International Journal of Research
Available at https://edupediapublications.org/journals
e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue 09
August 2017

Design and Analysis of Buried Pipe for Pressure Loads

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Abstract:

Generally Buried pipe was made up of steel and GRP. Different papers are published based on the Glass Reinforced Polymer(GRP) pipes. The papers focused on the stress developed on the GRP pipes. Buried Pipes undergoes corrosion due to Pressure. The project is aimed to need for lighter and more corrosion resistant components.

The aim of the project is to analysis the pipe for Eglass/Epoxy and Carbon/Epoxy by replacing GRP. Eglass Epoxy and Carbon Epoxy are considered based on their better material properties. These materials possess less weight and high corrosion resistance same as GRP. In this project, at first 3d modelling of the buried pipe is modelled using NX-CAD software. Next, 3d model of buried pipe with rectangular soil and circular soil was analyzed in ANSYS software. Buried pipe is analyzed for external pressure caused by soil and internal pressure caused by fluid. From the analysis best model is considered and used for further analysis. In further analysis, orientation of layers is considered for two composite materials. Comparison was done to determine the best material from Eglass Epoxy and Carbon Epoxy. Analysis is done for steel material and then follows for Eglass Epoxy and Carbon Epoxy.

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 tunnelling. Pipelines are generally designed on the basis of 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. Failure of a critical pipeline is extremely serious and has major consequences in terms of economic loss, social impacts and environmental issues. The failure of a pipe occurs when the applied stresses in the pipe exceeds the structural capacity of the pipe. The structural capacity reduces over time due to material deterioration, the mechanisms of which are dependent on the pipe material. The failures in the pipe barrel and joint result from a combination of causes such as operational condition (i.e., traffic load and pressure load), environmental factors (i.e., soil corrosivity and reactivity) and intrusion (i.e., third party damage). Figure (1) shows the causes of pipe failures and its contribution to the total number of failures in buried water pipeline. The corrosion has significant influence on the failure of buried pipeline followed by ground movement and pressure transient.

The failure modes of the pipeline differ depending on the level of applied external loads, operational conditions and pipe geometry (i.e., diameter and thickness etc). For example: (a) the longitudinal failure occurs due to increase in internal pressure that increases the tensile stress higher than the capacity; and (b) the circumferential failure occurs due to increase in flexural stress in the pipe exceed the bending capacity of the pipe. Moreover, the pipe corrosion both external and internal causes leakage and reduces the structural capacity.

PROBLEM DEFINITION

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 soil, external pressure is applied on pipe and internal pressure is applied due to fluid flowing in the pipe. Due these internal and external pressure loads, pipe undergoes some deformation. To check the structure behaviour

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analysis is carried out on buried pipe for external and internal pressure loads for two composite materials.

METHODOLOGY

The methodology in this project as follows:

- 3d model of buried pipe is generated by using 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 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.
- Analysis is done for best buried pipe for pressure loads by changing the layer orientation for Eglass/Epoxy material.
- 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.

3D MODELLING OF BURIED PIPE

3d modelling of buried pipe considering soil as rectangle:

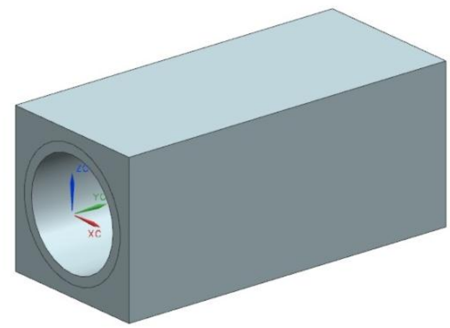

Fig shows Isometric view of buried pipe

3d modelling of buried pipe considering soil as circular:

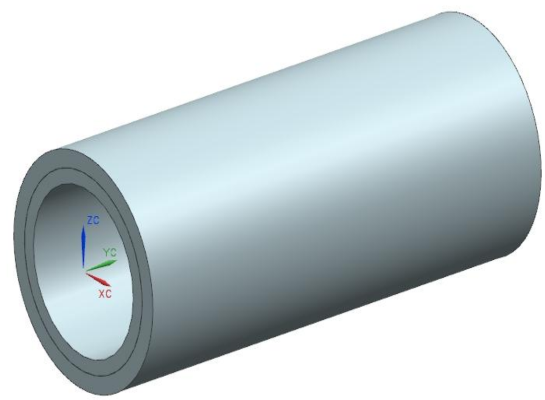

Fig shows Isometric view of Buried pipe

FINITE ELEMENT ANALYSIS OF BURIED PIPE

MATERIAL PROPERTIES:

Considering buried pipe is made of steel and soil is denser soil.

