Verification Report

DeepEX software program (Version 2025)

Document Version 1.0

Issued: 11-September-2025

Deep Excavation LLC

www.deepexcavation.com

www.deepex.com

1. Software Details

Software name: DeepEX
Current version: 2024
Developer: Deep Excavation LLC
Manuals: Extensive User's Manual, Theory Manual, Non-Linear Analysis Manual, Finite Element Analysis manual
Flowchart: Yes (see attached file)

2. Areas of application of the software

DeepEX is a powerful software program for deep excavation design and analysis. It can perform both geotechnical and structural design for many wall types that include soldier pile walls, sheet pile walls, and diaphragm walls with multiple sections of reinforcement. It takes into consideration external linear, strip and 3D loads. It calculates hydrostatic water pressures, simplified flow or a full flownet. DeepEX can also perform slope stability analysis with soil nailing. It comes packed with all structural and geotechnical design codes.

3. Brief description of the software, assumptions and theory

DeepEX includes the Limit Equilibrium method and Non-linear analysis method with use of finite element elastoplastic springs. Since DeepEX 2019, Finite Element Analysis method (2D FEM) is available within DeepEX, as an additional, optional module, allowing us to consider full soil-structure interaction. Since DeepEX 2024 we have released our 3D Finite Element Analysis engine (3D FEM) allowing the quick generation and evaluation of 3D excavation models with this approach.

All data can be inserted through user-friendly dialogs. DeepEX has implemented extensive steel beam databases. It also provides estimation tools that can help user estimate values based on scientific methods and processes.

Results can be presented graphically on the model area and in tables. In addition, DeepEX provides all equations and calculation procedure for the structural design of walls/supports. The result diagrams and the equations can be included in the report produced by DeepEX.

Water Analysis Options:

Hydrostatic	Water pressures are calculated as hydrostatic (γ_w x h)
Simplified flow	Water pressures next to the walls are calculated from a 1D flow analysis
Balanced	Water pressures are calculated as hydrostatic up to the excavation depth and as simplified flow after this
Full flownet	Water pressures are calculated from a 2D finite difference flownet analysis. No drop in groundwater elevations near the walls is considered.
User pressures	Switches water pressures to the user defined values. Please note that in the NL engine, for proper modeling zero water pressures should only start on any side from the exact water elevation on that side. In essence, do not define zero pressure points for elevations above.
Seal excavation	This is an advanced option. With this, we can seal the excavation and define an internal water level that is higher than the excavation level. In this case it is important to maintain positive effective vertical stress within the excavation

Thrust Options:

K_aK_p AUTO	DeepEX automatically selects the Ka and Kp equations depending on wall friction and seismic conditions. This mode is recommended.
K_aK_p USER	User defines which equations will be used from DeepEX for Ka and Kp at every stage.
K_aK_p MAN.	In this mode, DeepEX uses the Ka and Kp values defined in the Soils Type dialog of the software. In this mode, a separate tab appears in this dialog for Ka and Kp values for each soil type.

Wall Friction Options:

Option to set the wall friction to zero
Option to add wall friction as a percentage of soil friction (0 to 100%)
Option to use a specific value for the wall friction
Choice to set vertical adhesion on Su driving (limit equilibrium analysis)
Choice to set vertical adhesion on Su resisting (limit equilibrium analysis)
Choice to also include wall friction for clays

Active Pressure Methods (Limit Equilibrium Analysis)

- **Active pressures:** User can choose to use active pressure for the driving side.
- **Between Ka and Ko:** DeepEX calculates and uses a value between active and at rest pressures.
- **At-rest pressures:** User can choose to use at-rest pressures for the driving side.
- **Peck 1969 apparent:** User can define the multiplier for clay pressures. In addition there is a choice in stiff soil profiles not to allow pressures to drop to zero.
- **Custom trapezoidal:** User can define the multiplier for the active earth pressures M, the top triangular pressure to a percentage of excavation depth from top and the bottom triangular pressure to a percentage of excavation depth from bottom.
- **FHWA apparent:** User can define the multiplier for undrained clay pressures and the multiplier for the active earth pressures. In addition there is a choice in stiff soil profiles not to allow pressures to drop to zero.
- **Adaptive apparent pressures**: This method presents a more rational approach for creating apparent earth pressure envelopes for sites with mixed soil stratigraphy. The method is based on the original FHWA approach but pressures are adjusted for each layer by attributing a weighing factor that is calculated according to the strength of each soil.
- **Two step rectangular:** With this option lateral earth pressures above the excavation are calculated as M1 x Hexc above the water table and as Mz x Hexc below the water table.
- **User pressures:** User can define the values of pressures at several elevations.

