GeoStudio Example File
Pore-Water Pressures Defined using Ru

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Introduction

Prior to the advent of computer slope stability analyses, it was desirable to express the pore-water pressure conditions using a simple single parameter. The development of slope stability charts in particular, such as the ones created by Bishop and Morgenstern (1960), necessitated a pore-water pressure definition. One such approach is to define the pore-water pressure as a function of the overburden stress, which became known as a ratio called R_u.

The purpose of this example is to highlight the use R_u and to offer ways of using R_u so that it better represents the actual field pore-water pressure conditions.

Background

In equation form, the R_u is calculated as:

$$R_u = \frac{u}{\gamma z}$$ **Equation 1**

where u is the pore-water pressure, γ is the unit weight of the soil and z is the depth below ground. The denominator (γz) is also known as the overburden stress. The R_u ratio is in some ways similar to the Skempton (1954) pore-water pressure coefficient $\bar{B}$ which is defined as:

$$\bar{B} = \frac{\Delta u}{\Delta \sigma_1}$$ **Equation 2**

where $\Delta\sigma_1$ is the change in the major principal stress, which is often assumed, for simplicity, to be equal to the change in vertical stress (σ_v).

The coefficient then becomes:

$$\bar{B} = \frac{\Delta u}{\Delta \sigma_v}$$ **Equation 3**

Numerically, B-bar and R_u are often the same. However, B-bar has the added connotation of representing changes in pore-water pressure due to changes in vertical stress. B-bar is consequently associated more often with construction activities, where there are changes in stress due to the placement of fill.

The R_u ratio is a crude way of describing pore-water conditions in a slope stability analysis. A single R_u value can seldom, if ever, represent the actual field groundwater flow conditions. Although it is rarely used in practice, R_u remains an option in SLOPE/W for legacy reasons.

Numerical Simulation

The problem domain is shown in Figure 1. The objective is to explore the value of R_u required to represent the pore-water pressure conditions defined using a piezometric line. The suction in the zone above the piezometric line has been capped at 20 kPa. Figure 2 presents the R_u values calculated at the base of each slice along the critical slip surface, which varies from -1.14 to +0.54. However, a serious limitation to the R_u approach is that a single constant value is required. The only condition for which R_u is constant is when the piezometric line is at the ground surface, which rarely exists in nature. For simplicity, the average value of all slices (0.273) was used.

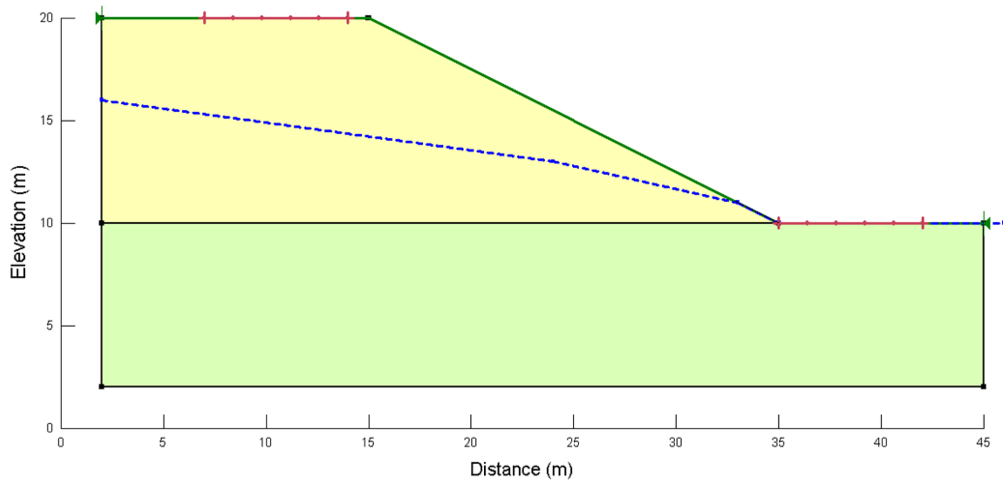

Figure 1. Stability analysis configuration.

