

Foundation Pile Example: Driven Steel Section

Deep Excavation LLC Software program: DeepFND Document version: 1.0 January 11, 2019 www.deepexcavation.com www.deepex.com

DEEP EXCAVATION

A. Project description

In this example we will design a steel beam foundation pile. The Figure below presents the project model. Tables 1 and 2 present the soil properties and the stratigraphy respectively. Table 3 presents the external loads applied on the pile head. Table 4 presents the pile section properties that we are going to use. The general ground surface is at El. Oft and the general water table is at El. -15 ft.



Figure: Project model.

Soil			G	Lateral properties						
Layer	Soil Type	ф' (deg)	C'/Su (psf)	γ (pcf)	γ _{dry} (pcf)	E _{LOAD} (ksf)	E _{reload} (ksf)	k (pci)	e50	Krm
F	Fill	25	0	120	120	300	900	60	-	-
С	Clay (Undrained)	-	1300	116	116	400	1200	-	0.005	-
S1	Sand	32	0	130	130	600	1800	60	-	-
S2	Sand	34	10	135	135	900	2700	90	-	-

Table 1: Soil properties.

Table 2: Stratigraphy.

Soil Layer	Elevation (ft)	OCR	Ко
F	-0	1	0.577
С	-5	1	0.515
S1	-18	1	0.47
S2	-27	1	0.441

Stage	Axial Load (kips)	Moment (k-ft)	Lateral Load (kips)		
Stage 0 (Compression)	150	0	20		
Stage 1 (Tension)	-100	0	20		

Table 3: External loads.

Table 4: Pile parameters.

Pile Type	Steel Driven
Steel pile section	W30x108
Steel Grade	A36
Initial pile depth	45 ft

B. Modeling with DeepFND

In DeepFND software, we should define initially the soil properties of all soils according to the geotechnical report, the model stratigraphy, the pile head loads and the pile initial depth and structural section.

• Define soil properties:

From the General tab of DeepFND we can select the option "Edit Soil Type Data". In the dialog that appears, we can modify the existing soils database or add new soils, and then for each one of them, we have to define the general soil properties, the soil model and the lateral soil properties. The soil parameters can be defined manually, or with the use of the software SPT estimator or local parameter estimation tools.



Figure: Edit Soil Type Data Dialog.

• Define stratigraphy:

From the General tab of DeepFND we can select the option "Edit Boring". In the dialog that appears, we can define the top of the soil layer elevation and the soil type for each soil layer.

Soil Layers								X			
Available Borings	1. General Boring Information - Coordinates										
Boring 1		Name Boring	g 1								
	Coordi	inates X 5	0 ft Y	0	ft						
	The x coordinate controls where the boring is shown in your design section view. Each design section uses one boring (soil strata). You can use a different boring on each design section.										
	2. Borir	ng Layers - Lay	er Elevations								
		Тор	Soil type		OCR	Ко	Edit				
	•	0	F	¥	1	0.577	Edit				
		-5	С	¥	1	0.5151	Edit				
		-18	S1	¥	1	0.47	Edit				
		-27	S2	¥	1	0.441	Edit				
	*			¥							
Add New Boring											
Delete Selected Boring (Stratigraphy) Insert Layer Delete Layer											
						0	к	Cancel			

Figure: Edit Soil Layers Dialog.

• Define external loads on pile head:

In any model in DeepFND we can add several stages. In our deep foundation software these can work as loading stages, so in each stage we can define a different load (load type, magnitude etc). In this example, we will use Stage 0 to define our maximum compression load, and Stage 1 to define our maximum tension load on the pile head.

First of all, we right-click on the Stage 0 tab right below the model area and we select to Add Stage (so Stage 1 is added):

EV+- ↑↓ +		S2	
/iew			×
≥φ A 🛛 🔢 🗟 ்		Boring 1	
Selected design section	Stage 0 Stage 1		
	Stage: 0/1 X: -15	Z: -42.43	
E	igura, Stagas in I		

Figure: Stages in DeepFND.

DEEPFND EXAMPLE: DRIVEN STEEL SECTION

After we create the stages, we double-click on the load in the model area. In the dialog that appears, we can add several loads in the list and define the load type and the magnitude of each load, in each stage. The summary of all loads will be applied on the pile head. If we apply a design standard (i.e. AASHTO LRFD), the loads will be factored depending on the load type (dead, live, wind, ice, vehicular etc.).

		l	Loads on p	ile			×				
List of loads Load 1, DL, DL: Dead load	Load propertie 1. Name Load 1, DL	35									
	2. Load Type DL: D	ead load (AASHTC) DC)	v							
3. Load magnitude ☐ Apply same load on all stages ✔ Activate for current stage											
	Load for every stage										
		Active	Axial force(k)	Moment(k-ft)	Horizontal						
	Stage 0	v	150	0	20						
Add new load	Stage 1 🗹 -100 0 20										
Delete selected load											
Apply to all design sec	tions	Pile weight Ig	nore pile weigh	t	✓ ОК	Cano	el				

Figure: Define loads on pile head.

