Investigation Depth of Buried Pipeline on Stress

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Abstract

This paper has invested stress-strain on the buried pipe line in soil, under seismic load and also effect of buried on stress and displacement of pipe line. Material of pipe is gray cast, its diameter is 1500 mm and thickness is 20mm. Pipe buried in depth of 2, 4, 6 meter from ground surface. Seismic load is according to El-Centro earthquake. In this study, finite element models of the pipeline and soil are established using the package ABAQUS. The results show increasing in depth of buried pipe line decrease the displacement. Maximum displacement is 1.94 cm for upper path of 2 meter depth and minimum displacement is 0.7 cm for bottom path of 6 meter depth. All stress plots showed stress on pipeline is less than yield stress of gray cast, so there is no plastic strain and plastic deformation.

Key words: Abaqus, Depth, Pipeline, Stress

1. Introduction

It is acknowledged that underground structures suffer less damage from earthquakes than structures on the ground surface. Earthquakes have damaged many lifeline structures. Buried gas and water pipelines are also no exceptions. The damage or disruption of buried pipelines due to earthquakes may severely affect civil lifeline structures since it may cause fires, economic losses, and disable of lifeline networks [1].

Subsequently, the seismic analysis and behavior of buried pipelines have been investigated by many researchers. Most of the studies mainly deal with the numerical modeling of buried pipelines, soil-pipeline interaction, and earthquake induced pipeline stress. The seismic response analysis of buried pipelines is somewhat complex since it considers the three-dimensional dynamic analysis of the soil-pipeline interaction under multipoint earthquake excitation [2]. Therefore, a rigorous analysis is impossible. For these reasons, it is necessary to use elaborate and state-of-the-art test devices in order to estimate failure aspects of buried pipeline. However, Finite Element Method (FEM) is also helpful for executing rigorous analysis for seismic response analysis of buried pipelines [3].

Investigating geotechnical problems using FEM has been widely used in this research area for many years even though there are limitations for analyzing such problems accurately. However, linear and nonlinear problems such as prediction of settlement and deformation between buried pipelines and soil is highly amenable to solution by FEM. For this reason, ABAQUS, which is used for general Finite Element Analysis (FEA), was chosen in order to estimate failure aspects of buried pipelines [4].

The main purpose of this study is to understand magnitude of stress on buried flexible pipeline caused by earthquake through FEA.

2. Method and Simulation

In this study, finite element models of the pipeline and soil are established using the package ABAQUS to carry out stress analysis of buried pipeline caused by static and seismic loads. In order to perform this analysis for a buried gray cast pipeline, it is necessary to accept three basic assumptions as below [5].

1- The welding between pipeline segments is not considered.
2- The soil is elasto-plastic characterized by Mohr Coulomb theory and the pipeline is isotropic, elastic and perfectly plastic.
3- Pipeline and soil are fully bonded each other and the interface between pipeline and soil is perfect without defects.

According to mention of Jeremy, there are a lot of factors, which influence the effect of seismic action on underground water pipelines, such as conditions of soil, severity of ground shaking, and surges in internal pressure, design dimensions including diameter and wall thickness and material strength of pipelines [6]. Each of these factors has to be considered in pipeline design and analysis in order to evaluate and reduce possible damage because each of these factors exerts different influence in different situations. It is impossible to execute accurate study for seismic behavior of pipelines, which considers all of factors from seismic action and pipelines because different failures of pipelines will be shown due to diverse factors. This means that it is necessary to choose limited variable associated factors for assessing damages of pipelines.

Leon and Wang reported that the movement of buried pipelines is closely linked to the ground in both lateral and longitudinal directions as verified by most field data [7]. It is rare for the inertia force caused by the motion of the buried pipelines to influence the response of buried structure itself. It is concluded that the ground displacement characteristics caused by an earthquake affect mainly the response of buried pipelines. Therefore, examining the relative seismic displacements between buried pipelines and ground are suitable for estimating failure aspects of buried pipelines caused by earthquake because the behavior of buried pipelines is mostly governed by relative ground movement from earthquake[8].

