International Journal of Civil Engineering and Technology (IJCIET)
Volume 8, Issue 8, August 2017, pp. 1589–1598, Article ID: IJCIET_08_08_173
Available online at http://http://www.iaeme.com/ijciet/issues.asp?JType=IJCIET&VType=8&IType=8
ISSN Print: 0976-6308 and ISSN Online: 0976-6316

DETERMINATION OF STRESS FACTORS OF A OVERHEAD CIRCULAR WATER TANK CONSIDERING AN AXISYMMETRIC ELEMENT

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ABSTRACT

A large number of water tanks is being constructed around the world. The objective of this project is to analyze the circular water tank as a axisymmetric element. Circular water tanks are more efficient for larger storage capacities. According to IS code provision, water tank wall and base are acting separately and that the base is rigid and flexible. In reality the wall and the base are consider as a monolithic structure. In this work, axisymmetric analysis has been carried out to study the stress distribution in the wall and the base slab of the circular tanks. This papers involves study of water tanks models by two cases – 1. Conventional. 2. Reality.

Conventional - ANSYS model of wall with fixed base was created and the results from the model found to be coincide with IS code 3370 coefficient. Reality - Based on the properties assigned in the previous model a new model is created in ANSYS considered the wall and base slab acts monolithically and the results from the model is not coincide with IS code 3370 coefficient. As the results both method were compared and studied.

Key words: Circular Water Tank, Axisymmeric, Monolithic, ANSYS.

Cite this Article: Shruthi M V, Determination of Stress Factors of A Overhead Circular Water Tank Considering An Axisymmetric Element. International Journal of Civil Engineering and Technology, 8(8), 2017, pp. 1589–1598.
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1. INTRODUCTION

The simplest form of water tank is circular tank, for the same amount of storage the circular tank requires lesser amount of material. More over for its circular shape it has no corner and can be made water tight easily. Water pressure will distribute equally in all sides. The side walls are designed for hoop tension and bending moments. Fig: 1 represent that the cross section of the circular water tank and the tank is fixed at base and free at top. Circular water tank are classified into flexible and rigid joints.

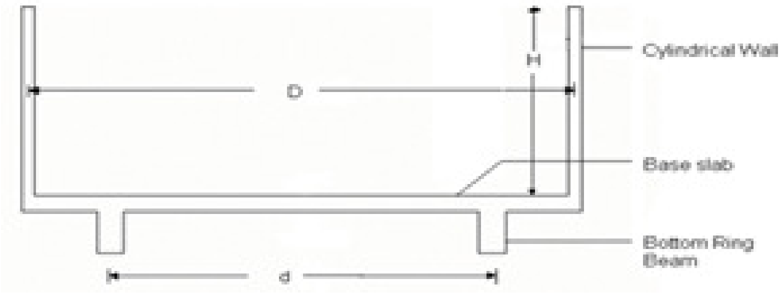
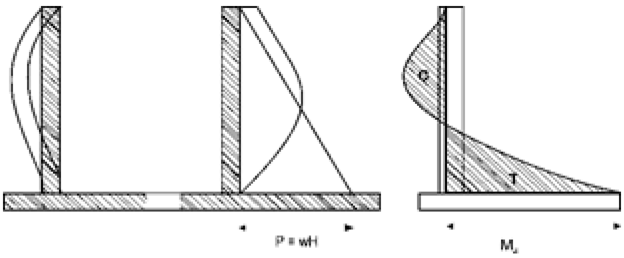


Figure 1 cross section of the circular water tank

In conventional method of water tanks, the cylindrical wall and base slab interaction is not taken into account because in that case wall and base are consider only as fixed, hinged. But in reality wall and base are constructed monolithically. So the stress distribution and the moments calculated from the coefficient which was in IS: 3370 (part IV) may be some what erroneous in conventional method. Fig: 2 shown that the base fixed to base



(a) Deformation of Wall (b) Load Distribution (c) Approx. B.M.D

Figure 2 Tank wall fixed at the base

Circular water tank can be analyses by 1. Reissner's method 2. Carpenter's method 3. Approximate method 4. IS code method.

