User's Manual for NAVFAC Deep Foundation Design

Axial Capacity Design Tool

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Although this application has been used with apparent success in testing, new or updated versions of this application may be written and released from time to time. All users are requested to inform Ryan Carpus immediately of any suspected errors found in the application.

No warranty, expressed or implied, is offered as to the accuracy of results from this web application. The application should not be used for design unless caution is exercised in interpreting the results and independent calculations are available to verify the general correctness of the results.

Users are assumed to be knowledgeable of the information in the program documentation (The user's manual and the web documentation) made available within the application. Users are assumed to recognize that variances in input values can have significant effect on the computed solutions and that input values must be chosen carefully. Users should have a thorough understanding of the relevant engineering principles, relevant theoretical criteria, and design standards.

Contents

Introduction

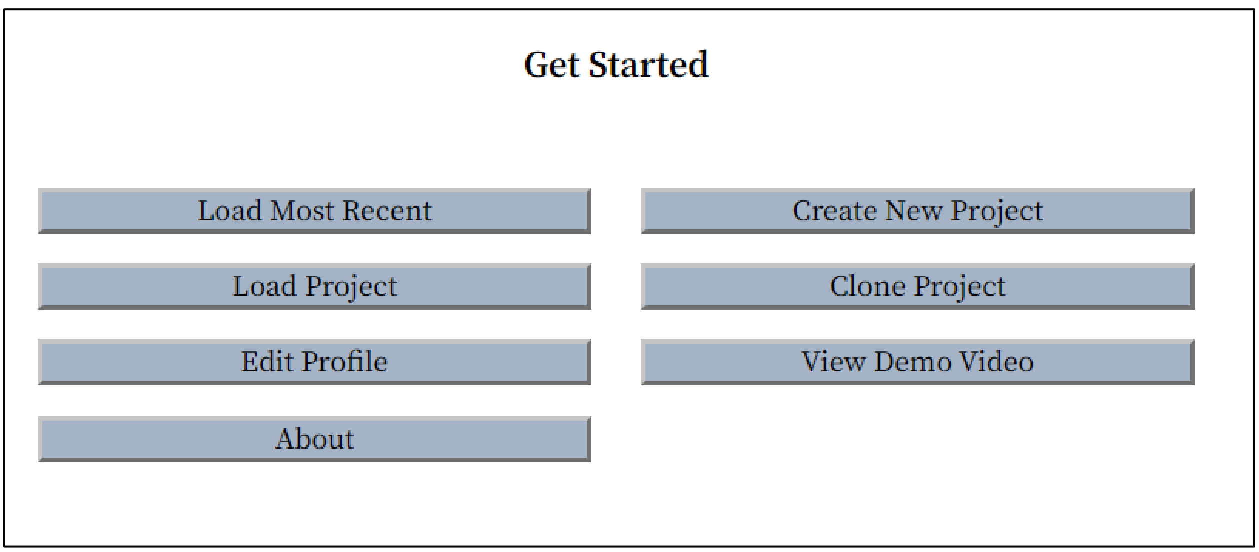
This application performs axial capacity analysis for a variety of deep foundation types in stratified soil profiles. The calculations are adapted from the NAVFAC Foundations & Earth Structures Design Manual 7.02, last edited September 1986. This tool allows users to input a custom soil profile with several layers, select a foundation type and installation type, and input a selection of foundation widths and bearing depths to analyze simultaneously.

After submitting an analysis, the user will be presented with a collection of summary tables showing the ultimate and allowable axial capacity of each foundation in compression and in tension. Beyond the summary tables, the user can view a detailed output for each individual pile showing the results of each calculation. The results may be downloaded in PDF form, and users can save their projects to enable tweaking the input parameters. Additionally, users can clone projects so they can easily analyze different pile types without needing to input the soil data again.

Getting Started

NAVFAC Deep Foundations is a free web app, but you must make an account before you can use the application. Making an account is free and easy, and I won't use your email for any reason other than to help you reset your password. Because this is a web-based application, you must have a working internet connection to use the application.

Home Screen



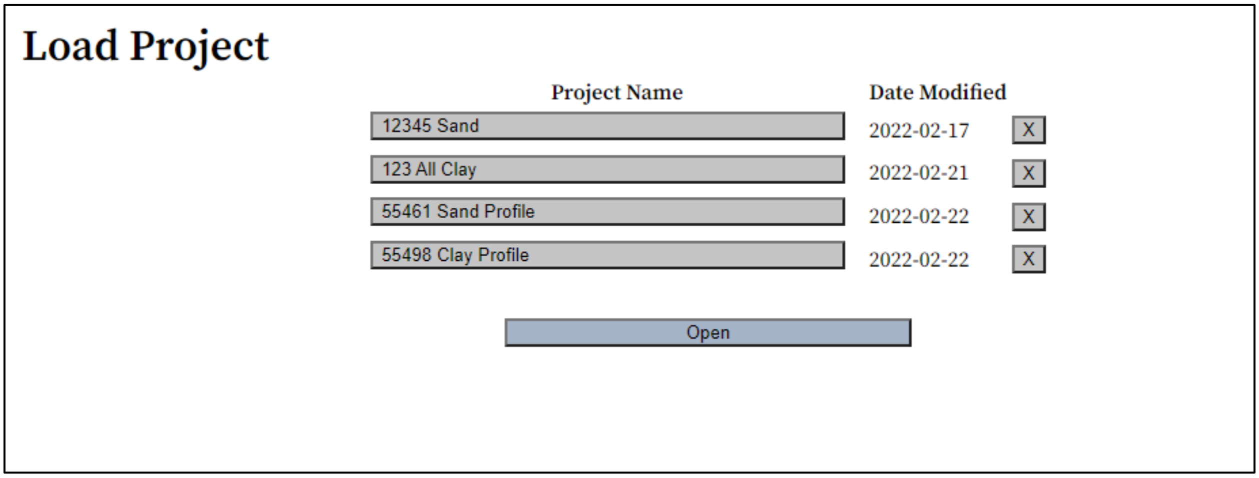
Below is as list of the functions available from the home screen with descriptions.

