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Effect of Ground Stack for Additional Internal Force and Deformation of Underground Pipeline

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Abstract: Based on a three-dimensional finite element model of an underground pipeline, the influence of additional ground loads on the stress characteristics of the pipeline was studied. Furthermore, the effects of different soil properties, load locations, and varying burial depths on the pipeline's stress characteristics were analyzed. The research results show that as the distance between the load center and the pipeline axis increases, the positions of the pipe's maximum displacement, bending moment, and shear force along the axis decrease significantly. However, when this distance reaches a certain value, the pipeline's maximum vertical displacement and internal forces approach zero. Different pipelines exhibit minimum values of maximum axial displacement and vertical displacement in soft soil, while maximum axial displacement occurs in clay, and the largest vertical displacement is observed in sandy soil. The maximum axial displacement of UPVC pipes in clay is twice that of soft soil. The vertical displacement of pipes made from different materials increases with burial depth, but for concrete and steel pipes, the maximum axial tension increases significantly with depth, whereas the change in UPVC pipes is more gradual.

Keywords: Finite element; Wall; Pipeline; Displacement; Axial force; Bending moment

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1. Introduction

The large-scale finite element general software ABAQUS is used to carry out numerical simulation of the pipeline, to study the influence of the ground wall on the mechanical characteristics of the lower pipeline, and to determine whether the pressure generated by the additional load generated by the upper wall on the pipeline exceeds its design pressure value [1]. In the simulation process, the model is simplified to a certain extent, and its basic assumptions are:

(1) The engineering geological conditions are simplified, and the soil layers are assumed to be uniformly distributed in the simulation process.

(2) The material of the soil layer is assumed to be an isotropic material.

(3) Boundary and loading conditions of the model: the upper surface is a free surface, and the lower surface is fully constrained, with displacement constraints applied in the X and Y directions. The surrounding

sides are horizontally constrained, with horizontal displacement constraints applied in the X direction. A gravity load is applied to all elements of the model [2].

(4) The model does not consider the regional tectonic stress, only the stress caused by gravity.

2. Finite element model of pipeline

To simplify the calculation, the constitutive model of the geotechnical material used in this paper is the Mohr-Coulomb constitutive model, and the pipeline adopts the elastic material model [3]. **Table 1** shows the material parameter characteristics of each material partition. Simultaneously, to consider the interaction between the soil and the pipeline, the Mohr-Coulomb contact model is used between the pipeline and the soil, and the embedded contact is used for the contact between the pipeline and the soil [4].

Table 1. Material parameters

Material	Density (g/cm^3)	E (Pa)	μ	Cohesion (kPa)	Internal friction angle (°)	Expansion angle (°)
Pipeline	7.8	2.05e11	0.3	/	/	/
Clay soil	1.85	4.5e7	0.35	25	24	15

3. Calculation results

3.1. Pipe overlaid flag stand

The flag stand is 4.8 m long, 1 m high, 3.3 m wide, and the pipeline is buried 1.3 m deep. The pipe diameter is 273.1 mm × 6.4 mm. The pipeline passes through the lower part of the longitudinal center of the flag platform, and the standard value of constant load is 25 kN/m^2, as shown in **Figure 1**.

The top flag platform is simplified as a uniform load acting on the foundation soil, as shown in **Figure 2**.

Figure 1. Pipe overlaid flag stand

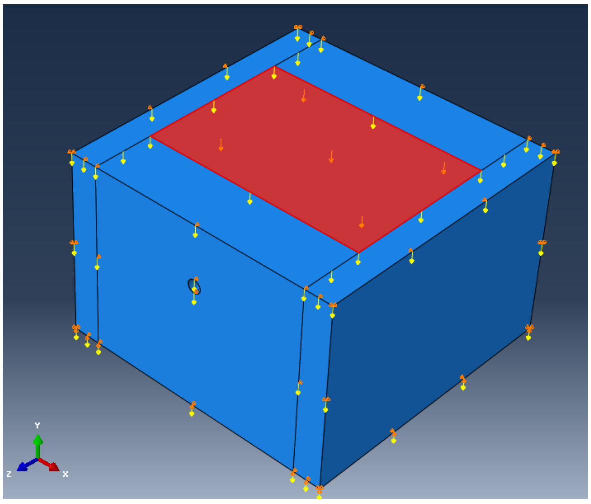
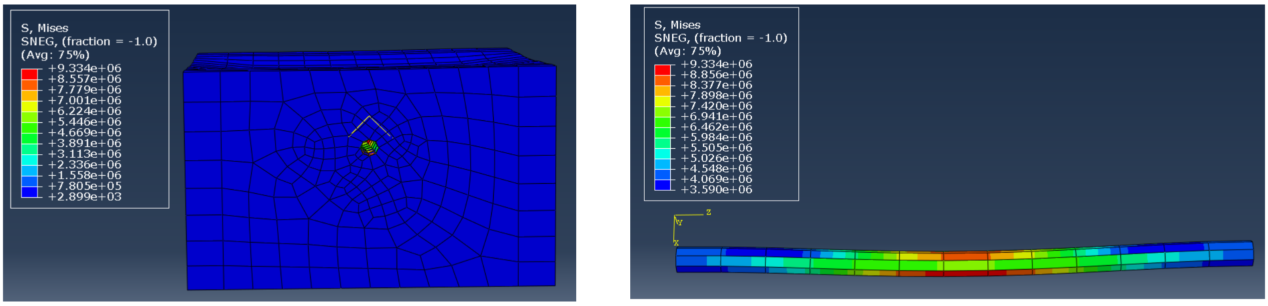


