



Incorporation of the spectral pseudo-static procedure into the limit equilibrium slope stability software - SVSLOPE

Mourad Karray, Mahmoud N. Hussien and Fady Ghobrial

Department of Civil Engineering, Faculty of Engineering, Sherbrooke University, Sherbrooke, Qc,

Marie-Christine Delisle, Pascal Locat, Rémi Mompin and Catherine Ledoux

Ministère des Transports, de la Mobilité durable et de l'Électrification des transports du Québec, Québec, Qc, Canada

Murray Fredlund, HaiHua Lu and Rob Thode

SOILVISION Systems Ltd.

120 - 502 Wellman Cres., Saskatoon, SK, Canada

ABSTRACT

The concept of the spectral pseudo-static procedure has been developed at the Université de Sherbrooke (UdeS) as an alternative to the conventional pseudo-static approach for the analyses of seismic stability of clayey slopes. Its results have been extensively validated by a series of physical tests and numerical simulations performed using the computer code FLAC7. In this study, a computation algorithm of the spectral pseudo-static procedure has been developed and incorporated into the limit equilibrium software, SVSLOPE (SOILVISION) so that the new approach can be directly applied to the analysis of seismic stability of clayey slopes in Eastern Canada. The outlines of the new approach and its implications in the current design practice of clayey slopes as well as a number of practical examples discussing the results obtained from the SVSLOPE software against the corresponding results from full dynamic analyses using FLAC7 are presented in this paper. The comparison showed the superiority of the spectral pseudo-static method over the conventional pseudo-static method not only in terms of the computed safety factors but also in the prediction of the failure surface locations, and thus allow for more complex and realistic field behaviors

RÉSUMÉ

Le concept de la méthode pseudo-statique spectrale a été développé à l'Université de Sherbrooke (UdeS) comme alternative à l'approche pseudo-statique conventionnelle pour l'analyse de la stabilité sismique des pentes argileuses. Ses résultats ont été largement validés par une série de simulations numériques effectuées à l'aide du code informatique FLAC7. Dans cette étude, un algorithme de calcul de la procédure pseudo-statique spectrale a été développé et incorporé dans le logiciel d'équilibre limite, SVSLOPE (SOILVISION), de sorte que la nouvelle approche peut être directement appliquée à l'analyse de la stabilité sismique des pentes argileuses dans l'est du Canada. Le présent article présente les grandes lignes de la nouvelle approche et ses implications dans la pratique actuelle dans l'analyse de stabilité sismique des pentes argileuses ainsi qu'un certain nombre d'exemples pratiques décrivant les résultats obtenus à partir du logiciel SVSLOPE par rapport aux résultats correspondants des analyses dynamiques complètes utilisant FLAC7. La comparaison a montré la supériorité de la méthode pseudo-statique spectrale par rapport à la méthode pseudo-statique conventionnelle, non seulement dans le calcul du facteur de sécurité, mais aussi dans la prédiction des surfaces de rupture, permettant ainsi de prédire les comportements de terrain plus complexes et plus réalistes.

1 INTRODUCTION

During the period 2011 to 2017, the geotechnical laboratory at the Université de Sherbrooke in collaboration with the Ministère des Transports, de la Mobilité durable et de l'Électrification (MTMDET) has developed the spectral pseudo-static approach as an alternative to the conventional pseudo-static approach for the analyses of seismic stability of clayey slopes (e.g., Ghobrial et al. 2015, 2017; Karray et al. 2017a, 2017b, 2017c). The destabilizing effect of an earthquake is approximated, in the new approach, by a static horizontal inertial force applied to the centroid of the potential sliding mass. This horizontal force is the product of a seismic coefficient (k_h) hyperbolically varies with depth and the weight of the soil mass prone to failure. The spectral pseudo-static results have been rigorously verified against

available static and dynamic laboratory tests (Ozkahriman 2009), and have been extensively validated by a series of simulations performed using the computer code FLAC7 (Itasca 2007) (Karray et al. 2017a). Good agreements have been achieved between the results of the spectral pseudo-static procedure and the complete numerical finite differences (FD) analyses, in terms of both the computed safety factors and the critical slip surfaces.

The next step in the ongoing development of the spectral pseudo-static producer is to implement it into one of the available limit equilibrium slope stability software such as the SVSLOPE software package (Fredlund and Thode 2011). This would provide a useful tool to thoroughly examine the reliability of the pseudo-static spectral method and assess the effect of dynamic soil characteristics on the proposed seismic coefficient profiles. A fundamental overview about the developed

spectral pseudo-static approach and the current static and seismic limit-equilibrium procedures are given in the beginning of this paper. Then, this study presents the methodology developed in the context of implementing the proposed procedure in the limit analysis program (SVSLOPE) developed by SOILVISION, to be followed by some practical examples showing the reliability and superiority of the use of the spectral pseudo-static approach in limit equilibrium analyses compared to the conventional pseudo-static approach.

