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Modeling of Buried Pipe Deformations

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Abstract : *The present paper investigates the mechanical behavior of buried PVC pipe below the ground surface. The pipe uses in sewage lines and it is on 7.4m below the ground surface. Also, the vertical and horizontal loads that come from burying under highways, railways, tall building, dams, and airports, they cause deformations for buried pipe. In this paper, it focuses on the effects of various soil and different loads on the buried PVC pipe. ABAQUS finite element software package, was used to modeling buried pipeline behavior underground surface-induced actions, using contact elements to describe the soil–pipe interaction and show the deformation on the pipe. Furthermore, an analytical methodology was presented by using different loads on the pipe (They cause vertical and horizontal pressure on the buried pipe), with different soil layers in the properties. The results from the present investigation are aimed at determining the fault displacement for buried pipe and can be used for pipeline design purposes. A simplified analytical model is also developed to illustrate the loads effects on buried pipe deformation.*
Keywords : *Buried PVC pipe, Deformations, Soil layers, Load effect, Mechanical behavior*

I. Introduction

Pipe used for transmission of water, and various other liquids can be divided into two main categories as flexible and rigid pipes. Moser,A.P., R.K. Watkins, and O. K. Shupe [1] studied the external soil pressure on the PVC pipes and recognized that, apart from the geometric and mechanical properties of the PVC pipeline, site conditions (i.e. the properties of the surrounding soil that it effects on the pipeline) may have a strong influence on pipeline response.. Gresnigt AM, Karamanos SA. [2] studied the local buckling strength and deformation capacity on the pipes. Bilgin [3] made test method to determine the in-place density and unit weight of soils using a sand cone apparatus. Radu Popescu and Arash Nobahar [4] made analyzing the effects of groundwater on the soil-pipe interaction forces, for various loading conditions, and assuming either drained or undrained conditions. Hurley, S. and Phillips, R.,[5] investigated the pipeline/soil interaction during lateral loading. Yeh, Y. H., [6] investigated the landslide effects to buried pipelines. The loads from different structures imposed on conduits buried pipe in the soil depend on the stiffness properties of both the pipe structure and the surrounding soil. The work described in the present paper is part of an extensive research effort aimed at investigating the mechanical behavior of buried PVC pipelines crossing active faults for various soil conditions.

II. numerical modeling

ABAQUS finite element analysis software package, was used for the parametric study in this paper. ABAQUS has been developed specifically for the analysis of deformation and stability in geotechnical engineering projects. The calculation itself is fully automated and based on robust numerical procedures. It should be noted that he simulation of geotechnical problems by means of the finite element method implicitly involves some inevitable numerical and modeling errors. Finite element methods adopted in commercial software ABAQUS has been used in the analysis of structural elements involving excavation procedures. However, past failures indicated that the successful analysis using the codes is essentially depended on the selection of constitutive model used to represent soil behavior and the selection of the related soil properties. With ABAQUS, it is possible to model different element types such as Displacement on the buried pipe during, various types of loads and soil layers on the pipe. In this paper, it considered behavior of pipe by applying load on it with using different loads, and it also studied the mechanical behavior of buried pipe during using various loads and soil layers.

Pipe Behavior By Applying Loads

The paper studied behavior of pipe by applying loads on it from 100 to 300 (Ib/in) to calculate the diameter changes in vertical and horizontal direction, by using Ring-Deflection Theory are given:

$$\Delta D_H = 0.137\frac{PR^3}{EI} \qquad (2.1)$$

and

$$\Delta D_V = -0.149\frac{PR^3}{EI} \quad (2.2)$$

Where:
P: The applied point load.
R: The pipe radius.
E: The Young's modulus of the pipe.
I: Moment of inertia per unit length of pipe.

$$I = \frac{t^3}{12} \quad (2.3)$$

Where:
T: The pipe wall thickness

$$P = \gamma H D_0 \quad (2.4)$$

Where:
γ: The total unit weight of the soil
H: The depth of pipe burial
D_0: The pipe outside diameter. (Bilgin,1999)