• Define pile section and initial length:

In DeepFND we have to define the pile type, installation method, structural section and original depth. Later, based on the analyses results, we can choose to optimize the pile section and the pile embedment. The required pile length can also be calculated by the software. We have to double-click on the pile and define the pile parameters in the dialog that appears. By pressing "Edit" on this dialog, we can define the pile type and the pile structural section.

In the Steel Sections dialog, we can select the steel beam type (H beam, Circular, Square hollow), and select the steel section from the software extensive database. All steel section properties are implemented within the software.

Important: In this dialog we should also define the steel Fy value (the default value is 0 leading to no results).

DEEPFND EXAMPLE: DRIVEN STEEL SECTION

Edit Pile Dim		×	
A. General B. Prestress-Unbraced C. Corrosion D. Results E. with Depth P-y Lat	eral		
A General B. Prestress-Undraced C. Corroson D. Results E. with Depth P-y Lat Pile Properties 1. Selection of Support Type Installation method Driven Concrete type Precast concrete Pile tip is plugged (for open steel sections 3. Dimensions 1.1 Coordinates at top of pile X0 ft Z0 ft Latree 5 ft 2. Pile Sections Length (ft) Section Type Edit Tapered with 45 H Pile V	Section Pile SideView 45ft 45ft 45ft 45ft 45ft 5ft 45ft 45ft 45ft 5ft 45ft 45ft 45ft 5ft 45ft 45ft 45ft 5ft	section A-A	
Chandell coloring		OK	Canad
Show full calculations		UK	Cancer

Figure: Define pile dimensions and data dialog.

		ete Sections				×		
Concrete Sections 5ft pile H Pile	Section name Section name H Pile	2	⊑ Steel (H, or pipes ▼	Section Drawing				
	Structural materials Concrete mat. 3 ksi Concrete v Rebar steel mat. Grade 60 v fy		Rectangular Circular			T		
	Steel Section - Hollow bar Section Properties	0	Circular Hollow					
	Edit Steel Section W30X108		Octagon Steel (H, or pipes) Timber pile					
	Has concrete Grout (used only for compression	on)			-			
				x	⊿ptions ∷-21 mm y:0 mm	Use user defined	reinforcement	
Add New Concrete Section								
Delete Selected Concrete Section						ок	Cancel	

Figure: Select the pile type and choose to edit the steel section.

DEEPFND EXAMPLE: DRIVEN STEEL SECTION

T		Edit Steel	Section Properties
	-1. Section Type		
	Use a steel I-Section	W30X108	
	O 🔘 Use a pipe section	W30X191 W30X173 W30X148	properties
4	O Use hollow sections	W30X132 W30X124 W30X116 W30X108	Select Fy k □ Edit properties manually fy 36
	3. Section Dimensions - Mechan	W30X99 W30X90	
	D 29.8 in A 31	W27X539 W27X368	E 29000 ksi rx 11.9 in
	bf 10.5 in tf 0.	W27X336 W27X307	k 1.41 in ry 2.15 in
	lxx 4470 in4 lyy 14	W27X281 W27X258	W 108 plf rT 2.61 in
	Sxx 299 in3 Syy 2	W27X235 W27X217	Zyy 43.9 In3 Cw 30900 In6
	📙 Database 📃 🗖	W27X194 W27X178	OK Cancel
		W2/X161	v: -16 mm V: -17 mm Use user defined reinforcement
		W2/X146 W/27X129	
		W27X123	
		W27X102	
		W27X94	
		W27X84	
		W24X370	
		W24A330	
		W24X279	OK Cancel

Figure: Define the steel beam type, select the steel section and define Fy.

C. Define Analysis Options

After we create the model in DeepFND, we have to define several analysis parameters.

• Pile length automatic optimization:

In the general tab of DeepFND we can select to optimize the pile length. In this case, we need to define the maximum pile depth and the step. The software will use the step to calculate the pile tensional and compressional capacity in several depths and compare them with the applied tension and compression loads respectively. It will stop the analysis when both capacities exceed the applied loads and return as a result the pile depth, the calculated capacities and the pile structural results (moment, shear, displacement etc.). If the software reaches the maximum depth and fails to find a suitable solution, it will stop the analysis and return as a result the calculated capacities etc. of the maximum depth.

If we leave this option unselected, the software will use the pile depth we manually specified for the analysis and return all analysis results.



Figure: Option to optimize pile length in the General tab.

• Analysis equations and settings:

In the Analysis tab of DeepFND, all analysis parameters are automatically defined according to the pile type (helical or non-helical) and the pile installation method (drilled, driven, caisson, micporile etc.).

General Properti	es Analysis Design	Settlement Lateral Results	Report View Help	
Method Meyerhof/Hansen *	Include shaft resistance	Use additional multipliers	Factors on c' FHWA-AASHTO: Driven F 🔻	method AASHTO-Norlund, Driver *
Equation AASHTO Driven: Nor 🔻	^δ on concrete 100	%	Additional factor at shaft	Rock Use specified soil bond 🔹
Consider disturbance Ed	δ on steel 50	%		
Bearing Capacity Method		Shaft resistance	Reductions on side c'	Cylinder method

Figure: Analysis settings, automatically selected.