2 DEVELOPMENT OF THE SPECTRAL PSEUDO-STATIC APPROACH

The pseudo-static method has been used for more than 50 years for seismic slope stability analyses. This method consists of replacing the dynamic action of an earthquake with a static horizontal inertial force applied to the centroid of the potential sliding mass. This horizontal force is the product of a seismic coefficient (k_h) and the weight of the soil mass prone to failure, W . The failure surface is first determined from static stability analysis and it is presumed that the same failure surface would be developed under seismic condition. In practice, the pseudo-static analysis is relatively simple and straightforward, what makes its computations easy to understand and perform by geotechnical engineers. However, it cannot provide a reliable evaluation of the seismic stability of slopes, as its results are substantially dependent on the selection of the seismic coefficient. Moreover, the representation of the complex effects of an earthquake by a single, permanent, unidirectional body force is obviously quite crude. In fact, the dynamic response of a slope substantially depends on its geometry, stiffness and on the dynamic characteristics (i.e., amplitude and frequency content) of the ground motion. For example, the lateral displacement field throughout the potential failure mass will be generally in phase in relatively stiff slopes subjected to low-frequency ground motions and thus the approximation of the pseudo-static approach with respect to the representation of the earthquake effect by a unidirectional single force appears to be quite acceptable. On the other hand, lateral displacements of slopes subjected to motions rich in high-frequency components might be out of phase. In other words, the inertial forces generated at different points within the failure mass would be acting in opposite directions and the resultant inertial force might be substantially less than the imposed pseudo-static force which implies that the pseudo-static procedure is very conservative.

Actually, the pseudo-static approach would be quite useful in estimating the safety factor of clayey slopes under seismic loading provided it has been modified and calibrated against adequate case histories. The attractive features of the pseudo-static approach, in particular its similarity to the static limit equilibrium analyses routinely conducted by geotechnical engineers worth doing more effort to enhance and optimize its results. As an alternative to the conventional pseudo-static approach, the concept of the spectral pseudo-static procedure has been developed at the Université de Sherbrooke in

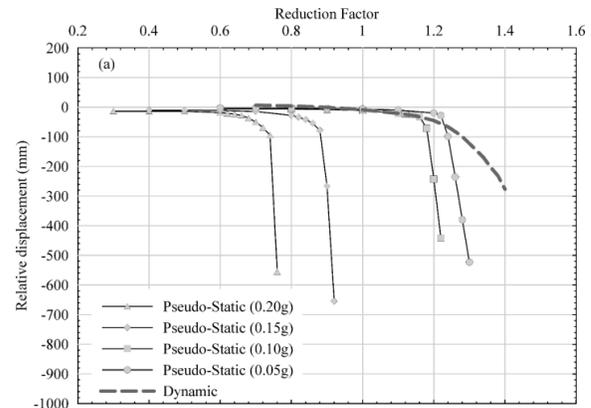


Figure 1 Pseudo-static and dynamic relative displacement-factor of safety curves of 3H: 1V slopes.

collaboration with Ministère des transports du Québec (e.g., Ghobrial et al. 2015, 2017; Karray et al. 2017a, 2017b, 2017c) for the analyses of seismic stability of clayey slopes. The development of the spectral pseudo-static procedure was primarily based on detailed static, dynamic, and conventional pseudo-static analyses using the two-dimensional (2D) explicit finite difference program, FLAC7 (Itasca 2007). In these analyses, the strength reduction procedure is utilized to determine the factor of safety. This approach constitutes a determination of a reduction factor of the resistance (C_u) of the cohesive soil that leads to slope failure. In other words, the main idea of this procedure is to initiate a systematic search for the value of the reduction factor (i.e., the factor of safety) that will bring the slope to fail. For a given static, pseudo-static, and dynamic analysis, the calculations are repeated several times with different values of soil shear strength, and the relative horizontal displacement between two arbitrary points (typically, at the slope toe and the corresponding point at the bedrock) is noted and plotted as a function of the applied strength reduction factor. The equivalent factor of safety can be then determined from this plot as the reduction factor corresponding to the general plastification (i.e., the significant and sudden variation in the relative horizontal displacement). The formation of the failure surface can be also established using the same FD analyses. Details of the strength reduction technique can be found in Karray et al. 2017a.

An example of the relative displacement-reduction factor curves of pseudo-static and dynamic analyses are presented in Fig. 1. The pseudo-static analysis is repeated several times with different values of the seismic coefficient as shown in Fig. 1 and the constant seismic coefficient giving the same dynamic factor of safety is about 0.05 which is generally less than its typical values.

For different geometries and dimensions of the clayey slopes, the pseudo-static and the dynamic analyses have been repeated and the seismic coefficient values that produce safety factors equal to those obtained from the complete dynamic analyses are plotted against the natural period of the soil deposit as shown in Fig. 2. The results presented in Fig. 2 indicate that seismic coefficient

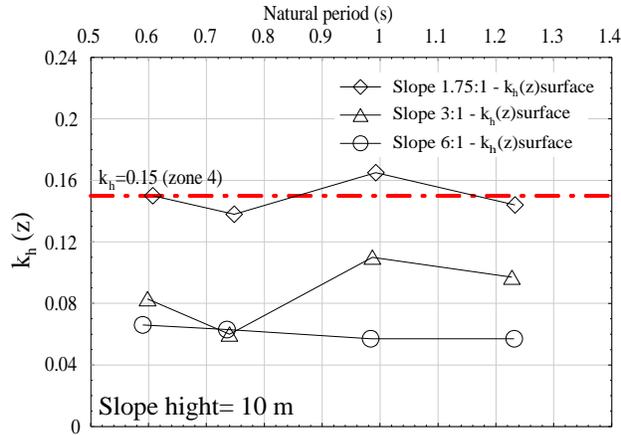


Figure 2 The seismic coefficient as a function of the natural period (T_0) of the deposit.

