Lateral Resistance of Buried Pipes by Frictional Limit Analysis

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Pipelines are vital means of transportation of liquids and gases over large geographical areas. Regarding hydrocarbons, they must be flow at high pressure and temperature to avoid wax formation. Low temperatures may lead to deposits at pipe walls, increasing the pressure or blocking the fluid flux. Under such thermal and mechanical loads and Poisson's effect, the pipe tends to expand longitudinally. Since longitudinal movements are restricted, high compressible forces are developed, leading to buckling occurrence if a critical value is reached. The occurrence of lateral buckling strongly depends on the surrounding soil, friction at pipe-soil interface, pipe diameter and buried depth and subsoil characteristics [1]. Then, the evaluation of soil lateral resistance that will entail an imminent breakout is important.

This work aims the analysis of the soil lateral resistance under limit analysis formulation considering friction at pipe-soil interface. Limit analysis is a direct method, posed as an optimization problem with constraints, and aims the determination of the collapse power of an elastic perfectly-plastic body and do not consider the load history. In this approach, the pipe is considered as a rigid body while the soil mass is a deformable one. Then, at imminent plastic collapse state, the contact between the rigid and deformable bodies is assumed as known, with permanent contact at normal direction and a slipping rule at tangential direction. Coulomb friction law is considered. The limit analysis problem is solved by a quasi-Newton algorithm and a condensation technique allied to Lemke algorithm is used to solve the complementarity problem at contact. The cohesive soil mass follows the yield criterion proposed by [3], derived from homogenization theory considering cohesion, material internal friction and porosity.

The soil lateral resistance is evaluated by limit analysis considering friction at soil-pipe interface and porosity of soil mass, discretized by finite elements and under plane strain hypothesis. As results, the soil resistance forces per length, the velocity and stress fields at soil mass are determined as well as the slip lines.

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