ANALYSIS AND DESIGN OF UNDERGROUND STORAGE TANKS OF POLYETHYLENE AND POLYMERS

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Major Project

on

ANALYSIS AND DESIGN OF UNDERGROUND STORAGE TANKS OF POLYETHYLENE AND POLYMERS

Submitted in partial fulfillment of the requirements

For the degree of

Master of Technology in Civil Engineering
(Computer Aided Structural Analysis & Design)

By

Makadia Hiral R.
(06MCL007)

Guide
Dr. B. S. Munjal

DEPARTMENT OF CIVIL ENGINEERING
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May 2008

CERTIFICATE

This is to certify that the Major Project entitled "Analysis and design of underground storage tank" submitted by Mr.Makadia Hiral R. (06MCL007), towards the partial fulfillment of the requirements for the degree of Master of Technology in Civil Engineering (Computer Aided Structural Analysis and Design) of Nirma University of Science and Technology, Ahmedabad is the record of work carried out by him under my supervision and guidance. In my opinion, the submitted work has reached a level required for being accepted for examination. The results embodied in this major project, to the best of my knowledge, haven't been submitted to any other university or institution for award of any degree or diploma.

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ABSTRACT

With the advent of high speed digital computers, now it is possible to handle real life structural analysis problems with confidence and aplomb. We know nowadays there is a volcanic proliferation in domain of computer software, pre processors, and post processors and computer hardware. Nowadays it is possible to carry out rigorous finite element analysis of structures, and suggest optimized geometry from the techno-commercial aspects of the structures.

In this piece of work, an attempt is made to thoroughly investigate various topological geometries of multipurpose tanks made up of High density polyethylene materials. Structure analysis runs are made, which includes also sensitivity analysis, structural optimization in stress and deflection domain and attempt is also made to investigate the problem from the point of view of studying at micro and macro levels, final geometry has been proposed after set of analysis runs. Out of three materials tried, composite material (fiber reinforced plastic) has been suggested after wide amount of analysis runs and load cases. These containers depending upon practical usage may fall in domain of underground septic tanks, petrol tanks or water tanks.

Effort has also been put in the domain of suggesting innovative, relative stiffener positions using different shapes and sizes of the containers. Parametric data bank is also generated in pictorial form; the study has been made not only from theoretical aspects but also from commercial aspects.

Summary and conclusions highlights the optimized geometry from the sensitivity point of view for composite material containers, with given loading conditions.

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CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVATION NOTATION AND NOMENCLATURE

ρ	Density of material
$\{u\}$	Displacement matrix
M_{xy}	Moment in x-y direction
M_{yx}	Moment y-x direction
E	Modulus of elasticity
N_y	Normal force in y direction
N_{xy}	Normal force in x-y direction
N_{yx}	Normal force in y-x direction
N_x	Normal force in x direction
r	Natural coordinate for the rectangular element
s	Natural coordinate for the rectangular element
ν	Poisson's ratio
$\{F\}$	Resultant nodal force matrix
$[K]$	Stiffness matrix
$[N']$	The Shape function of the parent rectilinear element
$\{x_n\}$	The nodal coordinates of the element
$\{d_n\}$	The nodal displacement
$[J]$	The Jacobian matrix
$[B]$	The strain displacement matrix
$[K]$	The stiffness matrix
V_x	Vertical force in x direction
V_y	Vertical force in y direction

1. INTRODUCTION

1.1 GENERAL

Polyethylene tanks are used for liquid storage purpose. It is generally used as water tank in building. Polyethylene water tanks are placed above building or on the ground, nowadays these kinds of tanks are used for liquid storage but it is embedded in ground, for fuel storage tank situated under ground. These tanks are also used for purpose of septic tank. Design of polyethylene tanks for transportation of liquid have been a continuous challenging work.

1.2 SEPTIC SYSTEM

A septic system is an on-site subsurface sewage disposal unit that is designed to have the sewage treated through the soil. The key components of system are a septic tank, leach lines seepage pit, and permeable unsaturated soil. The design life expectancy is 20 to 30 years for a properly designed and maintained septic system. A septic system is not an option if public sewer is readily available to the site. Arrangement is shown in Fig 1.1.

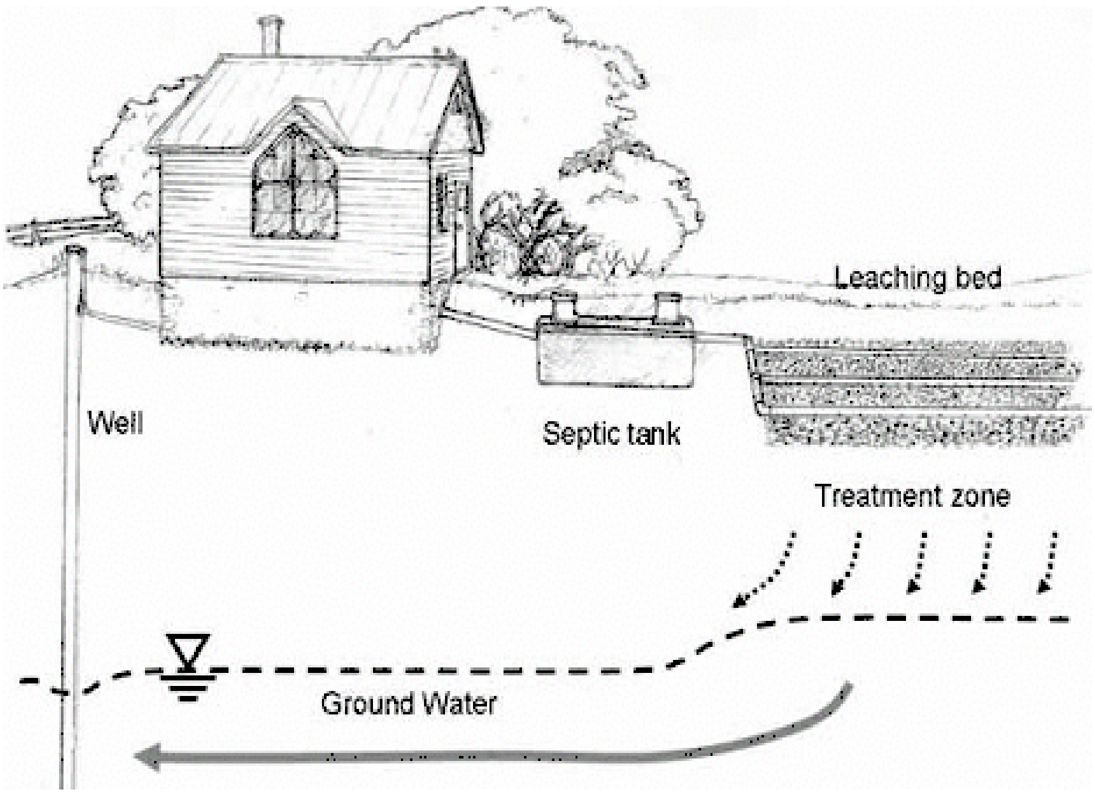


Fig 1.1 Septic system

1.3 SEPTIC TANK

A septic tank is a retention vessel designed to receive sewage, hold it for a period and then release a clarified effluent. Sewage is a mixture of toilet waste, kitchen wastes and so called grey waste i.e. liquids which include washing, bath and washing machine waste. A septic tank is primary a liquid/solid separation system, although there may be some limited biological activities within the sludge and liquid interface.

In India septic tanks are constructed by conventional method, with concrete or masonry, but nowadays plastic products (polyethylene products) are used for manufacturing of septic tank. These tanks are having more advantages in compare to other conventional septic tank. These tanks are pre-fabricated just installation at site is required for use. Tanks can be manufacture for different capacity according to number of persons using it. Tanks are also fabricated in different shape like vertical cylinder, horizontal cylinder, Spherical etc.

Septic system remains same only, but septic tank materials are different, earlier septic tanks were made up with concrete or masonry but nowadays different materials are available, polyethylene tanks are also available in market.

Fig 1.2 shows the typical tank with tradition material.

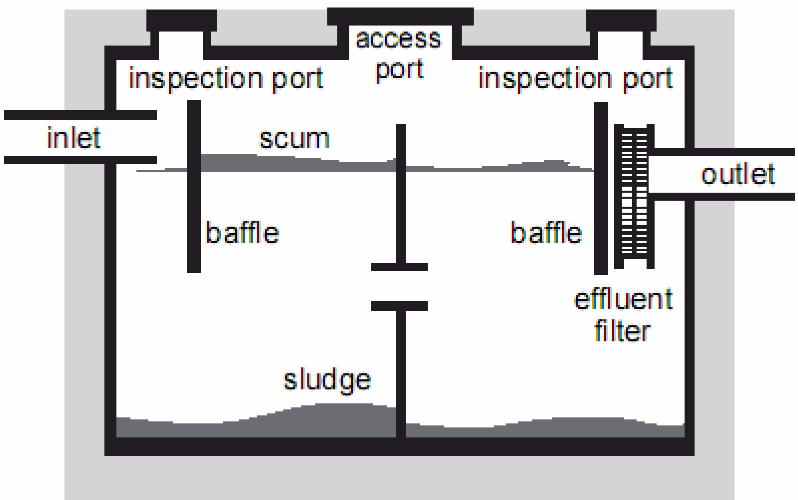


Fig 1.2 Conventional septic tank

Typical polyethylene tank is shown in Fig 1.3.

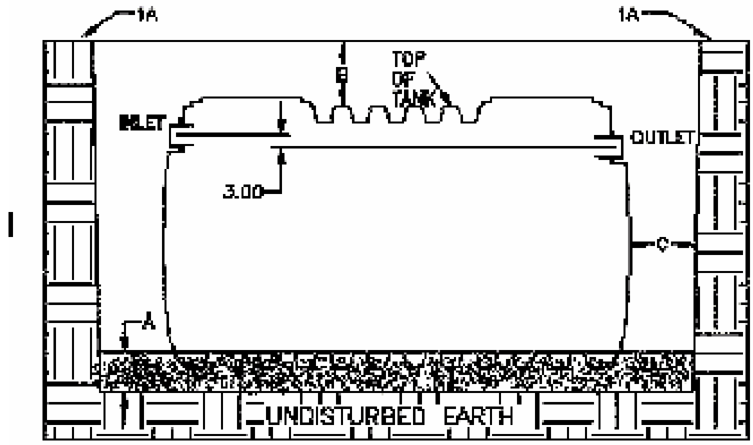


Fig 1.3 Polyethylene septic tank

The polyethylene family covering linear low-density polyethylene (LLDPE), high-density polyethylene (HDPE). Polyethylene family is over 35 million tons over the world for low price and easy process ability, and it seems to continue to grow by the new process technologies, driven by commercial interest. Cylindrical liquid storage tank has been manufactured from polyethylene, which are generally used for water retaining. Nowadays research is going on for polyethylene tanks to store other liquids, like fuel, septic tank for this purpose tanks need to be designed in a different manner by considering other effects because position of these tank is different. Earlier tanks were used for overhead water storage for buildings. It can be also installed on ground. But when it is used for storage of liquid under ground, design will be completely different,

Under ground liquid storage tanks are subjected to various loadings; liquid pressure in side the tank, soil pressure from outside of tank, and also subjected to gravity loading when some heavy load passing on it. As load cases are completely changes for tank used as storage at overhead or on the ground. Due to these reasons it is necessary to analyze and design tank for different loading when it is embedded in ground.

Plastic tanks can also be used for transportation of liquid. For these kinds of tanks analysis and design is based on vibration study. When tanks are transported on vehicle, due to movement of vehicle tank will subjected to sloshing effect by the liquid stored in it. When these vehicles pass over a curved road, centrifugal force acting on the wall of tank. Considering these effects these types of transportable tanks are designed.

1.4 OBJECTIVE OF THE STUDY

Underground tanks are generally made up of conventional materials like concrete or masonry, in some cases Ferro cement can be used for underground tank. Underground tank with different materials like polyethylene products or FRP have advantages over the conventional method of construction, Advantages of these types of underground tanks are:-

- Material (polyethylene, FRP) used for manufacturing are Eco friendly.
- These materials are rust proof.
- Tanks are leak proof, these tanks are pre fabricated and tested in factory therefore leakage problem is avoided.
- Materials are highly durable.
- In compare to other conventional materials used for underground tank like concrete, masonry these tanks are light in weight.
- Easy to install, tanks are pre fabricated in different sizes and shape, installation is easy.
- Economical than conventional septic system.

As mentioned above, these types of tanks have advantageous in comparison to other conventional system, Hence due to these advantages; it was envisage carrying out this study.

1.5 SCOPE OF WORK

Scope of work is limited to stress, deflection analysis and design of polyethylene tank, experimental work on underground polyethylene tank. It also includes, sensitivity analysis to get the optimum design, following is the scope of work.

- Finite element analysis polyethylene underground tank.
- Stress, deflection analysis.
- Analysis of underground tank for different loading conditions.
- Deciding thickness of polyethylene wall.
- Types of Stiffeners used in tank.
- Placement of stiffeners (outside or inside).
- Spacing of stiffeners.
- Techno-Commercial design by considering all criteria.

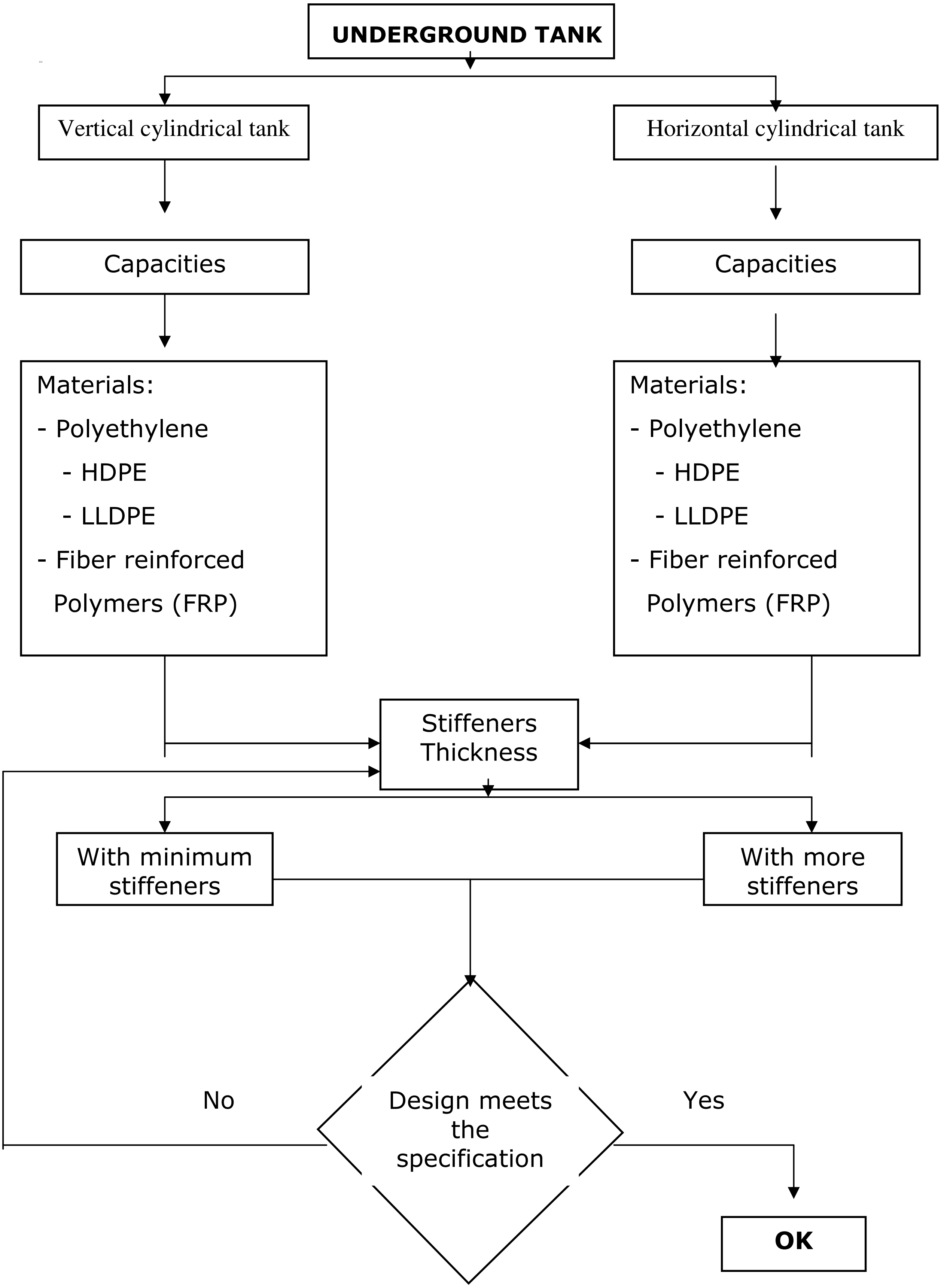


Fig 1.4 Flowchart of the approach synthesis

2. LITERATURE SURVEY

2.1 GENERAL

In India underground tanks were made up with conventional material, it required design of septic system, according to number of persons using these systems, after detailed design septic system was constructed on site. Recently septic tanks made up from other materials are available in market; these tanks are manufactured at factory. Tanks are available in different capacities according to use, these septic tanks directly fit to the system. Now process is simple in comparison to conventional systems. Septic tank is directly installed in system and it will work similar to other conventional septic systems.

Polyethylene or FRP tanks are having more advantages in comparison to conventional septic tanks. Materials are eco-friendly, easy to install, economical, materials are rust proof, tanks are leak proof, in comparison to other material tanks these septic tanks are light in weight. Materials like fiber reinforced polymers are having good strength also. The need is feet to carry out this study keeping in mind the higher strength to weight ratios of fiber reinforced plastic.

The first known installation of a septic tank in the United States was in 1876, although Louis Mouras of Vesoul, France was given a patent in 1881 and credited with the invention. Baffles, which regulate the flow, were added in 1905 to make the septic tank more efficient. The first baffles were made of oak boards. At the turn of the century, there were some very large community septic tanks. In 1903, four community tanks were constructed in Saratoga, New York, with a total capacity of one million gallons. By 1920, septic tanks began to be a common feature. After World War 2, septic tanks became important to housing developments in un-severed areas.

Septic system consist of different components, septic tank is one of the major component of system, septic tank work as a separator of solid/liquid. It will separate out the solid waste from the liquid waste; solid wastes will chock up the soil bed and create sewage sickness.

2.2 WORKING OF SEPTIC SYSTEM

A properly functioning septic system receives all the wastewater created from household use (including toilets, showers, sinks, dishwasher, washing machine, and so on), treats the wastewater to a safe level, and returns the treated effluent to the groundwater system [6]. A conventional septic system is composed of a septic tank and a soil filter called a leaching bed. A leaching bed may also be called a drain field, an absorption field or a tile field.

2.2.1 Components of septic system

A typical septic system has four main components: a pipe from home, a septic tank, a drain field, and the soil

2.2.1.1 Pipe from home

Your entire house holds waste water exits your home through a pipe to the septic tank.

2.2.1.2 Septic tank

The purpose of the septic tank is to separate liquid from solids and to provide some breakdown of organic matter in the wastewater. A septic tank is a buried, watertight container made from concrete, polyethylene or fiberglass. In the past, the tank was sometimes made of steel or wood (if you have a steel tank, it is likely rusted through and needs replacing. If you have a wooden one it is likely rotting and may need replacing.). The size of the septic tank will depend upon the size of the house (number of bedrooms) and household water use; tanks may have one or two compartments, depending upon when and where they were installed.

As wastewater from the house enters the septic tank, its velocity slows allowing heavier solids to settle to the bottom and lighter materials to float to the surface. The accumulation of settled solids at the bottom of the tank is called sludge while the lighter solids (greases and fats), which form a mass on the surface, is called scum. Anaerobic bacteria, which are always present in wastewater, digest some of the organic solids in the tank. Clarified wastewater in the middle of the tank flows by displacement into the leaching bed for further treatment in the soil layer.

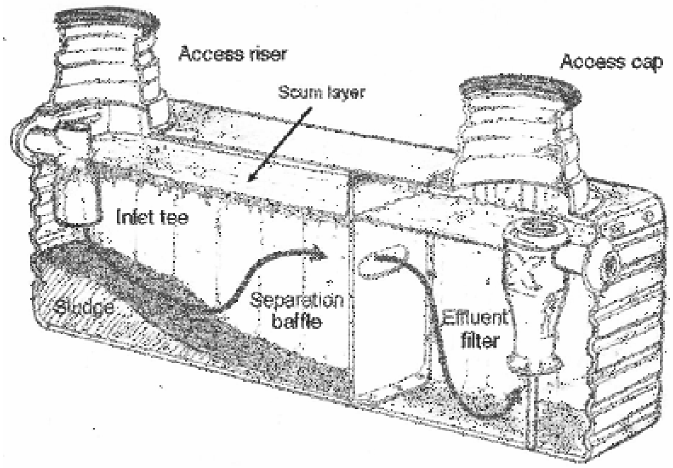


Fig 2.1 Common septic tank

2.2.1.3 Drain field

The waste water exits the septic tank and discharge into the drain field for further treatment by the soil. Every time new waste water enters the tank. Some time drain field will overloaded with too much liquid. A reserve drain field is required for this process. Septic system works without drain field also, in area where municipal is available treated water from septic tank is directly discharge these types of severs.

2.2.1.4 Soil

Septic tank waste water flows to the drain field, where it percolates into the soil, which provides treatment by removing bacteria, viruses, and nutrient. Suitable soil is necessary for successful waste water system.

2.3 PRODUCT OF SINTEX INDUSTRIES

There are various tanks available in market. These are made up with plastic materials. Polyethylene, FRP tanks are available in various capacities.

Sintex Water Tanks

Unique Features:

Rust proof

- Light weight and durable
- Hygienic
- Maintenance-free

- Tested and approved by leading laboratories, industries and institutions
- available in various capacities from 200 liters to 25,000 liters or even more

Fig 2.2 Water tanks of Polyethylene

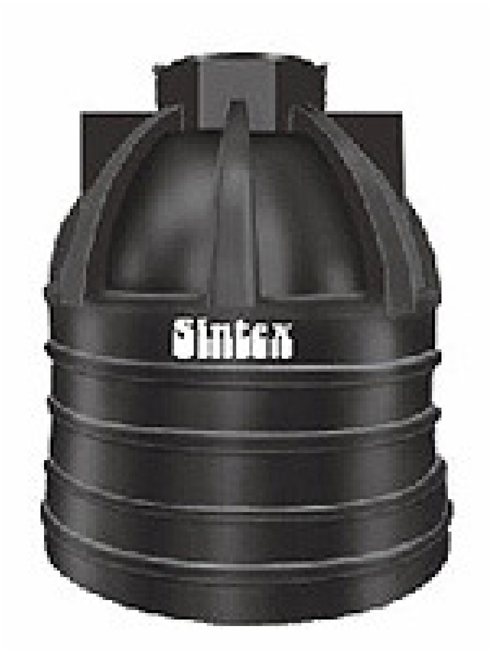


Fig 2.3 Underground water sumps

Fig 2.4 FRP underground water storage tank

Fig 2.5 Transportable water tanks

Fig 2.6 Chemical storage tanks

2.4 OVERVIEW OF LITERATURE STUDIES

R. Sturt, L. Shipley [1] has discussed finite element based analysis techniques for the evaluation of fluid-structure interaction in HLWST is first compared with simplified techniques to show the level of accuracy. These techniques are currently being used to analyze a typical HLWST, the structure configuration and liquid waste storage properties that affect the evaluation of the tank

The analysis techniques being used, utilizing the ADINA program, the evaluation of thermal hydraulic effects, soil-structure interaction and nonlinear structural behavior along with the satisfactorily representing the fluid. It can accurately include various HLWST characteristic encountered in practice the must be treated in an approximate manner by the available simplified techniques in the TSEP guidelines. These characteristic include variation of tank wall thickness; variation with height of the density of stored waste; the presence of rigid or semi-solid layer of salt-cake at the surface, variability in the stiffness of the end-condition of the tank, both at the base which often is a curved shell, and at the top where the primary tank is connected to the secondary confinement, higher mode tank vibration which may be significant exited by loadings. The improvement in accuracy using P-fluid formulation in place of D-fluid formulation is significant. Finite element modeling of tank is computationally efficient and reliable.

Bloys Rijkmans [2] has discussed stress-strain relationship is derived for finding information about tensile strength, elongation, flexural modulus and perhaps impact properties. Few people would design tanks with for example 900% elongation combined with a tensile stress at yield of 170Mpa. Normally a part is subjected to significantly lower applied stress over time period of years rather than minutes and elongation values are often expected to be below about 5%.

A different test procedure is needed for better approximate conditions. These is where tensile creep testing is constantly applied to a plastic part, in creep testing, much like the standard tensile test, test sample are subjected to a load and the strain measured over time at a set temperature. As the temperature is increases, the plastic become softer and weaker and stretch more when same stress is applied. Because of lower stress level increase test take month or even year to complete and are extremely expensive.

The FE analysis can predict how parts will behave over long time periods and highlight areas of high stress due to design or loading conditions. The rib in tank wall provides some rigidity to the tank wall but also changes the stress intensities within the tank.

[3] Yevgeny gorochov has discussed the result of experimental research were given for the stress and strain state of a near seam zone. The research was executed on large-scale model of a zone of vertical cylindrical tank assembly connection with a geometrical imperfection. As a result the independence was received between values of the basic stress, which take place in a tank wall of the ideal form, and local stress, which arise in a seam zone. It was proved by experiments that when the ring stress achieves value 100 MPa, then the local stress in a near seam zone achieves the stress of 280-300 MPa.

Hence they exceed three times their major importance. These stress values are coordinated satisfactory to the data, which are received by a theoretical way.

A. Chobey[4] has discussed that, When significant damage occurs in structure, there is a change in stiffness, which in turn affects frequency. To study this, a study was conducted to analyze the effect of crack on natural frequency in vessel. Finite element analysis has been used to obtain the dynamic characteristic of intact and damage vessel for the first eight modes of this structure. Two kinds of vessel, boiler and storage tanks were chosen and thought-thickness crack were analyzed. Different cases were examined by changing the size and location of crack with the help of FEM. Natural frequency and mode shapes were analyzed.

Mariana R. Kruntcheva [5] has discussed experimental study undertakes to provide a deeper understanding of the effect of different parameters on the coupled modal characteristic of circular cylindrical tanks. First, the most common case of clamped-free tanks resting on rigid foundation is investigated by using finite element modeling and holographic experiments. A good agreement between experiment and numerical results is a basis to draw a number of conclusions. For both tank geometries investigated, the frequencies for modes of circumferential parameter n=1 are found to be reduced most significantly by the presence of liquid. Very significant dependence of the radial shell mode shapes on the filling ratio is conformed both by the FE and experimental results.

In addition, nonclassical vibration pattern for radial shell modes were expected numerically and recorded experimentally. Special attention is paid to the pairs of shell modes. Second, the effects of a flexible foundation and axial compression are investigated using holographic interferometry. The modal response of shell-liquid system is found to be different from those of the existing theoretical model.

3. FINITE ELEMENT METHOD

3.1 GENERAL

Finite Element Method is used for analysis of real life problems; it is possible to analyze structural problems, hydraulic problem, mechanical problems etc.

3.1.1 Finite element method

The finite element was first used by Clough in 1960. In the same year engineers used the method for approximate solution of problems in stress analysis, fluid flow, heat transfer and other areas.

It is the method of numerical solution of field problems. FEM discreetize the structure into several elements and reconnect the elements at nodes. This process results in a set of simultaneous algebraic equation. Solving this algebraic equation results are obtained for particular element.

3.1.2 Degree of freedom (DOF)

In case of FEM degree of freedom is finite, while in case of continuum element it is infinite. Due to finite degree of freedom name finite element method was derived.

3.1.3 Fundamental concept

Basic concept in finite element method is to find displacement of structure under given structural force.

[K] Property
{u} Behavior
{F} Action

$$[K]\{u\} = \{F\} \rightarrow \quad \{u\} = [K]^{-1}\{F\}$$

It is difficult to solve algebraic equation of entire domain, divide the domain in small simple element. Adjust the element share DOF at connecting nodes. As shown in Fig 3.1. After dividing in the domain in small simple element obtain the algebraic equations for each element. Put all the algebraic equations together; solve the equations for the unknown variables at nodes.

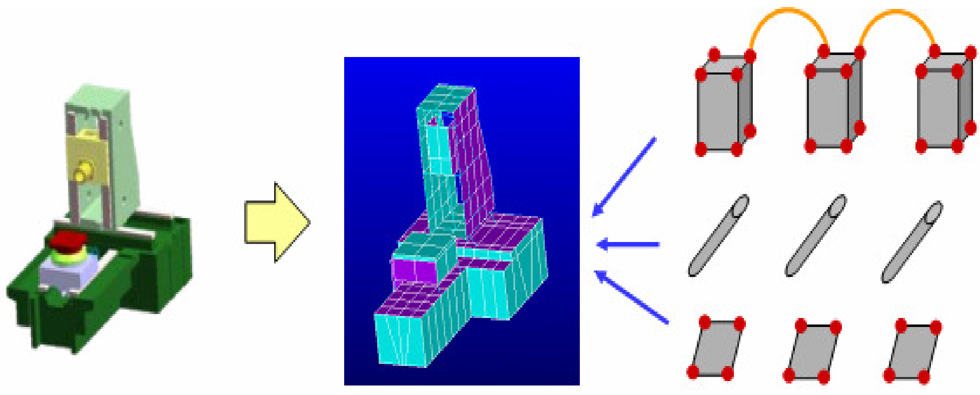


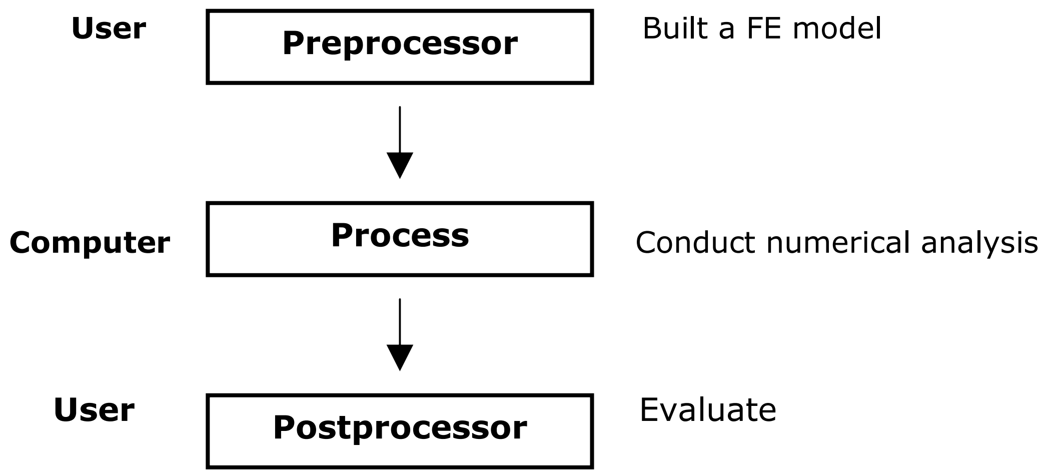
Fig 3.1 Division of domain to small element

3.1.4 Advantages of FEM

- Can readily handle very complex geometry.
- Can handle complex restraints-Indeterminate structures can be solved.
- Can handle complex loading.
- Nodal load (point loads).
- Element loads -distributed (pressure, thermal, inertial forces).
- Time or frequency dependent loading.

3.1.5 FEA procedure by commercial software

Typical procedure by software in case of finite element analysis is divide into the following manners.



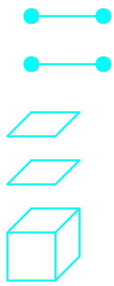
Process is shown here for analysis of structure in conventional finite element software.

3.1.6 Preprocessor

Preprocessing can be divided into different steps.

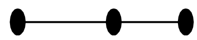
[1] Select analysis type: -Structural Static Analysis
-Modal Analysis
-Transient Dynamic Analysis
-Buckling Analysis
-Contact
-Steady-state Thermal Analysis
-Transient Thermal Analysis

[2] Select element type 2-D / 3-D Linear / Quadratic
Truss
Beam
Shell
Plate
Solid



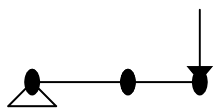
[3] Material properties E, α, γ, ρ

[4] Make nodes



[5] Build elements by assigning Connectivity

[6] Apply boundary conditions and load



3.1.7 Processor and postprocessor

[7] Process Solve the boundary value problem

[8] Post process -Displacement
-Stress
-Strain
-Natural frequency
-Temperature
-Time history

3.2 MESH

Mesh is the complex of elements discrediting the simulation domain, e.g. triangular or quadrilateral mesh in 2D, tetrahedral or hexahedral mesh in 3D.Meshing is required to construct discrete version of original problem.

3.2.1 Types of mesh

Basically mesh is of two types

- Structured mesh
- Unstructured mesh

3.2.1.1 Structured mesh

As shown in Fig 3.2 structured mesh is simple pattern in comparison to unstructured mesh. Mesh pattern is fully defined and regular. Body is regularly divided in small similar part. Elements are similar in shape and size. Triangular or trapezoidal mesh can be possible with structured mesh.

Structured mesh is shown in Fig 2.4 are triangular elements.

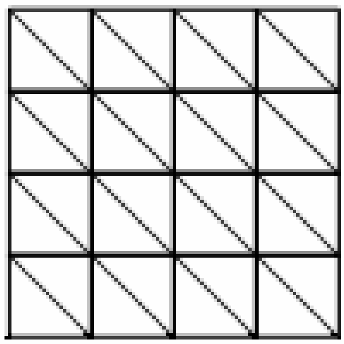


Fig 3.2 Structured meshes

- The number of elements surrounding an internal node is constant.
- The connectivity of the grid can be calculated rather than openly stored.
- simpler and less computer memory intensive
- Lack of geometric flexibility.

3.2.1.2 Unstructured mesh

Unstructured mesh is like random mesh, element can be of any size and placing of element is also random. Fig 3.3 shows the unstructured mesh.

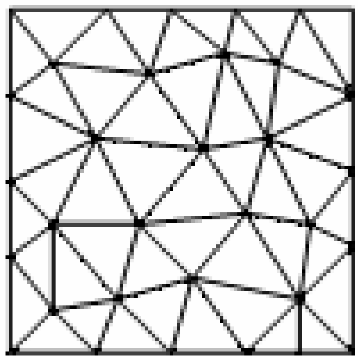


Fig 3.3 Unstructured meshes

- The number of elements surrounding an internal node can be arbitrary.
- Greater geometric flexibility.
- Expensive in time and memory requirements.

3.2.2 Criteria for a good meshing

Good meshing is depending upon shape of element, number of element in particular problem. It is also depending upon, what types of elements are used.

3.2.2.1 Shape of meshing

- Meshing should avoid both very sharp and at angles.
- May cause serious numerical problems in both finite element mesh generation and analysis.

Fig 3.4 Element with sharp and flat angle

3.2.2.2 Numbers of element

- Number of element should be moderate.
- Related to efficiency of finite element analysis.
- More elements consume more memory of processor.

3.2.3 Mesh Conversion

Some time mesh generator produces one type of mesh only and other type is required for solution, for this position mesh conversion is required.

- Quadrilaterals (Hexahedra) to Triangles (Tetrahedral) easy and well shaped mesh see Fig 3.5.

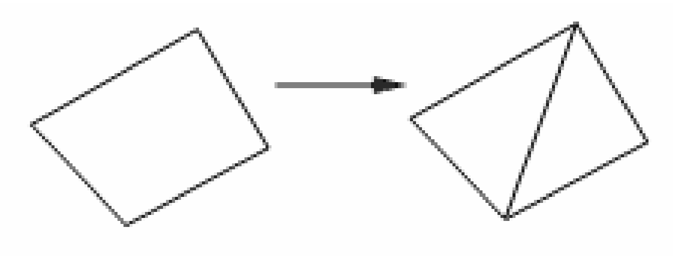


Fig 3.5 Mesh conversion quadrilaterals to triangular

- Triangles (Tetrahedral) to Quadrilaterals (Hexahedra)
- New node insertion: When new node is inserted in element shape of mesh will disturbed and it will produce flat angle see Fig 3.6.
- New node insertion will change the shape of element and analysis will be done on new element.
- It is possible on structured as well as unstructured mesh also.

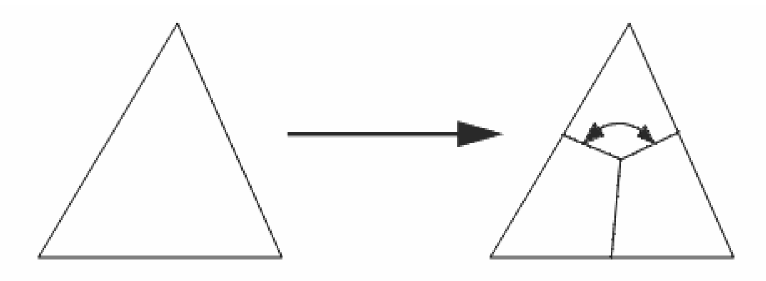


Fig 3.6 New node insertions

3.2.4 Mesh Conformity

If adjacent element share common vertex or whole edge or whole face we have conforming mesh. Otherwise mesh is non-conforming.

- Conform mesh is required less time to analysis.
- It will take more memory space.

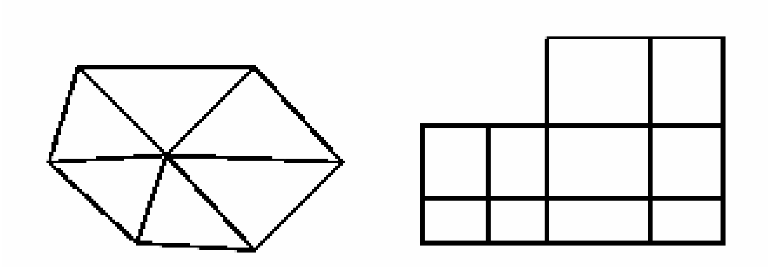


Fig 3.7 Conforming meshes

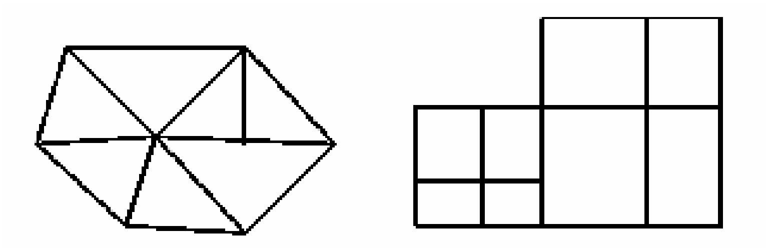


Fig 3.8 Non-conforming meshes

3.3 FINITE ELEMENT MODELING

A 3-D finite element model of septic tank is generated as per the detailed drawing proposed. The diameter for 5000 liters capacity is 2m, and diameter for 3000 liters tank is 1.5m. Cylindrical shell, spherical shell is modeled using 3 nodded shell elements. Finite element modeling and analysis is carried out using a commercial computer aided software tool ANSYS. Details of shell element are explained as follows.

