United States
Environmental Protection
Agency

Hazardous Waste Engineering
Research Laboratory
Cincinnati OH 45268

Research and Development

EPA/600/S2-86/109 Mar. 1987

EPA

Project Summary

Geotechnical Analysis for Review of Dike Stability (GARDS)

R. M. McCandless, A. Bodocsi, and P. R. Cluxton

The structure and capabilities of a user-friendly, interactive computer program developed for the stability analysis of dikes (GARDS) are described. The GARDS program is designed to guide a geotechnical nonspecialist (EPA regulatory personnel) through customary steps of earth dike analysis considering slope stability, settlement, liquefaction, hydraulic flow and pressure conditions, and piping. The GARDS package is designed for use on the IBM-PC/XT computer or compatibles.

... between ... sulting therefrom; and ... determine the critical exit gradient and the potential for piping failure.

User documentation consists of a combined Handbook/User's Manual which presents basic theory program operational procedures, and example long hand and computer solutions for each analysis.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Geotechnical Analysis and Review of Dike Stability (GARDS) is a user-friendly, interactive computer software package for the geotechnical analysis of dikes at hazardous waste sites. GARDS was developed to meet an expressed need for a geotechnical software tool to evaluate existing and planned earth dike structures at hazardous waste facilities. Moreover, the tool was designed for use by regulatory personnel with technical, but not necessarily geotechnical, background. The GARDS package is suitable for use as a design review tool where data describing site conditions and soil parameters have been supplied by a geotechnical professional.

Program Features

As developed, the GARDS software package consists of several distinct blocks. Each block is a program in itself and is called by the user through the use of menu displays. The main command structure of the GARDS program is as follows:

1. Control Block
2. Input Block
3. Input Data Check and Edit Block
4. Slope Stability Analysis Block
5. Settlement Analysis Block
6. Liquefaction Analysis Block
7. Summary Output Block

The following paragraphs present a brief description of each of the major program blocks.

Control Block

The control block is the first block encountered by the user. It gives an introduction to the program and other program blocks. Its primary function is to call the appropriate analysis block selected by the user from a "command menu" displayed on the screen. The menu is a list of the input/output and analytical options available to the user.

The Input Block

The input block is the first block to be selected by the user and offers three user-friendly options:

1. Initial data entry with text explanations and graphical examples.
2. Initial data entry without text explanations.
3. Data entry using an existing input data file.

The first input option is designed to guide the occasional user through the initial data entry procedures. Explanations and graphical examples of the types of required input data are displayed on the screen prior to data entry. The option to review any or all explanations prior to data entry is available to enable the user to proceed at his or her own pace.

The second input option contains all of the features of option one, except that the text explanations and graphical examples are not included. This option would be selected for initial data entry by the user who is experienced in the use of GARDS and is therefore familiar with the definitions of the required input data.

The third option is selected by the user who previously entered all data using options 1 or 2, has saved it on a data file, and elects to use the analysis features of the program at a later time. A listing of the data files available to the user is displayed. The data is assigned to the appropriate program variables internally. The use of this option eliminates the repeated entry of basic soil property and geometric data if the user wishes to re-analyze a particular dike section under different conditions.

An internal data check is performed automatically with all input options to verify that values of all input variables fall within specified ranges. If the value of the data item is not within the specified range, an error message will prompt the user to enter a value within the specified range. Once notified, the user has the option to override this error trap routine if warranted.

Input Data Check and Edit Block

After one of the options of the input block is used, the input data check and edit block provides for general verification and modification of input data. The user may check or edit all or selected portions of the input data in any existing data file. Since, however, input and internally generated data routinely are displayed as part of the Summary Output Block (described later), the primary function of this block is to edit portions of existing data files in order to model different conditions for subsequent runs. This block is also routinely used to conduct a visual check of geometric continuity of the section before proceeding with an analysis.

Hydraulic Block

The hydraulic block automatically determines the coordinates of the piezometric surface for any of six idealized hydraulic boundary conditions. The computations for the hydraulic block are made at the end of the input block so that the piezometric surface data is available for subsequent analyses. This block utilizes an existing finite element based program for solving steady-state problems of free surface or confined flow of water in a two-dimensional porous region. A support program was developed to internally generate an input data file from the general user-input data file. Another support program was developed to utilize the output exit gradient and to relay the amount of seepage through the dike section to the summary output block. The potential for an uplift pressure failure of an impermeable barrier such as a clay liner is also determined and noted in the summary output listing.

Slope Stability Analysis Block

The slope stability block used data defining the piezometric surface from the Hydraulic Block to perform either of two conventional slope stability analyses. The first is a rotational (circular slip surface) analysis which used the Simplified Bishop Methods of slices. The second is a translational (plane slip surface) analysis.

