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Analysis of Rectangular Water Tank Resting on Ground by Using Finite Difference Method

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Abstract: Water tanks are used to store water and are designed as crack free structures, to eliminate any leakage. In this research, analysis of rectangular water tank resting over ground is done by using Finite Difference Method (FDM). The finite difference method is probably the most transparent and the most general It is considered to be subjected to an arbitrary transverse uniformly distributed loading and is considered to be clamped at the two opposite edges and free at the other two edges. The ordinary Finite Difference Method (FDM) is used to solve the governing differential equation of the plate deflection. The proposed methods can be easily programmed to readily apply on a plate problem.
Keywords: water tank, Finite Difference Method (FDM), plate analysis

I. INTRODUCTION

Water tank is a container for storing liquid. The need for a water tank is as old as civilization, to provide storage of water for use in many applications, drinking water, irrigation, agriculture, fire suppression, agricultural farming, both for plants and livestock, chemical manufacturing, food preparation as well as many other uses [1]. A water tank is a structure used to store water to tide over the daily requirement. Cost, shape, size and building materials used for constructing water tanks are influenced by the capacity of water tank. Shape of the water tank is an important design parameter because nature and intensity of stresses are based on the shape of the water tank. The walls of these tanks are subjected to pressure and the base is subjected to weight of water. These tanks are rectangular or circular in their shape. The walls of rectangular tank are subjected to bending moments both in horizontal as well as in vertical direction. In this paper we are study analysis of rectangular water tank by using Finite Difference Method [3].

The finite difference method has emerged as a powerful tool of structural analysis. The method is economic and competitive with the well- known Finite Element Method. The finite difference method is probably the most transparent and the most general. Especially plate bending analysis is the classical field of the FDM. Today despite the existence of numerous finite element- based software packages, the FDM still be regarded as a numerical method that has merit due to its straight forward approach and a minimum requirement on hardware [2]. In applying the FDM, the derivatives in the governing differential equations are replaced by difference quantities at some selected points of the plates. These points are located at the joints of a square, rectangular, triangular or other reference network, called a finite difference mesh. The finite-difference method is the most direct approach to discretizing partial differential equations. You consider a point in space where you take the continuum representation of the equations and replace it with a set of discrete equations, called finite-difference equations. The finite-difference method is typically defined on a regular grid and this fact can be used for very efficient solution methods [4].

II. LITERATURE REVIEW

Dr. Sadjad A. Hemzah et.al., 2017 [1] in the study has investigated validity of the Finite Difference method to simulate thin sectorial steel plate under the effect of uniform and concentrated loads with different types of boundary conditions. The differential equation schemes of curved plate were solved by means of the Finite Difference method.

Trong Ha Nguyen et.al., [2]- in this paper studied the analysis of rectangular plates on resting Winkler and two parameter elastic foundation models by using the finite difference method. Authors utilized classical plate theory, Winkler and two parameter elastic foundation and F.D.M. Parametric tests were performed to study the effects of input parameters on the non-dimensional deflections and stresses. The obtained results showed the validity of this approach.

Md. Roknuzzaman et.al., [3]-in this research done shows rectangular steel plate is analyzed by a finite difference method (F.D.M.). The work covers the determination of displacement components at different points of the plate and checking the result by software (STAAD PRO) analysis. Thus, the study shows that the FDM analysis is found to be satisfactory as compared to STAAD PRO analysis.

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Ali Ghods *et.al.*, [4]- in this paper presents an investigation into the performance evaluation of Finite Difference method (F.D.M.) in modeling a rectangular thin plate structure. Given the difficulty and long analytical solution of the plate equations in some specific issues, using numerical methods is always a good practice, provided that the authenticity and accuracy of these methods can be evaluated and selecting optimized steps for iteration, both save time during the analysis of problems and get appropriate and acceptable accuracy.

III. METHODOLOGY

The whole project work is divided into various sub phases which is as elaborated below:

1) *Phase I:* Design of rectangular water tank using Staad pro software.
2) *Phase II:* Mesh Density (4x4) and (8x8).
3) *Phase III:* Solve using Finite Difference Method.

IV. DETAIL STUDY

Phase I: Design a rectangular water tank 5m x 4m with depth of storage 3m, resting on ground and whose walls are rigidly joined at vertical and horizontal edges. Assume M20 concrete and Fe415 grade steel.

