تحلیل تنش لوله های پلی اتیلن دفن شده با رفتار ویسکوالاستیک ؛ مطالعه اجزا محدود

English:

STRESS ANALYSIS OF POLYETHYLENE BURIED PIPES WITH A VISCOELASTIC BEHAVIOUR; A FINITE ELEMENT STUDY.

1. Definition of problems, objectives and hypotheses:

1.1 *Definition of the problem*:

Polyethylene buried pipes are utilized for various applications such as sewers, water and gas conveyance, highway drainage systems, and landfill drainage systems. The stresses developed within the polyethylene pipes affect the behaviour of other pipe materials in the system to which they are connected.

Performance of the buried pipes can only be evaluated based on the experience and thorough understanding the pipe-soil interaction. New pipe and backfill materials improve the pipe behavior, while new design procedures are emerging to enhance the durability and service life of these pipes.

The applied loads that are usually considered on a buried polyethylene pipe are;

1- Temperature changes in the soil.

2- The weight of the soil column above the pipe.

3- Overhead loads including traffic loads and dead loads on top of the pipe.

4- Internal pressure of the gas inside the pipe.

Although the overall behaviour of the pipeline depends on these loads; yet, understanding and modelling the polyethylene pipe for determination of stresses are the primary steps. The applied thermal and mechanical loads trigger the viscoelastic behavior of the pipes. Consequently, it is necessary to study the effect of this behavior on overall performance, and stress distribution in the pipe.

So, in this thesis the stress analysis of polyethylene buried pipes with viscoelastic behaviour will be studied using ANSYS software program. The effects of factors such as temperature, gas pressure, traffic load, as well as other types of loads will be studied on the viscoelastic behaviour of the buried polyethylene pipe and its junctions.

1-2 *Main goals:*

Polyethylene has highly time-dependent and temperature dependent properties. The mechanical properties of polyethylene can change significantly even within the range of temperatures found in typical Mechanical engineering applications, e.g., the modulus can change by a factor of two between 0 and 50°C. Under a constant strain rate, higher temperatures decrease the material modulus and increase material ductility. When the temperature is held constant during mechanical testing, strain rate has a significant effect on material properties. With a higher strain rate, molecular chains have less time to deform under load, leading to a stiffer response. In a viscoelastic material such as polyethylene, the stress generally is a function of both time and applied strain. Poisson's ratio in viscoelastic materials is a function of time. Earlier studies showed that linear viscoelasticity can be applied to polyethylene when the stresses are less than about 60% of the yield stress or when the strains are less than 0.01. When the thermal stresses in polyethylene pipes are concerned, a 0.01 strain would be caused by a temperature change of approximately 55°C. The temperature changes in buried polyethylene pipes are expected to be less than 55°C; therefore, the strains due to a thermal loading are expected to be less than 0.01.

The flexible nature of the PE pipe under overlying load or surface load allows the pipe to deflect and induce passive pressures against the surrounding soils as the sides of the pipe try to move outward with an increase in the horizontal deformation. Vertical pipe deformation relieves the load acting on the pipe and redistributes it around the pipe. A phenomenon called 'soil arching' reduces the load acting on the pipe as the load is redistributed to the surrounding soil. This behaviour of flexible pipe coupled with the time-dependent nature of pipe and soil has complicated the process of evaluation of the long-term performance of polyethylene pipes. Despite this, there has been a continuous increase in the use of polyethylene pipes as buried pipes.

The main goal of this thesis is to finite element modelling and also calculation the stress lifelong of PE pipe with viscoelastic behaviour.

1-3 *Assumptions:*

1. Pipe fittings and joints in the finite element model will be considered.
2. A multi-layer surrounding soil will be considered.
3. Interaction behaviour between the pipe and the soil is finite sliding contact.

2. Main specifications of the research and the stages of the project:

2-1 *Main specifications of the research plan and foundations*:

As mentioned before, the temperature is very high in the southern regions of the country, so in places where the temperature of the pipe reaches above 55 ° C, the pipe shows viscoelastic behaviour. Due to the importance of this phenomenon in pipe life, modelling and stress analysis in these conditions seems necessary. The main specification of this research is stress analysis buried PE pipe with viscoelastic behaviour.

2-2 *Steps involved in this project:*

The simulation process will involve the following stpes:

1- Model the pipe, junctions, and the soil
2- Using finite element, determine the equivalent von-Mises stress, as well as safty factor.
3- Determine the effect of the viscoelastic behavior of the pipe on its overall performance.