III. Result and Discussion

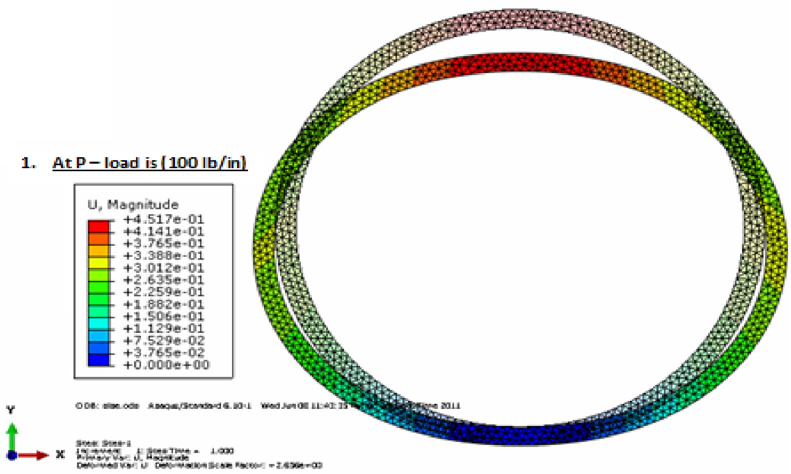

Fig.1 Deformed Shape during applying load (P = 100 Ib/in)

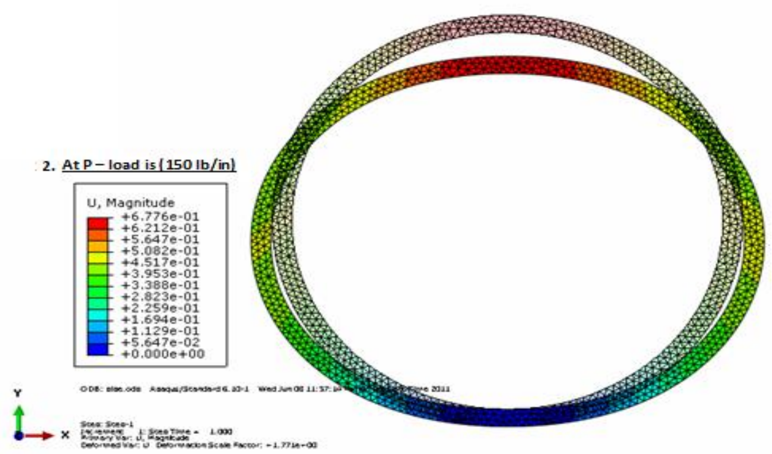

Fig.2 Deformed Shape during applying load (P = 150 Ib/in)

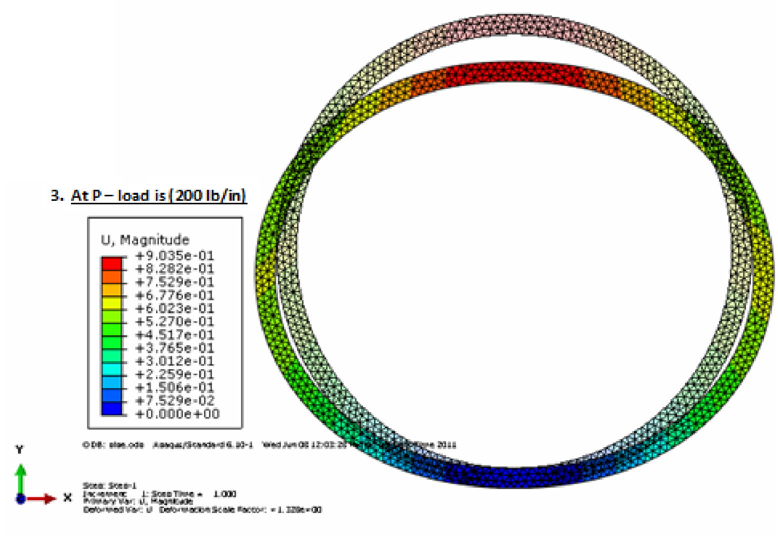

Fig.3 Deformed Shape during applying load (P = 200 Ib/in)

