Design of Deep Excavations - Methods and Software Application

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Our Company

- Software solutions for excavation and foundation professionals
- Consulting Services - Design of deep excavations and pile foundations
- Virtual Reality applications for geotechnical engineers and contractors

DeepEX  HoloDeepEX  DeepFND  HelixPile  SnailPlus  SiteMaster

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PART 1: DeepEX Software Features and Analysis Methods

Click here to learn more:
DeepEX – Software Features and Capabilities
DeepEx - Shoring Design Software

Full Structural and Geotechnical Design of any Deep Excavation Model

Wall Types in DeepEX
✓ Soldier Pile and Lagging Walls
✓ Sheet Pile Walls
✓ Secant / Tangent Pile Walls
✓ Concrete Diaphragm Walls (Slurry Walls)
✓ Soldier Pile and Tremied Concrete Walls
✓ Combined Sheet Pile Walls (King Piles)
✓ Box Sheet Pile Walls
✓ Custom Walls

Support Systems in DeepEX
✓ Anchored Walls (Tiebacks and Helical Anchors)
✓ Braced Excavations (Steel Struts and Rakers)
✓ Top/Down Excavations with Concrete Slabs
✓ Dead-man Walls
✓ Bin-Type Walls
✓ Cofferdams
✓ Circular Shafts

ANALYSIS METHODS: LIMIT EQUILIBRIUM ANALYSIS
- Soil Pressures: Active/Passive, At-rest, Apparent Pressures (FHWA, Peck, Adaptive, Custom Trapezoidal +more)
- Beam Analysis: Blum’s, FHWA Simple Span, CALTRANS +more

NON-LINEAR ANALYSIS (SOIL SPRINGS)
- Moments and Reactions from Spring Analysis
- Cumulative Results from Stages
- Realistic Displacements

FINITE ELEMENT ANALYSIS
- Moments and Reactions from Finite Elements
- Full Soil-Structure Interaction
- Calculate Surface Settlements

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# DeepEx Software - Wall Types

<table>
<thead>
<tr>
<th>Wall Type</th>
<th>Diagram</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soldier pile and lagging walls</td>
<td><img src="soldier_pile_lagging.png" alt="Soldier pile and lagging walls diagram" /></td>
</tr>
<tr>
<td>Secant pile walls</td>
<td><img src="secant_pile.png" alt="Secant pile walls diagram" /></td>
</tr>
<tr>
<td>Tangent pile walls</td>
<td><img src="tangent_pile.png" alt="Tangent pile walls diagram" /></td>
</tr>
<tr>
<td>SPTC walls</td>
<td><img src="sptc_pile.png" alt="SPTC walls diagram" /></td>
</tr>
<tr>
<td>Diaphragm (slurry) walls</td>
<td><img src="diaphragm_slurry.png" alt="Diaphragm (slurry) walls diagram" /></td>
</tr>
<tr>
<td>Sheet pile walls</td>
<td><img src="sheet_pile.png" alt="Sheet pile walls diagram" /></td>
</tr>
<tr>
<td>Combined sheet pile walls</td>
<td><img src="combined_sheet_pile.png" alt="Combined sheet pile walls diagram" /></td>
</tr>
<tr>
<td>Box sheet pile walls</td>
<td><img src="box_sheet_pile.png" alt="Box sheet pile walls diagram" /></td>
</tr>
<tr>
<td>Custom walls</td>
<td><img src="custom_wall.png" alt="Custom walls diagram" /></td>
</tr>
</tbody>
</table>
Anchored Walls (Tiebacks)

Braced Excavations (Struts and Rakers)

Circular Shafts (Ring Beams)

Dead-man Walls (Tierods)

Top-Down Excavations (Concrete Slabs)
Soils and Stratigraphy in DeepEX

✓ Create multiple soil types and define soil properties
✓ Soil properties estimation tools (NSPT values - test data)
✓ Create multiple borings and define the horizontal stratigraphy
✓ Add CPT logs and SPT Records - Estimate properties from records
✓ Custom Layer mode: Create inclined soil layers
✓ Soil Change Commands: Change soil properties through stages
Analysis Methods and Design Standards in DeepEX