4- Determine the effect of the surrounding soil, loads, connections, and temperature on the pipe performance.

5- Compare the results with theoretical equations when applicable

3. Background of the subject in Iran and the world

Depth, traffic load (additional load), and other complicated stimulation (e.g. excavation load [4–6], impact load [7], and ground settlement load [8]) are considered to be the most external contributions leading to the instability of buried pipelines beneath the roadway. The fact that deflection and buckling of pipelines rely on geometric and mechanical characteristics of the pipelines is deemed to be the interior contribution escalating into the failure of buried pipelines [9]. For buried pipes, especially the flexible buried pipes, the soil around the pipe is going to be compressed once the pipe is deformed, and on the contrary, the soil around the pipe will have elastic resistance, which can prevent the pipes from further deformation. In short, backfilled earth is both a load and a constraint for the pipe body. Theoretically, the relative modulus between soil and pipes plays a great impact on the mechanical performance of buried pipe which has been verified by some researchers [10, 11]. As a whole, the influential factors of the mechanical characteristics of buried pipelines include the distribution form and magnitude of the load, the buried depth of the pipelines, the geometric characteristics of the pipelines, and also the material properties, similarly because the physical and mechanical characteristics of the backfilled earth, and also the way during which backfilled earth interacts with the pipelines.

Among previous researches, there are many literatures about the mechanical characteristics and influencing factors of buried pipelines under different loads. Liu et.al [4] discussed the mechanical response of buried polyethylene pipelines under excavation load during pavement construction and conducted parametric analysis to discuss the effect of excavation position, pipe diameter, pipe wall thickness by means of 3D finite element model. The numerical investigation of mechanical behaviour of drainage pipeline under traffic load before and after polymer grouting trenchless repairing is conducted by Fang et.al [12]. In this literature, the effect of load type, load location, and buried depth on the mechanics of pipe are discussed in detail. And also discussed the mechanical properties of long distance gas pipeline in embankment, and analysed the influences of pipeline buried depth, embankment geometry parameters and soil mechanics parameters on the mechanical properties of pipeline. Han et.al [13] studied the mechanical behaviour of buried pipelines in hard rock areas under surface load, and discussed the influence of soil filling properties, load size and pipeline parameters. Yang et.al [14] established a three dimensional pipe-soil model based on contact unit by using ANSYS software, and discussed the influence of pipe burial depth, soil strength parameters and pipe-soil contact parameters on pipe-soil interaction. However, few of them focused on the inherent viscoelastic behaviour of polyethylene pipes which response to load in the form of material creep and stress relaxation [9, 15] and relative modulus between soil and pipe.

on finite element modelling of buried polyethylene gas pipes are applied to further estimate the maximum stress values in underground polyethylene gas pipe problems which are imposed to the local geometry changes in the form of socket joints and repair patches [16].

As above mentioned history in all researches, the behaviour of buried pipes has been done without considering the viscoelastic property, and one of the innovations of this dissertation is stress analysis considering the viscoelastic behaviour.

<u>References (based on sources mentioned in the history):</u>

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B- Type of Research Work:

Theoretical □ Practical □ Applied-Practical □ Applied-Theoretical ■

Work progress timing:

row	Stages and titles of the project in order of priority	Duration (month)	Essentials
1	Studying and reviewing valid sources, books and articles related to thesis.	1	
2	Modelling buried pipe with viscoelastic behaviour in ANSYS	2	
3	Simulation and analysis stress of the buried pipe.	1	
4	Extraction of formulations and problem theory information and resulting data from finite element software.	1	
5	Summarizing, presenting the results, suggestions and writing dissertations.	1	

*If necessary, send the details of the proposed thesis in the form of a research project to the attachment.

Titles of other theses in progress:

row	Student Name	Project Titles	Cross

C- Advisor's profile:

Name: M. Shishesaz Academic Rank: Professor

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D- Projected costs (with the case mentioned):

Rows	Spent Items	Price Forecast (Rials)
1	The cost of copying and duplicating the cost of reproduction, books and purchase of articles	
2	The cost of purchasing the software	
3	Other costs (travel, experiments, etc.)	
	Total costs	

The first and last name of the Co-advisor: **Dr. Hussam Ali Khalaf** **Date: Sept / 18 /2021**