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Study of Continuity Analysis in INTZE Type Tank using Conventional and Finite Element Method

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Abstract: *In this study only Intze type tank is considered, because in the present scenario of fast and large scale infrastructure development, most of water tanks are constructed of large to medium capacity having heavy load on bottom dome and its diameter is large, the ring beam needs large amount of reinforcement. It becomes more economical to reduce its diameter by introducing a conical dome to reduce the ring tension. The bottom ring beam in Intze tank required much lighter reinforcement as the thrust from the conical dome opposes the force from the bottom dome, hence Intze tank is economical. This study is carried out to know the importance of continuity analysis for practical consideration. In this study analysis of Intze type container of water tank is carried out by both methods by using conventional method and finite element method. In conventional method, the analysis of Intze type tank carried out in two parts as under,*

1) Considering only membrane forces, and

2) Considering effect of continuity along with membrane forces.

The finite element modelling and analysis are done by using of STAAD Pro Software. Two different capacity tanks were analysed by all three methods and with different ratios of height of the conical shell to height of the cylindrical shell.

Keywords*:* *Intze type tank, Continuity analysis, membrane analysis, Finite Element method, STAAD PRO.*

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I. INTRODUCTION

Generally water tanks are analysed and designed for membrane stresses only, because of small flexural rigidity, bending moment at supports are very small. In the big capacity of tank, at the joint of different elements the secondary stresses are developing due to effect of continuity. In the big capacity of tank, the Intze type container tank will be economical.

In the design of normal building structures, the most critical aspect of the design is to ensure that the structure retains its stability under the imposed loads. In the design of water retaining structures to retain water, it is usually found that, if the structure has been proportioned and reinforced so that the water is retained without leakage, then the strength is more than adequate.

A 15 lacs litres capacity tank is analysed by all the three methods, i.e. by membrane theory, considering effect of continuity along with membrane forces and finite element method's results were compared. The applicability of conventional method, considering effect of continuity was finalized after comparing results of conventional method with the finite element method.

Another 25 lacs litres capacity tank is analysed by all the three methods, i.e. by membrane theory, considering effect of continuity along with membrane forces and by finite element method and results were compared of both tanks.

It is seen that, the percentage effect of continuity is same and does not differ with respect to the capacity of tank.
Capacity of tank is taken as 15 lacs litres.
Angle of inclination of conical wall is taken as 45^0
The diameter of bottom dome is taken as 13.00 m.

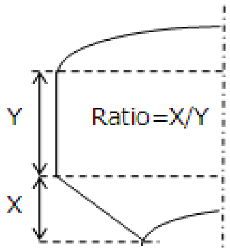

Fig. 1

II. LITERATURE

Shell structure

By virtue of its geometry a shell structure carries the applied load primarily by direct stresses lying in its plane. Because of small flexure rigidity, bending moment at supports is very small & usually neglected.

The Intze container consist of four shells, one conical shell and one cylindrical shell, and covered at top and bottom by spherical shell of dome. All these four shells are surfaces of revolution. Since the loads and forces on each shell are symmetrical about the axis of revolution, it is possible to support/carry these load mainly this loads by the development of membrane stresses in different shells, that is, only direct stresses will be created in each shell if its supports did not restrain its edge displacements. Bending and normal shear stresses will then be almost absent. These direct stresses are the meridional and hoop stresses.

Since supports restrain edge displacements, because of small flexural rigidity bending moments developed are very small and usually neglected. That is effect of continuity at joints of different elements is not usually not considered and shell elements are designed for membrane stresses only. (Chandrashekhar)

Objective of Study

1. The main objective of this study is to understand the difference in results of membrane analysis and analysis with effect of continuity.
2. It will help to designer to decide, whether analysis with effect of continuity is required or not.
3. Another objective is to study of results of analysis by finite element method.

Scope of Work

1. Analysis and Design of Intze type container by membrane analysis.
2. Analysis and Design of Intze type container with effect of continuity by conventional method.
3. Comparison of the results of membrane analysis and continuity analysis by conventional method.
4. Analysis of Intze type container using Finite Element method.
5. Comparison of the results of analysis by conventional method and Finite Element method.