The major features of the rotational analysis include:

- Dike slopes of any configuration and made up of up to 19 soil layers may be analyzed.
- Seepage conditions modeled in the form of the steady-state piezometric surface through the section are determined in the Hydraulic Block.
- Seismic effects may be included.
- The program has a radius contrc feature which produces trial circle that fall between specified limit defined by the soil layer geometry.
- The program conducts an automati search for the minimum factor o safety with trial arc centers specifie by internally-generated or user defined grids, or by user-specifie centers.

The major features of the translationa analysis option are the same as those fo the rotational case except that the tria surface consists of straight line segment which form the base of an active (thrust ing) wedge, a neutral or thrusting centra block, and a passive (restraining) wedge The automatic search routine for thi analysis is based upon selection of a tria central block defined by the surface an subsurface soil layer geometry, followe by computation of the coordinates for th associated active and passive wedges The analysis proceeds over all soil layer in the section using a standard (auto matic) or user-defined increment to define the location of subsequent trial centra blocks.

Both stability analyses may be performed using any of the six hydraulic boundary conditions described earlier an may employ unconsolidated drained soi strength parameters.

The results of the rotational analysis are presented as a tabulation of all factors of safety less than 2.5 along with the corresponding coordinates of the various failure arc centers, radii, and associate hydraulic boundary conditions. A plotting subroutine plots the dike section, the most critical circle passing through it, the factor of safety, and other pertinent project information.

Settlement Analysis Block

The settlement analysis block is used to determine the compression of foundation soils due to stresses caused by the weight of an overlying dike. The settlements are calculation using Boussinesq's Theory and Terzaghi's One-Dimensional Consolidation Settlement Theorem. Required soil parameters for each soil include unit weight, initial void ratio, compression and recompression indices, and the over consolidation ratio.

Settlements are calculated at the toes, crest points, and centerline of the dike. The consolidation of each soil is calculated for each layer and summed up for all soils to determine the total settlement at each point. Differential settlements are calculated between each toe and cres

toe and centerline, and crest and centerline.

Liquefaction Block

The liquefaction block determines the potential for liquefaction of the dike and foundation soils. The procedure applies mainly to site conditions involving sand or silty sand strata occurring below a level ground surface. The analysis uses soil parameters routinely obtained during site exploration and subsequent laboratory testing. Site seismic parameters may be estimated using published guidelines or may be obtained from site-specific investigation (preferred). The analysis uses an automatic search routine controlled by the section geometry to locate the area of highest liquefaction potential. Results are reported as a tabulation of soil layers and points having a factor of safety which is less than 2.50.

Summary Output Block

The summary output block allows the user to obtain a hard copy of the input data and the results of all analyses run for the dike section under study. The critical factors of safety, failure circle center coordinates, radium, and plane failure line segment coordinates are all highlighted in the output listing, along with the critical differential settlements, liquefaction potential, and critical exit gradient. If an analysis was not run, such is indicated in a summary table at the end of the output listing.

Software Support

Software support for GARDS consists of a combined Handbook/User's Manual. The Handbook section is intended to give the user sufficient background to understand the basic principle underlying the various analyses being performed. A separate chapter is devoted to each analysis included in the program. After a brief introduction stating the purpose of the analysis, explaining when the analysis should be used, and listing the capabilities and limitations of the program, a section of the basic theory and the method of solution of the program are presented. Following this, a complete step-by-step long hand example solution is given. To provide continuity, the same dike section is used for all analyses. A complete computer solution of the analysis of the dike section is presented in the User's Manual section for comparison.

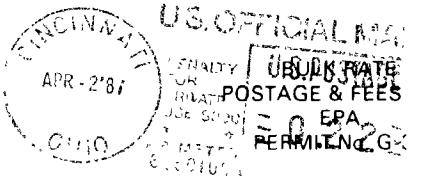
The User's Manual section includes a discussion of the capabilities, limitations, and essential details of each of the different blocks is presented, along with a complete interactive example for the user study. A sketch of the example section and all required data are provided, along with a summary output listing for the example section. Block flow charts, a program listing, and other pertinent materials are appended to the Handbooks/User's Manual.

The full report was submitted in fulfillment of Contract No. 68-03-3183, Work Assignment No. 19 by the University of Cincinnati under the sponsorship of the U.S. Environmental Protection Agency.

R. M. McCandless, A. Bodocsi, and P. R. Cluxton are with the University of Cincinnati, Cincinnati, OH 45221.
***Douglas Ammon** is the EPA Project Officer (see below).*
The complete report consists of paper copy and 4 computer diskettes, entitled "Geotechnical Analysis for Review of Dike Stability (GARDS)"
Paper copy (Order No. PB 87-130 951/AS; Cost: $18.95)
Computer diskettes (Order No. PB 87-130 969/AS; Cost: $125.00)
The above items will be available only from: (costs subject to change)
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
Hazardous Waste Engineering Research Laboratory
U.S. Environmental Protection Agency
Cincinnati, OH 45268

United States
Environmental Protection
Agency

Center for Environmental Research
Information
Cincinnati OH 45268



Official Business
Penalty for Private Use $300

EPA/600/S2-86/109