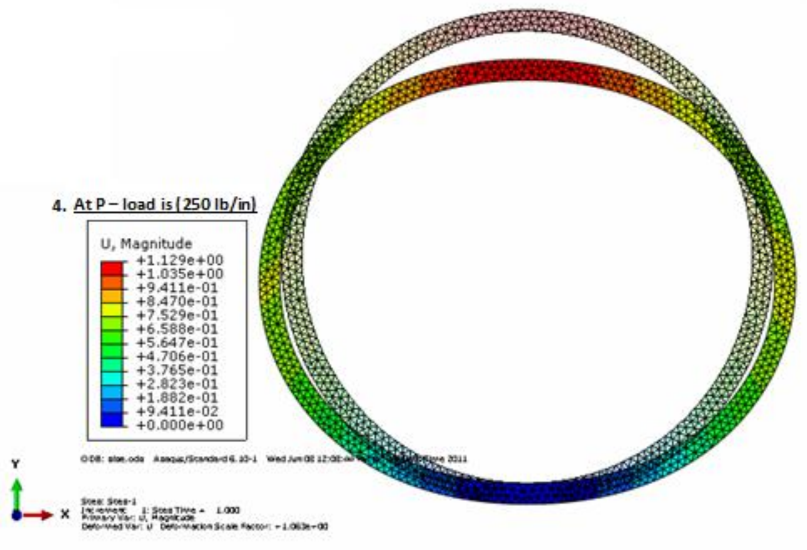

Fig.4 Deformed Shape during applying load (P = 250 Ib/in)

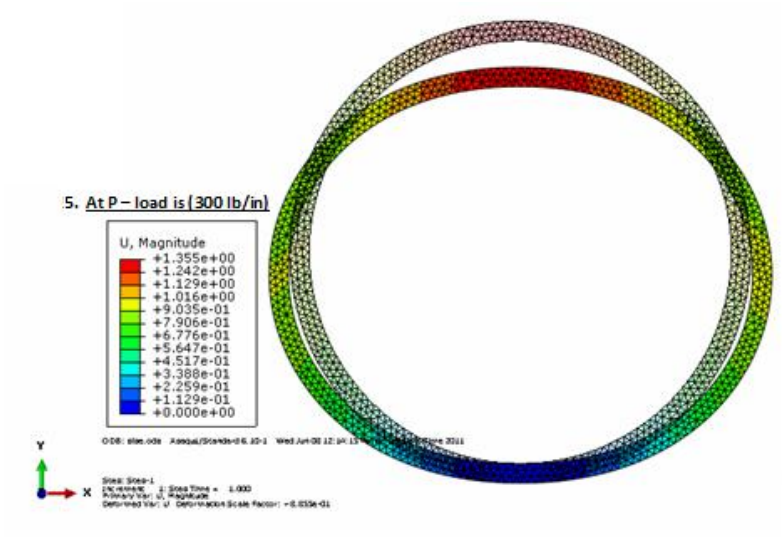

Fig.5 Deformed Shape during applying load (P = 300 Ib/in)

Table (1). It shows ΔD_V *and* ΔD_H in the pipe, and figures (6 to 7) shows the relationship between the loads and ΔD_V & ΔD_H.

Table (1): Horizontal and Vertical Deflection on the Pipe

Loads	ΔD_V	ΔD_H
100	-4.52E-01	4.10E-01
150	-6.77E-01	6.15E-01
200	-9.03E-01	8.20E-01
250	-1.13E+00	1.03E+00
300	-1.35E+00	1.23E+00

In this part when the loads increase, the deflection in horizontal and vertical direction increase as shown in figures (1 & 2). Also, the maximum deflection was in vertical direction because the horizontal direction equal KP where k is between (0.1-0.5). So, (P) in vertical direction is equal (0.1-0.5)* (P) in horizontal direction.

