Analysis and Design of Elevated Intze Watertank and its Comparative Study in Different Wind Zones - using SAP2000

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Abstract

Water tanks are the storage containers for storing water. Elevated water tanks are constructed in order to provide required head so that water will flow under the influence of the gravity, the construction practice of water tanks is as old as civilized man. The water tanks project have a great priority as it serves drinking water for huge population from major metropolitan cities to the small population living in towns and villages.Large capacity elevated Intze tanks are used to store a variety of liquids, e.g. water for drinking and fire,fighting, petroleum, chemicals, and liquefied natural gas. A water tank is used to store to tide over the daily requirements. Intze tank is a type of elevated water tank supported on staging. Intze tank is defined as bottom portion of circular tank is provided in flat shape, so in flat bottom, the thickness and reinforcement is found to be heavy.Design and analysis of elevated intze water tank both manually and by using SAP2000 software.The present work deals with the design of elevated INTZE type water tank with 12m diameter with a storage capacity of 1000m3. Usually water tank domes are designed as per the code IS 3370-1987 in working stress method and the staging (columns and beams) is designed as per IS 456-2000 in limit state method. The reinforcement details of for this proposed INTZE type overhead water tank is given and the structure is analysed for basic wind load. In addition the elevated intze tank (reinforced concrete) is designed and analysed for wind by using SAP2000software.Wind analysis of reinforced concrete Intze tank is carried out at different staging heights of tank by assuming to be located in different wind zones in India of different terrain categories. Different parameters like wind forces, displacements due to wind forces at different heights of water tank, area of steel etc., are compared in different wind zones.
Keywords: Elevated Water Tank, Wind Forces, Area Of Steel, Nodal Displacements

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I. INTRODUCTION

Water tanks are storage containers for water these tanks are usually Storing water for human consumption .The need for water tanks is old as civilized man .water tanks provide for the storage of potable drinking water, irrigation agriculture , fire suppression. Agricultural farming and live stoke, chemical manufacturing food preparation and many other applications
Various materials are used for constructing water tanks: plastic, polypropylene, fiber glass and concrete, steel (welded or bolted, carbon or stainless). Earthen ponds designed for water storage are also often referred to as tanks. “Ground water tank” is made of lined carbon steel, it may receive water from well or surface water allowing a large volume of water to be placed in inventory and used during peak demand cycles. Very large water tanks may be “Elevated water tanks by elevating the water tank, the increase elevation creates a distribution pressure at the tank outlet.”

II. METHODS OF ANALYSIS

A. *Code Based Wind Analysis:*

Designed based on IS-875 part –II
It is very important to analyse reinforced cement concrete elevated water tank properly against horizontal forces. The present study has been planned to check the severity of wind forces with height of the elevated water tank indifferent zones of India.

1) Computational Modeling:

It is very important to analyse reinforced cement concrete elevated water tank properly against horizontal forces. The present study has been planned to check the severity of wind forces with height of the elevated water tank in different zones of India. The analysis is carried out using sap 2000 software as per IS 875 (Part 3): 1987.

The magnitude of wind force mainly depends on following factors:

2) Classification Of Structure

The structures are classified into the following three different classes depending upon their sizes;

1) Class A - Structures and/or their components such as cladding, glazing, roofing, etc., having maximum dimension (greatest horizontal or vertical dimension) less than 20m.
2) Class B - Structures and/or their components such as cladding, glazing, roofing, etc., having maximum dimension (greatest horizontal or vertical dimension) between 20 and 50 m.
3) Class C - Structures and/or their components such as cladding, glazing, roofing, etc., having maximum dimension (greatest horizontal or vertical dimension) greater than 50m.

3) Terrain Category

There are four terrain categories. Terrain in which a specific structure stands shall be assessed as being one of the following terrain categories:

1) Category 1- Exposed open terrain with few or no obstructions and in which the average height of any object surrounding the structure is less than 1.5 m.
2) Category 2- Open terrain with well scattered obstructions having heights generally between 1.5 to 10 m.
3) Category 3- Terrain with numerous closely spaced obstructions having the size of structure up to 10 m in height with or without a few isolated tall structures.
4) Category 4- Terrain with numerous large high closely spaced obstructions.

4) Wind Speed:

Based on basic wind speed, there are six zones, zone I to zone VI. Basic wind speed shall be modified to include following effects to get design wind velocity at height for the chosen structure;

There are four terrain categories as per the code depending on the obstruction to the wind. From
the wind zone map of India shown in Figure 3.9. it is observed that based on basic wind speed, India is divided into six wind zones i.e. Zone I to zone VI.

Table – 1
Risk Coefficient K1 for Structure

Zone	*Basic wind speed (m/sec)*	*k1 factor*
I	*33*	*1.05*
II	*39*	*1.06*
III	*44*	*1.07*
IV	*47*	*1.07*
V	*50*	*1.08*
VI	*55*	*1.08*

5) DESIGN WIND SPEED (Vz):

The basic wind speed (Vb) for any site shall be modified to include the following effects to get design wind velocity at any height (Vz) for the chosen structure.

a) Risk level
b) Terrain roughness, height and size of structure
c) Local topography

It can be mathematically expressed as follows.

Vz = Vb * k1 * k2 * k3

Where ,

Vz = design wind speed at any height z in m/s
Vb = basic wind speed in m/s
k1 = probability factor (risk coefficient)
k2 = terrain, height and structure size factor and
k3 = topography factor.

6) Risk Coefficient (k1 Factor)

k1 factor gives basic wind speeds for terrain Category 2 as applicable at 6 m above ground level based on 50 years mean return period. The suggested life period to be assumed in design and the corresponding k1 factors for different class of structures for the purpose of design.

