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The Method of Horizontal and Vertical Slices: Comparing and Evaluating Exactitude in Soil Slope Stability Analysis

M. Khodaparast[1*] M. Khashei[2] R. M. Momeni[3]

1. Introduction

Soil slope stability analysis is one of the most important issues in the design of earth dams, roads, canals and levees. Another important issue in designing the embankment is the optimal design of the plan. The application of high safety factor in the design of the soil slope has a significant effect on the final cost of the project, which will be more important in the case of earth dams with a very high volume of land operations. Accordingly, methods chosen for the anlysis of the stability of the slope should be justified both sustainability and economically.

There are many methods for calculating the stability of the soil slope, which may have different results. One of the most common methods is the partial analysis of the soil slope using the parts method. This method, with the assumption that the slope is located at the slip threshold, examines the passive or active force and the moment to obtain the coefficient of stability of the slope. In this method, by considering a hypothetical slip wedge and dividing it into a number of smaller pieces, the effect of active or passive forces on each pieces is investigated. Finally, with the addition of forces and moments, the slope stability coefficient for the total slip surface is calculated. In this case, depending on whether the parts are vertical or horizontal, the method required for the calculation and formulation will differ.

In the past, research has been conducted on the development of the formulation of horizontal components and their application in the analysis of the stability of the slope. However, in the field of comparison and precision, this method has not been adequately investigated by other methods, including the method of vertical slices.

The main purpose of the present study is to compare the results of the stability analysis of the soil slope using the horizontal and vertical slices method and to determine the precision of each method.

2. Material and methods

In the present study, we used two methods of vertical slices (Flenius method and modified Bishop's method) and horizontal slices (2N formulation and 2N + 1 formulation). Four kinds of rupture surface were also considered: Transition slip with unlimited flat slip surface, limited slip on the flat surface slip, the circular slip in homogeneous adhesive soil (without internal friction angle) and the circular slip in soil with adhesion and internal friction angle. The safety factor against slip for several soil slopes with geometric and geotechnical specifications were determined. The stability analysis of the slopes is assumed to be homogeneous soil, regardless of the effects of earthquake force and water pressure.

In each step, an important problem with the precision measurement of these methods was considered. In this section, accurate analytical methods were used to calculate the safety factor against the stability of the soil slope, and then the data of the four methods were carefully investigated. In some methods, to accurately distinguish between different methods in determining the value of the coefficient of reliability, the coefficient of reliability changes diagram is plotted according to the adhesion values. In doing so, in the software, the effect of changing the adhesion value on the coefficient of reliability in different methods is calculated by considering the specified values for γ and φ for the slopes. Similarly, the same procedure is followed for other parameters such as specific gravity and the internal friction angle of the soil.

3. Conclusion

In the case of a flat surface slip, studies have shown that there is a slight difference (about 0.4%) between the results of the accurate method, the vertical and horizontal slices method,. The main reason for the accuracy of the methods in this case is the flatness of the slip surface. The values of slider wedge surfaces are accurately calculated and there is no approximation due to the presence of curvature at the slider wedge surface, and as a result, the weight of the parts, that is to say, the amount of force of the slices method in the process is accurately calculated.

In a sliding mode of the circle in homogeneous adhesive soil (without the internal friction angle), the accuracy of the same was observed with the use of the vertical slices method; the Flenius and modified Bishop methods. And the difference between the results and the exact amount is small. If the horizontal slices method is employed in the 2N formulation, the results will be less than the actual values (up to 20%) due to the approximation at the effect point of the force. However, in the formulation 2N+1, although it is not a complete method for formulating the horizontal slices method, in terms of accuracy, the results are identical in the method of Flenius, and in some cases they look the same in the Bishop method. In this case, with the linear increase of adhesion, the coefficient of reliability increased linearly (Fig. 1) and with the linear increase in the amount of soil specific gravity, the coefficient of reliability was reduced nonlinearly (Fig. 2).

[1*] Corresponding Author, Associate Professor, Civil Engineering Department, University of Qom, Faculty of Engineering. Email: mahdikhodaparast@yahoo.com
[2] Master of Science (MSc), Civil Engineering Department, University of Qom, Faculty of Engineering.
[3] Ph.D. student, Civil Engineering Department, University of Qom, Faculty of Engineering.

