SEISMIC ANALYSIS AND DESIGN OF EXISTING ELEVATED RC INTZE WATER TANK AT PEDANA AS PER LATEST IS PROVISIONS AND STADD PRO

D.Kumara Swamy¹, V. Srinivasa Rao²
¹M.Tech student, ²Associate PROFESSOR
Department of civil engineering, Usharama College of engineering and technology, Telaprolu, Krishna District, Andhra Pradesh, India.

Abstract: The Existing elevated water tanks in India designed using IS 1893:1984 needs to be checked for safety as per revised code (IS 1893-2002 code) by carrying out static analysis. As known from the past experiences, elevated water tanks were collapsed or heavily damaged during earth quakes all over the world. So most of the damages are observed during the earthquakes arise from the causes like unsuitable design of supporting system, mistakes on selecting supporting system. The main aim of this project is to understand the seismic behavior of the elevated water tank and comparison of various zones of seismic analysis parameters of the elevated reinforced concrete water tank with consideration and modeling of impulsive and convective water masses inside the container in Two Mass Model as per IS: 1893(part 2)-2007 Draft code and with stadd pro V8i software. The plan, sectional details are collected from Rural Water and Supply (RW&S). In this study Seismic Forces acting on an Intze Type Water tank for Indian conditions are studied. Most of the designers consider the wind effect and neglect the seismic effect on the structure. The comparative study of different zones seismic analysis of existed elevated reinforced Intze tank is done by using the IS codes and andstadd pro. Then finally concluded that in the earlier tank designed reinforcement is heavy, this will leads to uneconomical and it is considered as one of the disadvantage. From the recent code the base shear and overturning moment is less from that the reinforcement is reduced. It is very necessary to design and analyze the water tank as economical as possible. Finally the results have been presented in the form of graphs and tables.

Keywords: component; formatting; style; styling; insert (key words)

I. INTRODUCTION

1.1 EARTHQUAKES
An Earthquake is a wonder that outcomes from and is fueled by the sudden arrival of put away vitality in the outside layer that proliferates seismic waves. At the world's surface, quakes may show themselves by shaking the ground or dislodging of the ground and now and again torrents, which may prompts death toll and demolition of property. The word Earthquake is utilized to portray any seismic occasion whether a characteristic marvel or an occasion created by people that produces seismic waves. The Earth Quakes are happened actually which are identified with the tectonic way of the earth. Such Earth Quakes are called tectonic quakes.

The world's lithosphere is an interwoven of plates in moderate however consistent movement brought about by the warmth in the world's mantle and center. Plate limits grind past one another, making frictional anxiety. At the point when the frictional anxiety surpasses a basic quality, called nearby quality, a sudden disappointment happens. The limit of tectonic plates along which disappointment happens is known as the shortcoming plane. At the point when the disappointment at the flaw plane results in a rough relocation of the world's outside, the flexible strain vitality is discharged and seismic waves are emanated, along these lines an earth shudder happens.

1.2 CLASSIFICATION OF ELEVATED TANKS
In light of the limits of the tank, the conceivable order for distinctive sorts of raised tanks may be given as beneath.

a) For tank up to 50 m³ capacity must be square or circular in shape and supported on staging three or four columns.
b) Tanks of capacity above 50 m³ and up to 200 m³ must be square or circular in plan and Supported on minimum four columns.
c) For capacity above 200 m³ and up to 800 m³ the tank must be square, rectangular, circular or intze type tank. The number of columns to be adopted shall be decided based upon the column spacing which normally lies between 3.6 and 4.5 m.

II. LITERATURE REVIEW

2.1 GENERAL:
A brief survey of past studies with respect to seismic investigation of overhead tanks is given in this segment. These studies are essentially centered around comprehension the conduct of overhead water tanks under seismic loading.