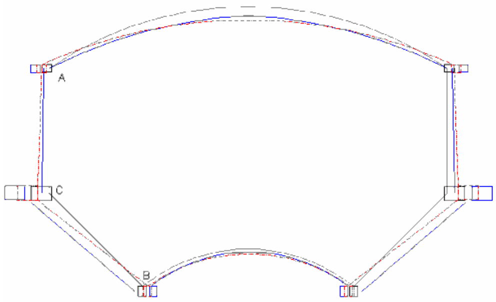

Fig.2 Deflected Shape of INTZE Container

Rotation of Joints Due to Effect of Continuity

The angle at corner A & C tends to close resulting in sagging moment, while the angle at B tends to increase resulting in hogging moments. Also, the edges of top dome and vertical wall at A are pulled outwards resulting in tensile hoop stresses, while the ring beam A is pushed inward and its hoop tension is reduced. Similarly the beam C and edges of conical dome at C are pushed inwards causing a reduction in hoop tension. At joint B, the conical wall is pushed in-wards, the bottom dome and beam B are pulled outwards. This causes a hoop compression in beam B and bottom dome. (O.P. Jain, 1987)

FINITE ELEMENT METHOD

Introduction and Principal of FEM

In last three decades there has been a great expansion and development and availability of numerical procedures. It is not possible to obtained analytical mathematical solutions for many engineering problems. This has opened a new era in analysis and design for complex problems. Most of the available techniques are based on the principle of discretization. In this a complex problem is divided into smaller equivalent units. In finite element methods the continuum is considered as an assemblage of the 'finite elements'. The finite element method is based upon the general principal known as “going from part to whole.”

Finite element analysis is the extension of techniques of analysis of one-dimensional structure into two-dimensional structures such as plates and shells and equally applicable to three-dimensional structures as well.

In a continuum, which is divided into a mesh, two adjacent elements placed side by side will have a common edge. As it adds to complication, to make analysis simpler the elements are assumed to be connected at nodal points only.

Once discretization is made, the analysis follows a set of procedure. The stiffness matrix of individual element is formulated. The forces actually distributed in real structure are transformed to act at the nodal points. Total structure obtained as an assembly of individual element is analysed similar to one-dimensional structure.

In finite element analysis a continuum is divided into a finite numbers of elements, having 'finite' dimension and reducing the continuum having infinite degrees of freedom to finite degrees of unknown. The accuracy increases with numbers of elements taken. The selection of mesh size and numbers of elements depends on past experiences and the trial & error method. In the region where stress concentration is high, finer division should be made.

In FEM, the physical body approximated by replacing it with an assemblage of discrete elements and these elements can be put together in number of ways. As a result FEM is preferred by engineers and scientists. (Abel, 1987)

III. ANALYSIS OF INTZE TYPE CONTAINER

By Conventional Method

Intze type container of water tank is analysed and designed by using conventional method, in two parts-

1. Considering only membrane forces.
2. Considering effect of continuity along with membrane forces.

By Finite Element Method (Using Staad Pro.)

Staad Pro. Software is used for modelling and analysis.

The nodes are inserted as per requirements of numbers and types of elements for model. Considered 2-D (two dimensional), quadrilateral element problem as shown in fig 1.

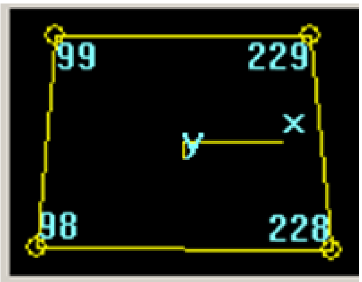

Fig.3 Two Dimensional Quadrilateral Element

Prepared 2-D elements by connecting nodes, and properties given as plate thickness.

Only D.L and Water loads are considered. As only container is analysed Wind load and/or Seismic load are not considered.

Loads are given as element load.

Given support condition as Fixed but releasing Fx, Fz, Mx and Mz, we can also give support condition as Fixed but releasing Fx, Fz, Mx, My and Mz, except one support must be pinned.

Two tanks are analyzed for different capacities as 15 lacs litres and 25 lacs litres.