2-1- material property & dimension

It is necessary to determine ground properties for studying interaction between soil and a buried structure when considering the design of the structure [9].

The stress and strain behavior of soils is not linearly elastic for the entire range of loading of practical interest but is considerably complicated and they show a great variety of behavior when subjected to different mechanical behavior of geometrical [10]. A lot of approaches and theories have been developed in order to provide a better prediction of complicated material behavior of soil. However, although the results obtained by more other sophisticated stress-strain criteria are more accurate in estimating actual soil behavior, coulomb theory related to soil's mechanical properties is a more straightforward method than others for dealing with mechanical behavior of soil[11].

Therefore, it is the best way is to create a soil model using the Mohr-Coulomb theory in order to execute a study will give a benefit for understanding interaction between soil and buried structure straightforwardly.

In order to accomplish the specific study for stress analysis of buried pipelines caused by earthquake, the relative large diameter gray cast pipeline which is used for water supply has been chosen, and an elastic, perfectly plastic and isotropic analysis for pipeline has been conducted on this study as following below table1

Table 1: Mechanical properties of pipeline

Mechanical properties	Term	Value
Elastic property	Density (kg/m3)	7300
	Young's modulus (MPa)	172000
	Passion ratio	0.28
Plastic property	Yield stress (Mpa)	230
	Tensile Strength (Mpa)	400

Pipeline dimensions given in below

Table2: Pipeline dimensions

Thickness	Length	Diameter
t= 18 mm	L= 30 m	D=1500 mm

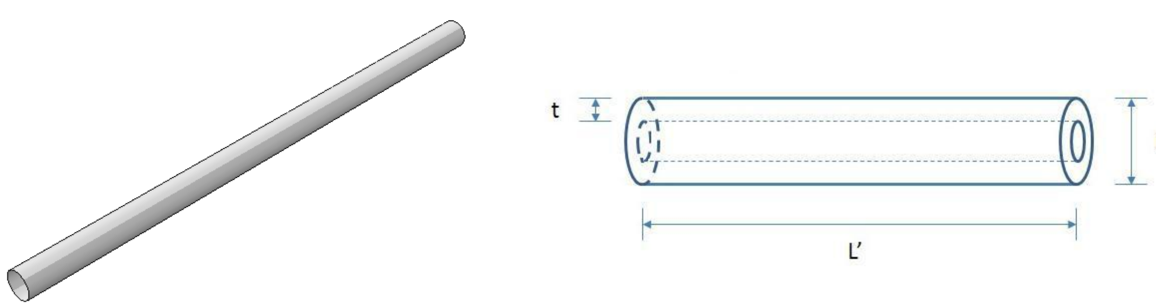


Figure 1: pipe line

in order to execute the study for interaction between soil and buried structure caused by earthquake, a typical type of soil was considered. Elasto-plastic analysis by Mohr-Coulomb theory has been conducted as mechanical properties of soil. For plastic property of soil, the representative maximum value of soil has been used for study as in Table 3.

Table 3: Mechanical properties of soil

Mechanical properties	Term	Value
Elastic property	Density (kg/m3)	1950
	Young's modulus (MPa)	50
	Passion ratio	0.32
Plastic property	Cohesive strength (Kpa)	15
	Friction angle (deg)	29
	Dilation angle (deg)	2