Cantilever wall analysis methods (Limit Equilibrium Analysis Method):

The following methods are available in DeepEX:

a) **Free Earth Method**
b) **Fixed Earth Method**
c) **Rowe's Moment Reduction Method:** This method can be applied to cantilever walls in only clay or frictional conditions. It is used to reduce free earth moments and it should be used in caution.

Beam analysis options (Limit Equilibrium Analysis Method):

Each of the method here offers simplistic means of analyzing a braced wall, and the user should be aware of the inherent limitations with each method (as limit-equilibrium ignores stage interaction effects, etc). The available analysis methods are:

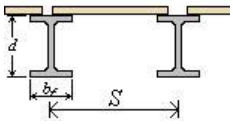
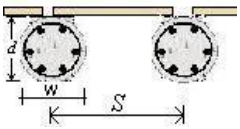
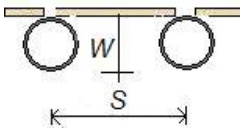
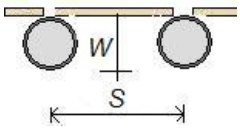
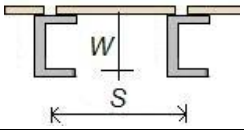
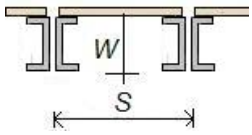
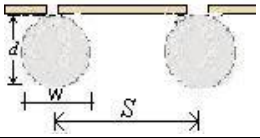
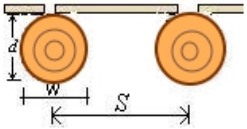
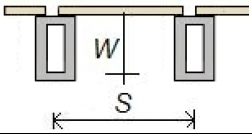
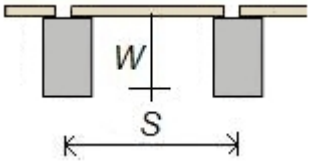
a) **Blum's method:** Blum's method is a very popular analysis method in the East coast, as well as in Germany. The method involves assuming hinges at support locations as well as at the point of zero net loading below the excavation subgrade.
b) **FHWA simple span method:** The method is described in FHWA GEC4. It assumes simple span bending between supports (with the exception of the top brace, where a continuous beam is assumed to the 2nd bracing level or to the excavation subgrade). The method assumes a hinge at the excavation subgrade.
c) **Simple span with negative moments:** Method is similar to FHWA described in b) but a hinge is assumed below the excavation at the point of zero net loading (similar to Blum's method.) The program also offers a method to reduce maximum moments by introducing a negative moment as a percent of the maximum positive span moments.
d) **California Trenching and Shoring Manual 2011:** This method is described in the CALTRANS Trenching and Shoring manual (2011), and is very popular in California. The method is similar to FHWA but fixity below the excavation is assumed at a point where rotational moments about the lowest bracing level are equal to zero (considering loads below the lowest support only). As a result, the method always computes a zero shear and zero moment at the point of assumed fixity. The program offers the option to consider reductions in the moments by including a negative moment percentage.
e) **WMATA Adjacent Construction Manual:** This method is outlined in the WMATA Adjacent Construction Manual (Washington DC). Continuous beam analysis with fixity at excavation subgrade.

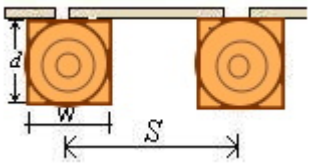
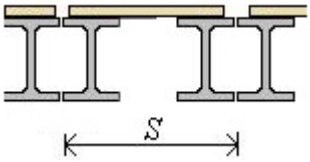
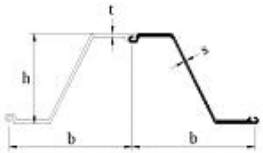
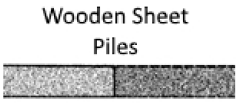
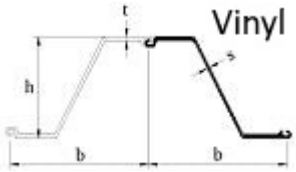
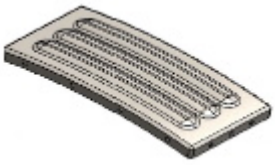
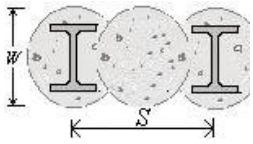
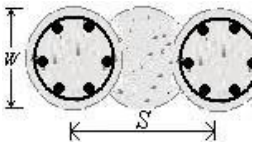
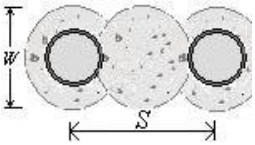
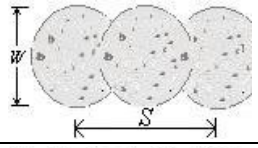
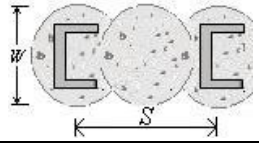
Slope Stability Analysis Methods:

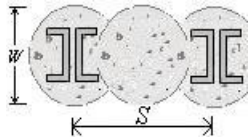
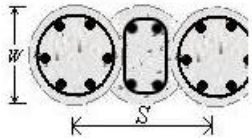
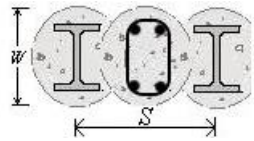
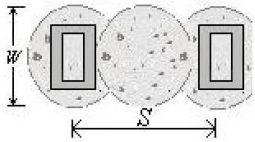
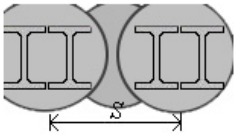
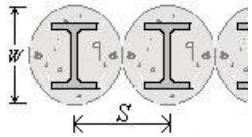
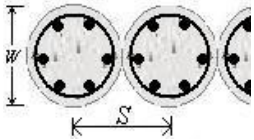
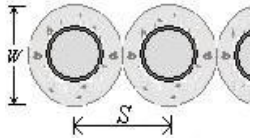
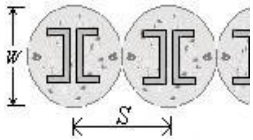
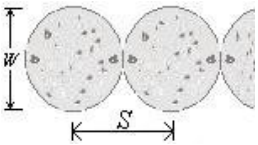
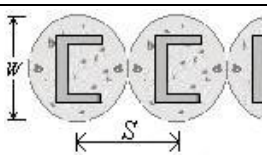
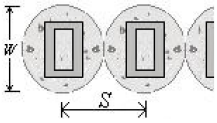
Bishop	Use the Bishop simplified method for analyzing slope stability (only circular surfaces)
GLE	Use the Morgenstern – Price method for analyzing slope stability
Spencer	Use the Spencer method for analyzing slope stability
Ordinary Swedish Method	Use the Ordinary Swedish Method for analyzing slope stability
Store intermediate surface results	With this option the program will store all intermediate slope stability surfaces and safety factors

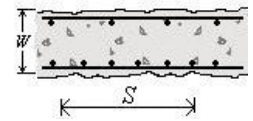
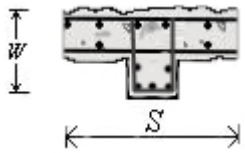
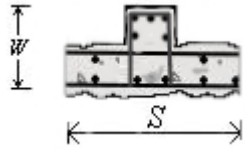
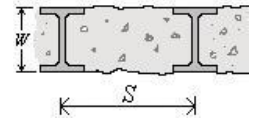
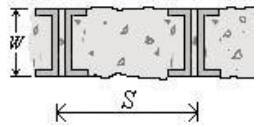
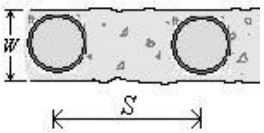
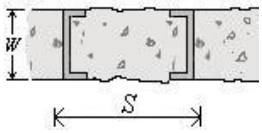
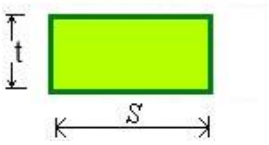
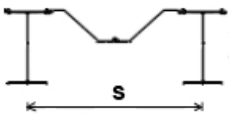
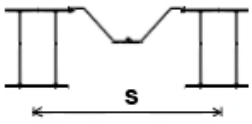
4. Program Limitations

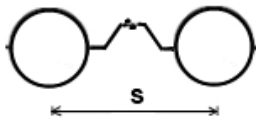
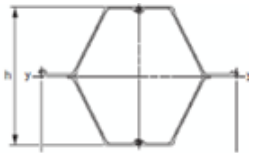
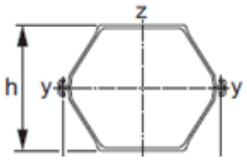
In DeepEX user can include up to two walls in the same model, simulating braced excavations. Additional wall elements can be used next to the walls. All commonly used wall sections can be analyzed:

Option	Description
	Select this option to use a soldier pile and lagging wall, supported by H-section steel beams. This option will deactivate all other wall type parameters.
	Select this option to use a soldier pile and lagging wall, supported by reinforced concrete beams. This option will deactivate all other wall type parameters.
	Select this option to use a soldier pile and lagging wall, supported by pipe-section steel beams. This option will deactivate all other wall type parameters.
	Select this option to use a soldier pile and lagging wall, supported by pipe-section steel beams, filled with concrete. This option will deactivate all other wall type parameters.
	Select this option to use a soldier pile and lagging wall, supported by channel-section steel beams. This option will deactivate all other wall type parameters.
	Select this option to use a soldier pile and lagging wall, supported by double channel-section steel beams. This option will deactivate all other wall type parameters.
	Select this option to use a soldier pile and lagging wall, supported by plain concrete beams. This option will deactivate all other wall type parameters.
	Select this option to use a soldier pile and lagging wall, supported by circular timber piles. This option will deactivate all other wall type parameters.
	Select this option to use a soldier pile and lagging wall, supported by rectangular hollow beams. This option will deactivate all other wall type parameters.
	Select this option to use a soldier pile and lagging wall, supported by rectangular concrete piles. This option will deactivate all other wall type parameters.

	Select this option to use a soldier pile and lagging wall, supported by rectangular timber piles. This option will deactivate all other wall type parameters.
	Select this option to use a soldier pile and lagging wall, supported by double H-section steel beams. This option will deactivate all other wall type parameters.
	Select this option to use a steel sheet pile wall. This option will deactivate all other wall type parameters.
	Select this option to use a wooden sheet pile wall. This option will deactivate all other wall type parameters.
	Select this option to use a vinyl sheet pile wall. This option will deactivate all other wall type parameters.
	Select this option to use a corrugated sheet pile wall. This option will deactivate all other wall type parameters
	Select this option to use a secant pile wall, supported by H-section steel beams. This option will deactivate all other wall type parameters.
	Select this option to use a secant pile wall, supported by reinforced concrete piles. This option will deactivate all other wall type parameters.
	Select this option to use a secant pile wall, supported by pipe-section steel beams, filled with concrete. This option will deactivate all other wall type parameters.
	Select this option to use a secant pile wall. This option will deactivate all other wall type parameters.
	Select this option to use a secant pile wall, supported by channel-section steel beams. This option will deactivate all other wall type parameters.

	Select this option to use a secant pile wall, supported by double channel-section steel beams. This option will deactivate all other wall type parameters.
	Select this option to use a secant pile wall, supported by reinforced concrete piles. The secondary piles can be reinforced as well. This option will deactivate all other wall type parameters.
	Select this option to use a secant pile wall, supported by H-section steel beams. The secondary piles can be reinforced as well. This option will deactivate all other wall type parameters.
	Select this option to use a secant pile wall, supported by rectangular hollow steel beams. This option will deactivate all other wall type parameters.
	Select this option to use a secant pile wall, supported by Double H-section steel beams. This option will deactivate all other wall type parameters.
	Select this option to use a tangent pile wall, supported by H-section steel beams. This option will deactivate all other wall type parameters.
	Select this option to use a tangent pile wall, supported by reinforced concrete piles. This option will deactivate all other wall type parameters.
	Select this option to use a tangent pile wall, supported by -section steel beams, filled with concrete. This option will deactivate all other wall type parameters.
	Select this option to use a tangent pile wall, supported by double channel-section steel beams. This option will deactivate all other wall type parameters.
	Select this option to use a tangent pile wall. This option will deactivate all other wall type parameters.
	Select this option to use a tangent pile wall, supported by channel-section steel beams. This option will deactivate all other wall type parameters.
	Select this option to use a tangent pile wall, supported by rectangular hollow steel beams. This option will deactivate all other wall type parameters.