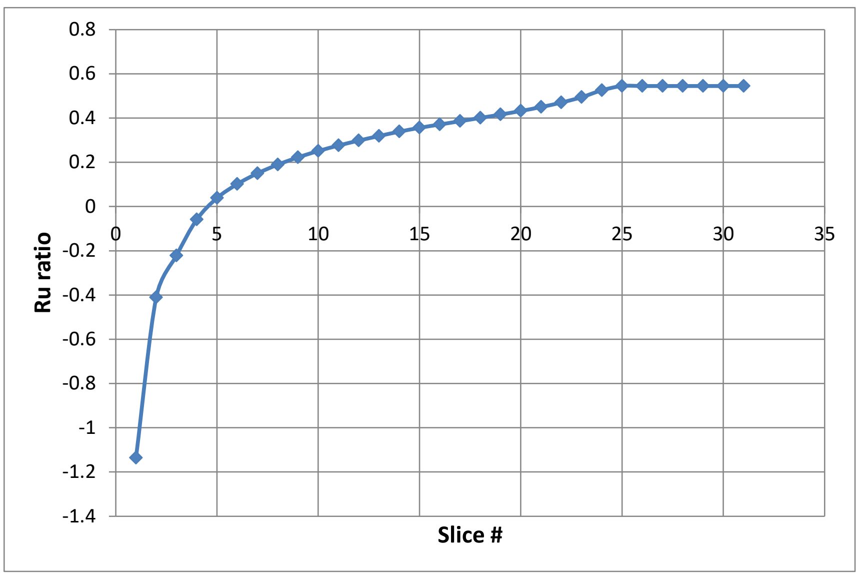

Figure 2. Variation of R_u ratios along a slip surface.

Results and Discussion

Figure 3 presents the computed factor of safety and critical slip surface when R_u is used to represent the pore-water pressure conditions. The overall factor of safety is not all that different compared to the piezometric line case. The position of the critical slip surface, however, is different. For the same slip surface the factors of safety are 1.424 and 1.315 for the piezometric line and R_u cases, respectively. This occurs because the average R_u was calculated for the critical slip surface from the piezometric line case.

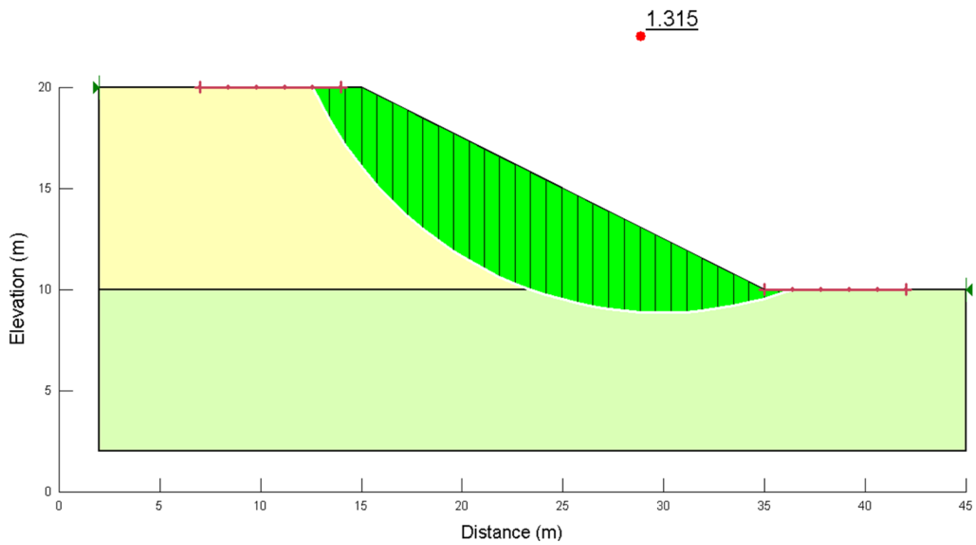

Figure 3. Stability analysis result with an average R_u.

The pore-water pressure distributions are very different (Figure 4). The use of R_u omits the presence of any negative pore-water pressures. Although the factor of safety is somewhat reasonable, the analysis is based on an erroneous pore-water pressure distribution.

