of staging,T_i = Time period in impulsive mode, T_c= Time period in convective mode.

$$T_c=2\pi\sqrt{\frac{m_c}{K_c}} \qquad (2)$$

Base shear (V)

$$V_i = (A_h)_i(m_i+m_s)g \qquad (3)$$

$$V_c = (A_h)_c m_c\ g \qquad (4)$$

Total base shear $\mathbf{V} = \sqrt{V_i^2+V_c^2}$ **(5)**

Design Horizontal seismic coefficient:

$$A_h = \left(\frac{Z}{2}\right) x \left(\frac{I}{R}\right) x \left(\frac{S_a}{g}\right)(6)$$

Where,

Z = zone factor,

I = Importance factor,

R = response reduction factor,

S_a/g = average response acceleration coefficient

c) Wind Parameters considered for the study (as per IS875 (Part 3): 1987 and IS 875(Part3): 2015)

Probability Factor [k_1] is considered treating the RCC elevated water tanks as “Important buildings and structures” category. The design wind loads are calculated with IS 875 (Part3) 1987 and 2015Revised versions.

The total wind load ‘f’ calculated as per IS 875 (part3): 1987 & 2015 from the equations 7to9.

$$V_z = V_b\ x\ k_1\ x\ k_2\ x\ k_3\ x\ k_4 \qquad (7)$$

Where V_z is designed wind speed at any height z in m/s, V_b is the basic wind speed for the zone, K_1= Probability factor/risk coefficient, K_2= terrain roughness (category 2) and height factor varies according to the height of a structure, K_3= topography factor and K_4 = importance factor for the cyclonic region (1,1.15 and 1.30)

$$P_z = 0.6\ x\ V_z^2 \qquad (8)$$

Where P_z is wind pressure at height “z”, in N/sqm

$$F = C_f\ x\ A\ x\ P_z \qquad (9)$$

d) Analysis and design

Linear static analysis is performed in the water tanks within the scope of the study and design properties are obtained from the design as per IS: 456-2000.Figures 1shows the structure of the elevated water tanks.

IV. RESULTSAND DISCUSIONS

Results of RCC Elevated water tanks

The results shown below represents the maximum bending moments, shear forces and the axial forces for the circular elevated water tanks as per IS 1893 (Part-1) 2002 and IS 1893 (Part-2) 2014 with the impulsive and the convective methods for the II, III, IV and V Zones. All the results that are presented below were compared with Zone II, because the structures that are considered reacted less in Zone II than compared with reaming Zones.