Soil dimensions given in below

Table 4: Pipeline dimensions

Distance from ground surface	height	length	width
H=5 m	h= 2,4,6 m	L= 30 m	W=10 m

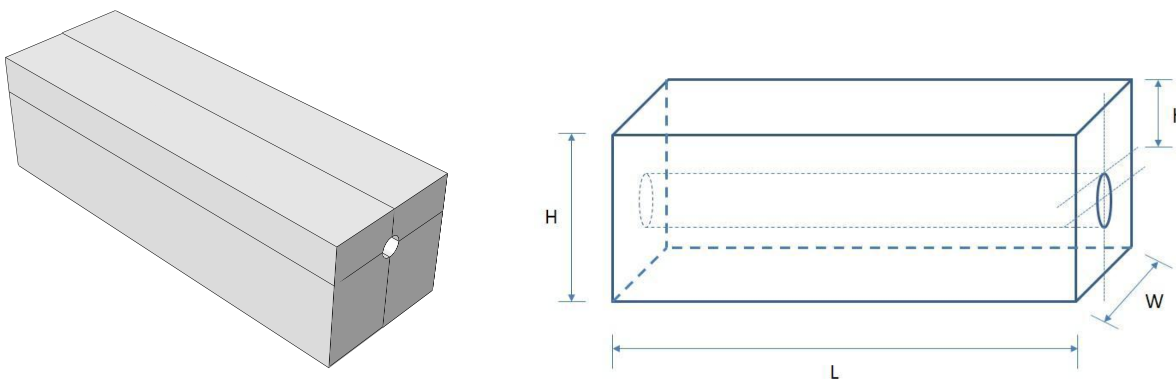


Figure 2: soil

All dimensions are in base of real dimension.

2-2- load & boundary condition

In general, several loads and load combinations affect buried pipe lines. Thus, the effect of these loads has to be considered in pipeline structure design and analysis. According to Yong (2001), loads can be fractionalized as functional loads and accidental loads; functional loads are the operated loads usually in normal condition and accidental loads are rarely loads influencing the structure.

In this study, the functional loads can be expressed as weight of soil and pipeline and internal pressure of pipeline and accidental loads can be manifested by seismic load.

Firstly weight of soil is mass of soil multiply gravity of earth and water pressure in pipelines is operated between about 276 kPa and 414 kPa. Therefore, 414 kPa, which is maximum water pressure in pipeline, will be considered in this study in order to examine critical state of buried pipeline [12].

Stress waves in the ground are produced by earthquakes and various directions of the earthquake movement are instigated. These waves make the movement of ground more complex by reflecting and refracting waves. That is, the ground motion parameters such as amplitude of motion, frequency content and duration of the ground motion change because the seismic waves propagate through overlying soil and are refracted until reaching the ground surface.

In order to apply seismic load in this study, the accelerogram dealing with amplitude of earthquake load, peak acceleration and time history has been used as in Figure 1.3 because the behavior between soil and buried structure under earthquake motion can be analyzed by the ground acceleration as a series of harmonic components [13].