IS code method for circular tanks

If the wall of a circular tank is fixed with the base, the walls are subjected to horizontal shear in addition to hoop tension. If the tank is tall with a small diameter, it will resist the liquid pressure primarily by ring tension and to a lesser degree by horizontal shear at base. If the tank is shallow and the diameter is large, it will resist liquid pressure primarily by cantilever action from base and to a lesser degree by hoop tension. If the tank height is medium, it will resist the loads by both hoop tension and by cantilever action.

For a circular tank with fixed base and free top, the shear and bending moment are zero at the top and at the bottom, the slope and deflection are zero. These conditions give the following equations. 1. At x = 0, deflection is zero, i.e. EI y = 0. 2. At x = 0, slope is zero, i.e. EI $\frac{dy}{dx}=0$ 3.At x = H, shear force is zero, i.e. EI$\frac{d^3y}{dx^3}=0$. 4. At x = H, bending moment is zero, i.e. EI $\frac{d^2y}{dx^2}=0$.From the equations, the solution of elastic curve is known. Hence the values of P_c and P_r can be found out at different heights. IS: 3370 (part IV) gives the hoop tension and bending moment at different heights and shear at the base.

The deflection, slope, BM, and shear force at any point on the tank wall can be found. Following are the simplifed expressions for defelection and BM.

$$Y = \frac{Wx}{4EI\alpha^4} + A \sin \alpha x\,(e^{ax} - e^{-ax}) + B \cos \alpha x\,(e^{ax} - e^{-ax}) - 2A\, e^{-ax} \cos \alpha x$$

Considering the BM causing tension at the outer face as positive, $Mx = - EI \frac{d^2y}{dx^2}$, $= - EI\, \alpha^2 .\, e^{ax}\ (2A \cos \alpha x - 2B \sin \alpha x) - EI\, \alpha^2 .\, e^{-ax}\,(2D \sin \alpha x - 2C \cos \alpha x)$

Final solution,

$$Mx = -2EI\alpha^2\,(A \cos \alpha x\,(e^{ax} - e^{-ax}) - B \sin \alpha x\,(e^{ax} - e^{-ax}) - 2\, e^{-ax} \sin \alpha x)$$

2. MODELING OF PROBLEMS

The container is an elastic, thin circular cylindrical of different thickness with one end fixed and other end free.

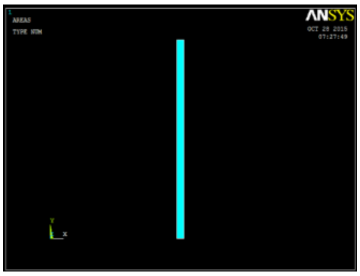
Component

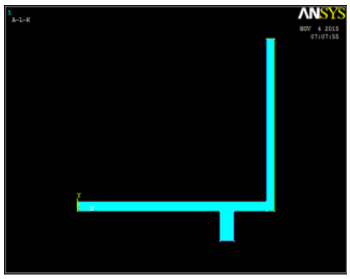
Preprocessor → solution → postprocessor

The numerical techniques like FEA are most effective due to advancement of high and large memory computers. These techniques can be applied for any minor change in the problem, which reduce the cost and time required for manufacturing and testing of several prototypes.

AXI – SYMMETRY

If a shape can be defined by rotating a cross section about a line (fig:3), then it is said to be axi-symmetric. If the loads and boundary condition are also axi-symmetric in nature, then the axi-symmetric analysis may be carried out.





A B

A- Wall and base acting separately B – wall and base acting together

Figure 3 cross section of the tank (ANSYS)

Element used

The element used in this project is PLANE82 (fig 1.4), a higher order version of the two-dimensional, four-node element (PLANE42). It provides more accurate results for mixed (quadrilateral-triangular) automatic meshes and can tolerate irregular shapes without as much loss of accuracy. The 8-node elements have compatible displacement shapes and are well suited to model curved boundaries.