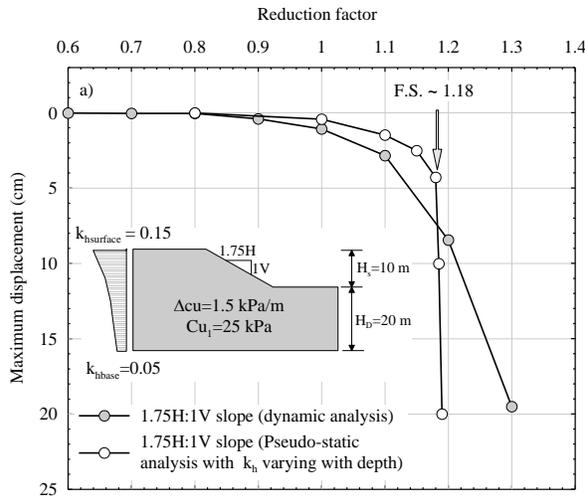


Figure 3 Comparison between relative displacement-factor of safety curves from dynamic and modified pseudo-static analysis

value is critically dependent on the slope geometry and dimension.

Based on the comparative results of the pseudo-static and the dynamic analyses discussed in Figs. 1 and 2 as well as the literature pertaining to the topic, it could be stating that one of the main crude approximations of the pseudo-static approach is that it uses a constant seismic coefficient over the entire height of the slope. Prof. Karray and his colleagues at the Université de Sherbrooke, Qc postulated that using either linear or segmental variation of the pseudo-static coefficient in analysing the cohesive slope would improve the outcomes of the whole procedure.

Several numerical analyses with different variations of the pseudo-static coefficient with depth have been tried (details can be found in Karray et al. 2017c) and the authors found that a variation of the seismic coefficient in the hyperbolic form (Eq. 1) would lead to a significant improvement of the pseudo-static procedure outcomes:

$$k_{hz} = k_{h0} [1 + 2(z/H_t)^2] \quad [1]$$

where k_{hz} and k_{h0} are the seismic coefficients at any distance z measured from the bed rock level and at the bedrock (initial value), respectively; H_t is the total height of both the slope and the deposit. The modified hyperbolic profile of the seismic coefficient could be then incorporated in the FD slope stability analysis by multiplying the mass of each row of soil elements in the slope model at a certain depth by the value of the seismic coefficient at the same elevation thus obtaining a non-uniform distributed seismic force along the entire depth of the slope. Figure 3 presents an example of the obtained results. Figures 3 compares the relative displacement-reduction factor curves obtained from the suggested pseudo-static analysis to those computed from the complete dynamic analysis for 1.75H: 1V slope. A value of the k_{h0} of 0.05 leads to a seismic coefficient at the ground surface of 0.15 (i.e., equal to the assumed value of the seismic coefficient in conventional pseudo-static procedure). These selected values produce factor of safety identical to that obtained from the complete dynamic analysis. These results means that the modified (spectral) pseudo-static approach can be integrated into any limit equilibrium software what provides a useful tool to examine the effect of dynamic soil characteristics (Soil rigidity, slope geometry, thickness of the deposit and the plasticity index, PI in cohesive soil as it is well-known that it has a direct impact on the degradation of the soil secant shear modulus and its damping ratio) on shape of seismic coefficient profile. An overview of the current static and seismic limit–equilibrium procedures are given next.

3 STATIC AND SEISMIC LIMIT EQUILIBRIUM SLOPE STABILITY ANALYSES

Limit equilibrium analyses consider force and/or moment equilibrium of a mass of soil above a potential failure surface. The principle assumptions of these analyses are: (1) the soil above the potential failure plane is rigid thus shearing can only occur on the potential failure surface; (2) the material is perfectly plastic which means that there is no shear deformation until soil resistance is reached; and (3) the shear strength is mobilized at the same rate along the failure surface (i.e., the factor of safety is constant along the entire failure surface).