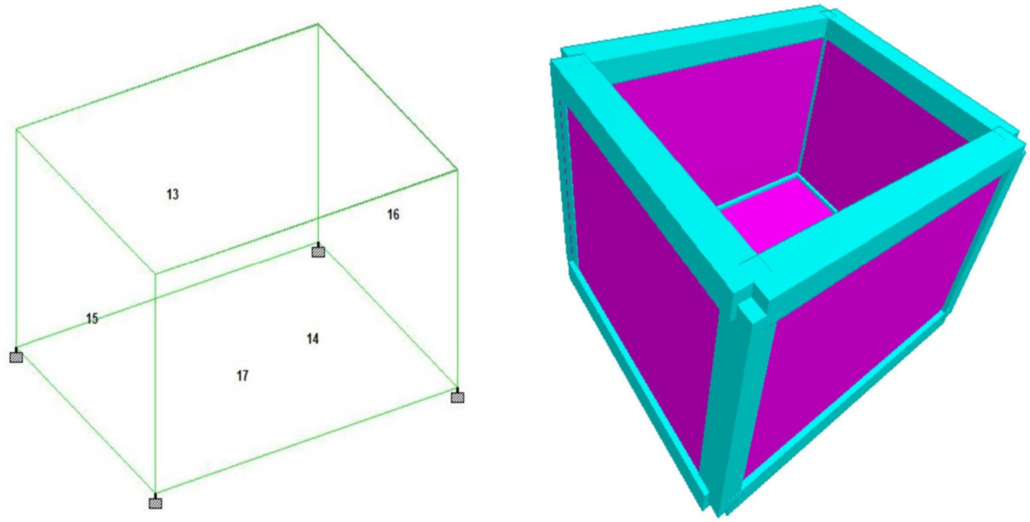

Fig 1. 2D & 3D image of rectangular water tank

Phase II & III: a) Rectangular water tank problem solves by generating Mesh of (4x4) using Finite Difference Method.
Rectangular plate fixed on two opposite sides and free on the other. Finite Difference method for nodal location I
Consider a plate of 5m x 3m, fixed on two opposite sides and free on the other. Plate is subjected to uniform pressure of intensity 6 KN/m2, and having thickness 1.25m. Take mesh size h=0.75m, v = 0.17 and 21.718 KN/m2
.

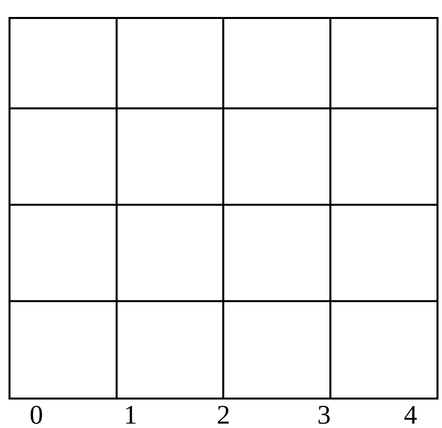

Fig 2. Nodes of 4x4 mesh

since Slope is zero at fixed edges, we get

W-1 = W1

i.e., displacements of imaginary point are equal to the displacement of image point. Keeping these points in mind, plate equation can be written for the points 1,2 & 3. The plate equation is,

Apply bi-harmonic equation, consider point 1,

Qh4/D = 20W1 – 32W2 +8W3 (1)

Plate equation at point 2 is,

Qh4/D = -8W1 + 25W2 -16W3 (2)

Plate equation at point 3,

Qh4/D = 2W1 – 16W2 + 23W3 (3)

Solving equation (1), (2), & (3) simultaneously,

W0=1.03, W1=0.75, W2=0.547

Now,

D= Et3/12(1-v2)

D= 3.22

Now,

W1 = 1.03 x qh4/D = 0.578 W2 = 0.75 x qh4/D = 1.053 W3 = 0.547x qh4/D = 0.578

b) rectangular water tank problem solves by generating Mesh of (8x8) using Finite Difference Method.

Rectangular plate fixed on two opposite sides and free on the other. Finite Difference method for nodal location I

Consider a plate of 5m x 4m, fixed on two opposite sides and free on the other. Plate is subjected to uniform pressure of intensity 6 KN/m2, and having thickness 0.625m. Take mesh size h=0.5m, v = 0.17 and 21.718 KN/m2

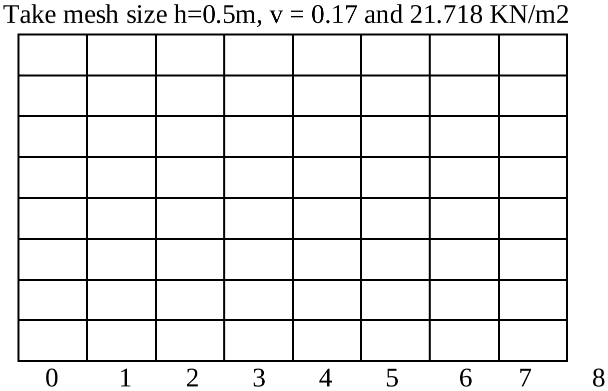

Fig 3. Nodes of mesh 8x8

Plate is fixed at supports. The deflection at the edges will be zero. Apply bi-harmonic equation,