7) Terrain, Height and Structure Size Factor (k2 Factor)

a) Terrain:

Selection of terrain categories shall be made with due regard to the effect of obstructions which constitute the ground surface roughness. The terrain category used in the Design of a structure may vary depending on the direction of wind under consideration. Wherever sufficient meteorological information is available about the nature of wind direction, the orientation of any building or structure may be suitably planned. The terrain categories are mentioned above.

b) Topography (k3 Factor):

The basic wind speed V**b** takes account of the general level of site above sea level. This does not allow for local topographic features such as hills, valleys, cliffs, escarpments, or ridges which can significantly affect wind speed in their vicinity. The effect of topography is to accelerate wind near the summits of hills or crests of cliffs, escarpments or ridges and decelerate the wind in valleys or near the foot of cliffs, steep escarpments, or ridges.

The effect if topography will be significantly at a site when the upward slope is greater than about 30, and below that, the value of k3 may be taken to be equal to 1.0. The value of k3 is confined in the range of 1.0 to 1.36 for slopes greater than 30. A method of evaluating the value of k3 for values greater than 1.0. It may be noted that the value of k3 varies with height above ground level, at a maximum near the ground, and reducing to 1.0 at higher level.

c) Design wind pressure (Pz):

The design wind pressure at any height above mean ground level shall be obtained by the following relationship between wind pressure and wind velocity.

$P_z = 0.6\ V_z^2$

8) Wind pressures and forces on buildings/structures General:

The wind shall be calculated for:

1) The building as a whole.
2) Individual structural elements as roofs and walls, and
3) Individual cladding units including glazing and their fixings.

9) Pressure Coefficients:

The pressure coefficients are always given for a particular surface or part of the surface of a building. The wind load acting normal to a surface is obtained by multiplying the area of that surface or its appropriate portion by the pressure coefficient (Cp) and the design wind pressure at the height of the surface from the ground.

Average values of pressure coefficients are given for critical wind directions in one or more quadrants. In order to determine the maximum wind load on the building, the total load should be calculated for each of the critical directions shown from all quadrants. Where considerable variation of pressure occurs over a surface, it has been subdivided and mean pressure coefficients given for each of its several parts.

In addition, areas of high local suction (negative pressure concentration) frequently occurring near the edges of walls and roofs are separately shown. Coefficients for the local effects should only be used for calculation of forces on these local areas affecting roof sheeting, glass panels, and individual cladding units including their fixtures. They should not be used for calculating force on entire structural elements such as roof, walls or structure as a whole.

III. MODELLING AND ANALYSIS

For the analysis of Intze type elevated water tank following dimensions are considered which are elaborated below. In the current study main goal is to compare various parameters like area of steel, axial force, displacements in different wind zones of India.
Design and Wind analysis of Elevated intze type water tank is performed using SAP2000 with following section properties,
Capacity of elevated water tank-1000m³
Height of the tank – 28m
Staging height (linear) – 16m
Number of columns -8

A. Frame Sections:

Table - 2

MEMBER	*SIZE(mm)*
Columns circular type	*diameter of 650mm*
Bracings	*500x500*
Top ring beam	*300x300*

Bottom ring beam	*600(deep) x1200*
Circular girder	*600x1200*

B. Area Sections:

Table – 3

MEMBER	*THICKNESS(mm)*
Thickness of top dome	*100mm*
Thickness of Cylindrical wall	*1200*
Thickness of conical wall	*600*
Thickness of bottom dome	*300*

C. Material Properties:

The material used for the analysis is reinforced concrete with M-20 grade and Fe-415 reinforcing steel.