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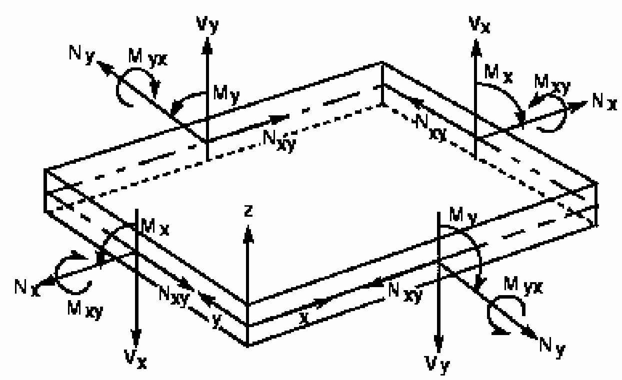


Fig 3.9 Direction of force and moment components for thin shell

4 nodded quadrilateral elements for thin shell is shown above, in which force and moment component directions are shown in Fig 3.9.

3.4 ISOPARAMETRIC ELEMENT

For the analysis of structural problem of complex shapes involving curved boundaries or surfaces, simple triangular or rectangular elements are no longer sufficient. This led to the development of element of more arbitrary shape and are called isoparametric element. These elements are widely used in the two and three dimensional stress analysis and, plate and shell problems.

The concept of isoparametric element is based on the transformation of the parent element in local or natural coordinate system to an arbitrary shape in the Cartesian coordinate system. A convenient way of expressing the transformation is to make use of the shape function of the rectilinear elements in their natural coordinate system and the nodal values of the coordinates. Thus the Cartesian coordinates of a point in an element may be expressed in Equations 3.1 to 3.3.

$$x = N'_1 x_1 + N'_2 x_2 + ... + N'_n x_n \quad (3.1)$$

$$y = N'_1 y_1 + N'_2 y_2 + ... + N'_n y_n \quad (3.2)$$

$$z = N'_1 z_1 + N'_2 z_2 + ... + N'_n z_n \quad (3.3)$$

Or in matrix form

$$\{x\} = [N']\{x_n\} \quad (3.4)$$

Where [N'] are the shape function of the parent element and $\{x_n\}$ are the nodal coordinates of element. The shape functions will be expressed through the natural coordinate system r, s.

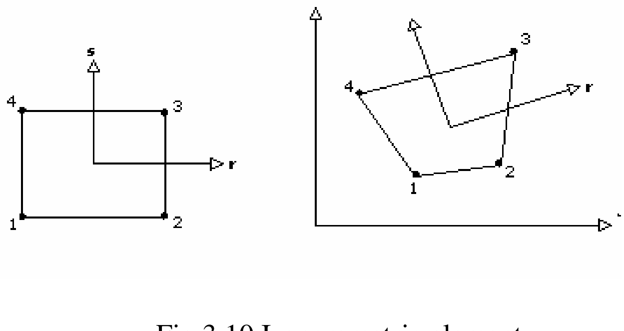


Fig 3.10 Isoparametric element coordinate transformation

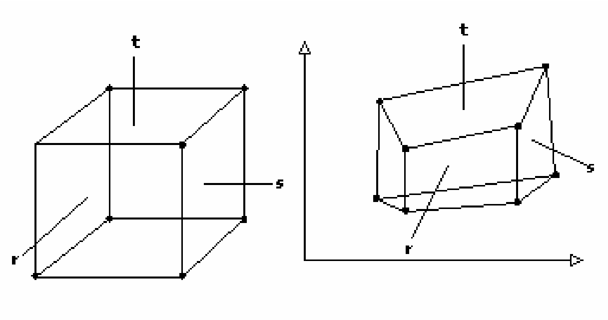


Fig 3.11 Isoparametric element
coordinate transformation

The shape function [N′] used in the above transformation thus help us to define the geometry of the element in the Cartesian coordinate system. If these shape function [N′] are the same as the shape function [N] used to represent the variation of displacement in the element, these elements are called 'isoparametric' elements.

$$\{X\} = [N]\,\{x_n\} \tag{3.5}$$

3.4.1 Four nodded isoparametric element

Consider a quadrilateral two dimensional element. The parent element is a rectangular mapped into a square in natural coordinates and this in turn is transformed into an arbitrary quadrilateral element with straight boundaries.

The shape function used for representing the variation of displacement for a four nodded rectangular element can now be used to describe the geometry of the arbitrary quadrilateral is the Cartesian system.

$$\begin{Bmatrix} X \\ Y \end{Bmatrix} = \begin{pmatrix} N_1 & 0 & N2 & 0 & N3 & 0 & N4 & 0 \\ 0 & N_1 & 0 & N2 & 0 & N3 & 0 & N4 \end{pmatrix} \begin{Bmatrix} x_1 \\ y_1 \\ x_2 \\ y_2 \\ x_3 \\ y_3 \\ x_4 \\ y_4 \end{Bmatrix} \tag{3.6}$$

Where Ni (1, 2, 3, 4) are shape functions.

- **Shape function for first order rectangular element**

The natural coordinate for the rectangular element shown in Fig 3.12 are defined by

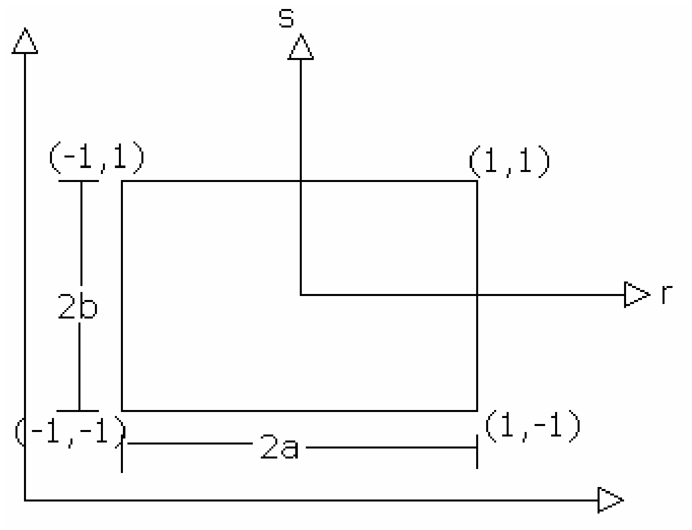


Fig 3.12 Four nodded rectangular element

$$r = \frac{x - x_c}{a} \qquad\qquad s = \frac{y - y_c}{b} \tag{3.7}$$

Where x_c and y_c are the coordinates of the centre of the element. Assuming the polynomial function in natural coordinates, the displacement u can be expressed by

$$u = \alpha_1 + \alpha_2 r + \alpha_3 s + \alpha_4 rs \tag{3.8}$$

The nodal displacement $\{d_n\}$ can be obtained by substituting the coordinates for the nodes as

$$\{d\} = \begin{Bmatrix} u1 \\ u2 \\ u3 \\ u4 \end{Bmatrix} = \begin{pmatrix} 1 & -1 & 1 & -1 \\ 1 & 1 & -1 & -1 \\ 1 & 1 & 1 & 1 \\ 1 & -1 & 1 & -1 \end{pmatrix} \begin{Bmatrix} \alpha_1 \\ \alpha_2 \\ \\ \alpha_3 \end{Bmatrix} \alpha_3 \tag{3.9}$$

And $$\{\alpha\} = [A]^{-1}\{d_u\} \tag{3.10}$$

$$[A]^{-1} = \begin{pmatrix} ¼ & ¼ & ¼ & ¼ \\ -¼ & ¼ & ¼ & -¼ \\ -¼ & -¼ & ¼ & ¼ \\ ¼ & -¼ & ¼ & -¼ \end{pmatrix} \tag{3.11}$$

Thus $\{N_2\}^T = \{\phi_2\}^T [A]^{-1}$ (3.12)

$$= [1 \quad r \quad s \quad r \quad s] \begin{pmatrix} ¼ & ¼ & ¼ & ¼ \\ -¼ & ¼ & ¼ & -¼ \\ -¼ & -¼ & ¼ & ¼ \\ ¼ & -¼ & ¼ & -¼ \end{pmatrix} \tag{3.13}$$

$$\{N_2\}^T = [\frac{(1-r)(1-s)}{4} \frac{(1+r)(1-s)}{4} \frac{(1+r(1+s)}{4} \frac{(1-r)(1+s)}{4}] \tag{3.14}$$

Or can be expressed in concise from as

$$\{N_2\}^T = [N_1 N_2 N_3 N_4] \tag{3.15}$$

N1, N2, N3, N4 are the shape functions.

This transformation relates a unit square in r and s coordinates to an arbitrary quadrilateral in Cartesian (x,y) coordinate system whose shape and size are determine by the eight nodal coordinates x1, y1, x2, y2, x3, y3, x4, y4. The above relation also helps to determine the x, y coordinates of any point in the element when the corresponding natural coordinates r and s are given.

$$\frac{\partial u}{\partial x} = \frac{b_1}{2A} u_1 + \frac{b_2}{2A} u_2 + \frac{b3}{2A} u_3 = \frac{1}{2A} (b_1 u_1 + b_2 u_2 + b_3 u_2) \tag{3.16}$$

Similarly $\frac{\partial u}{\partial x} = \frac{1}{2A} (b_1 v_1 + b_2 v_2 + b_3 v_2)$ (3.17)

It can be observed from equation (3.15) and (3.17) that we need to calculate the derivatives of the function with respect to the global, i.e. Cartesian coordinates. We, however, note that the shape function used for describing the geometry of the natural coordinates (r, s). The relationship between the two coordinate system can be computed by using the chain rule of partial differentiation and is given below;

$$\begin{Bmatrix} \frac{\partial}{\partial r} \\ \frac{\partial}{\partial r} \end{Bmatrix} = \begin{pmatrix} \frac{\partial z}{\partial r} & \frac{\partial y}{\partial r} \\ \frac{\partial x}{\partial r} & \frac{\partial y}{\partial r} \end{pmatrix} \begin{Bmatrix} \frac{\partial}{\partial x} \\ \frac{\partial}{\partial y} \end{Bmatrix} = [J] \begin{Bmatrix} \frac{\partial}{\partial x} \\ \frac{\partial}{\partial x} \end{Bmatrix} \tag{3.18}$$

Where [J] is the jacobian matrix. Hence, the derivatives with respect to Cartesian coordinate system can be given as

$$\begin{Bmatrix} \frac{\partial}{\partial x} \\ \frac{\partial}{\partial x} \end{Bmatrix} = [J]^{-1} \begin{Bmatrix} \frac{\partial}{\partial r} \\ \frac{\partial}{\partial r} \end{Bmatrix} \tag{3.19}$$

From equation (7.6)

$$x = \sum_{i=1}^{4} N_1 x_1 \quad \text{and} \quad y = \sum_{i=1}^{4} N_1 y_1 \tag{3.20}$$

Ni is a function in (r, s), the jacobian [J] can be evaluated as

$$[J] = \begin{pmatrix} \frac{\partial N_1}{\partial r} & \frac{\partial N2}{\partial r} & \frac{\partial N_3}{\partial r} & \frac{\partial N_4}{\partial r} \\ \frac{\partial N_1}{\partial s} & \frac{\partial N_2}{\partial s} & \frac{\partial N_3}{\partial s} & \frac{\partial N_4}{\partial s} \end{pmatrix} \begin{pmatrix} x_1 & y_1 \\ x_2 & y_2 \\ x_3 & y_3 \\ x_4 & y_4 \end{pmatrix} \tag{3.21}$$

Substituting the shape functions in equation (3.21)

$$[J] = \begin{pmatrix} -\frac{(1-s)}{4} & +\frac{(1-s)}{4} & +\frac{(1+s)}{4} & -\frac{(1+s)}{4} \\ -\frac{(1-r)}{4} & -\frac{(1+r)}{4} & +\frac{(1+r)}{4} & +\frac{(1-r)}{4} \end{pmatrix} \begin{pmatrix} x_1 & y_1 \\ x_2 & y_2 \\ x_3 & y_3 \\ x_4 & y_4 \end{pmatrix} \tag{3.22}$$

Let the inverse of [J] as required in equation (3.19) be expressed as

$$[J]^{-1} = \begin{pmatrix} J^*_{11} & J^*_{12} \\ J^*_{21} & J^*_{22} \end{pmatrix} \qquad (3.23)$$

It should be observed here that in order to transform the x and y coordinates into r and s coordinates the inverse of [J] must exist. Hence, the determinant of the jacobian [J] must be non zero at every point (r, s)..

$$\begin{Bmatrix} \frac{\partial u}{\partial x} \\ \frac{\partial u}{\partial y} \\ \frac{\partial v}{\partial x} \\ \frac{\partial v}{\partial y} \end{Bmatrix} = \begin{pmatrix} J^*_{11} & J^*_{12} & 0 & 0 \\ J^*_{21} & J^*_{22} & 0 & 0 \\ 0 & 0 & J^*_{11} & J^*_{12} \\ 0 & 0 & J^*_{21} & J^*_{22} \end{pmatrix} \begin{Bmatrix} \frac{\partial u}{\partial r} \\ \frac{\partial u}{\partial s} \\ \frac{\partial v}{\partial r} \\ \frac{\partial v}{\partial y} \end{Bmatrix} \qquad (3.24)$$

The strain displacement relations are given in equation (3.25). It can be observed that in order to compute the strains or the [B] matrix we need to compute the derivatives of displacement functions for u and v with respect to the Local or natural coordinate system.

$$\{\varepsilon\} = \begin{pmatrix} J^*_{11} & J^*_{12} & 0 & 0 \\ 0 & 0 & J^*_{21} & J^*_{22} \\ J^*_{21} & J^*_{22} & J^*_{11} & J^*_{12} \end{pmatrix} \begin{Bmatrix} \frac{\partial u}{\partial r} \\ \frac{\partial u}{\partial s} \\ \frac{\partial v}{\partial r} \\ \frac{\partial v}{\partial y} \end{Bmatrix} \qquad (3.25)$$

The displacement u and v are expressed through the shape functions as

$$u = \sum_{i=1}^{4} N_i u_i \quad \text{And} \quad v = \sum_{i=1}^{4} N_i v_i \qquad (3.26)$$

ui and vi are displacements of the nodes 1, 2, 3, and 4

The stiffness matrix for the element is given by

$$[K] = \int\int\int [B]^T [C][B] d_x d_y d_z \tag{3.27}$$

3.4.2 Triangular element

In some cases of discretization, isoparametric triangular elements are also needed. It is possible to degenerate a four nodded quadrilateral element to a three nodded triangular element by collapsing one of the sides and assigning the isoparametric triangular elements can be developed from the parent triangular elements in natural coordinate.

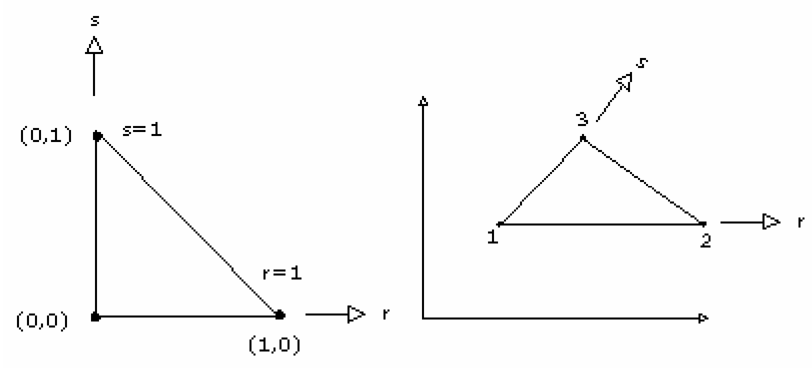


Fig 3.13 Three nodded triangular element

Two independent natural coordinates' r and s are taken for transformation to Cartesian coordinates as

$$x = \sum_{i=1}^{4} N_1 x_1 \quad \text{and} \quad y = \sum_{i=1}^{4} N_1 y_1 \tag{3.28}$$

Where N_i is the interpolation functions of the parent three nodded triangular element.

$$N_1 = 1 - r - s \qquad N_2 = r \qquad N_3 = s \tag{3.29}$$

For the evaluation of the element matrices, the Jacobinan matrix has to be work out which establishes the relationship between the two coordinate system. For a linear triangular element the jacobian matrix is given by

$$[J] = \begin{pmatrix} x_2 - x_1 & y_2 - y_1 \\ X_3 - x_1 & y_3 - y_1 \end{pmatrix} \tag{3.30}$$

3.5 SUMMARY

Finite Element Method (FEM) is a good approach for analysis of problems, as explained earlier it is possible to analyze plain stress and plain strain problem with confidence. For shell structure it is not possible to analyze structure manually, appropriate FE analysis tool should be used for irregular shell structures.

4. APPROACH SYNTHESIS

4.1 GENERAL

Approach synthesis is the work approach to the work. In this piece of work effort is made to design most techno-commercial design of underground storage tank. In this section it is explained to reach design by varying different geometry and properties of the tank.

First step is to decide the capacity of the tank, depending on capacity geometry is produced, on this geometry different parameters are varied. Loading are initially decided, by considering same load for all cases. Some of the parameters are geometry, stiffeners, materials etc.

4.2 GEOMETRY

4.2.1 General

Geometry is the basic parameter to decide initially. Depending on capacity, the tank geometry is decided. In this work different capacities are used, 3000 liters and 5000 liters. Dimensions are decided on these two capacities. When it is used for underground septic tank some basic parameters are required to consider deciding geometry.

4.2.2 Capacities

Capacity is the basic requirement to decide geometry of tank. Shape of tank can be horizontal or vertical. Dimensions are decided by tanking shape and capacities. In this work vertical cylindrical shape and horizontal cylindrical shape is produced. It is required to fix dimensions of tank according to its capacity.

In case of septic tank capacity is decided by the in flow rate of sewage. Sewage is the out come of household waste, Rate of outflow is decided by the number of persons living in to the house. By considering all the parameters total capacity required is decided, and then for that capacity dimensions are produced. In case of septic tank it is required to consider sludge accumulation in tank, it will require some capacity permanently, these capacities considered apart from the in flow of sewage. In this work two types of geometries are used for the present study, these two geometry are shown in Fig 4.1 and 4.2.

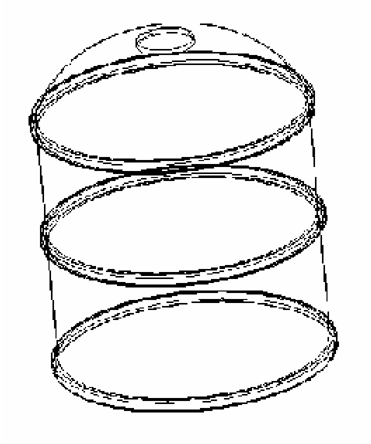


Fig 4.1 Vertical cylindrical tank

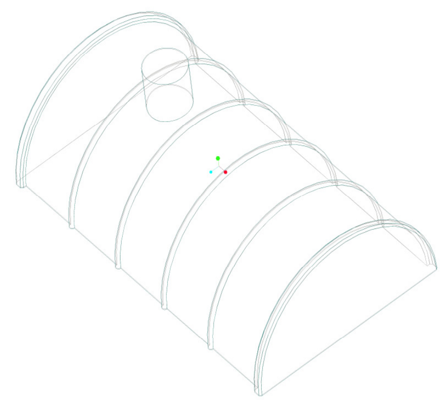


Fig 4.2 Horizontal cylindrical tanks

4.3 RETENTION TIME

This is the second parameter to decide geometry of the tank. In case of septic tank out flow of sewage will retain in tank, so it is possible to separate solids from the sewage. Septic tank works as a solid/liquid separation device. It separates maximum solids particles from the sewage and the treated liquid gets discharged to the field. According to velocity of the out flow it is required to give sufficient path to sewage, so maximum solids are settled down in tank.

Considering this effect, dimensions are decided. In these two geometries Fig 4.3 and 4.4 inlet and outlet pipes are minimum two meter apart from each. Between these two pipes sewage will travel with some velocity. Therefore path must be sufficient to allow maximum solids in bottom of tank.

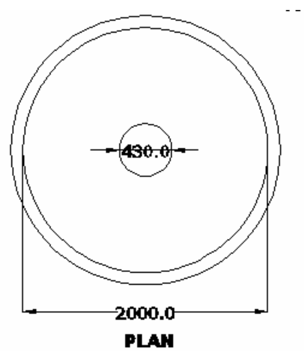


Fig 4.3 Plan of vertical tank

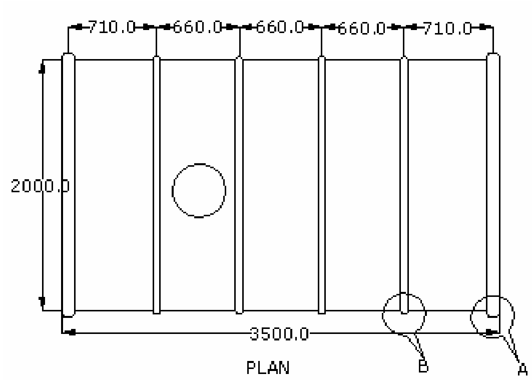


Fig 4.4 Plan of horizontal tank

In above geometries retention time is given in both the cases. Vertical tank having 2.0 meters of retention time and in case of horizontal tank 3.5 meter path is given. For same capacity one tank is having long sewage path, and this is advantageous to the sewage treatment. This phenomenon is called approach synthesis, come out best way from different options.

4.4 THICKNESS OF TANK

Thickness is the other parameter to optimize the design. Materials used for manufacturing are available in different thickness. Plastic sheets are fabricated from material, it is possible to fabricate plastic sheet of different thickness. Tanks can be manufactured from this thickness.

Thickness is the strength parameter, it is depending upon the loading on the tank, in case of analysis loadings are initially decided, different load combinations are used for analysis. By using different thicknesses, strength of tank is worked out after analysis. It is possible to minimize the weight of design by using lower thickness of tank. Some of the thicknesses used in this work are given below.

- 4 mm
- 5 mm
- 6 mm

4.5 MATERIALS

Material domain is also a criterion for designing of tank, for this study plastic materials are used. Plastic materials are Linear Low Density Polyethylene (LLDPE), High Density Polyethylene (HDPE), and Fiber Reinforced Polymers (FRP). Materials are available with different strength; it can be possible to carry out study on material domain.

In this work, for techno-commercial design study is started with low strength material, and with that material variation of other parameters is taken in to consideration. Study is also done with some high strength materials like HDPE and FRP, so this sensitivity can be possible to compare the cost of final product, and finalize the most economic design.
Materials used for study are listed below.

- Linear Low Density Polyethylene (LLDPE)
- High Density Polyethylene (HDPE)
- Fiber Reinforced Polymers (FRP)

4.6 STIFFENERS

4.6.1 General

In case of plastic tanks stiffeners are the major requirement for structural stability. Stiffeners are the elements provided in wall of tank to give stability and strength, it can be of any shape, and generally stiffeners with curved surfaces are used, because with sharp edge it will attract more stress at the corner of it. In this study different types of stiffeners are used. It can be clear from study that which stiffeners are helpful to reduce stress in walls of tank. Quantities of stiffeners are also considered for parametric study.

4.6.2 Shape of stiffeners

Shapes of stiffeners are one of the parameter to study their behaviors. For study purpose different types of stiffeners are used. Semi circular, stiffeners with edge, triangular shape can be used. Stiffeners are used for strength purpose; it is required to provide stiffeners which reduce the stress in walls of tank. Shapes are shown in Fig 4.5 and 4.6.

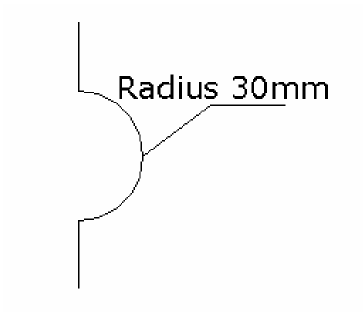


Fig 4.5 Semi circular stiffener

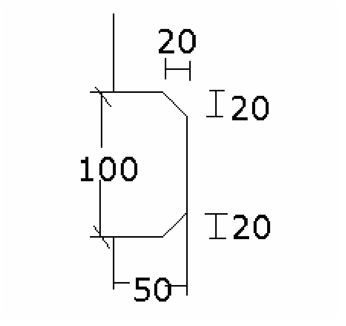


Fig 4.6 Stiffener with edge

These are the basic form of stiffeners, semicircular are the best suited to reduce stresses in walls of tank, second type of stiffener gives strength to tank but, but at the corner part stress will be more, when tank will subjected to heavy loads, there is a possibility that, it may crack from corners. Due to this phenomenon, corners are avoided in stiffeners.

Study is done with combinations of stiffeners.

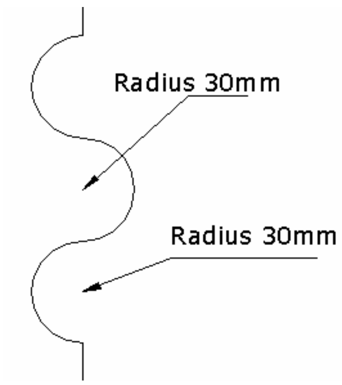


Fig 4.7 Semicircular combination

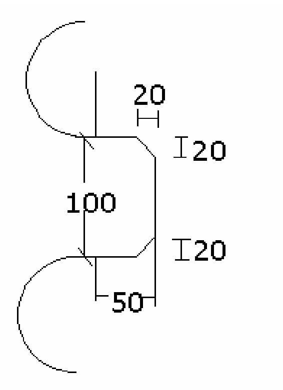


Fig 4.8 Semicircular and corner combinations

4.6.3 Spacing of stiffeners

Spacing of stiffeners is depending on strength requirement. Stiffeners are provided in tank wall at regular interval. When spacing is less it will take less stresses of wall, but when it is required to reduce more stresses from vertical wall stiffeners are provided with less spacing.

Study is carried out with basic minimum stiffeners in tank. Then after varying all other parameters on same arrangement, spacing in reduced and again study is carried out by all other parameters.

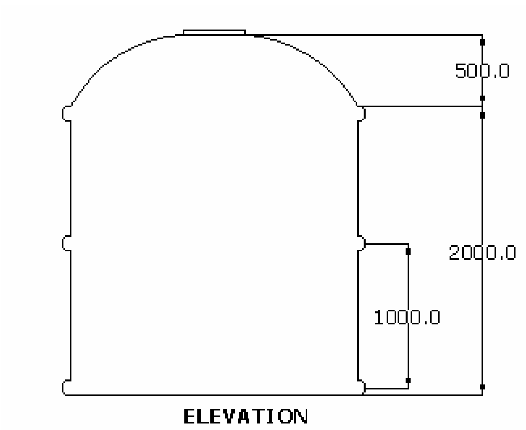


Fig 4.9 Tank with minimum stiffeners

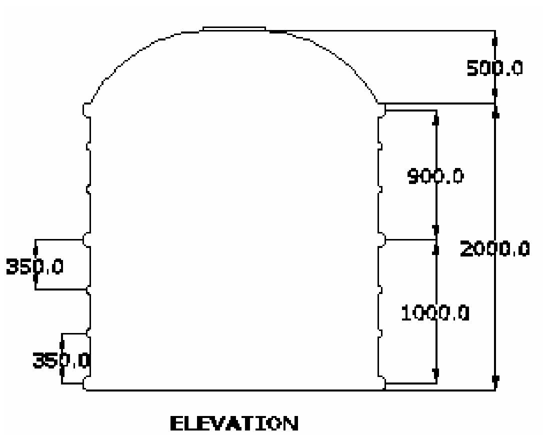


Fig 4.10 Tank with more stiffeners

As shown in the Fig 4.9 and 4.10 vertical cylindrical tank with the different spacing of stiffeners. Same study is done for other geometry of tanks. Stiffeners spacing can be reduced, if it is required for strength purpose, sometimes tank with continuous stiffeners are also designed. Shown in Fig 4.11 and 4.12.

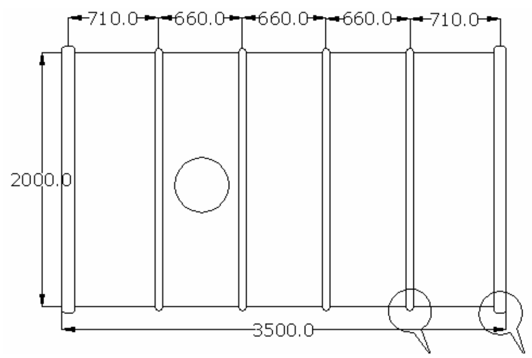


Fig 4.11 Plan of tank 2 with minimum stiffeners

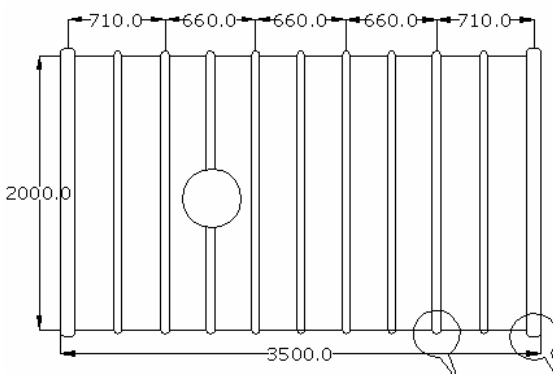


Fig 4.12 Plan of tank 2 with more stiffeners

4.6.4 Orientation of stiffeners

Orientation of stiffeners will affect the strength of tank, in the present study; stiffeners are taken both the ways inside, and outside. By taking these two different orientations for same geometry study is carried out. Fig 4.12 and 4.13.

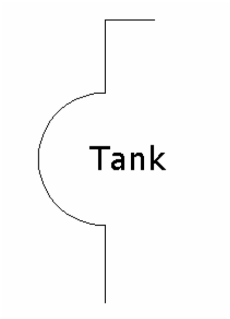


Fig 4.13 Stiffeners outside

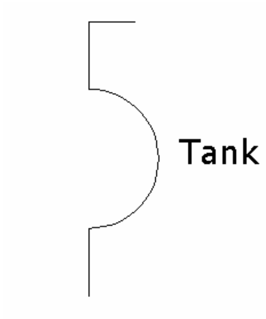


Fig 4.14 Stiffeners inside

For same geometry and similar stiffeners spacing of these two orientations are taken for study.

These are the different parameters which can possibly be changed for study purpose. Finally most techno-commercial design has been selected, which proves to bee safe against loadings on tank and is economical.

4.7 APPROACH SYNTHESIS CHART

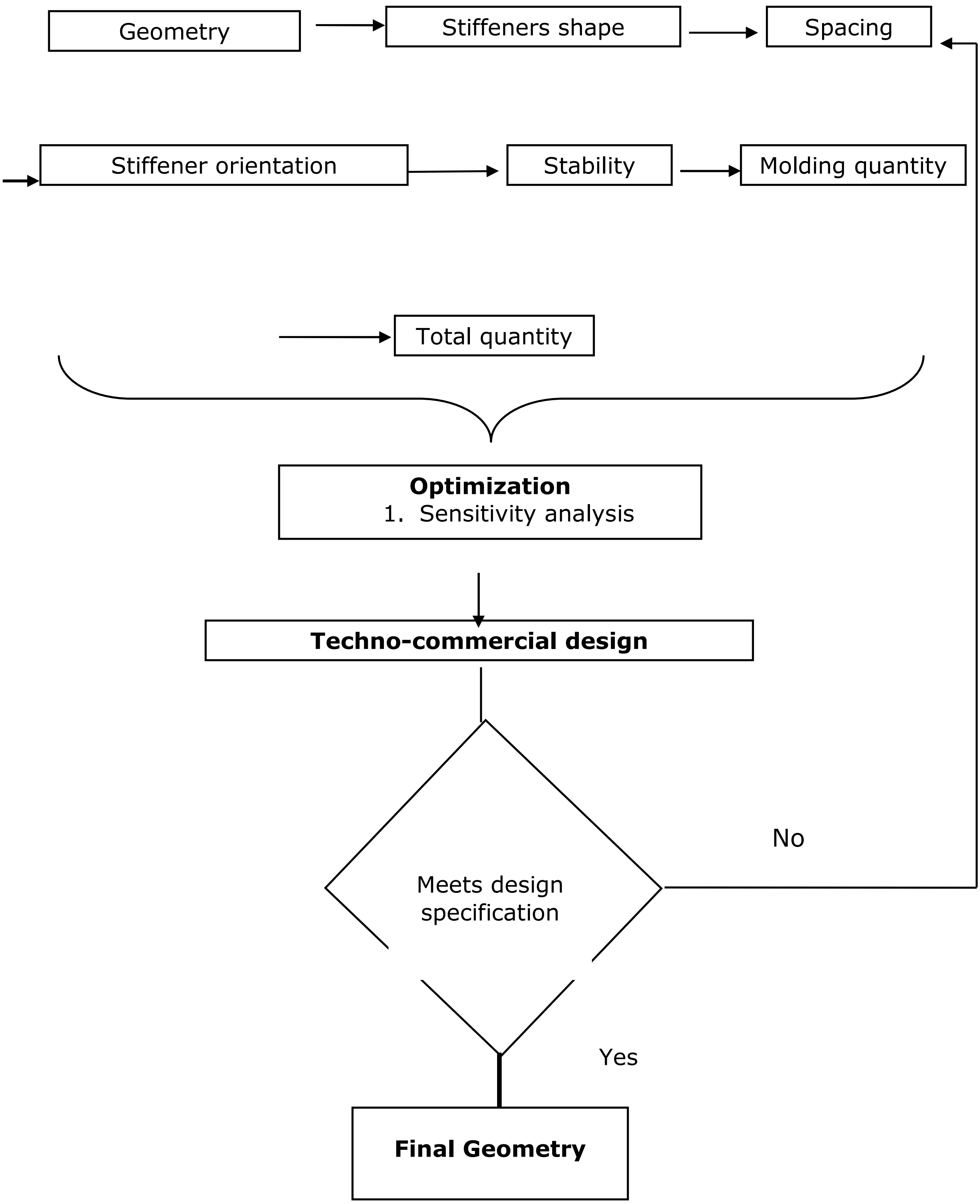


Fig 4.15 Approach synthesis chart

5. TANK MATERIALS

5.1 GENERAL

Generally septic tanks are made up with conventional materials viz, cement concrete, masonry etc. Ferro cement septic tanks are also in use but for this present study different materials are used as mention earlier like polyethylene materials and Fiber Reinforced Polymers.

These materials are having more advantages in comparison to conventional materials used for septic tank. Septic tanks from these materials are fabricated in factory, and on site construction is not required. These tanks can be fabricated in any size and shape.

5.2 POLYEHTYLENE PRODUCTS

Polyethylene is derived from ethylene gas (C_4H_4). Ethylene is obtained by natural gas or naphtha- a product of crude oil refinery. By joining together or 'polymerizing' of ethylene gas, polyethylene is produce, as a powder or in molten form. From which pallets are formed known as resins. The bulk resins are converted in to polyethylene products.

Generally polyethylene has been classified by its density. Low Density Polyethylene (LDPE), was the first type to be developed in UK in 1939. Later with the suitable catalysts High Density Polyethylene (HDPE) was introduce. As market demanded Linear Low Density Polyethylene (LLDPE) was developed in mid 1970. LLDPE is stronger and tougher than LDPE and less expansive to make. LLDPE is also durable then the LDPE, LDPE is use for making sheets and from which product can be manufactured.

Nowadays use of LLDPE is increasing in compare to LDPE. LLDPE is used for making, pipes, tank, storage vessels etc.

Flow of polymerizing process is given in Fig 5.1. Typical polyethylene products are produced by this method; it is also used for manufacturing of different types of plastics.

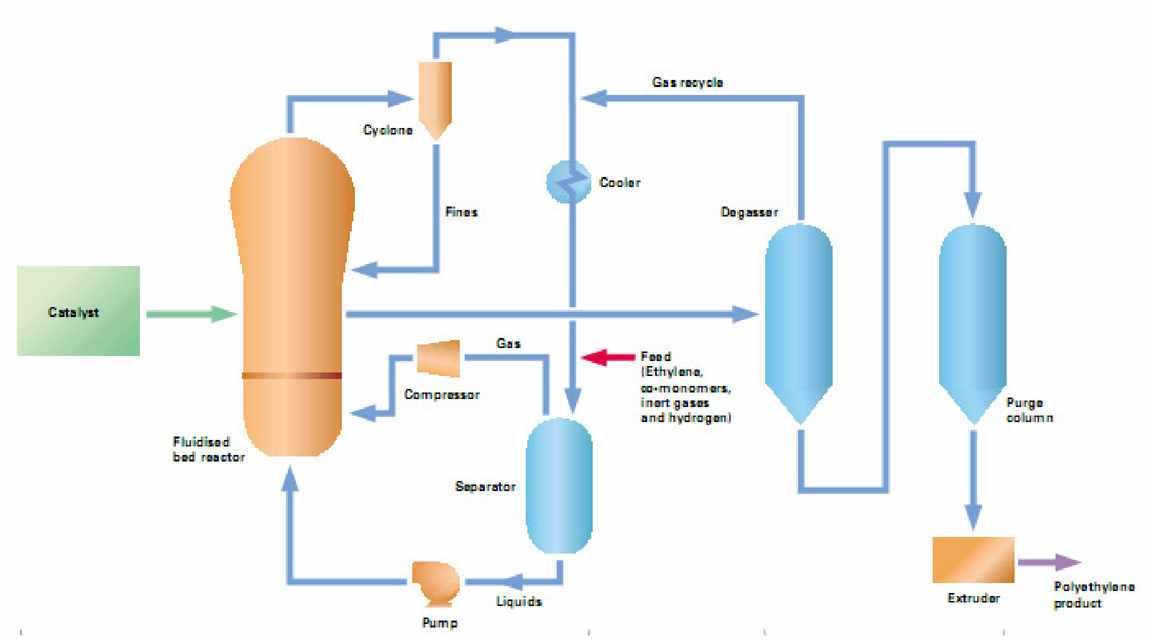


Fig 5.1 Polyethylene manufacturing process

World output of polyethylene is expected to grow by amount of 20% over the next few years, reached 60 million tones per annum by 2005.

5.2.1 Varieties of polyethylene

Varieties of polyethylene materials are as follows:-

- High Density Polyethylene (HDPE), Fig 5.2
- Low Density Polyethylene (LDPE), Fig 5.4
- Linear Low Density Polyethylene(LLDPE), Fig 5.3

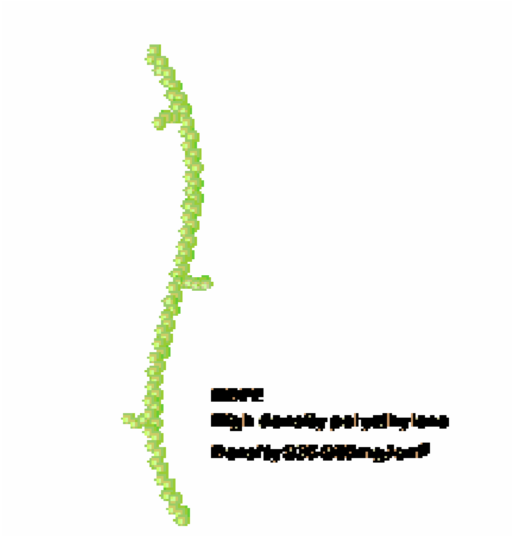


Fig 5.2 High Density Polyethylenes (HDPE)

HDPE is rigid plastic product, manufactured in many grades to required properties. It is use for bottles, under ground pipes, tanks.