Staad Pro

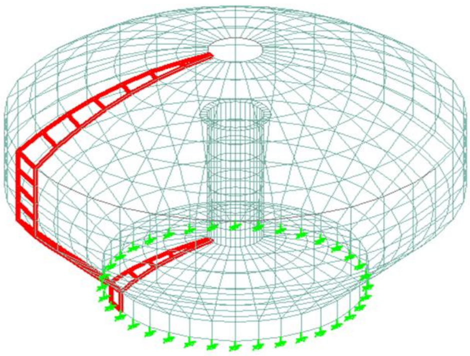

Fig 3. Staad Model

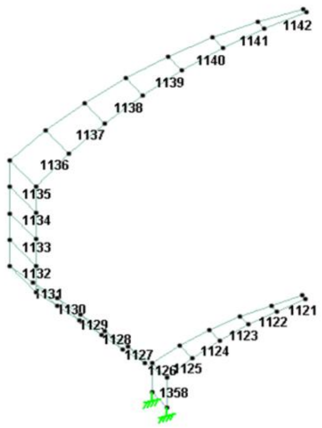

Fig 4. Plate number of different Component

Hoop Force Calculation

Height of cylindrical wall H	=	**3.400**	**m**
Height of conical portion h1	=	4.067	m
Total height h	=	7.467	m
Radius at cylindrical wall R	=	9.500	m
Radius at conical shell at mid ht $R_{av=}$	=	7.417	m
Unit weight of water	=	1.000	T/m^3
Hoop force in cylindrical shell=$0.5wH^2R$	=	54.91	T
Hoop force in conical shell= $wH_{av}hR_{av}$	=	163.901	T
Total hoop force	=	218.811	T
Variation with staad result	=	0.019	%

Table 1: Hoop Force Calculation

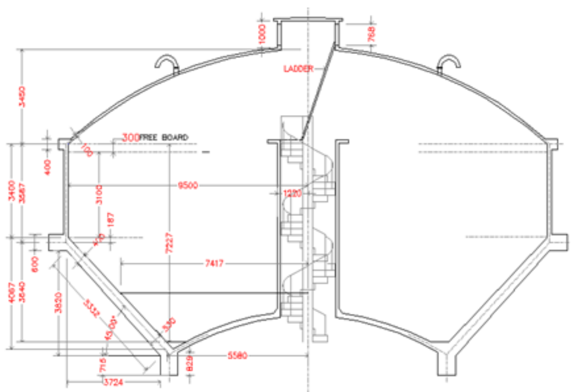

Fig 5. Dimensional Geometry of Container

Stress Diagram
Top Dome
Sign convention: -ve shows compression & +ve shows tension

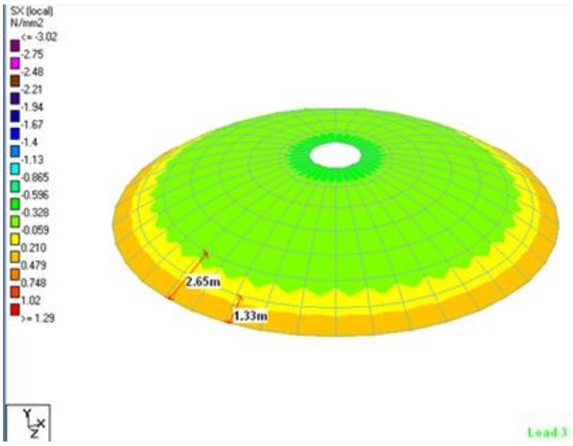

Fig 6. Stress Diagram of Top Dome

Observations:

- Near joint of top ring beam the tension is observed in dome due to continuity effect.
- The value of tensile stresses is varying from 0.495 N/mm^2 to 0.081 N/mm^2.
- This requires the reinforcement of 330 mm^2 to 54 mm^2.
- We have generally provided 8mm# @ 200 mm, which is 250 mm^2.
- It is necessary to provide 8mm# @ 150 mm c/c up to 1.30 m, which is 0.15m length.
- This requirement is fulfilled by extending the outside reinforcement of cylindrical shell up to required length, inside top dome.

Cylindrical Shell

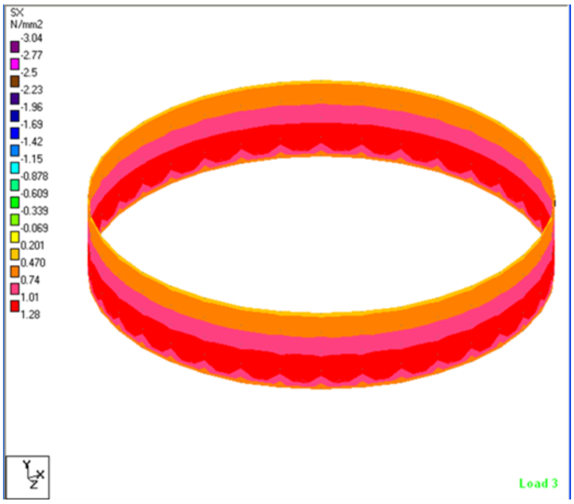

Figure 7. Stress Diagram of Cylindrical shell

Observations:

- Whole cylindrical wall is under tension.
- It is observed that tension is increased with respect to depth.