D. Loads Considered In the Analiysis Using Sap2000:

1) Dead load
2) Water pressure
3) Wind load

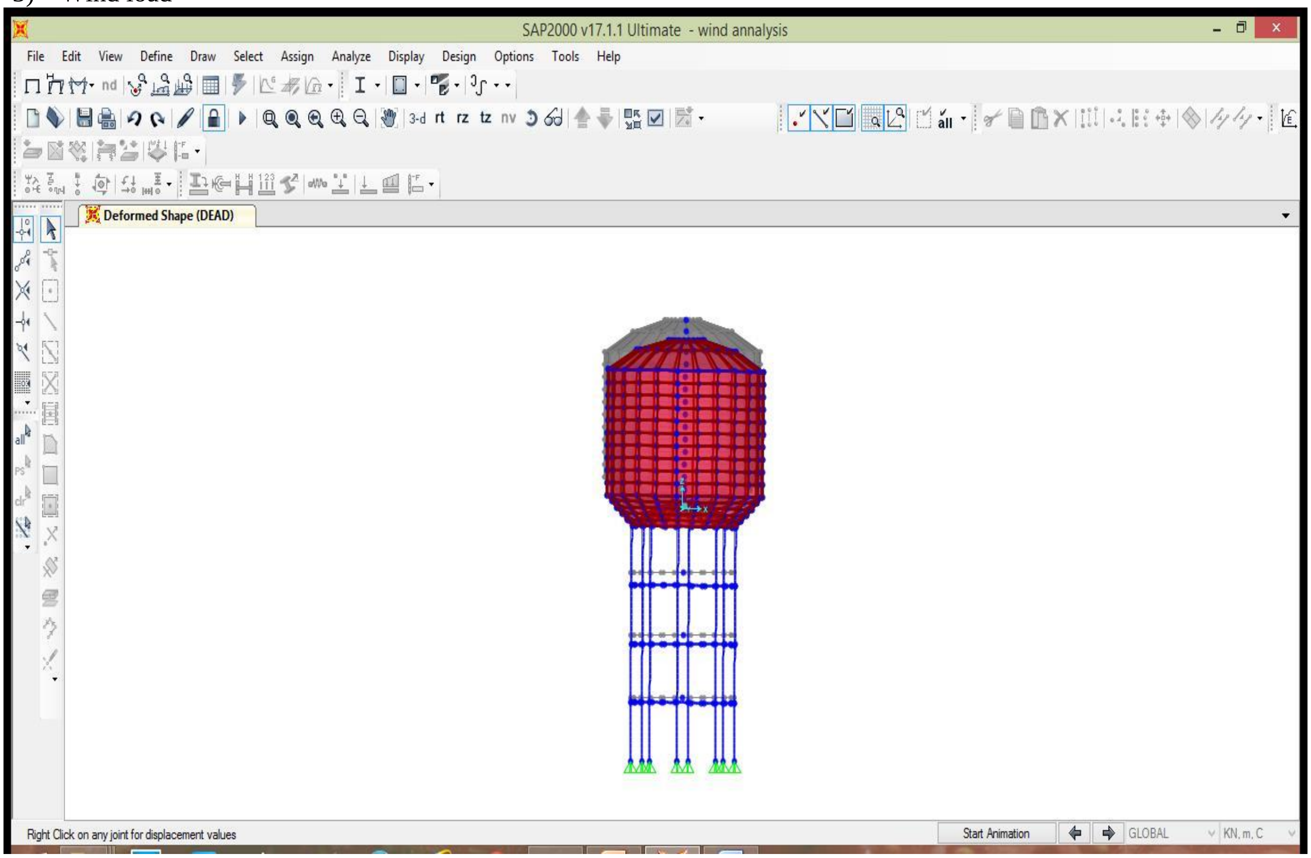

Fig. 1: Deformed Shape of Elevated Water Tank Due To Dead Load in Sap2000

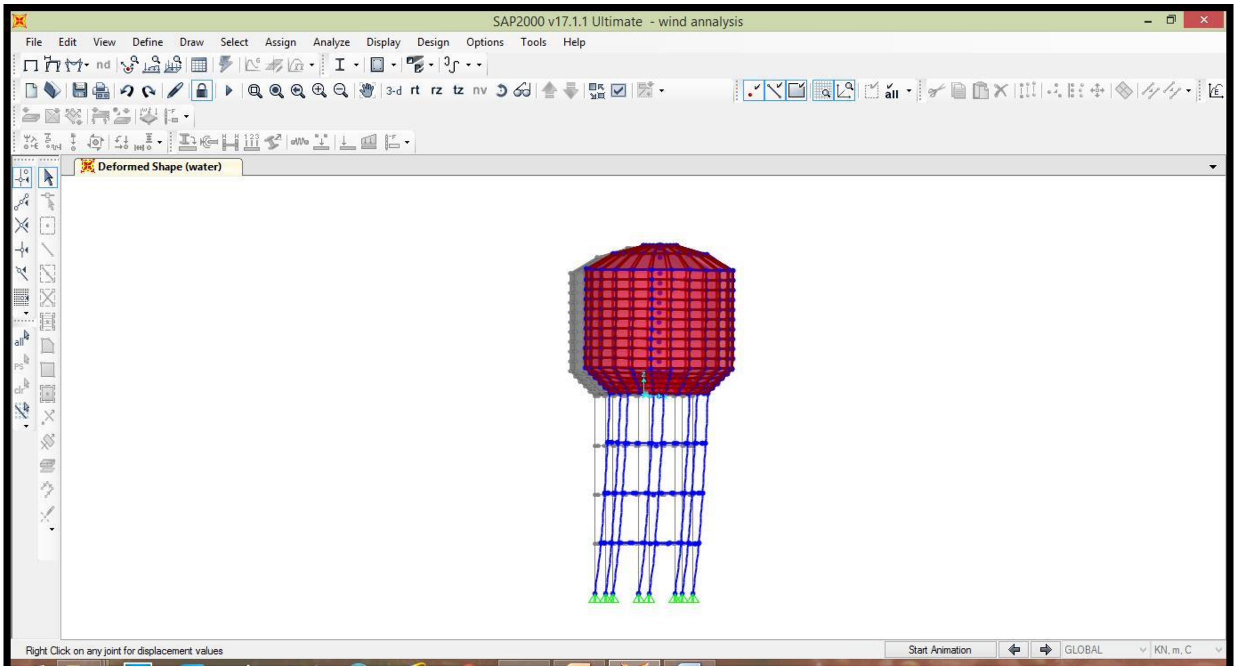

Fig. 2: Deformed Shape of Water Tank Using Sap Due To Water Load

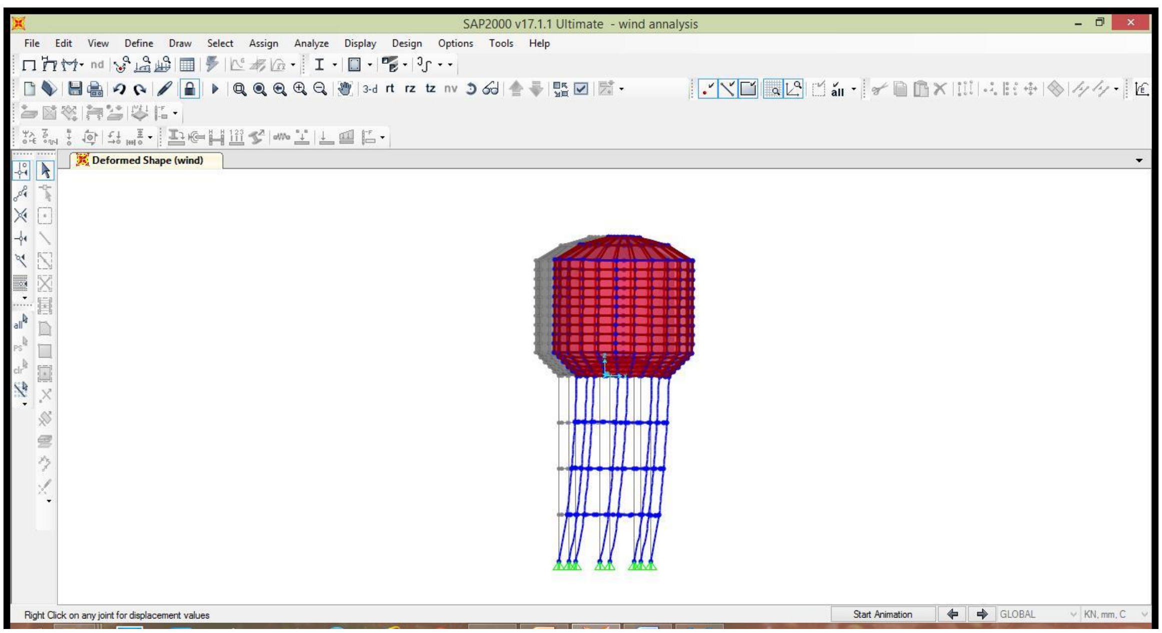

Fig. 3: Deformed Shape of Elevated Water Tank Using SAP2000 Due To Wind Load In Zone6

IV. Results and Discussions

Comparison of wind forces in different wind zones of India at different heights of staging

Table - 4.1.1

Wind Forces (Kn) For Different Wind Zones Of Terrain Category 1