Limit equilibrium analyses of clayey slopes stability can be done in the short (undrained) or in the long (drained) terms. As the dynamic condition is a short-term stability problem, total stress analysis was adopted for all types of analysis. For this reason, the developed calculation program in this study is based on undrained soil conditions ($\phi = 0$) assuming a circular failure surface. The equilibrium of the moments around the center of the circular failure surface can be used to estimate the factor of safety in static conditions as:

$$F.S_s = \frac{M_R}{M_0} = \frac{c_u \times r \times l}{W \times a} \quad [2]$$

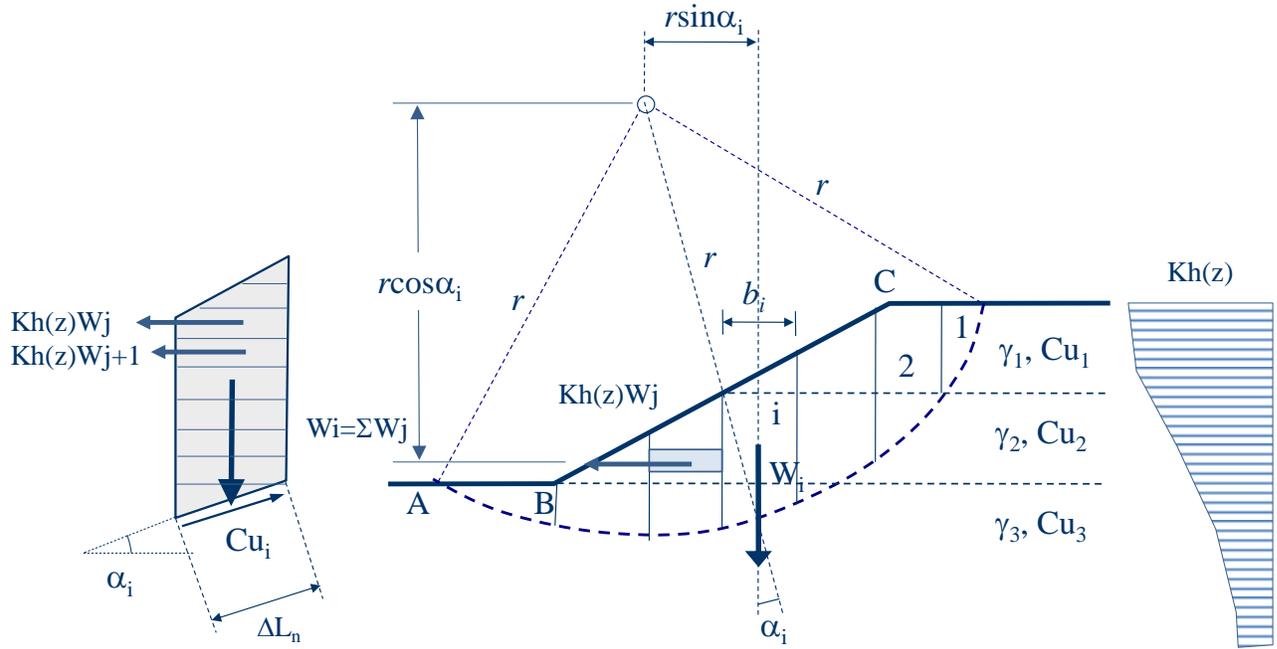


Figure 4 Principles of the limit equilibrium analyses taking into account the variation of the pseudo-static coefficient with the depth.

in which M_R is the resistant moment; M_0 is the overturning moment, C_u is the undrained shear strength, r is the radius of the assumed circular failure surface, W is the weight of the potentially failure slope, a is the horizontal distance between the center of gravity and the center of rotation of the slope. Equation 2 is applicable to soil deposits having constant undrained shear resistances along their depths. In practice, the soil strength varies with the depth and it is necessary to discretize the slope as shown in Fig. 4. Thus, for a deposit with a C_u profile that varies with depth, the safety factor for a circular failure surface can be written as:

$$F.S. = r \frac{\sum c_{ui} l_i}{\sum W_i a_i} \quad [3]$$

The dynamic factor of safety can be estimated with the soil discretization shown in Fig. 4 (using a simplified slice method that ignores the internal forces in-between the slices) as:

$$F.S_d = r \frac{\sum c_{ui} l_i}{\sum W_j \sin(\alpha_i) + \sum k_h(z) W_j \cos(\alpha_i)} \quad [4]$$

The seismic stress is thus taken into account in the form of an equivalent static load and introduced in a static stability limit equilibrium calculations.

In the spectral pseudo-static analysis, the most critical surface, corresponding to the most stressed surface, is first determined using conventional trial methods used in static analyses and then the analysis is conducted using

the seismic inertial forces. A calculation program has thus been constructed which makes it possible to evaluate the safety factor of an arbitrary circular failure surface. In this program, the failure surface was discretized horizontally and vertically to account for the variation in the undrained shear strength and to apply pseudo-static coefficients that vary with depth. With this program, it is possible to introduce the desired geometry, the C_u profile, the pseudo-static coefficient and the form of variation of this coefficient. The program then calculates the critical failure surface (radius of the circle and center of the circle). It also presents the variation of the static and the pseudo-static safety coefficient as a function of the variation of the coordinates of the center of the failure surface.