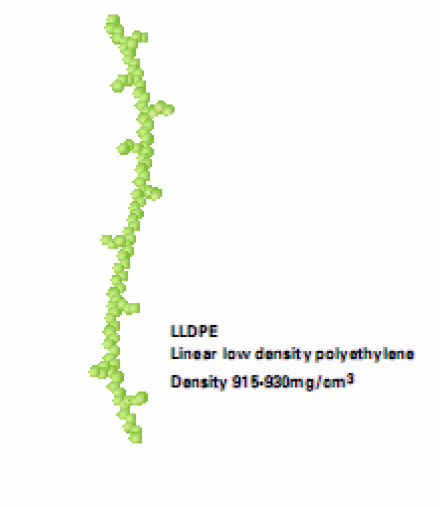


Fig 5.3 Linear Low Density Polyethylenes (LDPE)

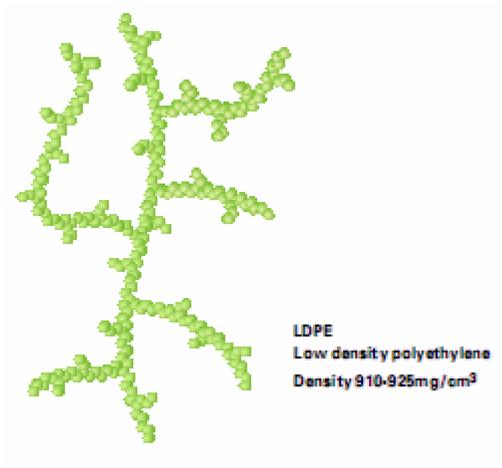


Fig 5.4 Low Density Polyethylenes (LLDPE)

Both LLDPE and LDPE are mainly used in the packaging film market.

5.3 COMMON MATERIAL PROPERTIES OF POLYETHYLENE

Common material properties used for this particular exercise are given below.

1. Young's modulus of elasticity   400 N/mm^2
2. Density   92 gm/cc
3. Poisson's ratio   0.3

5.4 FIBER REINFORCED POLYMER

Fiber reinforced polymer are composite material. Fiber reinforced polymers are made out of fibers and matrix. Fibers are generally acted as tensile resisting material; fibers are inside the polymer material. Load carrying mechanism is due to composite material from fibers and polymer.

Fibers are available in different length; selection of fiber is depending upon strength, stiffness, and durability requirement. Fibers can be stitch or woven in matrix, the common types of fibers used in composite are the

- Glass fiber,
- Carbon fiber,

Glass fibers are economical and carbon fibers are most expansive, E-glass fibers are commonly used in structural requirement. These fibers are manufactured from lime-alumina-borosilicate which can be easily obtained from abundance of raw materials like sand.

Glass fibers can also be use for manufacturing of septic tank

5.5 COMMON MATERIAL PROPERTIES OF FRP

Common material properties used for this particular exercise are given below.

1. Young's modulus of elasticity 72000 N/mm^2
2. Density 2.6 gm/cc
3. Ultimate tensile strength 1720 N/mm^2

6. MATERIALS TESTING

6.1 GENERAL

Polyethylene materials are tested to find their mechanical properties. Testing is done on raw material as well as on sheet. Sheet is formed by rotomodeling process. Basic mechanical properties are required to design tank, and understand behavior of plastic. Testing is done with the reference of American standard for testing of materials (ASTM).

Two kinds of test are performed, for determination of tensile properties of plastics and flexural properties of plastics. These tests were performed at M/S sintex India Limited; tests were performed to obtain the mechanical properties of materials.

6.2 STANDARD TEST METHODS FOR TENSILE PROPERTIES OF PLASTIC (ASTM D 790-03)

6.2.1 Scope

This test method covers the determination of the tensile properties of unreinforced and reinforced plastic in the form of standard dumbbell-shape test specimens. Specimens are tested under pretreatment, temperature, humidity, and testing machine speed. This method can be used for testing materials of any thickness up to 14 mm. testing is done on form of sheeting, including thin film of 1 mm in thickness. Thickness more than 14 mm is reduced by machining. This method is used to determine Poisson’s ratio at room temperature.

6.2.2 Significance of test

This is performed to determine tensile property for control specification plastic materials. These data are also useful for qualitative characterization and for research and development. Tensile property may vary with specimen preparation and with speed and environment of testing. For precise result these factors must be taken care while testing. The care must be taken to ensure all the samples are prepared in same way, unless the test is to include the effect of sample preparation. Similarly for referee purpose of comparison within any given series of specimens care must be taken to ensure the maximum degree of uniformity.

When uniaxial tensile force is applied to a solid, the solid stretches in the direction of the applied force (axially), but it also contracts in the both dimensions lateral to the applied force. If the solid is homogenous and isotropic, and the material remains elastic under the action of the applied force, the lateral strain bears a constant relationship to the axial strain. This constant called Poisson's ratio.

Poisson's ratio is used for the design of structure in which all dimensional changes resulting from the application of force need to be taken into account and in the application of the generalized theory of elasticity to structural analysis.

6.2.3 Test apparatus

Universal testing machine is used for this test. A test machine of the constant rate of crosshead movement type is used. This machine consists of two basic members, fixed member and movable member. Fixed member is stationary and carrying one grip, movable member carrying second grip. Shown in Fig 6.1.

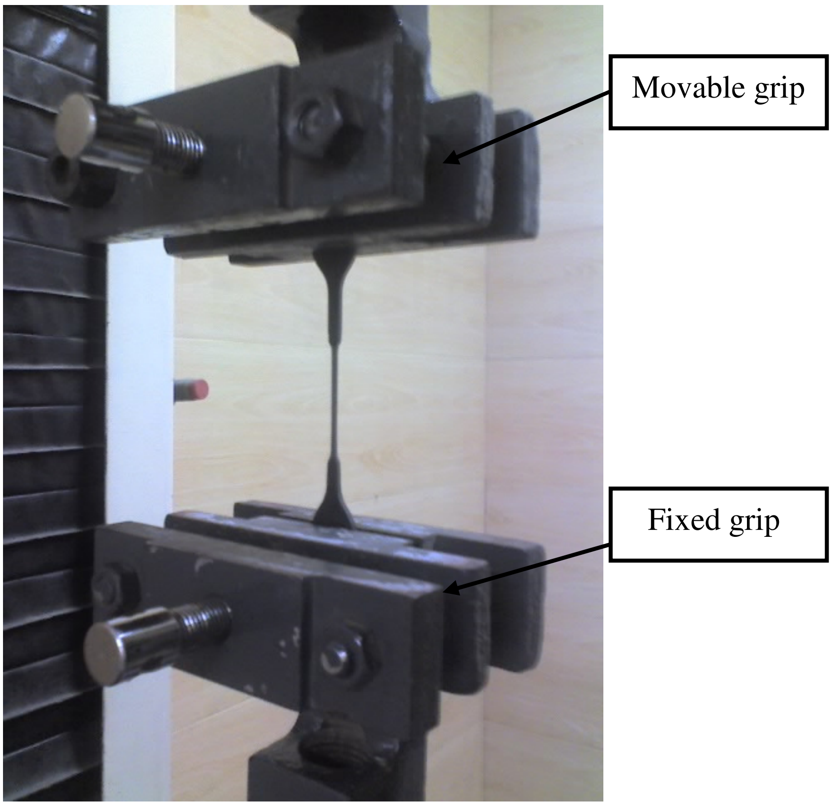


Fig 6.1 Universal testing machines

Grip is provided to hold the specimen in fixed member as well as movable member. Grip can be fixed or self aligning type. Fixed grip are rigidly attached to the fixed and movable members of the testing machine. When this type of grip is used care must be taken to insert specimen and clamp. It should be clamped in such a way that the long axis of the test specimen coincides with the direction of pull through the centre line of the grip assembly.
Self aligning grip are attached to the fixed and movable members of the testing machine in such a manner that they will move freely into alignment as soon as any load is applied so that the long axis of the test specimen will coincide with the direction of the applied pull through the centre line of the grip assembly. There is a limit to the amount of misaligning self aligning grips will accommodate.

The test specimen shall be held in such a way that slippage relative to grip is prevented as for as possible. Slippage will leads to breakage of specimen from grip side. It will affect the results of testing.

A drive machine for imparting to the movable member a uniform, it will control the velocity with respect to stationary member. Load indicator mechanism is attached to the machine. It will show the total tensile load carried by the test specimen when held by the grip. The accuracy of the testing machine shall be verified in accordance with practice E4.

A suitable extension indicator mechanism capable of showing the amount of change in the separation of the grips that is crosshead movement. This mechanism shall be essentially free of inertial lag at the specified rate of testing and shall indicate the crosshead movement with an accuracy of 10% of the indicated value.

A suitable instrument shall be used for determining the distance between two designated points within the gage length of the test specimen as the specimen is stretched. For referee purpose, the extensometer must be set at the full gage length of the test specimen as sown in Fig 6.2. It is desirable but not essential that this instrument automatically record this distance, or any change in it as a function of the load-time data must also be taken.

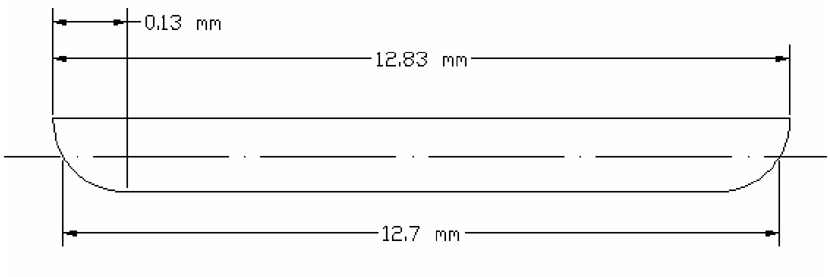


Fig 6.2 Tension test specimen for sheet, plate, and molded plastic

For modulus of elasticity measurement an extensometer with a maximum strain error of 0.0002 mm/mm that automatically and continuously records shall be used. For determining Poisson's ratio Bi-axial extensometer or axial and transverse extensometers capable of recording axial strain and transverse strain simultaneously. The extensometer shall be capable of measuring the change in strain with an accuracy of 1% if the relevant value of better.

6.2.4 Test specimens

Specimen can be prepared from sheet, plate or molded plastics. Test specimen is prepared with specific dimensions. Different sets of dimensions are specified in the ASTM D638-03.the test specimen shall conform to the dimensions shown in fig 5.4. These dimensions are used for thickness more than 7 mm and less than 14 mm.

6.2.5 Preparation of specimens

Test specimen shall be prepared by machining operation or die cutting, from material in sheet plate, slab or similar from material thicker than 14 mm, it must be machined to 14 mm. specimen can also prepared by molding the material to be tested.

Dumbbell shaped specimen is prepare from the sheet of plastic. According to ASTM D 638 type IV is selected testing, cutting die is available with the type IV dimensions. Typical cutting die is shown in Fig 6.3. Pressing this die on the plastic sheet will give the dumbbell shaped specimen with the type IV dimensions, after obtaining specimen it is required to measure its thickness, and also check all dimensions. Type IV specimen dimensions are shown in Fig 6.4. after that specimen is ready for testing.

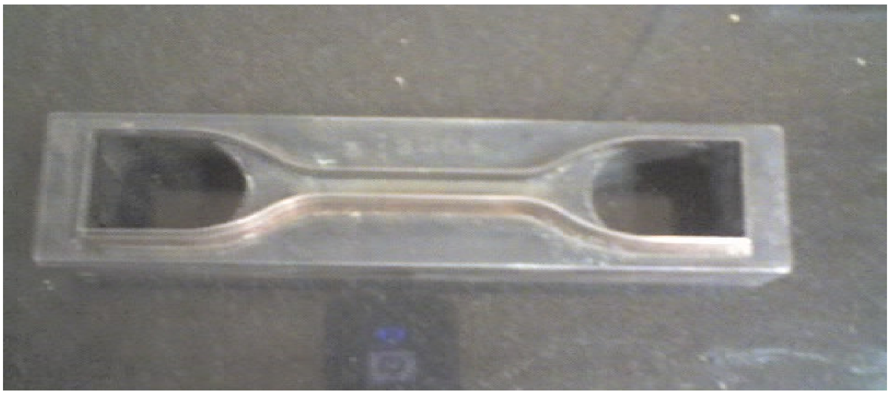


Fig 6.3 Die for the specimen type IV

As shown in Fig 6.3 with the sharp edge on one side, samples are cut with it, die can cut the sample having thickness up to 14 mm, pressing machine is required to cut the sample from sheet, sheet is placed on the cutting machine and above it this die is placed, now pressure is applied with the machine mechanism. Finally specimen is cut out from the plastic sheet.

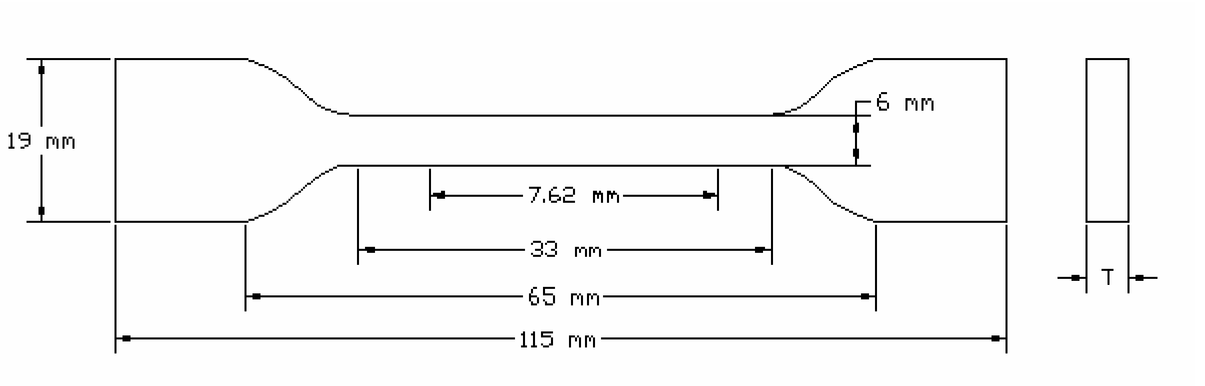


Fig 6.4 Specimen dimensions (type IV, thickness T)

Thickness T shall be varying with the sheet thickness. Maximum thickness 14 mm can be use for preparation of the test specimen. As shown in Fig 6.4.

6.2.6 Speed of testing

Speed of testing is the relative rate of motion of the movable grip, if it can be shown that the resulting speed of testing is within the limits of variation allowed. Choose the speed of testing from table given in ASTM D 638-03, when speed is not specified for material use lowest speed specified in ASTM D 638, which gives the rupture within ½ to 5 min testing time.

Modulus determinations may be made at the speed selected for the other tensile properties, when the recorder response and solution are adequate. The speed of testing for Poisson's ratio determination shall be 5 mm/min.

6.2.7 Procedure

- Measure the width and thickness of specimen to the nearest 0.025 mm, using applicable test method in D 5947.
- Measure the width and thickness of flat specimens at the centre of each specimen and within 5 mm of each end of the gage length.
- Place the specimen in the grip of the testing machine taking care to align the long axis of the specimen and the grips with an imaginary line joining the point of attachment of the grip to the machine. The distance between the ends of the gripping surfaces, when using flat specimen, shall as indicated in Fig 6.2. Tighten the grip evenly and firmly to the degree necessary to prevent slippage of the specimen during the test, but not to point where specimen would be crushed.

Fig 6.5 Placement of flat specimen for testing

- Universal testing machine is connected to computer software through a load shell.
- This assembly will measure the load applied to specimen and their relative deflections. It will produce the curve of Load – deflection.
- From this curve further calculation will carried out.
- Load application will started at the rate of 5mm/min. this is a specified speed for particular sample taking from ASTM D 638-03
- Polyethylene material is ductile. It will show some elongation.

Fig 6.6 Elongation of specimen

- Specimen will break in two pieces when load is reached to the breaking load of the specimen. Breaking is depending upon the different material of polyethylene. As shown in Fig 6.6.
- Poisson's ratio can be determined by this test.
- Poisson's ratio shall be determine at a speed of 50 mm/min. for material having a distinct linear elastic region on the stress-strain curve the ratio shall be determined in the same load range as that used for the measurement of the modulus of elasticity.

- Poisson's ration from this test can be used for further check
- If the material does not exhibit a linear stress to strain relationship the ratio shall be determined within the axial strain range of 0.0005 to 0.0025 mm/mm.
- If the ratio is determined in this manner it shall be noted in the report that a region of proportionality of stress to strain was not evident. As shown in Fig 6.7

Fig 6.7 Breaking of test specimen

6.2.8 Parameter settings

This particular testing is performed on linear low density polyethylene (LLDPE). Some parameters are required to set before performing test; followings are the settings for parameters.

• Test mode	Single
• Test type	Tensile
• Section	Rectangular, Width=5.99mm, Thickness=3.15 mm
• Gage length	25 mm

• Test speed	50 mm/min
• Test range	200 To 1000(1:5) N
• Pre tension load	0 N
• Max elongation	400
• Load cell	000 N
• Max speed	100 mm/min
• Least count	0.01 mm
• Load unit	Newton

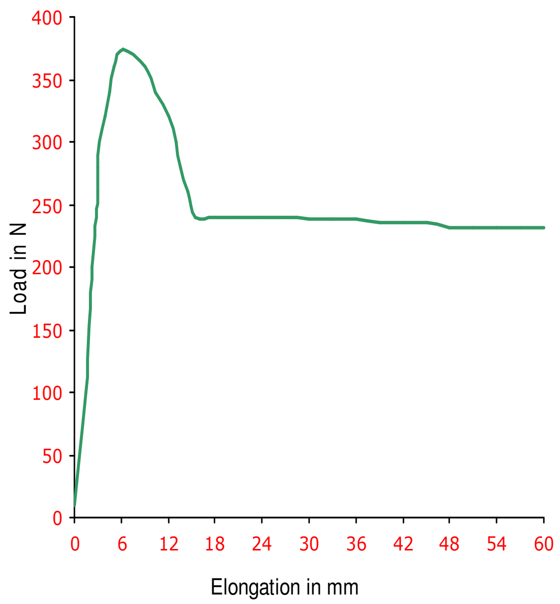


Fig 6.8 curve for load v/s elongation

6.2.9 Results

After testing results are directly carried out from the graph plotted by software.

• Max load	373.75 N
• Elongation at max load	5.52 mm
• % Elongation	22.08
• Elongation at break	72.41 mm
• % elongation	289.64
• Tensile strength	19.089 N/mm^2

6.2.10 Calculation

Calculate the tensile strength by dividing the maximum load in Newton by the average original cross section area in the gage length segment of the specimen in square meters. Express the result in Pascal and report it to three significant Figs as tensile strength at yield or tensile strength at break, whichever term is applicable. When a nominal yield or break load less than the maximum is present and applicable, it may be desirable also to calculate, in a similar manner, the corresponding tensile stress at yield or tensile stress at break and report it to three significant Figs.

- Max load 373.75 N
- Width 5.99 mm
- Thickness 3.15 mm

Area = 18.866 mm^2

$$TS = \frac{M.L}{Area} \tag{6.1}$$

$$TS = \frac{373.75}{18.886}$$

$$TS = 19.822 N / mm^2$$

Percentage elongation is the change in gage length relative to the original specimen gage length, expressed as a percent. Percent elongation is calculated using the apparatus used in universal testing machine. Percentage elongation at yield can be calculated by reading the extension at the yield point. Divide that extension by the original gage length and multiply by 100.

Percentage elongation at break can be calculated by reading the extension at the point of specimen rupture. Divide that extension by the original gage length and multiply by 100.

6.3 STANDARD TEST METHODS FOR FLEXURAL PROPERTIES OF PLASTIC ASTM D 790-03

6.3.1 Scope

This test method covers the determination of flexural properties of unreinforced and reinforced plastic. These test methods are generally applicable to both rigid and semi rigid materials. However flexural strength cannot be determined for those materials that do not break or that do not fail in the outer surface of the test specimen within the 5% strain limit of these test method. These test method utilized three point loading system applied to a simply supported beam. A four point loading system method can be found in test method of D 6272.

A bar of rectangular cross section rests on two supports and is loaded by means of a loading nose midway between the supports. A supports span to depth ration of 16:1 shall be used unless there is reason to suspect that a larger span to depth ratio may be required, as may be the case for certain laminated materials. The specimen is deflected until rupture occurs in the outer surface of the test specimen or until a maximum strain of 5% is reached, whichever occurs first.

6.3.2 Significance

Flexural properties as determined by these test methods are especially useful for quality control and specification purpose. Materials that do not fail by maximum strain allowable under these test method may be more suited to a four point bend test. The basic difference between the two test methods is in the location of the maximum bending moment and maximum axial fiber stresses. Flexural properties may vary with specimen depth, temperature, and atmospheric condition.

6.3.3 Apparatus

A properly calibrated universal testing machine is used. At a constant rate of cross head motion over the range indicated, and in which the error in the load measuring system shall not exceed 1% of the maximum load expected to be measured. It shall be equipped with a deflection measuring device. The stiffness of the testing machine shall be such that total elastic deformation of the system does not exceed 1% of the total deflection of the test specimen during testing or appropriate correction shall be made. The load indicating mechanism shall be essentially free from inertial lag at the crosshead rate used.

The loading nose and support shall have cylindrical surface in the order to avoid excessive indentation or failure due to stress concentration directly under the loading nose, the radii of the loading nose and supports shall be 5 mm unless otherwise specified or agreed upon between the interested clients. When other loading noses and supports are used, they must comply with the following requirements; they shall have a minimum radius of 3.2 mm for all specimens and for specimens 3.2 mm or greater in depth, the radius of the supports may be up to 1.6 times the specimen depth.

Suitable micrometer for measuring the width and thickness of the test specimen to an incremental discrimination of at least 0.025 mm should be used. All width and thickness measurements of rigid and semi rigid plastic may be measured with a hand micrometer with ratchet.

6.3.4 Specimens

The specimen may be cut from sheet, plate, or molded shapes, or may be molded to the desired finished dimensions. Sheet materials shall be of 1.6 mm or greater in thickness. For the flat wise tests, the depth of the specimen shall be the thickness of material. For edgewise tests, the width of the specimen shall be the thickness of the sheet and the depth shall not exceed the width. For all test, the support span shall be 16 times the depth of the beam. Specimen width shall not exceed one fourth of the support span for specimen greater than 3.2 mm in depth. Specimen 3.2 mm or less in depth shall be 12.7 mm in width. The specimen shall be long enough to allow for overhanging on each end of at least 10% of the support span, but in no case less than 6.4 mm on each end. Overhanging shall be sufficient to prevent the specimen from slipping through the supports.

Molding material – the recommended specimen for molding material is 127 by 12.7 by 3.2 mm tested flat wise on a support span, resulting in a support span-to –depth ratio of 16. Thicker specimen should be avoided if they exhibit significant shrink marks or bubble when molded.

Fig 6.9 Specimen for flexural test

Fig 6.9 shows the sheet specimen for testing. Material less than 1.6 mm thickness, the specimen shall be 50.8 mm long by 12.7 mm wide.

6.3.5 Procedure

- Use untested specimen for testing
- Measure the width and depth of the specimen to the nearest 0.03 mm at the centre of the support span.
- For specimen less than 2.54 mm in depth, measure the depth to the nearest 0.003 mm. Fig 6.10.
- These measurements shall be made in accordance with test method D 5947.
- Determine the support span as per specified in section 7 of ASTM.

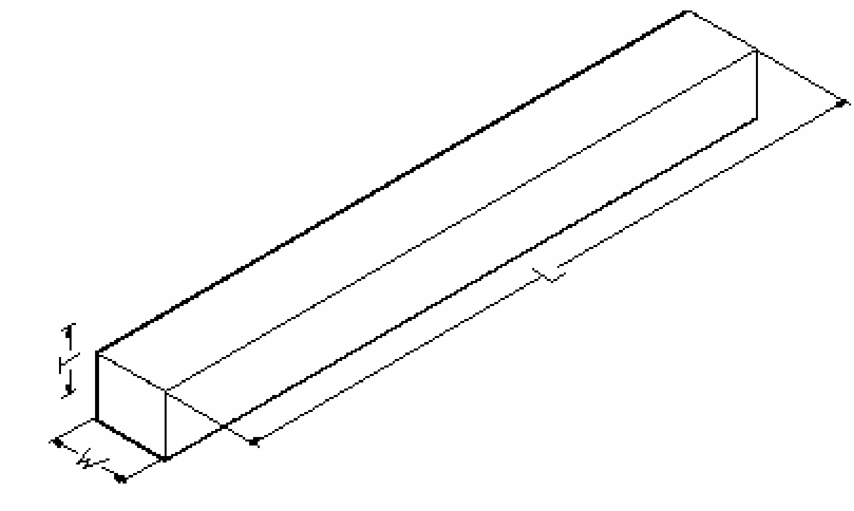


Fig 6.10 Shape of test specimen

- Measure the span accurately to the nearest 0.1 mm for span less than 63 mm and to the nearest 0.3 mm for span less than 63 mm and to the nearest 0.3 mm for span greater than or equal to 63 mm.
- Use the actual measures span for all calculations. For flexural fixtures that have fixed machined span for all calculation.
- Verify the span distance the same as for adjustable span for that position and is used for calculation applicable to all subsequent tests conducted at that position.
- Align the loading nose and supports so that the axes of the cylindrical surface are parallel and the loading nose is midway between the supports.

- The parallelism of the apparatus may be checked by means of a plate with parallel grooves into which the loading nose supports will fit when properly aligned.
- Centre the specimen on the supports, with the long axis of the specimen perpendicular to the loading nose and support.

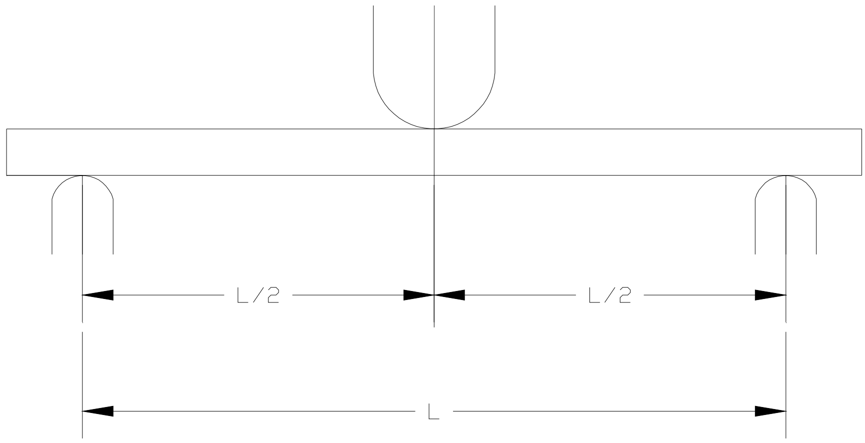


Fig 6.11 Loading assemblies for testing

- Apply the load to the specimen at the specified crosshead rate, and take simultaneous load-deflection data.
- Measure deflection either by a gage under the specimen in contact with it at the centre of the support spans, the gage being mounted stationary relative to the specimen supports, or by measurement of the motion of the loading nose relative to the supports.
- Load-deflection curve may be plotted to determine the flexural strength, chord or secant modulus or the tangent modulus of elasticity, and the total work as measures by the area under the load-deflection curve.

6.3.6 Parametric settings

This particular testing is performed on linear low density polyethylene (LLDPE). Some parameters are required to set before performing test; followings are the settings for parameters.

- Test mode Single
- Test type bending

- Section — Rectangular Width 12.2 mm Thickness 8.1 mm
- Gage length — 130 mm
- Test speed — 5 mm/min
- Test range — 5 To 25 (1:2) N
- Pre tension load — 0 n
- Max elongation — 10
- Load cell — 50 N
- Max Speed — 100 mm/min
- Least count — 0.01
- Load unit — N

6.3.7 Results

After testing results are directly carried out from the graph plotted by software.

- Max load — 17.956 N
- Bending strength — 4.373 N/mm^2
- Flexural modulus — 615.89 N/mm^2

6.3.8 Calculation

When a homogenous elastic material is tested in flexure, as a simple beam supported at two points and loaded at the midpoint. The maximum stress in the outer surface of the test specimen occurs at the midpoint.

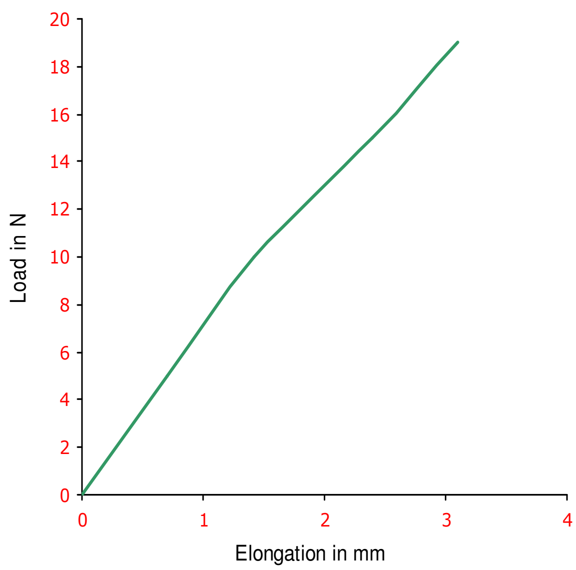


Fig 6.12 curve for load v/s elongation

$$\sigma_f = \frac{3PL}{2bd^2} \quad (6.2)$$

Where

σ = Stress in outer fiber at mid span MPa.

P = Load in given point in N.

L = Support span in mm.

b = Width of beam in mm.

d = Depth of beam in mm.

Modulus of elasticity can be determined by the given equation 6.3.

$$E_B = \frac{L^3 m}{3bd^3} \quad (6.3)$$

Where

E_B = Modulus of elasticity in MPa.

L = Support span in mm.

b = Width of beam in mm.

d = Depth of beam in mm

m = Slope of tangent of curve.

$$E_B = \frac{L^3(F_2 - F_1)}{4bd(y_2 - y_1)}$$

$$E_B = \frac{(130)^3(4.86 - 1.16)}{4(12.2)(8.1)^3(0.68 - 0.2)}$$

$$E_B = 653.N / mm^2$$

6.4 LIMITING VALUES

Limiting values for different types of materials are specified below.

- Linear Low Density Polyethylene (LLDPE) 22 MPa
- High Density Polyethylene (HDPE) 43 MPa
- Fiber Reinforced Polymers (FRP) 132 MPa

6.5 SUMMARY

These two tests are performed on the molded plastic to carry out their basic properties, before designing any component from material it is required to find out their properties, these tests are helpful to find their properties. From above tests it is possible to know tensile strength, Poisson's ratio, flexural strength and modulus of elasticity.

7. LOADINGS ON UNDERGROUND TANK

7.1 LOADINGS

Loadings are basic requirement for analysis of any structures; in this case, loadings are depending upon different parameter. Depending on tank location different types of loadings are carried out, some of the loadings are soil pressure, liquid pressure, vertical load of vehicle (tractor axle), human, animals etc, vehicular load is the case of underground tank out side. When tanks are embedded out side of house premises it may be possible some time that whole vehicle passes on it. Loading types are described in the following subsequent sections.

7.2 TRACTOR AXLE LOAD

When underground tank is installed out side of house premises, or when it is under the road, in both the cases vehicular load will transfer to the tank. Generally, for these cases, one wheel axle load is considered on it. Therefore half tractor load is considered for analysis purpose. As shown in Fig 7.1 load is transferred to septic tank.

When tank is installed within the boundary of house, vehicular load will not act on the tank. For this case vehicular load may be neglected for analysis. But for design and safety purpose wheel axle load is consider for analysis. In this piece of work, general analysis is carried out therefore for safety purpose tractor axle load is considered. After manufacturing it will install in side the house premises or some time it will be out side too. Design is done by considering worst case of loadings, acting on the tank.

Tractor axle load is considered as 4.5 tones acting on top surface of tank. Basically it is assumed to be acting on one point but actually tanks are embedded 500mm below the ground level, so load will be spread over the top surface of tank. Position of tank and wheel arrangement is shown in fig 7.1. This load is heavier than other load acting on tank, tractor axle load is considered for analysis. Along with this load, other load combinations are carried out. And most sever case is considered for analysis.

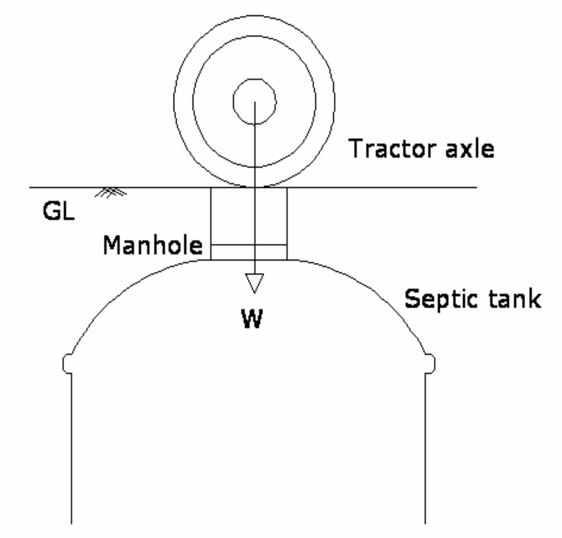


Fig 7.1Wheel axle load

7.3 HUMAN + ANIMAL LOAD

It is obvious that human would be passing over the embedded underground tank. Sometimes animals are also standing on it. Combined load of Human and animals are considered for analysis. 550 kg load is considered for this case. This case is shown in Fig 7.2.

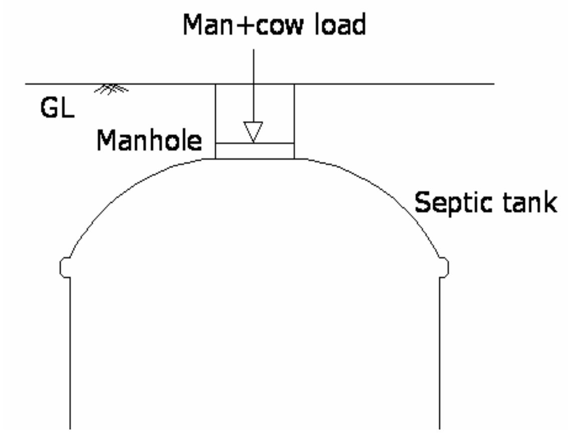


Fig 7.2 Human + cow load

7.4 LIQUID PRESSURES

Waste water from house is discharged to septic tank; it is full of waste water when septic tank is in use. Liquid inside the septic tank would create pressure on walls of septic tank. Liquid pressure is considered from density of waste water and depth of septic tank. Liquid pressure on tank is shown in Fig 7.3.

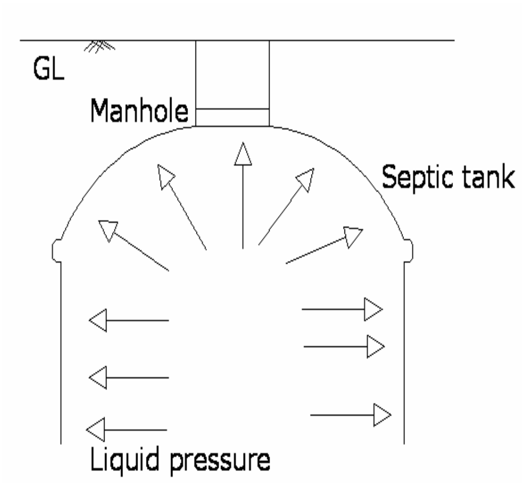


Fig 7.3 Liquid pressure

7.5 SOIL PRESSURE

Underground tank is surrounded by soil, soil will create pressure on the tank, pressure is depend upon the types of soil in which tank is embedded. It is taken as 10 Psi. As shown in Fig 7.4.

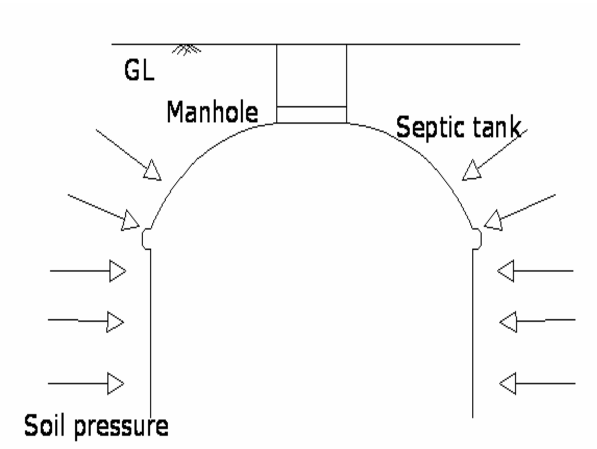


Fig 7.4 Soil pressure

7.6 SOIL LOAD FROM MANHOLE COVER

Septic tank is embedded 500mm deep into the ground. For this condition 500mm soil load is transferred to manhole cover and from it ultimately to the tank. So pressure is considered on top part of tank.

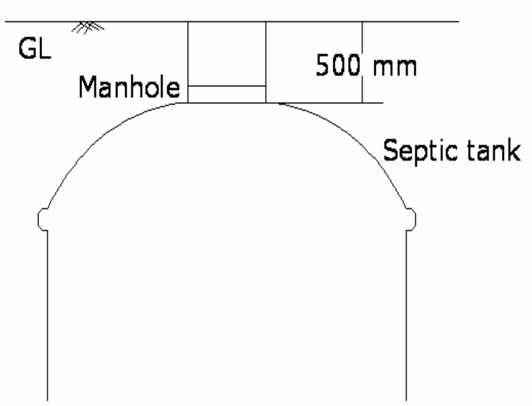


Fig 7.5 Soil load from manhole cover

These are the basic types of load which will act on tank when it is embedded in ground. From above load cases combinations are carried out, and for those combinations, analysis is done by taking most sever load combination.

7.7 LOAD COMBINATIONS

Load combinations are required for analysis purpose, from the available loadings combinations are carried out. There are two types pressure in tank; one is soil pressure outside of tank and liquid pressure from in side. Soil pressure is acting constantly on tank after installation, but liquid pressure will act constant on the tank, when tank is empty only soil pressure from outside. Combinations are carried out with this phenomenon. Two combinations are tank empty condition and tank full condition.

8. MODELING OF UNDERGROUND STORAGE TANKS

8.1 GENERAL

The underground tank is used for liquid storage purpose, for particular case septic tank is receiving waste water created from household use, it will treat the waste water to some extent and then discharge it to ground water or to the municipal sewer pipe. When waste water enters to septic tank it will allow to slow down, heavy material will settled down and accumulation of these heavy materials is called sludge. Sludge is pumped out at regular interval.

This is a completely underground structure, for design of septic tank analysis is carried out with the use of software ANSYS, Finite element modeling is done in ANSYS for underground tanks of 3000 liters, and 5000 liters capacities.

8.2 MODELING OF UNDERGROUND TANK

Septic tank is modeled using finite element approach. Geometric and material modeling is discussed in detail in subsequent sections.

First geometry dimensions are decided for septic tank, dimensions are modified for the other model. These two models are used for the finite element analysis. And results are compared for these two different models. Depending upon results other different dimensions are decided for analysis.

