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Chapter 13
GEOTECHNICAL ENGINEERING DESIGN SOFTWARE

Computer software is used by MDT's project geotechnical specialists to assist in the interpretation of field data and design work. This Chapter presents a summary of the software programs that are currently used by MDT, describes some of their major features, provides sources of additional information regarding computer programs and references other chapters of the *Manual* that should be consulted when using the software.

Computer software is used by MDT's project geotechnical specialists in areas ranging from pile design to the evaluation of slope stability. This software has greatly simplified design and evaluation by allowing the MDT staff to quickly and efficiently evaluate the effects of soil properties, load variations, groundwater regimes and other factors on the response of soils, slopes, embankments, structures and foundations. The computer software also allows designs to be completed with consistency and accuracy from project to project.

13.1 GENERAL

13.1.1 Use of Computer Programs

Computer programs provide designers with an important and useful design tool. However, all programs have limitations and cannot be expected to fully model the true physical conditions of a project. For successful use of any software package, it is essential that the project geotechnical specialist:

1. Understand the Principles Behind the Analysis Method. This understanding is essential to adequately discern whether the computer software provides an appropriate method of evaluating a problem. Engineering judgment and experience are often critical to this understanding.

2. Choose Soil or Rock Properties that are Consistent with Site Conditions and the Anticipated Loading Mechanism. Engineering properties of soil are sensitive to the drainage conditions and, therefore, the user must understand whether drained or undrained soil properties are likely to govern behavior. Likewise, soil properties always contain degrees of uncertainty, even for the most thorough and careful field exploration and laboratory testing programs. Computer programs provide the designer with efficient tools for conducting parametric analyses and for evaluating uncertainties in soil parameters and other inputs.

3. Select Geometries and Boundary Conditions that are Representative of the Field Condition. For example, thin low-strength soil layers will often control the stability of a slope and, therefore, the computer model must provide a reasonable approximation of this geometry to avoid unnecessarily conservative or unconservative results.

4. Validate Results Using Simple Analytical or Empirical Checks or Alternate Analysis Methods. Sometimes, validations can be made using simpler geometries or conditions

to confirm that that the analysis is reasonable. Often, a simple hand calculation can be used to confirm whether the results are reasonable (e.g., estimation of pile capacity).

5. Obtain an Independent Review of the Results by Another Knowledgeable Person in the Geotechnical Section. This review should confirm the reasonableness of the problem being modeled, as well as the validity of the input information.

6. Ensure the Appropriate Units are Inputted into the Software Package. Review the software manual to ensure that the appropriate unit of measurement (e.g., inches vs. feet, US Customary vs. metric) is inputted into the program.

7. Use Appropriate Number of Significant Digits When Presenting Results: Results from computer analyses can be obtained with several decimal points of accuracy. However, the uncertainty of input information usually does not justify this level of accuracy. In reports, present the results of the computer analyses to appropriate significant digits.

The validity of the computer analysis will depend on selection of appropriate boundary conditions and appropriate soil properties in the computer model. If the wrong soil properties or wrong boundary conditions are used, the results can easily be invalid and could lead to a failure or inefficient design. As long as reasonable care is used, computer programs offer the project geotechnical specialist a powerful method for achieving cost-effective designs.

13.1.2 References

Chapter 13 presents a summary of the software that is currently used by MDT. For further guidance on geotechnical engineering software, the project geotechnical specialist should review the following documents:

- Design and Construction of Driven Pile Foundations Reference Manual – Volumes I and II, FHWA-NHI-05-042 and FHWA-NHI-05-043;
- Drilled Shafts: Construction Procedures and Design Methods, FHWA-IF-99-025;
- Mechanically Stabilized Earth Walls and Reinforced Soil Slopes, Design and Construction Guidelines, FHWA-SA-96-071;
- Comparison of Computer Programs for Analysis of Reinforced Slopes, Virginia Technical Institute and State University, Pockoski and Duncan, 2000; and
- Rock Slope Engineering, Institution of Mining and Metallurgy, John Bray and E. Hoek, 2007.