4 APPLICABILITY OF THE SPECTRAL PSEUDO-STATIC METHOD USING THE CONCEPT OF LIMIT-EQUILIBRIUM

4.1 Static analyses

To examine the possibility of the incorporation of the new spectral pseudo-static method into limit equilibrium analyses, the static safety factors of the clayey slopes (1.75H: 1V and 3H: 1V) were determined and compared to those obtained from the complete dynamic analyses using the computer code FLAC7 (Itasca 2007) adopting the strength reduction technique described above. The relative displacement-reduction factor curves of the static analyses are presented in Fig. 5a, while the corresponding failure surfaces are plotted in Figs. 5b and 5c for both 1.75H: 1V and 3H: 1V slopes, respectively. Figure 5a shows that the safety factors obtained for the 1.75H: 1V and 3H: 1V slopes, respectively are 1.55 and

1.82. These values agree well with those estimated using popular limit equilibrium methods such as the Bishop's modified (Bishop 1955), the Spencer (Spencer 1967), the Morgenstern-Price (Morgenstern and Price 1965), and the Fredlund-Krahn (GLE) (Fredlund and Krahn 1977) methods as presented in Table 1. Figures 5b and 5c, respectively portray the corresponding yielded zones obtained from FLAC analyses for 1.75H: 1V and 3.0H: 1V slopes. The slip circles determined from the limit equilibrium analyses are also reported on Figs. 5b and 5c, and they generally fall within or close to the plastified zones determined by the current FD model.

4.2 Pseudo-static analyses

The pseudo-static analyses were conducted using the same conditions of the static analyses and the corresponding reduction factors-displacement curves are plotted in Fig. 6a. A pseudo-static coefficient of 0.15 was used to calculate the equivalent horizontal inertial forces. Figure 6a shows that the safety factors obtained for the 1.75H: 1V and 3H: 1V slopes are 0.975 and 0.955 respectively, and they are successfully compared to those estimated using typical limit equilibrium methods as presented in Table 1. Figures 6b and 6c, respectively portray the corresponding yielded zones obtained from FLAC analyses for 1.75H: 1V and 3H: 1V slopes. The slip circles determined from typical static limit equilibrium analyses are also reported in Figs. 6b and 6c. The failure surface obtained from the pseudo-static analysis is very deep and passes in both slope cases by the bedrock, and there is a great difference between those surfaces and the failure surfaces estimated from the static limit equilibrium analyses. These results confirm the flaw of the conventional pseudo-static method in predicting realistic failure surfaces which is already well-recognized by practitioners working in the field. This particular limitation is definitely one of the main reasons to constrain the incorporation of the conventional pseudo-static approach in finite element (FE) or finite difference (FD) codes to analyse the seismic stability of slopes.

4.3 Spectral pseudo-static analyses

Figure 7 shows the results of a limit equilibrium analysis by applying a variable pseudo-static coefficient for the clayey slopes (1.75H: 1V and 3.00H: 1V) with a height of 10 m and a deposit thickness of 20 m. Figures 7a and 7b compare the relative displacement-reduction factor curves obtained from the suggested pseudo-static analysis to those computed from the complete dynamic analysis for both 1.75H: 1V and 3.0H: 1V slopes, respectively. For the 1.75H: 1V slope (Fig. 7a), a value of the k_{ho} of 0.05 leads to a seismic coefficient at the ground surface of 0.15 (equal to the assumed value of the seismic coefficient in conventional pseudo-static procedure). As shown in Fig. 7a, these selected values produce factor of safety identical to that obtained from the complete dynamic

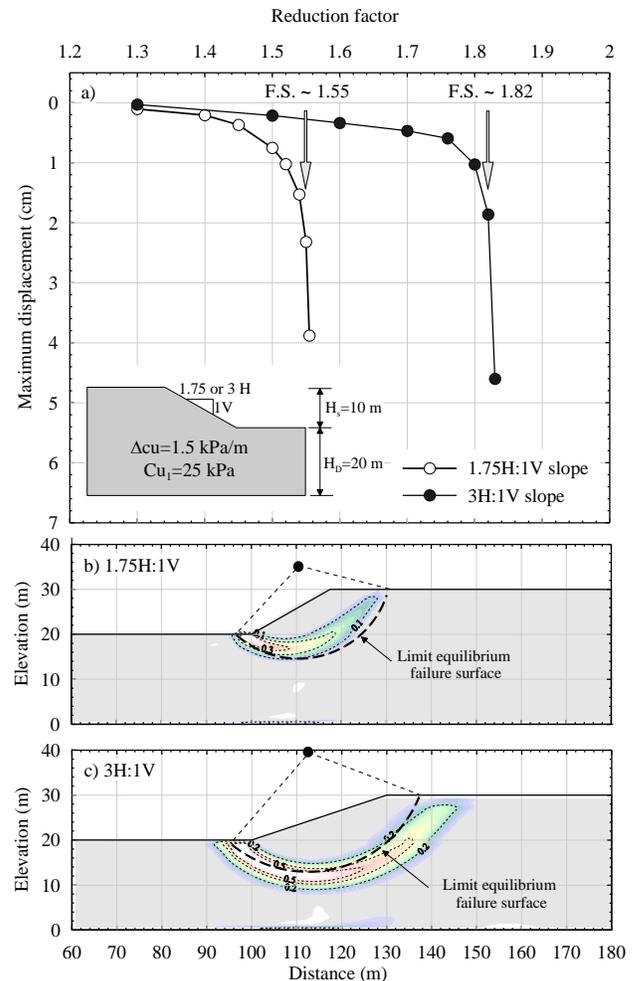


Figure 5 Static analysis: (a) relative displacement-factor of safety curves; failure surface of slopes: (b) 1.75H: 1V and (c) 3H: 1V.