8.2.1 Geometry of underground tank

Geometry is decided by capacity of the underground storage tank, dimensions are proposed with two different capacities, 3000 liters and 5000 liters. Depending on numbers of domestic users of septic tanks dimensions are decided. 5000liters tanks are suitable for 16 numbers of users, and 3000 for 8 numbers of users. These geometries are shown in Fig 8.1a to Fig8.7b.

Septic tanks are made up with different form of polyethylene and fiber reinforced polymers. Comparative study has been carried out with different material and with the various thicknesses of septic tank wall. Thickness tried for it are 4mm, 5mm, 6mm, other dimensions of tank are remain same for different thickness.

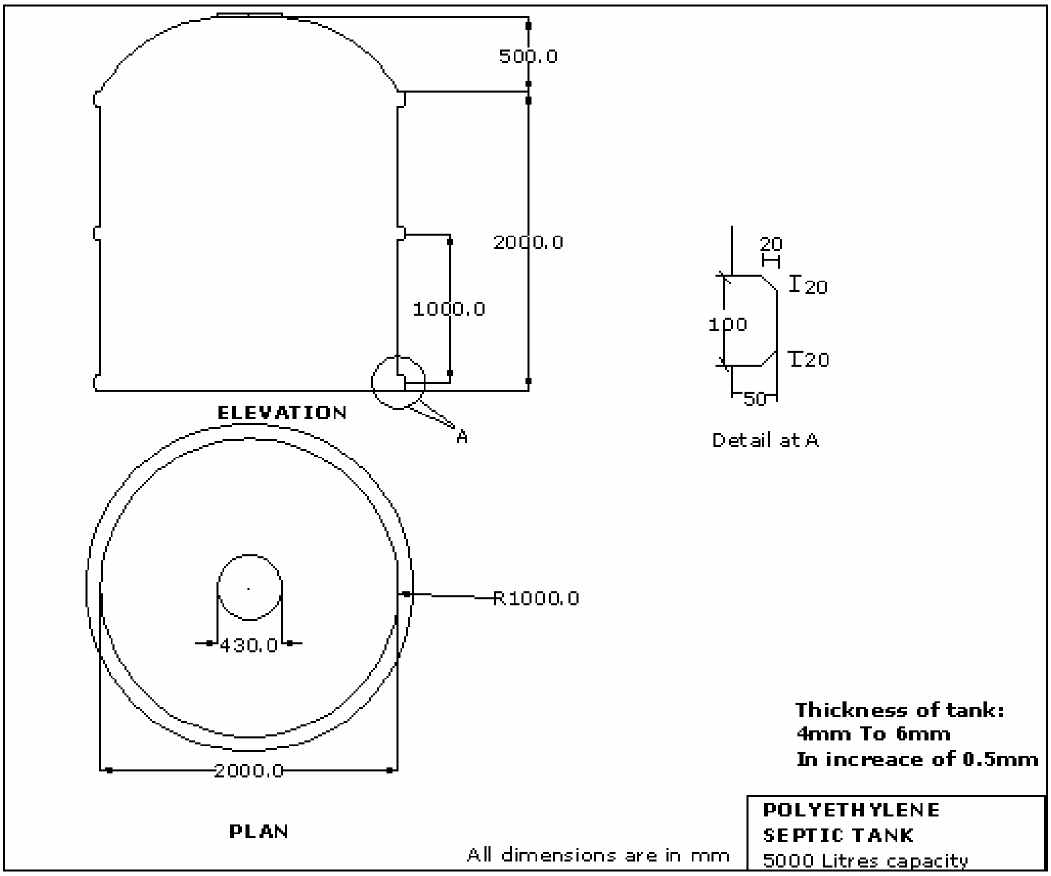


Fig 8.1a Detail drawing of underground tank type-1 model-1

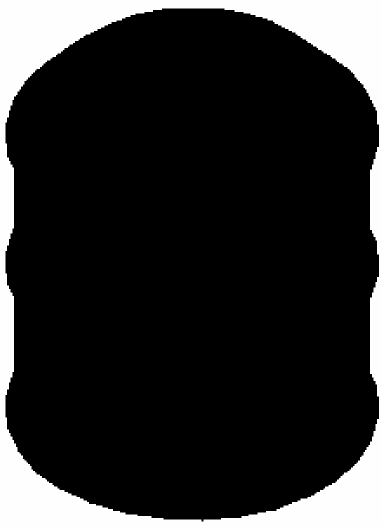


Fig 8.1b 3D model of underground tank

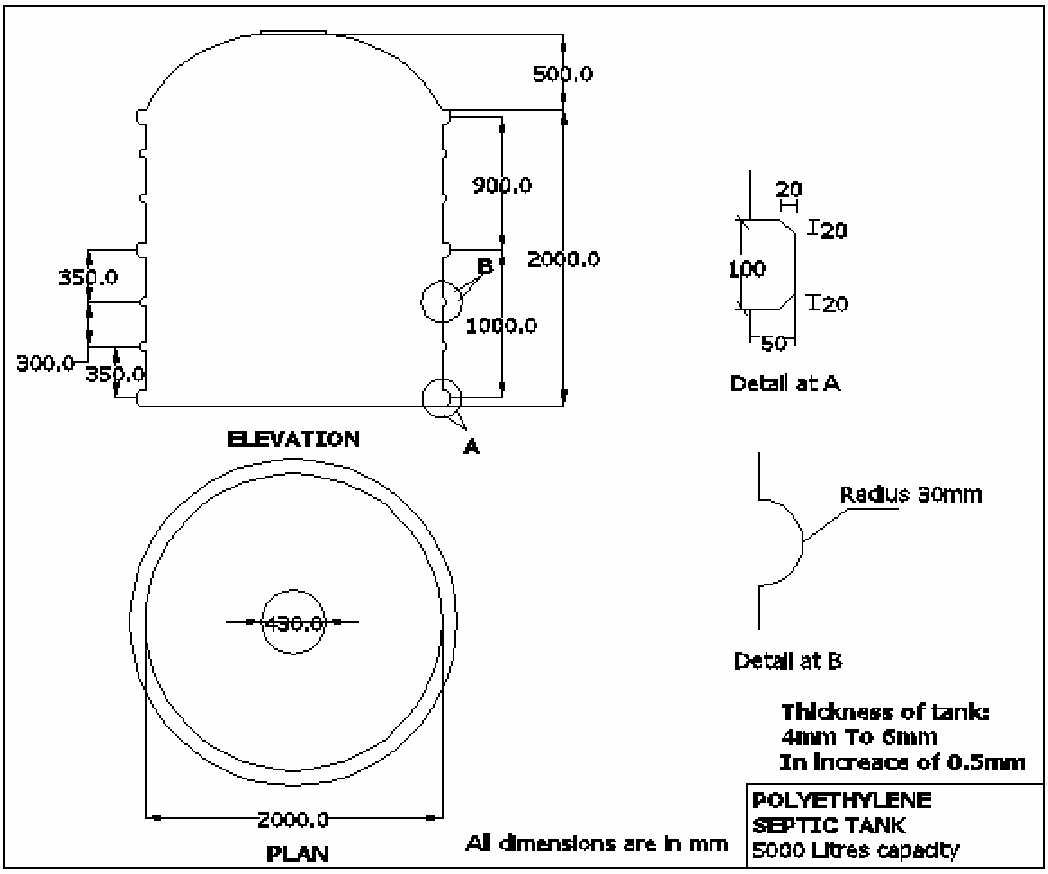


Fig 8.2a Detail drawing of underground tank type-1 model-2

Fig 8.2b 3D model of underground tank

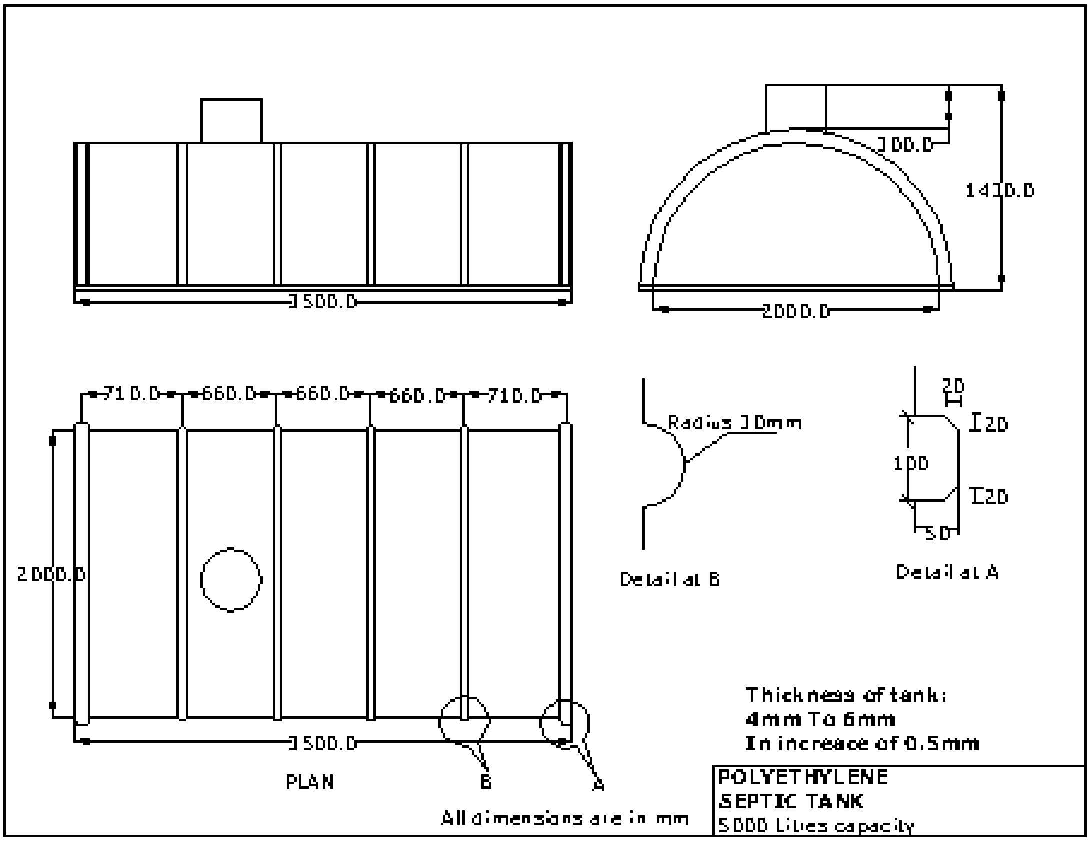


Fig 8.3a Detail drawing of underground tank type -2, model-1

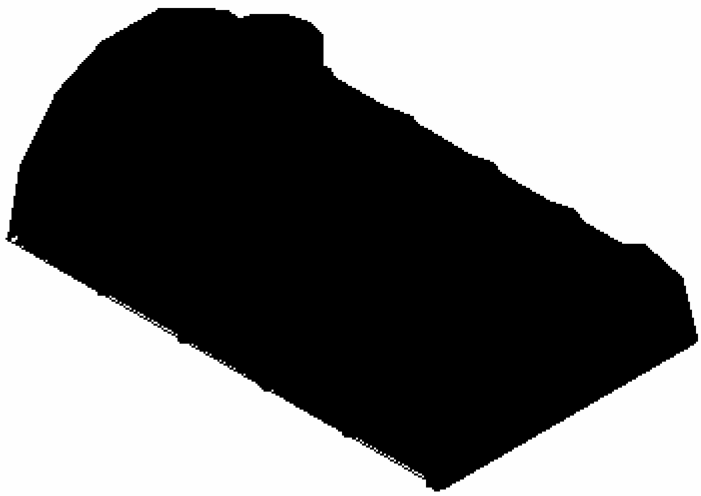


Fig 8.3b 3D model of underground tank

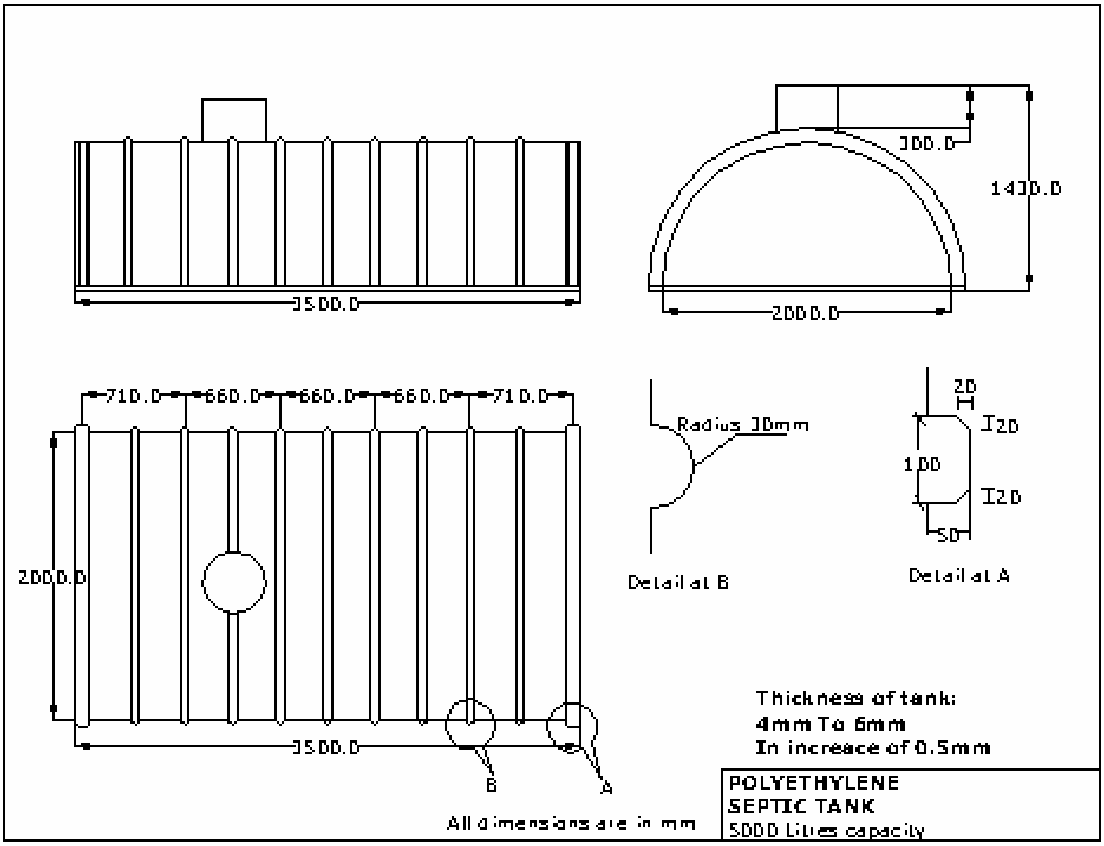


Fig 8.4a Detail drawing of underground tank type -2, model-2

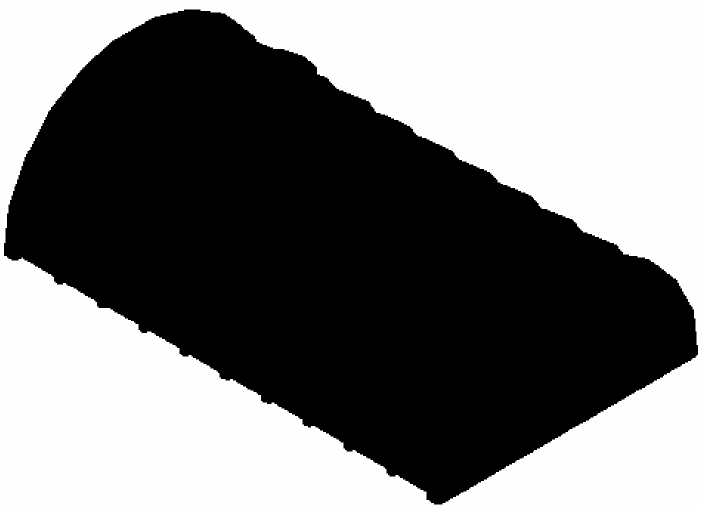


Fig 8.4b 3D model of underground tank

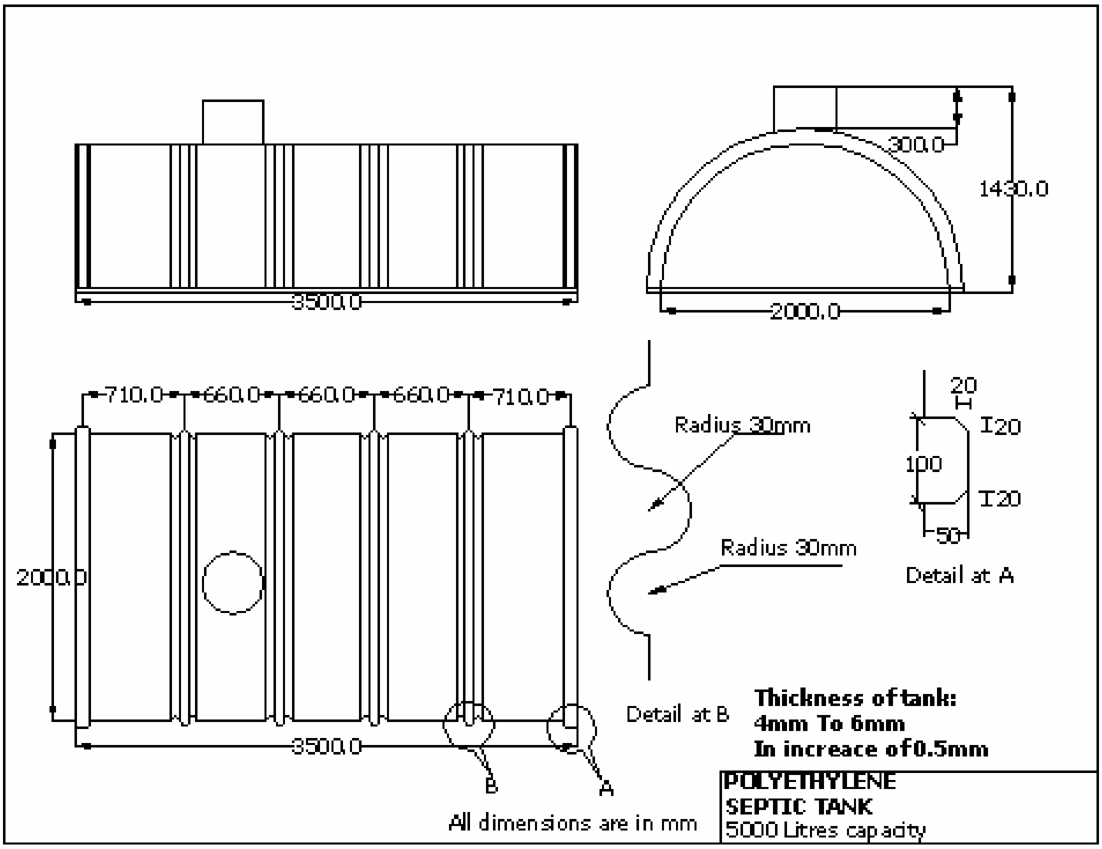


Fig 8.5a Detail drawing of underground tank type -2, model-3

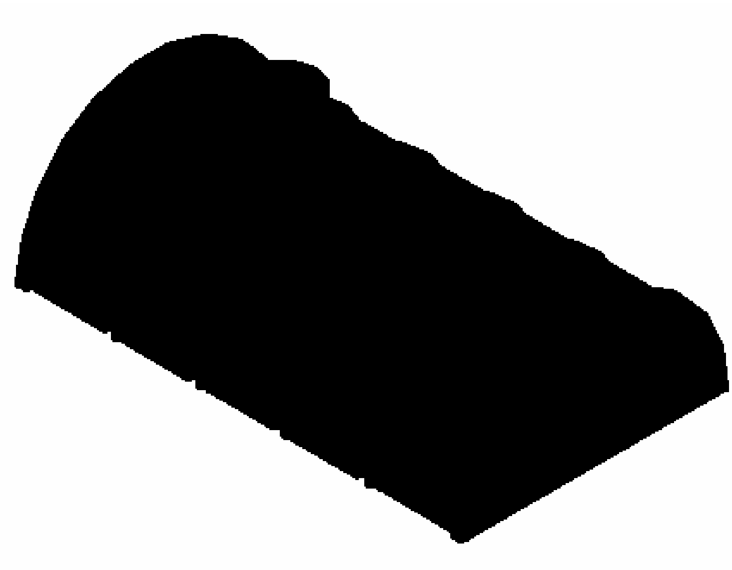


Fig 8.5b 3D model of underground tank

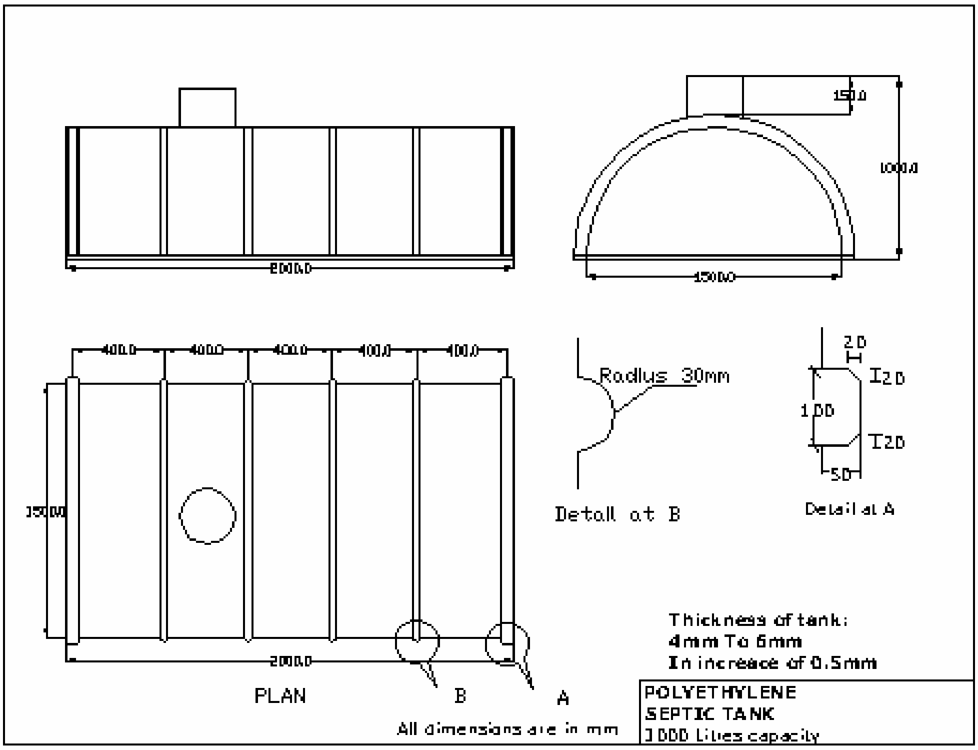


Fig 8.6a Detail drawing of underground tank type -3 (3000 liters), model-1

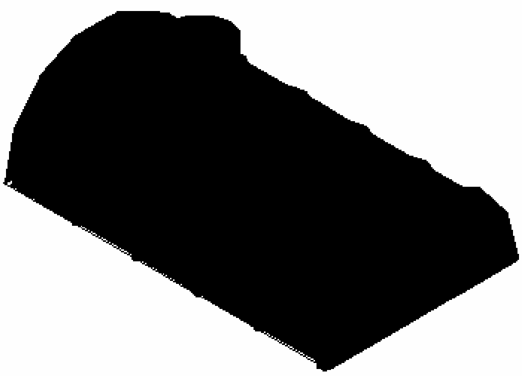


Fig 8.6b 3D model of underground tank

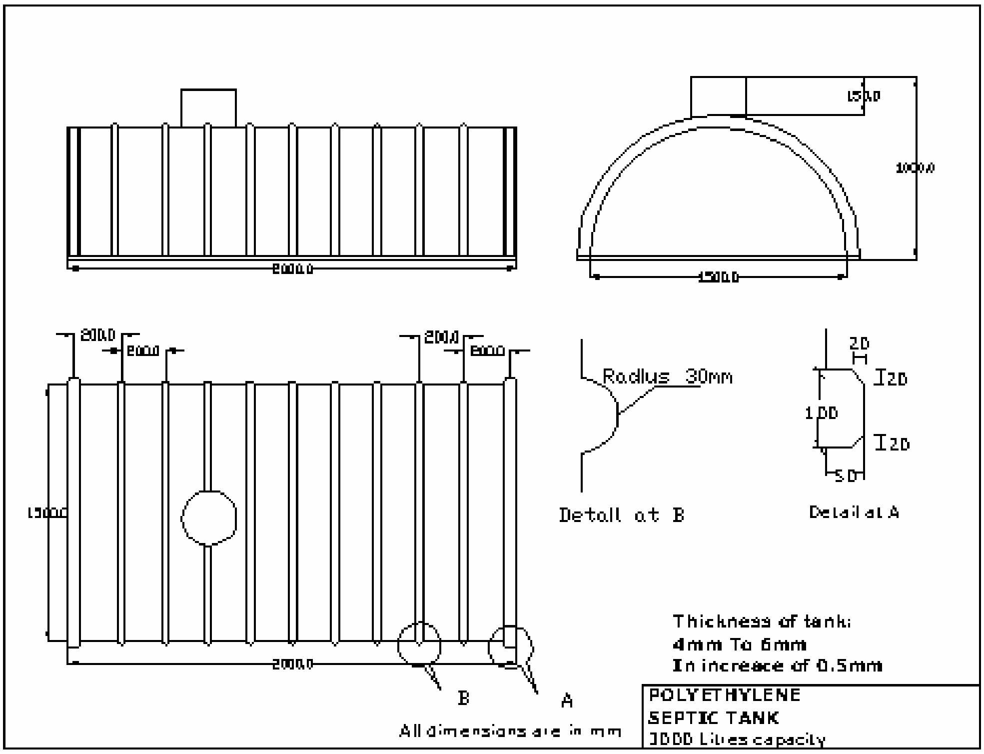


Fig 8.7a Detail drawing of underground tank type -3 (3000 liters), model-2

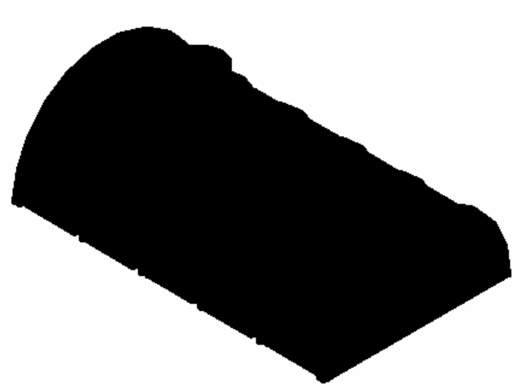


Fig 8.7b 3D model of underground tank

Present study is carried out with underground tank with minimum ribs as shown in Fig 8.1a, secondly with the more ribs distributed in septic tank as shown in Fig 8.2a. These dimensions are used for finite element modeling.

8.2.2 Material modeling

Material properties for septic tank are depending upon different material used for it; two different materials are used for septic tank. Polyethylene and FRP (Glass fibers) are used for modeling.

- Polyethylene product (LLDPE, HDPE).
- Fiber Reinforced Polymers (Glass fibers).

8.2.3 Boundary condition

Tank is completely embedded in ground. These types of tanks are an underground structure; tanks are surrounded by soil. Soil applies pressure on surrounding walls of underground tank. For analysis purpose base area of tank is considered as a fix. At the base whole area is restrained against translation and rotation.

8.2.4 Loadings

Loadings are explained in chapter 6. Analysis is done by different loading cases and by making combination of loads. For worst condition analysis results are consider for check. Two kinds of combinations are carried out, tank empty and tank full condition. Loadings are explained in chapter 7.

8.2.5 Finite element modeling

- Maximum Finite Element in the model 10300
- Maximum nodes in the FE model 11625
- Types of element Triangular element

Numbers of elements will affect the stress and deflection; results are reduced when more numbers of elements are used for analysis. Study is done with different numbers of elements. Tank model used for analysis is same for all cases, only numbers of elements were different for each analysis. Results are explained by graphical presentation. This is shown in Fig 8.8 and 8.9.

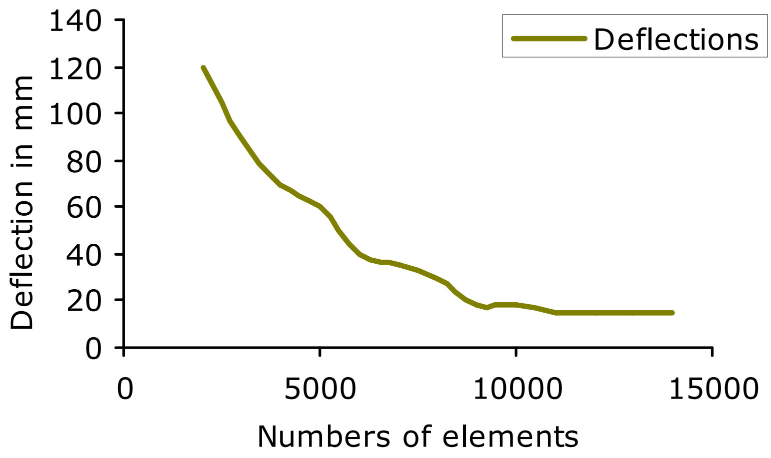


Fig 8.8 Deflection comparisons for different elements numbers

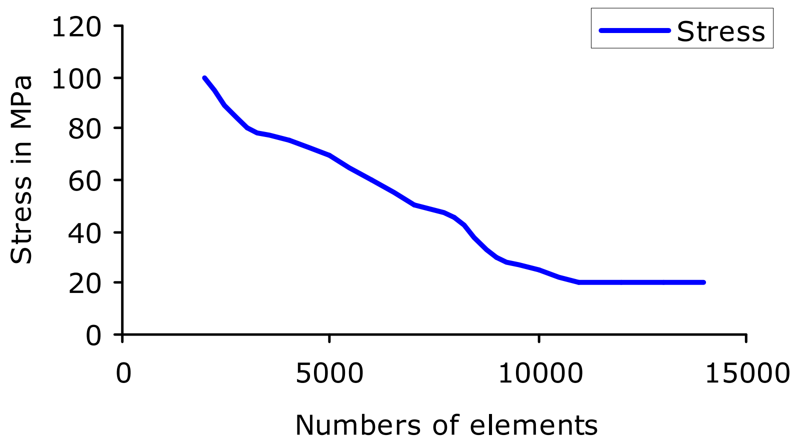


Fig 8.9 Stress comparisons for different numbers of elements

8.3 SUMMARY

In this chapter different model of tanks are explained with their different stiffeners arrangement, at last one study was done to understand effect of element size in Finite element analysis. Results are concluded in above Fig 8.8 and 8.9.

9. RESULTS AND DISCUSSION

9.1 GENERAL

Analysis of underground tank is a major part of design appropriate system. Stresses and deflection estimation is carried out with finite element analysis in ANSYS software. With the use of obtained results tank design is checked. If it increases to limiting values of particular material then underground tank should be redesigned. Redesign can be done by changing the dimension of tank, spacing of ribs, dimensions of ribs, and increasing thickness of wall by using different material (HDPE, LLDPE, and FRP).

Subsequent section of this chapter presents the results with discussion of stress and deflection analysis of the septic tank of 5000 liters, and 3000 liters capacities.

9.2 ANALYSIS OF POLYETHYLENE UNDERGROUND TANK

Considering 5000 liters, and 3000 liters capacities tanks dimensions are carried out with the minimum numbers of the ribs in septic tank. Model is prepared in the ANSYS software. Other models are prepared with different arrangement of ribs, and also work is carried out in material domain.

Geometric models are created in AutoCAD and exported to SAT format then imported for analysis in finite element software. Shown in Fig 8.1a and 8.1b.

9.2.1 Meshing of the model

After preparing geometric, model transferred to software. Basically shell 63 element is used for analysis. Meshing is done with the smart mesh tool available in software.

Isoparametric triangular meshing is used, as shown in Fig below. Free meshing is used for this particular analysis; mapped mashing can be use for further study. Mashed model is shown in Fig 9.2, for other model same meshing is carried out for analysis. Smart meshing has been used which divides the whole part appropriately.

9.2.2 Material properties

Material used for particular analysis is linear low density polyethylene (LLDPE), properties are taken as per explained in the chapter 4.

9.2.3 Restraints in model

Underground tanks are embedded in ground; soil pressure is act on all parts of tank. For analysis purpose bottom area of tank is consider as fix, as shown in Fig 8.2b, bottom area is restrained against translation as well as rotation.

9.2.4 Load cases

Loadings act on septic tank are discussed in chapter 4. Now for analysis different cases are used. After applying various load cases tank is checked for worst case.

9.3 RESULTS OF UNDERGROUND TANK TYPE-1

Now analysis is done with different cases. Using load data given in table 8.1, 8.2, 8.3 for analysis stress and deflection are obtained. These models are checked for only 6 mm thickness of tank wall, without any ribs at present. In absent of ribs large deflection has been observed.

Analysis of model-2 is done with same load cases, with wall thickness of 6 mm, in this case. It is observed that tanks with less thickness report large deflections.

9.3.1 Deflection in underground tank

When loadings are applied on tank displacement and stress are exceed from their limiting values.
Fig 9.3a gives the displacement of tank at various locations, displacement shown in mm.

From above results maximum deflection 1313 mm at top. Top portion of tank is subjected to animal load and 500 mm thick soil load. Considering most sever condition of loading value of deflection is 914 mm, again this value is higher then the allowable value. Results are shown in Fig 9.3a. Deflection is higher for this material can be reduced by using another materials or adding more ribs in top part.

In case of model 1 and 2 deflection is higher because of top semi spherical portion of septic tank is without ribs, now same model is again checked with providing ribs in top portion also. Analysis is carried out for this tank, deflection is reduce to 880 mm. Model is shown in Fig 9.5; deflections are shown in Fig 9.6. For model-2 with the increase numbers of ribs in wall of tank deflection is reduce to 350 mm, deflection is higher for this case also, when septic tank is subjected to tractor axle load some critical location is cracked.

9.3.2 Stress results for underground tank

Von Misses Stress refers to a theory called the "Von Misses - Hencky criterion for ductile failure".

In an elastic body that is subject to a system of loads in 3 dimensions, a complex 3 dimensional system of stresses is developed. That is, at any point within the body there are stresses acting in different directions, and the direction and magnitude of stresses changes from point to point. The Von Misses criterion is a formula for calculating whether the stress combination at a given point will cause failure.

There are three "Principal Stresses" that can be calculated at any point, acting in the x, y, and z directions. (The x, y, and z directions are the "principal axes" for the point and their orientation changes from point to point, but that is a technical issue.). Von Misses found that, even though none of the principal stresses exceeds the yield stress of the material, it is possible for yielding to result from the combination of stresses. The Von Misses criterion is a formula for combining these 3 stresses into an equivalent stress, which is then compared to the yield stress of the material. (The yield stress is a known property of the material, and is usually considered to be the failure stress.)

For different load cases maximum value of stress is comes out to be 228 Mpa which is higher then the permissible yield stress of material (25 Mpa), stresses in tanks are shown in Fig 9.3b. For most sever condition maximum value of stress is 25 Mpa, value is higher then the permissible value for material. HDPE or FRP can be used for these types of tanks.

For model-2 with more stiffeners in wall of septic tank analysis results are reduce in compare of the model-1 with minimum ribs. For this model, critical value of stress is 71 Mpa which is permissible in compare to allowable yield stress of the material. Stresses are shown in Fig 9.8b.

