ON THE PROBABILITY OF COLLAPSING OF SUPPORTS IN A PIPELINE MOUNTED ON FLEXIBLE SUPPORTS

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Abstract

When laying pipelines using concrete supports and frames in the overhead laying scheme, the pipes may experience deformation and tension due to the height at which they are installed, typically between 1.0-1.5m from the ground surface. The installation of overhead pipeline on hard or collapsible foundations causes bending due to the combined weight of the pipes and the transported product. This text discusses the use of three moment equations to solve this problem.

Keywords: pipeline, support, bending moment, supporting reaction, collapse coefficient

I. Introduction

Experience indicates that supports installed on pipelines operated at hazardous production facilities commonly exhibit the following types of defects:

- corrosion damage to support elements [1-3]
- external corrosion of pipelines in the area of supports
- failure of welded joints of support elements welded along the pipe;
- crushing;
- slipping of pipelines from support surfaces;
- collapse of supports;
- failure of hangers, etc.

It is widely acknowledged that the three moment equations can be expressed as [4-6]:

$$M_{n-1}l_n + 2M_n(l_n + l_{n+1}) + M_{n+1}l_{n+1} =$$
$$-6\left(\frac{\omega_n a_n}{l_n} + \frac{\omega_{n+1} b_{n+1}}{l_{n+1}}\right) - 6EJ\left(\frac{\Delta_{n+1}-\Delta_n}{l_{n+1}} - \frac{\Delta_n-\Delta_{n-1}}{l_n}\right) \quad (1)$$

Here: Δ, $\Delta_{n-1}, \Delta_n, \Delta_{n+1}$-collapse of supports, i.e., vertical displacement of supports as a result of rock collapse;EJ - is the hardness of the pipe.

According to Winkler's hypothesis, vertical subsidence can be calculated as:

$$\Delta_n = R_n \cdot \delta \quad (2)$$

Here: R_n-support reactions, δ-rock (soil) settlement capacity, $m/k\,N$.

It is evident that the support collapses due to the displacement of the rock. As shown in expression (2), the collapse of the support is directly proportional to its reaction. [7-8]

II. Methods

Let 's consider the beam (pipeline) installed on rubber supports (Fig . 1).

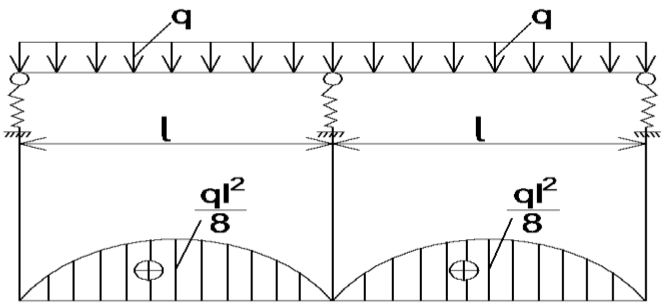

Figure 1: *Pipeline on elastic supports*

If the load on a beam is evenly distributed across its spans, the three moment equations for a beam with *n* spans and a distance of l_n between supports are as follows:.

$$M_{n-1}l_n + 2M_n(l_n + l_{n+1}) + M_{n+1}l_{n+1} =$$
$$-6\left(\frac{\omega_n a_n}{l_n} + \frac{\omega_{n+1} b_{n+1}}{l_{n+1}}\right) \quad (3)$$

Here, ω_n -q represents the areas of the bending moment curves caused by the load. a_n represents the distance from the center of each epur to the left support, while b_{n+1} represents the distance from the center of each subsequent epur to the right support.

$$\omega_1 = \omega_2 = \omega_3 = \cdots = \omega_{n-1} = \omega_n = \frac{2}{3}\frac{ql^2}{8} \cdot l = \frac{ql^3}{12},$$
$$l_1 = l_2 = l_3 = \cdots = l_n = l, a_1 = b_2 = a_2 = b_3 = \cdots = \frac{l}{2}$$
$$\frac{\omega_n a_n}{l_n} = \frac{\omega_{n+1} b_{n+1}}{l_{n+1}} = \frac{ql^3}{12} \cdot \frac{l}{2 \cdot l} = \frac{ql^3}{24}$$

Starting from this point, we can write:

$$\frac{\omega_1 a_1}{l_1} + \frac{\omega_2 b_2}{l_2} = \frac{ql^3}{12}, \qquad 6\frac{ql^3}{12} = \frac{ql^3}{2}$$

According to Figure 2.5, we can write using expression (1):

$$\frac{\Delta_{n+1} - \Delta_n}{l_{n+1}} - \frac{\Delta_n - \Delta_{n-1}}{l_n} = \frac{\Delta_2 - \Delta_1}{l} - \frac{\Delta_1 - \Delta_0}{l} = \frac{1}{l}(\Delta_2 - 2\Delta_1 + \Delta_0)$$

According to formula (3).

$$\Delta_2 - 2\Delta_1 + \Delta_0 = \delta(R_2 - 2R_1 + R_0)$$

In Figure 2.5, since $M_0 = M_2 = 0$, we can express the reactions as follows:

$$R_2 = \frac{1}{l}\left(\frac{ql^2}{2} + M_1\right) = R_0,$$
$$R_1 = \frac{1}{l}(ql^2 - 2M_1)$$

and

$$R_2 - 2R_1 + R_0 = \frac{1}{l}(-ql^2 + 6M_1)$$

In this case, formula (1) can be written as follows :

$$4M_1 = -\frac{ql^2}{2} - \frac{6EJ\delta}{l^2}(R_2 - 2R_1 + R_0)$$
$$= -\frac{ql^2}{2} - \frac{6EJ\delta}{l^3}(-ql^2 + 6M_1) \quad (4)$$