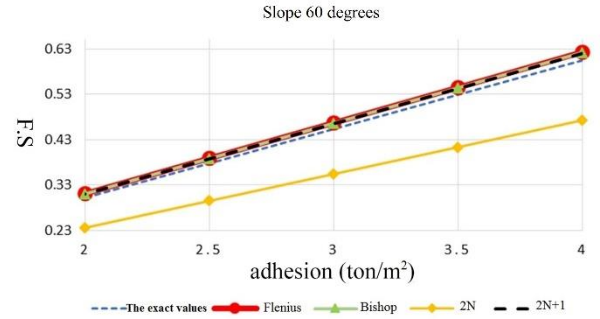

Fig. 1 The chart of changes in the coefficient of confidence according to the adhesion values in the soil with a gradient of 60° and a specific gravity of 1.8 tons per cubic meter

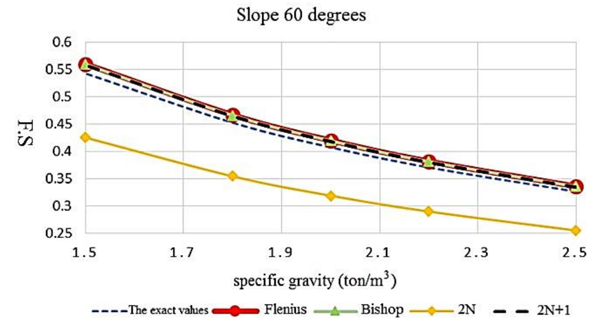

Fig. 2 The chart of changes in the coefficient of confidence according to the specific gravity values in the soil with a gradient of 60° and an adhesion of 3 tons per square meter

As with the circular slip on the soil with the adhesion and internal friction angle, the coefficient of reliability of the modified Bishop method is the highest and the coefficient is assured by the Flenius method, and then the confidence coefficient obtained from the 2N+1 horizontal slices method is located. The lowest level of reliability is related to the simplified method of horizontal slices of 2N. In this case, with the linear increase of adhesion, the value of the coefficient of confidence is increased linearly (Fig. 3). And with the linear increase in the volume of specific gravity of soil, the value of the coefficient of confidence is reduced nonlinearly (Fig. 4). Also, with an increase in the linear angle of the internal friction of the soil, the value of the coefficient of confidence increased nonlinearly (Fig. 5).

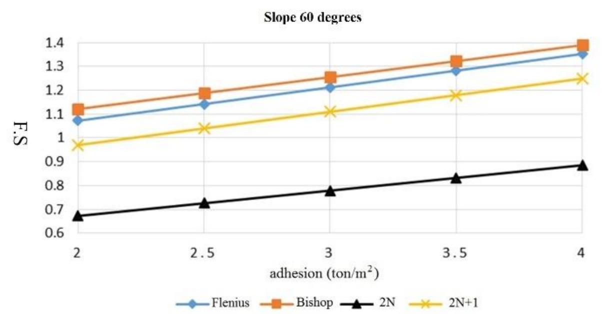

Fig. 3 The chart of coefficient of confidence changes in terms of adhesion values in soil with a gradient of 60° and a specific gravity of 2 tons per cubic meter and an internal friction angle of 30°

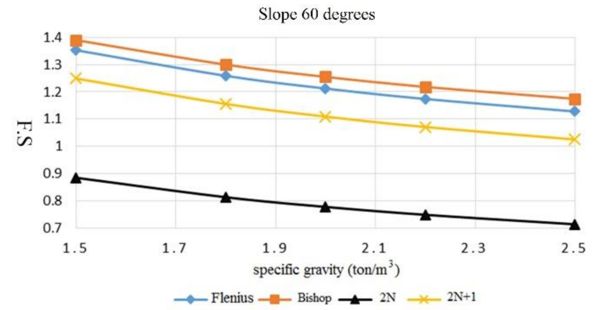

Fig. 4 The chart of changes in the coefficient of confidence in terms of specific gravity in soil with a gradient of 60° and adhesion of 3 tons per square meter and an internal friction angle of 30°

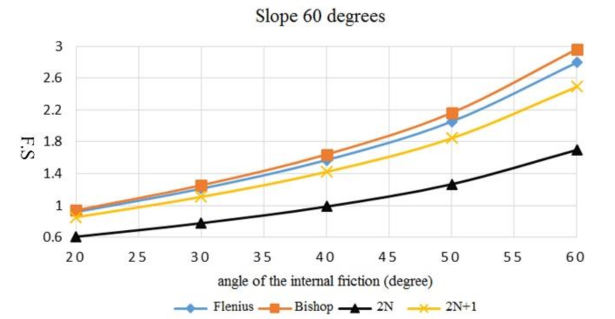

Fig. 5 The chart of coefficient of confidence changes based on the values of the internal friction angle in the soil with a gradient of 60° and adhesion of 3 tons per square meter and specific gravity of 2 tons per cubic meter

In conclusion, the vertical slices method provides more accurate results with a slight margin of confidence for the soil slope while the results of the horizontal slices method strongly depend on the formulation. In the horizontal slices method, the 2N formulation method shows fewer values for the slope stability coefficient whereas the 2N+1 method, which—in terms of formulation—is not among the advanced methods of the horizontal slices method, provides acceptable results—similar to the results of the vertical slices method. By choosing the appropriate formulation, the horizontal slices method can be highly accurate and it should be noted that where the soil has a horizontal layering or horizontal force problem such as the presence of horizontal hardening or component of earthquake force, etc., the method of the horizontal slices provides much higher ease of use.