Staging height (m)	*Zone I*	*ZONE II*	*ZONE III*	*ZONE IV*	*ZONE V*	*ZONEVI*
4	*20*	*28*	*37*	*42*	*49*	*59*
8	*24*	*34*	*45*	*51*	*59*	*71*
12	*28*	*40*	*52*	*59*	*68*	*83*
16	*32*	*45*	*59*	*68*	*78*	*94*

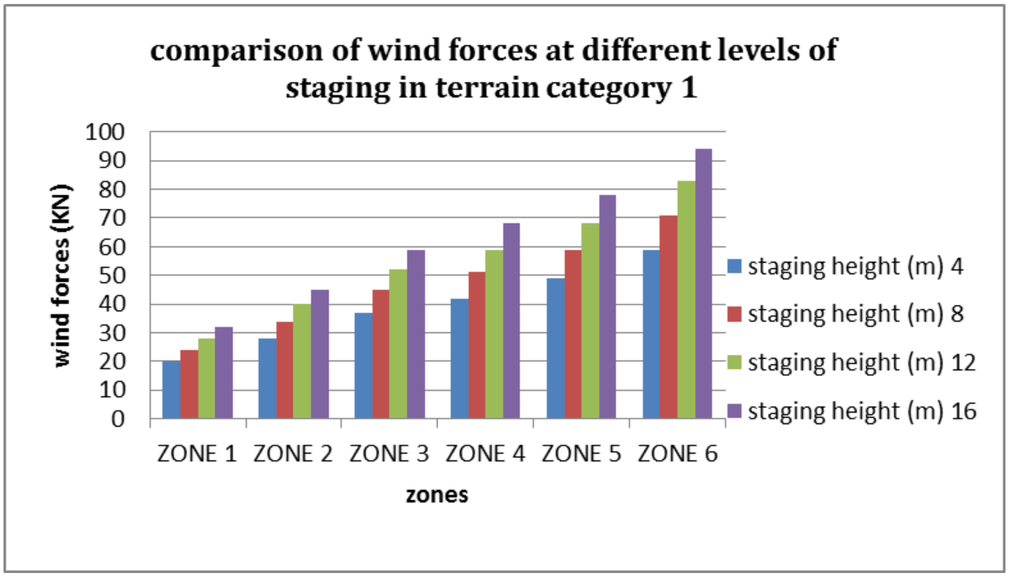

Fig. 4: Variation of Wind Forces in Different Wind Zones of Terrain Category I

Table - 4.1.2
Wind Forces for Different Wind Zones of Terrain Category 2

Staging height (m)	*Zone I*	*ZONE II*	*ZONE III*	*ZONE IV*	*ZONE V*	*ZONEVI*
4	*18*	*26*	*34*	*39*	*45*	*54*
8	*22*	*31*	*41*	*47*	*54*	*65*
12	*25*	*36*	*47*	*54*	*63*	*76*
16	*29*	*42*	*54*	*62*	*71*	*86*