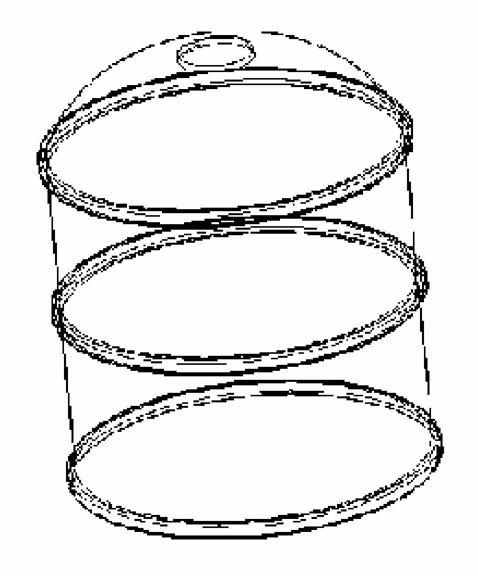


Fig 9.1a Model-1

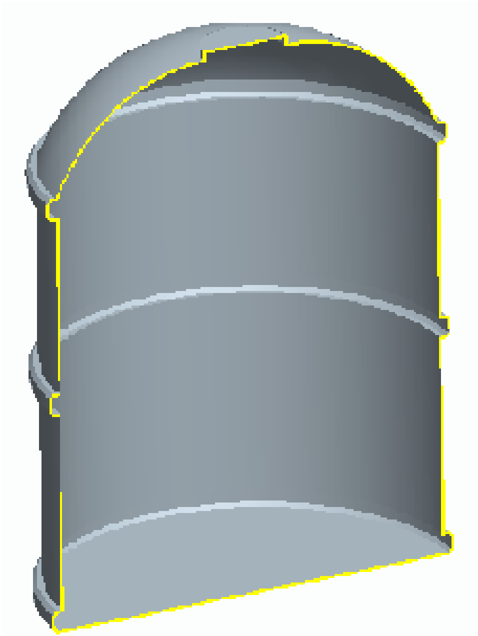


Fig 9.1b Section of Model-1

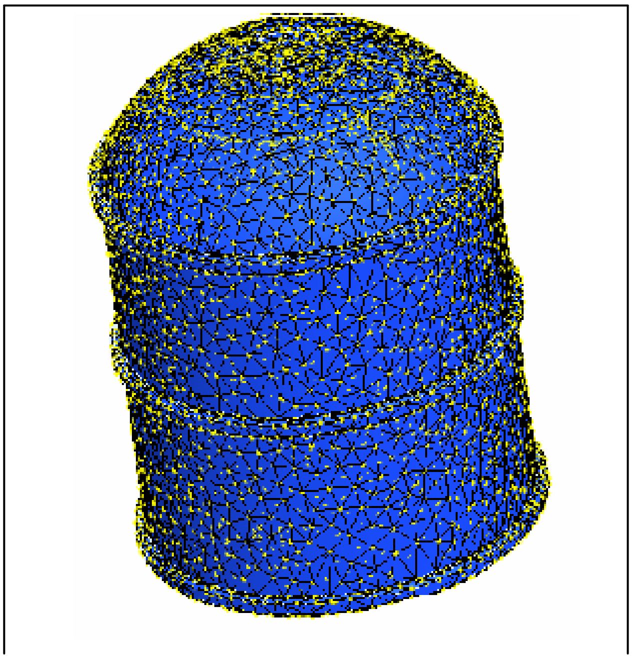


Fig 9.2a Meshing of tank

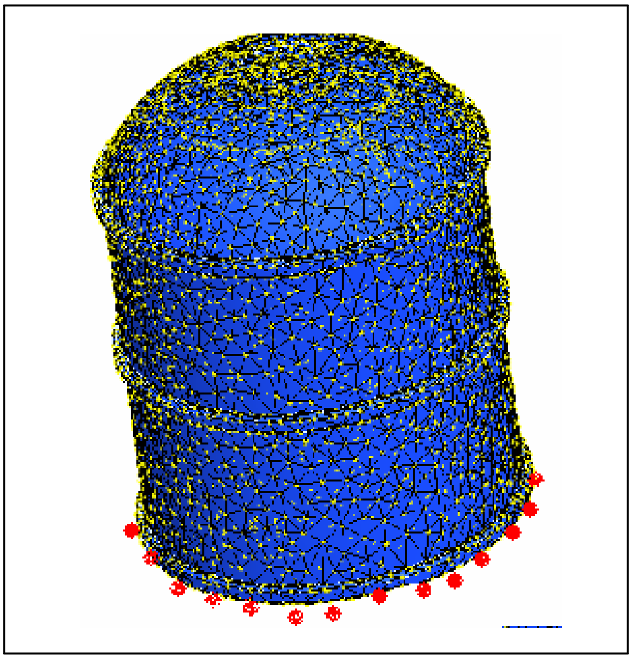


Fig 9.2b Restraint at base

Table 9.1 Load case-1 for model-1

	Model – 1
FEATURE	Minimum RIBS
Thickness	6.00 mm
Material	Polyethylene - LLDPE
Load -1	5500 N – ANIMAL LOAD
Load -2	0.0689 MPa Soil Pressure
Load-5	500 mm soil load

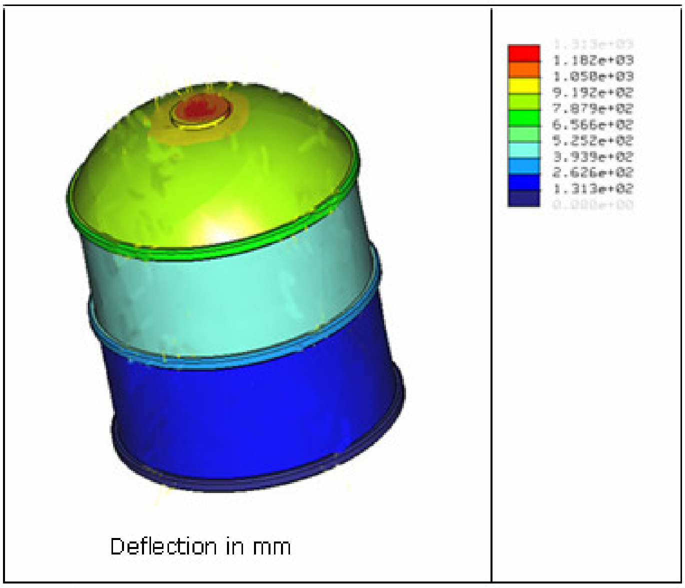


Fig 9.3a Deflection contour (With minimum stiffeners, FS=2)

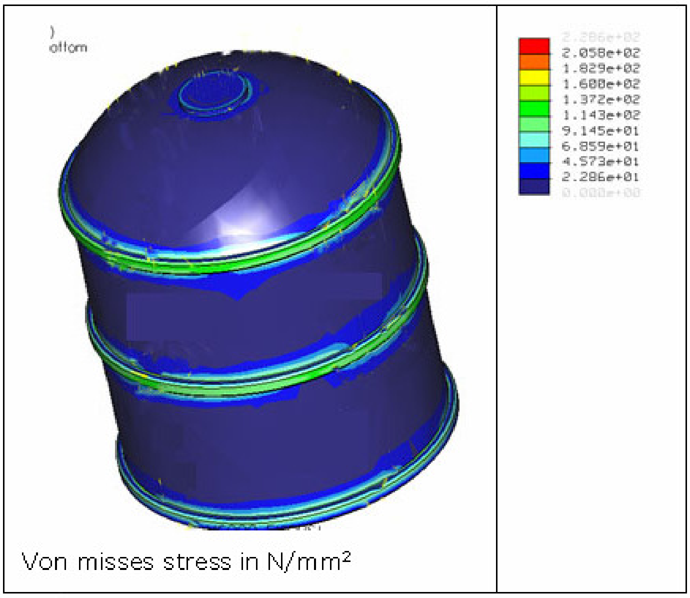


Fig9.3b Von misses stress (With minimum stiffeners, FS=2)

Table 9.2 Load case-2 model-1

FEATURE	Model – 1 Minimum RIBS
Thickness	6.00 mm
Material	Polyethylene – LLDPE
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load -3	0.0620 MPa Liquid Pressure
Load -5	500 mm soil load

Most sever condition will be the tank empty condition. At the time of installation or some time when system is in not working this load combination will act.

Table 9.3 Load case-3 model-1

FEATURE	Model - 1 Minimum RIBS
Thickness	6.00 mm
Material	Polyethylene - LLDPE
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load-5	500 mm soil load

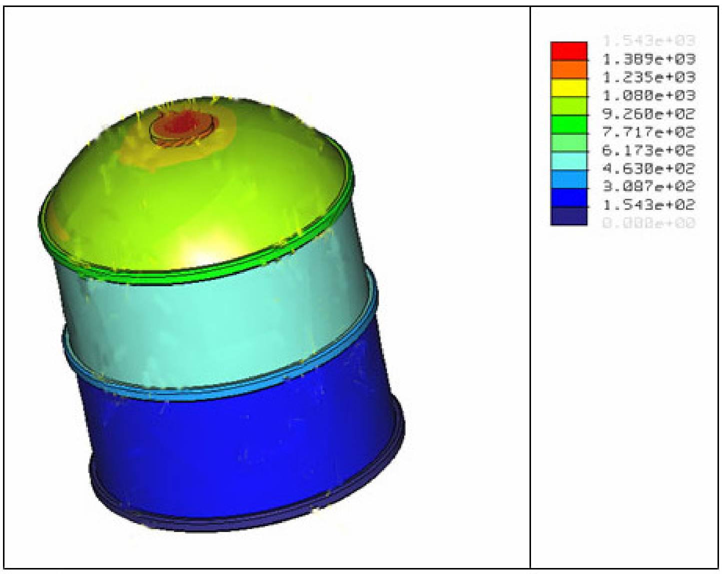


Fig 9.4a Displacement contour for most sever load case (With minimum stiffeners case, FS=2)

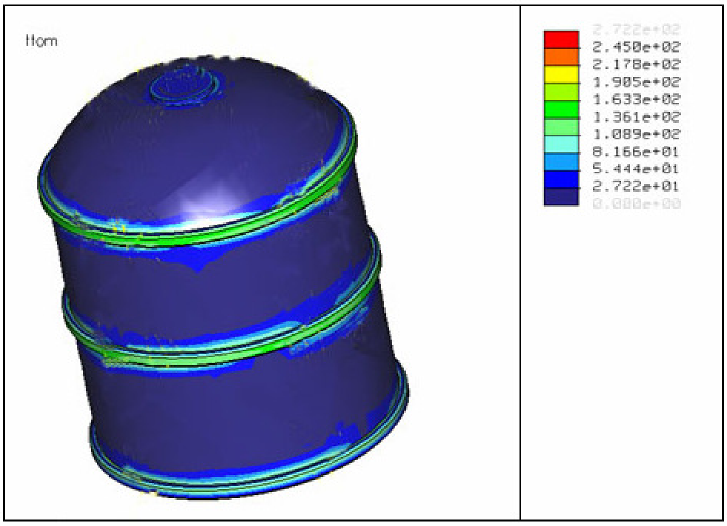


Fig 9.4b Von misses stress for load case-3 (With minimum stiffeners case, FS=2)

Table 9.4 Displacement for model-1 (Minimum stiffeners case)

Load case	In X dir mm	In Y dir mm	In Z dir mm
1	1021	1313	915
2	990	1009	900
3	1220	1349	980

Table 9.5 Stresses for model-1 (with minimum stiffeners case)

Load case	In X dir MPa	In Y dir MPa	In Z dir MPa	Vm MPa
1	201	70	90.1	228.8
2	62.5	213.3	276	71.5
3	239.7	82	108.8	272.2

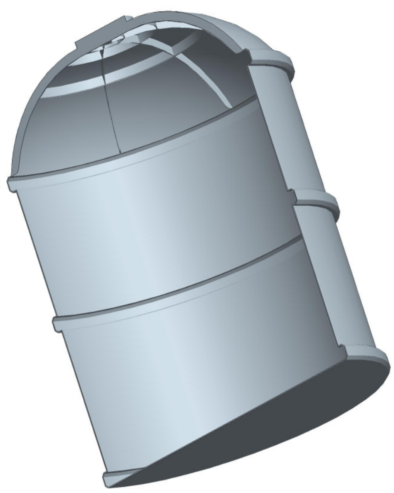


Fig 9.5 Model-1 with ribs in top part

Same Load cases are used for analysis of model-2. Model-2 is with more numbers or ribs. Due to higher deflection in top part ribs are added to top part also analysis is carried out with same load combination.

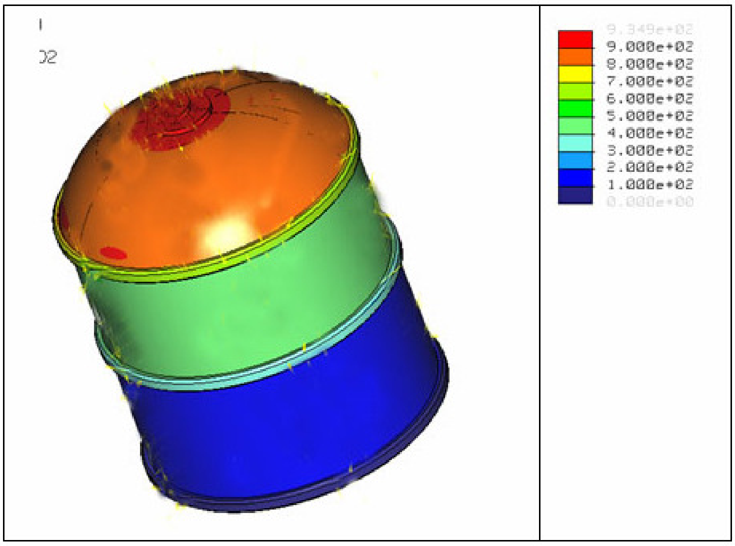


Fig 9.6 Displacement contours (With stiffeners at top part, FS=2)

Analysis of model-2 is also done by considering different load cases. Load cases are already specified in analysis of tank model-1. Same load cases are used foe these tanks. In this case conditions are similar only spacing or stiffeners are changed, spacing is reduced and numbers of stiffeners are increased, so it will reduce the stress in tank wall, and ultimately gives more strength to the tank, it will safe against loadings. Geometry is shown in Fig 9.7a and Fig 9.7b.

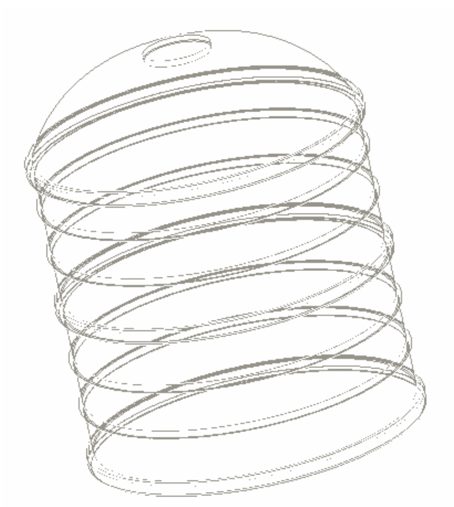


Fig 9.7a Model-2

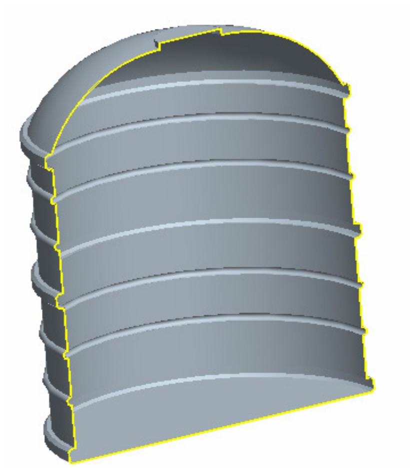


Fig 9.7b Section of Model-2

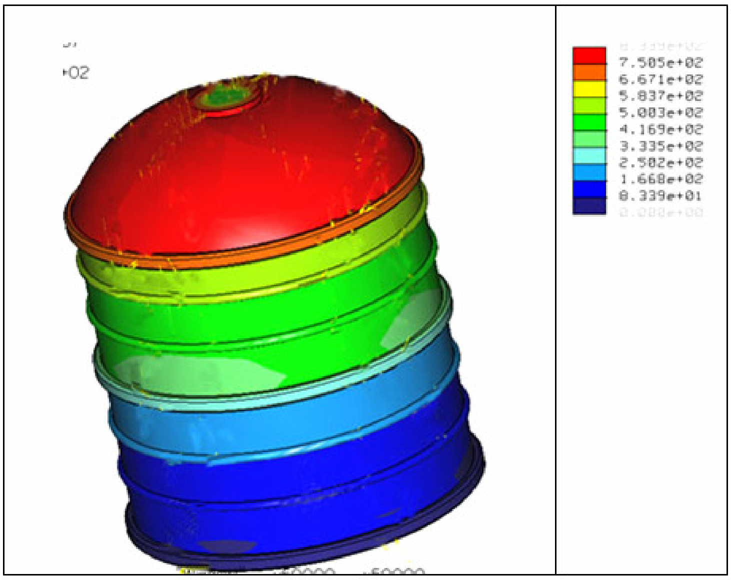


Fig 9.8a Displacement contour model-2 (With more stiffeners in tank, FS=2)

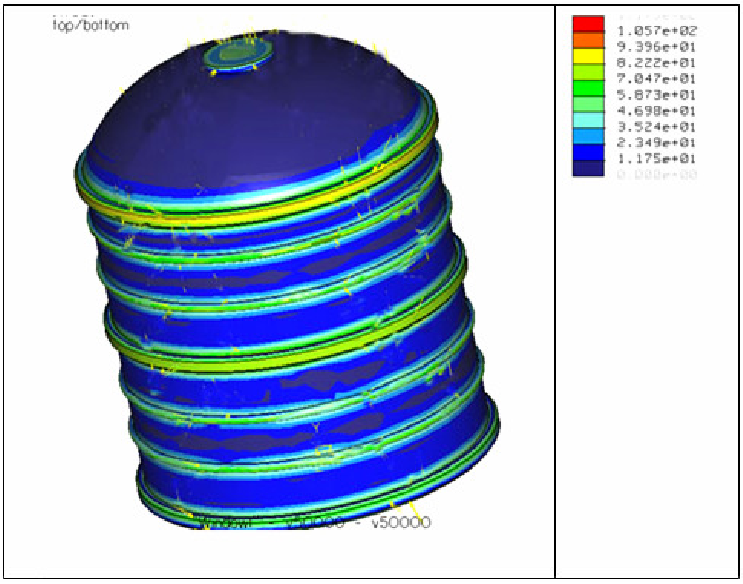


Fig 9.8b Von misses stress model-2 (With more stiffeners in tank, FS=2)

Deflections and stresses are tabulate in table 9.6 and 9.7

Table 9.6 Displacement for model-2 (With more stiffeners in tank)

Load case	X dir mm	Y dir mm	Z dir mm
1	650	810	618
2	550	780	600
3	528	700	750

Table 9.7 Stresses for model-2 (With more stiffeners in tank)

Load case	X dir MPa	Y dir MPa	Z dir MPa	Vm MPa
1	139	62	82	172
2	43.4	21.8	18.1	108
3	107.5	46	37.8	82.2

9.4 DISCUSSIONS

Results are obtained in above analysis. Now it should be checked for permissible value of the underground tank material. Deflection and stresses are compared for different load cases.

Model-1 displacement and stress for load cases are shown here

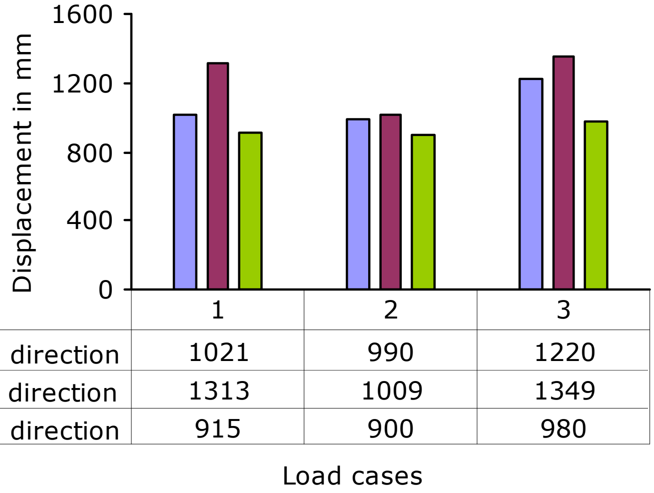


Fig 9.9 Displacement for model-1 (With minimum stiffeners, FS=2)

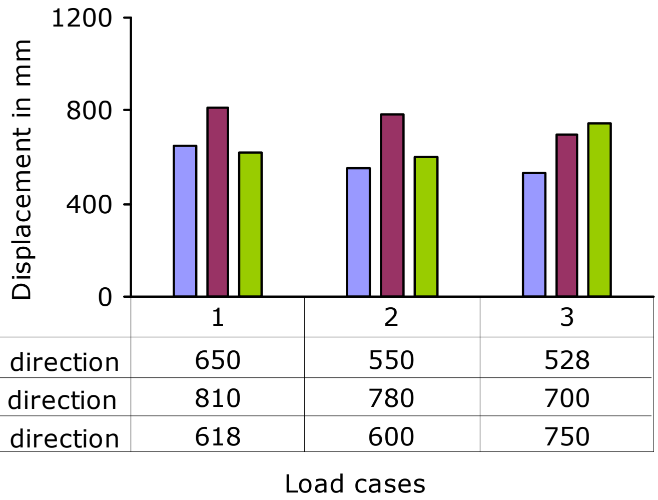
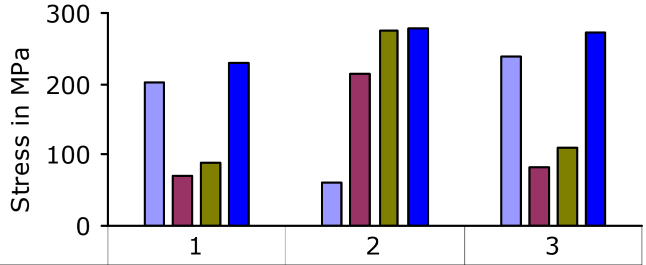


Fig 9.10 Displacement for model-2 (With more stiffeners, FS=2)

Stresses are also calculated for both the model. Stress obtained from different load cases are shown in table 9.5 and 9.7. Von misses stress is consider for comparison with the material properties.

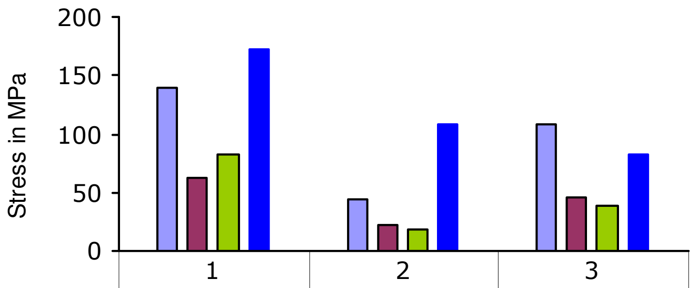
Stresses are comparing in X direction, Y direction, Z direction and von- misses. Comparison is shown in Fig 9.11 and 9.12. For all analysis factor of safety considered is 2.



	1	2	3
X Direction	201	62.5	239.7
Y Direction	70	213.3	82
Z Direction	90.1	276	108.8
Von misses	228.8	277.2	272.2

Load cases

Fig 9.11 Stresses for model-1 (With minimum stiffeners in tank, FS=2)



	1	2	3
X direction	139	43.4	107.5
Y direction	62	21.8	46
Z direction	82	18.1	37.8
Von misses	172	108	82.2

Load cases

Fig 9.12 Stress for model-2 (With more stiffeners in tank, FS=2)

9.5 COMPARISONS

Two model of Septic tank are analyzed by finite element method. Both the models are of different geometry. From obtained results deflection and stresses are compared for model-1 and model-2, with fewer stiffeners and with more numbers of stiffeners.

For comparison different location on tanks are considered, stresses and deflection are tabulated for that location, as shown in table 9.8 and 9.9 deflection for deferent location in tanks are compared. Same comparison for model-1 and model-2 is done for von misses stress, stress comparison is shown in Fig 9.14.

To study the effect of ribs in tank, stress and deflection are compared at every 0.2 m height of the tank. Comparative results are shown in Fig 9.15 and Fig 9.16.

Fig 9.15 plotted for deflection comparison in which it is observed that at the top portion of tank deflection is higher, it is reducing with the depth, at bottom of the tank deflection is minimum. This is due to heavy vertical load of tractor axle, and top part is without ribs. Ribs in top part will reduce this vertical deflection, for study purpose model-1 is created with ribs in top portion and it is observed that deflection is reduced in tank. Stiffeners in top portion may further be increase in number or size.

Stresses are tabulated at every 0.2 m level of tank height and plotted in graphical formation. After plotting results in graph, it is observed that stress is more at the bottom, where tank is restrained. In wall of tank stresses are reduced in between the ribs, at the ribs location stresses are again increasing, from above observation, it is clear that ribs are used to reduce stress in tank wall. Fig 8.16 showing the stress variation in model-1 and model-2. Model-2 with more number of ribs shows the stress reduction in wall of tank.

Table 9.8 Deflection comparisons for model-1 & model-2

Location on Tank (m)	Deflection of tank Model-1 (mm)	Deflection of tank Model-2 (mm)
0	154	83
0.2	154	90
0.4	308	106
0.6	463	150
0.8	463	250
1.0	463	250
1.2	617	335

1.4	617	516
1.6	650	500
1.8	680	589
2.0	920	600
2.2	950	657
2.4	980	700
2.5	980	750

Table 9.9 Stress comparisons for model-1 & model-2

Location on Tank (m)	Von misses stress in model-1 MPa	Von misses stress in model-2 MPa
0	108.9	70
0.2	81.6	58
0.4	54.4	29
0.6	27.2	46.5
0.8	81.6	17.5
1.0	136.6	58
1.2	81.6	29.5
1.4	54.2	46.5
1.6	27.2	17.5
1.8	81.6	46
2.0	136.6	58
2.2	81.6	17.5

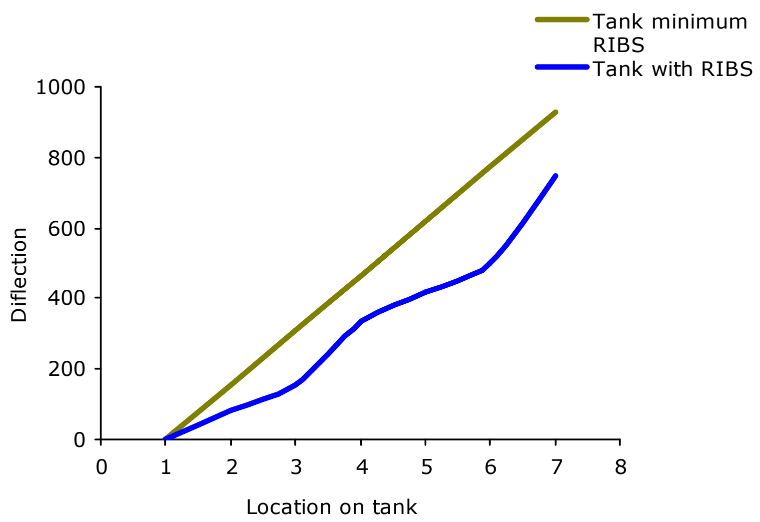


Fig 9.13 Displacement comparisons for model-1 & model-2

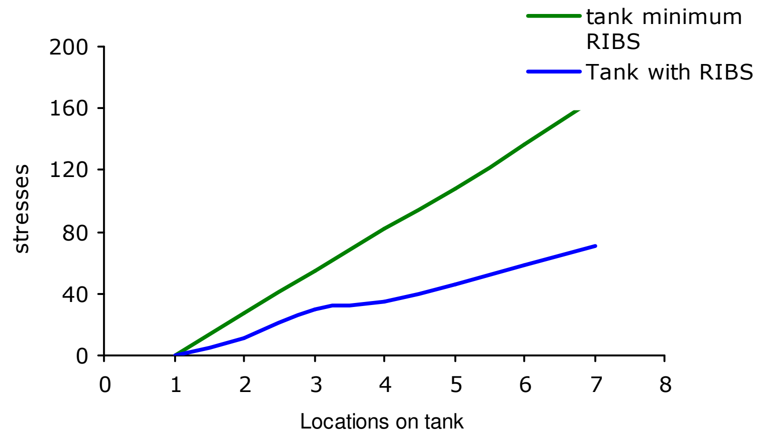


Fig 9.14 Stress comparisons for model-1 & model-2

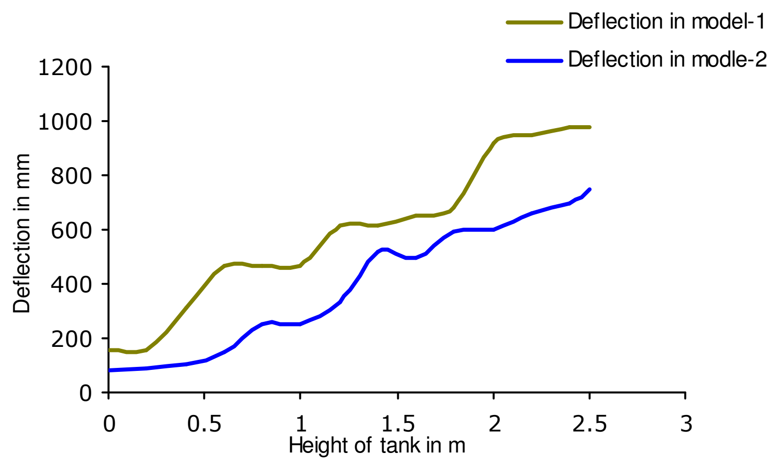


Fig 9.15 Displacement comparisons for model-1 & model2 at 0.2 m location

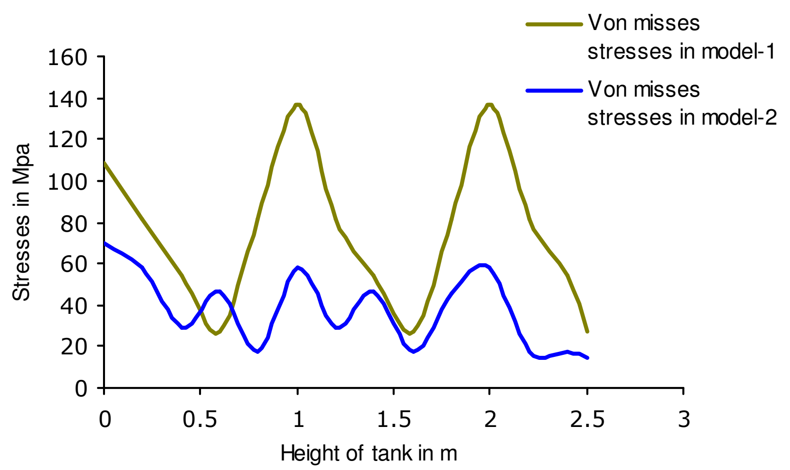


Fig 9.16 Stress comparisons for model-1 & model-2 at 0.2 m location.

These are the results for the vertical cylindrical tank, same way horizontal shape is proposed for study purpose. In case of this geometry tanks are subjected to large amount of deflection at top part, therefore top part of tank required more stiffeners. These tanks are suitable for small capacities. In case of large capacities different shape is produced for analysis.

9.6 RESULTS OF UNDERGROUND TANKS TYPE-2

For techno commercial design it is required to analyze tank with different geometry and different parameters with same geometry. Horizontal cylindrical tank is analyzed for two capacities.

- Horizontal cylindrical shape 5000 liters capacity.
- Horizontal cylindrical shape 3000 liters capacity.

9.7 RESULTS OF UNDERGROUND TANK TYPE-2, 5000 LITERS CAPACITY.

Now analysis is done with different load cases as explained in type-1 tanks. Results are carried out in stress and deflection domain. These tanks are analyzed for different three materials, and thickness is varied from 4mm to 6mm. materials used for these tanks are,

- Linear low density polyethylene (LLDPE).
- High density polyethylene (HDPE).
- Fiber reinforced polymers (FRP).

For each material thickness used are 4mm, 5mm, and 6mm, results are compared for these cases.

9.7.1 Results of tank type-2 with Linear Low Density Polyethylene (LLDPE)

First analysis is carried out with the linear low density polyethylene material. With same material tanks are analyzed for different thickness and different stiffeners configuration. First case is with 4 mm thickness, as explained in chapter 7; two types of loading conditions are taken in consideration.

After analysis comparison is done for deflection and stress domain, results of stress and deflections are listed below. Results are also checked with the permissible stress and deflection for material; properties of LLDPE are carried out by testing as explain in chapter 6. (Testing is done with the reference of ASTM 638-03, for the materials used)

- Horizontal cylindrical shape.
- Capacity 5000 liters.
- Material LLDPE.
- Thickness 4mm.

Modeling is done in finite element software; with considering 4mm thickness of wall, meshing is done with smart mesh option which divides the shell into small triangular elements.

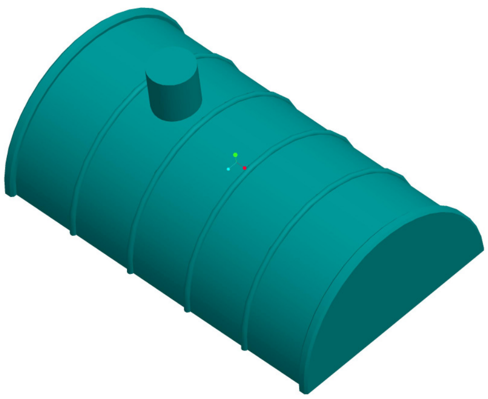


Fig 9.17a Model of horizontal cylindrical tank

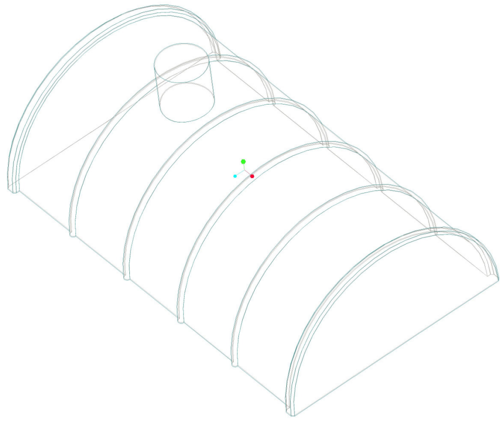


Fig 9.17b Wire mesh model of tank

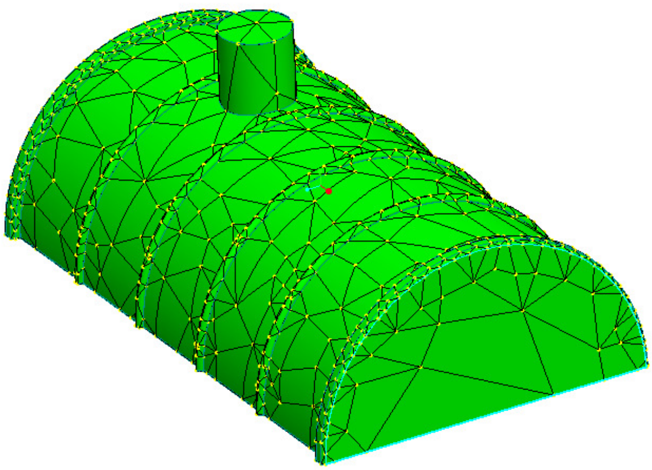


Fig 9.18 Mesh model of tank

Table 9.10 Load case-1 model-1

	Model – 1
FEATURE	Minimum RIBS
Thickness	4 mm
Material	Polyethylene – LLDPE
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load -3	0.0620 MPa Liquid Pressure
Load -5	500 mm soil load

This is the first loading condition, with this loading condition analysis is carried out and results are listed below, meshing is done with smart mesh so that whole tank is divided in numbers of triangular element.

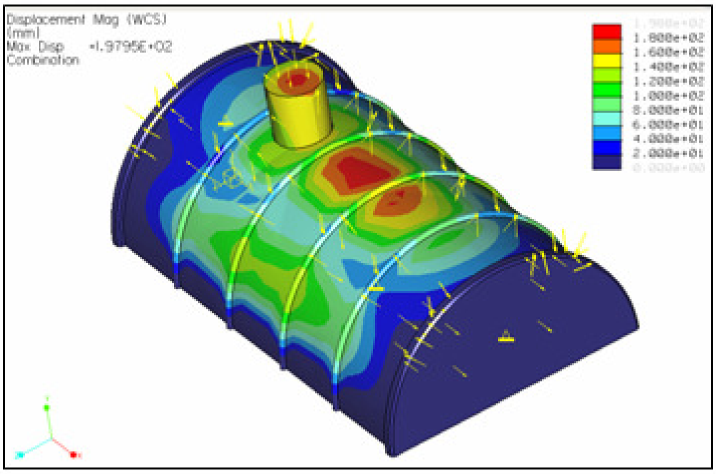


Fig 9.19a Displacement contour (Model-1 with minimum stiffeners, FS=2)

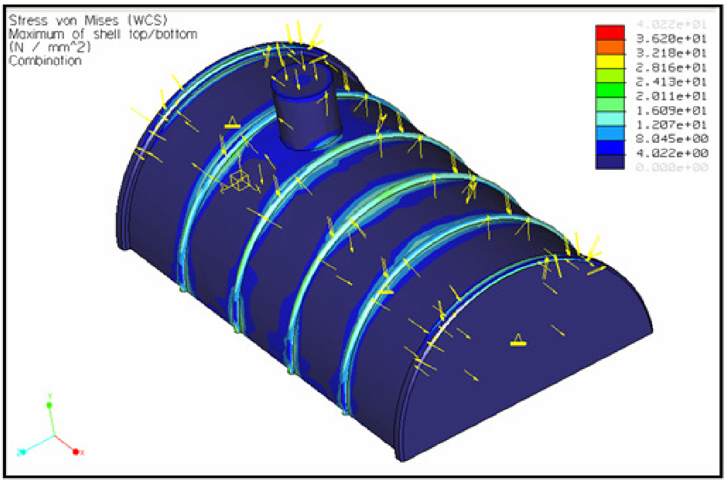


Fig 9.19b Stress contours (Model-1 with minimum stiffeners, FS=2)

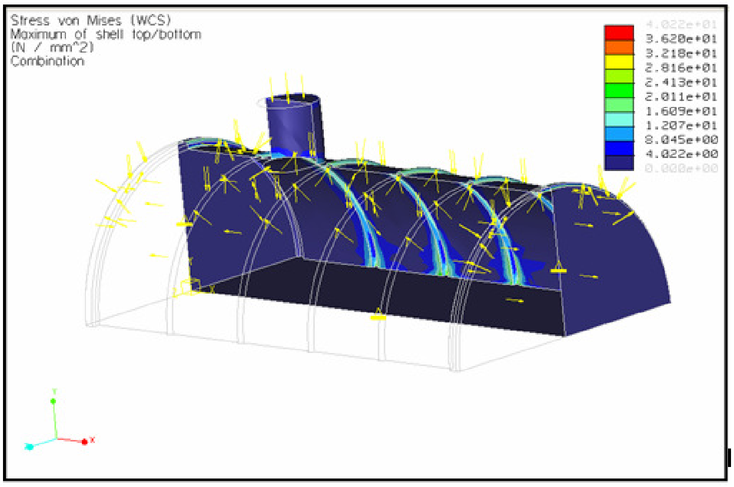


Fig 9.19c Section of stress contours (Model-1 with minimum stiffeners, FS=2)

Now this load combination with liquid pressure, but in actual case soil pressure and liquid pressure combine gives less stresses. And it is possible that only soil pressure will act from outside of tank. When tank is empty at the time of installation or at the time of empty tank, different loadings are act on tank.

Table 9.11 Load case-3 model-1

FEATURE	Model - 1 Minimum RIBS
Thickness	4 mm
Material	Polyethylene - LLDPE
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load-5	500 mm soil load

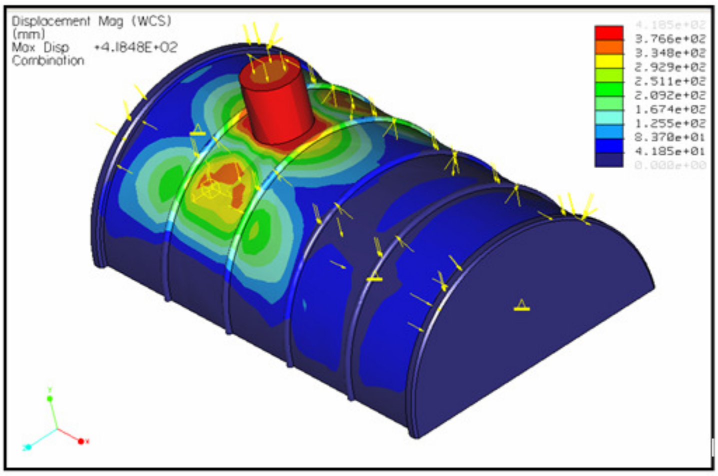


Fig 9.20a Displacement contour (Model-1 with minimum stiffeners, FS=2)

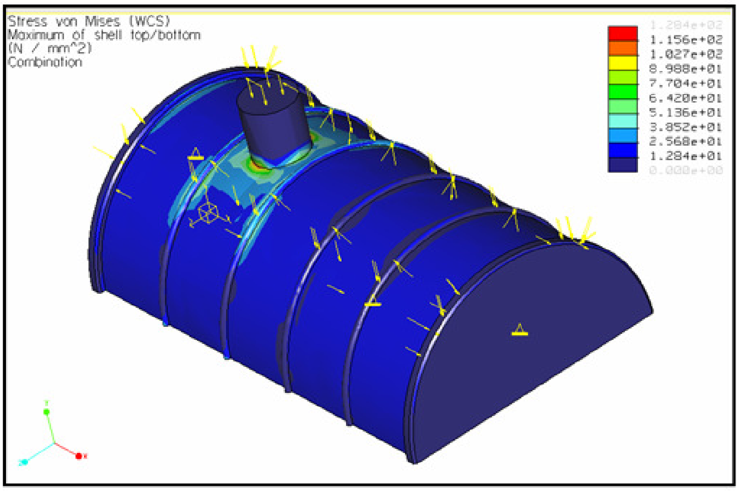


Fig 9.20b Stress contours (Model-1 with minimum stiffeners, FS=2)

Comparative study is done at the end of chapter, now thickness is changed from 4mm to 5mm and 6mm.

- Capacity 5000 liters.
- Material LLDPE.
- Thickness 5mm.

