Analysis Of Buried Pipe Subjected To Internal And External Load Conditions

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Abstract- *The previous project focuses on the stress analysis of Glass Reinforced Polymer (GRP) pipes. Pressure piping made from GRP is becoming increasingly popular due to its high corrosion resistance and high strength to weight ratio. The development is driven by the need for lighter and more corrosion resistant components. This project involves stress analysis of E-glass/Epoxy and Carbon/Epoxy by replacing GRP. Eglass Epoxy and Carbon Epoxy have high corrosion property, and they are lighter in weight same as GRP. In this project, structural analysis is carried out on the pipe for external load caused by soil and an internal load of pressure by the fluid. This project also involves a change in orientation of layers for two composite materials. The project extends in comparison of results of two composite materials to find best suitable material for a pipe. 3d modeling of a pipe is generated by using CAD software. Structural analysis of pipe is done in ANSYS software. In this project, at first, the analysis is carried for steel material then followed with Eglass Epoxy and Carbon Epoxy.*

I. INTRODUCTION

Pipelines are a safe and economical means of transporting gas, water, sewage and other fluids. They are usually buried in the ground to provide protection and support, and the construction techniques involve either conventional trenching and backfilling, or trenchless methods such as micro tunneling. Pipelines are designed to the flow requirements and the operating pressure. For buried pipelines, additional design requirements are needed such as the maximum and minimum cover depth, the trench geometry and backfill properties

II. LITERATURE REVIEW

Stress Analysis of Underground GRP Pipe Subjected to various Internal and External Loading Conditions by Nimish Kurien Thomas, Saj P. George, Steve Mathews John, Sam P. George. This research work focuses on the stress analysis of Glass Reinforced Polymer (GRP) pipes and their accommodation to society. Pressure piping made from GRP is becoming progressively popular due to its great corrosion resistance and the ratio of high strength to its weight. This development is driven by the requirement for more corrosion resistant and lighter components. In the beginning, GRP piping was limited mainly to applications with moderate fluid pressurization. With increasing knowledge of failure mechanisms, improved damage predictability and pipe quality, GRP piping is increasingly being considered in the field of high-pressure fluid conveyance with pressurization more than much more megapascals. Since the GRP material is a composition of the number of layers, the analysis of stresses developed in it is complicated. Therefore, as the initial approach towards the project, the stress analysis of steel pipes is performed using ANSYS, which was followed by a comparative study of steel and GRP pipes. Finite Element Analysis of Buried UPVC Pipe by R. Nirmala and R. Rajkumar. Understanding the mechanics of buried pipes is complicated due to the imprecision in the properties of the soil envelope. This paper deals with the study of the behaviour of flexible Un-Plasticized Poly Vinyl Chloride pipes buried in loose and dense sand backfill. A design methodology is proposed for prediction of the performance of pipes using the finite element method ANSYS. The pipe soil interaction under static loading conditions is investigated. The height of the soil above the pipe varies with the ratios of the diameter of the pipe. The numerical results are compared with the available values calculated using the theoretical approach Spangler Deflection theory. Provision of geogrid reinforcement above the crown of a buried pipe is suggested to minimize the vertical deflection of buried Un-Plasticized Poly Vinyl Chloride pipes.

III. PROBLEM DEFINITION AND METHODOLOGY

Pipelines are a safe and economical means of transporting gas, water, sewage and other fluids. They are usually buried in the ground to provide protection and support. Due to the soil, external pressure is applied to the pipe and an internal pressure is applied due to fluid flowing in the pipe. Due to these internal and external pressure loads, pipe undergoes some deformation. To check the structure behaviour analysis is carried out on the buried pipe for external and internal pressure loads for two composite materials.