Figure 2. Diagram of load action of a calculation example

In order to determine whether the force of the lower pipe meets the design value when the wall is laid on the upper part of the pipe, the force of the pipe after the wall is laid is analyzed, as shown in **Figure 3**.



(a) Overall (b) Pipeline

Figure 3. Mises stress diagram of pipeline

It can be seen from the calculation that the Mises equivalent stress generated by the upper wall to the pipeline is 9.33 MPa, and its maximum value appears at the bottom of the pipeline.

3.2. Pipe overlaid brick wall

The pipelines are mainly buried in the cover layer with an average depth of 1.3 m. The width of the overlying wall is 0.40 m, the height of the wall is 4.5 m, the length of the wall is 4 m, the standard value of constant load is 86 kN/m^2, and the standard value of ground stacking or personnel load is 2.5 kN/m^2, as shown in **Figure 4**.

The top wall is simplified as a uniform load acting on the foundation soil, as shown in **Figure 5**.

Figure 4. Brick wall on the pipeline

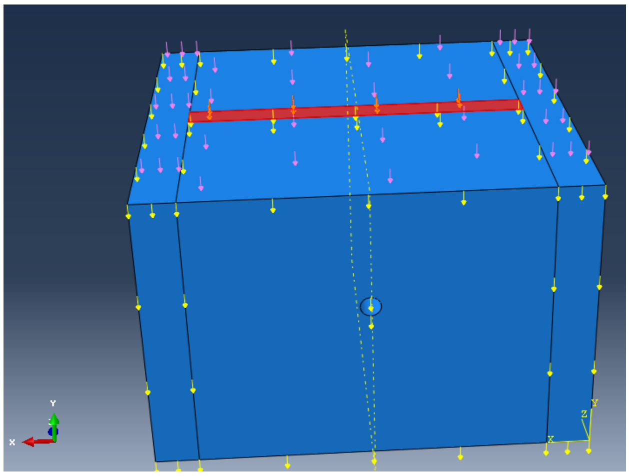
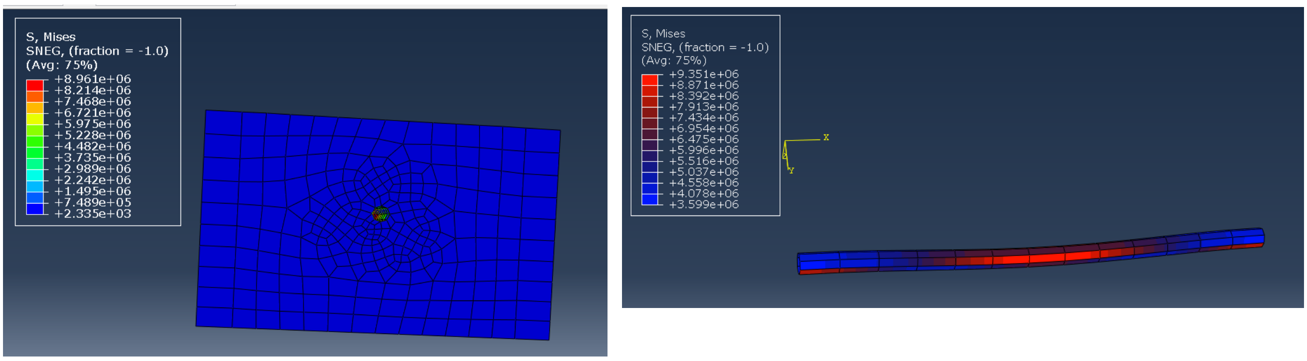


Figure 5. Diagram of load loading

To determine whether the force of the lower pipe meets the design value when the wall is laid on the upper part of the pipe, the force of the pipe after the wall is laid is analyzed, as shown in **Figure 6**.



(a) Overall (b) Pipeline

Figure 6. Mises stress of pipeline

As shown in **Figure 6**, it can be seen from the calculation that the Mises equivalent stress generated by the upper brick wall to the pipeline is 8.96 MPa, and its maximum value appears at the top of the pipeline.

4. Conclusion

The large-scale finite element analysis software ABAQUS was used to calculate the additional pressure generated when a wall is placed above the pipeline. The results show that the stress on the pipeline under working condition 1 exceeds the design allowable value of 10 MPa, which could pose a danger. In working condition 2, the stress is close to 10 MPa, making it similarly dangerous

Disclosure statement

The author declares no conflict of interest.

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