Properties of soil:

Density = **1733.5 Kg/m^3**

Young'smodulus = **19 MPa**

Properties of steel material:

Density = **7850 Kg/m^3**

Young'smodulus = **200 GPa**

Yield strength **= 250 MPa**

Element used is: **10 NODE SOLID92**

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

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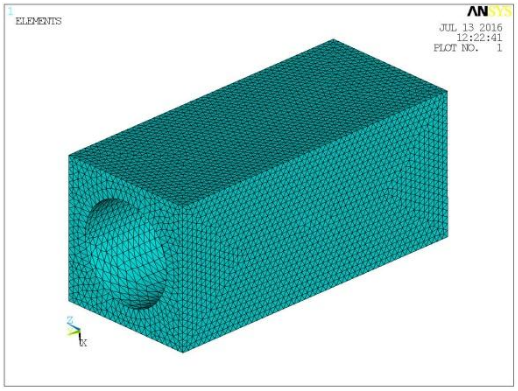

Fig shows finite model of buried pipe

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.

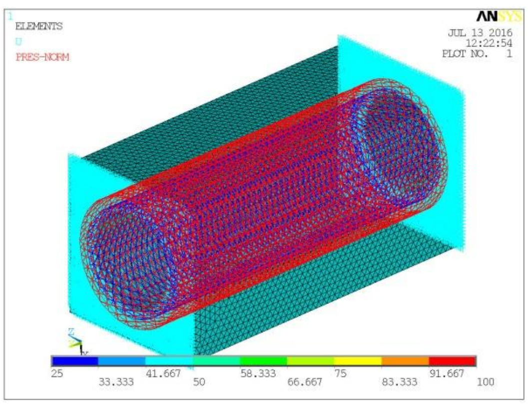

Fig shows boundary conditions on buried pipe

Results:

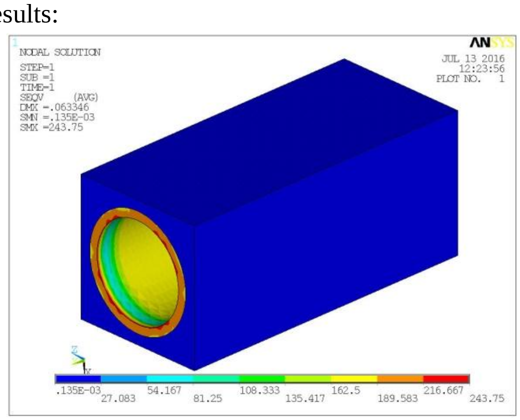

Fig shows Vonmises stress of buried pipe

From analysis results, the resultant displacement observed on buried pipe is 0.0633 mm.

The Vonmises stress observed on buried pipe is 243.75MPa. The yield strength of steel material is 250MPa. The Vonmises 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:

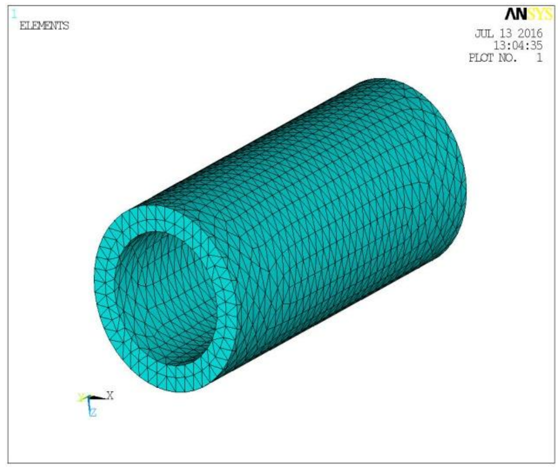

Fig shows finite model of buried pipe

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.

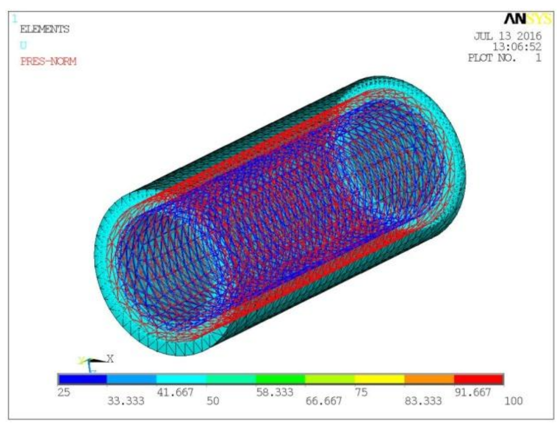

Fig shows boundary and load conditions on buried pipe

RESULTS:

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p-ISSN: 2348-795X
Volume 04 Issue 09
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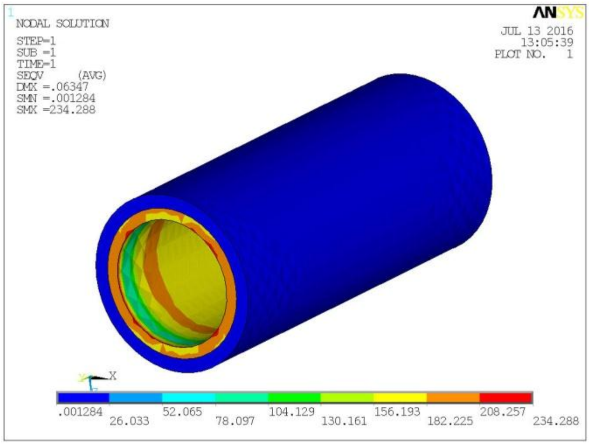