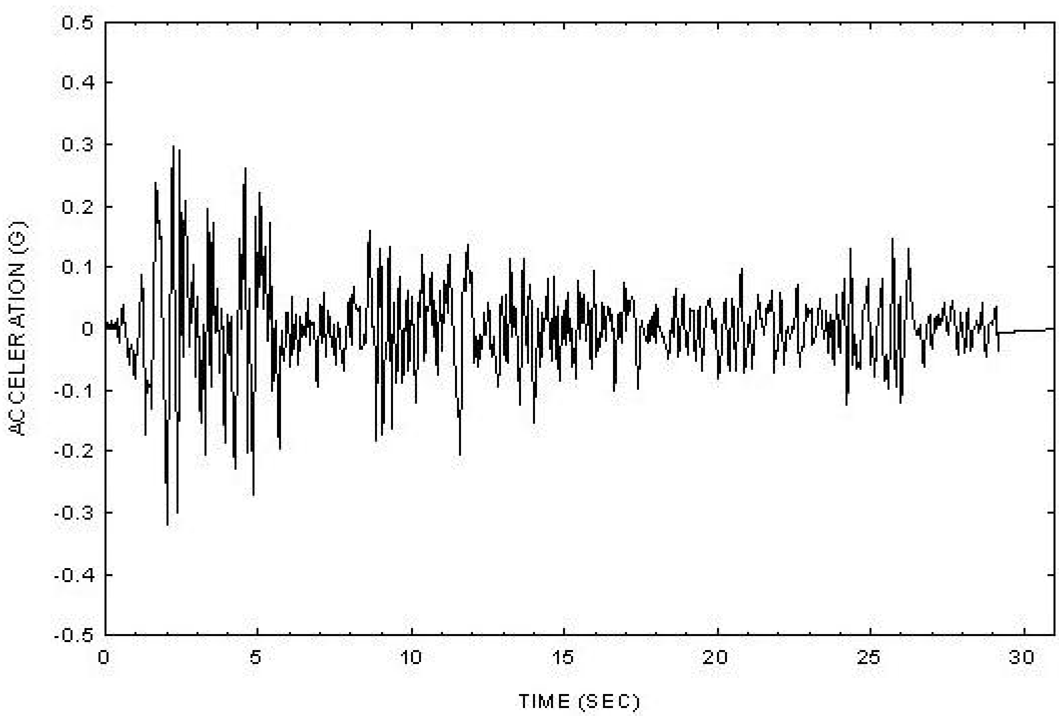


Figure 3: earthquake acceleration

Table 5: loads

Static loads	Gravity (m/s2)	9.81
	Internal water pressure in pipeline (kPa)	276 to 414
Seismic load	Peak acceleration of earthquake (g)	0.3
	History time (sec)	31.18

2-3-Boundary condition

For this study, assumed infinite length for buried pipeline. It is acceptable to consider roller as the boundary of the ends of pipeline because the buried pipeline may be moved with soil relatively

Additionally, the bottom surface of 3D-FE soil model is proposed to be completely fixed This is because the bottom boundary is selected at the known location of a bedrock surface.

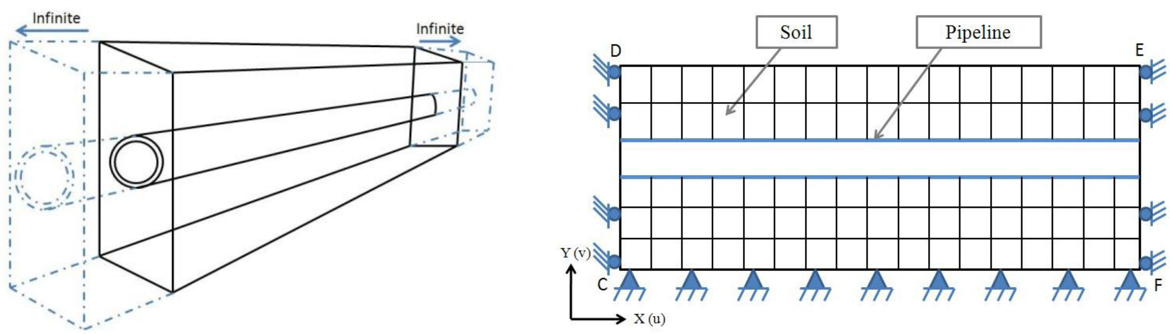


Figure 4: soil- pipeline boundary condition

2-4-Mesh study

For Finite Element Analysis (FEA), it is very important to determine the type of element, the shape of element and the number of elements in order to obtain the more accurate results based on the available computational capacity [14].

Mesh refinement for selecting the optimal number of elements is a difficult issue. This is because there is no regulation which number of meshed elements is an optimum number for the accuracy of analysis. Thus, in order to examine the best adaptable number of elements, it is necessary to investigate all the cases of each number of elements from a coarse mesh to a fine mesh within the range based on available computational capacity [15]. After several examinations, best number for element and node is like below

Table 6: number of element

Total number of nodes	Total number of elements
14637	12400

400 linear quadrilateral elements of type S4R for pipe and 12000 linear hexahedral elements of type C3D8R for soil

