Limit Analysis on Evaluation of Lateral Resistance of Partially Embedded Pipes with Frictional Pipe-Soil Interface
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ABSTRACT

Underwater pipes are submitted to severe loadings, such as external pressure due to water depth and thermal stresses. Pipes are also supported by anchors and its displacement is restricted. Then, compressive stresses are developed along its length and this structure works like a column and it may buckle if it reaches a critical load. If it buckles in an uncontrolled way, the structure collapses over a long length, causing economic and environmental losses. However, inducing controlled lateral buckling may be a solution to relief such stresses, according to [1]. Thus, modelling this phenomenon is worthy to evaluate its formation.

In order to model this problem, the pipe is treated as a rigid body and the soil as a deformable body, and under limit analysis method, upper bound solutions are proposed by [2] and [3] to evaluate the lateral resistance for shallow pipe embedment considering the soil as a von Mises material. In [6], an incremental method was implemented in commercial finite element software and the results were fitted by a power law curve. Nevertheless, these models consider the frictionless pipe-soil interface. Then, friction between pipe and soil shall be included to accurately evaluate the lateral buckling formation process.

Accordingly, considering Coulomb friction law and the bipotential theory developed by [4], friction dissipation is included in limit analysis formulation. As a boundary condition, a horizontal velocity field is applied to depict the pipe movement action. For that, a limit analysis formulation is derived to meet this boundary condition. From continuum formulation, the discretized formulation is derived under 2-D plane strain finite elements. From the straight line between limit analysis and linear programming, the set of optimum equations and inequations are solved by an optimization algorithm using contraction and relaxation techniques [5].

Therefore, the aim of this work is to apply the limit analysis with prescribed velocity and friction dissipation formulation in order to calculate the necessary horizontal power that will cause soil plastic collapse. The results with frictionless contact are compared to classical solution found in literature and after that the horizontal power is evaluated considering friction between pipe-soil contact interface. From finite element method it is also possible to extract the tangential velocities at contact boundary and evaluate whether there is slip or adhesion between pipe and soil.

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