2.2 DESCRIPTION:
Housner [8] in his exploration paper proposed Two Mass Model for raised tanks which is more fitting and is as a rule regularly utilized as a part of the vast majority of the universal codes including Draft code for IS 1893 (Part - II). The weight created within the liquid because of the dynamic movement of the tank can be isolated into rash and convective parts. At the point when a tank containing fluid with a free surface is subjected to even quake ground movement, then the tank divider and fluid are subjected to level quickening. The fluid in the lower area of tank carries the weight of the tank, while the top fluid because of the quickening vectors an earth shudder happens.
divider. This mass is termed as hasty fluid mass which
quickens alongside the divider and instigates indiscreet
hydrodynamic weight on tank divider and comparatively
on base. Fluid mass in the upper locale of tank experiences
sloshing movement. This mass is termed as convective fluid
mass and it applies convective hydrodynamic weight on tank
divider and base. For these two models and with a specific
end goal to incorporate the impact of their hydrodynamic
weight in examination, spring mass model is adopted for Two
Mass Model for elevated tanks.

Sudhir Jain K. & M. S. Medhekar [17] The basic information
behind in this paper is to modify the suggestion in IS: 1893-
1984. The major revisions suggested are:
1. No provision for ground supported tanks with rigid and
flexible walls in above IS code. This provision must be
included in the seismic analysis.
2. The single degree of freedom idealization of tank is to be
replaced by two or three degree of freedom idealization.
3. A performance factor (K) of 3.0 is suggested for all types
of tank.
4. The bracing beam flexibility is to be included in the
calculation of lateral stiffness of supporting system of tank.
5. In the seismic analysis, the effect of convective
hydrodynamic pressure is to be included.
6. A simplified hydrodynamic pressure distribution is
suggested for stress analysis of tank wall.

O. R. Jaiswal & S. K. Jain [17] Recognizing the impediments and shot comings in
the procurement of IS:1893-1984, Jain and Medhekar, Jain and
Sameer an arrangement of procurements on a seismic
configuration of fluid stockpiling tanks, the creator has given
a few proposals –
1. Design horizontal seismic coefficient given in revised IS:
1893(Par-1)-2002 is used as value of response reduction
factor for different types of tanks are proposed.
2. Different spring mass model for tanks with rigid &
flexible wall are done away with; instead, a single spring-
mass model for both types of tank is proposed.
3. Expressions for convective hydrodynamic pressure are
corrected.

III. PROVISIONS OF INDIAN CODE

3.1 GENERAL DESIGN REQUIREMENTS (I.S)
3.1.1 Plain Concrete Structures:
Plain concrete member of reinforced concrete liquid retaining
structure may be designed against structural failure by
allowing tension in plain concrete as per the permissible
limits for tension in bending. This will automatically take
care of failure due to cracking. However, nominal
reinforcement shall be provided, for plain concrete structural
members.

3.1.2. Permissible Stresses in Concrete:
(a) For resistance to cracking: For calculations relating to
the resistance of members to cracking, the permissible stresses in
tension (direct and due to bending) and shear shall confirm to
the values specified in Table 1. The permissible tensile
stresses due to bending apply to the face of the member in
contact with the liquid. In members less than 225mm, thick
and in contact with liquid on one side these permissible
stresses in bending apply also to the face remote from the
liquid.
(b) For strength calculations: In strength calculations the
permissible concrete stresses shall be in accordance with
Table 1. Where the calculated shear stress in concrete alone
exceeds the permissible value, reinforcement acting in
conjunction with diagonal compression in the concrete shall
be provided to take the whole of the shear.