The methodology in this project as follows:

3d model of the buried pipe is generated by using the NX-CAD software.
3d model is converted to Parasolid file.
The Parasolid file is imported to ANSYS software to perform analysis on buried pipe.
Static analysis is done on the buried pipe for pressure loads considering soil as rectangular part.
Static analysis is done on buried pipe for pressure loads considering soil as circular part.
Compare the results of both and best one is selected.
An analysis is done for best-buried pipe for pressure loads by changing the layer orientation for E-glass/Epoxy material.
An analysis is also done for best-buried pipe for pressure loads by changing the layer orientation for Carbon/Epoxy material.
Results of both materials are compared, and best material is selected.

IV. 3D MODELLING OF BURIED PIPE

The 3D model of the buried pipe is generated using the NX-CAD software. NX-CAD is the world's leading 3D product development solution. This software enables designers and engineers to bring better products to the market faster. It takes care of the entire product definition to serviceability. NX delivers measurable value to manufacturing companies of all sizes and in all industries.

This is a project, in which soil is considered in two ways (i.e. rectangle and circular).

3d modelling of buried pipe considering soil as a rectangle:

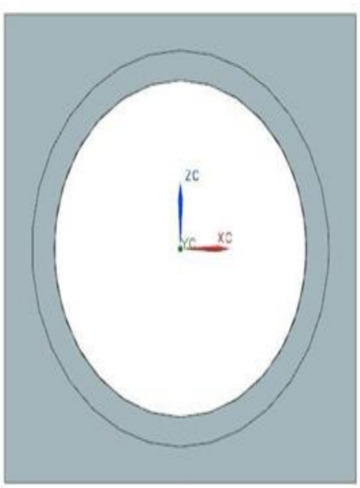

Figure 1. shows front view of buried pipe

V. FINITE ELEMENT ANALYSIS OF BURIED PIPE

Finite Element Modelling (FEM) and Finite Element Analysis (FEA) are two most significant mechanical engineering applications offered besides existing CAE systems. This is attributed to the truth that the FEM maybe the most popular numerically performed technique for solving engineering problems. The method is general enough to handle any complex shape of geometry (problem domain), any material properties, any boundary conditions and any loading conditions. The generality of the FEM fits the analysis requirements of today's complex engineering systems, and designs, where closed form solutions are governing equilibrium equations, are not available. Also, it is an efficient design tool by which designers can perform parametric design studying various cases (different shapes, material loads etc.) analyzing them and choosing the optimum design.

MATERIAL PROPERTIES

Considering buried pipe is made of steel and soil is denser soil.
Properties of soil:
Density = 1733.5 Kg/m3
Young's modulus = 19 MPa
Properties of steel material:
Density = 7850 Kg/m3
Young's modulus = 200 GPa
Yield strength = 250 MPa
Solid 92 element description

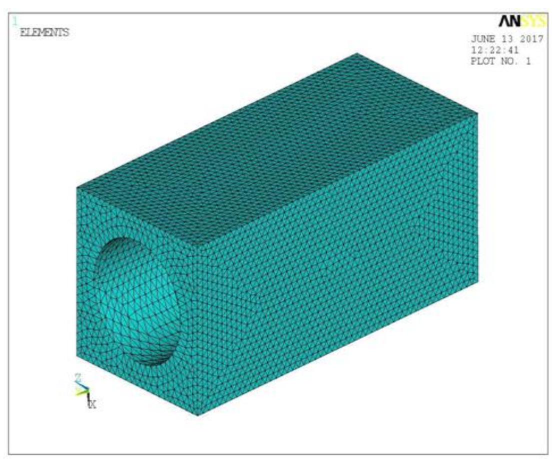

Figure 2. shows finite model of buried pipe

Boundary conditions

An external pressure of 100 MPa is applied on outer areas of the pipe.

An internal pressure of 25 MPa is applied on inner areas of the pipe.
Both sides of soil and pipe are constrained in all dof.