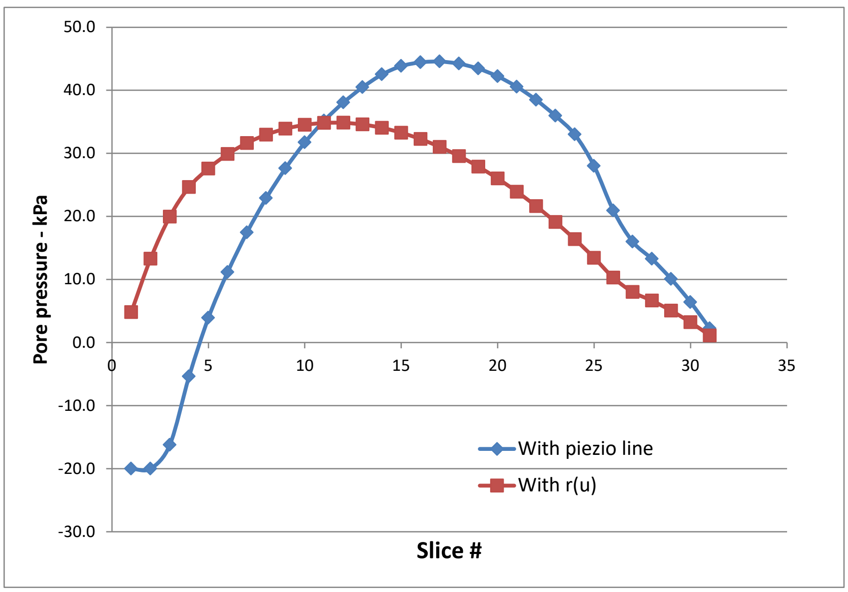

Figure 4. Comparison of pore-water pressure distributions.

From the observation above, it is possible to find an average R_u that gives a reasonable factor of safety. Determining the average value is not a trivial task. In the above analysis, an average was found by first using a piezometric line in the analysis. In practical field problems, this would be nonsensical as there would be no need to use an average R_u if the piezometric position is already known. Smith (1974) actually proposed a procedure that is shown in Figure 5.

Consider a scenario where field measured piezometric data is available at a particular site. These measurements could be converted into equivalent R_u values, and then somehow averaged for a stability analysis. Again, this approach seems paradoxical given that the values could be used directly in SLOPE/W via a piezometric line or spatial head function.

Determination of an average value for r_u

Generally r_u will not be constant over the cross section of an embankment and the following procedure can be used to determine an average value.

In Fig. 5.18 the stability of the downstream slope is to be determined.

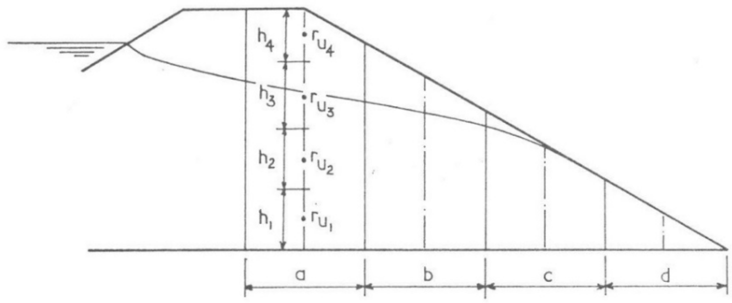

Fig. 5.18 Determination of average r_u value

From the centre line of the cross section divide the base of the dam into a suitable number of vertical slices, and on the centre line of each slice determine r_u values for a series of points as shown. Then the average pore pressure ratio on the centre line of a particular slice,

$$r_u = \frac{h_1 r_{u1} + h_2 r_{u2} + h_3 r_{u3} + \ldots}{h_1 + h_2 + h_3 + \ldots}$$

The average r_u for whole cross section

$$= \frac{A_a r_{ua} + A_b r_{ub} + A_c r_{uc} + \ldots}{A_a + A_b + A_c + \ldots}$$

where A_a = area of the slice a and r_{ua} = average r_u value in slice a.

Figure 5. Determination of an average value for r_u (after Smith, 1974, p. 146).

Summary and Conclusions

Selecting a single R_u ratio to describe the pore-water pressure conditions for a SLOPE/W analysis can be difficult. The method was developed to be used with stability charts and cannot accommodate even slightly complex groundwater flow systems. Regardless, the method can be used in SLOPE/W, but the limitations should be fully understood.

References

Bishop, A.W. & Morgenstern, N. (1960). Stability coefficients for earth slopes, *Géotechnique* 10 (4). p. 129-153.

Skempton. A.W. (1954). The pore-pressure coefficients A and B, *Géotechnique* 4 (4). p 143-147.

Smith, G.N. (1974). *Elements of Soil Mechanics for Civil and Mining Engineers*, Crosby Lockwood Staples, London, 3rd Edition.