Table 1: Permissible concrete stress in calculations relating
to resistance to cracking

<table>
<thead>
<tr>
<th>Grade of concrete</th>
<th>Permissible stresses (N/mm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Direct Tension, σtd</td>
</tr>
<tr>
<td>M 15</td>
<td>1.1</td>
</tr>
<tr>
<td>M 20</td>
<td>1.2</td>
</tr>
<tr>
<td>M 25</td>
<td>1.3</td>
</tr>
<tr>
<td>M 30</td>
<td>1.5</td>
</tr>
<tr>
<td>M 35</td>
<td>1.6</td>
</tr>
<tr>
<td>M 40</td>
<td>1.7</td>
</tr>
</tbody>
</table>

3.1.3 Permissible Stresses in Steel:
(a) For resistance to cracking: When steel and concrete are
assumed to act together for checking the tensile stress in
concrete for avoidance of crack, the tensile stress in steel will
be limited by the requirement that the permissible tensile
stress in the concrete is not exceeded so the tensile stress in
steel shall be equal to the product of modular ratio of steel and
concrete, and the corresponding allowable tensile stress in
concrete.
(b) For strength calculations: In strength calculations the
permissible stress shall be as follows:
(i) Tensile stress in member in direct tension 1000 kg/cm²
(ii) Tensile stress in member in bending on liquid retaining
face of members or face away from liquid for members less
than 225mm thick 1000 kg/cm²
(iii) On face away from liquid for members 225mm or more
in thickness 1250 kg/cm²
(iv) Tensile stress in shear reinforcement. For members less
than 225mm thickness 1000 kg/cm².
For members 225mm or more in thickness 1250 kg/cm²

IV. SEISMIC ANALYSIS

DESIGN OF INTZE TANK WITH FRAME STAGING

The design will be collected from the Rural Water and
Supply (RW&S) and is given below.

Preliminary data:-

Table 2: Sizes of various components

<table>
<thead>
<tr>
<th>S.NO</th>
<th>Component</th>
<th>Size(mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Top dome</td>
<td>80 thick</td>
</tr>
<tr>
<td>2</td>
<td>Top ring beam</td>
<td>350 x 650</td>
</tr>
<tr>
<td>3</td>
<td>Cylindrical wall</td>
<td>120</td>
</tr>
<tr>
<td>4</td>
<td>Bottom ring beam</td>
<td>400 x 1100</td>
</tr>
<tr>
<td>5</td>
<td>Circular ring beam</td>
<td>480 x 700</td>
</tr>
</tbody>
</table>
4.1.2. Weight calculations:-

i). Top dome:
- Effective span=19.92M.
- Rise (h) =2.54M.
- Bottom radius of the dome (r) =9.96 M.
- Thickness of the dome (t) =80mm.

Radius of the dome (R) = ((r²+h²) / (2*h)) = ((9.96²+2.54²) / (2*2.54)) =20.8m.
- Weight of the top dome =2πr²x20.8x2.54x(0.08x25) =663.90KN.

ii). Top ring beam:
- (19.8+0.35) x0.35x0.65x25=360.036KN
- Cylindrical wall (19.92x0.12x2.65x25) =497.51KN.

Bottom ring beam =πx (19.8+0.40) x0.4x1.10x25=698.06KN.

v). Circular ring beam =πx (15.4x0.48x0.7x25) =406.39KN.

vi). Bottom dome:
- Radius of the dome (r2) = ((15.4/2²)/2.07)=2.87M.
- Length of cone, (Lc) = (1.85²+2.87²)¹/₂ =2.87M.

Weight of the conical dome = πx((19.92+15.4)/2)x2.87x0.465x25 =1851.038KN.

vii). Conical dome:
- (πx19.8²x2.65/4)+ (πx1.5²x(15.33-1/3)/3)x9.81 =9772.329KN.

ix). Columns:
- Volume of water = 9773/9.81 =996.22 m³.
- Mass of water (m) =99620 KG.
- Inner diameter of tank (D) =19.8M.

Let h be the height of equivalent circular cylinder, π (D/2)²h = 996.22

h = 996.22 / (πx(19.8/2)²) = 3.23m.