13.2 SOFTWARE PACKAGES

13.2.1 General

This Section covers software that can be used for:

- estimating the capacity of piles and drilled shafts,
- designing retaining walls,
- evaluating the stability of slopes and embankments,
- preparing boring logs following the completion of the field work,
- performing foundation designs, and
- addressing special issues.

The software listed in this Chapter is not the only software that will be used or accepted by the MDT Geotechnical Section. This Chapter describes computer programs that are routinely considered by the MDT Geotechnical Section and their consultants. For a more complete listing of software programs available to the project geotechnical specialist, see either the Geoengineeer Software Listing website or the Geotechnical and Geoenvironmental Software Directory website.

13.2.2 Pile and Drilled Shaft Design

Computer software is available for the design of both drilled shaft and pile foundations. Chapter 16 provides background information on the design principles used within these software programs.

13.2.2.1 Axial Pile and Drilled Shaft Capacity

The typical software used by project geotechnical specialists for the determination of the axial capacity of driven piles and drilled shafts are the computer programs DRIVEN and SHAFT; see Figure 13.2-A.

Proper characterization of soil and groundwater conditions at the site is necessary to obtain reliable capacity estimates for driven pile and drilled shafts using DRIVEN and SHAFT. Chapter 16 provides more guidance on site characterization requirements.

13.2.2.2 Lateral Response of Piles and Drilled Shafts

The software program LPILE, see Figure 13.2-B, is used to evaluate the lateral response of driven piles and drilled shafts to lateral loads and bending moments. The ability of LPILE to provide reliable pile information depends on a number of factors, including the characterization of the soil and groundwater, the stiffness of the pile and its variation with load and the fixity at the top of the pile. Additional discussions of lateral pile analysis and design are included in Chapter 16.

Software Name	Features	Source
DRIVEN 1.2	DRIVEN is used to analyze the axial capacity of driven piles. The DRIVEN program uses the methods and equations presented in the FHWA *Design and Construction of Driven Pile Foundations Reference Manual – Volume I and II*. Input to the program can be Standard Penetration Test (SPT) blowcounts, or values of soil friction and cohesion. This software replaces the SPILE program that was developed by FHWA. It can handle multiple water tables, scour, soft compressible soil and negative skin friction, and can be used to create an input file for the GRLWEAP software.	FHWA website
SHAFT 5.0	SHAFT is used to compute the axial capacity and the short-term load versus settlement curves of drilled shafts. The program allows for single-layer or multi-layered subsurface profiles. Analytical methods used by SHAFT are based on the latest version of the FHWA manual *Drilled Shafts: Construction Procedures and Design Methods.*	Ensoft, Inc. website

Figure 13.2-A — AXIAL PILE CAPACITY DESIGN SOFTWARE

Software Name	Features	Source
LPILE PLUS 5.0	LPILE uses the P-y curve method to analyze pile foundations subjected to lateral loads. The program determines pile deflection, rotation, bending moment, and shear forces using an iterative process that considers the nonlinear response of the foundation soils. The program can model various soil and rock conditions, pile head fixity (e.g., free, restrained, fixed), cracked and uncracked section modulus, sloping ground effects and cyclic loading. LPILE can perform push-over analyses and can evaluate pile behavior after the development of plastic hinges. Soils can be modeled as c - ϕ materials, as well as strong and weak rock. The program can analyze pile behavior for free-field, lateral soil movement.	Ensoft, Inc. website

Figure 13.2-B — LATERAL RESPONSE OF PILES AND DRILLED SHAFTS DESIGN SOFTWARE

13.2.2.3 Pile Drivability

GRLWEAP is used by MDT for evaluating pile drivability; see Figure 13.2-C. The primary requirements for successful use of the GRLWEAP software are accurate modeling of the static soil resistance, proper selection of dynamic soil properties (quake and damping) and the selection of an appropriate hammer system.