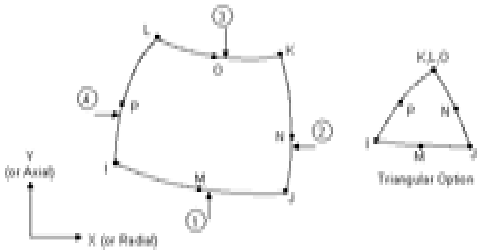
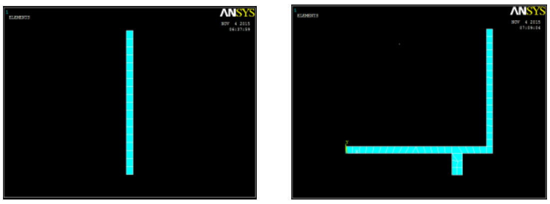


Figure 4 Plane 82

Meshing element

In this paper 8 nodal plane 82 element is used as an axisymmetric element. It gives more accurate result for quadrilateral- triangular automatic meshes shown in fig.



A B

A- Wall and base acting separately B – wall and base acting together

Figure 5 Meshing of the element

Boundary condition

Nodes at the base are assumed to be fixed. Same boundary condition are followed in this two types, 1.wall and base are not acting together, 2. Wall and base are acting together. Fig: 6 represent the boundary condition

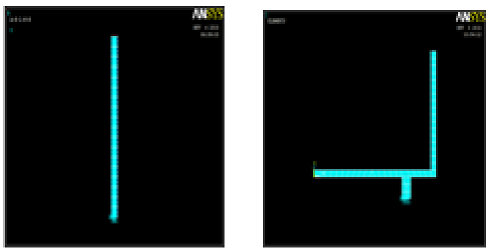


Figure 6 boundary condition

Material properties

The material is assumed to be homogeneous isotropic, and linearly elastic.

Element used	: 8 node 82
Material	: combination of steel and concrete
Loading condition	: hydrostatic pressure
Poisson ratio	: 0.15
Young's modulus	: 22360
Density	: 2.5×10^{-6} kg/mm^3

These are the properties assigned for the models created using ANSYS. For different dimension of the circular water tanks the model, of circular water tank were created.

Model Creation

Input data: Structural data, nodel data, material properties, element data, nodel loads, meshing type.

Output data: stress, displacement.

3. RESULT AND DISCUSSION

Case: 1

Wall and Base Acting Individually

Model is created for base and wall are not acting together. From the model maximum and minimum stress can be calculated. Stress are founded along the X direction (s_X), Y direction (s_Y), Z direction (s_Z).

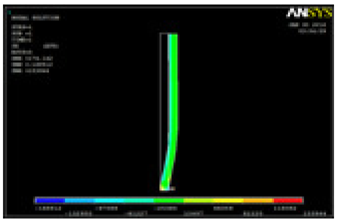


Figure 7 stress along x direction (sx)

Stress acts in the inside corner of the wall along x direction in (fig: 7). Blue colour indicates zero stress and red colour indicates the failure mode

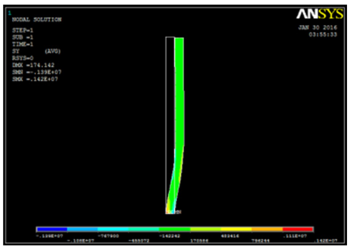


Figure 8 stress along y direction (sy)

Stress acts in the inside corner of the wall along y direction in (fig:8). Y direction shows the bending moment. Blue colour indicates zero stress and red colour indicates the failure mode.