For h / D = 3.23 / 19.8 =0.163, m₁ / m = 0.25;

m₂ = 0.25 x 99620 = 149433Kg.

m₃ / m =0.75;

m₄ =0.75 x99620 =747165KG.

h₁ / h = 0.375; h₁ = 0.375 x 3.23 =1.21m.

h₁ / h = 2.5; h₁ =2.5 x 3.23 =8.075m.

h₂ / h = 0.51; h₂ = 0.51 x 3.23 =1.64m.

h₃ / h = 2.5; h₃ =2.5 x 3.23 =8.075m.

Mass of empty container + one third mass of staging,

Mᵢ = (5175.68+2713.17/3) x (1000 / 9.81) = 619778.79 kg.

i). Time period:
- Time period of impulsive mode
  Tᵢ = 2π√((m₁+m₃)/K₁) =2π√((149433+697354)/44434.98) = 0.86 sec.
- Time period of convective mode,
  Tᵢ = Cᵢ√((D)/g)
  For h /D = 0.163 Cᵢ = 4.50
  Thus, Tᵢ = 4.5 x√(19.8/9.81) = 6.39sec.

ii). Design of horizontal seismic coefficient:

At zone-3:-
- Design of horizontal seismic coefficient for impulsive mode,
  (Aᵢh) = (0.16/2) x (1.5/2.5)x1.5 = 0.072
- Design horizontal seismic coefficient for convective mode,
  (Aᵢk) = (0.16/2) x (1.5/2.5)x0.58= 0.027

At zone-4:-
- Design of horizontal seismic coefficient for impulsive mode,
  (Aᵢh) = (0.24/2) x (1.5/2.5)x1.5 = 0.108
- Design horizontal seismic coefficient for convective mode,
  (Aᵢk) = (0.24/2) x (1.5/2.5)x0.58= 0.041

At zone-5:-
- Design of horizontal seismic coefficient for impulsive mode,
  (Aᵢh) = (0.36/2) x (1.5/2.5)x1.5 = 0.162
- Design horizontal seismic coefficient for convective mode,
  (Aᵢk) = (0.36/2) x (1.5/2.5)x0.58= 0.062

iii). Base shear:

At zone-3:-
- Base shear at the bottom of staging, in impulsive mode,
  Vᵢ = (Aᵢh) (m₃ + m₄) g = 543.309KN.

Similarly, base shear in convective mode,
  Vᵢ = (Aᵢk) x m₃ x g = 197.91KN.

Total base shear at the bottom of staging,
  Vᵢ = Vᵢ + Vᵢc
  =543.309+197.91 = 741.219KN. ~741 KN.

At zone-4:-
- Base shear at the bottom of staging, in impulsive mode,
  Vᵢ = (Aᵢh) (m₃ + m₄) g = 814.96KN.

Similarly, base shear in convective mode,
  Vᵢ = (Aᵢk) x m₃ x g = 300.517KN.

Total base shear at the bottom of staging,
  Vᵢ = Vᵢ + Vᵢc
  =814.96+300.517 = 1115.47KN. ~1116 KN.

At zone-5:-
- Base shear at the bottom of staging, in impulsive mode,
  Vᵢ = (Aᵢh) (m₃ + m₄) g = 1222.44KN.

Similarly, base shear in convective mode,
  Vᵢ = (Aᵢk) x m₃ x g = 454.44KN.

Total base shear at the bottom of staging,
  Vᵢ = Vᵢ + Vᵢc
  =1222.44+454.44 = 1676.88KN. ~1677 KN.

iv). Base moment:

At zone-3:-
- Overturning moment at the base of staging in impulsive
mode,
\[ M_i = (A_{bh})(m(h_i + h_b) + m_{h2}) \times g \]
= 11709.941 KN-M.
Similarly over turning moment in convective mode,
\[ M_i = (A_{bh})(m(h_i + h_b) + m_{h2}) \times g \]
= 5211.73 KN-M.
Total overturning moment
\[ M = M_i + M_o \]
= 11709.941 + 5211.73 = 16921.67 KN-M.