RESULTS

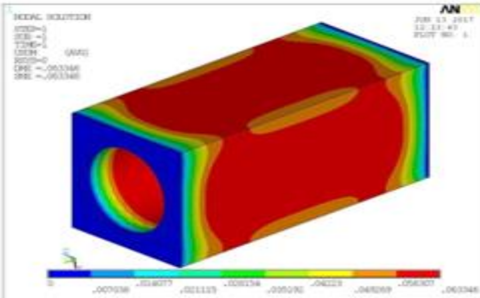

Figure 3. shows resultant displacement on the buried pipe

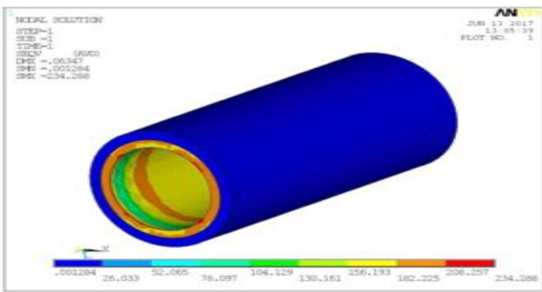

Figure 4. shows Von mises stress of buried pipe

VI. STRUCTURAL ANALYSIS OF BURIED PIPE WITH CIRCULAR SOIL STRUCTURE FOR EGLASS/EPOXY MATERIAL

Structural analysis is carried out on the Buried pipe for external and internal pressure to determine displacements and stresses. The analysis is conducted on the buried pipe for E-glass/Epoxy material. This analysis is also performed on the buried pipe for different layer orientation for E-glass/Epoxy material.

RESULTS

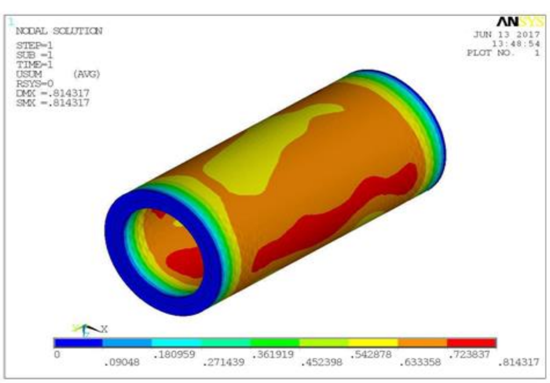

Figure 5. shows Resultant displacement on Buried pipe

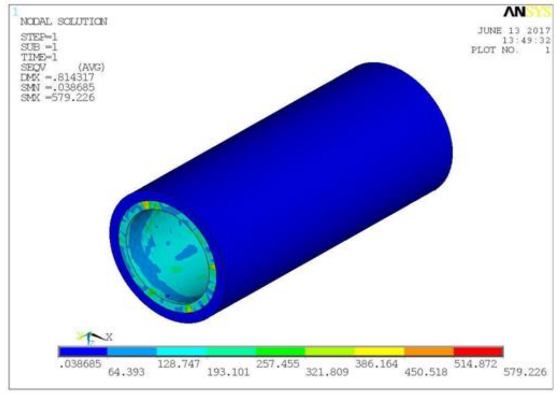

Figure 6. shows Von mises stress of Buried pipe

From results, The maximum displacement of 0.814mm is observed on the buried pipe. The von misses stress of Buried pipe is 579.22 MPa. The yield strength of E-glass/Epoxy material is 800 MPa in fibre direction. The von misses stress of Buried pipe is less than the yield strength of material. Hence, the Buried pipe is safe for pressure loads.

Boundary conditions

An external pressure of 100 MPa is applied to outer areas of pipe.
An internal pressure of 25 MPa is applied on inner areas of pipe.
Both sides of soil and pipe are constrained in all dof.