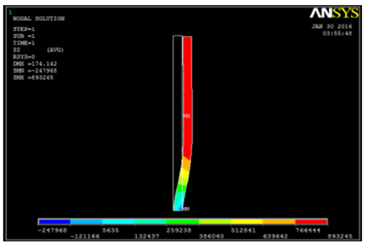
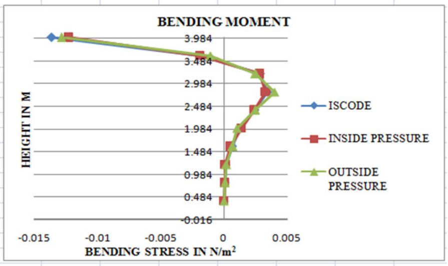


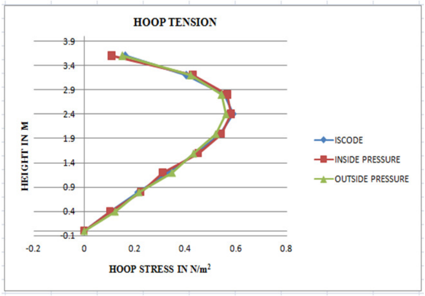
Figure 9 stress along z direction (sz)

Stress acts in the base of the wall along Z direction in (fig: 9). Tension acts in Z direction. Under the base of the wall contain more failure. This picture also give same indication that we seen in fig: 7, 8.



Graph 1 Bending stress (sy)

Graph: 1 Bending stress explain fig: 8 results. This graph explain about the comparesion of conventional and analytical method.



Graph 2 Hoop stress (sz)

Graph: 2 Hoop stress explain fig: 9 results. This graph explain about the comparesion of conventional and analytical method.

Graph – 1, 2 represents the coefficient was arrived by the model. Conventional method contain inward pressure only but analytical method shows that the inward and outward pressure. And the pressure was compared with IS code coefficient, and it said to be equal. By using the method base and wall are not acting together.

Note: The remaining 13 results are resembles the same method of case 1.

Case – 2

The wall and the base acting monolithically

Base slab is an important component of the water tank. The BMD in radial as well as hoop directions are plotted below and compared with the conventional results.

The analyses was made with three d/D ratios, **(0.75,0.65,1)** with different dimension which was used in the case -1 model.

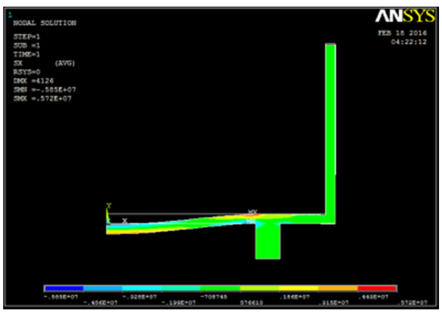


Figure 10 Stress along x direction (sx)

Fig: 10 shows the bending stress. Blue colour indicates zero stress and red colour indicates the failure mode.

The conventional methods of design, it was thought that there would be maximum tension only at the centre of base slab. But ANSYS changes the picture, and the above fig: 12 shows a failure mode of maximum tension in the water face above the ring beam.

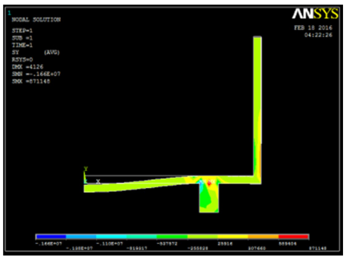


Figure 11 Stress along y direction (sy)

The fig: 11 shows the y direction, Blue colour indicates zero stress and red colour indicates the failure mode.

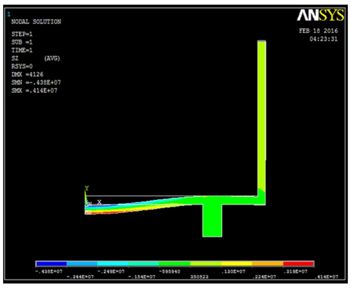
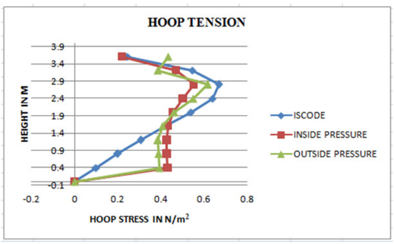


Figure 12 Stress along z direction (sz)

Fig: 12 represent the hoop tension S_z at the midspan region of the base slab, and is also considerable hoop tension on the tank wall near its base.

