

MECHANICAL ANALYSIS OF OVALIZATION, STRESSES AND DEFORMATIONS IN BURIED PIPELINES USING MEMBRANE THEORY

Marius Serban FETEA

¹ Technical University from Cluj Napoca, Building Services Faculty

Abstract

The analysis performed is for the case of a pipeline network having different dimensional values in terms of ring diameter and length. For the study, the action of the earth's weight was considered, as well as the external action of traffic loads. For the case study considered, analyzed and treated in this paper, groundwater was not taken into account up to the level corresponding to the upper generator. The physical-mechanical and static parameters of the required pipelines were determined, using the method within the membrane theory.

Keywords: membrane, theory, displacements, stress, tensile,

INTRODUCTION

The problem of approximate determination of stresses, displacements and deformations is a challenge for every mechanical engineer. The problem is related to the external loads that the pipelines are subjected to during their operation. It is very important that they can correspond technologically and in terms of operating time. In the vast majority of cases, the mechanical calculation of pipelines is carried out based on the following types of external loads (Soare, 1999):

- soil weight;
- pipeline weight;
- groundwater action;
- road traffic load.

In the case of this work, the following types of loads were taken into account:

- soil load;
- road traffic load.

For the present case studied, 5 pipe sections with the same ring diameter and different lengths were considered. The calculation performed by the author is based on the membrane theory method.

MATERIAL AND METHOD

When analyzing and determining the intensity of the loads, the following initial data of the problem were taken into account (Bors I, 2005):

p_v^{LT} – vertical earth pressure;

$\gamma_P \left[\frac{KN}{m^3} \right]$ – specific (technical) weight of the earth;

;

$h[m]$ the angle of internal friction of the material is the filling;

$D_E[m]$ – the outer diameter of the pipeline.

The soil in which the polypropylene pipe was placed was considered to be part of group G4, which is part of the category of granular soil mixtures with a large fraction and moderate cohesion such as: very loamy mixtures of sand-coarse gravel, very clayey mixtures of coarse gravel-sand, very loamy or clayey sands, fine loamy or clayey sand, low plasticity mud.

The mechanical analysis performed is based on writing the equilibrium equations for an infinitesimal pipe element acted on in the X, Y and Z directions by the weight of the ground (Ille, Bia, Soare 1983).

The pressure created by road traffic depends on the nature of the terrain and the traffic under which the pipeline is located. The calculation relationships used to calculate the traffic pressure are the following (Ille V 1977):

$$P_{tsLT} = a_T D_T p_T \left[\frac{N}{mm^2} \right]$$

$$a_T = 1 - \frac{0.9}{0.9 + Z}$$

$$Z = \frac{4\varnothing^2 + \varnothing^6}{1.1 D_m^{0.67}}$$

$$D_m = \frac{D_E + D_I}{2}$$

$$p_T = 0.0826 \left[\frac{N}{mm^2} \right]$$

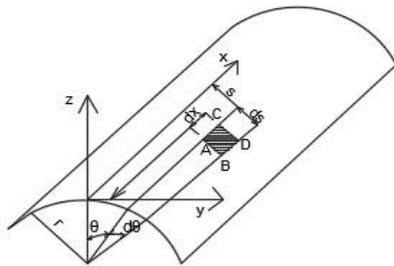


Figure 1. Infinitesimal pipe element

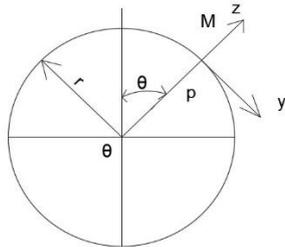
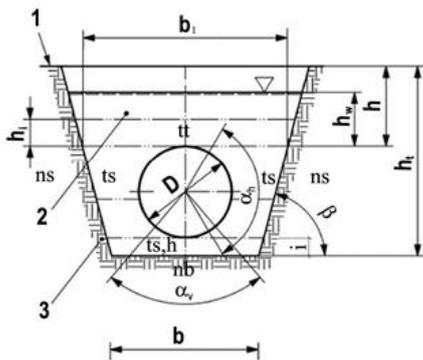


Figure 2. Ring tensions

RESULTS AND DISCUSSIONS

By applying the membrane theory, the ovalizations and the stress state were determined for each of the sections considered (Ghinea, Fireteanu. 2004). (Soare, 1999), (Ille V 1977), (Ille, Bia, Soare 1983).