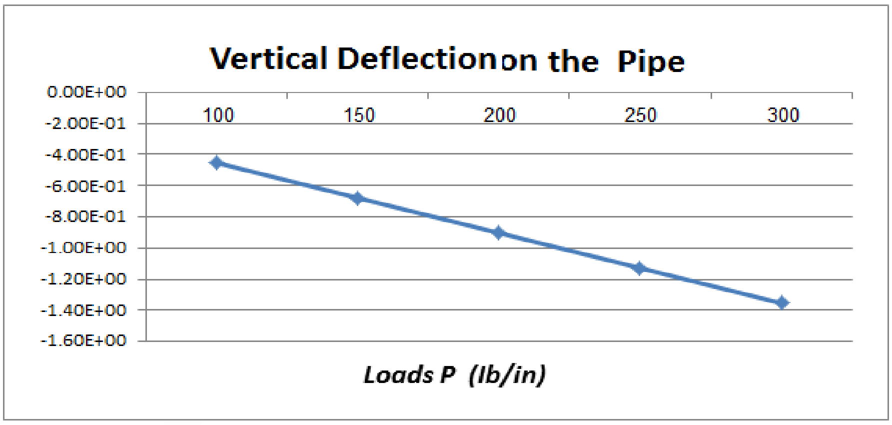

Fig.6 Vertical Deflection on the pipe

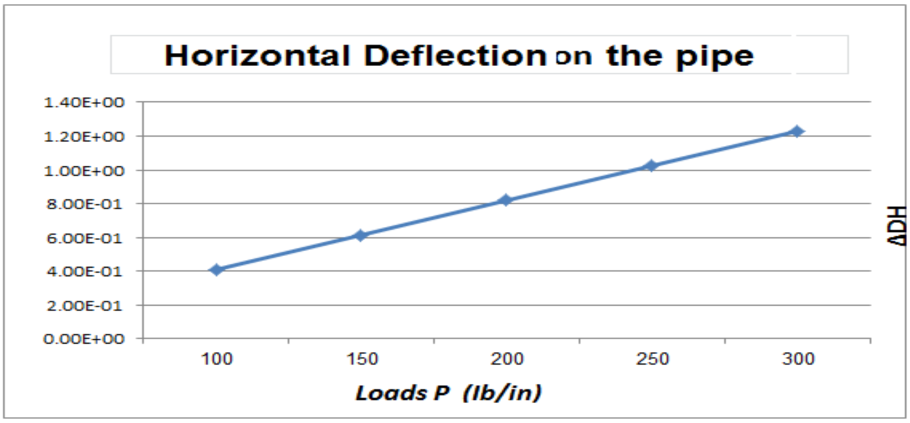

Fig.7 Horizontal Deflection on the pipe

IV. Modeling Buried Pipe Deflection

In this paper, it used different layers of soil (5 layers) with different elastic properties. Also, it used PVC pipe as shown in Table (2) because PVC has three good types:

Type I: Normal impact, very high chemical resistance and highest requirements for mechanical material strength.
Type II: High impact strength but sacrifice chemical resistance and tensile strength.
Type III: Medium impact strength, low chemical resistance. (Moser,1990)

The modeling has 20m length, 9m high, and 5m width. The pipe is on 7.4m from ground surface, and the diameter of the pipe is (0.6m). The high each layers is 2m and last one is 1m. The first layer has E=10,000Kpa, second layer has E= 10,000Kpa, third layers has E= 12,000 kpa, fourth layer has E = 8,000Kpa, and fifth layer has E =10,000 Kpa, and The Poisson's ratio also is 0.3 for all. While the pipe has E = 337,8452 Kpa and Poisson's ratio is 0.44).

Table (2): For reference, some values of Poisson's ratio and Young's modulus E for different materials

Material	Modulus	Poisson's ratio
steel	$30 \times 10^6\ Ib/in^2$	0.30
Ductile	$24 \times 10^6\ Ib/in^2$	0.28
Copper	$16 \times 10^6\ Ib/in^2$	0.30
Aluminum	$10.5 \times 10^6\ Ib/in^2$	0.33
PVC	$4 \times 10^6\ Ib/in^2$	0.45
Asbestos-cement	$3.4 \times 10^6\ Ib/in^2$	0.30
Concrete	$57{,}000\ (f_c')^{1/2} Ib/in^2$	0.30

The first load from weight of soil (P1) on the pipe and another loads are (P1+50Kpa),(P1+200Kpa), and (P1+800Kpa). We calculated P1 form soil:

$$Load\ P = H_n \times \gamma_{soil} \qquad (2.5)$$

Where:

H_n : The high of layers.

γ_{soil} : The specific weight of soil.