Software Name	Features	Source
GRLWEAP Version 2005	GRLWEAP simulates the behavior of a pile and the surrounding soil or rock under the impact of a pile driving hammer. It allows estimation of dynamic pile stresses, bearing capacities, blow counts and installation time for a given hammer/pile system. The software contains a hammer database with over 650 hammer models and extensive driving system data. Results of the stress computations allow the user to determine whether the pile will be overstressed at a certain penetration or if refusal will likely occur before a desired pile penetration is reached.	Pile Dynamics, Inc. website

Figure 13.2-C — PILES DRIVABILITY DESIGN SOFTWARE

13.2.2.4 Other Pile-Related Software

Three other software packages may be used during the design of pile groups: FB-MULTIPIER, GROUP and DFSAP; see Figure 13.2-D. Although the MDT Geotechnical Section has not used these software packages in the past, it is possible that in the future the software may be used by the Geotechnical Section or MDT Bridge Bureau or consultants working for MDT. The primary requirements for successful use of these programs include accurate soil and groundwater modeling, as well as accurate structural modeling and appropriate determination of load combinations.

Bridge engineers will likely often take the lead in using these programs. In this case, the project geotechnical specialist would characterize the subsurface conditions and provide appropriate parameters for analysis. These could include soil strength parameters, P-y curves, soil density and groundwater conditions. For seismic loading cases, it could also include assessments of liquefaction potential. Each of these software packages has different requirements; therefore, communication and interaction between the geotechnical specialist and the Bridge Bureau is necessary to adequately model the project attributes.

Software Name	Features	Source
FB-MULTIPIER Version 4.10 (formerly FB-Pier)	FB-MULTIPIER is a three-dimensional, nonlinear finite element program capable of analyzing the combined axial, lateral and rotational resistance of single pile, pile groups, pile bents, sounds walls, retaining walls, signs and high-mast lighting structures. Each pier structure is composed of pier columns and cap supported on piles or drilled shafts surrounded by nonlinear soils. P-y and t-z springs are used to model the lateral and axial behavior of piles.	Bridge Software Institute website
GROUP 7.0 (3D) for Windows	GROUP is a three-dimensional design tool for analyzing the behavior of piles in a group subjected to axial and lateral loading and to overturning moments. Piles may be installed vertically or on a batter and the heads of the piles may be fixed, pinned or elastically restrained by the pile cap. Soils are represented by nonlinear t-z and q-w curves for axial loading, P-y curves for lateral loading and t-r curves for torsional loading.	Ensoft, Inc. website
DFSAP (formerly S-Shaft)	DFSAP is a three-dimensional analysis program used to assess the response of isolated short, intermediate or long individual piles or pile groups, with or without a cap. Liquefied or non-liquefied soils can be simulated, including lateral spreading and sloping ground. The program uses the Strain Wedge model to represent the soil, and is capable of analyzing vertical piles, drilled shafts, piers and caissons. The slope of the ground and the direction of lateral loading (up-slope or down-slope) are considered.	Washington State Department of Transportation website

Figure 13.2-D — OTHER PILE-RELATED DESIGN SOFTWARE

13.2.3 Retaining Wall Design

Chapter 17 provides background information on the design principles used in software programs for the design of retaining walls.

13.2.3.1 MSE Walls and Reinforced Slopes

Two software packages are available for the design of Mechanically Stabilized Earth (MSE) walls and reinforced slopes; see Figure 13.2-E. These programs are considered together

because of their similarity in design concept. Both are available through FHWA to State DOTs, or commercial versions can be purchased by non-DOT groups.

The ability of MSEW and ReSSA to provide reliable design information is determined by accurate characterization of soil and groundwater conditions at the site and appropriate determination of reinforcement geometry and properties. Chapter 17 provides additional guidance of site characterization requirements.