### 4.4 Convective hydrodynamic pressure

**At zone-3:-**
Convective hydrodynamic pressure on the wall
\[ P_{cw}(y) = Q_{cw}(y)(A_{bh})pgd [1-1/3\cos^2\phi] \cos\phi \]
= 0.436 x 0.027 x 9.81 x 19.8 [1-1/3 (1)^2] 1
= 1.52kN/m^2
At zone-4:-
Convective hydrodynamic pressure on the wall
\[ P_{cw}(y) = Q_{cw}(y)(A_{bh})pgd [1-1/3\cos^2\phi] \cos\phi \]
= 0.436 x 0.041 x 9.81 x 19.8 [1-1/3 (1)^2] 1
= 2.314kN/m^2

**Convective hydrodynamic pressure on Base Slab**
At zone-3:-
Convective hydrodynamic pressure on Base Slab
\[ P_{cb}(y) = Q_{cb}(y)(A_{bh})pgd \]
\[ P_{cb}(y) = 0.289 x 0.027 x 1 x 9.81 x 19.8 = 1.519kN/m^2 \]
At zone-4:-
Convective hydrodynamic pressure on Base Slab
\[ P_{cb}(y) = Q_{cb}(y)(A_{bh})pgd \]
\[ P_{cb}(y) = 0.289 x 0.041 x 1 x 9.81 x 19.8 = 2.301kN/m^2 \]
At zone-5:-
Convective hydrodynamic pressure on Base Slab
\[ P_{cb}(y) = Q_{cb}(y)(A_{bh})pgd \]
\[ P_{cb}(y) = 0.289 x 0.062 x 1 x 9.81 x 19.8 = 3.480kN/m^2 \]

### 4.5. ANALYSIS FOR TANK EMPTY CONDITION

- Mass of empty container + one third mass of staging, \( m_e = 619778.79kg \).
- Stiffness of staging, \( K_s = 44434.98KN/M \).
- Time period:
  \[ T = 2\pi x \sqrt{\frac{m_s}{K_s}} \]
  \[ T = 0.74 \text{ sec.} \]

**Empty tank will not convective mode of vibration.**

**ii)** Design horizontal seismic coefficient:

**At zone-3:-**
Design horizontal seismic coefficient corresponding to impulsive time period \( T_1 \).
From the code (IS 1893 (Part 1):)
\( (A_{bh}) = (0.16/2) x (1.5/2.5)x1.7 = 0.08 \).
At zone-4:-
Design horizontal seismic coefficient corresponding to impulsive time period \( T_1 \).
From the code (IS 1893 (Part 1):)
\( (A_{bh}) = (0.24/2) x (1.5/2.5)x1.7 = 0.122. \)
At zone-5:-
Design horizontal seismic coefficient corresponding to impulsive time period \( T_1 \).
From the code (IS 1893 (Part 1):)
\( (A_{bh}) = (0.36/2) x (1.5/2.5)x1.7 = 0.183. \)

**iii)** Base shear:

- Total base shear,
  \[ V = V_i = (A_{bh})x m_s x g \]
= 0.08 x 619778.79 x 9.81 = 486.40 KN.

At zone-4:
Total base shear,
\[ V = V_i = (A_h)(m_s\times g) \]
= 0.122 x 619778.79 x 9.81 = 741.76 KN.

At zone-5:
Total base shear,
\[ V = V_i = (A_h)(m_s\times g) \]
= 0.183 x 619778.79 x 9.81 = 1112.64 KN.

iv). Base moment:
At zone-3:
Total base moment,
\[ M = (A_h)(m_s\times h_{cg}) \times g \]
= 0.08 x 619778.7 x 18.26 x 9.81 = 8881.70 KN-m.

At zone-4:
Total base moment,
\[ M = (A_h)(m_s\times h_{cg}) \times g \]
= 0.12 x 619778.7 x 18.26 x 9.81 = 13544.60 KN-m.