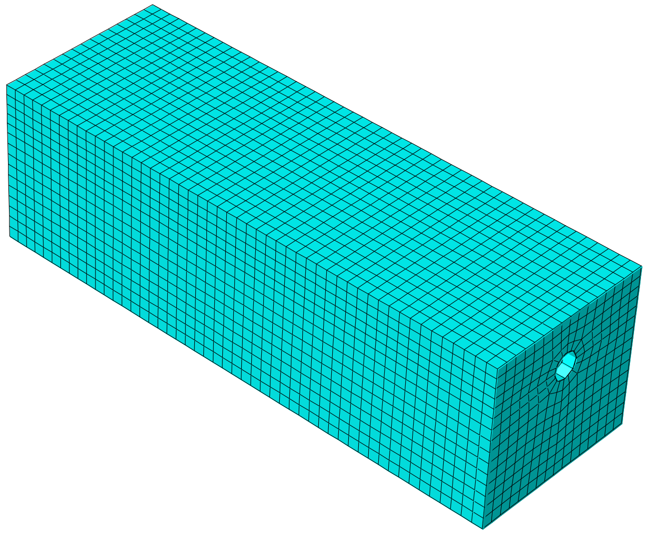


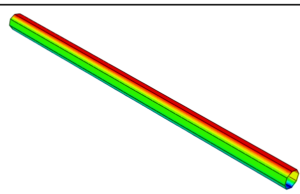
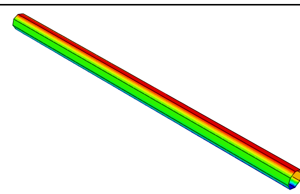
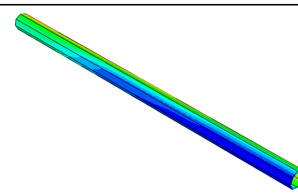
Figure 5: soil- pipeline element

4. Results and Analysis

3-1- Displacement of pipeline

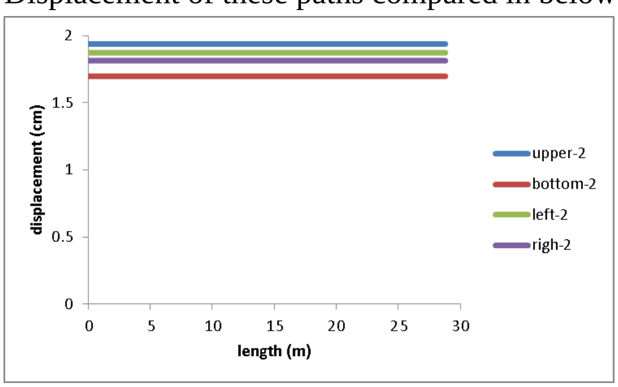
Displacement of pipe line under load, showed in table 7 for several depths

Table 7: displacement of pipe lines

Depth=2 m	Depth=4 m	Depth=6 m
		
Max displacement =1.94 cm	Max displacement =1.78 cm	Max displacement =1.06 cm

For compression displacement in pipe line, defined four paths in up, down, right and left corner of pipeline.

