STUDY AND ANALYSIS OF THE DETERIORATION OVER TIME OF BURIED PIPELINE NETWORKS WITH VARIABLE LENGTHS AND GEOMETRIC DIMENSIONS OF THE RING THICKNESS

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Abstract

The stress state analysis was performed using vector and matrix calculations, obtaining the maximum normal stress on the pipe crown. The stress state analysis was performed using vector and matrix calculations, obtaining the maximum normal stress on the pipe crown. From the results obtained, it is observed that the longitudinal normal stresses are of a different order of magnitude than the tangential stresses at the ring, the latter being much smaller. Applying the principle of superposition of effects, the equivalent normal stresses on the crown, median and base are obtained. The equivalent stress was determined using one of the resistance criteria from the strength of materials.

INTRODUCTION

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.

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 mechanical study of the behavior of pipes under the action of external loads was carried out taking into account the membrane theory.

Considering the underground location of the pipes, which are located in the municipality of Toplița in Harghita County. A number of 7 sections on the first branch of the pipe network, respectively a number of 4 sections on the second branch of the network, were taken into account. Each of the pipe sections considered had different lengths and diameters of the pipe rings.

In the present work, the author determined the state of tension on the ring of each network section, respectively the ovalization of the pipes depending on the angle at the center of the ring.

MATERIAL AND METHOD

Within the membrane theory on the basis of which the mechanical calculation of the pipes was carried out, the following stresses were taken into account:

- Axial normal stresses σ_X ;
- Arch stresses in the direction perpendicular to the cylinder generator σ_θ ;
- Tangential stresses on the ring thickness: ζxσ= ζσx .

The distribution of these stresses. It is considered to be uniform over the ring thickness.

Considering the uniform distribution of stresses on the pipe ring, the ovalization was carried out taking into account the median plane of the pipe. The resultant internal stresses are represented in the membrane theory by the stresses:

- Nσ- arch effect;
- Nx- longitudinal effect;
- Nxσ= Nσx - sliding effect

The results regarding ovalization and the state of stress were obtained by designing specific calculation programs for pipes using the Matlab program.

The mechanical calculation was performed taking into account only the load from the weight of the earth located above the upper generators of the pipes.

In the membrane theory the stresses are considered to be constant on the thickness h of

the ring having a uniformly distributed distribution.

The ovalization efforts that arise in the median plane of the plate are:

- Nx= σ_X *h ;

- Nxσ = Nσx = ζxσ * h;

- Nσ= σ_θ *h;

ϰp=1800 [kg/m3] the specific gravity (technical) of the soil;

- $h = 1.0[m]$ the burial depth of the pipe;

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.
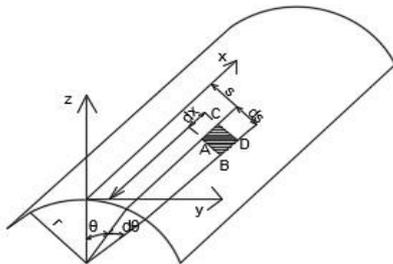

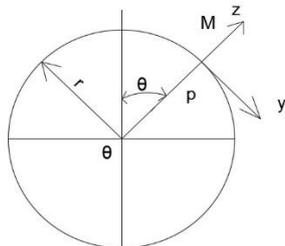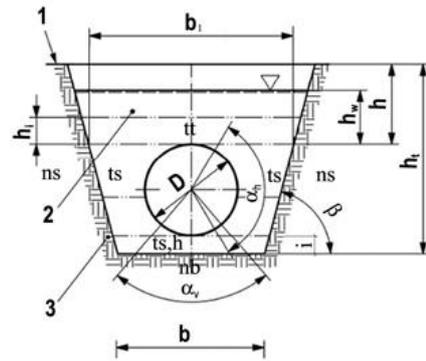Figure 1. Infinitesimal pipe element

Figure 2. Ring tensions

(Soare, 1999).
(Ille V 1977), (Ille, Bia, Soare 1983).

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).

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

For the first branch of the network, 7 sections of different pipe sizes were considered. NUMERICAL CALCULATION PROGRAM FOR BURIED PIPES

% CASE OF PIPELINE SECTION 1 (l = 19.62 [m], D = 70 * 3.5)

GAMAP = 17.65; % [KN/m3] specific gravity of the soil.

r = 0.07 ;% [m] average radius of the pipe;

Hp = 1.1 % [% [m] depth to the upper generator of the pipeline

h = 0.0035 % [m] pipe ring thickness

h1=6

L= 9.8 % [m] pipe length

x= 0

teta = [0 pi/2 pi 3*pi/2] % the angle on the pipe dial ring

teta1 = [0 pi/2 pi 3*pi/2 2*pi]

L1= [-3000 -1500 0 1500 3000]

cos(teta)

Nt = GAMAP*r*(Hp+r*(1-cos(teta)))

sgmt = ((GAMAP*r)*(Hp+r*(1-cos(teta))))./h

f = @(teta) ((GAMAP*r)*(Hp+r*(1-cos(teta))))./h

ezpolar(f);