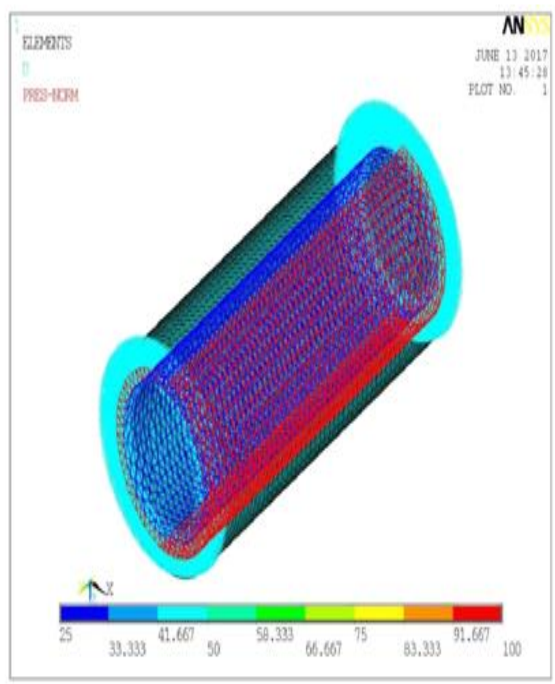

Figure 7. shows boundary and load conditions of Buried pipe

RESULTS

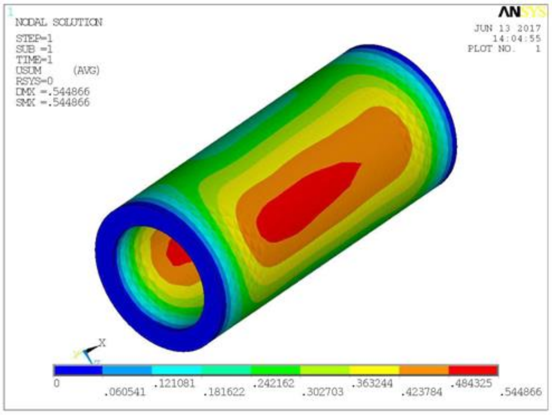

Figure 8. shows Resultant displacement on Buried pipe

From results, The maximum displacement of 0.54mm is observed on the buried pipe. The von misses stress of Buried pipe is 270.87 MPa. The yield strength of E-glass/Epoxy material is 800 MPa in fibre direction. The von misses stress of Buried pipe is less than the yield strength of material. Hence, the Buried pipe is safe for pressure loads.

Boundary conditions

An external pressure of 100 MPa is applied to outer areas of pipe.
An internal pressure of 25 MPa is applied on inner areas of pipe.
Both sides of soil and pipe are constrained in all dof.
RESULTS