Software Name	Features	Source
MSEW 1.0 and 3.0	MSEW is an interactive program for the design and analysis of mechanically stabilized earth walls. It follows the design guidelines in *AASHTO98/Demo 82* (Publication No. FHWA-SA-96-071**),** AASHTO02 **(***FHWA-NHI-00-043), the 2007 edition of the AASHTO LRFD Specifications* and *NCMA97/98.* The NCMA design procedure, as implemented in MSEW(3.0), is detailed in: • *Design Manual for Segmental Retaining Walls*, 2nd Edition, edited by James C. Collin, 1997. Publication No. TR-127A. • *Segmental Retaining Walls - Seismic Design Manual*, 1st Edition, authored by R. J. Bathurst, 1998. Publication No. TR-160. MSEW Version 1.0 has been designated exclusively for use by State highway and Federal agencies. ADAMA Engineering offers Version 3.0 to the public. Various types of reinforcement can be modeled (e.g., geogrids, geotextiles, metal mats, metal strips). Effects of walls with a batter of up to 20 degrees, surcharges and seismicity can be considered.	FHWA website or ADAMA Engineering, Inc. website
ReSSA 1.0 and 2.0	ReSSA is a program for assessing the rotational and translational stability of slopes with horizontally placed reinforcement. Reinforcement properties follow *AASHTO 98* and FHWA's *Mechanically Stabilized Earth Walls and Reinforced Soil Slopes Design Guidelines*. However, the user can override all default values. Version 1.0 has been designated exclusively for use by State highway and Federal agencies. ADAMA Engineering offers version 2.0 to the public. Effects of tension cracks, water pressure, surcharges and seismicity can be evaluated.	FHWA website or ADAMA Engineering, Inc. website

Figure 13.2-E — MSE WALLS AND REINFORCED SLOPES DESIGN SOFTWARE

13.2.3.2 Soil Nail Walls

The software packages SNAILZ and GOLDNAIL are used for the design of soil nail walls; see Figure 13.2-F. The SNAILZ program was developed by the California Department of Transportation (Caltrans) and is available at no cost on the Caltrans website. The GOLDNAIL program was developed by Golder Associates and is sold commercially.

Numerous slope stability programs have the capability to model various types of reinforcement, including soil nails. Although soil nails can be incorporated in these programs, the design of the nails (e.g., nail lengths, facing capacity, tensile loads) is usually not treated directly, making their use for soil nail design more difficult. A discussion of some of the relative advantages and limitations of these alternative programs is provided in the *Comparison of Computer Programs for Analysis of Reinforced Slopes Report* (Pockoski and Duncan, 2000).

Software Name	Features	Source
SNAILZ	SNAILZ is based on a two-dimensional limit equilibrium method that considers only force equilibrium. The failure surface in the analysis is either bi-linear or tri-linear. The tri-linear method is used for evaluating geometries of the slope in front of the wall. Up to seven soil layers can be modeled and two slope segments at the toe of the wall. The program also handles surcharges, internal or external forces, and seismic loading.	California Department of Transportation website
GOLDNAIL	GOLDNAIL can operate in three modes: design, factor of safety and nail service loads. In the design mode, a trial run is initiated and the program can modify the nail properties (i.e., bond strength, length, spacing) until a desired safety factor is achieved. In the factor of safety mode, the global factor of safety is calculated for specified input parameters. In the nail service load mode, the program provides maximum tensile forces in the nail to use for selecting bar diameter and facing characteristics. The program satisfies both moment and force equilibrium.	Golder Associates website

Figure 13.2-F — SOIL NAIL WALLS DESIGN SOFTWARE

13.2.3.3 Other Retaining Wall Software

Various other computer programs are used on occasions for the design of certain wall types, as listed in Figure 13.2-G.

Several of the programs listed in Figure 13.2-G are specific to the product (e.g., GWAC, KEYWALL). Other vendors of modular block, bin and similar walls have their own software. In regards to sheetpile walls, CWALSHT is a limiting equilibrium program, while PY-WALL is a displacement-based approach. In cases where wall displacements are important to the design, the displacement-based approach may be preferable.

Wall Type	Software Name	Application	Source
Gabion	**GAWAC**	Design of gabion walls. Gives number of baskets required to meet stability requirements. Includes exterior and seismic loads.	Maccaferri website
Keystone Walls	**KEYWALL/ 2007**	Design of Keystone walls following LRFD methods. Includes seismic design.	Contech Construction Products, Inc. website
	CWALSHT	Design of sheetpile walls by either fixed-earth or free-earth support methods, with and without anchors and surcharge loads.	eCOW College of Engineering, University of Wisconsin-Madison website
	CSHTSSI	Used for soil-structure interaction analysis of sheet pile retaining walls. Model employed for analysis of wall-soil system is a special case of a general beam-column.	eCOW College of Engineering, University of Wisconsin-Madison website
	PY-Wall	Considers soil-structure-interaction by using a generalized beam-column model and analyzes the behavior of a flexible retaining wall or soldier pile wall with or without tiebacks or bracing systems.	Ensoft, Inc. website