Table 9.12 Load case-3 model-1

	Model - 1
FEATURE	Minimum RIBS
Thickness	5 mm
Material	Polyethylene - LLDPE
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load-5	500 mm soil load

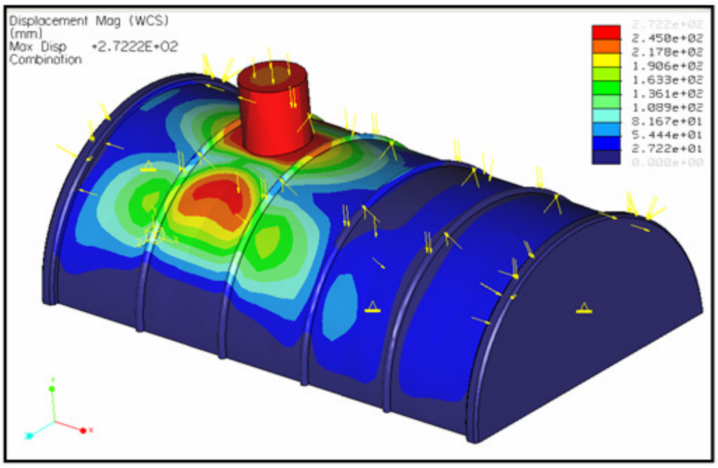


Fig 9.21a Displacement contours (Model-1 with minimum stiffeners, FS=2)

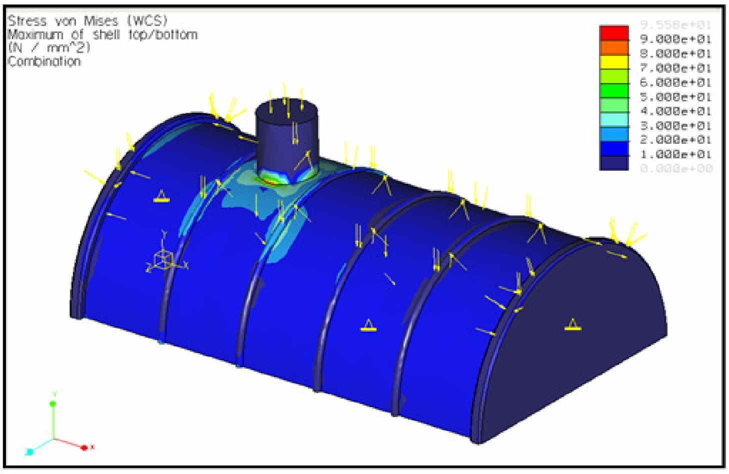


Fig 9.21b Stress contours (Model-1 with minimum stiffeners, FS=2)

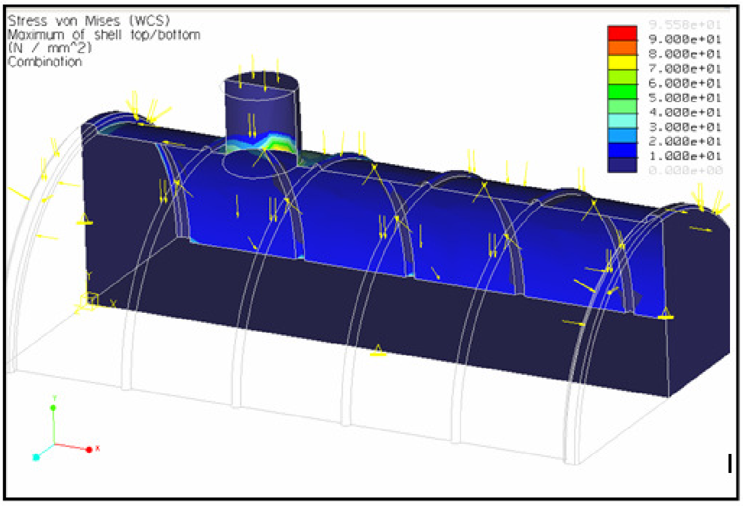


Fig 9.21c Section of stress contours (Model-1 with minimum stiffeners, FS=2)

- Horizontal cylindrical shape.
- Capacity 5000 liters.
- Material LLDPE.
- Thickness 6mm.

Table 9.13 Load case-3 model-1

	Model - 1
FEATURE	Minimum RIBS
Thickness	6 mm
Material	Polyethylene - LLDPE
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load-5	500 mm soil load

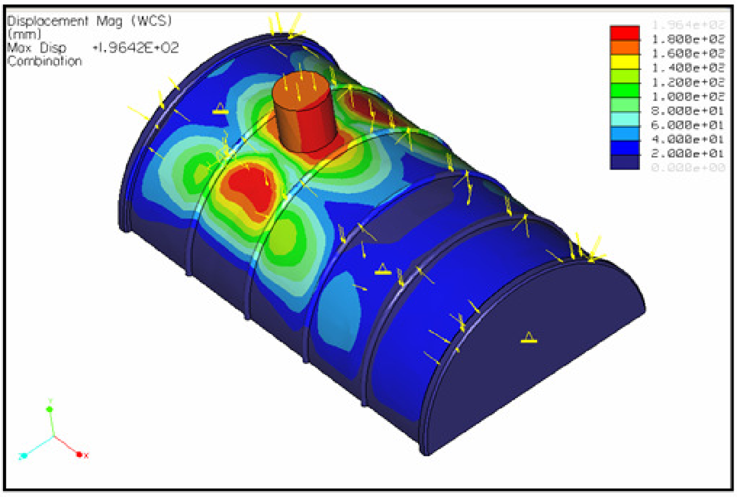


Fig 9.22a Displacement contour (Model-1 with minimum stiffeners, FS=2)

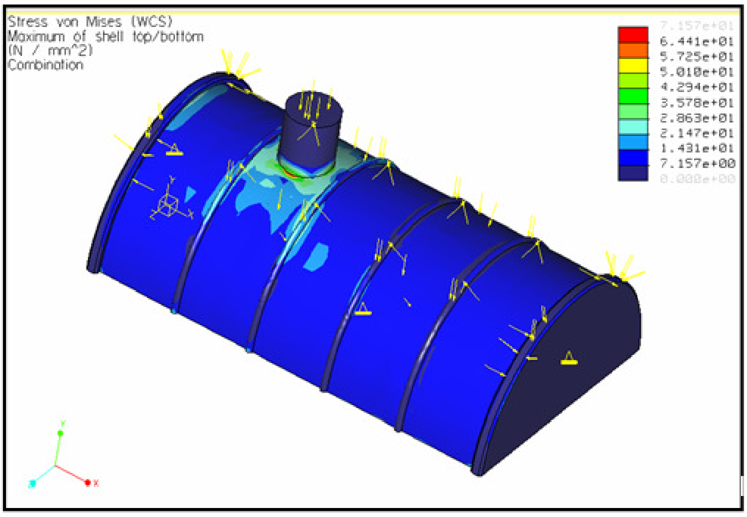


Fig 9.22b Stress contours (Model-1 with minimum stiffeners, FS=2)

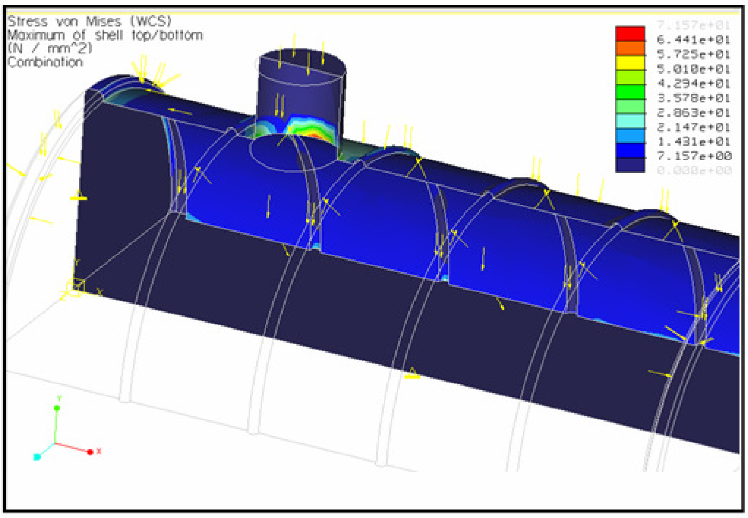


Fig 9.22c Section of Stress contours (Model-1 with minimum stiffeners, FS=2)

These are the stress and deflection results for 4mm, 5m, and 6mm thickness of tank. These results are only for the model-1; model-1 is with minimum numbers of stiffeners. Now considering maximum stress results and deflection result, check is carried out whether this tank is safe against the loading. Model-1 was failing due to higher amount of deflection. Due to less stiffeners in tank body deflection also increased.

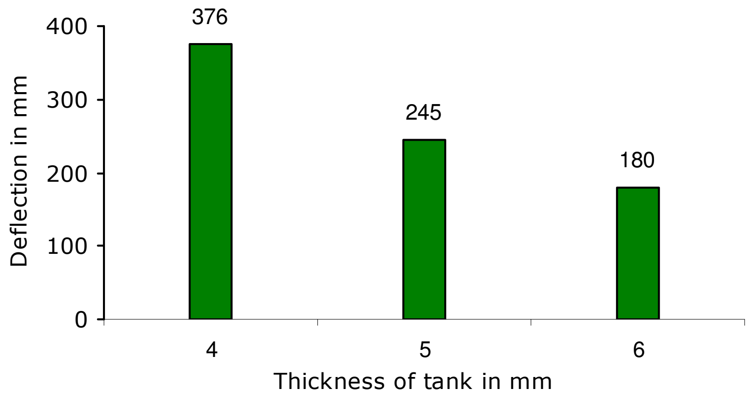


Fig 9.23 Deflections in model-1 (With minimum stiffeners, FS=2)

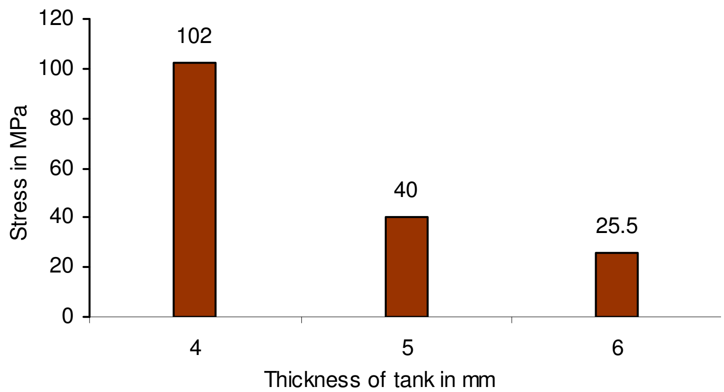


Fig 9.24 Stresses in model-1 (With minimum stiffeners, FS=2)

Fig 9.23 and 9.24 shows the maximum stress and deflection for model-1 tank, three tanks are analyzed with 4mm, 5mm, and 6mm wall thickness of tank. From results it is cleared that deflection in tank is much higher and stresses are also higher for 4mm and 5mm thickness of tank. In case of 6 mm thick tank stresses are nearly permissible; this assembly can be used for underground storage tank.

Model-2 is prepared with more stiffeners in tank, material used is linear low density polyethylene, and load cases are same as above. More ribs are provided by reduce spacing between them. These tanks are more stable then model-1, therefore stiffeners are reducing the stress from the tank wall.

Basic data for model-2 are given here, geometry and dimension of model-2 is specified in the chapter of modeling of underground tank. Analysis is done by finite element software.

- Horizontal cylindrical shape.
- Model-2
- Capacity 5000 liters.
- Material LLDPE.
- Thickness 4mm.

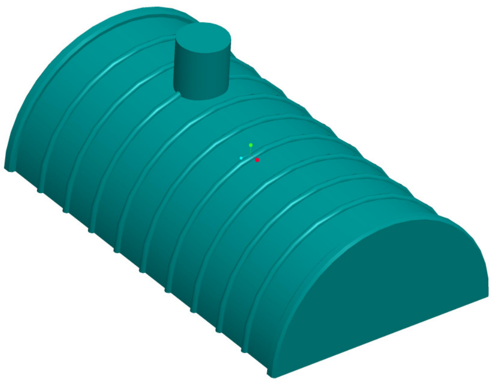


Fig9.25a Model of horizontal cylindrical tank, model-2

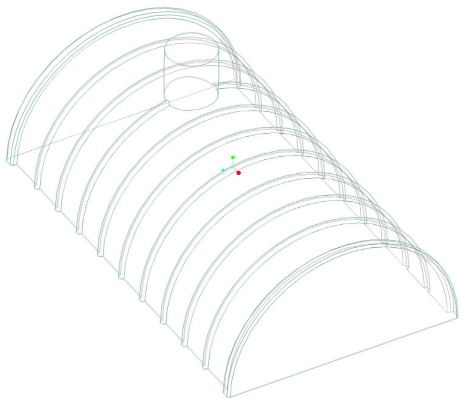


Fig 9.25b Wire mesh model, model-2

These tanks are also analyzed for both conditions tank empty and tank full, but tank empty condition is considered for analysis. All results are plotted here for the second load combination. In underground storage tank empty condition will be the most sever condition.

Table 9.14 Load case-3 model-2

	Model - 2
FEATURE	More RIBS
Thickness	4 mm
Material	Polyethylene - LLDPE
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load-5	500 mm soil load

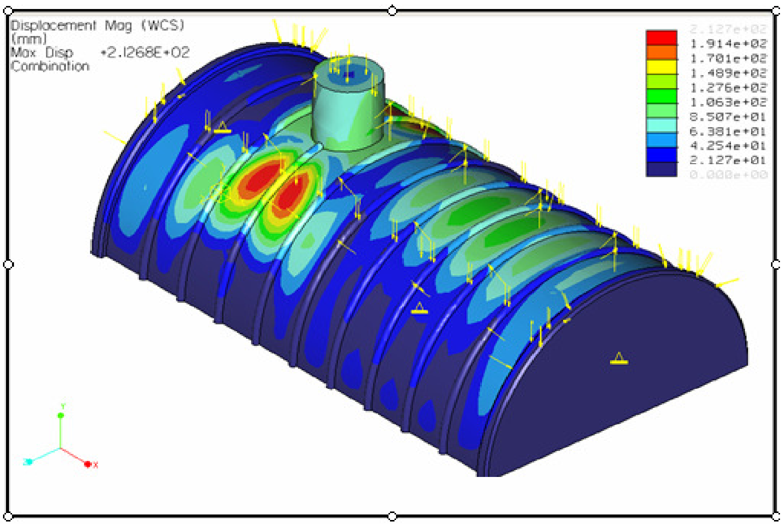


Fig 9.26a Displacement contour (Model-2 with more stiffeners, FS=2)

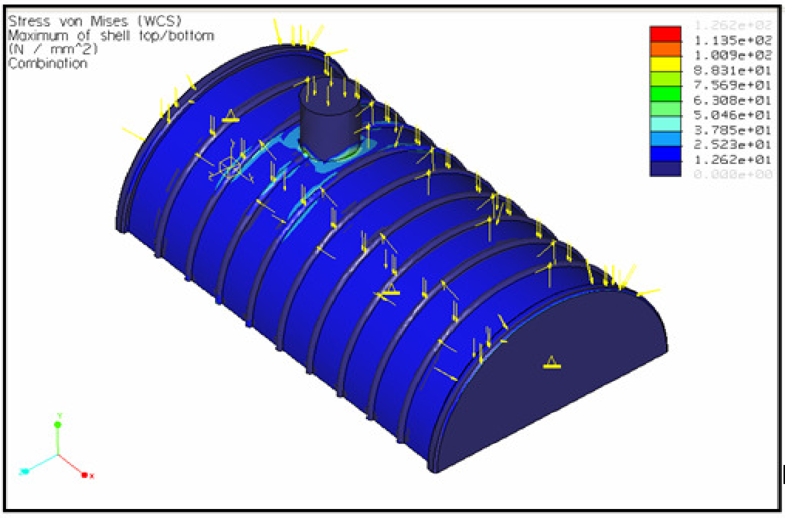


Fig 9.26b Stress contour (Model-2 with more stiffeners, FS=2)

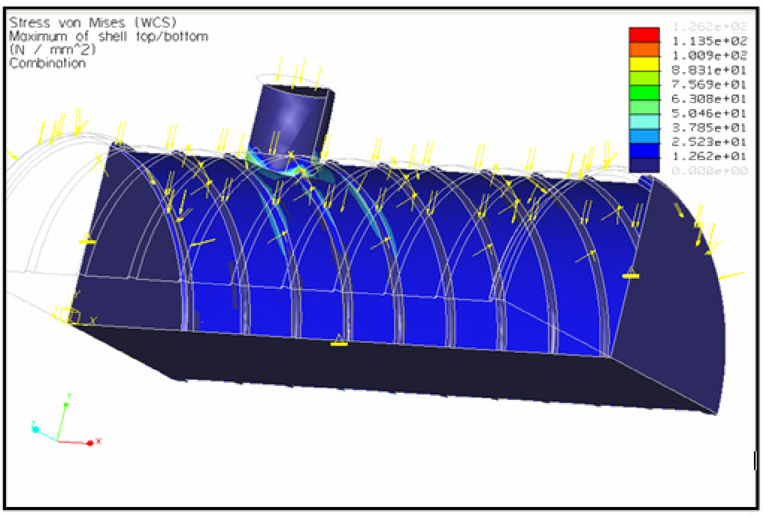


Fig 9.26c Section of stress contours (Model-2 with more stiffeners, FS=2)

- Model-2
- Capacity 5000 liters.
- Material LLDPE.
- Thickness 5mm.

Table 9.15 Load case-3 model-2

	Model - 2
FEATURE	More RIBS
Thickness	5 mm
Material	Polyethylene - LLDPE
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load-5	500 mm soil load

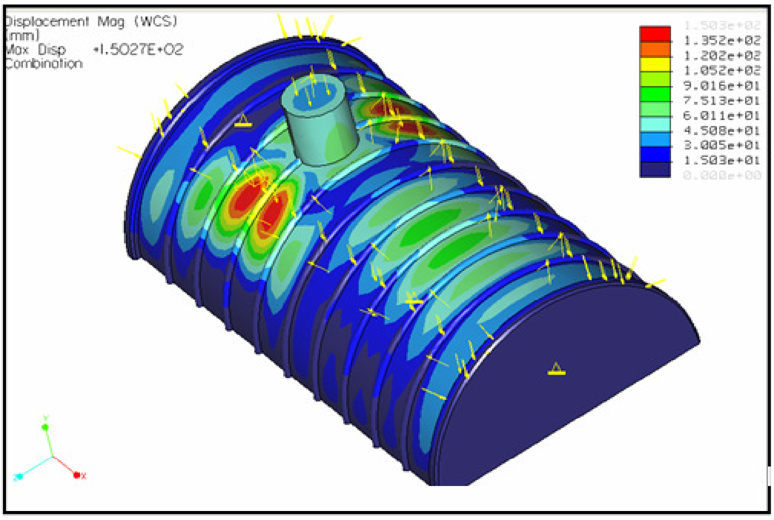


Fig 9.27a Displacement contours (Model-2 with more stiffeners, FS=2)

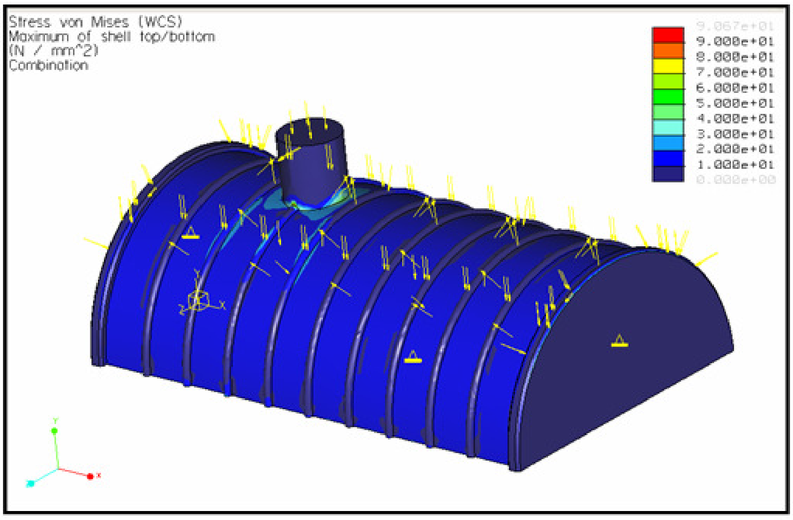


Fig 9.27b Stress contours (Model-2 with more stiffeners, FS=2)

- Model-2
- Capacity 5000 liters.
- Material LLDPE.
- Thickness 6 mm.

Table 9.16 Load case-3 model-2

FEATURE	Model - 2 More RIBS
Thickness	6 mm
Material	Polyethylene - LLDPE
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load-5	500 mm soil load

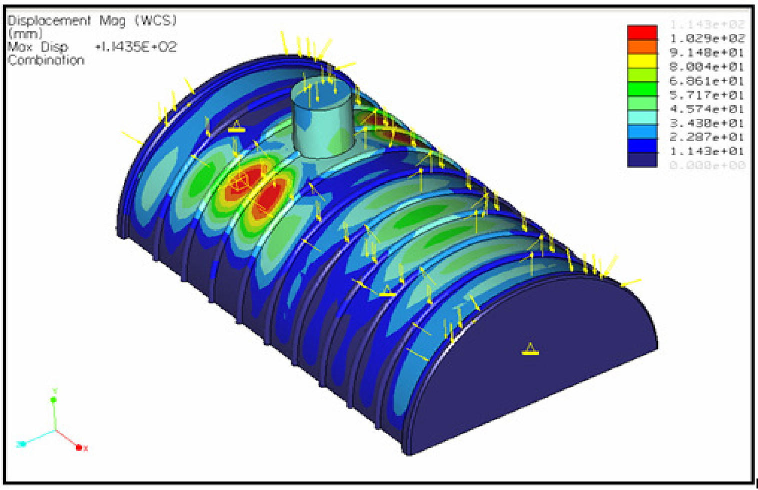


Fig 9.28 a Displacement contours (Model-2 with more stiffeners, FS=2)

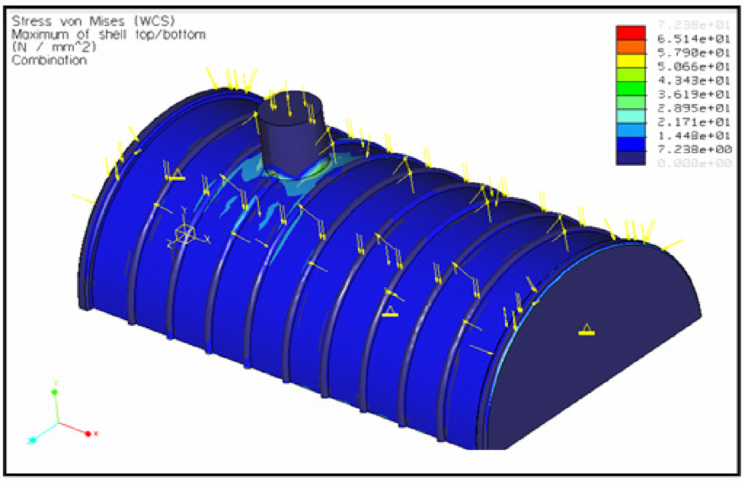


Fig 9.28b Stress contours (Model-2 with more stiffeners, FS=2)

These are the stress and deflection results for 4mm, 5m, and 6mm thickness of tank. These results are only for the model-2; model-2 is with more numbers of stiffeners. Now considering maximum stress results and deflection result, check is carried out whether this tank is safe against the loading. Model-1 is fail due to higher amount of deflection.

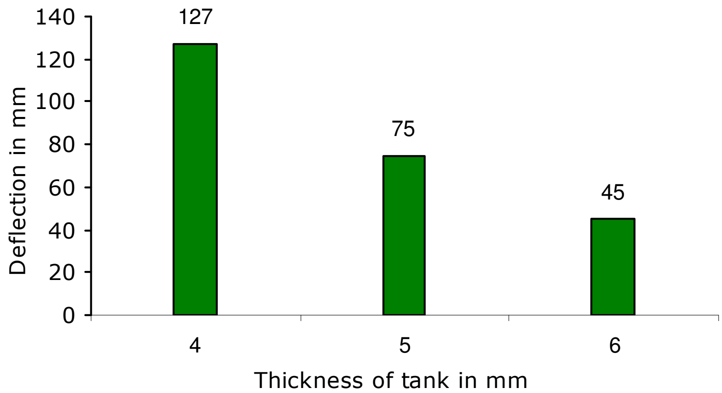


Fig 9.29 Deflections in model-2 (With more stiffeners in tank, FS=2)

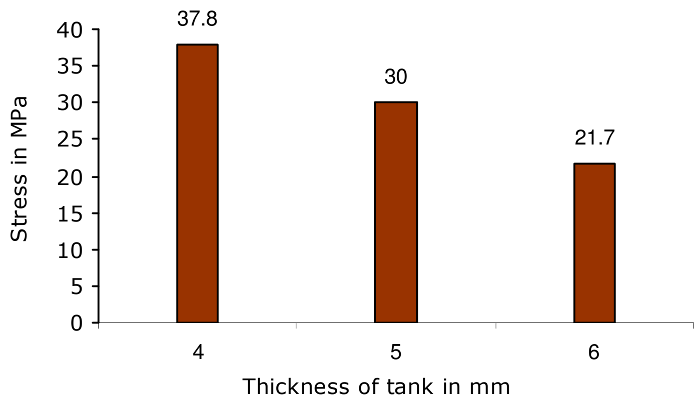
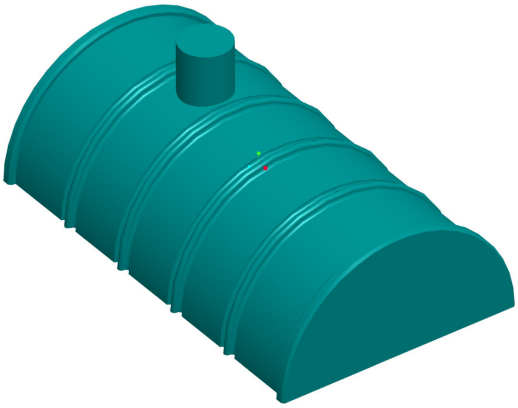


Fig 9.30 Stresses in model-2 (With more stiffeners in tank, FS=2)

Basic data for model-2 are given here, geometry and dimension of model-2 is specified in the chapter of modeling of underground tank. Analysis is done by finite element software.

- Horizontal cylindrical shape.
- Model-3
- Capacity 5000 liters.
- Material LLDPE.
- Thickness 4mm.



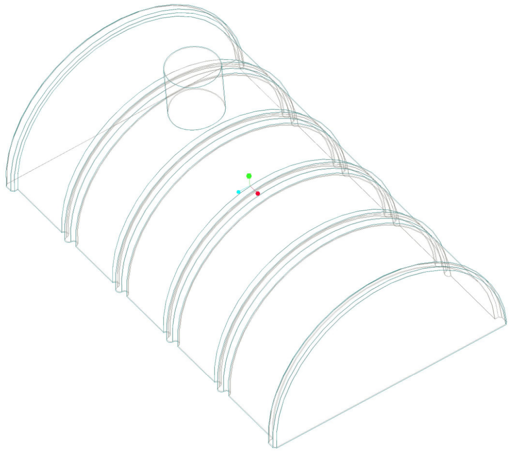


Fig 9.31a Model of horizontal cylindrical tank, model-3   Fig 9.31b Wire mesh model, model-3

Model-3 is same as model-2 but only stiffeners shape is changed, to study stiffener shape effect in tank, it is required to design stiffener with different shape, and therefore model-3 is propped with different stiffeners shape this shape is already specified in modeling chapter. Analysis is done with the same loading condition and material.

Table 9.17 Load case-3 model-3

	Model - 3
FEATURE	Inside RIBS
Thickness	4 mm
Material	Polyethylene - LLDPE
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load-5	500 mm soil load

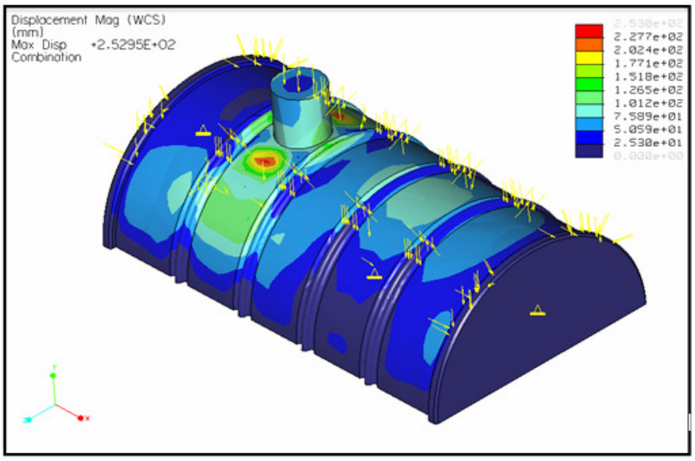


Fig 9.32a Displacement contour (Model-3 with inside stiffeners)

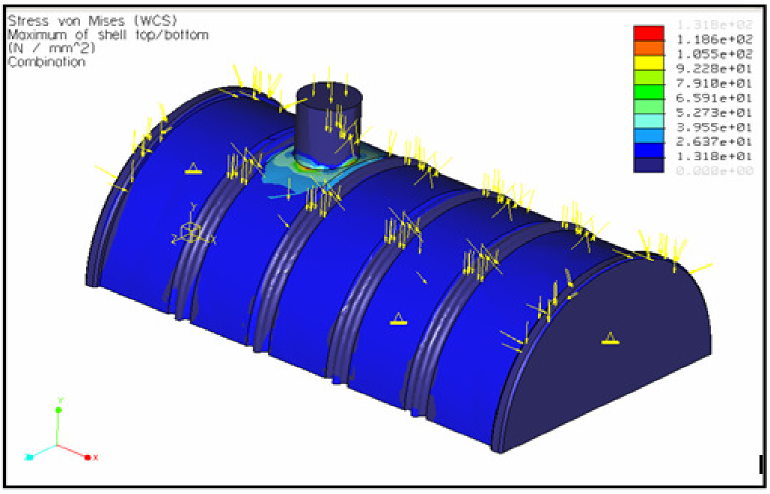


Fig 9.32b Stress contour (Model-3 with inside stiffeners)

- Model-3
- Material LLDPE.
- Thickness 5 mm.

Table 9.18 Load case-3 model-3

	Model - 3
FEATURE	Inside RIBS
Thickness	5 mm
Material	Polyethylene - LLDPE
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load-5	500 mm soil load

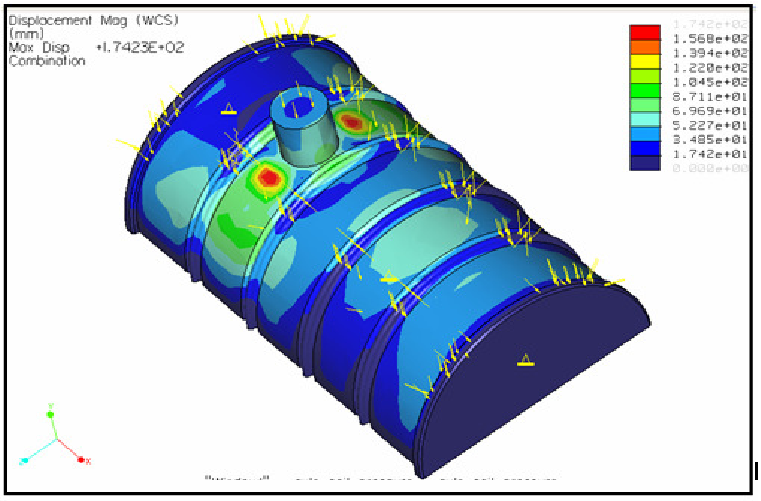


Fig 9.33a Displacement contours (Model-3 with inside stiffeners, FS=2)

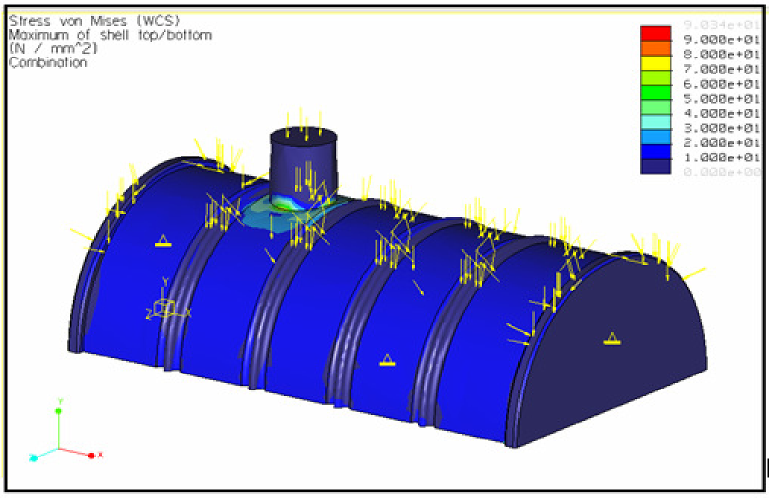


Fig 9.33b Stress contours (Model-3 with inside stiffeners, FS=2)

- Capacity 5000 liters.
- Material LLDPE.
- Thickness 6 mm.

Table 9.19 Load case-3 model-3

	Model - 3
FEATURE	Inside RIBS
Thickness	6 mm
Material	Polyethylene - LLDPE
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load-5	500 mm soil load

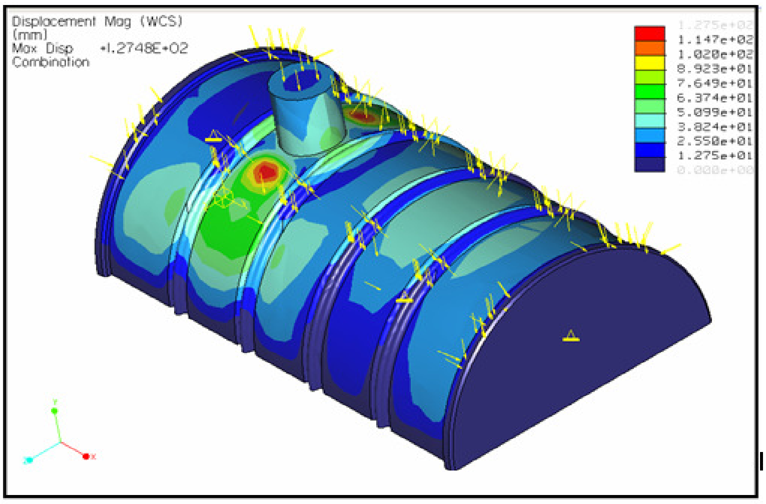


Fig 9.34a Displacement contours (Model-3 with inside stiffeners, FS=2)

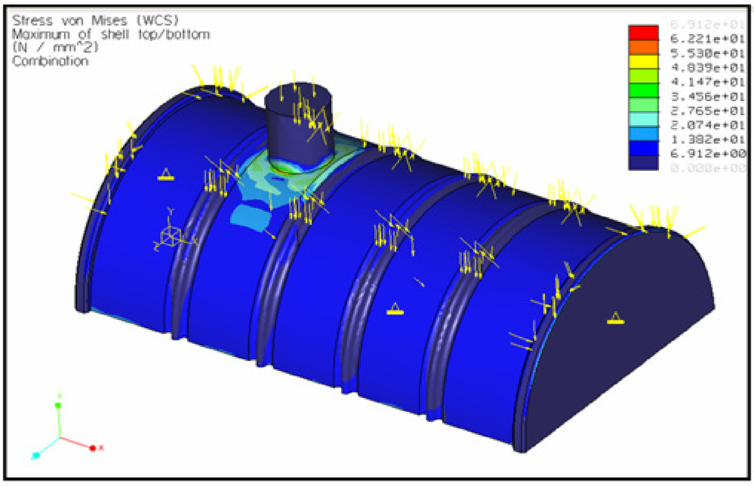


Fig 9.34b Stress contours (Model-3 with inside stiffeners, FS=2)

These are the stress and deflection results for 4mm, 5m, and 6mm thickness of tank. These results are only for the model-3; model-3 is with inside stiffeners. Now considering maximum stress results and deflection result, check is carried out whether this tank is safe against the loading. Stresses and deflection are reduced in comparison to model-1,

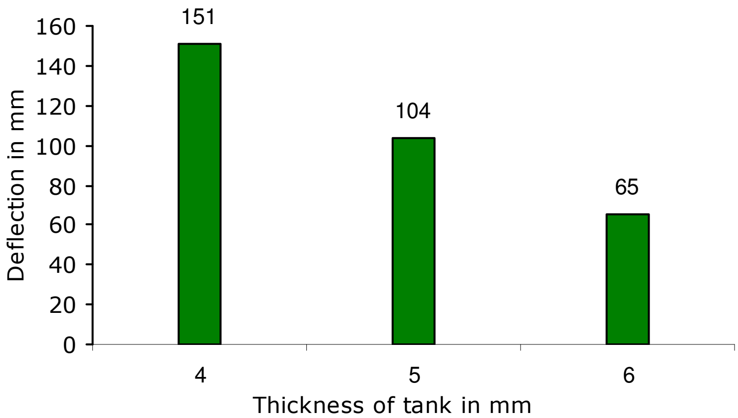


Fig 9.35 Deflections in model-3 (With inside stiffeners, FS=2)

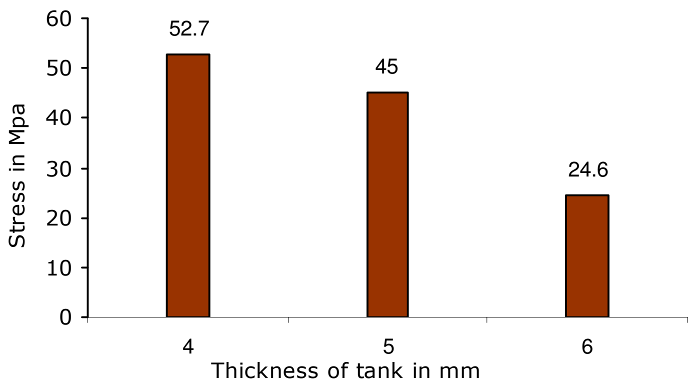


Fig 9.36 Stresses in model-3 (With inside stiffeners, FS=2)

9.7.2 Results of tank type-2 with High Density Polyethylene (HDPE)

Material domain is a another part of study, therefore high density polyethylene is used as second material, this is from same polyethylene family but having different formation as explained in materials chapter. Now study is carried out in same tanks as done in case of LLDPE.

- Horizontal cylindrical shape.
- Model-1
- Capacity 5000 liters.
- Material HDPE.
- Thickness 4 mm, 5 mm, and 6 mm.

