LS-G-TN1
Software: LimitState:GEO 2.0e
Date: July 2010

Technical Note - Principles of Slope Stability Analysis

1 Introduction

This Application Note outlines the principles applied when performing a slope stability analysis using LimitState:GEO.

In a conventional slope stability analysis (e.g. using the method of slices) a pre-determined slip surface is assumed and the stability of the failing soil mass is evaluated by comparing resisting and disturbing forces/moments. Usually many trial slip surfaces are investigated and the most critical one identified. This typically requires specification of a search zone and entry and exit points, and can be very sensitive to the shape of slip surfaces used (e.g. circular or non-circular).

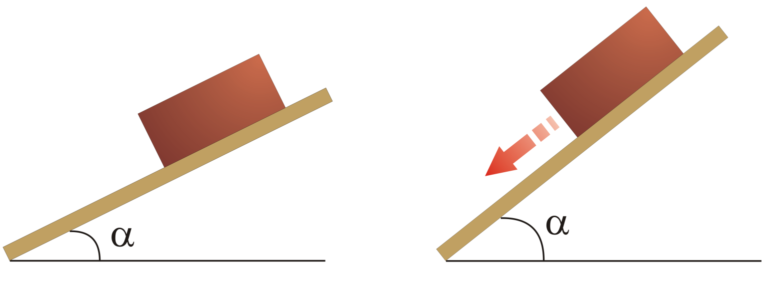
In contrast the general purpose limit analysis procedure used by LimitState:GEO does not require the form of the collapse mechanism to be pre-specified. However, the use of a general purpose procedure does mean that an particular approach must be adopted to identify the critical failure mechanism.

2 Slope stability Limit Analysis

In LimitState:GEO, it is necessary to drive the problem to collapse by applying a multiplier (or **Adequacy factor**) to an unfavourable load.

In a foundation problem this is conceptually straightforward: the load on the foundation is increased until the underlying soil fails, indicating that the ultimate limit state has been reached.

Similarly, in a slope stability problem the self weight of the soil forming the slope could be increased until collapse occurs. However, a simple example will help show that this is not necessarily the best approach, particularly for problems involving purely frictional soils. Thus see Figure 1, which shows a brick placed on a plank of wood. For a given angle of inclination of the plank, the brick will either be stable or unstable. However, factoring up the weight of the brick will not affect its stability, i.e. applying the **Adequacy factor** to the self weight of the brick will not drive the problem to failure (and will typically return a solution of *unstable* or *locked* in LimitState:GEO).



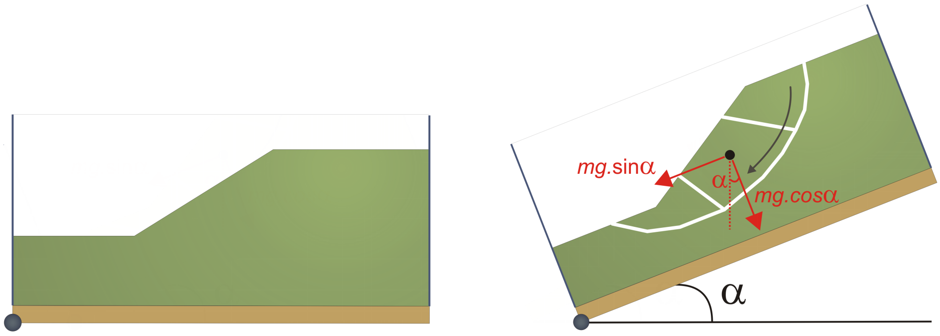
(a) Stable ($\alpha < \phi$) (b) Unstable ($\alpha > \phi$)

Figure 1: Stability of a brick on an inclined plank with brick/plank interface friction angle ϕ.

Alternatively, consider a laboratory model of a slope stability problem with the model contained within a tank, such that the tank may be pivoted about one end as depicted in Figure 2. In order to establish how close to the point of stability the slope is, the tank could be slowly tilted from the horizontal to a steeper and steeper angle α_{crit} until failure occurs. The larger this angle the more stable the slope.

Typically a factor of safety is required in terms of a factor (F) on soil strength such that the slope collapses with soil properties c'/F and $\tan\phi'/F$. The problem then becomes on of finding F such that $\alpha_{crit} = 0$[1].

[1] In LimitState:GEO, a strength reduction approach such as this can be undertaken in a semi-automatic way by using the Scenario Manager (see Section 10.2 and Chapter 26 of the User Manual for more information).



(a) Model as constructed (stable, $\alpha = 0$) (b) Model tilted until failure occurs ($\alpha > 0$)

Figure 2: Laboratory slope stability model.

Alternatively, from a Eurocode 7 perspective (Design Approach 1, Combination 2, and Design Approach 3), a specified factor is applied to the soil strength and stability evaluated. In this context a value of $\alpha_{crit} \geq 0$ indicates stability. As will be seen, either of these principles can be applied when using LimitState:GEO.

3 Application in LimitState:GEO

Tilting the tank is analogous to modifying the body forces exerted by any mass of soil or structure. Within the frame of reference of the tank, the vertical body force becomes $mg \cos \alpha$ and a horizontal body force is introduced $mg \sin \alpha$, as shown in Figure 2, where m is the mass of the body and g the acceleration due to gravity.

In LimitState:GEO, horizontal body forces can be introduced using the **Seismic Actions** facility in the **Property Editor**. By setting the **Horizontal Accel. k$_h$ (g)** to 1.0, **Adequacy (on k$_h$)** to *True* (and ensuring Adequacy is not set on any other parameter), this requires the software to find the horizontal acceleration required to cause collapse. This will be returned as the **Adequacy factor** (AF).

This can be converted to an equivalent value of α_{crit} using the expression $\alpha_{crit} = \tan^{-1}(AF)$. Thus the problem is stable if $AF \geq 0.0$.

It is important to note that:

1. Whereas in normal usage stability normally corresponds to $AF \geq 1.0$ (e.g. for a foundation stability problem), in this special case a value of $AF \geq 0.0$ is required.
2. The significance of the order of magnitude of AF will differ from conventional usage. For example, a $24.8°$ slope of soil of friction angle $30°$ is just stable with a factor of safety of 1.25 on soil strength. This corresponds to a value of $\alpha_{crit} = 5.2°$ (or $AF = 0.091$). It is thus recommended to conceptually interpret the **Adequacy factor** as an angle $\alpha_{crit} = \tan^{-1}(AF)$.

A worked example of a slope stability problem using LimitState:GEO may be found in Application Note LS-AN2.

For more information: www.limitstate.com/geo