Figure 13.2-G — RETAINING WALL SOFTWARE

13.2.4 Embankment and Cut Slope Stability

Computer programs are used for the evaluation of existing slopes and embankment fill slopes comprised of either soil or rock. Chapter 15 provides background information on the design

principles used within these software programs. This information includes references to the computational methods used by each program to determine the factor of safety against instability. The reliability of these software programs is determined by the user's ability to appropriately characterize geologic layering, if any, within the slope, soil/rock strengths and groundwater conditions, and external loads (e.g., results from traffic or earthquakes).

13.2.4.1 STABL-Based Programs

In the 1980s, FHWA funded the development of the slope stability program STABL at Purdue University; see Figure 13.2-H. This program was one of the primary tools for the assessment of slope stability through early 2000. A number of other commercial versions of the STABL program are now marketed.

Software Name	Features	Source
GSTABL7, PCSTABL, XSTABL, WINSTABL	PCSTABL is a computer program for the general solution of slope stability problems by two-dimensional limiting equilibrium methods and includes the analysis of reinforced soil slopes with geosynthetics, nailing and tiebacks. The calculation of the factor of safety against instability of a slope is performed by the Simplified Bishop Method, the Simplified Janbu Method or the Spencer Method.	Purdue University website Interactive Software Design website Gregory Geotechnical Software website Wisconsin Geotechnical Software website

Note: Descriptions of the commercial versions of STABL can be found within the software summary for slopes on the Geotechnical and Geoenvironmental Software Directory website.

Figure 13.2-H — STABL-BASED PROGRAMS

13.2.4.2 Other Slope Stability Software

A number of other programs are commonly used for evaluating the stability of slopes and embankments. The programs described in Figure 13.2-I provide additional modeling capabilities beyond the features available in STABL, particularly in the areas of different stability theories, soil-property modeling and statistical assessment capabilities. For special cases, these alternative programs may be preferred.

Software Name	Features	Source
SLOPE-W	SLOPE-W is a circular and non-circular soil and rock slope stability program. This software carries out stability analyses by the methods of Fellenius, Bishop simplified, Janbu simplified, Spencer, Morgenstern-Price, US Corps of Engineers and Lowe-Karafiath. The program handles multiple soil types, partial submergence, variable thickness and discontinuous soil strata, impenetrable soil layers, dry and water filled tension cracks and seismic loads.	Geo-Slope International Ltd. website
SLIDE	SLIDE (5.0) is a two-dimensional limiting equilibrium program that includes sensitivity, probabilistic and back analysis capabilities. Safety factors are calculated based on Bishop Simplified, Spencer and GLE/Morgenstern and Price. It models both soil and rock slopes using strength models (e.g., Generalized Hoek-Brown, Barton-Bandis, Power Curve). A wide range of support types and techniques can be modeled, including tiebacks, soil nails, geotextiles, piles and micropiles.	Rockscience Inc. website
UTEXAS3	UTEXAS3 is a slope stability analysis program that can handle virtually any subsurface stratigraphy and soil condition, including embedded walls, tunnels and voids. Shear strengths are defined by cohesion and friction angle. "Two-stage" strengths may be used. Other features include distributed surface loads, line loads, tension cracks and seismic coefficients for pseudo-static analyses.	Shinoak Software website

Figure 13.2-I — OTHER SLOPE STABILITY SOFTWARE

13.2.4.3 Stability of Rock Slopes

The slope stability programs identified in Section 13.2.4 can be used to evaluate the stability of rock slopes, providing the geometry of the rock mass can be modeled adequately with a two-dimensional representation, and the interface and intact rock properties can be defined. There are two cases, rock block failures and rock falls, that cannot be analyzed reliably using conventional slope stability software. The software summarized in Figure 13.2-J differs from the soil stability software in that they consider two mechanisms specific to rock — three-dimensional block failures and rockfalls; see Figure 13.2-J. Additional discussions of rock slope stability are included in Chapter 15.