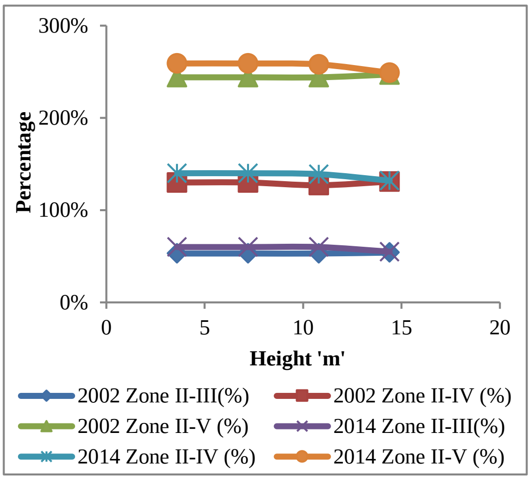

Figure 2Comparisonof bending moment percentages in 1000KL water tank

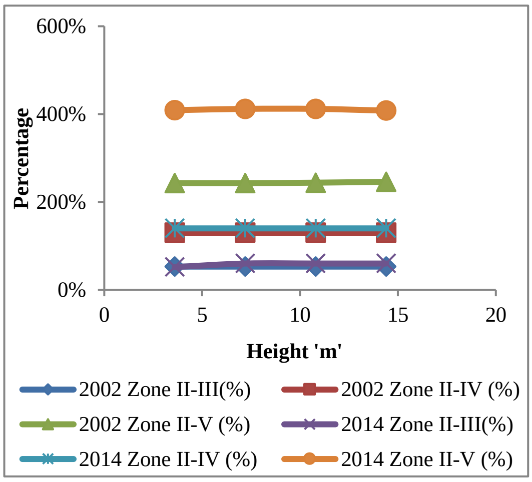

Figure 3Comparisonof Shear force percentages in 1000KL water tank

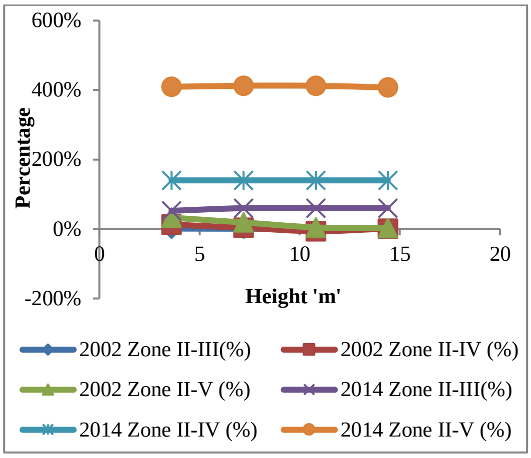

Figure 4Comparisonof Axial force percentages in 1000KL water tank

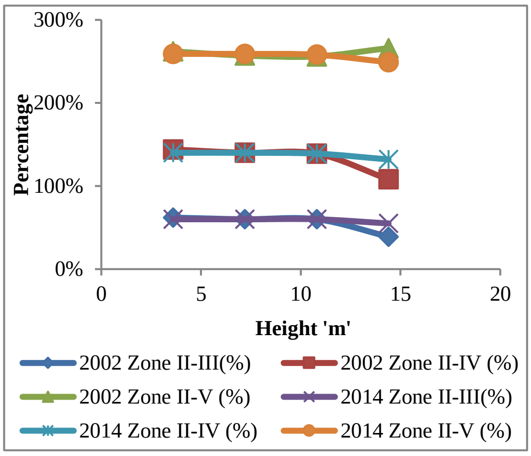

Figure 5Comparison of bending moment percentages in 1500KL water tank

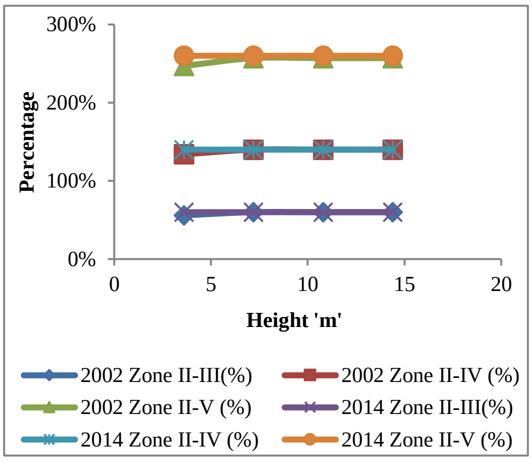

Figure 6Comparison of Shear force percentages in 1500KL water tank

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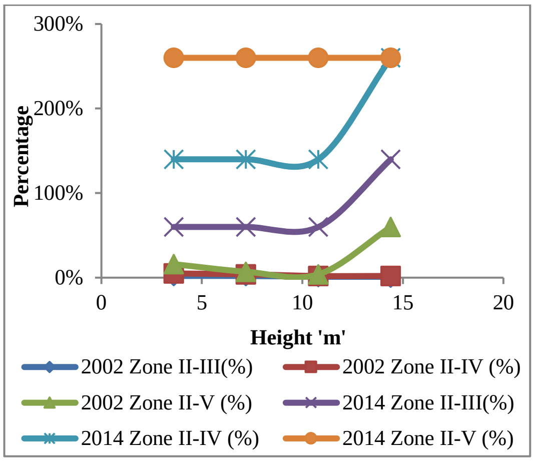