Table 1: Safety factors calculated using popular limit equilibrium methods and strength reduction using FLAC.

Slope	F.S. Bishop	F.S. Spencer	F.S. M-P	F.S. GLE	F.S. (FLAC)
Static analysis					
1.75H:1V	1.354	1.570	1.570	1.570	1.550
3H:1V	1.797	1.797	1.797	1.797	1.820
Pseudo-static analysis $k_h = 0.15$					
1.75H:1V	0.915	0.965	0.965	0.965	0.975
3H:1V	0.986	0.986	0.986	0.986	0.955

analysis. On the other hands, the best factor of safety in the 3.0H: 1V slope case has been reached at values of seismic coefficients at bedrock and the ground surface of 0.041 and 0.123 as shown in Fig. 7b. The corresponding failure surfaces have been also improved when the suggested profile of the seismic coefficient is included in the pseudo-static analysis. Figures 8a and 8b show the slip surfaces obtained from the spectral pseudo-static analysis over the slip surfaces from the dynamic analysis plotted in dashed lines for the slopes 1.75H:1V and 3H:1V, respectively. It is observed that both yield

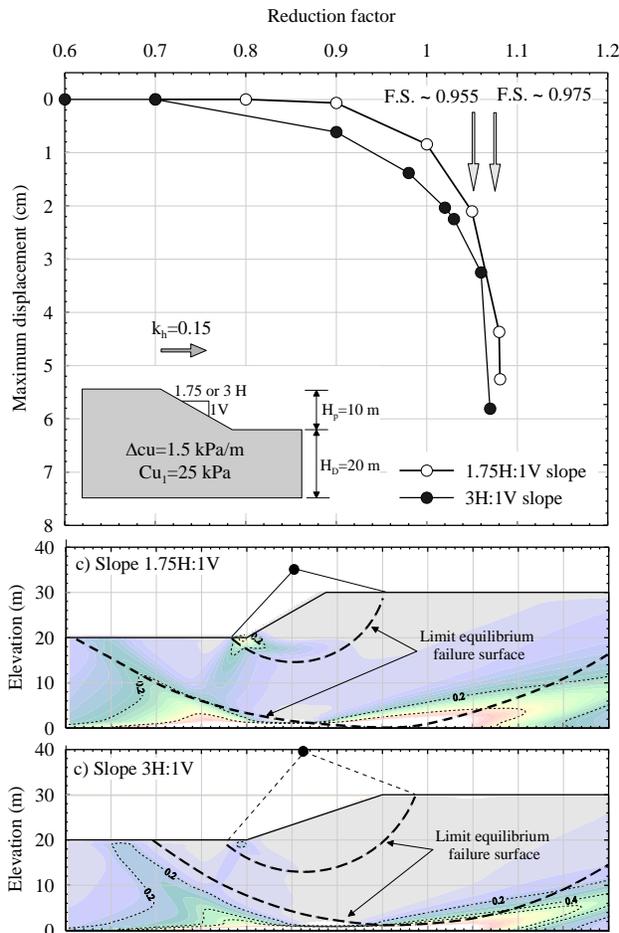


Figure 6 Pseudo-static analysis: (a) relative displacement-factor of safety curves; failure surface of slopes: (b) 1.75H: 1V and (c) 3H: 1V.

surfaces are very similar. Moreover, the deeper failure surface previously observed in the dynamic analysis of the 3H:1V slope has appeared in the suggested pseudo-static analysis.

The above discussion confirms that the use of the spectral pseudo-static method produce factors of safety and failure surfaces very similar to that obtained from the complete dynamic analyses. This study therefore justifies the use of the pseudo-static procedure in finite element or finite difference programs to analyze the seismic stability of slopes

5 IMPLANTATION OF THE SPECTRAL PSEUDO-STATIC METHOD IN THE SVSLOPE SOFTWARE (SOILVISION)

The pseudo-static spectral method, which comprises dividing the potentially unstable soil mass into vertical and horizontal slices, as shown in Fig. 4, was formulated into a simple algorithm based on the hypothesis of a circular failure surface and the equilibrium of moments. This

