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Reliability of state of practice for selection of shear strength parameters for waste containment system stability analyses

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Abstract

In this paper, reliability analyses are performed using the results of slope stability analyses on example waste slopes to address two sources of uncertainty involved in waste slope stability assessments. These include the uncertainty associated with using shear strength parameters derived from non-project-specific sources and the uncertainty associated with the conditions required to make the development of a progressive failure mechanism, and subsequent mobilization of large-displacement shear strengths, possible. The results of the slope stability and reliability analyses performed demonstrate that less reliable or overly conservative designs can result from the use of shear strength parameters obtained from non-project-specific sources and that reliability analyses, even simple ones, provide information that can be used to establish confidence levels in factor of safety calculations. Reliability analysis results also show that slope stability calculations based on the full mobilization of large-displacement shear strengths are conservative since such analyses implicitly assume that a progressive failure mechanism develops. A method is presented that considers one particular progressive failure mechanism for the development of large-displacement conditions. The method provides a framework for evaluating the reliability of slopes where the potential for progressive failure exists.

Keywords: Clay; Geomembrane; Landfill; Slope stability; Reliability analysis

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1. Introduction

The design of liner systems for waste containment facilities requires assessments of the stability of the waste mass overlying the liner system. These liner systems typically include layers of soil and geosynthetic materials. Most practicing engineers involved in the design of these systems understand that the interfaces between these material layers (which are considered in this paper to also include the internal shear strength of geosynthetic clay liners) are relatively weak and often represent critical potential slip surfaces that need to be considered in slope stability analyses. For this reason, project-specific laboratory testing is often performed during the design phase to evaluate liner system shear strength parameters for slope stability analyses. In some cases, however, design engineers use laboratory-measured shear strength parameters from previous projects to perform stability analyses, or rely on values from published technical papers that describe "similar geosynthetic and soil materials". Many liner systems have been designed in the US using the latter two methods.

The state of practice used today for waste slope stability assessments involves calculating a factor of safety (*FS*) using limit equilibrium methods and peak interface shear strengths and comparing the calculated *FS* to a target value, typically $FS = 1.5$ for permanent (i.e., post-closure) slopes. There is much precedent for using this *FS*; however, the strict adherence to achieving this target value does not necessarily guarantee acceptable performance or a safe design unless the uncertainties associated with the *FS* calculation (e.g., material shear strengths, slope geometry, location of critical slip surface, etc.) are adequately considered. In the authors' experience, $FS = 1.5$ has been used for cases in which project-specific shear strength information has not been available.

More and more engineers are utilizing a secondary criterion for waste slope stability assessments that involves using limit equilibrium methods, large-displacement interface shear strengths, and a target *FS* of 1.15–1.3 or lower (Stark and Poeppel, 1994; Gilbert and Byrne, 1996; Thiel, 2001). This secondary criterion is intended to address the potential for progressive failure due to waste settlement-induced liner system shear stresses, construction-induced shear stresses, and/or interface creep. Although the authors are only aware of the Kettleman Hills landfill failure (Seed et al., 1990; Mitchell et al., 1990) as an example where progressive failure is needed to explain waste slope instability, the authors believe it is prudent to evaluate this secondary stability criterion as part of the current state of practice.

2. Definition of standard of care

Engineers have a duty to perform their services in a manner consistent with the "standard of care" of their profession. Many definitions of the standard of care exist; however, a reasonable working definition for a design professional is, "that level of skill and competence ordinarily and contemporaneously demonstrated by professionals of the same discipline practicing in the same locale and faced with the same or