Numerical investigation of ground movements and pulling forces during static pipe bursting

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ABSTRACT

A study to understand the geomechanics of pipe bursting is presented. Two dimensional finite element analyses were conducted to examine ground movements associated with pipe replacement using static pipe bursting. The analyses provided good estimates of ground movements and stresses in the plane perpendicular to the pipe axis. An average value of stress across the location of the earth pressure cell was compared to test measurements. The comparisons were reasonably effective. The plane strain numerical model was then used to conduct parametric studies in cohesionless (sands) and cohesive (clays) soils and charts for ready estimation of ground movements during pipe bursting projects are provided.

Axisymmetric finite element analysis was developed to explore the advance of the bursting head, the ground resistance to that advance, the magnitude of longitudinal ground movements, and the effect of soil characteristics on the response of the burst head and the surrounding ground. The calculated response was compared to Yu and Houlsby's and plane strain numerical model solutions and to laboratory measurements of ground movement and pulling force to evaluate the significance of the processes that were modeled in the analysis, and those that were neglected.

The axisymmetric finite element analysis was performed using either a stress free boundary or a zero deformation boundary at radial position R_{ext}. The choice of R_{ext} and the fixity condition at that location had a very significant effect on the radial pressures needed to expand the cavity, and the shear stresses that were expected between the bursting head and the soil.

The study indicated that the load path should be subdivided into many (e.g. 1000) solution steps to provide a stable analysis, explicit inclusion of longitudinal progression in the analysis of pipe bursting increases the radial extent of the zone of shear failure calculated in the vicinity of the bursting head, explicit inclusion of longitudinal progression and axial surface friction in the analysis of pipe bursting reduces the magnitude of radial stresses estimated in the vicinity of the pipe bursting operation, the axisymmetric model captures the maximum values of pulling force within the range of experimental measurement, and most of the pulling force is associated with resistance to forward movement of the burst head for short burst lengths.

Recommendations on the utilization of the axisymmetric model and charts for estimation of ground movements were provided. Aspects of static pipe bursting that need further investigations were given.