The numerical method applied by the program is the finite element method, which is based on the theory of elasticity and plasticity (Martian, 1999). The physical-mechanical characteristics of the pipeline sections discussed in the paper are presented.

A Matlab calculation program of the form presented below was created for each of the sections considered separately.

Section 1

% Section D=140[mm], ring thickness 3.5 [mm],
 Length 9.8[mm]
 GAMAP = 17.65 % [KN/m3] specific weight of the soil
 r = 0.07 % radius [m] average radius of the pipe
 Hp = 1.1 % [m] depth to the upper generator of the pipe
 h = 0.0035 % [m] pipe ring thickness
 L= 9.8 % [m] pipe length
 x = [-L/2 -L/4 0 L/4 L/2]
 theta = [0 pi/2 pi 3*pi/2 2*pi] % angle on the pipe quadrant ring
 sgmadm = 150 % [N/mm^2]
 E=1400 % modulus of elasticity = stiffness (5000 [N/mm2]/I)
 miu=0.28 % Poisson's ratio
 I=3.5^3/12 % Axial moment of inertia.

Section 2

Section 2. D=168[mm], ring thickness 3.5 [mm],
 Length 2.811[m]
 GAMAP = 17 % [KN/m3] specific weight of the soil
 r = 0.084 % radius [m] average radius of the pipe
 Hp = 1.4 % [m] depth to the upper generator of the pipe
 h = 0.0035 % [m] pipe ring thickness
 L1=2811.2 % Total length of the section [m]
 L= L1/300 % [m] pipe length between 2 supports
 x = [-L/2 -L/4 0 L/4 L/2]
 theta = [0 pi/2 pi 3*pi/2 2*pi] % angle on the pipe quadrant ring
 sgmadm = 150 % [N/mm^2]
 E=1400 % modulus of elasticity
 miu=0.28 % Poisson's ratio
 I=3.5^3/12 % Axial moment of inertia.

Section 3

% Section 2 D=168[mm], ring thickness 3.5 [mm], Length 9.53[m]
 GAMAP = 17 % [KN/m3] specific weight of the soil
 r = 0.084 % radius [m] average radius of the pipe
 Hp = 1.4 % [m] depth to the upper generator of the pipe
 h = 0.0035 % [m] pipe ring thickness
 L1=953.8 % Total length of section 2
 L=L1/100 % [m] length of section 2 of the pipe taken for analysis between two of its supports
 x = [-L/2 -L/4 0 L/4 L/2]
 theta = [0 pi/2 pi 3*pi/2 2*pi] % angle on the pipe quadrant ring
 sgmadm = 150 % [N/mm^2]

E=1400 % modulus of elasticity
 miu=0.28 % Poisson's ratio
 I=3.5^3/12 % Axial moment of inertia.

Section 4

% Section 4 D=168[mm], ring thickness 3.5 [mm], Length 70.28[m]
 GAMAP = 17 % [KN/m3] specific weight of the soil
 r = 0.084 % radius [m] average radius of the pipe
 Hp = 1.4 % [m] depth to the upper generator of the pipe
 h = 0.0035 % [m] pipe ring thickness
 L1=70.28 % Total length of the section [m]
 L= L1/10 % [m] pipe length between 2 supports
 x = [-L/2 -L/4 0 L/4 L/2]
 theta = [0 pi/2 pi 3*pi/2 2*pi] % angle on the pipe quadrant ring
 sgmadm = 150 % [N/mm^2]
 E=1400 % modulus of elasticity
 miu=0.28 % Poisson's ratio
 I=3.5^3/12 % Axial moment of inertia