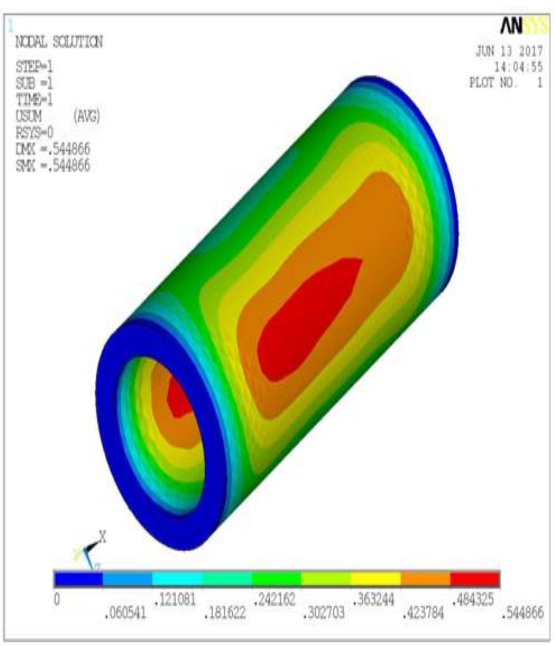

Figure 9. shows Resultant displacement on Buried pipe

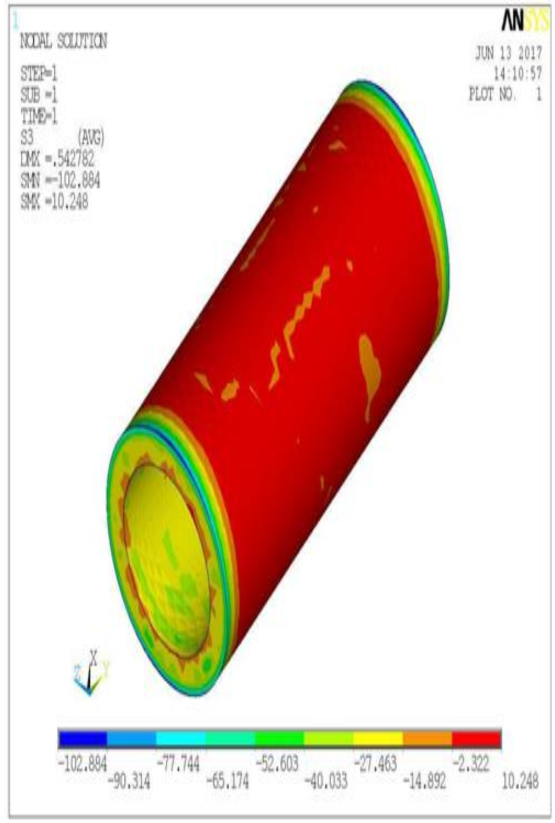

Figure 10. shows Von mises stress of Buried pipe

VII. STRUCTURAL ANALYSIS OF BURIED PIPE WITH CIRCULAR SOIL STRUCTURE FOR CARBON/EPOXY MATERIAL

Structural analysis is carried out on Buried pipe for external and internal pressure to determine displacements and stresses. The analysis is performed on buried pipe for Carbon/Epoxy material. This analysis is also carried out on buried pipe for different layer orientation for Carbon/Epoxy material.

MATERIAL PROPERTIES OF SOIL

Properties of soil
Density = 1733.5 Kg/m3
Young's modulus = 19 MPa
MATERIAL PROPERTIES OF PIPE
Carbon/Epoxy Mechanical Properties
Boundary conditions

An external pressure of 100 MPa is applied on outer areas of pipe.
An internal pressure of 25 MPa is applied on inner areas of pipe.
Both sides of soil and pipe are constrained in all dof.

RESULTS:

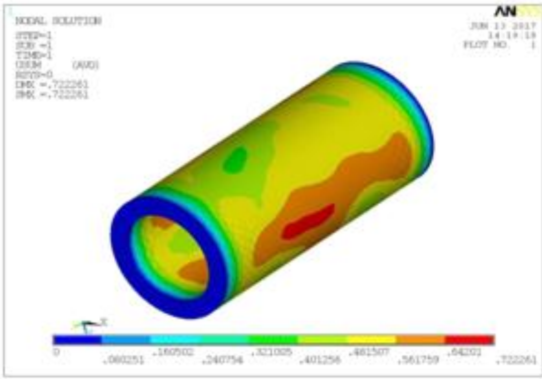

Figure 11. shows Resultant displacement on Buried pipe

Case-2: Layer Orientation (i.e. 45,0,45) of Buried pipe for
Carbon/Epoxy material

Boundary conditions

An external pressure of 100 MPa is applied to outer areas of pipe.
An internal pressure of 25 MPa is applied on inner areas of pipe.
Both sides of soil and pipe are constrained in all dof.

RESULTS

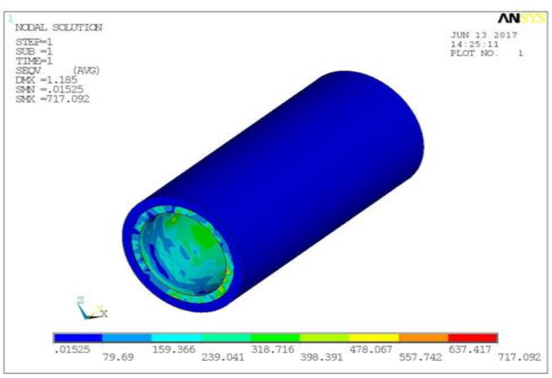

Figure 12. shows Von mises stress of Buried pipe

From results, The maximum displacement of 1.1mm is observed on the buried pipe. The von misses stress of Buried pipe is 717.092 MPa. The yield strength of Carbon/Epoxy material is 945MPa in fibre direction. The von misses stress of Buried pipe is less than the yield strength of material. Hence, the Buried pipe is safe for pressure loads.