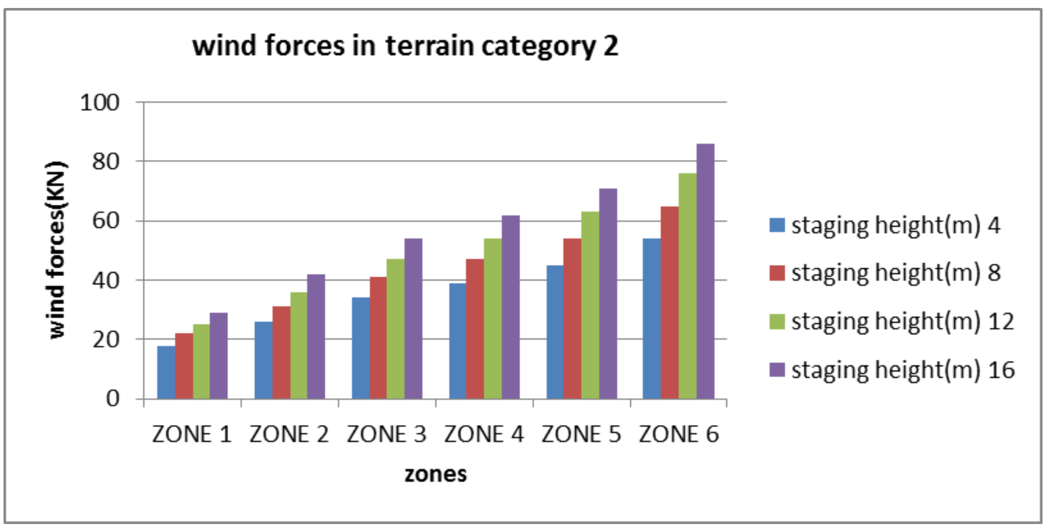

Fig. 5: Variation of Wind Forces in Different Wind Zones of Terrain Category2

Table - 4.1.3
Wind Forces for Different Wind Zones of Terrain Category 3

Staging height (m)	*Zone I*	*ZONE II*	*ZONE III*	*ZONE IV*	*ZONE V*	*ZONEVI*
4	*16*	*22*	*29*	*33*	*39*	*47*
8	*19*	*27*	*35*	*40*	*46*	*56*
12	*22*	*31*	*40*	*46*	*53*	*65*
16	*25*	*35*	*46*	*52*	*60*	*73*

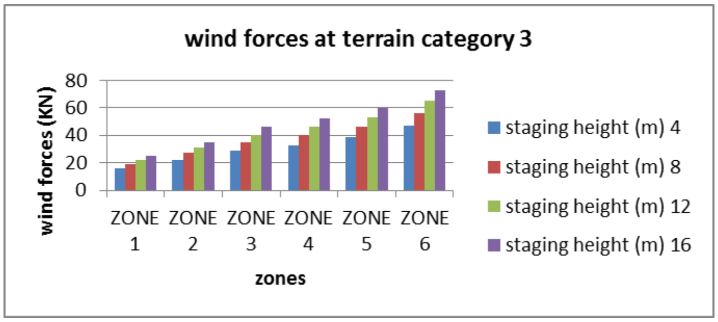

Fig. 6: wind forces at terrain category 3

Table - 4.1.4
Wind forces for different wind zones of terrain category 4

Staging height (m)	*Zone I*	*ZONE II*	*ZONE III*	*ZONE IV*	*ZONE V*	*ZONEVI*
4	*10*	*15*	*19*	*22*	*25*	*31*
8	*12*	*18*	*23*	*27*	*31*	*37*
12	*15*	*21*	*27*	*31*	*36*	*44*
16	*17*	*24*	*31*	*36*	*41*	*50*

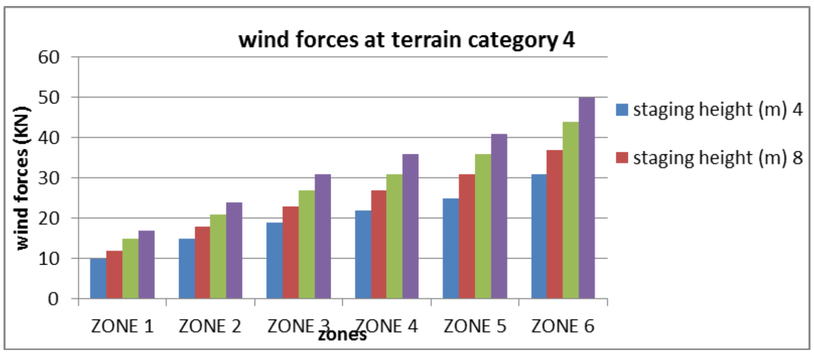

Fig. 7: Variation of Wind Forces in Different Wind Zones of Terrain Category4

Table - 4.2
Lateral displacements at various heights of staging in various zone of India of terrain category 1

			ZONE1	*ZONE2*	*ZONE3*	*ZONE4*	*ZONE5*	*ZONE6*
Stagingheight(m)		*4*	*8.52*	*11.91*	*15.16*	*16.9*	*19.5*	*23.6*
		8	*13.32*	*18.61*	*23.69*	*26.5*	*30.5*	*37*
		12	*16.79*	*23.46*	*29.86*	*33.4*	*38.5*	*46.6*
		16	*18.88*	*26.38*	*33.58*	*37.5*	*43.2*	*52.3*
		18	*19.06*	*26.62*	*33.88*	*37.9*	*43.7*	*52.9*
		22	*19.47*	*27.2*	*34.62*	*38.7*	*44.7*	*54*
		24	*19.88*	*27.77*	*35.35*	*39.5*	*45.6*	*55.2*
		26	*20.08*	*28.05*	*35.71*	*39.9*	*46.11*	*55.8*

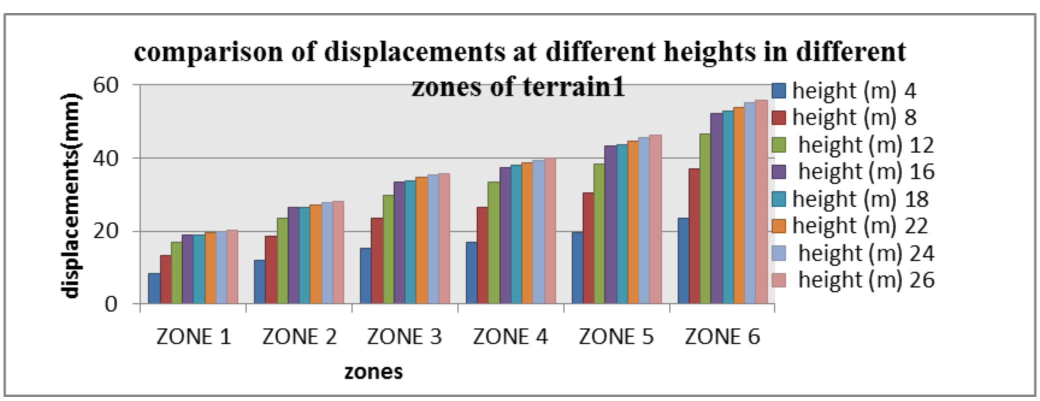

Fig. 8: comparison of displacements at different heights in different zones of terrain1