Consider point 1,

Qh4/D = 20W1 – 32W2+ 4W3 + 8W4 (1)

Consider point 2,

Qh4/D = – 8W1 + 25W2 -8W3-15W4 +4W5+ 2W6 (2)

Consider point 3,

Qh4/D = W1– 8W2 +20W3-4W4 -16W5 +4W6 + 2W7 (3)

Consider point 4,

Qh4/D = 2W1 – 16W2 + 4W3+22W4-8 W5 -7W6 + 2W7 +W8 (4)

Consider point 5,

Qh4/D = 3W2– 8W3 -6W4+21W5-6W6 -8W7 +2W8 + W9 (5)

Consider point 6,

Qh4/D = 4W2 – 8W3 -6W4+ 2W5 + 21W6 -8W7 -8W8+2W9 (6)

Consider point 7,

Qh4/D = 3W3+2W4 -8W5-6W6+20 W7-6W8 -8W9 +20 W10 (7)

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Consider point 8,
Qh4/D= 2W4+2W5-7 W6 - 8W7 + 20 W8 +2W9 -8W10 (8)
Consider point 9,
Qh4/D = W4+2W5+2 W6 - 16W7 -8 W8 +20W9 -8W10 (9)
Arranging in Matrix form,
Now,
D= Et3/12(1-v2)
D= 4.55
Now, W1 = 0 W2 = 0.221 W3 = 0.654 W4 = 1.030
W5 = 1.170 W6 = 1.030 W7 = 0.654 W8 = 0.221
W9 = 0

V. OBSERVATION AND REMARK

Centre line graph for Finite Difference Method

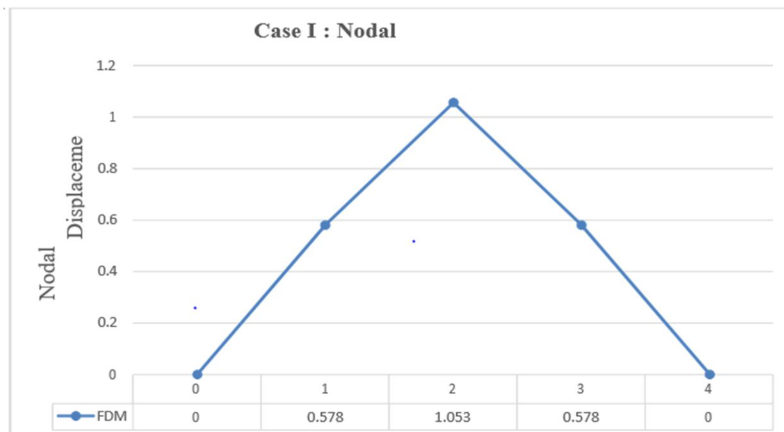

Fig 4: Central Displacement Profile for mesh density 4x4

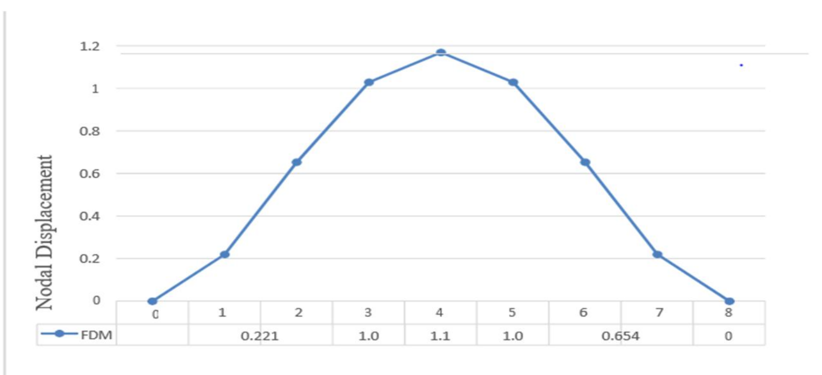

Fig 5: Central Displacement Profile for mesh density 8x8

Remark: The displacement values changes with change in mesh.

VI. CONCLUSION

From the results obtained for considered plate element using Finite Difference Method, it can be concluded that-
With change in mesh density, the displacement results obtained for various tank walls that include size of 5x3 and 5x4 sqm with meshing of 4x4 and 8x8 size, the values changes making displacement profile curve smooth and sharp.
Similarly, when the cases are considered for Finite Difference method with change in mesh size, it can be seen that the values of displacement changes to some extent making the displacement profile sharp.

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