Fig shows Vonmises stress of buried pipe

From analysis results, the resultant displacement observed on buried pipe is 0.0634 mm. The Vonmises stress observed on buried pipe is 234.28MPa. The yield strength of steel material is 250MPa. The Vonmises 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 Vonmises 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 OF BURIED PIPE WITH CIRCULAR SOIL STRUCTURE FOR EGLASS/EPOXY MATERIAL

Material properties of soil:

Properties of soil:

Density = **1733.5 Kg/m³**

Young'smodulus = **19 MPa**

Material properties of pipe:

Eglass/Epoxy Mechanical Properties:

Table: Properties of E-Glass/Epoxy

Sl.No	Property	Units	E-Glass/Epoxy
1.	E_{11}	GPa	50.0
2.	E_{22}	GPa	12.0
3.	G_{12}	GPa	5.6
4.	ν_{12}	-	0.3
5.	$S^t_1 = S^c_1$	MPa	800.0
6.	$S^t_2 = S^C_2$	MPa	40.0
7.	S_{12}	MPa	72.0
8.	ρ	Kg/m^3	2000.0

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

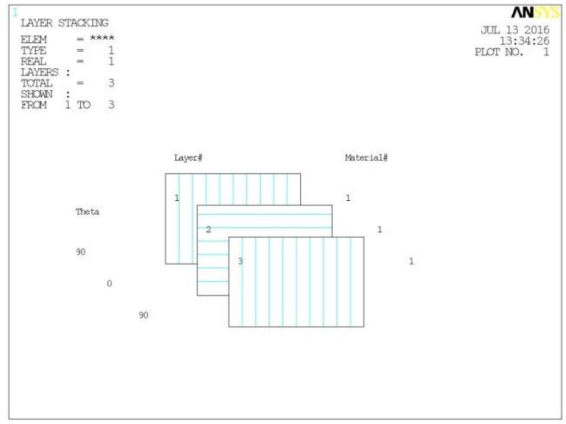


Fig shows Layer orientation for Eglass/Epoxy material of Buried pipe

RESULTS:

Displacements:

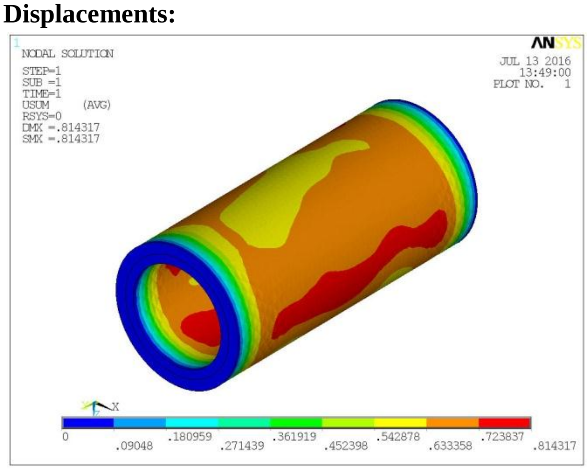


Fig shows Resultant displacement on Buried pipe

Stresses:

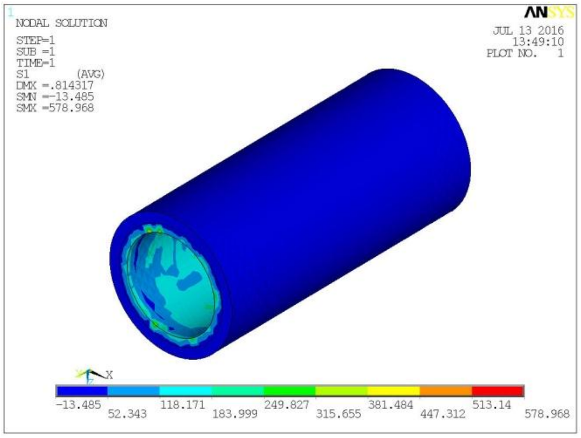


Fig shows 1st principal stress observed on Buried pipe

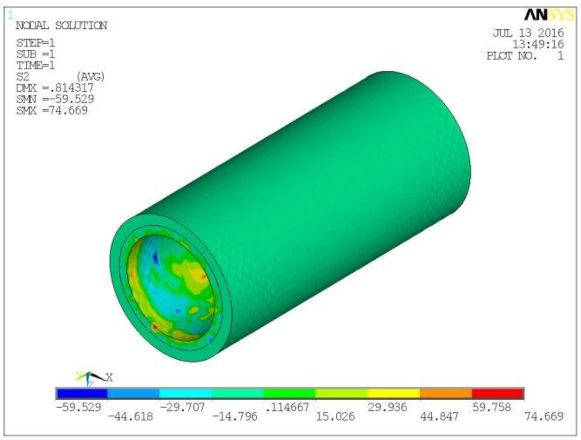


Fig shows 2nd principal stress observed on Buried pipe

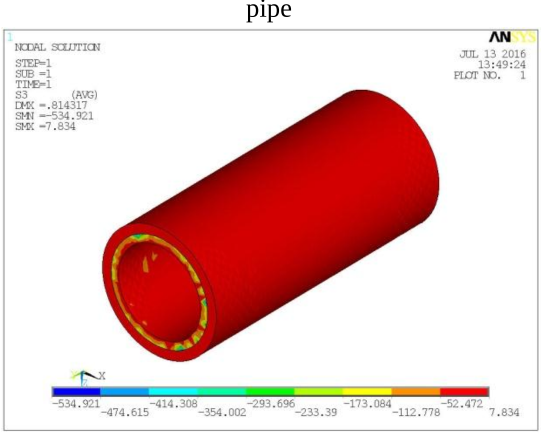


Fig shows 3rd principal stress observed on Buried pipe

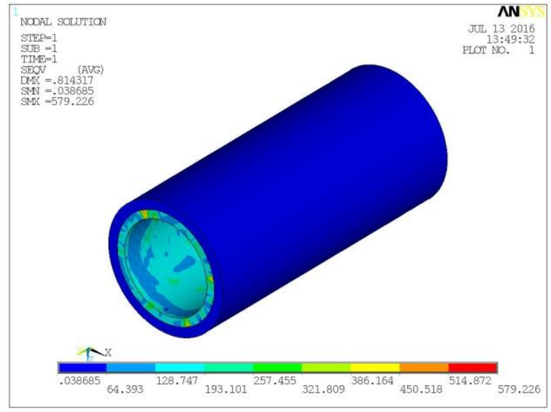


Fig shows Vonmises stress of Buried pipe

From results, the von misses stress of Buried pipe is 579.22 MPaandthe yield strength 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):

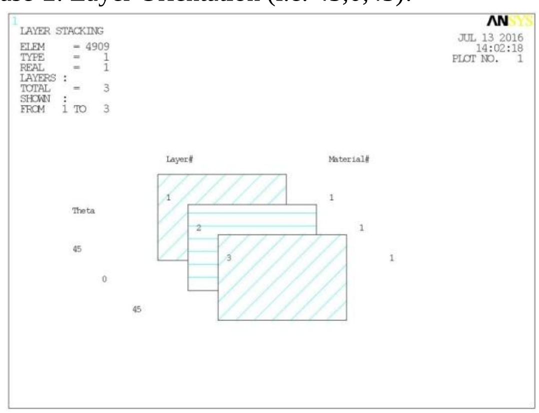
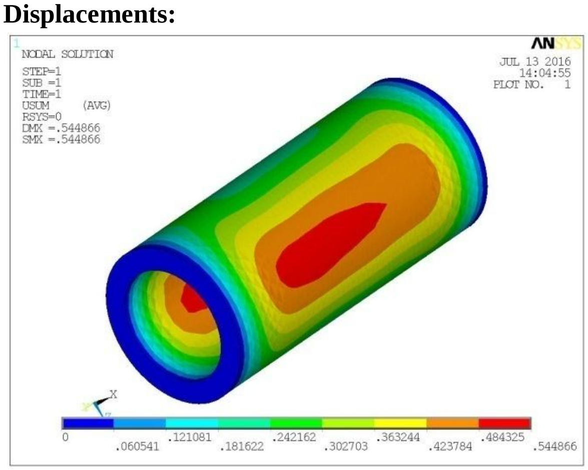


Fig shows Layer orientation for Eglass/Epoxy material of Buried pipe

RESULTS:

Displacements:



e-ISSN: 2348-6848
p-ISSN: 2348-795X
Volume 04 Issue 09
August 2017

Fig shows Resultant displacement on Buried pipe

Stresses:

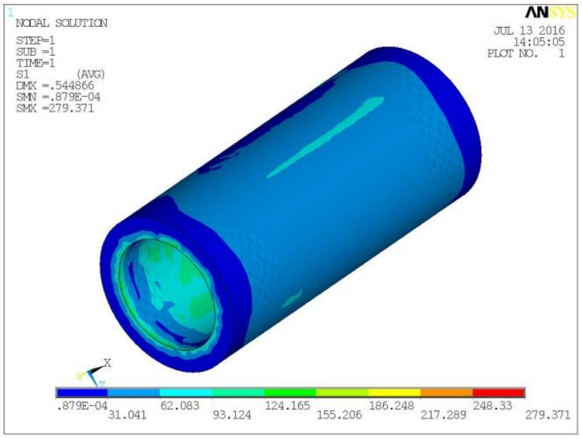


Fig shows 1st principal stress observed on Buried pipe

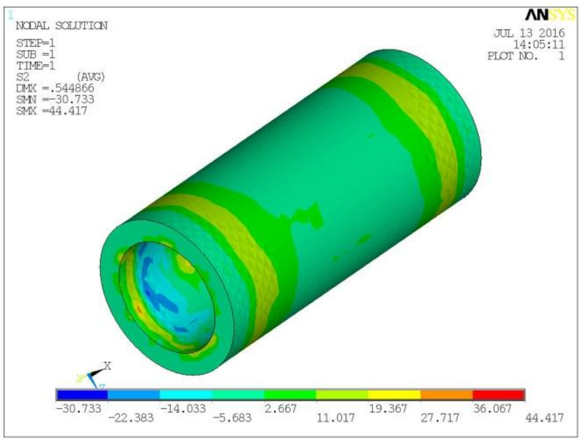


Fig shows 2nd principal stress observed on Buried pipe

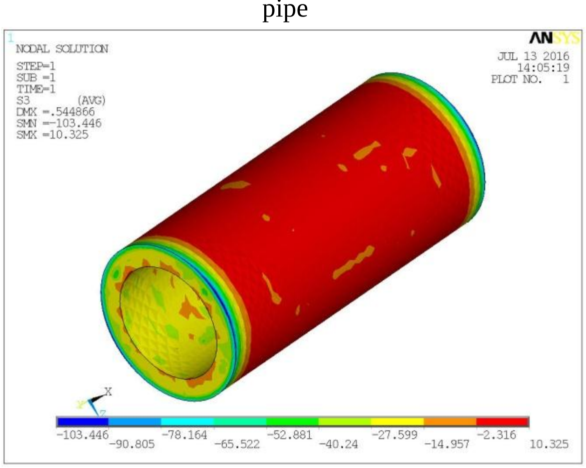


Fig shows 3rd principal stress observed on Buried pipe

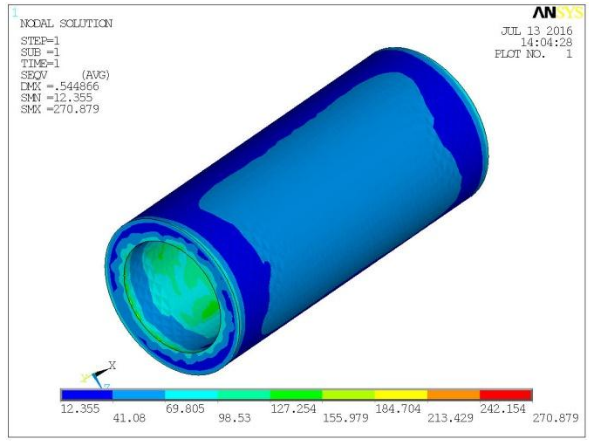


Fig shows Vonmises stress of Buried pipe

From results, the von misses stress of Buried pipe is 270.87 MPa**.** The yield strength of Eglass/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:

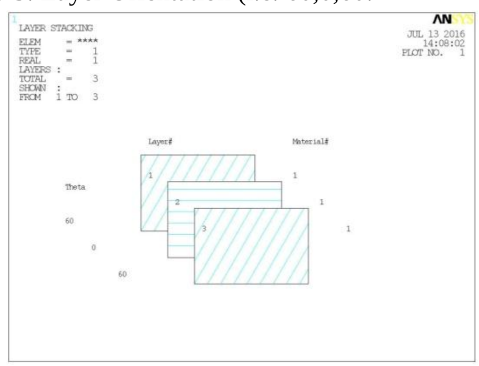


Fig shows Layer orientation for Eglass/Epoxy material of Buried pipe

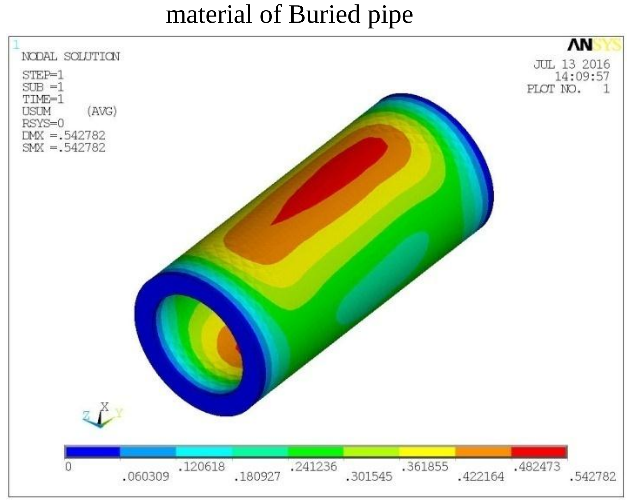


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Fig shows Resultant displacement on Buried pipe

Stresses:

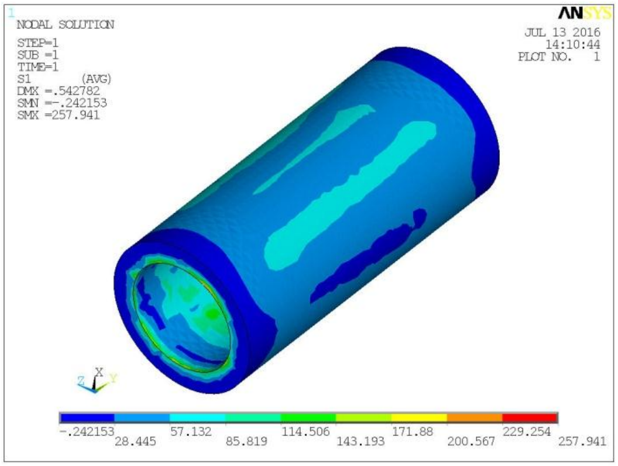


Fig shows 1st principal stress observed on Buried pipe

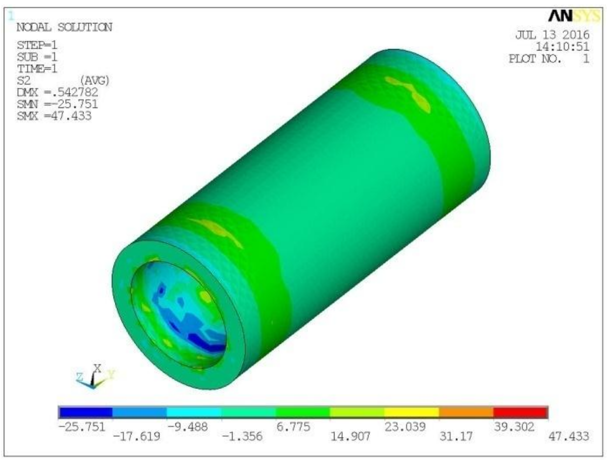


Fig shows 2nd principal stress observed on Buried pipe

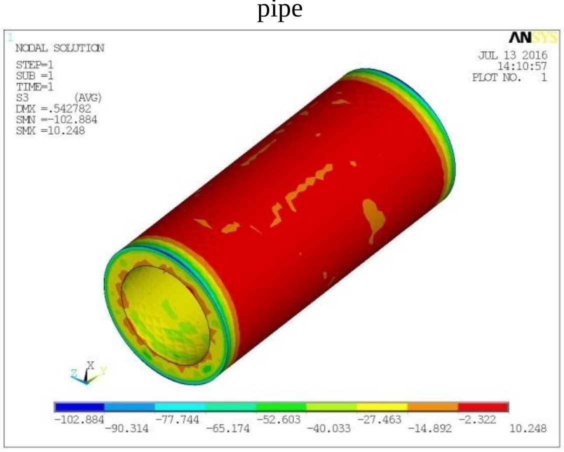


Fig shows 3rd principal stress observed on Buried pipe

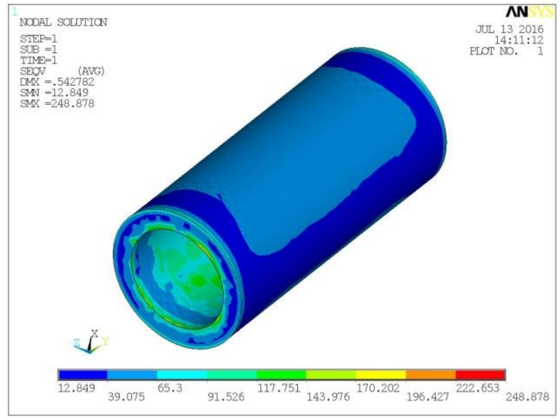


Fig shows Vonmises stress of Buried pipe

From results, the von misses stress of Buried pipe is 248.878 MPa**.** The yield strength of Eglass/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.

GRAPHS:

Graph between displacements vs. layer orientation of Buried pipe for Eglass/Epoxy is shown below

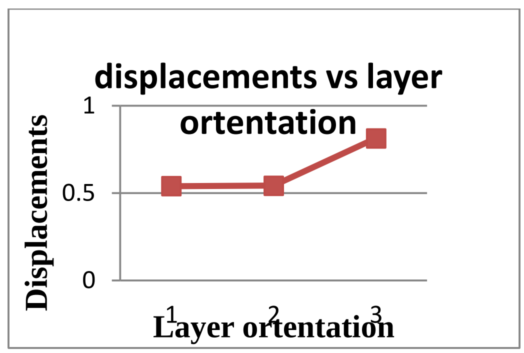
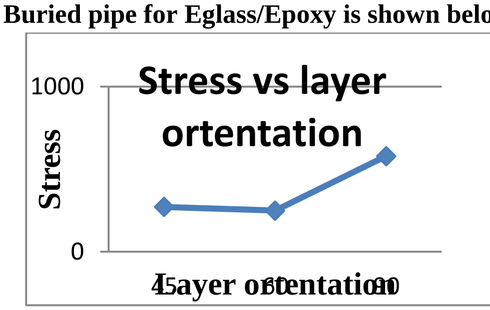


Fig shows Graph between displacements vs. layer orientation of Buried pipe for Eglass/Epoxy material

Graph between Stresses vs. layer orientation of Buried pipe for Eglass/Epoxy is shown below



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Volume 04 Issue 09
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Fig shows Graph between stress vs. layer orientation of Buried pipe for Eglass/Epoxy material

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

Case-1: Layer Orientation (i.e. 90,090) of Buried pipe for Carbon/Epoxy material:

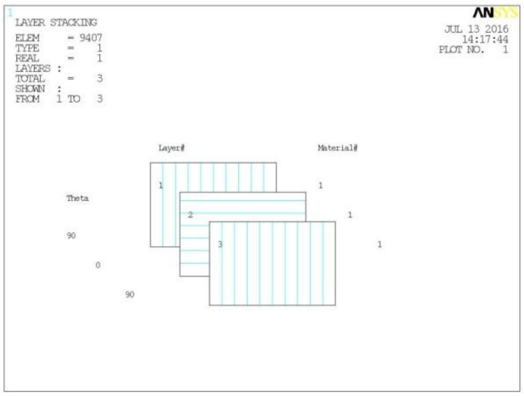

Fig shows Layer orientation for Carbon/Epoxy material of Buried pipe

RESULTS:

Displacements:

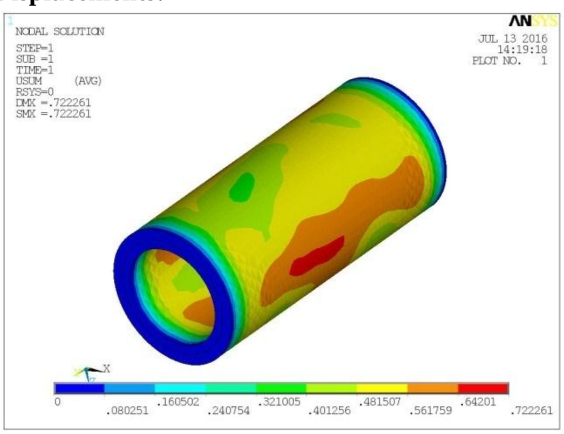

Fig shows Resultant displacement on Buried pipe

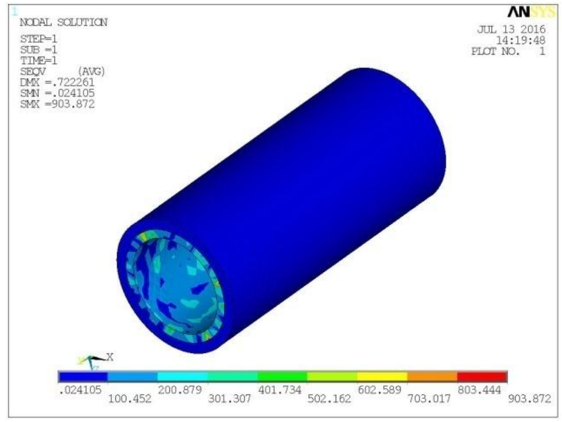

Fig shows Vonmises stress of Buried pipe

From results, 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) :

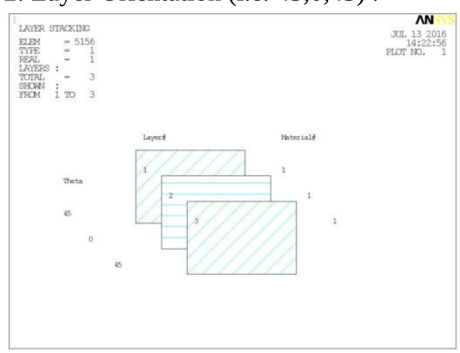

Fig shows Layer orientation for Carbon/Epoxy material of Buried pipe

Stresses:

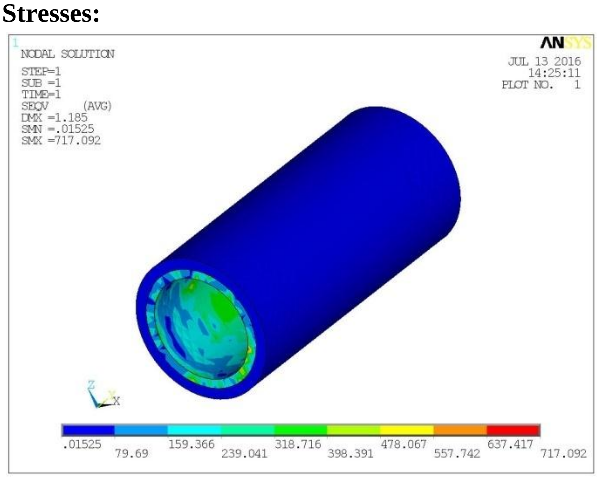

Fig shows Vonmises stress of Buried pipe

From results, 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):

