PUTTING RESEARCH TO WORK

BRIEF

Lateral Deflection Contribution to Settlement Estimates

The Wisconsin Department of Transportation (WisDOT) occasionally constructs embankments and retaining walls over compressible materials using staged construction. Staged construction is a technique used to build an embankment or retaining wall in stages, allowing the compressible and weak soil to consolidate and gain strength over time. As part of the staged construction, the fill placement is instrumented and monitored for pore water pressure, settlement and lateral deflection. The construction of tall embankments or retaining walls on soft soils typically requires staged construction, which leads to an increase in effective stress, reduction in void ratio and settlement and gain in shear strength. However, tall embankments are not fully constrained, contributing to the potential of global failure of the foundation soil and generation of lateral movements that magnify vertical settlements of the embankments.

What is the problem?

In current practice, the contribution of lateral deflection on the magnitude of the settlement is not well defined. Therefore, there is a need to evaluate data from a project where settlement and lateral movement have been recorded to estimate the amount of vertical settlement due to lateral deflection.

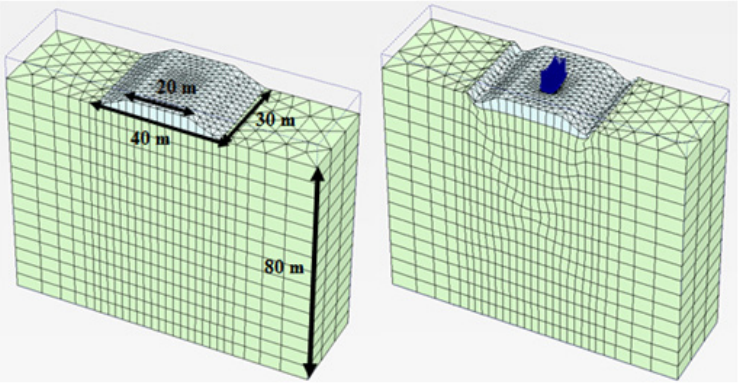
Research objective

The objective of the research was to evaluate the contribution of lateral deflection when determining settlement estimates. Data collected from WIS 29 and US 41 projects in Howard, WI, were used to evaluate lateral spreading and settlement. The data collected was applied to the development of finite element based models to obtain a further understanding of how field conditions impact the contribution of lateral deflection to settlement estimates.

Methods

The procedure to achieve the objective of this research included the following steps:

- Review of engineering properties of a mechanically stabilized wall (MSE) in Howard, WI.
- Develop a numerical model to investigate the mechanical response of the MSE wall using the finite element software PLAXIS.
- Conduct parametric studies of the various factors that govern the failure of MSE wall. The effects of the following parameters were studied, including the effect of embankment height (H), backfill friction angle, and soft foundation soil properties such as undrained shear strength (Su), Young's modulus (Eu), and Poisson's ratio (v).
- Analyze the contribution of lateral displacements to vertical settlements by conducting parametric studies.
- Compare geotechnical instrumentation data from the construction site with numerical analysis results.



Soil Embankment Finite Element Model Geometry and Deformed Shape after Consolidation

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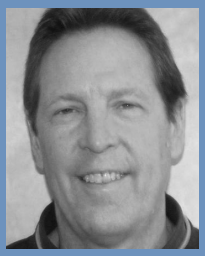
Results

- The increase in backfill friction angle leads to an increase in factor of safety. As the ratio of MSE wall height to reinforcement length (H/L) increases, factor of safety against instability of the MSE wall decreases since increase in embankment height causes an increase in driving forces.
- The increase in dimensionless Su/Eu (ratio of undrained shear strength to undrained Young's modulus of foundation soil) due to an increase in Su of the critical soil layer leads to an increase in factor of safety since Su directly affects the safety of the foundation soil.
- An increase in dimensionless ratio (γH)/Su (where γ is the unit weight of the soil) leads to a decrease in factor of safety because increase in driving forces whether an increase in embankment height or backfill unit weight causes a decrease in factor of safety.
- Poisson's ratio does not contribute to factor of safety since factor of safety is only related with the strength of the soil layer. However, change in Poisson's ratio (ν) directly affects the settlements. Higher horizontal displacements and lower vertical settlements were seen under higher Poisson's ratios.
- The decrease in the dimensionless ratio Su/Eu due to an increase in Young's Modulus, Eu, leads to a decrease in vertical settlements. Moreover, the ratio of vertical settlement to lateral displacement is not affected by the change in Young's modulus.
- The contribution of lateral displacements to vertical settlements is maximum for normally consolidated clays. As the over-consolidation ratio increases, the contribution of lateral displacements to vertical settlements decreases. For heavily over-consolidated clays, lateral displacements tend to go to zero. At this time, one-dimensional consolidation is the only reason for vertical settlements. This observation has important engineering implications, as the settlement of embankments over heavily over-consolidated soils can be calculated using simple consolidation settlement analyses, whereas in the case of embankments founded on normally consolidated soils, strip footing analysis must still be used.
- Dissipation of excess pore water pressure of soft soils is slow due to the low hydraulic conductivity. The excess pore water pressure was around 30 kPa after 25 days consolidation. After 200 days of consolidation, the excess pore water pressure decreased only by half to 16 kPa. Moreover, location of transducers affects the measured excess pore pressure value. Deeper transducer measures higher excess pore water pressure.
- The presence of wick drains greatly contributes to the reduction of construction times in soft soils and must be considered to improve the overall performance of foundation systems in saturated soft soils. Water pressure dissipation rate is slow due to the low hydraulic conductivity of soft soils.

Recommendation

Field measurements, numerical modeling and parametric study in this research help explain the effects of soil properties and geometry conditions on settlement of tall embankments and retaining walls. Vertical settlement of an embankment over heavily, over-consolidated soils can be estimated from one-dimensional consolidation tests. However, for normally-consolidated soils, strip footing analysis must be used to estimate the settlement. Due to slow pore water pressure dissipation of soft soils, installation of draining systems such as wick drains is recommended to reduce the construction time and improve embankment performance.

Project Manager



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