Limit Equilibrium Analysis (LEM)

Non-Linear Analysis (NL) (Elastoplastic Springs)

Finite Element Analysis (FEM)

Structural Codes: Eurocodes 1, 2 & 8, ACI, LRFD, AISC, AS 3600 & 4100, CN (China) + more

Design Standards: Eurocode 7, DIN, BS, XP, AASHTO LRFD, CALTRANS, CN (China) + more

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✓ Assume lateral earth pressures.
✓ Determine fixity locations for forces at subgrade.
✓ Analyze wall beam with assumed loads.
✓ Advantages: Easy method to verify. Gives a back check for more rigorous methods.
✓ Disadvantages: Soil-structure interaction ignored.

Limit Equilibrium Analysis Concept (LEM)
### Earth Coefficients in DeepEX Software

#### DeepEX Automatic Method Selection According to Project Parameters

<table>
<thead>
<tr>
<th>Active Coefficient $K_a$</th>
<th>Parameters</th>
<th>Horizontal Surface</th>
<th>Inclined Surface</th>
<th>Wall Friction Considered</th>
<th>Seismic Effects Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>Rankine</td>
<td>Coulomb</td>
<td>Coulomb</td>
<td>No Effect</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Passive Coefficient $K_p$</th>
<th>Parameters</th>
<th>Horizontal Surface</th>
<th>Inclined Surface</th>
<th>Wall Friction Considered</th>
<th>Seismic Effects Applied</th>
</tr>
</thead>
<tbody>
<tr>
<td>Method</td>
<td>Rankine</td>
<td>Coulomb</td>
<td>Caquot-Kerisel</td>
<td>Lancelotta</td>
<td></td>
</tr>
</tbody>
</table>

- **Active Coefficient $K_a$**
  - Method: Rankine, Coulomb
  - Wall Friction Considered: Coulomb
  - Seismic Effects Applied: No Effect

- **Passive Coefficient $K_p$**
  - Method: Rankine, Coulomb
  - Wall Friction Considered: Caquot-Kerisel
  - Seismic Effects Applied: Lancelotta

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For more information, visit [www.deepexcavation.com](http://www.deepexcavation.com) or [www.deepex.com](http://www.deepex.com)

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LEM: Soil Pressures Methods

Cantilever Excavations

At-Rest Pressures

Peck 1969 Pressures

FHWA Apparent Pressures

Custom Trapezoidal Pressures

Active - Passive Pressures

Two-Step Rectangular Pressures

WMATA Pressures

New York City DEP Pressures

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Water Pressure Methods in DeepEX Software

Simplified Flow

Hydrostatic

Full Flownet Analysis
External Loads in DeepEX: Types and Pressure Methods

Loads on ground surface:
- Strip surcharges
- Linear loads
- 3D loads (buildings, footings, 3D surface loads)

Loads on the wall:
- Strip surcharges
- Linear loads
- External moments
- Prescribed displacements

Load modeling options:
- Elasticity equations
- Two-way distribution angle
- One-way distribution angle
- One-way distribution angle from soil friction
- Elasticity to vertical stress $x$ Ka (or Ko)
- CIRIA Special Pub 95 - 1993
Seismic Pressure Methods in DeepEX Software

Procedure in DeepEX
- Define Seismic Accelerations Ax and Az
- Select Seismic Pressures Calculation Method
- Select a Seismic Design Standard

Seismic Pressure Methods
- Semirigid
- Mononobe-Okabe (frictional soils)
- Wood Automatic
- Wood Manual

Semirigid Method
- Total Vertical Stress at Bottom of Wall \( x \times B \)
- \( B = 0.75 \) in DeepEX
- Rectangular Pressure Diagram

Mononobe-Okabe Method (Frictional Soils)
- Extension of the Coulomb Static Theory
- Accelerations added to a Coulomb Wedge
- Seed & Whitman (1970) Seismic Thrust Redistribution
- Inverse Trapezoid Pressure Diagram

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Cantilever Wall Analysis Concept

**Fixed earth method**
Balances out Moment and Shear

**Free earth method**
Balances out moment
Shear not balanced
Increase length by 1.2 to get FS 1.0
Then apply additional safety factors
Beam Analysis - Blum’s Method

Pinned supports - continuous beam

Point of zero net soil shear below subgrade.