	Select this option to use diaphragm wall. This option will deactivate all other wall type parameters.
	Select this option to use T-section diaphragm wall. This option will deactivate all other wall type parameters.
	Select this option to use inverted T-section diaphragm wall. This option will deactivate all other wall type parameters.
	Select this option to use a soldier pile and tremied concrete wall, supported by H-section steel beams. This option will deactivate all other wall type parameters.
	Select this option to use a soldier pile and tremied concrete wall, supported by double channel-section steel beams. This option will deactivate all other wall type parameters.
	Select this option to use a soldier pile and tremied concrete wall, supported by -section steel beams, filled with concrete. This option will deactivate all other wall type parameters.
	Select this option to use a soldier pile and tremied concrete wall, supported by channel-section steel beams. This option will deactivate all other wall type parameters.
	Select this option to create a wall with manually defined properties. This option will deactivate all other wall type parameters.
	Select this option to use a combined wall with H-section beams and sheet piles. This option will deactivate all other wall parameters.
	Select this option to use a combined wall with double H-section beams and sheet piles. This option will deactivate all other wall parameters.

	Select this option to use a combined wall with pipe section beams and sheet piles. This option will deactivate all other wall parameters.
	Select this option to use a box sheet pile wall with CAZ sheet pile sections. This option will deactivate all other wall parameters.
	Select this option to use a box sheet pile wall with CUZ sheet pile sections. This option will deactivate all other wall parameters.

There is no limitation on the number of the external loads and supports used in a DeepEX model. User can create an unlimited number of load combinations.

DeepEX includes all load combinations of the following standards:

1. Eurocode 7, 1997 and 2007
2. Eurocode 7, Greece
3. Italy - DM 2008
4. French - XP-P94
5. Germany - DIN1054, 2005
6. AASHTO LRFD, 2012, 2018 and 2020
7. British - BS EN 1997-1
8. British PAS 8810-2026
9. PEN DOT AASHTO, 2010
10. CALTRALS LRFD, 2012
11. China - CN Level 1, 2 and 3
12. Canada - NR24-28-2018
13. Canada - CSA S6:19
14. AREMA 2021
15. ASCE/SEI 7-22

Concrete design codes in DeepEX:

1. United States- ACI 318-11 and ACI 318-19
2. Eurocode 2, 2004 - General recommendations
3. Eurocode 2 with National Annexes (German, Cyprus, Austrian, Italian, Greek, French, Netherlands, Czech, Belgium, Slovakian, Danish, Finish, Swedish)
4. Eurocode 8 with National Annexes (Greek, Italian, Austrian, Bulgarian, Cyprus, Slovenian, French)
5. Australia / New Zealand - AS3600, 2009 and 2018
6. China - CN
7. AREMA 15 and AREMA 21
8. India - IS 456-2000
9. Canada – CSA A23.2:19

Steel design codes in DeepEX:
1. ASD, 1989
2. Eurocode 3, 2005 - General recommendations
3. Eurocode 3, 2005 with National Annexes (Bulgaria, Slovenia, UK, Norway, Sweden, Finland, Denmark, Portugal, Germany, Singapore, Greece)
4. LRFD 13th Edition, 2005
5. NTC, 2008
6. ANSI/AISC 360-10, 360-16 and 360-22
7. British - BS 5950-1:2000
8. Australia / New Zealand - AS/NZS 4100
9. Hong Kong H 2021
10. India – IS 800: 2007
11. AREMA 2021

5. Verification Method – Verification Result
Several verification documents and benchmarking examples have been created, verifying the produced results according to several scientific methods (see attached files). Additional verification examples can be produced upon user's request.

6. Other relevant information supporting the application
DeepEX includes an extensive User's Manual, a Theory Manual and a Non-Linear Analysis Manual.
Several examples can be reviewed in Deep Excavation LLC website through the following link, explaining the use of the software in several project types:

https://www.deepexcavation.com/post/deepex-software-training-materials

Deep Excavation LLC offers online free training upon request, to help users get started using the software program. In addition, Deep Excavation offers professional and personal technical support.

7. Software Upgrades:

DeepEX software is upgraded annually, with major improvements, updated structural and geotechnical design codes and load combinations, and new features and capabilities.