• Design standards and Safety factors:

In the Design tab we can define the structural codes and the safety factors applied on the bearing, shaft and structural capacities. Alternatively, we can select a load combination of a specific geotechnical design standard (we will not use one in the current example).

1	۰	General	Properties	Analysis	Desig	gn	s	ettle	ment		Late	ral	Res	ults	Report	View	Help
	co	DES		DES	🔲 Use m	ob.	axial f	for S	「R ch	ecks		Custo	om STR	V Ad	just ultimat	e STR capac	ity by FS
H	DE	Steel-Desi	an: General	Members:	Safety Fac	ctor	Shaft	2			STR	.des	0.6	Safety	Factor 1.6		
ŀ	options *	AISC 360-10	ALL. * Settings	US Sizes *	Safety Fac	ctor	Bearii	ng 2						Metho	od Internati	onal Buildir	ng Coi 👻
		Struc	tural code o	otions	×			Safe	ty fac	tors					Structu	ral factors	
	Concre	ete Code Option	s														
	1-ACL	210.11													Base	model	
	1.701	510-11				c' zef)	Su (psf)	đř (dea)	Ksub (pci)	e50	Qu (ksf)	RQD (%)	krm -				
	Steel (Code Options				0	- 1300	25	30	-	•	•	•				
	17.410	C 200 10 ALL				0	•	32	50	•	•	•	•				
	17.743	5C 360-10 ALL.			*												
	Timbe	r Code Options													150 k		
	Servic	e, a=0.36			~										1		
				ок	Cancel	F						5.0	r		-20 x y		•
												5 ft					

Figure: Define structural codes and structural/geotechnical safety factors.

Design	Select Load Combination or Design Approach 💌		
Use mob. axial	Design Approach	Single 🔹 Mult. •	Examine corrosion effects
afety Factor Shaf	O Do Not Use A Code		
afety Factor Bear	Analyze only one Code Case	Approach: Service	
		Load combinations	Design Life
	Design Code		_
<mark> γt c' Su</mark>	AASHTO LRFD (2010) *		-
te (pcf) (psf) (psf) 120 0 -	Load Case		
ID.) 116 - 1300 130 0 -	Strength Ib *		-
135 10 -			_
	When you are analyzing a wall with LRFD or ULS procedures you will need to define the appropriate load combination or design approach. Select 1st the design code, and then select the appropriate case. Load combinations can be applied at each stage or you can create different design sections where dirrent load combinations are assumed.		

Figure: Option to assign a design standard load combination.

• Settlement analysis options:

In the Settlement tab we can select the option to perform settlement analysis. Also there, we can define pile settlement acceptance criteria.

General Properties Analysis	Design Settlement	Lateral Results Report View Help					
Perform settlement analysis	Use when optimizing length	Inflection factor for shaft response Rm 4					
Calculate design capacity from PY response		Maximum settlement vMax 2 in					
Include corrosion effects in PY response		Effective area percentage factor Aeff 100 %					
Settlement analys	is	Settlement Parameters Pile acceptance criteria					
Units Base model		Pile acceptance criteria					
English Units (ft, inch, kips)	Available criteria	Acceptance criteria					
Design sections Tree view	Elastic	1. Name					
	ICC-AC358	Bastic Color					
Design Sections		2. Set active/visible					
C: Base model		✓ Criterion is active (to be analyzed)					
		Criterion is visible (on graphs)					
		3 Equation					
		$y = 0 + 0 D_{PL} + 0 D_{S} + 1 PL/AE$					
		D = Plate diameter D = Shaft diameter					
		Average plate size					
		Define maximum net settlement					
		Ultimate load criterion (Criteria determines ultimate load)					
		Determine load from criterion					
		Use deflection load slope					
	Add annu aiteria						
1	Add new chtena	Reset to Elastic Reset to ICC355 Reset to Davisson					
EV+-++	Delete oritoria						
View	Delete Cilteria	Butler-Hoy NYC 2011-011					
		OK Cancel					

Figure: Option to perform settlement analysis and pile settlement acceptance criteria.

• Lateral pile analysis options:

In the Lateral tab we can select the lateral pile analysis method. The available options are either to calculate pile moment, shear and displacement for the defined lateral loads, or perform a pushover analysis and report the required load to achieve a specific displacement.



Figure: Lateral load options.

D. Analysis and Results

Since the model is ready, we can choose to calculate the design section. After the analysis is succeeded, the Summary table appears. The table below includes the calculated compression and tension capacities, the optimized pile depth, the lateral pile results and more. By closing the summary table, we can review the results graphically on the model area.

	Analysis and Checking Summary									
Extended Summary										
	Calculation	Pile type	Fmax compression (k)	Cap. compression (k)	Fmax tension (k)	Cap. tension (k)	Max. stress check	Pile length (ft)	Pile OD (in)	Bearing
Base model	Calculation succ	Driven	150	156.1	100	145	0.961	41	10.5	Atip= 0.22 ft2

Table: Analysis and Checking Summary table.



Figure: Pile geotechnical capacities and settlement.



Figure: Pile displacement, shear and moment diagrams.