Methods for block stability or rockfall assessments require detailed geologic efforts to map rock conditions on the slope.

Software Name	Features	Source
ROCKPACK III	ROCKPACK III is a package of 18 programs linked together by a master menu for rock slope stability analysis based on the Institution of Mining and Metallurgy's *Rock Slope Engineering*, with modified approaches developed with the US Corps of Engineers, the US Forest Service and State DOTs. It supports the user from the data collection phase through geologic analysis by stereonet, safety factor calculations by limit equilibrium methods and finally to slope design and design of artificial support, if required. ROCKPACK III considers water pressures, surcharges and seismicity, as well as the design of rockbolt or cable support.	Rockscience Inc. website
SWEDGE	SWEDGE (5.0) is an interactive analysis tool for evaluating the geometry and stability of surface wedges in rock slopes. Wedges are defined by two intersecting discontinuity planes, the slope surface and an optional tension crack. Rock bolts, shotcrete or support pressure can be applied to increase the wedge safety factor.	Rockscience Inc. website
ROCFALL	ROCFALL is a statistical analysis program designed to assist with risk assessment of slopes susceptible to rockfalls. Energy, velocity and "bounce height" envelopes for the entire slope are all determined by the program as is the location of rock endpoints. Distributions of energy, velocity and "bounce height" are also calculated along the slope profile.	Rockscience Inc. website
GEOROCK	GEOROCK (GeoStru) performs a statistical simulation of rock falls using the Lumped Mass or CRSP model. For the Lumped Mass method the slope profile consists of a number of straight line segments in which the falling block is reduced to a point and air resistance is considered to be zero. The CRSP (Colorado Rockfall Simulation Program) models the fall of blocks of spherical, cylindrical or disc form, with the circular section in the vertical plane of the section.	GeoStru Software website

Figure 13.2-J — ROCK SLOPE STABILITY SOFTWARE

13.2.5 Borehole Logs

MDT's project geotechnical specialists use the gINT program for creating borehole logs; see Figure 13.2-K. Guidelines for development of boring logs using gINT are outlined in Chapter 8.

A number of other borehole logging programs are available. Descriptions of these packages can be found within the "Borehole Log Production Index" within the geotechnical software summary listed on the Geotechnical and Geoenvironmental Software Directory website.

Software Name	Features	Source
gINT	gINT is a customizable borehole log report generator and relational database manager for geotechnical and geo-environmental investigations. Data are entered into a user-definable database using a standard Windows grid format. The database, report templates and symbols can all be customized and user-defined to produce boring logs meeting MDT requirements, as well as fence diagrams showing the variation in geologic stratigraphy between borehole locations.	gINT Software website

Figure 13.2-K — BOREHOLE LOG SOFTWARE

13.2.6 Foundation Design

Various software packages are available for foundation design. These programs can be used to evaluate settlements and bearing capacities for embankment and foundation loads. Some of these programs, their applications and the sources are listed in Figure 13.2-L. Chapters 15 and 16 provide background information on the design principles used within these programs.

The suitability of the software for use in design depends on the specific project requirements. Generally, the accuracy of these methods will be a function of the accuracy of the soil and groundwater characterization, the types of load combinations that are considered and secondary geologic features.

13.2.7 Other Specialized Software

Additional specialized software is available for interpreting results of field testing or for advanced numerical modeling. These programs generally are for special applications and require specialized knowledge or training for their correct use.

