Review on Comparison of Traditional Methods and Finite Difference Method for Computing Safety Factors of Slope Stability

KEYWORDS: Slope stability; finite difference method (FDM); Safety of factor; Bishop simplified method; Janbu corrected method; Spencer method

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ABSTRACT *In this paper, for the purpose of comparing the traditional methods (Spencer, Janbu corrected and Bishop simplified) results for computing safety factor of slope stability with finite difference method (FDM) results, safety factors of 135 difference slopes with four mentioned method calculated under effect of their weights. Results are been obtained by varying values of parameters such as cohesion, internal friction, density. In these experiments, Flac/Slope software has been used for analysis of slopes stability with FDM, also Slide.6 software is used to achieve the results of the Spencer, Janbu, and Bishop methods. The analysis shows that, determination coefficient or R2 , between the results of every methods and finite difference numerical method (FDM) is 0.99 and also the obtained results indicate a close correspondence of mentioned traditional methods exists with the found results for the finite difference method (FDM) used in the process.*

INTRODUCTION
After observing the first phenomenon of slopes slide in the world, lots of scientists analyzed and studied this phenomenon. Bishop (1955), Janbu (1954), Spencer (1967) and Fellenius (1936), were scientists those presented the different methods about finding most critical for slide surface and determined safety factor of slope stability. Multiplicity of slope analyzes method and in the other hand, appearance of numerical methods like finite difference method (FDM), sometimes makes this question that which methods are dependable for determining of slope stability analyzes. We are trying to compare the result of numerical methods of specified scientist/engineers A. W. Bishop, N. Janbu and E. Spencer with FDM results. Thus,

In this paper 135 different slopes with various basic parameters i.e. cohesion, internal friction, density has been evaluated by Flac/Slope software, and Slide software to achieve the results for the Spencer, Janbu, and Bishop methods.

FLAC Slope Modeling
FLAC/Slope using square and parallelogram meshes. Parallelogram meshes are using in slope direction. Basic step in the Solve stage is grid generation. In this step four zoning choices are Available: coarse, medium, fine and user-selected (special). The coarse-grid model is recommended for preliminary analyses. The solution for this model is quite rapid a project with several models can easily be run to provide a quick estimate for the effect of different conditions on the factor of safety. A medium-grid model is recommended for more comprehensive studies. The results for this type of zoning are found to be in good agreement with limit analyses and limit-equilibrium model results. A fine-grid model is recommended as a check on analyses made with the medium-grid model. The Factor of safety calculation with the fine-grid model should agree very closely with that from the medium-grid model. However, because this type grid takes longer to calculate a safety factor, it usually is not warranted to use fine-grid models for comprehensive studies. (Flac Slope Manual, 2002)

ANALYTICAL METHODS
Simplified Bishop Procedure
Referring to the slice shown in the Fig.1 and resolving force in the vertical direction, the following equilibrium equation can be written for forces in the vertical direction (Duncan, 2005):

Also a good agreement has been found between the factor of safety calculated by simplified

Bishop procedure and limit equilibrium procedures that fully satisfy static equilibrium Also

(Wright et al., 1973) have shown that the factor of safety calculated by the simplified Bishop procedure agrees favorably (within about 5%) with the factor of safety calculated using stresses computed independently using finite element procedure.

Spencer Procedure

(Spencer E., 1967) procedure is based on the assumption that the interslice forces are parallel (i.e., all interslice forces have the same inclination). The specific inclination of the interslice forces is known and is computed as one of the unknowns in the solution of the equilibrium equation. Spencer´s procedure also assumes that the normal force (N) acts at the center of the base of each slice. This assumption has negligible influence on the computed value for the unknowns provided that a reasonably large number of slices in used; virtually all calculations with Spencer´s procedure are performed by computer and a sufficiently large number of slices are easily attained. Spencer originally presented his procedure for circular slip surfaces, but the procedure easily extended to noncircular slip surface. (Duncan, 2005)

Janbu procedure

The factor of safety is computed in this procedure by performing successive force equilibrium solution. In Janbu procedure the factor of safety is computed by performing successive force equilibrium solution. Initially, the interslice forces are assumed to be horizontal and the unknown factor of safety and horizontal interslice forces, E, are calculated. Using this initial set of interslice forces, E, new interslice shear forces, x, are calculated from Eq.(15) and the force equilibrium solution is repeated. This process is repeated, each time making revised estimate of the vertical component (X) of the interslice force and calculating the unknown factor of safety and horizontal interslice forces, until the solution converges (i.e., until there is not a significant change in the factor of safety).This procedure (Janbu, 1954) frequently produces a factor of safety that is nearly identical to values calculated by procedure that rigorously satisfy complete static equilibrium. However the procedure does not always produce a stable numerical solution that converges within acceptable small errors. This procedure satisfies moment equilibrium in only an approximate way [Eq. (15) rather than (14)] (Duncan, 2005). It can be argued that once the approximate solution is obtained, a solution can be forced to satisfy moment equilibrium by summing moments for each slice individually and calculating the location for the normal force (N) on the base of the slice, which will then satisfy moment equilibrium rigorously. This, however, can be done with any of the force equilibrium procedure described in this chapter but by summing moment only after a factor of safety calculated, there is no influence of moment equilibrium on the computed factor of safety.