$\frac{6EJ\delta}{l^3} = \eta$ If we sign with , we get :

$$4M_1 = -\frac{ql^2}{2} + \eta q l^2 - 6\eta M_1.$$

or

$$M_1(4+6\eta) = -\frac{ql^2}{2}(1-2\eta)(5)$$

Consider its effect on the stiffness of the supports (EJ) by setting different values of the settlement coefficient δ:

1. $\delta = 3 \cdot 10^{-4}$ m/kN ; $ql^2 = 2060\ kNm$; $E = 2{,}1 \cdot 10^5\ MPa$; $J = 57 \cdot 10^{-4} m^4$; $l = 20m$; $\eta = 0{,}425$.
Then

$$4 + 6\eta = 6{,}55; 1 - 2\eta = 0{,}15$$

becomes and we get $M_1 = -47{,}2\ kNm$

M_1 a small value of the moment indicates that the stiffness of the elastic support is low. In order to increase the hardness, let's accept the value of the coefficient of collapse of the rock as small:

2. If $\delta = 2 \cdot 10^{-4}\ m/kN$if, then $\eta = 0{,}2835$ and $M_1 = -156{,}46\ kNm$. The bearing moment value increase suggests that as the subsidence coefficient decreases, the rock stiffness increases. This causal relationship indicates that the bearing moment also increases.. It should be noted that the stiffness of the pipe and the stiffness of the rock (elastic support) are different concepts.

If the supports were not elastic in the considered case:

$$M_1 = -\frac{ql^2}{2} = -2060 kNm \text{and} M_1 = -515 kNm$$

would be taken. This means that large flexibility cannot be allowed, that is, as the coefficient of collapse increases, the pipeline can bend more. As a result, it is inevitable that greater stress and deformations will occur in the pipeline. Therefore, it is necessary to increase the stiffness of the supports as much as possible.

Let's consider the calculation of the support moment generated at one transition of the pipeline on elastic supports (Fig. 2).

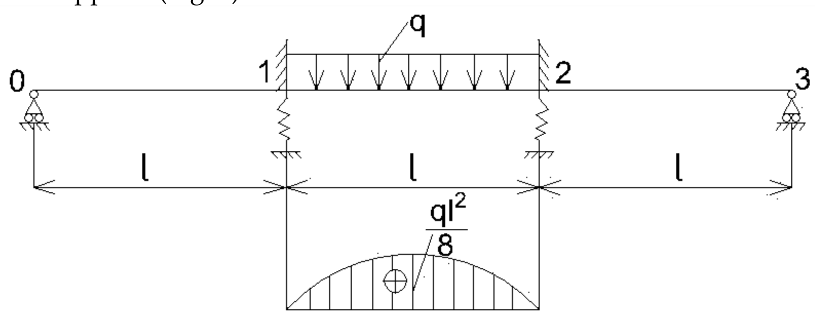

Figure 2: *A pipeline span on elastic supports*

Applying formula (1), we can write down the following expressions from Figure 2:

$$\begin{cases} 2M_1 + M_2 = -\frac{ql^2}{4} - 2\eta(M_1 - M_2) \\ M_1 + 2M_2 = -\frac{ql^2}{4} - 2\eta(M_2 - M_1) \end{cases}$$

and:

$$\begin{cases} 2(1+\eta)M_1 + (1-2\eta)M_2 = -\frac{ql^2}{4} \\ (1-2\eta)M_1 + 2(1+\eta)M_2 = -\frac{ql^2}{4} \end{cases}$$

Assuming $\delta = 1 \cdot 10^{-4} sm/kq$, then $\eta = 0{,}142$ and

$$\begin{cases} 2{,}284M_1 + 0{,}716M_2 = -103 \\ 0{,}716M_1 + 2{,}284M_2 = -103 \end{cases}$$

will be. Hence $M_1 = -M_2 = -341kNm$. This means that when the core fracture ratio is small, the bearing moment increases.

Applying equation (1) to the pipeline (beam) on the supports shown in Fig. 3 and making the appropriate transformations yields the following system of equations for this beam:

$$\begin{cases} 2(1+\eta)M_1 + (1-3\eta)M_2 + \eta M_3 = -(1+2\eta)\dfrac{ql^2}{4} \\ (1-3\eta)M_1 + (4+6\eta)M_2 + (1-3\eta)M_3 = -(1-2\eta)\dfrac{ql^2}{2} \\ \eta M_1 + (1-3\eta)M_2 + 2(1+\eta)M_3 = -(1+2\eta)\dfrac{ql^2}{4} \end{cases}$$

$$\eta = \frac{6EJ\delta}{l^3}; \delta = 1 \cdot \frac{10^{-4}m}{kN}; \frac{ql^2}{4} = 1030kNm$$

by accepting

$$\frac{ql^2}{2} = 2060kNm$$

etc. by solving the required equations ,

$$M_1 = M_2 = M_3 = -343\ kNm$$

we get

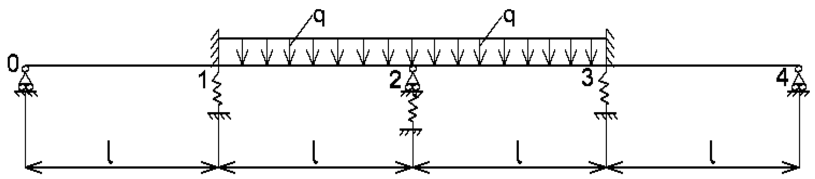

Figure 3: *Two spans of the pipeline on elastic supports*

III. Results

The impact of the settlement coefficient's smallness on the support moments' value is evident. Additionally, the support moments' calculation indicates that all transitions are under the same conditions and subject to the same effects. The rock's inability to subside corresponds to the subsidence coefficient's small value.

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