Case-3: Layer Orientation (i.e. 60,0,60) of Buried pipe for
CARBON/Epoxy material

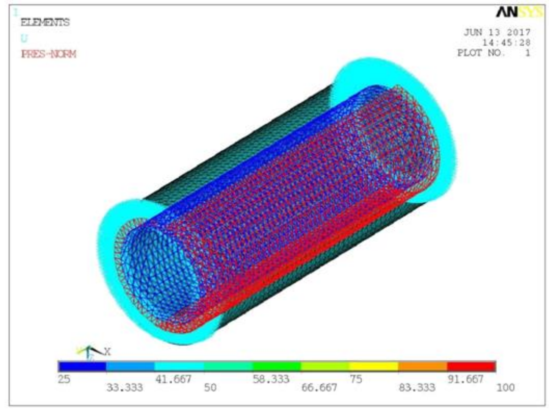

Figure 13. shows boundary and load conditions of Buried pipe

RESULTS

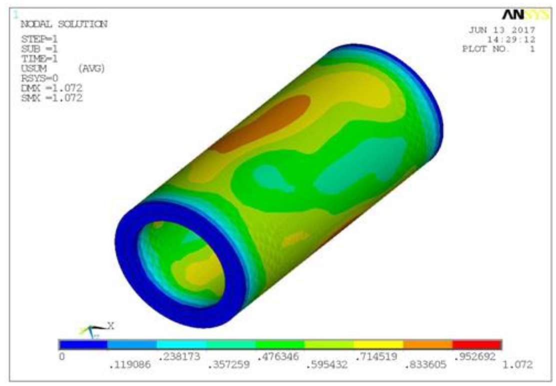

Figure 14. shows Resultant displacement on Buried pipe

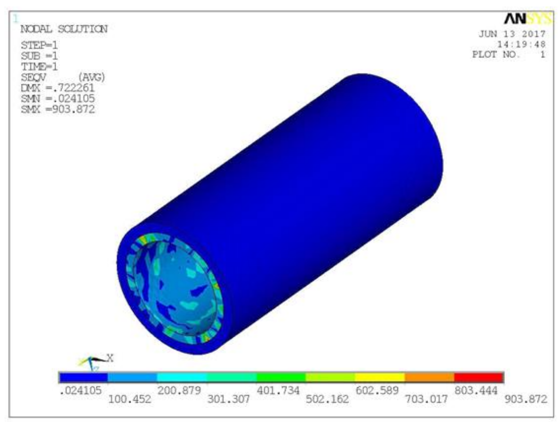

Figure 15. shows Von mises stress of Buried pipe

From results, The maximum displacement of 0.72mm is observed on the buried pipe. The von misses stress of Buried pipe is 903.87MPa. The yield strength of Carbon/Epoxy material is 945MPa in fibre direction. The von misses stress of Buried pipe is less than the yield strength of material. Hence, the Buried pipe is safe for pressure loads.

Case-2: Layer Orientation (i.e. 45,0,45) of Buried pipe for
Carbon/Epoxy material

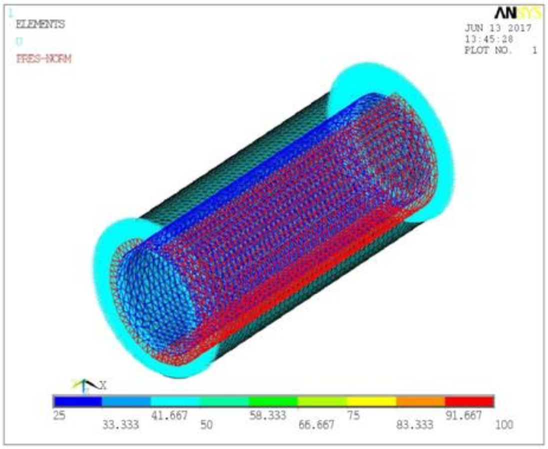

Figure 16. shows boundary and load conditions of Buried pipe

RESULT

From results, The maximum displacement of 1.1mm is observed on the buried pipe. The von misses stress of Buried pipe is 717.092 MPa. The yield strength of Carbon/Epoxy material is 945MPa in fibre direction. The von misses stress of Buried pipe is less than the yield strength of material. Hence, the Buried pipe is safe for pressure loads.