Conical Shell

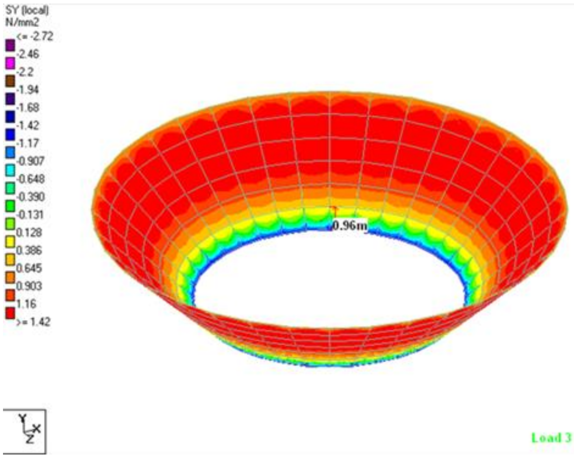

Fig 8. Stress Diagram of Conical shell

Observations:

- Most of conical shell is under tension except bottom edge.

Bottom Dome

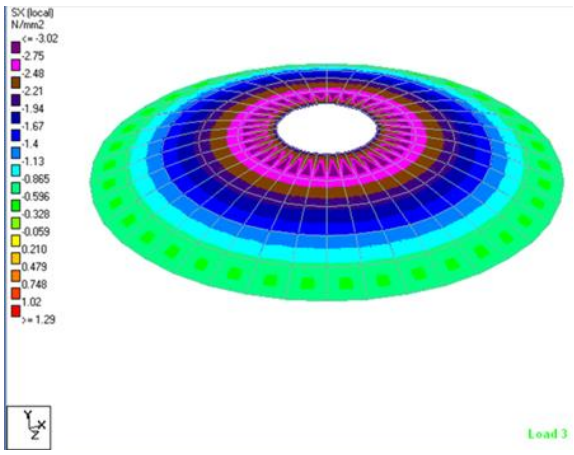

Figure 9. Stress Diagram of Bottom Dome

Observations:

- Whole bottom dome is under compression.

Similarly, Staad Model of 25.0 lacs litres tank can also be analysed

IV. COMPARISON OF RESULTS

Comparison of Beam Forces

		Axial Force in kN		
Member	Location	Membrane	With Continuity	FEM
1177	Top ring beam	-184	-77	-80
1213	Middle ring beam	-827	-650	-628
1251	Bottom ring beam	47	26	20

Table 2: Beam Forces of 15 lacs litres

Negative = tension
Positive = compression

Comparison of Plate Stresses

		Stress in N/mm2		
Plate	Location	Membrane	With Continuity	FEM
1136	Top Dome @ Top ring	-0.250	0.480	0.495

	beam			
1135	Vertical Wall @ Top	0.094	0.480	0.477
1132	Vertical Wall @ Bbottom	0.408	1.389	1.330
1131	Conical Wall @ Top	1.253	1.389	1.300
1126	Conical Wall @ Bottom	1.104	-0.108	-0.435
1125	Bottom dome @ Bottom	-2.400	-0.104	-0.435

Table 3: Plate Stresses of 15 Lacs Litres

Comparison of Design Requirements

Member	**Location**	**Member Size**	**Membrane Analysis**	**Continuity Analysis**
	Joint A (Near Top Ring Beam)			
Top Dome	Near top ring beam	100mm thick	8mm @ 200mm c/c both ways	8mm @ 150mm c/c required
Top Ring	Beam	400 x 400	7 Nos – 16mm dia	5 Nos – 12mm dia
Vert-wall	Near ring beam	100mm thick	10mm @ 270mm c/c both face	10mm @ 250mm c/c required
	Joint C (near Middle Ring Beam)			
Vert-Wall	Near middle ring beam	180mm thick	12mm @ 260mm c/c both face	12mm @ 130mm c/c both face
Middle Ring	Beam	780 x 600	18 nos – 20mm dia	14 Nos – 20mm dia
Coni-Wall	Near middle ring beam	400mm thick	20mm @ 145mm c/c both face	20mm @ 165mm c/c both face
	Joint B (Near Bottom Ring Beam)			
Coni-Wall	Near bottom ring beam	550mm thick	20mm @ 135mm c/c both face	12mm @ 170mm c/c both face
Bottom Ring	Beam in Compression	380 x 200	8 Nos – 16mm dia	8 Nos – 16mm dia
			200mm thick	360mm thick
Bottom Dome	Near bottom ring beam		8mm @220mm c/c both ways	10mm @ 100mm c/c

Table 4: Design Requirements for Both the methods.

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