Usage, requirements and features of slope stability computer software (Canada, 1977)

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A survey of Canadian universities and consulting engineering firms was conducted to ascertain the present status of slope stability software usage in Canada. The results indicate that most universities have access to at least one slope stability computer program. However, there is limited usage of computer programs as a teaching tool at the undergraduate or graduate level. In general, the programs are poorly documented and not distributed. Consulting engineering firms indicate that more education on the relationship between the various methods of slices, on available software and its application to practical problems would be beneficial. The most commonly used procedures are the simplified Bishop method for circular failure surfaces and the Morgenstern–Price method for noncircular failure surfaces.

Several well-documented slope stability computer programs are available to the geotechnical engineer at the cost of reproduction. The source for obtaining the programs is listed in the paper. Computer programs are available for all the commonly used methods of slices and the features of each program are also summarized in the paper.

Une enquête a été conduite auprès des universités et des firmes de génie-conseil pour évaluer l'utilisation que l'on fait au Canada des programmes d'ordinateur pour l'analyse de stabilité des talus. Les résultats indiquent que la plupart des universités ont accès à au moins un programme de calcul de stabilité de talus. Cependant, l'utilisation des programmes d'ordinateur comme outil d'enseignement aux niveaux sous-gradué et gradué est limité. De façon générale, les programmes ne sont pas bien documentés ni bien diffusés. Les firmes de génie-conseil sont d'avis qu'il serait profitable d'assurer une éducation plus poussée portant sur les relations entre les diverses méthodes de tranches, sur les programmes disponibles et sur leurs applications aux problèmes pratiques. Les procédés les plus couramment utilisés sont la méthode simplifiée de Bishop pour les surfaces de rupture circulaire et la méthode Morgenstern–Price pour les surfaces de rupture non-circulaires.

Plusieurs programmes d'ordinateur bien documentés pour l'analyse de stabilité des talus sont disponibles pour l'ingénieur en géotechnique au coût de reproduction. Une liste des endroits où ces programmes peuvent être obtenus est donnée dans l'article. Des programmes d'ordinateur sont disponibles pour toutes les méthodes de tranches couramment utilisées et les particularités de chaque programme sont également résumées dans l'article.

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Introduction

Many factors must be evaluated when assessing the stability of an earth slope. The coordinates of the surface of the slope along with the boundaries of all stratigraphic units must be determined. Suitable shear strength parameters must be evaluated for each soil type. Also, the present and (or) future pore-water pressures within the slope must be measured or predicted. Once the above information is assembled, a complete analysis for the minimum factor of safety involves considering a grid of potential slip circle centers with several radii considered at each center. It is easy to visualize the above analysis involving in excess of 1000 factor of safety computations. In addition, an iterative procedure is required to solve all factor of safety equations, with the exception of the ordinary method of slices. Due to the voluminous computations involved in determining the minimum factor of safety, it is highly advantageous to utilize a digital computer to perform calculations accurately, within a reasonable time scale.

The use of the digital computer for slope stability analysis has been highly advocated since the late 1950's (Little and Price 1958; Horn 1960). In 1967, Whitman and Bailey estimated that from 25 to 50 slope stability computer programs had been written in the United States. Most of these were not comprehensive and used "very approximate procedures". At present there are a limited number of slope stability computer programs that can be considered properly documented, portable and fully debugged. The features of available programs are described later in this paper.

There are two main areas where computer software can be used to great advantage in slope stability problems. These are:

(1) At the design stage — the shear strength

parameters and pore-water pressures associated with each stratigraphic unit must be determined in the design of excavations or embankments so that a minimum factor of safety can be computed for various side slope conditions. A similar procedure is applicable for the assessment of stability of natural slopes when some modification in the environment and (or) loading conditions is anticipated.

(2) In back analysis of failures — the slope has already failed and suitable remedial steps must be taken. The factor of safety is set equal to 1 and the shear strength parameters for the most crucial soil stratum are computed using a 'back analysis' technique. These shear strength parameters are then used to assess the benefits of such factors as berming, excavation of the top of the slope and dewatering.

The back analysis of failed slopes also serves a useful research role since there is still a need for detailed, carefully investigated and fully documented case histories.

The computer program must be regarded as only one of the tools required in analyzing slopes, keeping in mind, however, that it is a very important tool. The following steps are suggested with respect to the use of slope stability computer software: (1) Obtain an approximate solution for the problem, either from stability charts or from hand calculations on a simplified form of the problem. (2) Perform the computer analysis of the actual problem. (3) Compare the 'approximate' and 'computer' results and resolve anomalies. (4) Modify appropriate variables (e.g. geometry, soil properties or water conditions) and check the sensitivity of the factor of safety to these variables. (5) Make the necessary engineering decisions and plot the significant results.