Table - 4.2.1
Lateral Displacements at Various Heights of Staging in Various Zone Of India of Terrain Category 2

			ZONE1	ZONE2	ZONE3	ZONE4	ZONE5	ZONE6
staging height(m)		4	7.8	10.89	13.86	15.5	17.9	21.6
		8	12.19	17.03	21.67	24.2	27.9	33.87
		12	15.37	21.47	27.33	30.6	35.3	42.7
		16	17.25	24.1	30.67	34.3	39.6	47.9
		18	17.45	24.38	31.03	34.7	40	48.4
		22	17.83	24.91	31.71	35.5	41.1	49.5
		24	18.21	25.44	32.38	36.2	41.8	50.6
		26	18.4	25.7	32.71	37.3	42	51.1

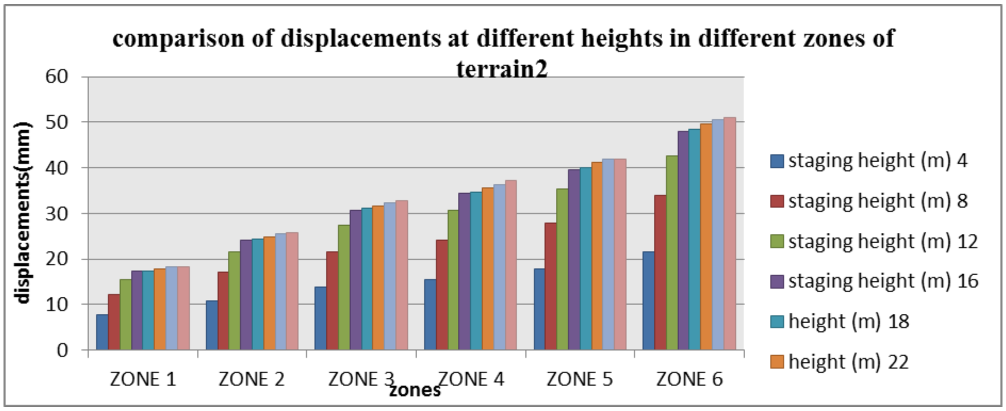

Fig. 9: Displacements at Different Staging Heights of Tank in Various Zones of India of Terrain Category 2

Table - 4.2.3
Lateral displacements at various heights of staging in various zone of India of terrain category 3

			ZONE1	ZONE2	ZONE3	ZONE4	ZONE5	ZONE6
Staging height(m)		4	6.62	9.25	11.78	13	15.2	18.4
		8	10.37	14.49	18.44	20	23.8	28.8
		12	13.11	18.31	23.3	26	30	36.4
		16	14.73	20.58	26.19	29	33.8	40.9
		18	14.91	20.82	26.5	29	34.2	41.4
		22	15.23	21.37	27.09	30	34.9	42.3
		24	15.56	21.74	27.67	30	35.7	43.23
		26	15.72	21.96	27.95	31	36.1	43.68

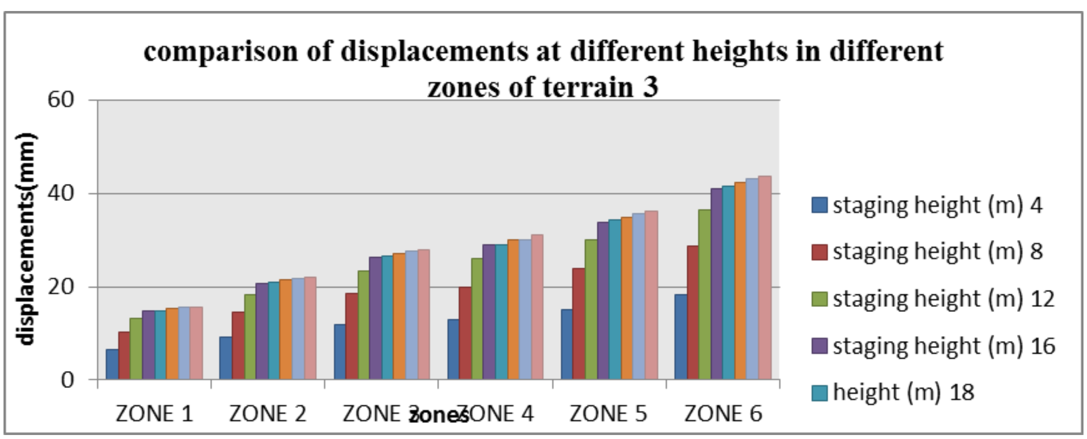

Fig. 10: Variation of Displacements at Different Staging Heights of Terrain 3

Table - 4.2.4
Lateral displacements at various heights of staging in various zone of India of terrain category 4

			ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6
staging height (m)		4	4.53	6.33	8.05	9	10.4	12.5
		8	7.07	9.88	12.58	14	16.2	19.6
		12	8.91	12.45	15.84	17	20.4	24.7
		16	9.99	13.96	17.81	19	22.9	27.8
		18	10.11	14.12	17.98	20	23.2	28.1
		22	10.33	14.44	18.37	20	23.8	28.7
		24	10.55	14.74	18.77	21.02	24.2	29.3
		26	10.66	14.9	18.95	21.2	24.4	29.6