Case-3: Layer Orientation (i.e. 60,0,60) of Buried pipe for CARBON/Epoxy material

Boundary conditions

An external pressure of 100 MPa is applied to outer areas of pipe.
An internal pressure of 25 MPa is applied on inner areas of pipe.
Both sides of soil and pipe are constrained in all dof.

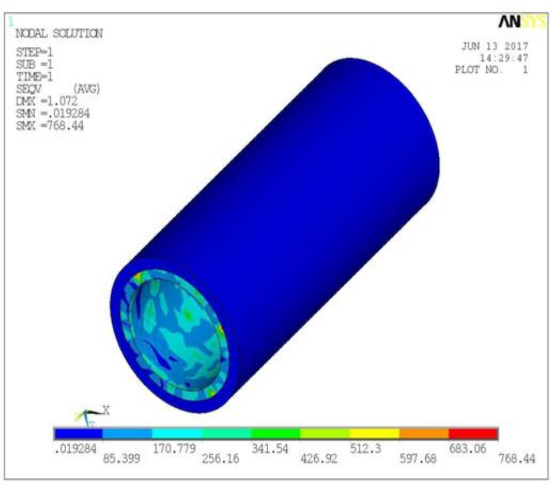

Figure 17. shows Von mises stress of Buried pipe

VIII. RESULTS AND CONCLUSION

Buried pipe with two soil structures (i.e. Circular and Rectangular structure) was studied for structural analysis for steel material.

Case-1: structural analysis of buried pipe considering soil as rectangular structure:

From analysis results, the resultant displacement observed on buried pipe is 0.0633 mm. The Von mises stress observed on buried pipe is 243.75MPa. The yield strength of steel material is 250MPa. The Von mises stress of buried pipe with rectangular soil structure is less than the yield strength of the material. Hence the buried pipe is a safe in design.

Case-2: structural analysis of buried pipe considering soil as Circular structure:

From analysis results, the resultant displacement observed on buried pipe is 0.0634 mm. The Von mises stress observed on buried pipe is 234.28MPa. The yield strength of steel material is 250MPa. The Von mises stress of buried pipe with Circular soil structure is less than the yield strength of the material. Hence the buried pipe is a safe in design.

From analysis of buried pipe in both cases, that buried pipe with Circular soil structure has less Von mises stress than buried pipe with Rectangular soil structure. Hence, it is concluded that buried pipe with Circular soil structure is better than buried pipe with Rectangular soil structure. Hence, Buried pipe with Circular soil structure is considered for Structural analysis for composite materials.

Structural analysis was carried out on buried pipe with Circular soil structure for two composite materials. Structural analysis was also carried for different layer orientation for composite materials.

STRUCTURAL ANALYSIS OF BURIED PIPE WITH CIRCULAR

SOIL STRUCTURE FOR EGLASS/EPOXY MATERIAL FOR

DIFFERENT LAYER ORIENTATION:

Case-1: Layer Orientation (i.e. 90,0,90) of Buried pipe for E-glass/Epoxy material:

From results, The maximum displacement of 0.814mm is observed on the buried pipe. The von misses stress of Buried pipe is 579.22 MPa. The yield strength of E-glass/Epoxy material is 800 MPa in fibre direction. The von misses stress of Buried pipe is less than the yield strength of material. Hence, the Buried pipe is safe for pressure loads.