Section 5

% Section 5 D=168[mm], ring thickness 3.5 [mm], Length 2.811[m]
 GAMAP = 17 % [KN/m3] specific weight of the soil
 r = 0.084 % radius [m] average radius of the pipe
 Hp = 1.4 % [m] depth to the upper generator of the pipe
 h = 0.0035 % [m] pipe ring thickness
 L1=301.2 % Total length of the section [m]
 L= L1/30 % [m] pipe length between 2 supports
 x = [-L/2 -L/4 0 L/4 L/2]
 theta = [0 pi/2 pi 3*pi/2 2*pi] % angle on the pipe quadrant ring
 sgmadm = 150 % [N/mm^2]
 E=1400 % modulus of elasticity
 miu=0.28 % Poisson's ratio
 I=3.5^3/12 % Axial moment of inertia.
 Ovalizations of pipe sections number 1 to 5.

Table 1

Ovalizations of pipe sections number 1 to 5.

The angle of the ring	0	pi/2	pi	3*pi/2	2*pi
SECTION 1	0.2287	0.2417	5.7397	0.2417	0.2287
SECTION 2	0.2047	0.2162	5.3328	0.2162	0.2047
SECTION 3	0.2047	0.2162	2.7912	0.2162	0.2047
SECTION 4	0.2047	0.2162	5.9335	0.2162	0.2047
SECTION 5	0.2047	0.2162	6.7824	0.2162	0.2047

Table 2

Vault Stresses, normal tension and tang. Tension.

Pipe Sections	Vault stresses	Tension tang.	Tension normal SIGMA X
Section1	0.6399	1.0077	53.67
Section1	0.6399	1.0077	53.67
Section1	0.6388	0.7555	30.19
Section1	0.6388	1.0723	61.61
Section1	0.6388	1.1511	70.10

Table 3

Displacements from ground loading

Displacement from ground loading	0	pi/2	pi	3*pi/2	2*pi
Section 1	0.0344	0.0363	0.8634	0.0363	0.0344
Section 2	0.0344	0.0363	0.8959	0.0363	0.0344
Section 3	0.0344	0.0363	0.4689	0.0363	0.0344
Section 4	0.0344	0.0363	0.9968	0.0363	0.0344
Section 5	0.0344	0.0363	1.1394	0.0363	0.0344

CONCLUSIONS

Based on the calculation programs designed by the author, the following conclusions can be drawn for the first table:

1. It is noted that for the angle $\theta = \pi$, on the circumference of the ring, the maximum value of ovalization expressed in percentage was obtained for section 5, when the maximum admissible value is exceeded by 0.78%.

2. The ovalization values for angles $0, \pi, 3\pi/2$ and 2π , remain the same for the different lengths of sections considered.

3. The minimum value of ovalization will be recorded for the case of section 3 when a pipe length between the 2 supports of approximately 7 [m] was considered.

4. There are two possibilities for decreasing the ovality, one technological by interposing several supports and therefore implicitly decreasing the length of the analyzed pipeline within each section and the second case by modifying the physical-mechanical parameters of the material, which also leads to modifying the dimensions related to the thickness of the ring.

For the second table:

1. The maximum value of the stress is recorded along the longitudinal axis of the pipe.

2. The maximum value is obtained for the case of section 5

3. The minimum value of the longitudinal stress is obtained for section 3 where the ovalization is also minimal.

4. The arch stress is the same for all sections considered.

5. The tangential stresses have negligible values compared to the longitudinal normal stresses.

6. The maximum values of the longitudinal normal stresses are below the maximum allowable stress of $120\{N/mm^2\}$.

For the third table, the conclusions are:

1. The values of the displacements of the points on the circumference of the pipes for angles $0, \pi/2, 3\pi/2$ and 2π are the same for all sections.

2. The maximum values are recorded for the angle $\theta = \pi$, and section number 5.

3. The minimum value is recorded for section 3.

Following the data obtained through the created calculation programs, it is found that through an appropriate choice of all physical-mechanical, elasticity and material parameters, the values obtained and entered in tables 1-3 are within the limits established by static or mechanical calculations for determining admissible values.

The mechanical analysis carried out by the author represents, through the numerical values obtained regarding the ovalization state, the stress state and the displacement state, it constitutes a validation of the membrane theory applied by the author.

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