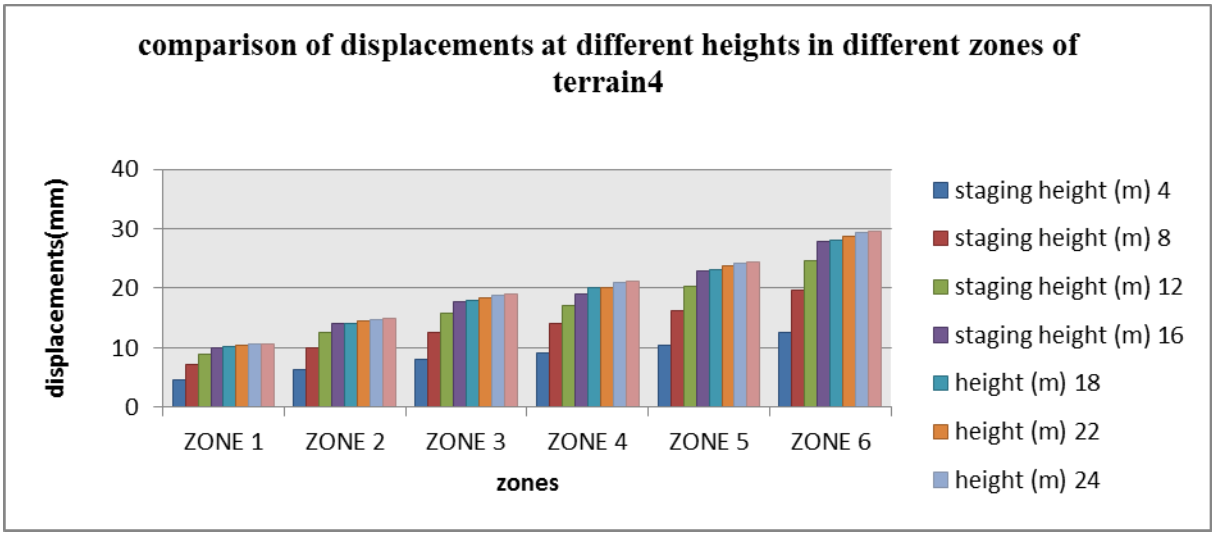

Fig. 11: Variation of Displacements at Different Staging Heights of Tank in Various Zones of India of Terrain Category 4

E. Design of Tank Using Sap 2000 for Different Wind Zones:

Table - 4.3.1
Area of Steel at Various Heights of Staging in Various Zones of India of Terrain Category 1

			ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6
staging height(m)		16	2654.64	2654.64	2893.81	3107.4	3971.17	4951
		12	2654.64	2758.46	2985.27	3782.04	4540.29	5400
		8	2749.97	3519.74	4874.98	5438.97	5969.65	7617
		4	3735.84	5445.58	6976.04	8174.2	9301.63	11379

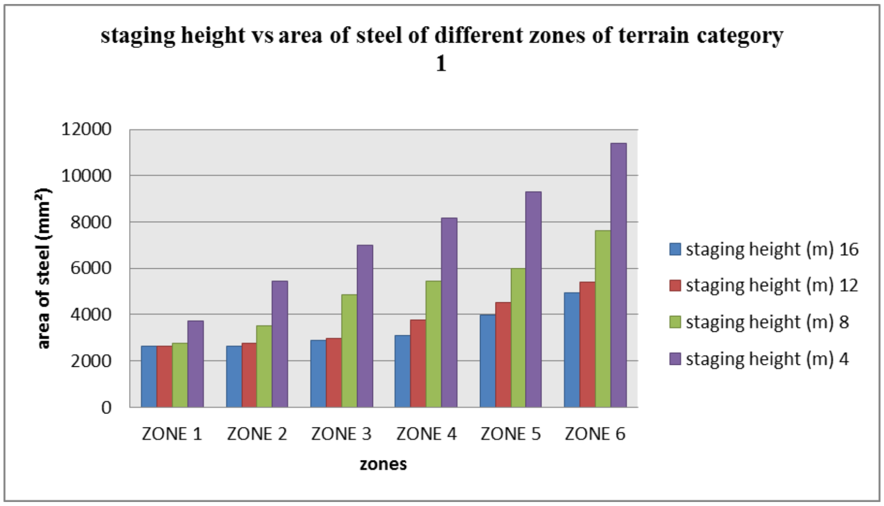

Fig. 12: Area of Steel at Different Staging Heights of Tank in Various Zones of India of Terrain Category 1

Table - 4.3.2
Area Of Steel At Various Heights Of Staging In Various Zones Of India Of Terrain Category 2

			ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6
staging height (m)		16	2654.64	2654.64	2818.14	2934.21	3476.27	4541
		12	2654.64	2669.54	2916.71	3268.94	4094.94	5031
		8	2654.64	2985.45	4456.69	5074.08	5651.13	6784.4
		4	3203.49	5070.98	6080.86	7384.62	8616.77	10090

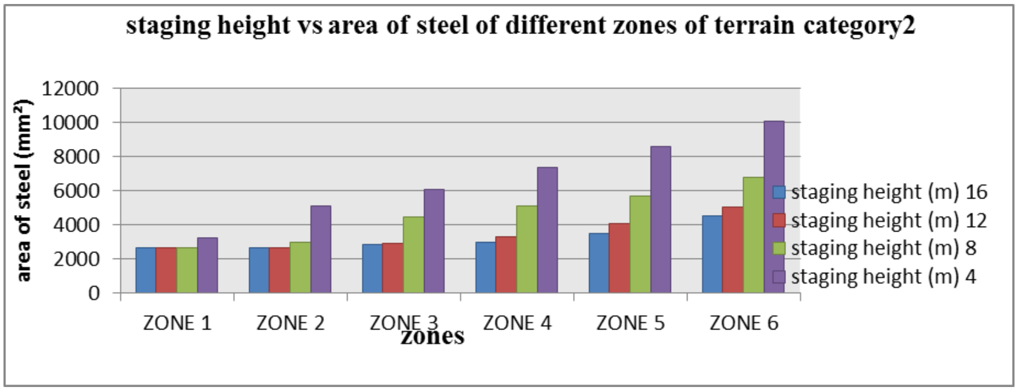

Fig. 13:

Table - 4.3.3
Area of steel at various heights of staging in various zones of India of terrain category 3

			ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6
staging height (m)		16	2654.64	2654.64	2674.1	2807.98	2933.95	3763
		12	2654.64	2654.64	2781.83	2901.36	3219.74	4307
		8	2654.64	2853.47	3607.56	4326.99	5003.95	5771
		4	2882.81	4296.79	5482.37	5975.75	7196.31	8840

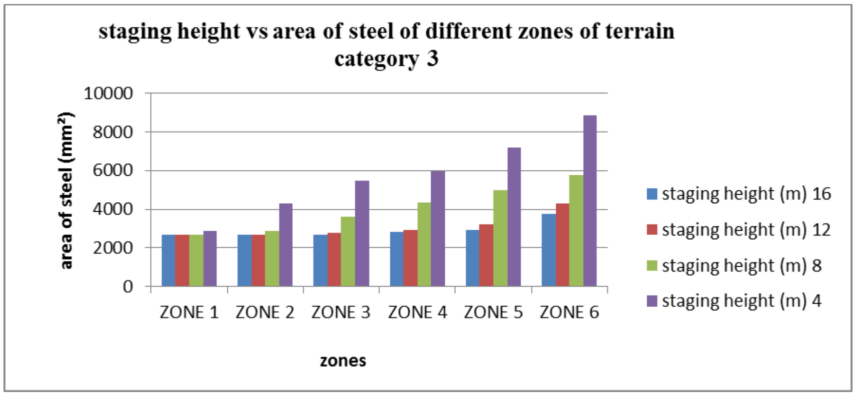

Fig. 14: Variation of Area of Steel at Different Staging Heights of Tank Invarious Zones of India of Terrain Category 3

Table - 4.3.4
Area of steel at various heights of staging in various zones of India of terrain category 4

			ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6
stagingheight (m)		16	2654.64	2654.64	2654.64	2654.64	2654	2734.85
		12	2654.64	2654.64	2654.64	2654.64	2655.33	2845.13
		8	2654.64	2654.64	2731.47	2858.56	2978.14	4048.15
		4	2882.81	2858.82	3635.2	4357.65	5037.44	5808.63

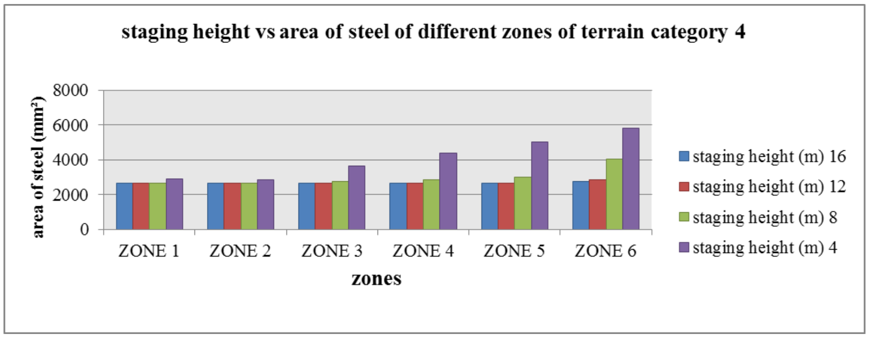

Fig. 15: Variation of Area of Steel at Different Staging Heights of Tank in Various Zones of India of Terrain Category4

V. CONCLUSIONS

The wind forces, area of steel, lateral displacements, axial force, and base shear for elevated intze water tank are investigated and compared in different zones of India in different terrain categories.
Following are the conclusions drawn from the study,

A. Wind Force:

Wind forces for zone I is about 28 to 30% less than the that of zone II, about 45 to 47% less than that of zone III, about 52 to 53 % less than that of zone IV, about 58 to 60% less than that of zone V, about 66-67% less than that of zone VI. Wind forces for zone II is about 23 to 25% less than that of zone III, about 33 to 34% less than that of zone IV, about 42 to 43% less than that of zone V, about 52 to 53% less than that of zone VI.

The wind forces increases from wind zone I to VI because of the increase in basic wind speed due to increase in risk coefficient k1.

The wind forces are compared for every 4m height of the staging it is observed that the wind forces increases by 20% with 4m increase in height in every zone. Wind forces increased with increase in staging height. This is because exposed area terrain height and size factor k2 increases with increase in staging height.

It is also observed that of all the terrain categories 1,2,3,4 of wind zones, the terrain category1 is observed to be critical since it is open terrain with no obstructions.

B. Area of Steel:

Area of steel for zone I is about 32% less than that of zone II, about 43 to 46% less than that of zone III, about 54 to 56% less than that of zone IV, about 59 to 62% less than that of zoneV, about 67 to 69% less than that of zone VI. Area of steel for zone II is about 16 to 22% less than that of zone III, Area of steel for zone II is about 28 to 34% less than that of zone IV, area of steel for zone II is about 40 to 43% less than that of zone V, area of steel is about 49 to 52 % less that of zone VI.

Area of steel is observed to be 50% more at bottom of the column when compared to top of the column, this is because the strength should be increased as we go bottom of the structure since all the loads to be transferred to soil from the bottom part of structure.

For each terrain there is an increase of 42% and of all terrains, terrain category 1 is observed to be designed for more steel in all zones.

C. Lateral Displacements:

Lateral displacements for zone I is about 28% less than that of zone II, about 30% less than that of zone II, about 41 to 44 % less than that of zone III, about 45 to 49% less than that of zone IV, about 56 to 58% less than that of zone V, about 63 to 65 % less than that of zone VI.

There is an increase in lateral displacement from zone I to VI, there is also increase in lateral displacement with increase in height of staging because of increase in wind forces.

With increase in staging height there is an increase of 62% for every 4m height.

D. The area of steel for dead load by sap 2000 is about 15% more when compared to manual values.

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