Slope Stability

Slope stability analyses are performed on a variety of geotechnical projects and are used to evaluate the overall (global) stability. These analyses focus on shear failures within the soil mass and provide no information on slope deformations. Slope stability analyses are typically performed for:

- Cut and fill slopes with heights ≥ 10 ft or constructed over soft soils.
- Retaining walls (including permanent and temporary shoring systems) with heights ≥ 5 ft or constructed over soft soils.
- Shallow and deep foundations for structures supported on or adjacent to slopes.

In addition, slope stability analyses can also be used to evaluate slopes that have experienced distress (slopes that have failed) by assessing potential slope failure mechanisms through back analysis. These same analyses can then be used in the design of mitigation techniques to repair the failure.

Potential Slope Conditions

The stability of slopes depends on the height of the slope and applied surcharge loading, as well as the resistance of the subsurface soils (shear strength) to that loading. The loading conditions for the stability analysis should match the anticipated field conditions, with typical loading conditions or analysis cases listed below.

Typical analyses performed by the Soils Design Section for each project:

- End-of-construction (short term).
- Long-term.

Other analyses that may be necessary and performed by the Soils Design Section, based on special field or construction conditions:

- Infinite slope (shallow sloughing).
- Staged construction.
- Surcharge loading.
- Partial submergence.
- Earthquake.
- Rapid drawdown.
- Back analysis (on slopes that have failed).

Development of Strength Parameters for Slope Stability Analysis

Each of the above slope/loading conditions requires the selection of appropriate soil strength parameters. Section 200E-1 provides a more detailed discussion on the selection of drained and undrained soil shear strength parameters, and the differences in total and effective stress. In general, total stress parameters are used in materials where the pore pressure increases with the application of load (fine grained soil), and effective stress parameters are used in materials were loading does not produce a change in pore pressure (coarse grained material).

For most projects, a total stress analysis will be performed for the embankment construction (application of load, end of construction case) and an effective stress analysis will be performed on the final embankment configurations (long term condition). Special exploration, testing, and analyses may be required for bridge abutments or retaining walls constructed over complex and soft geologic deposits.

Piezometric (i.e., Ground water) Levels

Assessment of the ground water levels within and beneath the slope should be performed as part of the field study, and is an important input to the stability analysis. Depending on the complexity of the subsurface and ground water conditions, data from multiple locations and depths within and below the slope will likely be needed. Long term monitoring using wells or piezometers may need to be conducted if ground water levels have seasonal variations or are responsive to significant rainfall events. In the latter case, the use of an on-site precipitation recorder could be used to aid in determining the ground water level response to rainfall events, although this would be rare.

Types of Analyses

The most common modes of slope movement include rotational, translational (block), irregular surfaces, and infinite slope. The Soils Design Section has essentially completed the transition from using PCSTABL to using GEO5 for slope stability analysis, and is currently using GEO5 for basically all analysis. Since starting to use GEO5, the Soils Design Section has typically used the Modified Bishop method for slip-circle analysis, and the Morgenstern-Price method for slip-block (polygonal) analysis. The simplified Janbu or Spencer methods of analysis may also be used when appropriate to assess global slope stability within commercially available slope stability programs similar to PCSTABL, GEO5, or SLOPE/W. In cases where the stability failure mode is not well modeled by limit equilibrium techniques, a more sophisticated analysis may be necessary using finite element/difference methods such as the computer program FLAC. Common methods of improving global slope stability include flattening the slope, improving drainage, and constructing stability berms.

If the potential slope failure mechanism is anticipated to be relatively shallow slumping (within 10 to 15 feet of the surface) and parallel to the slope face, with or without seepage affects, an infinite slope analysis may be appropriate. Vegetation on the slope can help to reduce this problem, as the vegetation roots, once established, will improve stability. Conducting an infinite slope analysis does not preclude the need to check for deeper slope failure mechanisms, as indicated above. The detailed guidance for slope stability analysis is provided in Abramson, et al. (1996).

Design Safety Factors for Slope Stability Analysis

The evaluation of overall stability of earth slopes should be performed at the Service I Load Combination with an appropriate resistance factor (or minimum factor of safety). Since the slope stability evaluation is performed at the Service Limit state, the resistance factors are combined with a load factor of 1.0. Thus, resistance factors of 0.75 and 0.65 are equivalent to a safety factor of 1.3 and 1.5, respectively. The safety factors (resistance factors) in Table 1 are recommended for design of slopes.

Table 1: Design safety factors for slope stability analysis.

slope configuration or condition analyzed	minimum factor of safety	maximum resistance factor (LRFD)
end of construction	1.3	0.75
long term		
a) slopes adjacent to but not directly supporting structures or geotechnical information is well defined.	1.3	0.75
b) slopes that support structures such as bridges and retaining walls or only limited geotechnical information is available.	1.5	0.65
infinite slope	1.2	0.85
earthquake	1.1	0.9

References

Abramson, L., Boyce, G., Lee, T., and Sharma, S., 1996. Slope Stability and Stabilization Methods, Wiley, ISBN 0471106224.

Chronology of Changes to Design Manual Section:

200F-001 Slope Stability

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