Figure 7Comparisonof Axial force percentages in 1500KL water tank with

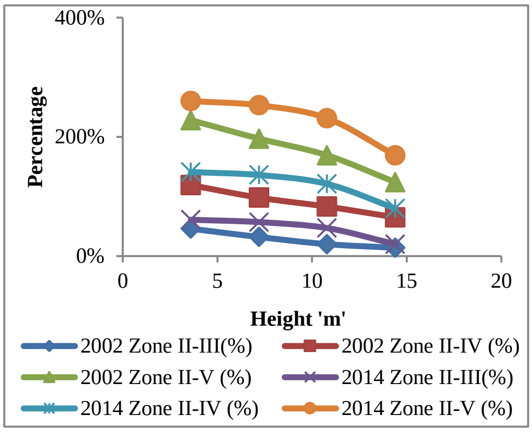

Figure 8Comparisonof bending moment percentages in 2000KL water tank

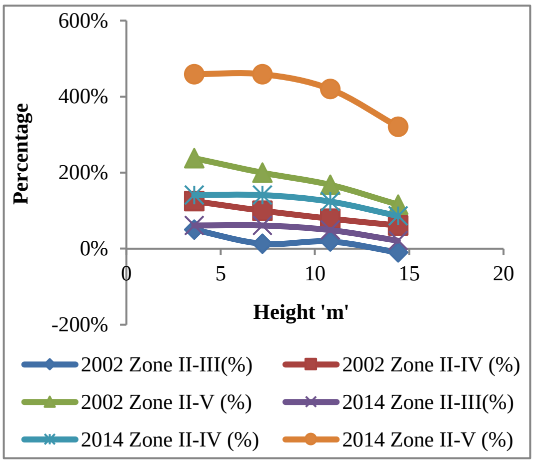

Figure 9Comparisonof Shear force percentages in 2000KL water tank

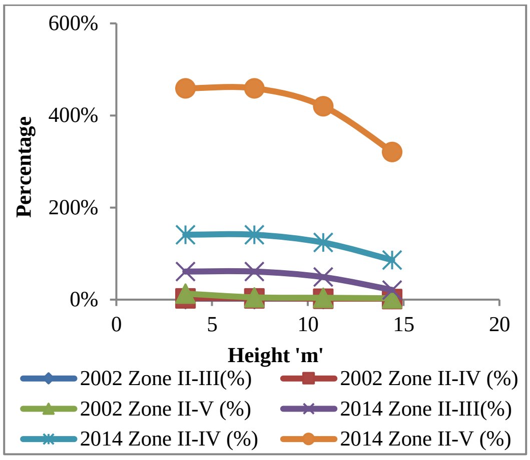

Figure 10Comparison of Axial force percentages in 2000KL water tank

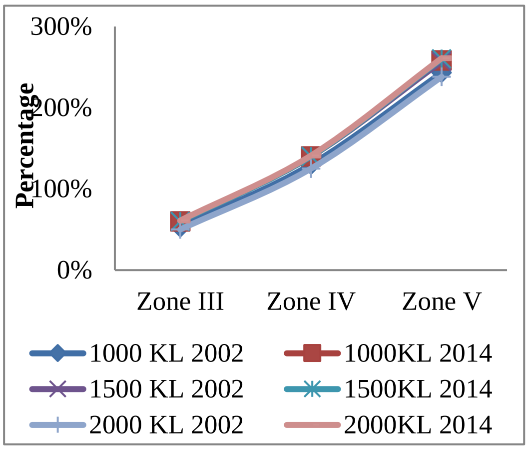

Figure 11Comparisonof base shear percentages in all water tanks.

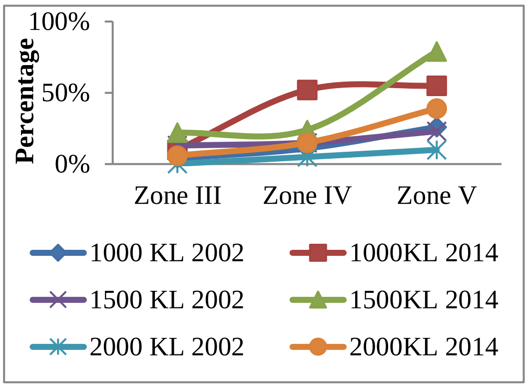

Figure 12 Comparison of Reinforcement for water tanks with respect to ZoneII

V. DISCUSSIONS

Circular RCC elevated water tanks of 1000Kl,1500Kl and 2000Kl capacities have been simulated for computing the bending moments, shear forces, axial forces and to calculate the reinforcement with IS 1893 (part1):2002 and IS 1893 (part2):2014 code provisions..

For the above three water tanks the base shear increased 60% when compared to Zone II to Zone III for 2002 code and 2014 code.

The bending moment for 1000KL water tank increased by 53% from Zone II to III for 2002 code and 60% for 2014 code.

The bending moment for 1500KL water tank increased by 62% from Zone II to III for 2002 code and 60% for 2014 code.

The bending moment for 2000KL water tank increased by 46% from Zone II to Zone III for 2002 code and 61% for 2014 code.

The shear forces for 1000KL water tank increased by 53% from Zone II to III for 2002 code and 60% for 2014 code.

The shear forces for 1500KL water tank increased by 56% from Zone II to III for 2002 code and 60% for 2014 code.

The shear forces for 2000KL water tank increased by 50% from Zone II to Zone III for 2002 code and 61% for 2014 code.

The axial forces for 1000KL water tank increased by 1% from Zone II to III for 2002 code and 60% for 2014 code.

The axial forces for 1500KL water tank increased by 2% from Zone II to III for 2002 code and 60% for 2014 code.

The axial forces for 2000KL water tank increased by 1% from Zone II to Zone III for 2002 code and 61% for 2014 code.

The estimation of reinforcement for 1000KL water tank increased by 4% from Zone II to III for 2002 code and 10% for 2014 code.

The estimation of reinforcement for 1500KL water tank increased by 13% from Zone II to III for 2002 code and 22% for 2014 code.

The estimation of reinforcement for 2000KL water tank increased by 0.3% from Zone II to Zone III for 2002 code and 6% for 2014 code.

VI. CONCLUSIONS

RCC elevated water tanks of 1000KL, 1500KL and 2000KL models were simulated and compared the same models for both IS 1893 (Part-1):2002 and IS 1893 (Part-2):2014. Similarly the water tanks are considered under all types of Zones and compared the results of all Zones with ZoneII. After through discussions as above, the following are a few conclusion have been drawn.

1) When the structure is subjected to both the wind and seismic loadings, the structure is more risk under seismic condition due to its heavy mass and does not have much effect under wind loadings.
2) When the structure is analysed and compared with Zone II and III the results of total base shear, bending moment, shear force and axial forces increased.
3) The bending moments and shear forces is higher in the tank floor slab due to its mass.
4) The reinforcementrequired is more in Zone V when the structure is compared to Zone II,III and IV.
5) The analysis concluded that the results are high in Zone V compared to both the earlier and revised code provisons i.e., (IS 1893 (Part-1): 2002 and IS 1893 (Part-2):2014)

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