Software Name	Features	Source
FoSSA	The FoSSA program computes the lateral and vertical foundation stresses and the magnitude and rate of settlement resulting from roadway loading conditions (e.g., earth retaining structures, embankments and all forms of temporary and permanent loads). The program uses analytical soil mechanics theories to solve one- and three-dimensional deformations based on the application of applied loads of varied geometry, intensity and orientations. It can consider the effects of staged construction and prefabricated vertical drains (PVD's).	FHWA website
CBEAR	CBEAR analyses the bearing capacity of shallow foundations. It can analyze strip, rectangular and square footings. It also considers the effects of embedment, inclined and eccentric loads, sloping ground surface and surcharge. The program incorporates the general bearing capacity equations and factors.	Prototype Engineering, Inc. website
UNISETTLE	UNISETTLE calculates stress and settlement distribution (total and differential) in clays and sands. It considers multi-layered soils; loaded areas placed at different elevations, excavation to different depths and/or change of groundwater table and pore pressure. Stress distribution is calculated by Boussinesq, Westergaard or 2:1 methods.	UniSoft Ltd. website
SETTLE 3D	*Settle3D* is a 3-dimensional program for the analysis of consolidation and settlement under foundations, embankments and surface excavations. This software combines one-dimensional analysis with visualization capabilities. The software allows calculation of vertical settlement under surface loads for complex soil profiles and loading conditions. Modeling can be staged, and time-dependent consolidation analysis can be performed including primary and secondary consolidation (creep) at user defined time intervals. Groundwater elevation can be staged and horizontal and vertical drainage conditions can be specified.	Rocscience website
CONSOL3.0	CONSOL is an interactive program for analysis of magnitudes and rates of consolidation settlement. The program uses one-dimensional finite difference equations, allows variations of soil properties with depth, and models non-linear stress strain (linear e-log p) behavior.	Virginia Polytechnic Institute website

Figure 13.2-L — FOUNDATION DESIGN SOFTWARE

13.2.7.1 Field Data Interpretation Software

Software used for field data interpretations are listed in Figure 13.2-M. These software packages are part of equipment used by MDT project geotechnical specialists during field exploration programs. In most cases, the software was obtained with the purchase of the field equipment. As new or additional equipment is obtained, this list of programs is expected to change.

Software Name	Features	Source
SEIS-OPT	This software is used for the interpretation of seismic refraction surveys. Measurements made in the field during the refraction survey are collected and analyzed to show geologic layering and compressional wave velocities. The ReMi module of the software also has the ability of estimating average shear wave velocities obtained from microtremor recording from the refraction equipment.	Optim Software
DIGIPRO	DIGIPRO is used to graph results of slope inclinometer surveys. Measurements processed by this software are used to monitor slope or retaining structure deformations with time. Inclinometer data are stored in the Slope Indicator's database format. The software interacts directly with data from the Slope Indicator's DataMate Manager program to produce displacement, deviation and checksum graphs for each set of measurements.	Durham Geo Slope Indicator website

Figure 13.2-M – FIELD DATA INTERPRETATION SOFTWARE

13.2.7.2 Numerical Modeling Software

Two advanced numerical software packages, PLAXIS and FLAC, are being used by consultants and some DOTs for evaluating soil-structure interaction problems; see Figure 13.2-N. At one time, this type of software was primarily used by researchers; however, with the introduction of Windows-based platforms, these programs are now in common use.

These numerical modeling software packages provide capabilities for modeling and evaluating relatively complex soil-structure interaction problems and more complex problems that cannot be accurately modeled by some of the software previously described. As with any software, the reliability of these numerical methods is a function of soil and groundwater information, boundary conditions and loads that are imposed in the model. Information from these numerical models can be very valuable when making decisions on design alternatives for complex loading problems and for projects that involve instrumentation and monitoring activities during construction.

Software Name	Features	Source
FLAC	FLAC is an explicit two-dimensional finite difference program used to model geotechnical problems that consist of several stages (e.g., sequential excavations, backfilling, loading). Groundwater flow and consolidation problems can also be modeled. Optional modules are available for the modeling of creep, dynamic and thermal problems. A three-dimensional option is also available.	Itasca Consulting Group, Inc. website
PLAXIS	PLAXIS is a finite element program for plane strain and axisymmetric modeling of soil and rock. Elements exist to model walls, plates, anchors, geotextiles and soil-structure interaction. Staged construction enables realistic simulation of the construction process. Models can contain both drained and undrained soil layers. Seismic and three dimensional options are available.	Lachel Felice and Associated, Inc. website

Figure 13.2-N — NUMERICAL MODELING SOFTWARE