Case-2: Layer Orientation (i.e. 45,0,45) of Buried pipe for E-glass/Epoxy material:

From results, The maximum displacement of 0.54mm is observed on the buried pipe. The von misses stress of Buried pipe is 270.87 MPa. The yield strength of E-glass/Epoxy material is 800 MPa in fibre direction. The von misses stress of Buried pipe is less than the yield strength of material. Hence, the Buried pipe is safe for pressure loads.

Case-3: Layer Orientation (i.e. 60,0,60) of Buried pipe for E-glass/Epoxy material:

From results, The maximum displacement of 0.542mm is observed on the buried pipe. The von misses stress of Buried pipe is 248.878 MPa. The yield strength of E-glass/Epoxy material is 800 MPa in fibre direction. The von misses stress of Buried pipe is less than the yield strength of material. Hence, the Buried pipe is safe for pressure loads

STRUCTURAL ANALYSIS OF BURIED PIPE WITH CIRCULAR SOIL STRUCTURE FOR CARBON/EPOXY MATERIAL FOR DIFFERENT LAYER ORIENTATION

Case-1: Layer Orientation (i.e. 90,0,90) of Buried pipe for Carbon/Epoxy material:

From results, The maximum displacement of 0.72mm is observed on the buried pipe. The von misses stress of Buried pipe is 903.87MPa. The yield strength of Carbon/Epoxy material is 945MPa in fibre direction. The von misses stress of Buried pipe is less than the yield strength of material. Hence, the Buried pipe is safe for pressure loads.

Case-2: Layer Orientation (i.e. 45,0,45) of Buried pipe for Carbon/Epoxy material

From results, The maximum displacement of 1.1mm is observed on the buried pipe. The von misses stress of Buried pipe is 717.092 MPa. The yield strength of Carbon/Epoxy material is 945MPa in fibre direction. The von misses stress of Buried pipe is less than the yield strength of material. Hence, the Buried pipe is safe for pressure loads.

Case-3: Layer Orientation (i.e. 60,0,60) of Buried pipe for CARBON/Epoxy material

From results, The maximum displacement of 1.01mm is observed on the buried pipe. The von misses stress of Buried pipe is 768.44 MPa. The yield strength of Carbon/Epoxy material is 945MPa in fibre direction. The von misses stress of Buried pipe is less than the yield strength of material. Hence, the Buried pipe is safe for pressure loads.

GRAPHS

Graph between Comparisons of stress vs layer orientation of Buried pipe for two composite materials

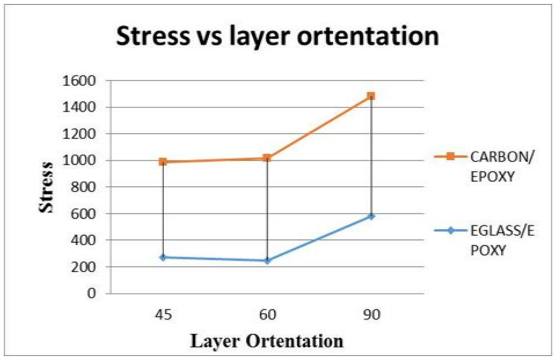

Figure 18. shows Comparison of stress vs layer orientation of Buried pipe for two composite materials

IX. CONCLUSION

In this project, 3d model of the buried pipe is generated in NX-CAD software. Buried pipe with two soil structures (i.e. Circular and Rectangular structures) is studied for structural analysis for external and internal pressure loads for steel material. From analysis, it is concluded that Buried pipe with Circular soil structure is better than Buried pipe with Rectangular soil structure. So, Buried pipe with Circular soil structure is studied for two composite materials (i.e. E-glass/Epoxy and Carbon/Epoxy materials) with different layer orientation. From analysis, the Von Mises stress of Buried pipe for E-glass/Epoxy material with various layer orientation is less compared to Buried pipe for Carbon/Epoxy material with different layer orientation. Hence, it is concluded that E-glass/Epoxy material is alternative material for Buried pipe.

REFERENCES

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