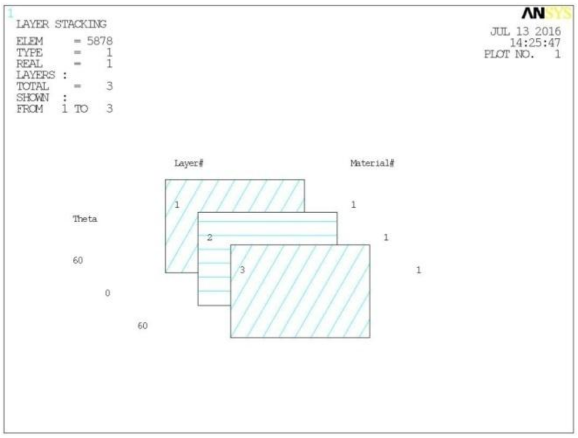

Fig shows Layer orientation for CARBON/Epoxy material of Buried pipe

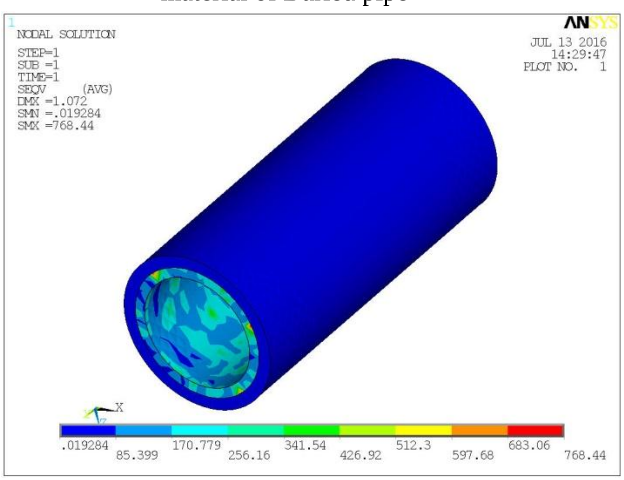

Fig shows Vonmises stress of Buried pipe

From results, 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 displacements vs. layer orientation of Buried pipe for Carbon/Epoxy is shown below

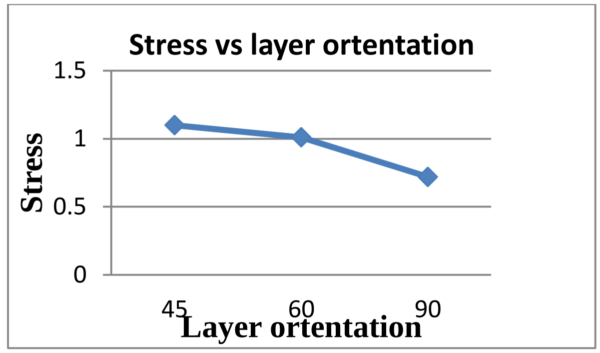

Fig shows Graph between displacements vs. layer orientation of Buried pipe for Carbon/Epoxy material

Graph between Stresses vs. layer orientation of Buried pipe for Carbon/Epoxy is shown below

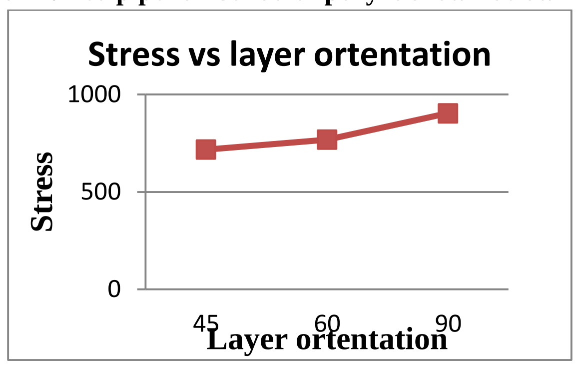

Fig shows Graph between stresses vs. layer orientation of Buried pipe for Carbon/Epoxy material

RESULTS AND CONCLUSION

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

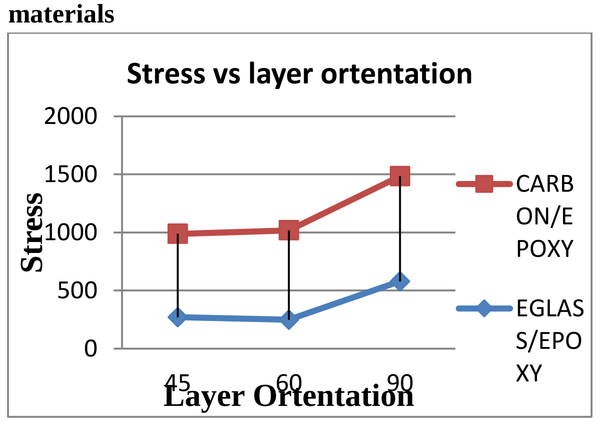

Fig shows Comparison of stress vs. layer orientation of Buried pipe for two composite materials

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

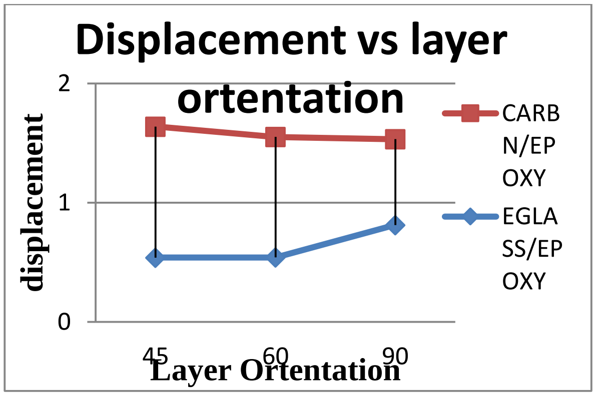

Fig shows Comparison of stress vs. layer orientation of Buried pipe for two composite materials

Conclusion:

In this project, 3d model of buried pipe was generated in NX-CAD software. Buried pipe with two soil structures (i.e. Circular and Rectangular structures) was 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 was studied for two composite materials (i.e. Eglass/Epoxy and Carbon/Epoxy materials) with different layer orientation. From analysis, the Von mises stress of Buried pipe for Eglass/Epoxy material with different layer orientation is less compared to Buried pipe for Carbon/Epoxy material with different layer orientation. Hence, it is concluded that Eglass/Epoxy material is alternative material for Buried pipe.

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