Soil Nail Wall Proposed Design Specifications

Issues to be Considered

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June 13, 2017

Key Issues

- Application of limit equilibrium design to strength Limit State soil nail wall design for internal, compound, and overall (global) stability
  - Currently, overall stability is in Service Limit State – should it be moved to Strength Limit State and treat slope stability FS as the load factor?
  - How to treat the nail resistance in the limit equilibrium program?
  - Consistency with articles for other wall types regarding overall and compound stability
- Should foundation loads on wall be factored or is slope stability load factor (see above) sufficient?
- Facing structural design may need more development – e.g., need better approach to estimate the nail load at the face, T_0 – only limited empirical equation is provided
- Seismic design, corrosion design, and soil nail testing needs further development

Soil Nail Wall Strength Limit State Design - Concepts

- Limit equilibrium (slope stability) internal, compound, and overall stability analyses for wall
  - Load factor (i.e., slope FS = 1.3 to 1.5) with resistance factor of 1.0 addresses soil failure
  - Limit equilibrium analysis provides nail loads for rest of LRFD design analyses (T_{max}, but T_0 uncertain)
  - Typical soil nail wall programs adjust critical failure surfaces using the controlling limit state (e.g., nail bar rupture, nail pullout, facing resistance, etc.) to limit T_{max} in nails
- LRFD design check done using conventional limit state equations for each reinforcement layer and specified load and resistance factors

Soil Nail Wall Internal and External stability Design

- Slope stability limit equilibrium methods typically used
  - Currently, slope stability analysis is in Service
  - Need to move slope stability analysis to Strength Limit (do as separate agenda item)
    - Soil nail wall design programs consider all possible failure modes at once (purely internal, compound, and overall stability)
    - Since these failure modes are a collapse scenario, belongs in strength limit
    - FS from geotechnical slope stability analysis must be treated as load factor
  - Resistance factors for this limit state tied to nail and pullout resistance
  - Slope stability load factor considers footing load uncertainty if footing load present (i.e., γ_{EV} increases from 1.3 to 1.5), so no need to factor footing load
  - Are there other loads in load group that are usually factored, and how should those be handled?
- This will also affect MSE walls regarding overall and compound stability calculations (do as separate agenda item)

Soil Nail Wall Internal and External stability Design

- Soil nail tensile and pullout resistance must be treated as a negative driving force

$$FS = \frac{\text{Resisting Forces}}{\text{Driving Forces}} = \frac{\sum_1^n (W \cos\alpha) \tan\phi}{\sum_1^n (W \sin\alpha) - T(\cos\alpha)} \qquad \frac{\sum_1^n (W \cos\alpha) \tan\phi}{FS} \geq \sum_1^n (W \sin\alpha) - T(\cos\alpha)$$

  Doing so prevents double factoring, as “T” from this analysis is not reduced by FS

- This approach conflicts with what is provided in Article 11.10.4.3 for MSE walls, in that the tensile and pullout resistance are described as restoring forces – could cause confusion

Soil Nail Wall Internal and External stability Design

- Conducting LRFD checks
  - Check is done at each reinforcement “layer”
  - Uses T_{max} obtained from slope stability limit equilibrium analysis
  - If wall supports structure footing, T_{max} will contain the additional load needed to support the structure
- Load and resistance factors for layer specific LRFD checks
  - For load factor, apply γ_{EV} to T_{max} from slope stability analysis
  - If T_{max} includes structure footing load, should increase from normal 1.35 value to 1.5 to be consistent with MSE wall design and load factors normally used for footing loads

Nail Pullout Design

- Slope stability analysis provides unfactored soil nail loads at each layer considering what controls the design (nail tensile strength, nail pullout resistance, and possibly facing resistance)
- What value of L_p to use for each layer?
  - Defined as length of nail behind critical failure surface
  - If assess what is required for nail layers for intermediate construction stages, the critical failure surface for each construction stage will change, resulting in different L_p values for each nail layer
  - If focus on final wall state to do LRFD check, there will only be one critical failure surface to use to get L_p

Soil Nail Wall Facing Design

- How to calculate nail load at face, T_0?
  - Could assume that $T_0 = T_{max}$
  - For simpler cases, could use empirical equation in commentary
- Similar to rest of wall, should higher load factor ($\gamma_p = \gamma_{EV}$ = 1.35 to 1.5?) be used if wall supports a structure footing?

Other Remaining Issues/Tasks

- All of these need further development
  - Seismic design
  - corrosion design
  - Soil nail testing
- Soil nail wall construction specifications
  - Draft specifications have been developed
  - Needs committee review

T15 Next Steps

- Consider moving overall stability to Strength Limit State
- Update MSE wall articles regarding overall and compound stability to be consistent with Soil Nail articles
- Decide on whether or not to increase γ_{EV} from 1.35 to 1.5 if wall supports a structure foundation
- Decide on how T_0 (i.e., nail load at face) should be determined
- Discuss and finalize draft at T15 mid-year meeting (October?)
- Submit as Subcommittee agenda item for Subcommittee consideration in 2018

Comments and Questions