Use point of zero shear as a virtual support.

Shear | Moments | Net loading

| Reaction for embedment $F_{xb}$ | Virtual support | Available resistance $R_x$ | FS, passive $= \frac{R_x}{F_{xb}}$ |

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Beam Analysis - FHWA Simple Span Approach

Pin support at excavation base, simple spans

Shear | Moments | Net loading

Reaction for embedment $F_{xb}$

Virtual support Available resistance $R_x$

$FS_{passive} = \frac{R_x}{F_{xb}}$
Beam Analysis - CALTRANS Approach

Pinned supports - simple span
Base at point of zero moment below bottom support
Shears and moments balance out

Shear | Moments | Net loading

No Embedment Reaction
Virtual support

FS.rotation = \frac{\text{Resist}}{\text{Fdrive}}
Non-Linear Analysis Concept (Soil Springs)

Soil Models
- Linear elastic perfectly plastic
- Exponential
  \[ E = E_0\left(\sigma_y + a_1 \sigma_b\right)^n \]
- Subgrade modulus
- Small strain hardening
  Re试行 stiffness linear 3 to 5 x loading E
Finite Element Analysis in DeepEX (Additional Module)

- Moments and reactions calculated with Finite Elements
- Consider full soil-structure interaction
- Calculate surface settlements
- Design Tiedowns, Foundation Piles and Steel Columns

Soil Models:
- Elastoplastic Model:
- Exponential (Hyperbolic) Model (approximate solution)
- Exponential (Hyperbolic) Model (complete solution): Soil hardening model

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Finite Element Analysis in DeepEX (Additional Module)

Tunnel Options:
- Tunnel Analysis with FEM
- TBM Tunnels
- NATM Tunnels
- Oval and Complex Tunnel Shapes
- Tunnel Model Wizard
- Cut-and-Cover Tunnels
✓ Bishop Method
✓ Morgenstern Price Method (G.L.E.)
✓ Spencer Method
✓ Ordinary (Swedish) Method
✓ Automatic Slope Search Method
✓ Single Point Slope Center
✓ Rectangular Slope Center
✓ Define Radius Search Limits
✓ Clouterre Standards for Soil Nails
PART 2: Projects Designed with DeepEX

More information: Click here to learn more: DeepEX – Project Gallery

2000+ users – more than 10000 projects worldwide!
LaBrea Metro Station, Los Angeles, California, USA

- 100 ft (30.5 m) Excavation
- Soldier Piles and Lagging
- Lateral Bracing (Struts)
- Full Design with DeepEX
- 5 Stations designed and under construction

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New Tapan Zee Bridge Cofferdams, New York, USA

✓ $3.9 billion project
✓ 90x45ft (27.5x13.7m) Cofferdams
✓ Lateral Bracing (Struts)
✓ Full Design with DeepEX
Soldier Pile Excavation Pits with Diagonal Struts and Tiebacks, Arkansas, USA

- 90 ft (27.5m) Excavation
- Soldier Piles and Lagging
- Pipe Struts
- 9 rows of Tiebacks
Soldier Pile Excavation Pits with Diagonal Struts, Arkansas, USA

- 24 ft (7.3m) Excavation
- Soldier Piles and Lagging
- Pipe Struts
- Full Design with DeepEX

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DeepEX Software - Project - Cofferdam

All American Canal, Imperial Irrigation District, Yuma, Arizona

- Cofferdam
- Water Wall Design
- Water Depth up to 20’ (6m)
- Sheet Pile System
- Post Tension cable Ties
- Full Design with DeepEX

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PART 3: DeepEX Additional Modules and Standard Packages

More information:
Click here to learn more:
DeepEX – Software Versions
2D Sections and 3D Models Design - Export Holograms

- Full Design - 2D Sections and 3D Model
- Structural & Geotechnical design of Tiebacks and Struts
- 3D Building Loads
- Full Model Optimization (Walls and Supports)
- Virtual Reality Model Visualization - Export Model to HoloDeepEX

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Building Damage Assessment - Additional Module to DeepEX 3D

✓ Perform Damage Assessment of all Buildings close to an excavation site
✓ Review Crack widths, Damage Categories, Strains etc. for all building walls.