The following table summarizes the features that are included in each software version:

	SOFTWARE VERSION	DEEPEX 2017	DEEPEX 2018	DEEPEX 2019	DEEPEX 2020	DEEPEX 2021	DEEPEX 2022	DEEPEX 2023	DEEPEX 2024	DEEPEX 2025
ANALYSIS METHODS	Limit Equilibrium	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Non-Linear	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Combination (LEM+NL)	✓	✓	✓	✓	✓	✓	✓	✓	✓
	2D Finite Element Analysis (2D FEM)	–	–	✓	✓	✓	✓	✓	✓	✓
	Combination (LEM+FEM)	–	–	✓	✓	✓	✓	✓	✓	✓
	3D Finite Element Analysis (3D FEM)	–	–	–	–	–	–	–	✓	✓
ADDITIONAL MODULES	Cost Estimation	✓	✓	✓	✓	✓	✓	✓	✓	✓
	3D Frame Analysis	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Gravity Walls	✓	✓	✓	✓	✓	✓	✓	✓	✓
	DXF Drawings	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Building Damage Assessment	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Pile Supported Abutments	–	–	✓	✓	✓	✓	✓	✓	✓
	MSE – Soil Reinforcements	–	–	–	–	–	–	✓	✓	✓
	Soil Estimation Statistical Analysis	–	–	–	✓	✓	✓	✓	✓	✓
	Quay Walls – Wave Pressures	–	–	–	–	✓	✓	✓	✓	✓
	Steel Connections	–	–	–	–	✓	✓	✓	✓	✓
	Integration with Monitoring Data	–	–	–	–	–	–	✓	✓	✓
	Citywide Damage Assessment	–	–	–	–	–	–	✓	✓	✓
	AI Assistant	–	–	–	–	–	–	–	–	✓
GENERAL FEATURES	Custom Layers	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Excavation Model Wizard	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Embankment Model Wizard	–	–	–	–	–	–	✓	✓	✓
	Caterpilar Shape Excavation Wizard	–	–	–	–	–	–	–	✓	✓
	Slope Stability	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Additional Wall Elements	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Mechanical /Hydraulic Struts	✓	✓	✓	✓	✓	✓	✓	✓	✓
	SPT/CPT Test Data	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Voice Recognition	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Optimize Structural Section	✓	✓	✓	✓	✓	✓	✓	✓	✓
	Optimize Support Location	–	✓	✓	✓	✓	✓	✓	✓	✓
	Wall Rotation	–	✓	✓	✓	✓	✓	✓	✓	✓
	Multiple Walls	–	–	✓	✓	✓	✓	✓	✓	✓
	Train Loads (AREMA etc)	–	–	✓	✓	✓	✓	✓	✓	✓
	Include Tiedowns for Slabs	–	–	–	✓	✓	✓	✓	✓	✓
	Include Vertical Steel Columns	–	–	–	✓	✓	✓	✓	✓	✓
	Include Pile Rows	–	–	–	✓	✓	✓	✓	✓	✓
	Prestressed Concrete – GFRP Walls &	–	–	–	–	✓	✓	✓	✓	✓
	Import 3D Buildings from Google Maps	–	–	–	–	✓	✓	✓	✓	✓
	Tunnels in 3D map / Tunnel Analysis	–	–	–	–	✓	✓	✓	✓	✓
	Splays in Frame Module	–	–	–	–	✓	✓	✓	✓	✓
	Import Topographic Data from Google	–	–	–	–	–	✓	✓	✓	✓
	3D Flood Embankment Generation	–	–	–	–	–	✓	✓	✓	✓
	Subway Line & Tunnel Project Lines	–	–	–	–	–	✓	✓	✓	✓
	Soil Zones with Changeable Soil	–	–	–	–	–	✓	✓	✓	✓
	Import City Map from Google & Draw	–	–	–	–	–	✓	✓	✓	✓
	Settlements caused by Soil Loss	–	–	–	–	–	✓	✓	✓	✓
	Settlements caused by Consolidation	–	–	–	–	–	✓	✓	✓	✓
	Soil Reinforcements & Stone Columns	–	–	–	–	–	–	✓	✓	✓
	Transportation Analysis	–	–	–	–	–	–	✓	✓	✓
	Dynamic Analysis & Time Histories	–	–	–	–	–	–	✓	✓	✓
	3D FEM Caterpillar SOE	–	–	–	–	–	–	–	–	✓
	Soil nailing and hybrid soil nailing with V-	–	–	–	–	–	–	–	–	✓
	Preliminary diagnostics (LEM & Water	–	–	–	–	–	–	–	–	✓
	Bracket beams, deck beams, and slabs	–	–	–	–	–	–	–	–	✓
	Horizontal Directional Drilling (HDD)	–	–	–	–	–	–	–	–	✓

GENERAL DEEPEX CALCULATION FLOWCHART

ADDITIONAL DOCUMENTATION PROVIDED WITH THE ATTACHMENTS