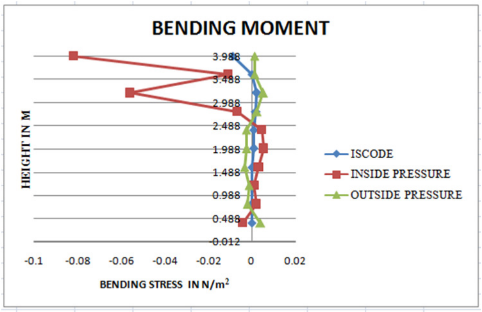
Wall

Below graphs represent the wall and base are acting monolithically.



Graph 3 Hoop stress (sz)

Graph: 3 hoop stress represent the fig: 12 result. Wall and base acting together, when the results compared with IS 3370 coefficient it will not be equal. Because there was some error in IS 3370 coefficient.



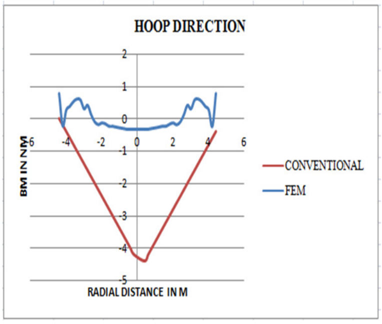
Graph 4 Bending stress (sy)

Graph 4 bending stress represent the fig: 11 result. Wall and base acting together, when the results compared with IS 3370 coefficient it will not be equal. Because there was some error in IS 3370 coefficient.

Graph 3, 4 represents that the coefficient was arrived by the analytical method. Conventional method contain inward pressure only but analytical method shows that the inward and outward pressure. But in reality wall and base are acting together. And the coefficient was compared with IS code coefficient, and it said to be not equal.

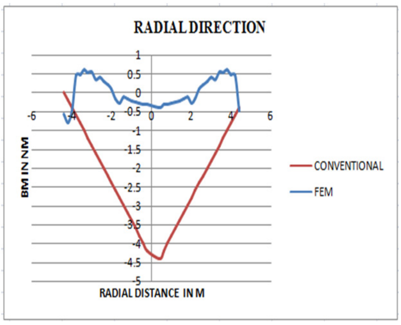
Base slab

Base slab is an important component of the water tank. The BMD in radial as well as hoop directions are plotted below and compared with the conventional results.



Graph 5 BMD of base slab in hoop direction

Graph: 5 Hoop direction represent the fig: 12 base result. Comparison of hoop direction between conventional and analytical method.



Graph 6 BMD of base slab in radial direction

Graph: 5 radial direction represent the fig: 10 base result. Comparison of radial direction between conventional and analytical method.

The conventional method shows a sagging moment at the centre of the base slab. But in reality, the base slab experiences higher hogging moment and its depending upon the ring beam position.

Note: similar to the previous drawing all model was created.

Ring beam position

Ring beam has placed at the distance of 3 different position are 0.65d,0.75d,d. depending upon the position of ring beam the base slab radial and hoop direction will differ.

4. CONCLUSION

An analysis of overhead circular water tank considering axisymmetric element was done. Model was created, consider that wall and base are not acting together. The result were found to coincide with the result from IS 337.-2009.

A new model was created consider with wall and base are acting together. The result were found does not coincide with the result from IS 3370-2009.

In both cases same material properties are used.

While optimized position of ring beam result were change depending upon the distance.

Based on the axisymmetric new procedure for the analysis of water tank was proposed.

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