V. Result and Discussion

For buried pipes under pressure, The loadings are usually placed in two broad categories: internal pressure and external loads. The internal pressure is made up of the hydrostatic pressure and surge pressure. The external loads are usually considered to be those caused external soil pressure and /or surface live loads. The analysis for this modeling is conducted in two steps: gravity loading is applied first on the buried pipe and, the loads from the surface. The vertical boundary nodes of the first block remain fixed in the horizontal direction (x-direction) and including the end nodes of the PVC pipeline. When the gravity loads effect on the pipe, it gets stresses and displacements in horizontal and vertical direction. Also, the displacements increase with increasing the loads as shown in figures (11 to 14). For example, when applied the loads from weight of soil (P1=133.2 Kpa), the vertical deformation = 0.02241m and horizontal deformation = 0.00056m. See figure (8 &9) those loads caused lateral load on the pipe but it is less than vertical load so $\Delta D_V > \Delta D_H$. Also, in figure (10), it shows the stresses on the buried pipe in the vertical and horizontal direction.

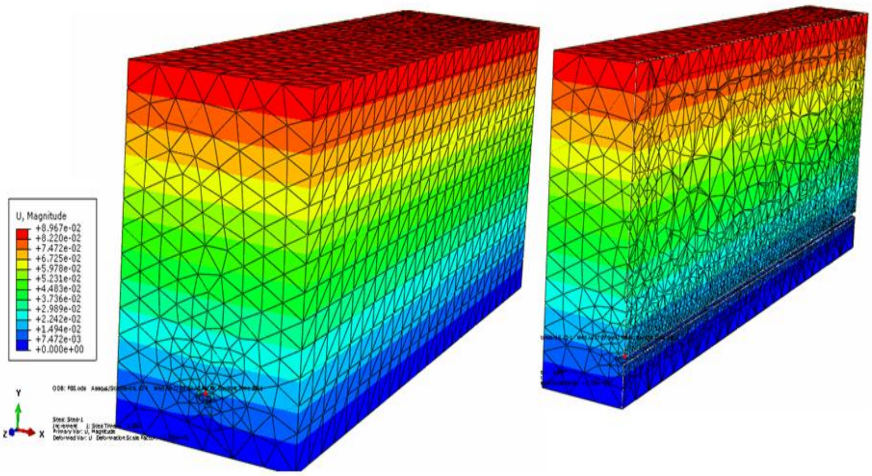

Fig.8&9 Displacement at the edge and middle of the pipe

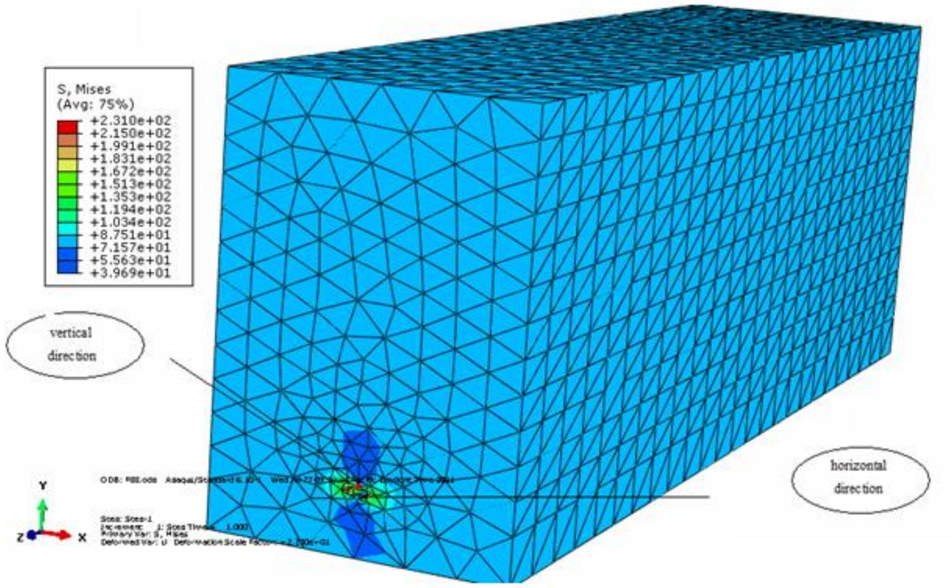

Fig.10 Stresses at the edge and middle of the pipe

Table (3): Vertical and Horizontal Deflection at Middle of the Pipe

Loads	□ v	□ H
133.2	2.24E-02	5.60E-04
183.2	3.08E-02	7.70E-04
233.2	3.92E-02	9.80E-04
333.2	5.61E-02	1.40E-03
533.2	8.97E-02	2.24E-03
933.2	1.57E-01	3.92E-03