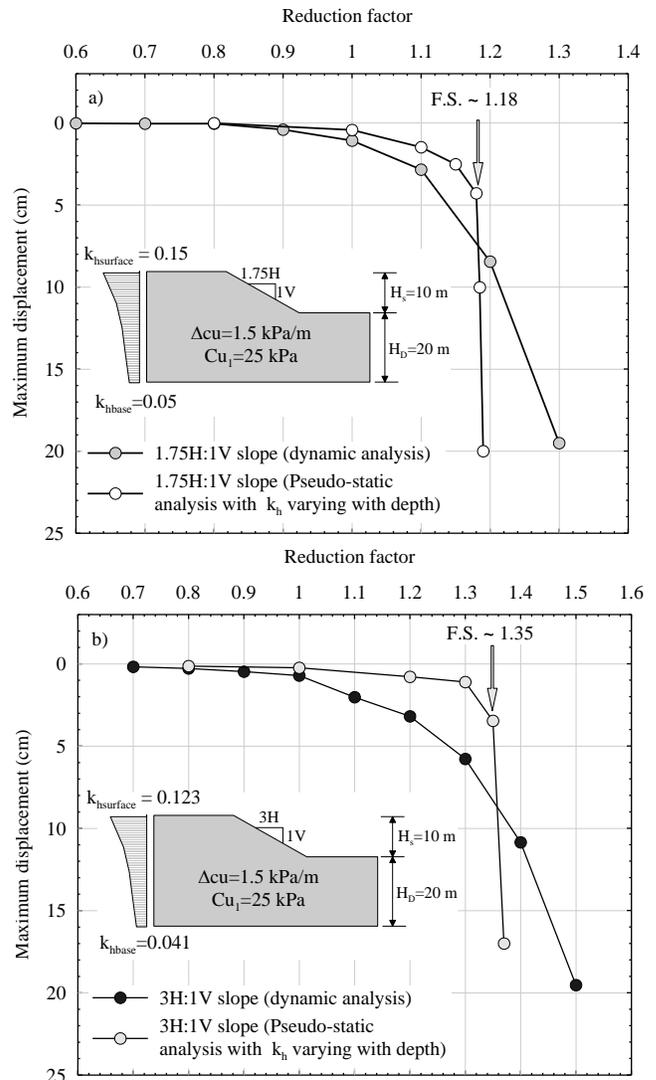


Figure 7 Comparison between relative displacement-factor of safety curves from dynamic and modified pseudo-static analysis: (a) 1.75H: 1V and (b) 3H: 1V.

algorithm was incorporated into the well-known the SVSIOPE software package (Fredlund and Thode 2011) in 2D and 3D analyses. The SVSIOPE software provides a useful tool to thoroughly examine the reliability of the pseudo-static spectral method and assess the effect of dynamic soil characteristics on the proposed seismic coefficient profiles. Four examples have been considered in this paper to test the reliability of the new spectral pseudo-static method coded in the SVSIOPE software. This program makes it possible to carry out analyzes with surfaces of failures more general while respecting the equilibrium of the moments and the forces. The four examples considered correspond to the clays slopes (1.75H: 1V and 3H: 1V) having variable heights (10m and 20 m) and deposit depths (10m and 20 m). The analyzes were carried out by varying the values of k_h at

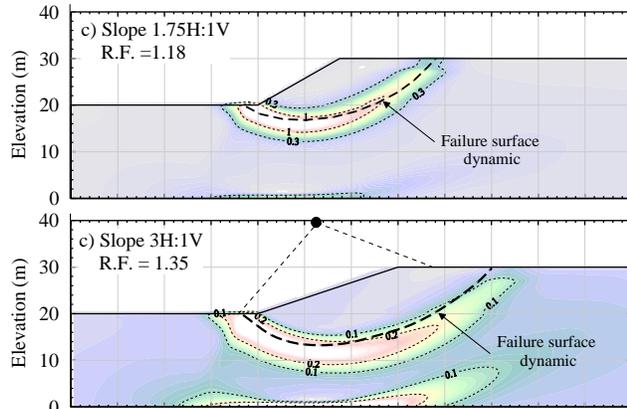


Figure 8: Modified pseudo-static analysis: failure surface of slopes: (a) 1.75H: 1V and (b) 3H: 1V.

the ground surface while respecting the values of the proposed constant a and b . Figures 9 and 10 show comparisons between the failure surfaces obtained by

6 CONCLUSION

The analyses carried out in this paper have led to the conclusion that the developed spectral pseudo-static method can be implemented in a calculation program based on the limit equilibrium. A program developed in the framework of this study validated the proposed analysis approach. The method was implemented in a SVSIOPE program developed by SOIIVISION and examples were discussed to show the reliability of the approach. Calculations made using SVSIOPE on some examples show that the method works well. It would be also necessary to test the program with more examples to validate the robustness of the new approach.

ACKNOWLEDGEMENTS

The authors would like to thank the MTMDET for financial support throughout this research project.

REFERENCES

- Bishop, A. W. 1955. The use of the Slip Circle in the Stability Analysis of Slopes. *Géotechnique* 5: 7
- Fredlund, D. G.; Krahn, J. 1977. Comparison of slope stability methods of analysis", *Canadian Geotechnical Journal*, 14 (3): 429–439
- Fredlund, M.D., and Thode, R. 2011. SVSIOPE theory manual. SOIIVISION Systems Inc., Saskatoon, Sask.
- Ghobrial, F., Karray, M., Delisle, M.-C. and Ledoux, C. 2015. Development of Spectral Pseudo-Static Method for Dynamic Clayey Slope Stability Analysis. 68th Canadian Geotechnical Conference, Quebec City, Quebec, Canada.

rigorous dynamic analysis and those of the limit equilibrium analysis (SVSIOPE) for clayey slopes of 1.75H: 1V and 3.00H: 1V, respectively. For all practical purposes, the failure surfaces are identical. Table 1 presents a comparison between the seismic coefficient at the bedrock k_h values determined using FLAC analyses and those of SVSIOPE limit equilibrium analyses at the same safety factors. The results are almost identical with differences less than 5%.