Nx = -((GAMAP*(L^2))/8)*cos(teta)

sgmx = Nx./h

sgmxMAX = -(GAMAP/2)*((Hp/r)+cos(pi)).*((L^2)/4)

tauxtMAX = (GAMAP*(L/2)*r*sin(pi/2))./(2*h)

Nt = ((GAMAP*r)*(Hp+r*(1-cos(teta))))

Nx = -(GAMAP/2)*((Hp/r)+cos(teta)).*(((L^2)/4)-(4.9^2)) % Pentru L=-4.9 m

NxMAx = -(GAMAP/2)*((Hp/r)+cos(teta)).*((L^2)/4) % Pentru x = 0

Nxt = -((GAMAP*(L/2))*(Hp-r*sin(teta))).

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SECTION 2.
% Section D=89[mm], ring thickness 3.5 [mm], Length 11.72[mm]
GAMAP = 17.65 % [KN/m3] specific weight of the soil
r = 0.089 % 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= 11.72 % [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;
SECTION3
% Section D=108[mm], ring thickness 4 [mm], Length 10.95mm]
GAMAP = 17.65 % [KN/m3] specific weight of the soil
r = 0.054 % radius [m] average radius of the pipe
Hp = 1.1 % [m] depth to the upper generator of the pipe
h = 0.004 % [m] pipe ring thickness
L= 10.95 % [m] pipe length
SECTION 4
% Section D=89[mm], ring thickness 3.5 [mm], Length 6.21[mm]
GAMAP = 17.65 % [KN/m3] specific weight of the soil
r = 0.0445 % 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= 6.21 % [m] pipe length
SECTION 5
% Section D=121[mm], ring thickness 4 [mm], Length 11.59 [mm]
GAMAP = 17.65 % [KN/m3] specific weight of the soil
r = 0.0605 % radius [m] average radius of the pipe
Hp = 1.1 % [m] depth to the upper generator of the pipe
h = 0.004 % [m] pipe ring thickness
L= 11.59 % [m] pipe length

SECTION 6
% Section D=89[mm], ring thickness 3.5 [mm], Length 7.62[mm]
GAMAP = 17.65 % [KN/m3] specific weight of the soil
r = 0.0445 % 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= 7.62 % [m] pipe length
SECTION 7
% Section D=95[mm], ring thickness 3.5 [mm], Length 6.14[mm]
GAMAP = 17.65 % [KN/m3] specific weight of the soil
r = 0.04745 % 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= 6.14 % [m] pipe length

Table 1

Efforts and tensions

SECTIONS	OVALIZATION MINIMUM	Tang. Tensions	Normal Tensions SIGMAX	Total Tensions SGMTMAX	OVALIZATION MAXIMUM
SECTION R1	0.78	1.40	98.26	0.46	5.67
SECTION R2	0.38	0.27	59.41	0.27	2.82
SECTION R3	0.1	0.59	38.57	0.30	0.87
SECTION R4	1.02	0.94	85.98	0.30	6.57
SECTION R5	0.09	0.67	35.08	0.34	0.68
SECTION R6	0.015	0.54	22.56	0.34	0.16
SECTION R7	0.46	0.91	64.38	0.34	3.06

Table2

Ovalization Of Pipe Sections On The First Branch

THE ANGLE AT THE CENTER ON THE CIRCUMFERENCE OF THE RING	0	pi/2	pi	3*pi/2	2*pi
SECTION R1	5.67	0.82	0.78	0.82	5.67
SECTION R2	2.82	0.41	0.38	0.41	2.82
SECTION R3	0.87	0.12	0.10	0.12	0.87
SECTION R4	6.57	1.07	1.02	1.07	6.57
SECTION R5	0.68	0.11	0.09	0.11	0.68
SECTION R6	0.16	0.02	0.01	0.02	0.16
SECTION R7	3.06	0.50	0.46	0.50	3.06

CONCLUSIONS

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

1. It is found that for the angle theta = pi , on the circumference of the ring, the maximum value of ovalization expressed in percentages was obtained for section 4, when the maximum admissible value is exceeded by 0.57%.

2. The ovalization values for angles 0, pi, 3*pi/2 and 2*pi are variable for the different lengths of sections considered.

3. The minimum value of ovalization will be recorded for the case of section R1-1.6.

4. There are two possibilities to decrease ovalization, one technological by intercalating several supports and therefore implicitly decreasing the length of the analyzed pipe within each section and the second case by modifying the physical-mechanical parameters of the pipe material and the dimensions related to the thickness of the ring.

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

6. The maximum value is obtained for the case of section 1.4

7. The minimum value of the longitudinal stress is obtained for section R1-1.6 where the ovalization is also minimal.

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

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

10. The maximum values of the longitudinal normal stresses are below the maximum allowable stress of 120[N/mm^2].

The application of membrane theory to thin cylindrical plates allows for the precise determination of the static parameters of the pipes, facilitating a decision regarding the type of pipe that can be used depending on the external loads and the type of soil.

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