Displacement of these paths compared in below figures for defined paths



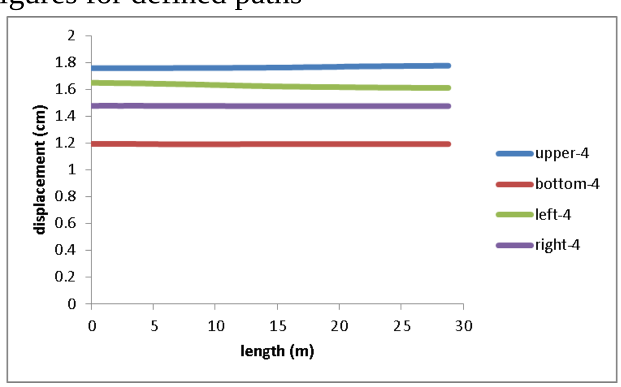


Figure 6: Displacement for depth 2 m

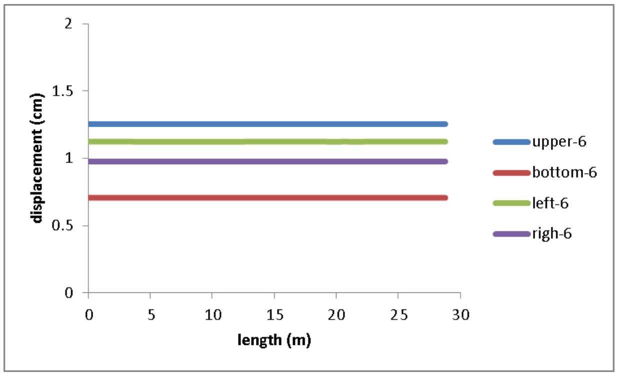


Figure 8: Displacement for depth 4m

Figure 7: Displacement for depth 4 m

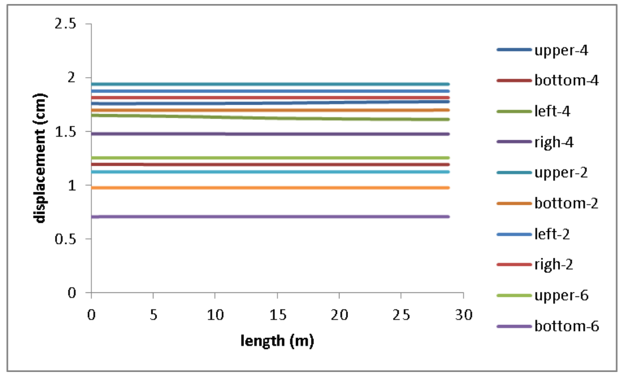


Figure 9: Displacement for all depths in different depths

It's obvious from these figures displacement in the upper of pipeline more than bottom of pipeline. Displacement for upper path of pipelines in depth of 2 m from ground surface is 1.94 cm and for the bottom path is 1.69 cm also for upper path of pipelines in depth of 4 m from ground surface is 1.76 cm and for the bottom path is 1.19 cm and for upper path of pipelines in depth of 6 m from ground surface is 1.25 cm and for the bottom path is 1.06 cm

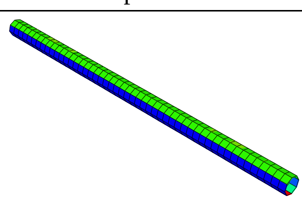
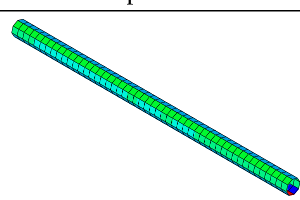
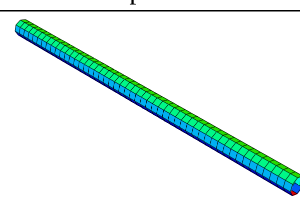
Maximum displacement is 1.94 cm for upper path of 2 meter depth and minimum displacement is 0.7 cm for bottom path of 6 meter depth.

So with increasing 200% in depth (2m to 6m) displacement decrease about 0.64%

3-2-Stress

There are two type stresses on pipe: inner stress and outer stress. Inner stress is more than outer stress because of water pressure, so for this study maximum von misses' stress has considered.

Table 8: displacement of pipe lines

Depth=2 m	Depth=4 m	Depth=6 m
		
Max von misses stress =34 MPa	Max von misses stress =74 MPa	Max von misses stress =55 MPa

For compression von misses stress in pipe line, defined four paths in up, down, right and left corner of pipeline like pervious section.

Von misses stress of these paths compared in below figures for defined paths.