RESULTS

Now, the results of modeled slopes will show as graphs. In this graphs the vertical axis is indicate safety factors resulting by finite difference method (FDM) and horizontal axis indicates safety factors resulting from one of the mentioned traditional methods. If the points are closer to the center line, the results of both methods are more similar together. Furthermore, two dotty line both side of center line, are show limit of %10 error.

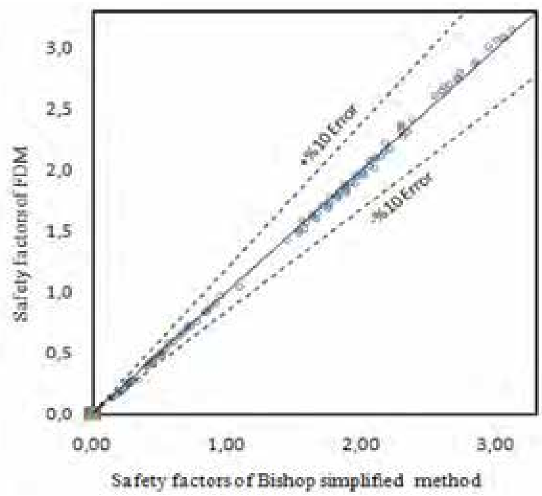

Figure 1: Safety factors of BISHOP simplified method versus Finite difference method.

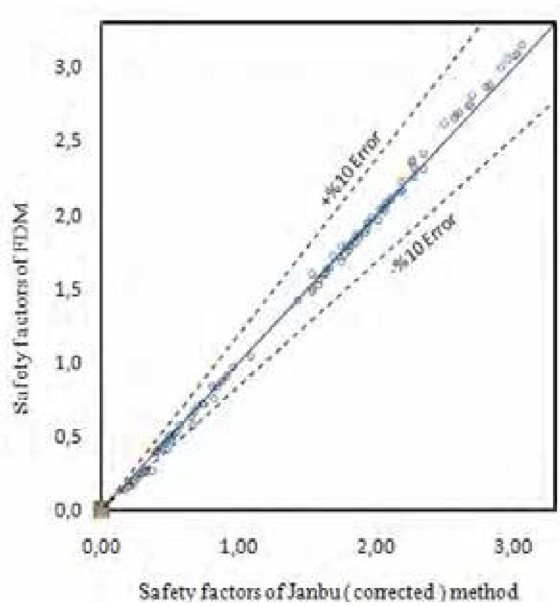

Figure 2 : Safety factors of JANBU (corrected) method versus Finite difference method.

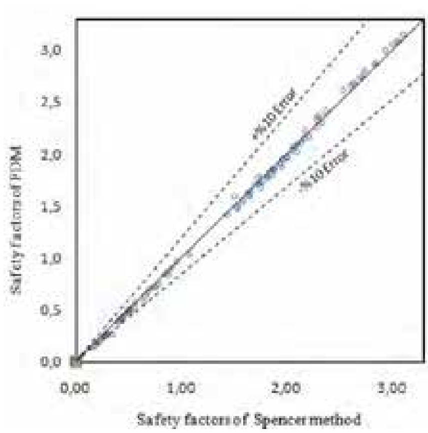

Figure 3 : Safety factors of SPENCER method versus Finite difference method.

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CONCLUSION

Using 135 different slopes and calculation of their safety factors by Spencer, Janbu (corrected) and Bishop simplified methods and comparing them with the results of finite difference method (FDM), and evaluating the obtained results will indicate that the mentioned methods results are very close and therefore can be considered acceptable with the high degree of accuracy. Comparing results of each mentioned traditional method and FDM, determination coefficient, R2, equal to 0.99 and square root means squared error value or RMSE, is between with 0.06 to 0.07 would be negligible; although these methods which have different theories, graph analysis indicate that the results obtained from these methods are very much alike, almost identical in fact. Hence, developing new numerical methods to calculation of slope stability safety factor, with the intricacy and time consuming programs, using traditional methods (Spencer, Simplified Bishop and Janbu corrected) are reliable as well as most importantly practical.

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