Table (4): Vertical and Horizontal Deflection at Edge of the Pipe

Loads	□ v	□ H
133.2	1.83E-02	1.64E-03
183.2	2.51E-02	2.25E-03
333.2	2.70E-02	4.10E-03
933.2	1.28E-01	1.15E-02

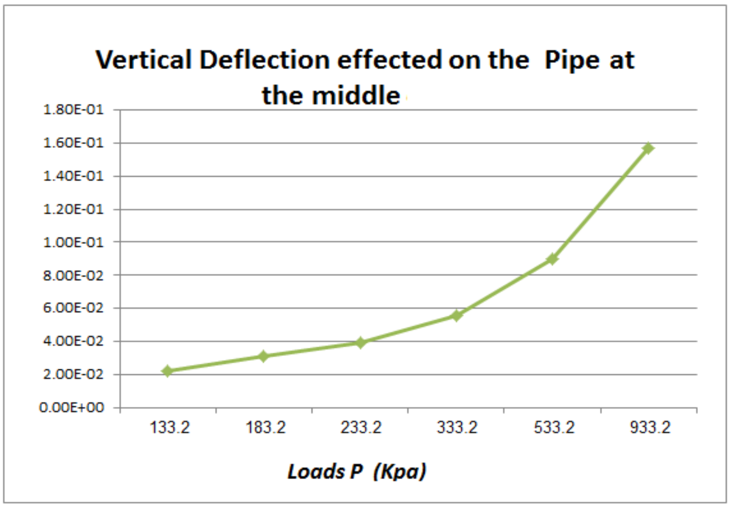

Fig.11 Vertical Deflection at middle of the pipe

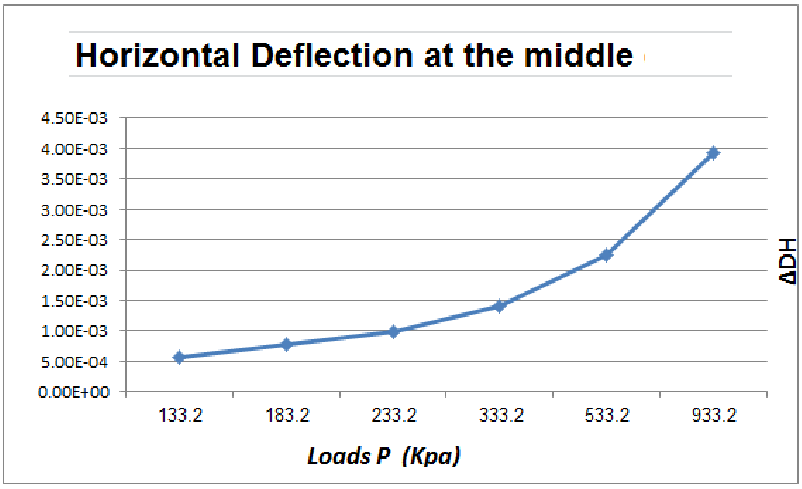

Fig.12 Horizontal Deflection at middle of the pipe

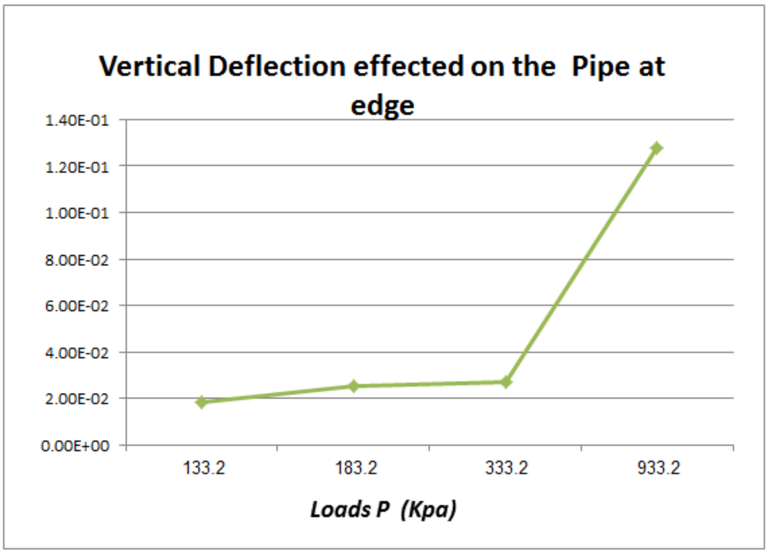

Fig.13 Vertical Deflection at edge of the pipe

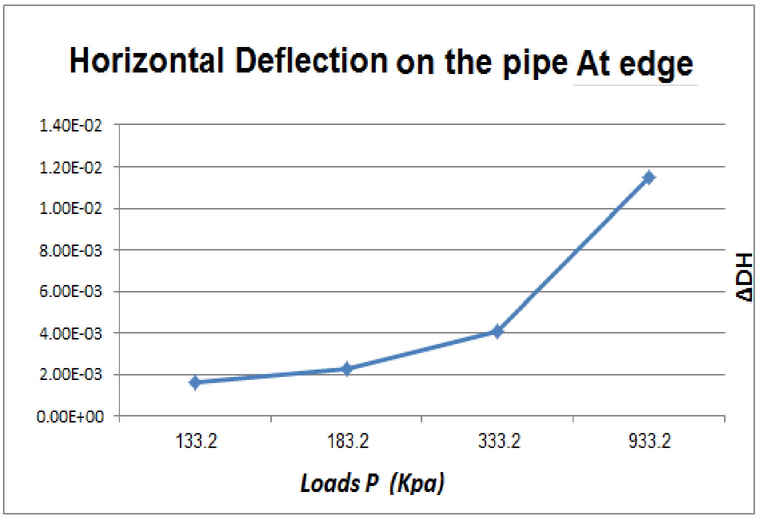

Fig.14 Horizontal Deflection at edge of the pipe

VI. Conclusion

Using advanced finite element is developed primarily for use in analysis of complex structural systems.

The technique was developed to analyze structural responses to different loading condition (Moser,1990). In this study, the loads and soil layers behaviors investigated to determine their effects on buried PVC pipe. from soil and live load on any structural underground surface. It was found that vertical deformation increases with increase the loads with using various soil layers. This deformation may cause buckling on the pipe. Analysis of buried pipe at other different material may be carried out to compare the results.

References

[1] Bilgin, Ö., Density and unit weight of soil in place by sand – cone method, Annual book of ASTM standards, V.4.08, 1992, Philadelphia,PA.