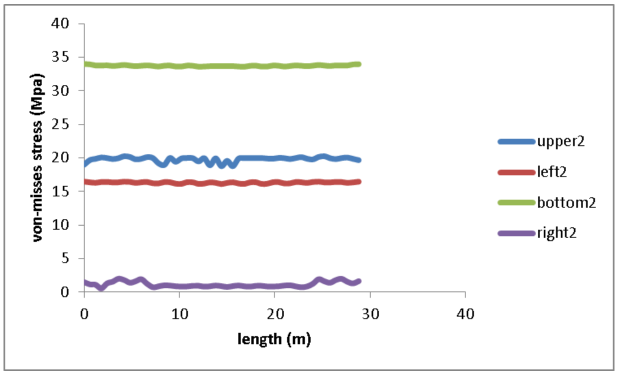


Figure 10: von misses stress for depth 2 m

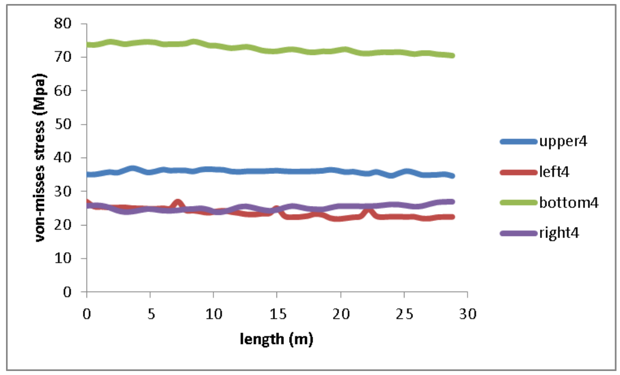


Figure 11: von misses stress for depth 4 m

It's obvious from these figures von misses stress in the bottom of pipeline more than upper of pipeline. Von misses' stress for bottom path of pipelines in depth of 2 m from ground surface is 34 MPa and for the upper path is 20 MPa also for bottom path of pipelines in depth of 4 m from ground surface is 74 MPa and for the bottom path is 35 Mpa.

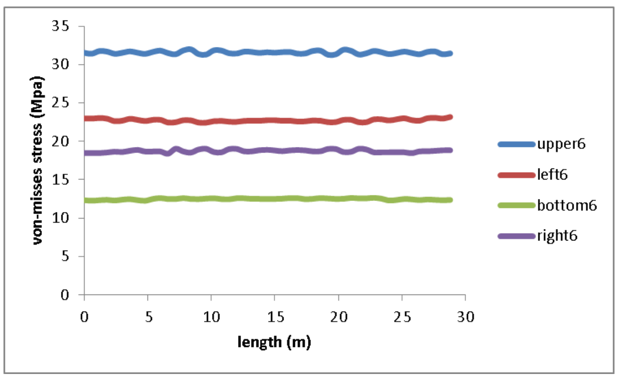


Figure 12: von misses stress for depth 6 m

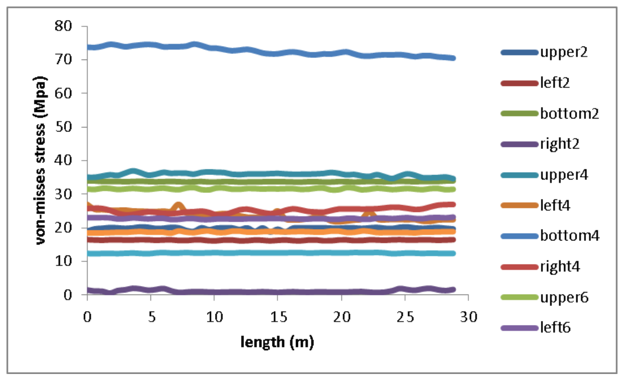


Figure 13: von misses stress for all depths in different depths

All plots in upper figures have showed stress on pipeline is less than yield stress of gray cast (230 MPa), so there is no plastic strain and plastic deformation.

5. Conclusions

In this paper has invested stress on the buried pipe line in soil, under seismic load and also effect of buried on stress and displacement of pipe line. Material of pipe is gray cast, its diameter is 1500 mm and thickness is 20 m. Pipe buried in depth of 2, 4, 6 meter from ground surface. Seismic load is according to El-Centro earthquake. In this study, finite element models of the pipeline and soil are established using the package ABAQUS. The results show displacement in the upper of pipeline more than bottom of pipeline and also increasing in depth of buried pipe line decrease the displacement. Maximum displacement is 1.94 cm for upper path of 2 meter depth and minimum displacement is 0.7 cm for bottom path of 6 meter depth. So with increasing 200% in depth (2m to 6m) displacement decrease about 0.64%. All stress plots showed stress on pipeline is less than yield stress of gray cast (230 MPa), so there is no plastic strain and plastic deformation.

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