Although slope stability computer programs have been in circulation for approximately two decades, there has been difficulty in their coordination. The main objectives of this paper are to present the status of slope stability computer program usage in Canada, outline the requirements for satisfactory slope stability software and elaborate on the features of readily available slope stability software known to the author. The paper is concerned primarily with two-dimensional stability analyses.

Status of Slope Stability Program Usage

A survey was conducted of most of the universities, many of the engineering consulting firms, government agencies and large engineering-contracting companies to ascertain the present status of slope stability computer program usage. The survey was performed only in Canada; however, many of the findings are also relevant to other countries.

Some of the results of the survey of 15 universities are presented in Table 1. The following points can be made based on the complete survey.

(1) Most universities in Canada have one or more slope stability computer programs available for their use.

(2) Most computer programs have been developed either by a graduate student or a staff member to solve for the factor of safety by one of the methods of slices. The programs serve an immediate need but they are not comprehensive and suitable for distribution.

(3) The programs are generally in an *ad hoc* state with poor documentation. As a result they are not distributed outside of the university.

(4) The programs are generally used by one university staff member for some teaching (graduate and (or) undergraduate) and a limited amount of consulting. However, most universities still do not make significant use of a slope stability computer package as a teaching tool in geotechnical engineering. Generally programs are used at either the undergraduate or graduate level but not both.

(5) There are only a couple of slope stability programs developed at universities that are well-documented and distributed on a routine basis.

(6) Universities appear to be slow, in general, to seek out and use programs they have not written.

(7) Few universities are presently involved in the development of new slope stability software. The main reasons appear to be the widespread emphasis on the finite element numerical technique and the shortage of financial assistance for software development.

(8) The most commonly available computer programs are for the simplified Bishop method and the Morgenstern–Price method. Several universities have developed small computer programs for the simplified Bishop method.

(9) At many universities, there seems to be little emphasis on the possible uses of slope stability programs.

(10) Very little consideration is given to three-dimensional slope stability programs.

(11) The integrated system software package LEASE (simplified Bishop method) appears to be used on only two university computer systems in Canada.

The results of the survey of engineering consulting firms are as follows:

(1) There is fairly extensive use of slope stabil-

ity software by large engineering consulting firms in Canada. Their use has commenced during the past few years as a result of involvement in large engineering projects.

(2) Upkeep of the programs and familiarity with their usage are problems that arise mainly is a result of the large time intervals between successive runs of the program.

(3) Small engineering consulting firms generally do not maintain their own slope stability software. They sometimes get assistance from larger consulting firms or utilize computer programs made available by software companies. Most often they attempt to manage without using computer programs.

(4) The most commonly used methods are the simplified Bishop method and the Morgenstern–Price method. There is limited use of the ordinary or Fellenius method and Janbu's generalized method.

(5) There has been a definite reduction in use of the ordinary or Fellenius method by geotechnical engineers during the past few years. At present, there is little use of this method in practice.

(6) Consulting engineering firms desire to see more education at universities on the usage of slope stability programs.

(7) Consulting engineering firms often have difficulties with the theory related to the slope stability analyses. This is particularly true with respect to the relationship between the various methods of slices and the significance of each method. There is often confusion over the use of circular versus composite (or noncircular) modes of failure and the information required for a complete slope stability study.

(8) Approximately one half of the consulting engineering firms have attempted to work in cooperation with software companies.

Numerous government agencies are presently in the process of gaining access to slope stability software. There seems to be an increased awareness of the usefulness of slope stability programs. Some government agencies have opted to use the large integrated systems such as ICES LEASE-1 (Hsiung and Christian 1969) and GENESYS (Allwood 1974).

TABLE 1. Slope stability computer program usage in Canada

University	Method of analysis*	Written at university	Documented and distributed	Usage†		
				Teaching	Consulting	Research
1	B	No	No	1	1	1
2	—	—	—	—	—	—
3	B, MP	B (No), MP (Yes)	B (No), MP (Yes)	0	2	2
4	F, B, JG	Yes	No	1	1	1
5	B, MP	B (Yes), MP (No)	No	1	1	1
6	B	No	No	1	1	0
7	F, B, S, C, JS, JG, MP	Yes	Yes	2	2	2
8	B	No	No	1	1	1
9	B, MP	No	No	2	1	2
10	B, JG, MP	B (Yes), others (No)	B (Yes)	1	1	2
11	F, B, JG	JG (Yes), others (No)	No	1	1	2
12	B	Yes	No	0	0	1
13	F, B, MP	No	No	2	2	1
14	B	Yes	Yes	1	1	1
15	B	No	No	1	0	1

*F, Fellenius or ordinary; B, simplified Bishop; S, Spencer; C, Corps of Engineers; JS, Janbu's simplified; JG, Janbu's generalized; MP, Morgenstern–Price.
†0, no usage; 1, limited usage; 2, considerable usage.

Requirements of a Slope Stability Computer Program

There are many factors that must be given consideration in selecting a suitable slope stability computer program (Schiffman and Jubenville 1975*a*).