At zone-5:
Total base moment,
\[ M = (A_h)(m_s\times h_{cg}) \times g \]
= 0.183 x 619778.79 x 18.26 x 9.81 = 20316.90 KN-m.

V. RESULTS AND DISCUSSIONS
Comparison of different zones seismic analysis parameters with Indian standard codes of Intze tank supported on frame staging is shown in below tables. In that tables all parameters from the codes IS 1893 (part 2): 2007 draft code for the frame staging are summarized.

**BASE SHEAR:**

<table>
<thead>
<tr>
<th>Zone</th>
<th>Tank Empty</th>
<th>Tank with Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>486.4</td>
<td>741.21</td>
</tr>
<tr>
<td>4</td>
<td>741.76</td>
<td>1115.47</td>
</tr>
<tr>
<td>5</td>
<td>1112.64</td>
<td>1676.88</td>
</tr>
</tbody>
</table>

**OVER TURNING MOMENTS:**

<table>
<thead>
<tr>
<th>Zone</th>
<th>On Wall</th>
<th>On Base</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2.44</td>
<td>2.38</td>
</tr>
<tr>
<td>4</td>
<td>3.66</td>
<td>3.57</td>
</tr>
<tr>
<td>5</td>
<td>5.49</td>
<td>5.355</td>
</tr>
</tbody>
</table>

**IMPULSIVE HYDRODYNAMIC PRESSURE:**

Graph 3: Impulsive hydrodynamic pressure in different zones

**CONVEXTIVE HYDRODYNAMIC PRESSURE:**

Graph 4: Convective hydrodynamic pressure in different zones

**PRESSURE DUE TO WALL INERTIA AND VERTICAL EXCITATION:**

Graph 5: Pressure in due to wall inertia and vertical excitation different zones
VI. CONCLUSIONS

- It can be observed from the earlier code IS 1893: 1984 can used only single degree of freedom and from the later existing tank compared with water code IS 1893 (part 2): 2007 draft code it can follow the Two Mass Modal.
- The distribution of impulsive and convective hydrodynamic pressure is represented graphically for convenience in analysis, the impulsive hydrodynamic pressure on wall and base of existing water tank is lower the values when compared to zone-4 is 33% and with zone-5 is 55%.
- The convective hydrodynamic pressure on wall and base of existing water tank is lower the values when compared to zone-4 is 34% and with zone-5 is 56%.
- Effect of vertical ground acceleration and pressure due to wall inertia on hydrodynamic pressure is also considered while analysis the tank by two mass modal in zone-3 and lower the values when compared to zone-4 is 33% and zone-5 is 55%.
- The Base Shear and Overturning moments obtained from the code IS 1893 (part 2): 2007 draft code in zone-3, zone-4 and zone-5, whereas the values of the base shear and over turning moments of existing tank is lower when compared to the zone-4 is 33% and zone-5 is 55%.
- The maximum hydrodynamic pressure of existing water tank is lower the values when compared to zone-4 is 44% and with zone-5 is 63%.
- The sloshing wave height of the existing tank is within the free board and in the zone-4 and zone-5 the sloshing wave height is not within the free board.
- Then finally concluded that in the earlier code the reinforcement is heavy, this will leads to uneconomical and it is considered as one of the disadvantage. From the recent code the base shear and overturning moment is less from that the reinforcement is reduced. It is very necessary to design and analyze the water tank as economical as possible.

FUTURE SCOPE:

From the design and seismic analysis of Reinforced Concrete Intze water tank using the SAP Software the moments are high and hence they are providing heavy reinforcement and cost is high. By using the SAP Software, the reinforcement which is provided in the elevated structure can be reduced because the moments obtained in the analysis are less. The basic need of any structure is to design as economical as possible, reinforcement in a structure plays an important key role in the elevated water tank and it should not be over-reinforced.

REFERENCES

[4]. IITK-GSDMA guidelines for seismic design of liquid storage tanks.