Table 2: Pseudo-static coefficients determined using SVSIOPE.

Slope	Deposit height	k_h (FLAC)	k_h SVSIOPE
1.75H :1V	10	0.137	0.147
	20	0.165	0.165
3.00H :1V	10	0.060	0.060
	20	0.110	0.105

- Ghobrial, F., Karray, M., Ledoux, C. and Delisle, M.C. 2017. Novel Spectral Pseudo-Static Method for Dynamic Clayey Slope Analysis, submitted to *Computers and Geotechnics*.
- Itasca 2007. *FLAC - Fast Lagrangian Analysis of Continua, Version 6. User's Manual*. Itasca Consulting Group, Inc. Minneapolis, Minnesota, USA.
- Karray M, Hussien MN, Delisle MC, Ledoux C. 2017a. Framework to assess the pseudo-static approach for the seismic stability of clayey slopes. To be submitted to *Computers and Geotechnics*.
- Karray M, Hussien MN, Souilem M, Delisle MC, Ledoux C. 2017b. Adjustment of the spectral pseudo-static approach to account for soil plasticity and zone seismicity. To be submitted to *Computers and Geotechnics*.
- Karray M, Souilem M, Ghobrial F, Hussien MN. 2017c. Développement de la méthode pseudo-statique spectrale pour l'analyse de stabilité dynamique des talus argileux. Report No. Geo-02-17.
- Morgenstern, N. R.; Price, V. Eo 1965. The analysis of the stability of general slip surfaces. *Géotechnique*, 15 (1): 79–93.
- Ozkahriman F. Physical and numerical dynamic response modeling of slopes and embankments. Ph.D thesis, Drexel University, 2009.
- Spencer, E. 1967. A method of analysis of the stability of embankments assuming parallel inter-slice forces. *Géotechnique*.

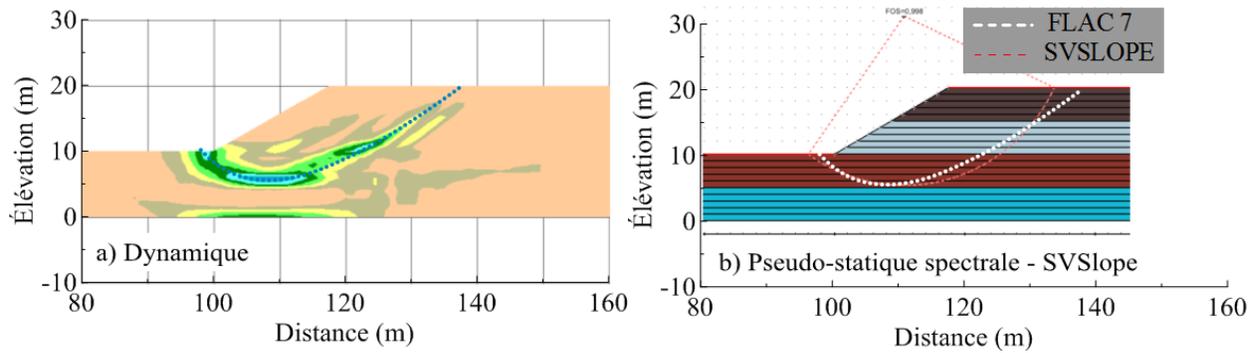


Figure 9 Comparison of the failure surface determined using dynamic analysis and that determined using SVSIOPE - Slope of 1.75H: 1V 10 m high with a 10 m deposit.

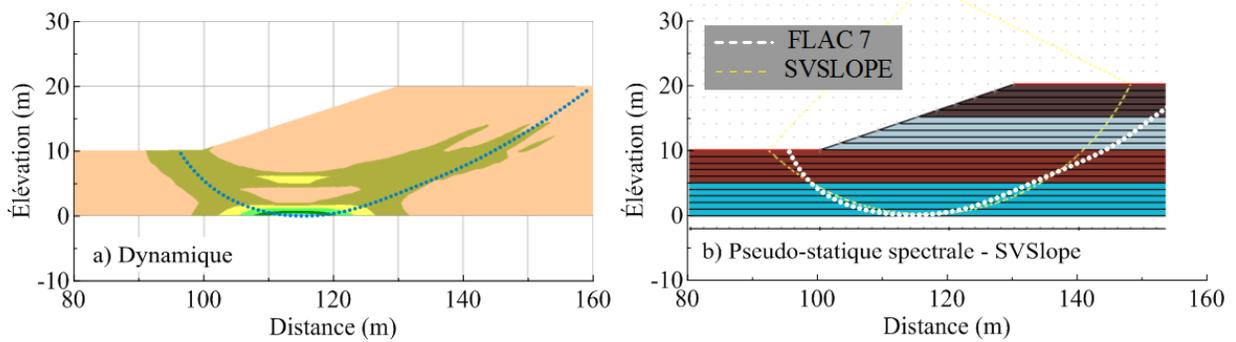


Figure 10 Comparison of the failure surface determined using dynamic analysis and that determined using SVSIOPE - Slope of 1.75H: 1V 10 m high with a 10 m deposit.