[2] Yeh, Y. H., Landslide effects to buried pipelines. Proc. Of the sixth International Conference on Numerical Method in Geomechanics, Innsbruck, ed. Swobda, G., Vol.2, 1988, pp. 901-905.

[3] Radu Popescu and Arash Nobahar, C-CORE Report: R-02-029-076, 3D Finite Element Analysis of Pipe-Soil Interaction- Effects of Groundwater., Memorial University of Newfoundland, Canada, 2003.

[4] Hurley, S. and Phillips, R., Large scale modelling of pipeline/soil interaction under lateral loading. Contract Report for Minerals Management Service, U.S. Department of the Interior, C-CORE Publication,2003, 99-C25.

[5] Liang J, Sun S. Site effects on seismic behavior of pipelines: a review. ASME Journal of Pressure Vessel Technology 2000;122(4):469–75.

[6] Moser,A.P., R.K. Watkins, and O. K. Shupe, Design and Performance of PVC Pipes Subjected to External Soil Pressure, Buried Structures laboratory, Utah states university, Logan, Utah,1990.

[7] Gresnigt AM, Karamanos SA. Local buckling strength and deformation capacity of pipes. In: Proceedings of the 19th International Offshore and Polar Engineering Conference, Osaka, Japan, 2009. p. 212–23.

[8] Uni-Bell PVC pipe association, handbook of PVC pipe design and construction, Dallas, Tex., 1982.

[9] Ellenberger,J. Phillip, " Piping systems & pipleline," the McGraw-Hill Companies,2005.