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Export All Project Sketches to DXF

2D Sections:
✓ Export all 2D Sections Sketches for each Construction Stage
✓ Export Wall Section Details
✓ Export 2D Sections with Result Diagrams

3D Models:
✓ Export all 2D Sections and Wall Details
✓ Export Full Project Plan Sketches
✓ Export Elevation Sketches for each Project Wall

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Gravity Walls and Pile Supported Abutments

- Design gravity walls (any shape)
- Design pile supported abutments
- Use footings (3D loads) and design the foundation piles

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RELIABLE GEOEXPERTISE
RELIABLE GEOEXPERTISE

Sea Walls - Quay Walls - Wave Pressures - Overtopping

- Load combinations for British Standards 6349 Parts 1-2 (Marine Structures-Quay Walls)
- Wave pressures with Sainflou, McConnel, Proverbs
- Average overtopping volume calculations
- Block/segmental walls with individual shear resistances and densities
- Quay caisson walls (3D) with infill zones. The program can calculate the 3D weight
- Quay wall wizard

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Steel Connections

- Generate all steel connections
- Check Steel Connections (Struts and Walers)
- Optimize Steel Connections with a Click
- Adjust weld sizes and apply plate stiffeners
Soil Estimation - Statistical Analysis

✓ Estimate Soil Properties with different methods
✓ Review a statistical analysis of the estimated properties
✓ Select the project values with a high level of certainty
# DeepEX - Standard Packages and Additional Modules

## Standard DeepEX Software Packages

<table>
<thead>
<tr>
<th>Package</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DeepEX 2D Basic Version</strong></td>
<td>Design 2D Sections with LEM and NL Methods</td>
</tr>
<tr>
<td><strong>DeepEX 2D + FEM</strong></td>
<td>DeepEX 2D + Finite Element Analysis</td>
</tr>
<tr>
<td><strong>DeepEX Marine Walls</strong></td>
<td>DeepEX 2D + Gravity Walls + Sea Walls/Quay Walls + Soil Estimation</td>
</tr>
<tr>
<td><strong>DeepEX 3D</strong></td>
<td>DeepEX 2D + 3D Frame Analysis + Project Cost Estimation + Export 3D Holograms + Steel Connections</td>
</tr>
<tr>
<td><strong>DeepEX 3D + FEM</strong></td>
<td>DeepEX 3D + Finite Element Analysis</td>
</tr>
</tbody>
</table>

## Available Additional Optional Modules – Expand the Standard Version Capabilities

<table>
<thead>
<tr>
<th>Module</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finite Element Analysis</td>
<td>Available Add on</td>
</tr>
<tr>
<td>Gravity Walls &amp; Pile Abutments</td>
<td>Available Add on</td>
</tr>
<tr>
<td>Gravity Walls &amp; Sea Walls/Quay Walls</td>
<td>Available Add on</td>
</tr>
<tr>
<td>Soil Estimation &amp; Statistical Analysis</td>
<td>Available Add on</td>
</tr>
<tr>
<td>Export Sketches to DXF</td>
<td>Available Add on</td>
</tr>
</tbody>
</table>

## DeepEX Licensing Options

- Single Licenses (activated in specific devices), Single USB Keys, Network USB Key Solutions
- 1 Year of full Technical Support (training, questions, file reviews) is included in any software purchase
- Optional Annual Maintenance options (after the first year)
- Discounts for Additional Licenses
- Additional Modules can be purchased and activated at any point in any software package

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