Table 9.20 Load case-3 model-1

	Model - 3
FEATURE	Inside RIBS
Thickness	4 mm
Material	Polyethylene - HDPE
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load-5	500 mm soil load

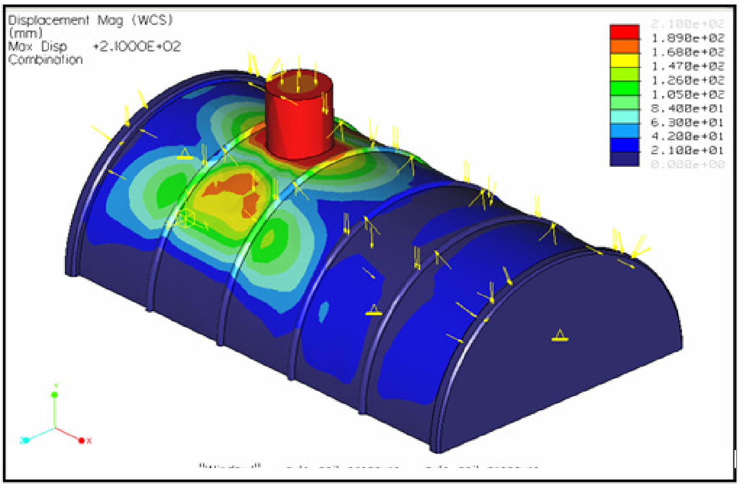


Fig 9.37a Displacement contours (THK4 mm, with minimum stiffeners, FS=2)

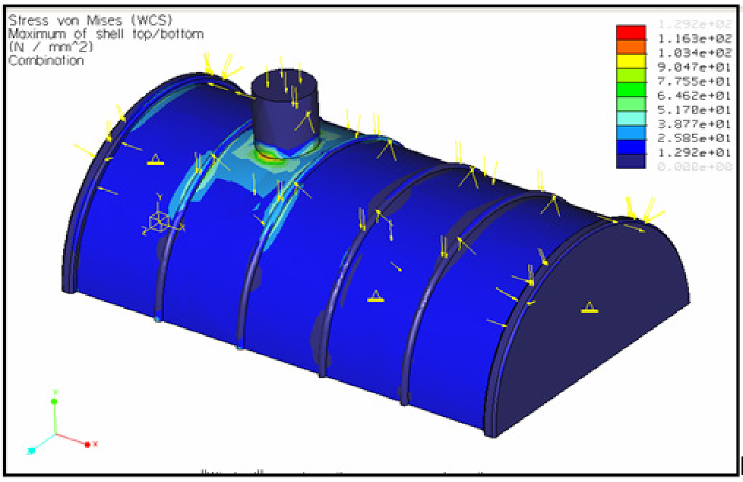


Fig 9.37b Stress contours (THK 4 mm, with minimum stiffeners, FS=2)

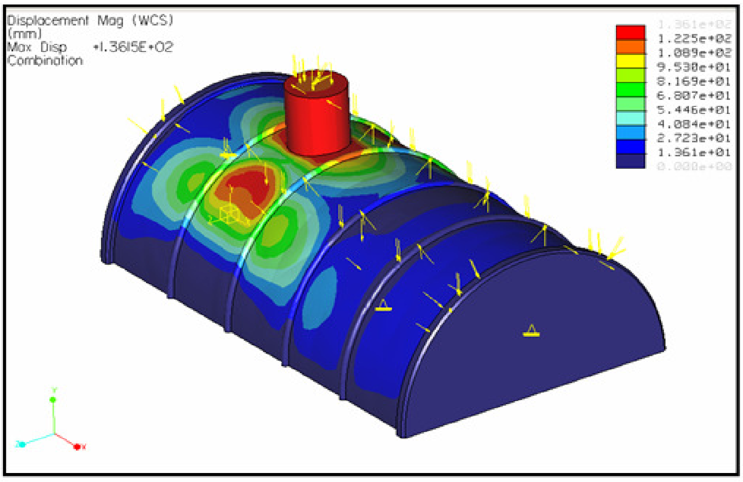


Fig 9.38a Displacement contours (THK 5 mm, with minimum stiffeners, FS=2)

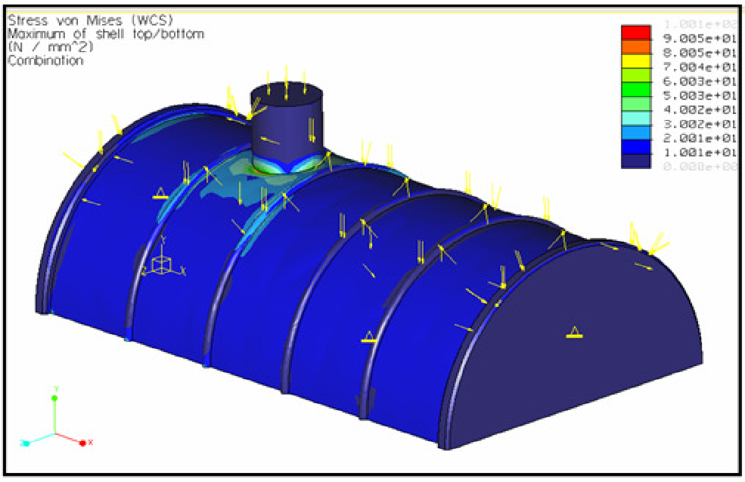


Fig 9.38b Stress contours (THK 5mm, with minimum stiffeners, FS=2)

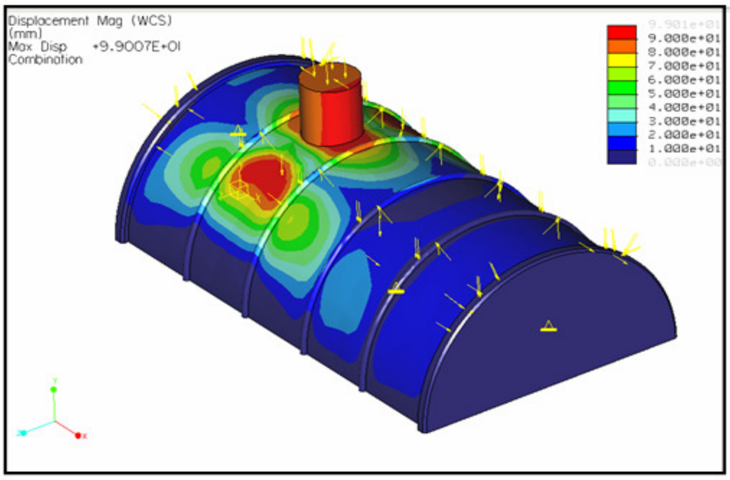


Fig 9.39a Displacement contours (THK 6 mm, with minimum stiffeners, FS=2)

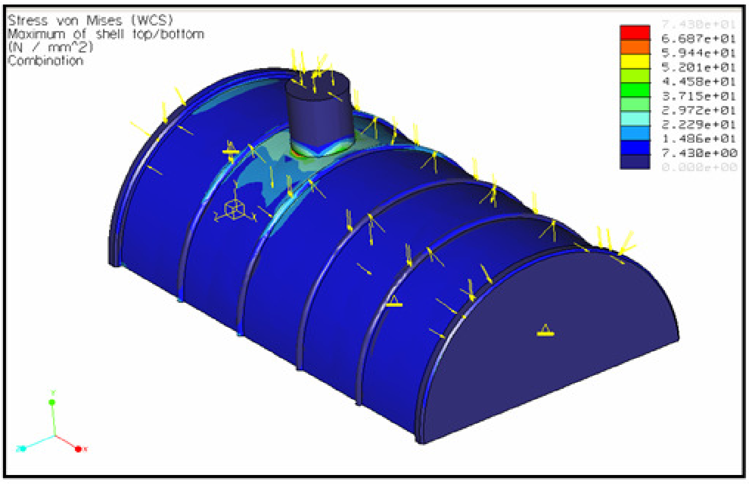


Fig 9.39b Stress contours (THK 6 mm, with minimum stiffeners, FS=2)

These are the stress and deflection results for 4mm, 5m, and 6mm thickness of tank. These results are only for the model-1; model-1 is with minimum numbers of stiffeners. Now considering maximum stress results and deflection result, check is carried out whether this tank is safe against the loading. Model-1 is fail due to higher amount of deflection. Due to less stiffeners in tank body deflection is increases.

For maximum values of stress and deflection Fig 4.40 and 4.41 are drawn with all three thickness of tank wall, deflection is again higher for 4 mm thick tank, other thickness of wall are stable against loadings given to it.

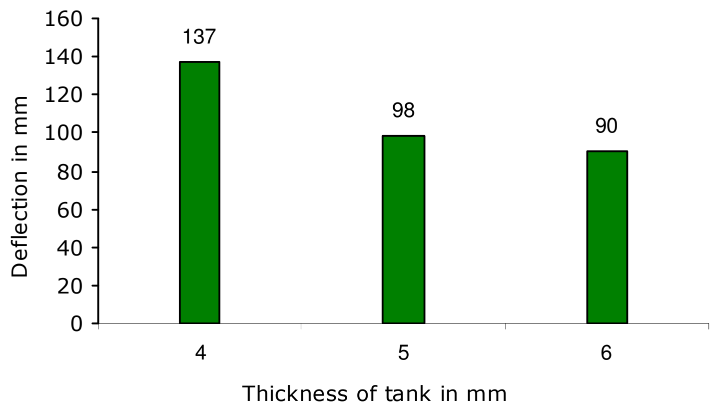


Fig 9.40 Deflections in model-1 (with HDPE material, minimum stiffeners, FS=2)

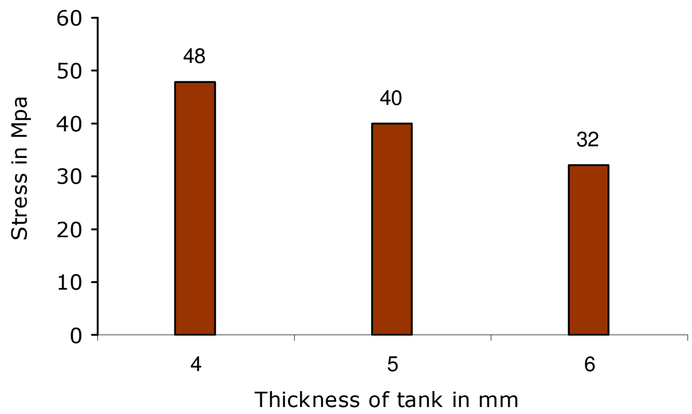


Fig 9.41 Stresses in model-1 (with HDPE material, minimum stiffeners, FS=2)

Analysis of model-2 is carried out with same condition as explained above.

- Model-2

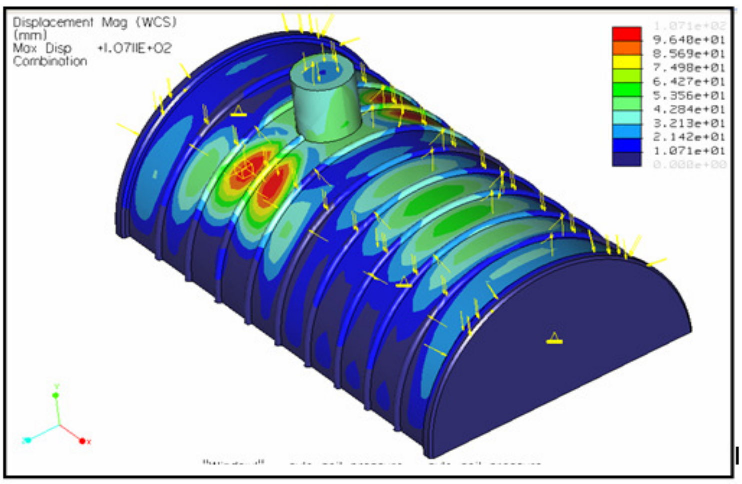


Fig 9.42a Displacement contours (THK 4 mm, with more stiffeners, FS=2)

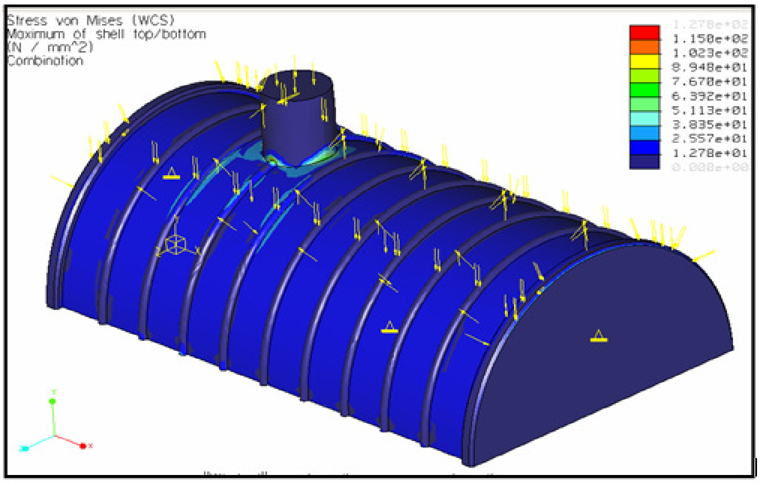


Fig 9.42b Stress contours (THK 4 mm, with more stiffeners, FS=2)

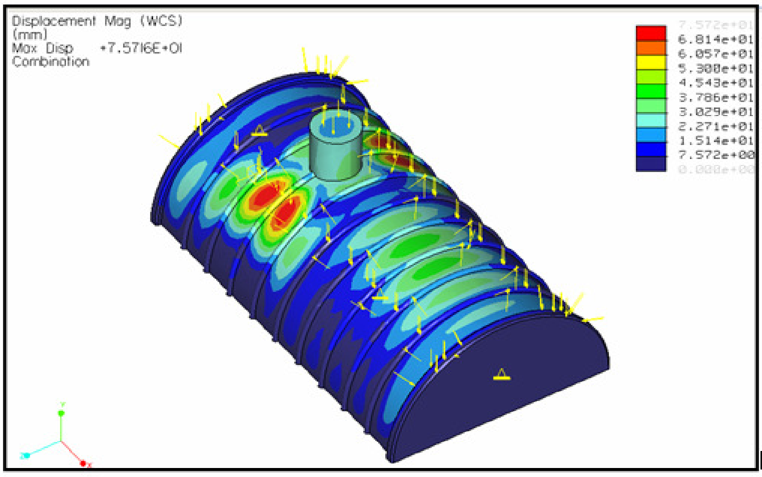


Fig 9.43a Displacement contours (THK 5 mm, with more stiffeners, FS=2)

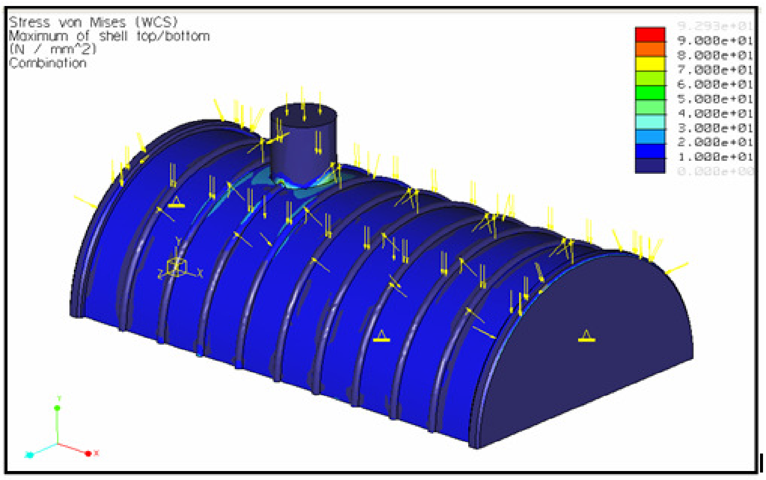


Fig 9.43b Stress contours (THK 5 mm, with more stiffeners, FS=2)

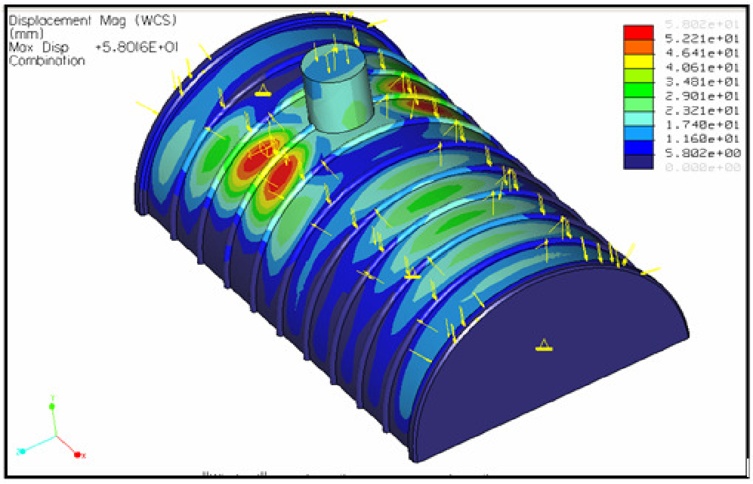


Fig 9.44a Displacement contours (THK 6 mm, with more stiffeners, FS=2)

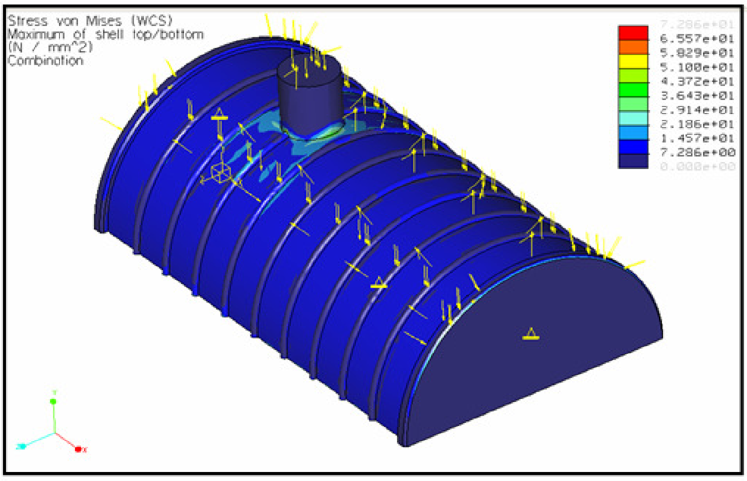


Fig 9.44b Stress contours (THK 6 mm, with more stiffeners, FS=2)

These are the stress and deflection results for 4mm, 5m, and 6mm thickness of tank. These results are only for the model-2; model-2 is with more numbers of stiffeners. Now considering maximum stress results and deflection result, check is carried out whether this tank is safe against the loading.

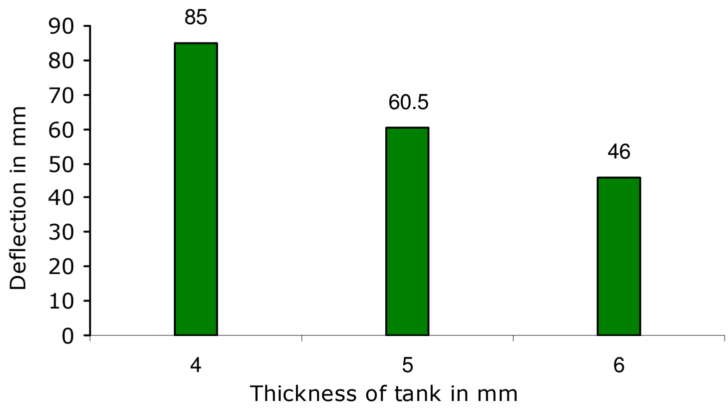


Fig 9.45 Deflections in model-2 (with HDPE material, with more stiffeners, FS=2)

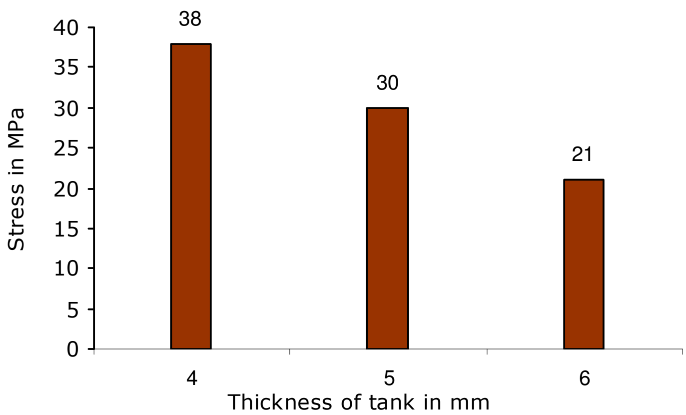


Fig 9.46 Stresses in model-2 (with HDPE material, with more stiffeners, FS=2)

Analysis of model-3 is carried out with same condition as explained above.

- Model-3

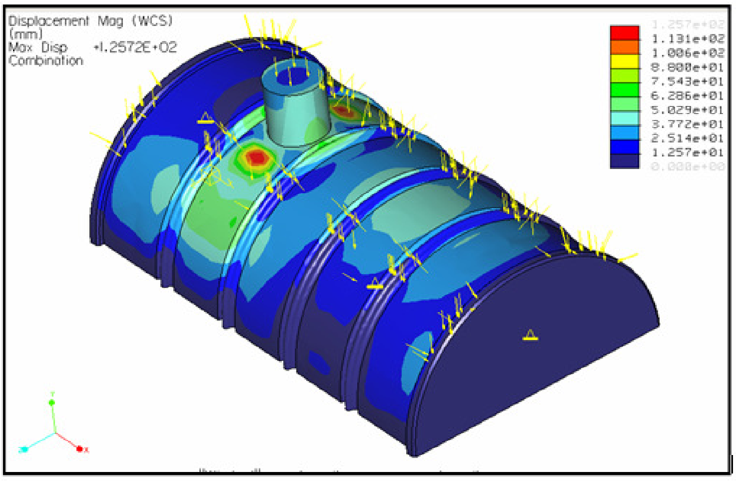


Fig 9.47a Displacement contours (THK 4 mm, with inside stiffeners, FS=2)

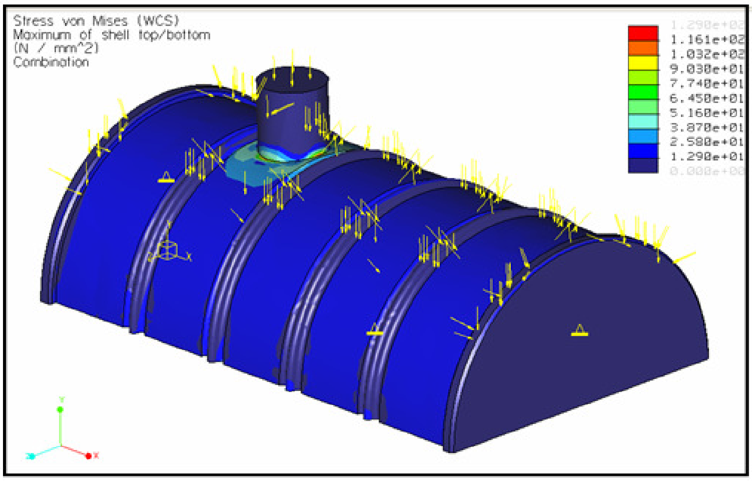


Fig 9.47b Stress contours (THK 4 mm, with inside stiffeners, FS=2)

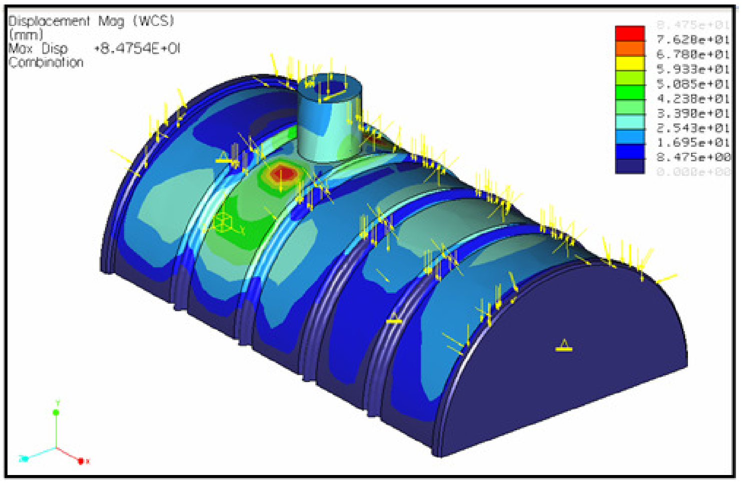


Fig 9.48a Displacement contours (THK 5 mm, with inside stiffeners, FS=2)

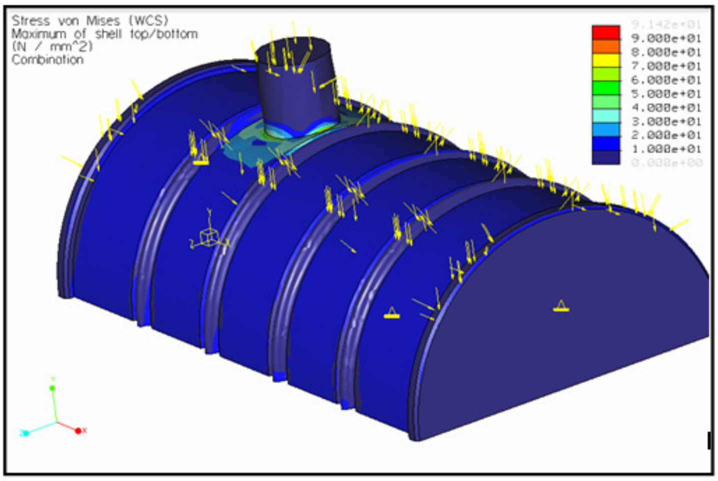


Fig 9.48b Stress contours (THK 5 mm, with inside stiffeners, FS=2)

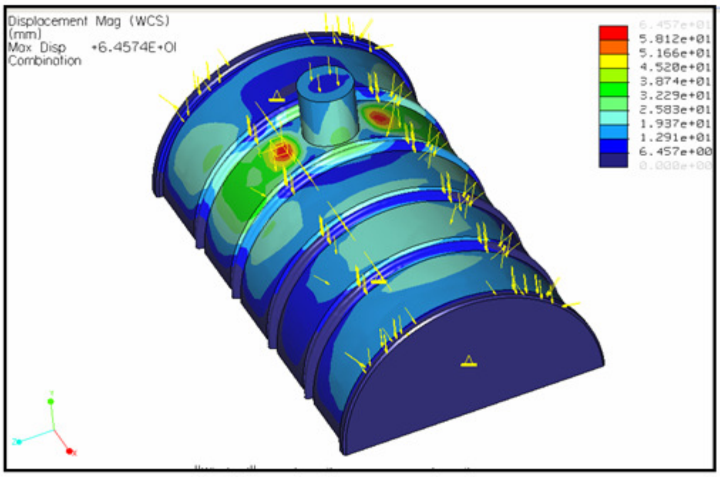


Fig 9.49a Displacement contours (THK 6 mm, with inside stiffeners, FS=2)

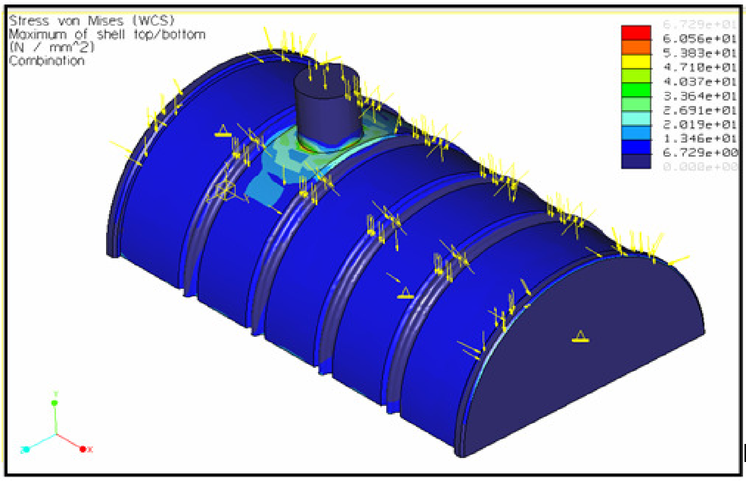


Fig 9.49b Stress contours (THK 6 mm, with inside stiffeners, FS=2)

These are the stress and deflection results for 4mm, 5m, and 6mm thickness of tank. These results are only for the model-3; model-3 is with inside stiffeners. Now considering maximum stress results and deflection result, check is carried out whether this tank is safe against the loading. Stresses and deflection are reduced in compare to model-1, due to more numbers of stiffeners and different shape of stiffeners.

It can be concluded from Fig 9.50 and 9.51 that deflection values are reduced in compared to tank with simple geometry of stiffeners. Stiffeners attract the stresses, though stress in wall will reduce to permissible stress.

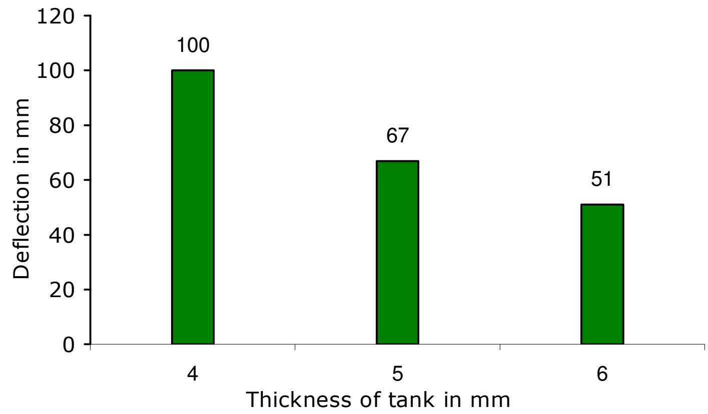


Fig 9.50 Deflections in model-3 (With HDPE, with inside stiffeners, FS=2)

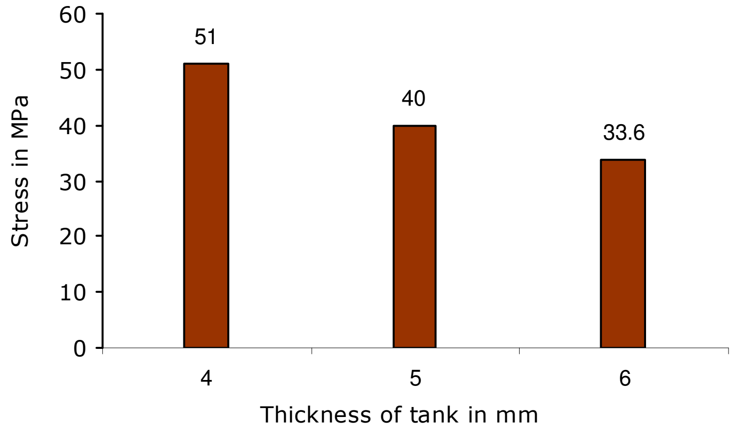


Fig 9.51 Stresses in model-3 (With HDPE, with inside stiffeners, FS=2)

9.7.3 Result of tank type-2 with Fiber Reinforced Polymers (FRP)

Tank is also checked for higher strength material, modeled are analyzed for fiber reinforced polymers. FRP is having higher tensile strength compare to polyethylene products. Tank design is safe for this material, but for commercial design only model-1 is checked with FRP material.

Loading condition is taken same as LLDPE and HDPE, model-1 used with same dimensions.

- Horizontal cylindrical shape.
- Model-1
- Capacity 5000 liters.
- Material – fiber reinforced polymers (FRP).
- Thickness 4mm, 5mm, and 6mm

Table 9.21 Load case-3 model-1

	Model - 1
FEATURE	Minimum RIBS
Thickness	4 mm
Material	Fiber reinforced polymers -FRP
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load-5	500 mm soil load

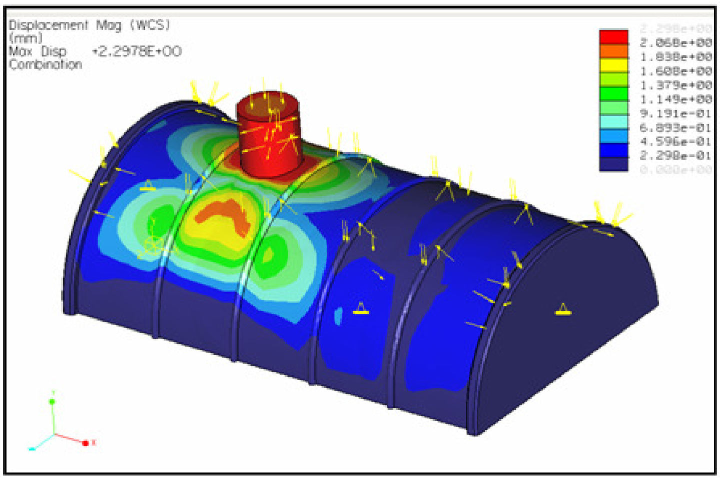


Fig 9.52a Displacement contours (THK 4 mm, with minimum stiffeners, FS=2)

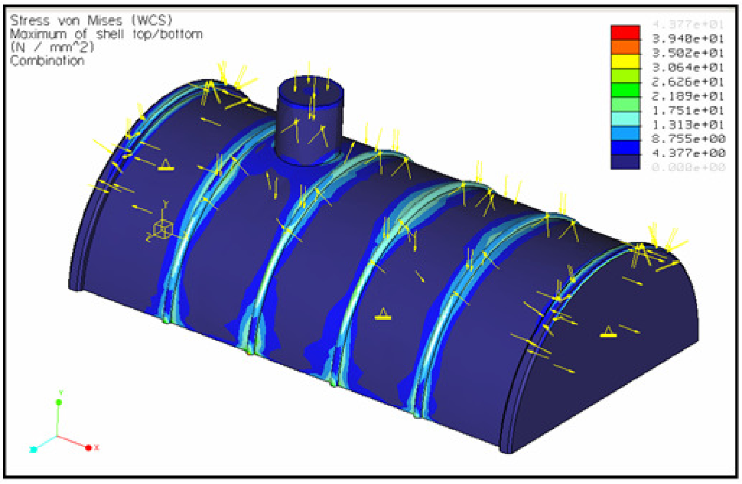


Fig 9.52b Stress contours (THK 4 mm, with minimum stiffeners, FS=2)

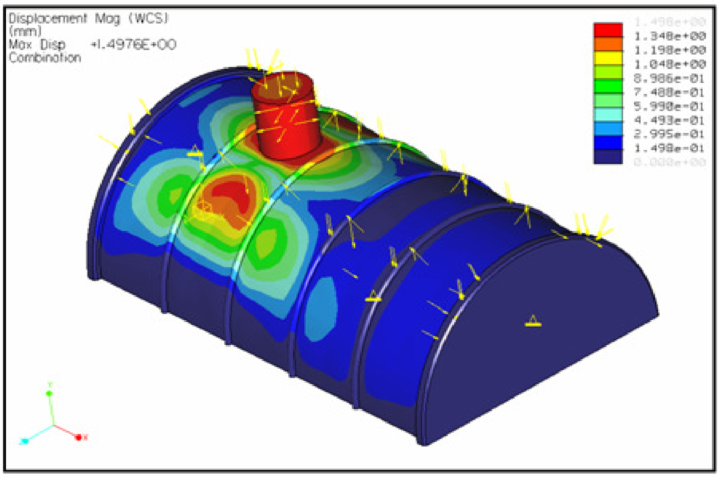


Fig 9.53a Displacement contours (THK 5 mm, with minimum stiffeners, FS=2)

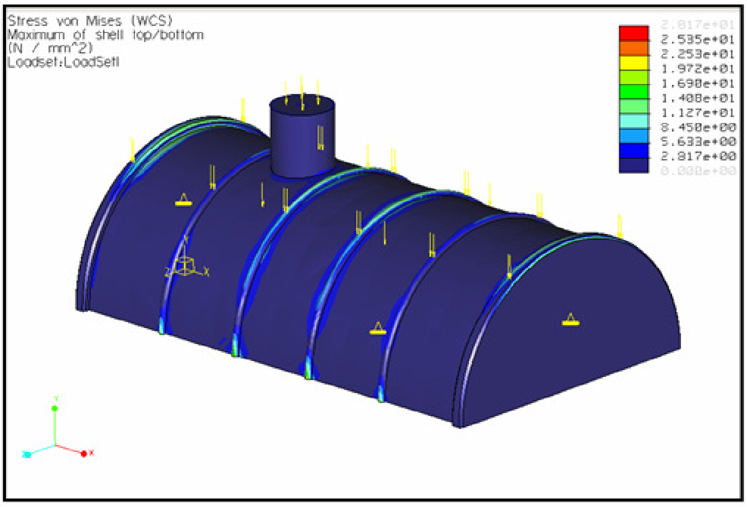


Fig 9.53b Stress contours (THK 5 mm, with minimum stiffeners, FS=2)

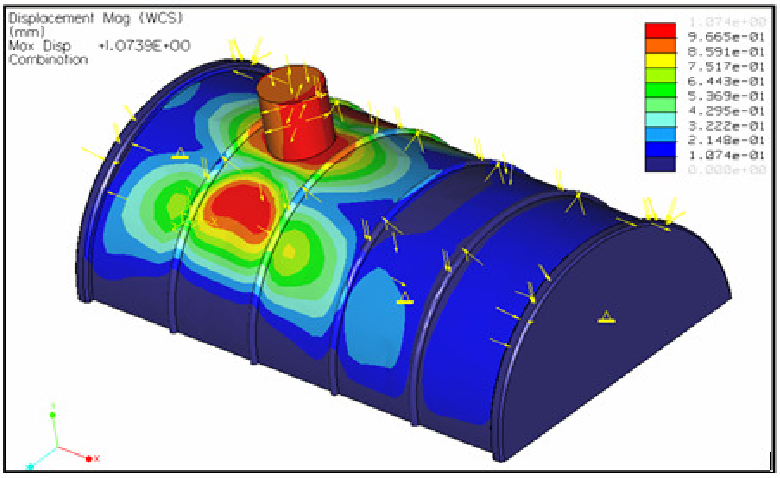


Fig 9.54a Displacement contours (THK 6 mm, with minimum stiffeners, FS=2)

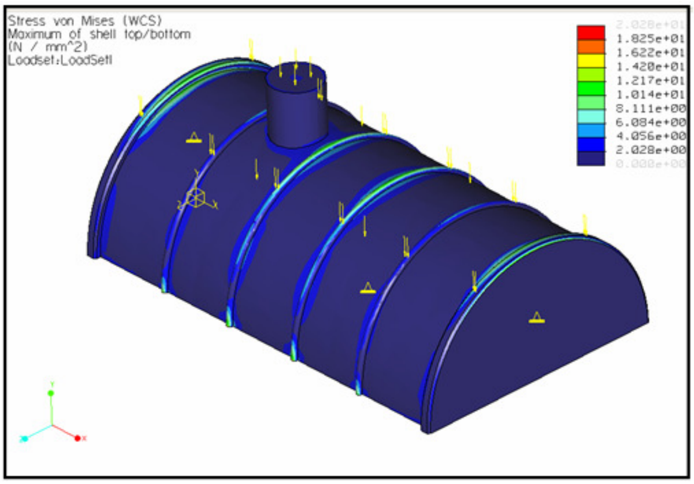


Fig 9.54b Stress contours (THK 6 mm, with minimum stiffeners, FS=2)

FRP having higher strength compared to other material, in this case model-1 with minimum ribs is having less deflection as well as stress. FRP material is not economic compared two polyethylene materials, otherwise FRP is the suitable material option to design underground storage tank.

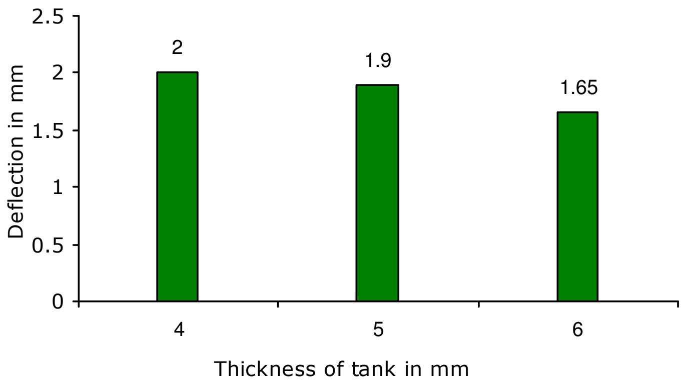


Fig 9.55 Deflections in model-1 (With FRP material, with minimum stiffeners, FS=2)

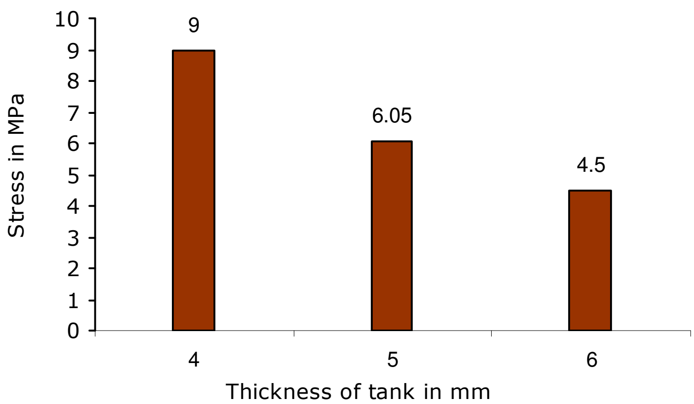


Fig 9.56 Stresses in model-1 (With FRP material, with minimum stiffeners, FS=2)

9.8 RESULTS OF UNDERGROUND TANK TYPE-2, 3000 LITERS CAPACITY.

9.8.1 General

Always it is not possible to use single capacity tank, 5000 liter tank is for bigger house hold use, this tank is sufficient for family having nearly 15 to 18 members, but this is always not appropriate to use 5000liter tank in all cases, it is economic to design small capacity tank which suits a small family having 4 to 6 members in it. Considering this aspect work is done on 3000liter tank capacity also.

This tank is smaller then earlier, therefore these tanks are subjected to less stresses and deflection, same geometry tank is used for study purpose, model-1 is analyzed with 3000 liter capacity with different materials.

9.8.2 Results of tank type-2 with Linear Low Density Polyethylene (LLDPE)

First analysis is carried out with the linear low density polyethylene material. With same material tanks are analyzed for different thickness and different stiffeners configuration. First case is with 4mm thickness, as explained in chapter 6; two types of loading conditions are taken in consideration.

- Capacity 3000 liters.
- Material LLDPE.
- Thickness 4mm, 5 mm, 6mm

Table 9.22 Load case-3 model-1

	Model - 3
FEATURE	Minimum RIBS
Thickness	4 mm
Material	Polyethylene - LLDPE
Load -1	50000 N – tractor axle load
Load -2	0.0689 MPa Soil Pressure
Load-5	500 mm soil load

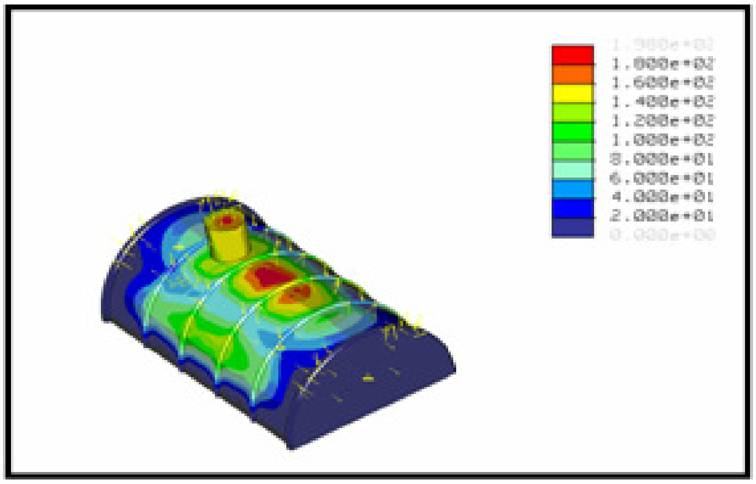


Fig 9.57a Displacement contours (THK 4 mm, with minimum stiffeners, FS=2)

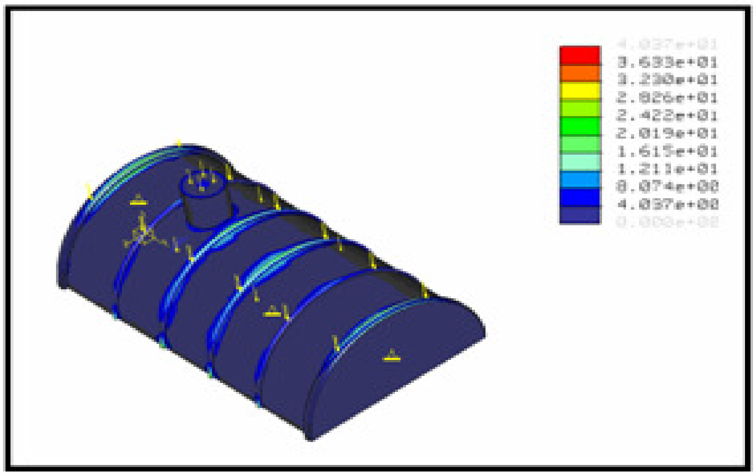


Fig 9.57b Stress contours (THK 4 mm, with minimum stiffeners, FS=2)

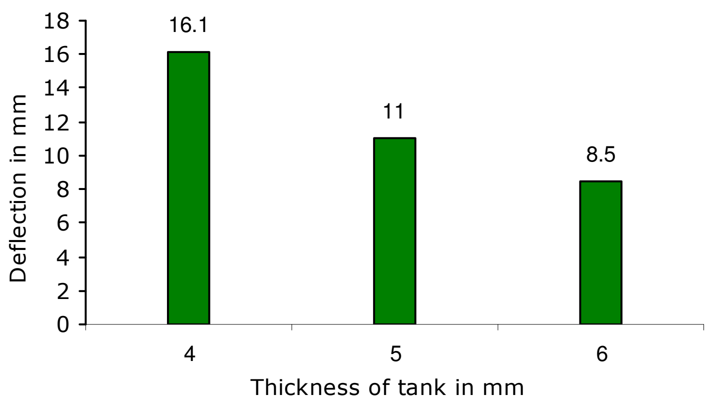


Fig 9.58 Deflections in model-1 (With LLDPE, with minimum stiffeners, FS=2)

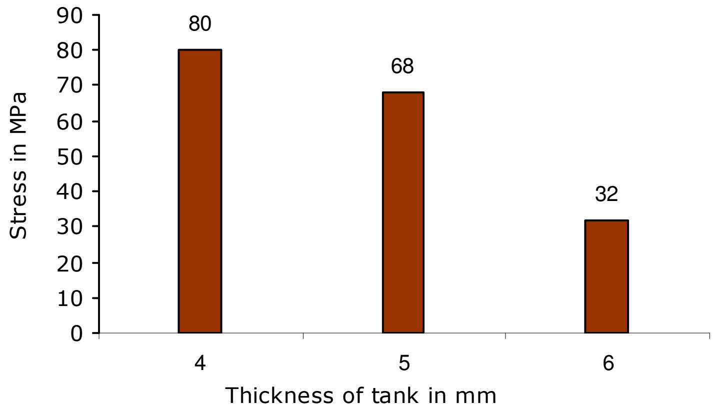


Fig 9.59 Stresses in model-1 (With LLDPE, with minimum stiffeners, FS=2)

9.9 SUMMARY

In this chapter analysis of different types of tanks are analyzed for two load cases. Results are tabulated in this chapter; values are exceeding from their allowable value specified in chapter 6. For 4 mm thick tank stresses are more and deflection is also about 120 mm which higher than allowable. But in case of 5 mm and 6 mm stresses are low. From results it is cleared that most effective design is model-1, 2, and 3 with fiber reinforced polymer.

10.1 GENERAL

Study is carried out with different parameters, comparative study is carried out to understand effects of these parameters, study is done for material domain, size of stiffeners, shape of stiffeners, spacing of stiffeners, orientation of stiffeners, capacity of tank, geometry of tank. In this piece of work these comparisons are done.

10.2 COMPARISON OF 5000LITER TANK

Three types of tanks are analyzed with different parameters. Study is done in material domain, stress and deflection is considered for analysis.

Material	:	LLDPE
Young's modulus	:	400 Mpa
Poisson's ratio	:	0.3
Density	:	0.936 gm/cc

Von misses Stress: Results are compared at 0.1m from top.

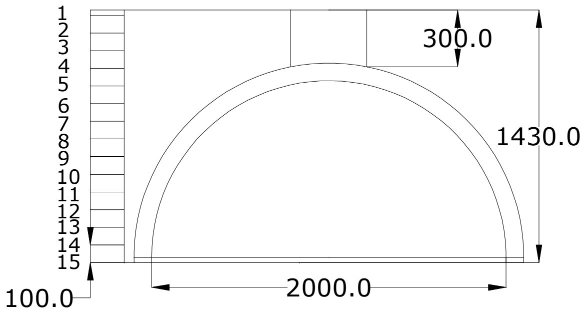


Fig 10.1 Location of points in tank

Study of stress and deflection is done at the location shown in tank, for each analysis stress and deflection is carried out at particular specified point, same points are use for other type of tank, therefore comparative study is possible, stress at top part of tank is higher due to loadings on it, it will reduces toward the downward side and again increase at the bottom part, bottom part is fixed in analysis this is the reason to increase of stresses. There effect is observed in all types of tanks

Table 10.1 Deflection in tank at different location model-1

NO	Distance from top(m)	Deflection mm 4mm THK	Deflection mm 5mm THK	Deflection mm 6mm THK
1	0.2	167	143	125.5
2	0.4	150	120	105
3	0.6	148.5	100.1	98
4	0.8	130	78.5	70
5	1.0	125	60	55
6	1.2	98	55.7	48
7	1.43	72	48	23

Table 10.2 Stresses in tank at different location model-1

NO	Distance from top(m)	Stress MPa 4mm THK	Stress MPa 5mm THK	Stress MPa 6mm THK
1	0.1	77.2	50.0	42.0
2	0.2	75.0	48.2	40.5
3	0.3	70.1	45.0	40.0
4	0.4	51.0	40.2	35.7
5	0.5	45.0	40.0	34.2
6	0.6	38.2	30.0	28.6
7	0.7	25.6	25.5	21.4
8	0.8	25.0	20.0	14.3
9	0.9	12.8	12.0	14.0
10	1.0	12.8	11.0	14.0
11	1.1	12.5	11.0	10.0
12	1.2	12.0	10.0	7.14
13	1.3	12.0	10.0	7.14
14	1.4	14.5	14.0	13.0
15	1.43	20.0	15.5	15.0

Same way all models results are tabulated and final graphical form of it is shown in this chapter, after this comparative study is essential for study. So it is done with considering all parameters related to it.

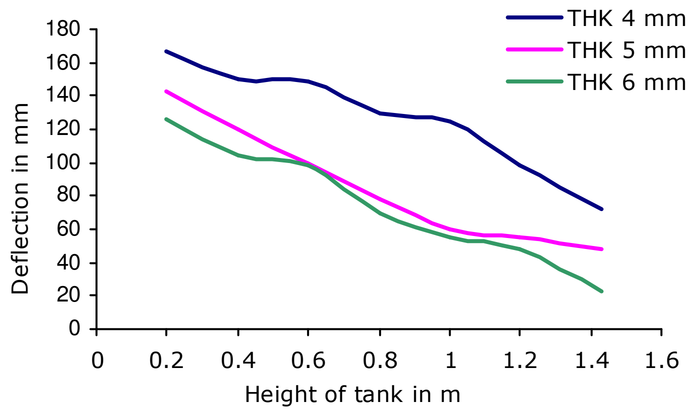


Fig 10.2 Deflection comparisons for tank model-1 (with minimum stiffeners, FS=2)

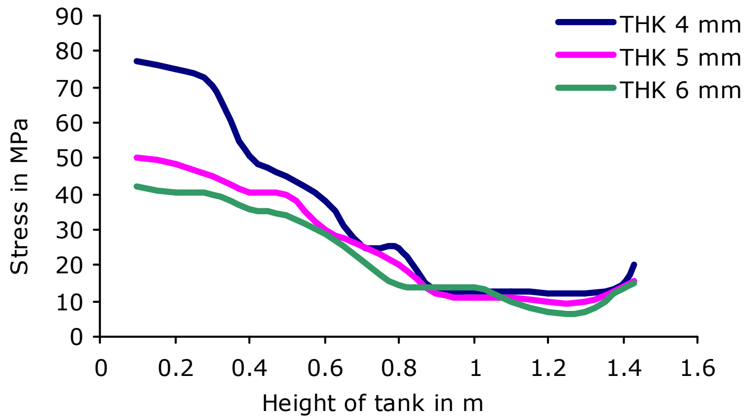


Fig 10.3 Stress comparisons for tank model-1 (with minimum stiffeners, FS=2)

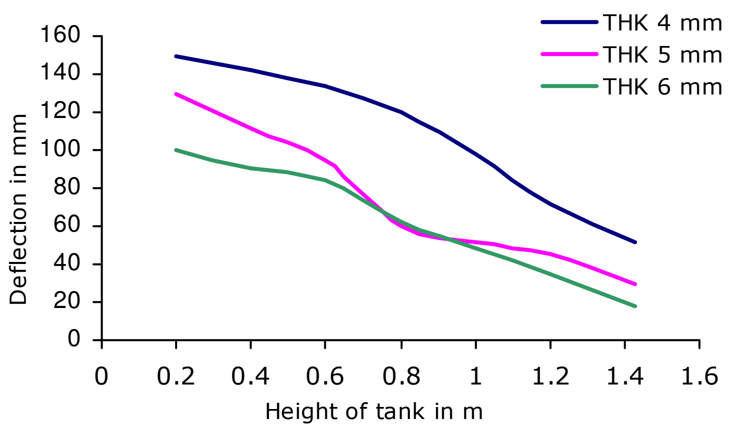


Fig 10.4 Deflection comparisons for tank model-2 (With more stiffeners, FS=2)

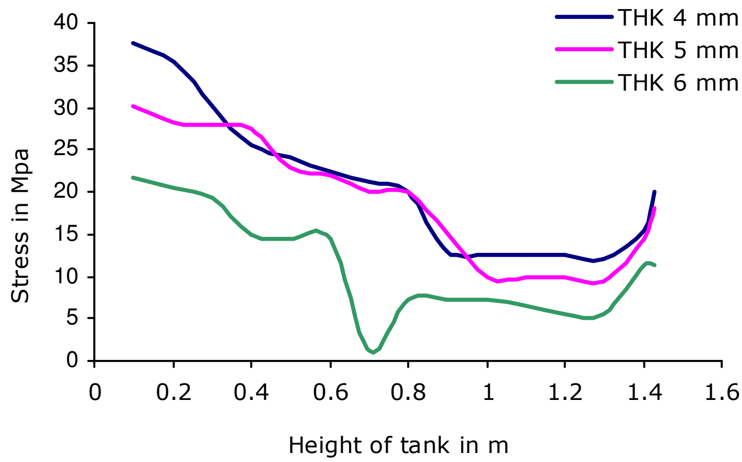


Fig 10.5 Stress comparisons for tank model-2 (With more stiffeners, FS=2)

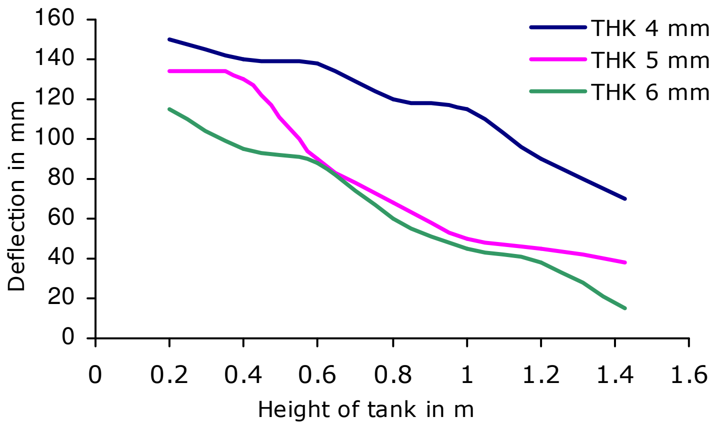


Fig 10.6 Deflection comparisons for tank model-3 (with inside stiffeners,FS-2)

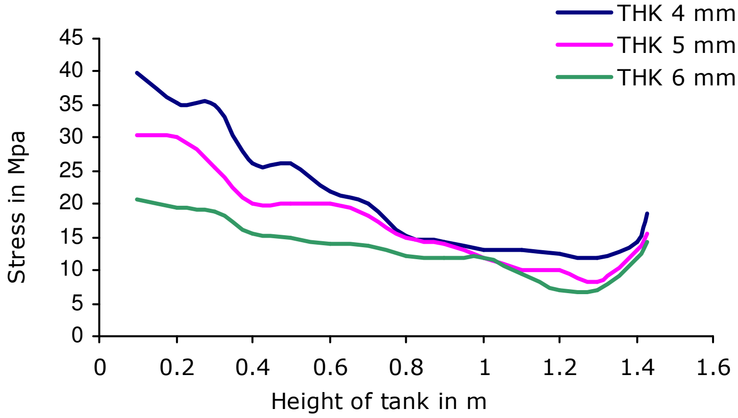


Fig 10.7 Stress comparisons for tank model-3 (With inside stiffeners, FS=2)

10.3 COMPARISONS FOR STIFFENERS SHAPE

There are three types of stiffeners used in study. Shape of stiffeners will affect on stress and deflection in tank, to study this analysis is carries out.

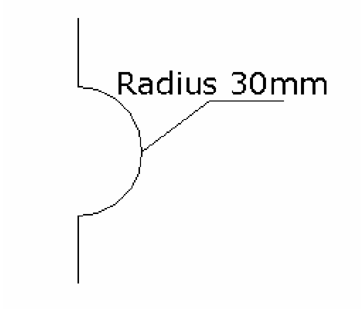


Fig 10.8 Stiffener type-1

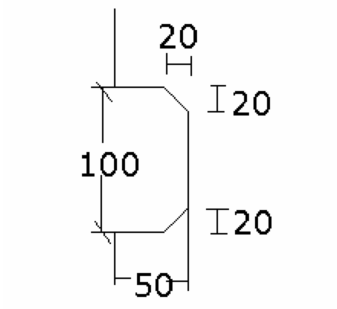


Fig 10.9 Stiffener type-2

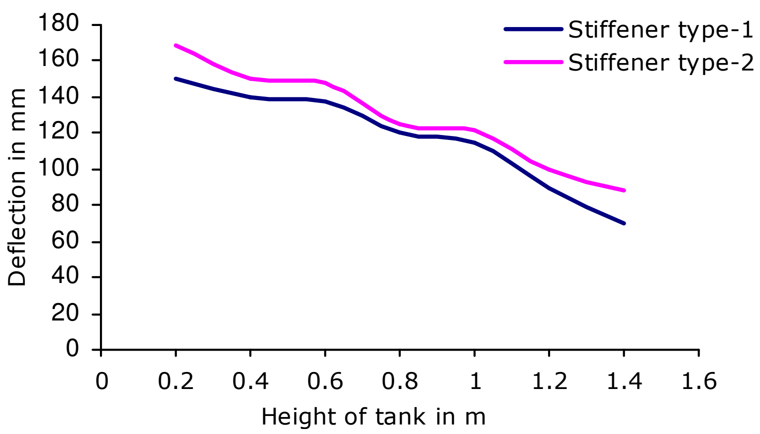


Fig 10.10 Deflection comparisons for tank (With FS=2)

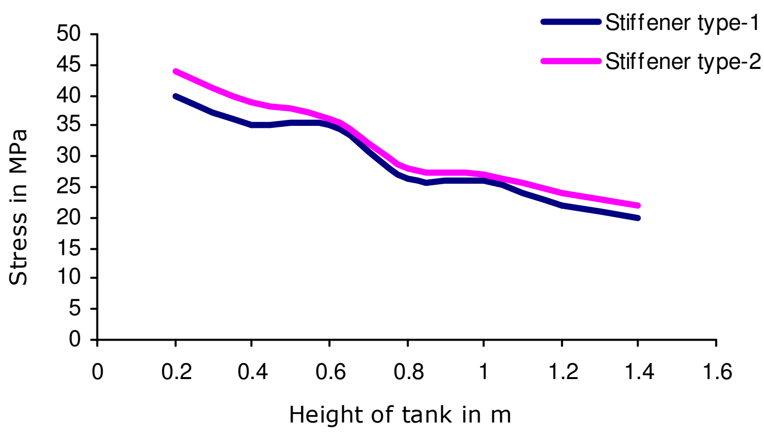


Fig 10.11 Stress comparisons for tank (With FS=2)

10.4 COMPARISONS FOR SPACING OF STIFFENERS

Spacing is a major parameter to affect the stress and deflection in tank, study is carried out with different types of spacing, one tank is analyzed with minimum numbers of spacing and another model with the more numbers of stiffeners.

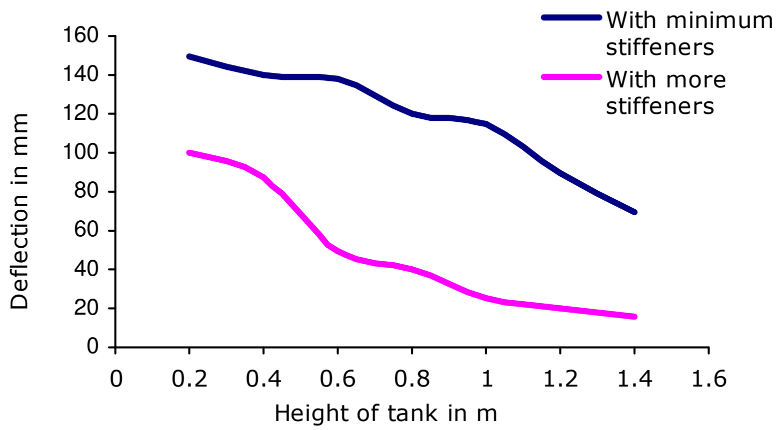


Fig 10.12 Deflection comparisons for tank (With FS=2)

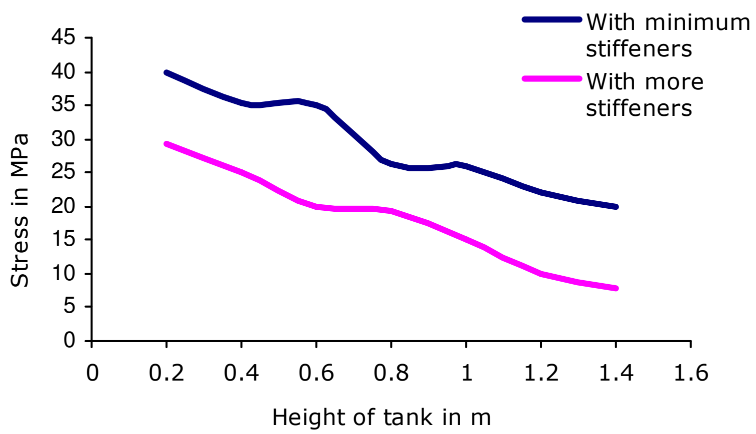


Fig 10.13 Stress comparisons for tank (With FS=2)

It is observed from above results that when more numbers of stiffeners are added to tank it will reduced the stress in tank, stiffeners gives strength to the tank walls, it is possible to use stiffeners where higher amount of stresses are acting, this study is carried out in case of model-1. In model-1 due to less stiffeners and higher loading top part is subjected to higher amount of deflection study is carried out by adding more stiffeners in top part of tank, and it will help to reduced stress and deflection from top part of tank.

10.5 COMPARISONS FOR ORIENTATION OF STIFFENERS

Stiffeners can be fabricated in any direction, sometime it will provide out side in tank, or it can be possible to provide it inside.

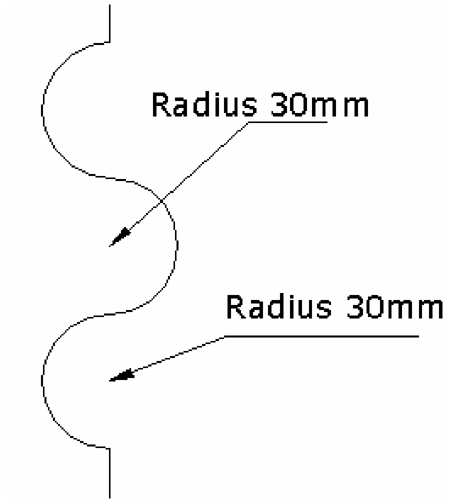


Fig 10.14 Stiffener type-3

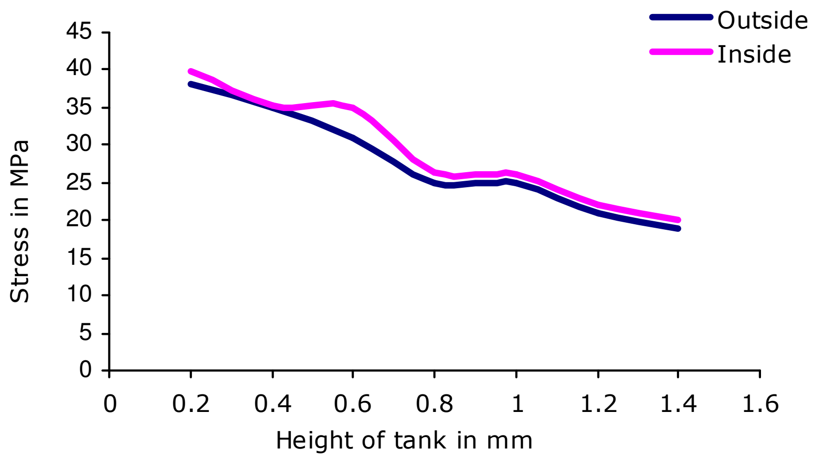


Fig 10.15 Stress comparisons for tank (With FS=2)

This study carried out with semicircular stiffeners of same shape and size, orientation is different for both cases. Considering surface of tank one type of stiffeners are outside of the tank and other type is fabricated inside of the tank. Analysis is done on same capacity tank having same spacing between stiffeners only orientation is different

It is observed that it will not affect too much on deflection and stresses of tank.

10.6 COMPARISONS FOR MATERIALS OF TANK

Tank can be manufactured with different types of material, to check suitability of materials study is done with three different types of materials

- Linear Low Density Polyethylene (LLDPE)
- High Density Polyethylene (HDPE)
- Fiber Reinforced Polymers (FRP)

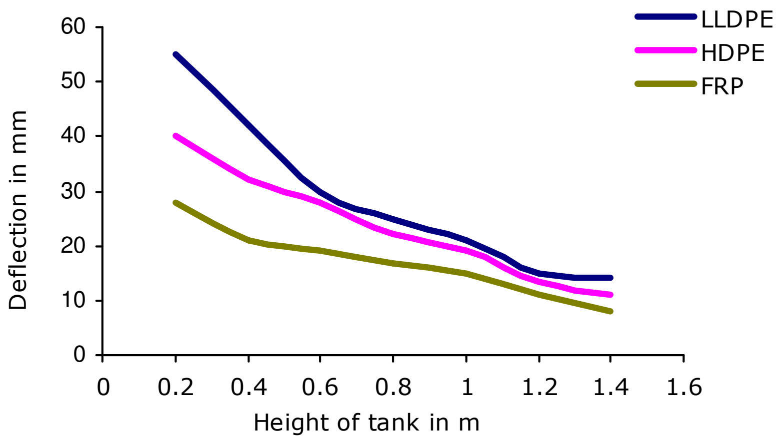


Fig 10.16 Deflection comparisons for tank (With FS=2)

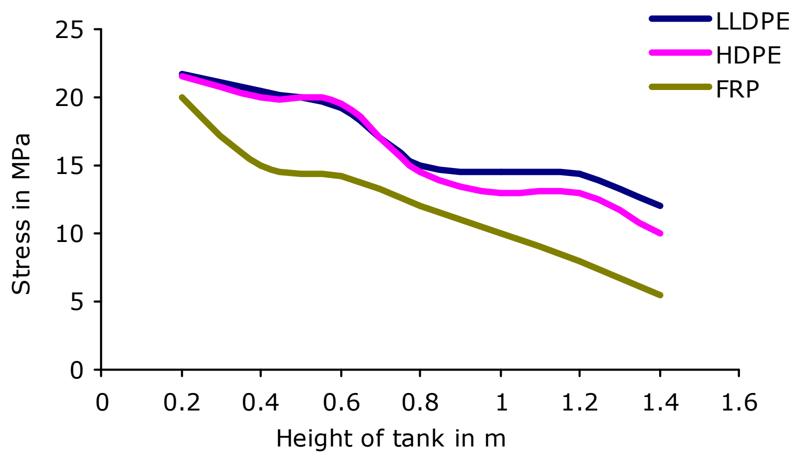


Fig 10.17 Stress comparisons for tank (With FS=2)

Strength of material will effect on this exercise, FRP is having higher strength compared to other materials, in case of FPR stresses and deflection is very less and in case of LLDPE it is more compared to other two materials. This particular case is for 6mm model-2 tank, which safe against applied loading for LLDPE material also.

10.7 COMPARISONS FOR CAPACITIES OF TANK

It is demand of market that tank is available in more than one capacity; therefore here two capacities are used for analysis, 5000liter tank and 3000liter tank. Now comparison is done to understand stresses in tank of small capacity and large capacity.

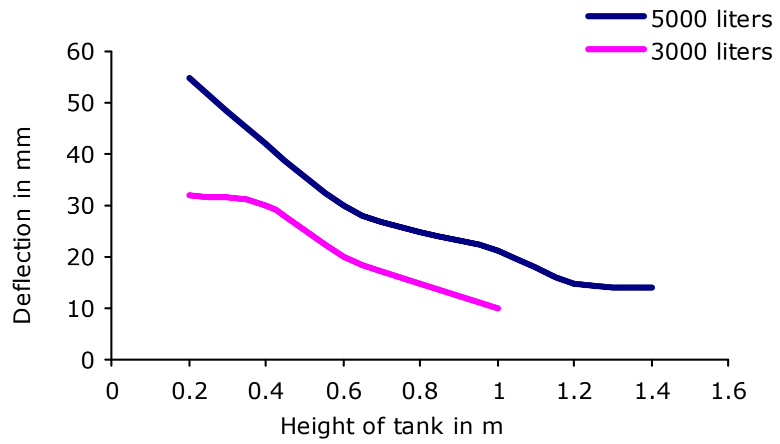


Fig10.18 Deflection comparisons of tank (With FS=2)

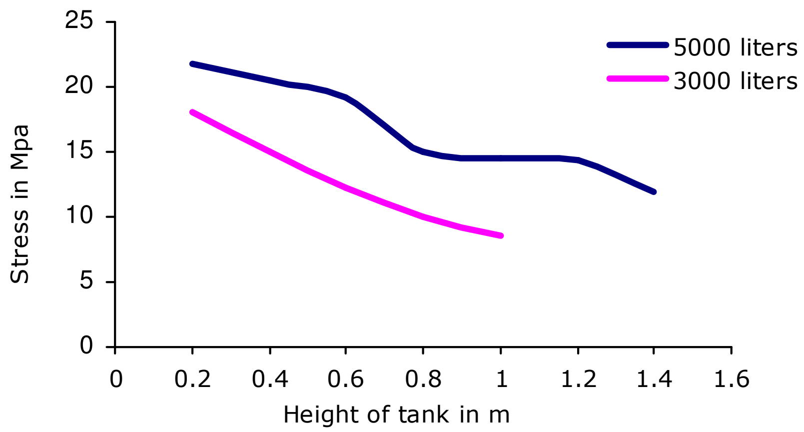
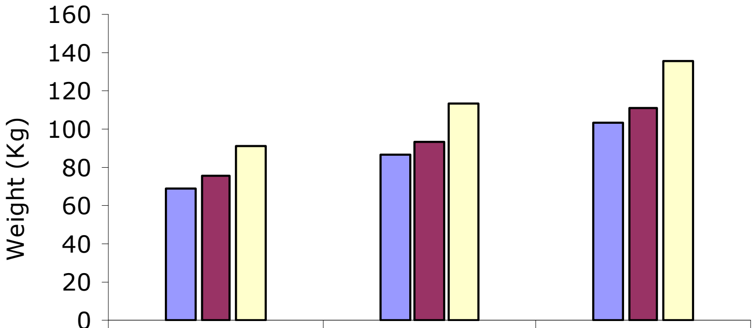


Fig 10.19 Stress comparisons of tank (With FS=2)

It is observed that when tank size is small it is safe against stresses. Large size of tank will gives higher stresses and deflection. Here two capacity tanks are analyzed in which 3000 liters tank is having lesser amounts of stress and deflection compared to 5000 liters of tank.

10.8 MATERIAL QUANTITY COMPARISON OF TANKS

This is also a major part to carry out most effective commercial design. For each model quantity is carried out in term of Kg. Increase in stiffeners will increases the quantity of material. For optimum design it is required to minimize design by finding out most effective way in term of stability and material quantity.



	4	5	6
Model-1	69.25	86.9	103.23
Model-2	75.05	93.84	111.5
Model-3	90.68	113.35	136.03

Thickness of tanks (mm)

Fig 10.20 Weight comparisons of tanks

11. CONCLUSIONS AND SCOPE FOR FUTURE WORK

11.1 GENERAL

Underground tank is an important part of house; it is used for storage of the liquid. Septic tank is also acting as underground storage tank, it acts as a domestic water treatment system. It will treat the water coming out from kitchen, bathroom, wash. This works for separation of solid from the waste water and discharge the treated water to drain field or some time to the municipal sewer pipe.

Septic system tank is used for separation of solids and liquid. This tank is made up with masonry or concrete work but nowadays polyethylene products are used for fabrication of this type of septic tank. Presently, analysis is carried out for different types of septic tank of 5000 liters capacity. Results are obtained for the same. Based on results, tanks are modified or redesigned.

11.2 SUMMARY AND CONCLUSIONS

(i) Analysis of septic tank with two different geometries is successfully carried out. Vertical and horizontal cylindrical shape tank are used for analysis. Capacities of tanks are 5000 liters and 3000 liters.

(ii) For initial study simple cylindrical shape is selected, with the spherical dome shape at top portion.

(iii) Results are obtained for stress and deflection for both the models.

(iv) In case of tank type-1, model-1 with minimum number of ribs give higher value of deflection at top portion and it reduces at bottom; it is observed that top portion of tank may fail due to higher deflection.

(v) As a critical case, particular tractor axle load is very heavy. Most of the deflection is due to this load and it is acting vertically on the tank.

(vi) For model-1, values of stresses are also high in some part, Von misses stress is considered for study of all affect. Some part of tank is subjected to stress more then 200 Mpa but for particular material of tank (HDPE) it is more then it's limiting value.

(vii) Model-2 is prepared with more ribs in tank wall but top part has been kept same as model-1. Hence, in this case deflection is again higher, but overall deflection has reduced in comparison to model-1. In this case due to more ribs stress is reducing and comes down to permissible values.

(viii) One more study is carried out for same tank with ribs on top portion. In this study deflection is reduced in top part. Earlier, deflection was more in particular top part but it can be reduce by ribs.

(ix) In case of type-2 tank, model-1 is subjected to higher amount of stresses but in case of 6mm thick wall, model-1 is safe against loadings.

(x) Model-2 contains more numbers of stiffeners, it is safe for 5mm and 6mm thickness of wall, in case of 4mm thickness stresses are little more due to heavy tractor axle load.

(xi) Model-3 is analyzed with FRP material. FRP material is having higher strength in comparison to other two materials. Therefore, in case of FRP all the models are safe against stresses and deflections. Limiting values of material is very high in case FRP.

(xii) Analysis is also carried out for 3000 liters tank capacity. It is observed that lesser capacity tanks are having less stresses and deflection compared to high capacity tank.

(xiii) It can be observed from study that ribs in tank will reduce the deflection of overall tank.

(xiv) Stresses in tanks are affected by stiffeners provided in tank

(xv) Stiffener shape, size, spacing and orientations are also affecting the tank stresses and deflection.

(xvi) Stresses are concentrated near the stiffeners but it will reduce stress in other parts of wall. It can be observed from models analyzed for the present study.

(xvii) It can be concluded that by adding adequate optimum number of stiffeners in tank, it will be safe against loading.

11.3 SCOPE FOR FUTURE WORK

For future work, it is possible two design multipurpose tank, which can be used as underground storage tank as well as these kinds of tanks can be used as transportation mobile tank. These studies may include sloshing analysis of tank. It is possible to produce more economical geometry by considering structural and working aspects of tank.

Work can be done by producing more effective stiffeners; shape of stiffeners can be changed. In this piece of work, only up to 5000 liters tank study is carried out, now it may be possible to create larger capacity tanks, which will be multi-functional and with technical insect serve more household users.

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APPENDIX-B QUANTITY OF UNDERGROUND STORAGE TANKS

For techno commercial design weight of tank is major criteria to minimize, therefore calculation of weight of tank is essentially required for design.

QUANTITY OF POLYETHYLENE TANK

Type of tank - 1

Volume of tank - 5000 Liters

Quantity of sheet (curved part)

Length of sheet = 3140 mm

Width of sheet = 2580 mm

Thk of sheet = 6 mm

Volume = 48607200 mm3

Weight= 45.49 Kg Density= 0.936 gm/cc

Quantity of Bottom

Length = 3500 mm

Width = 2100 mm

Thickness = 6 mm

Volume = 44100000 mm3

Weight= 41.27 Kg

Quantity of stiffeners type-A

Length = 3140 mm

Width = 180 mm

Thickness = 6 mm

Volume of one stiffener 3391200 mm3

Weight of one stiffener 3.17 Kg

Numbers of stiffeners= 12

Weight = 38.08 Kg

Quantity of stiffeners type-B

Length = 3140 mm

Width = 94.42 mm

Thickness = 6 mm

Vol of one stiffener = 1778872.8 mm3

Weight of one stiffener= 1.66 Kg

Numbers of stiffeners= 4

Weight = 6.66 Kg

Quantity of manhole

Manhole area = 802584 mm2

Thickness = 6 mm

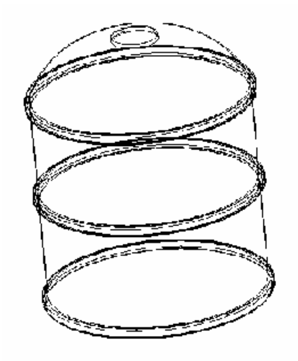
Volume = 4815504 mm3

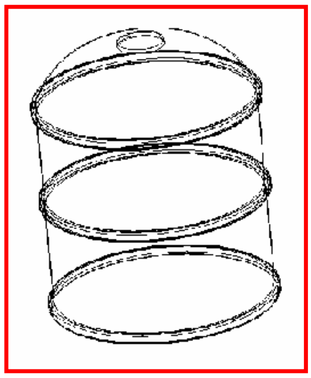
Weight = 4.50 Kg

TOTAL WEIGHT OF TANK = 136.03 Kg

- **Weight comparisons**

When LLDPE materials is used for analysis with minimum ribs, wall thickness should be more than 8 mm, taking 10 mm wall thickness it is weighted 230 Kg, but in case of FRP with minimum ribs tank is stable against loading and quantity required is just 69.2 Kg.





LLDPE materials
Required 10 mm THK

QTY= 230 Kg

FRP materials
Required 4 mm THK

QTY= 69.25 Kg