Load Most Recent

Load the most recent project that was opened by the user. This option is unavailable before you've opened a project, and if you log out and log back in, the option will become unavailable again until you've opened a project.

Load Project

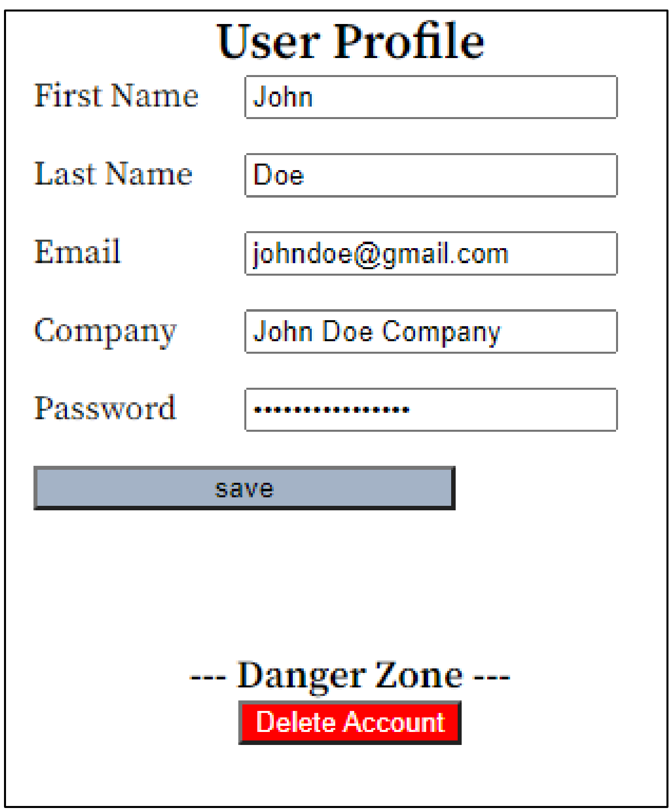
Opens a new view that allows the user to select an existing project to load or to delete an existing project.



Warning: Deleted projects cannot be restored. Only delete projects if you are sure you don't need it anymore.

Edit Profile

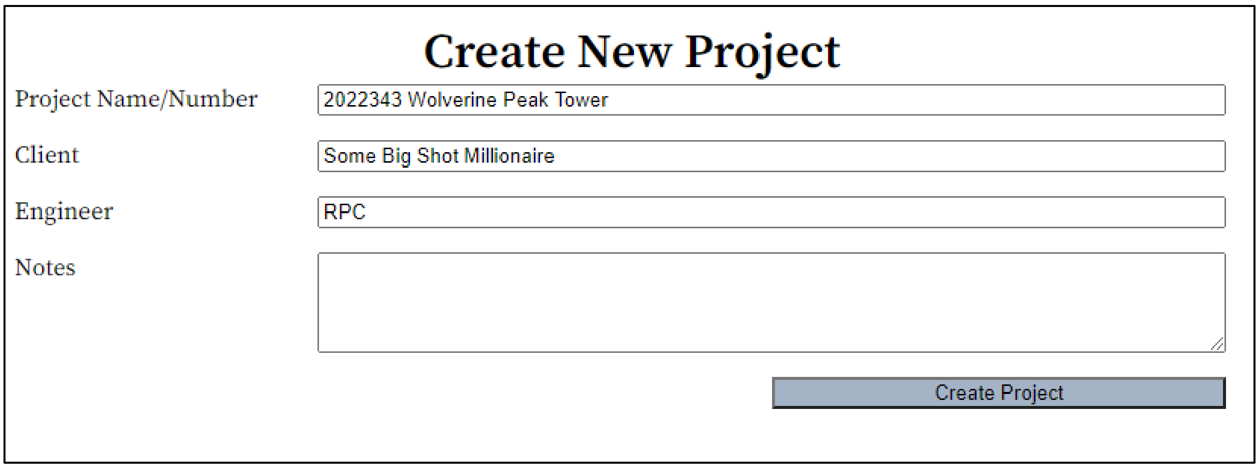
Opens a new view that allows the user to edit their account information, including their name, email, company, and password. The user can also delete their account from this screen.



Warning: Deleted user accounts cannot be restored. Only delete your account if you are sure you don't need it anymore.

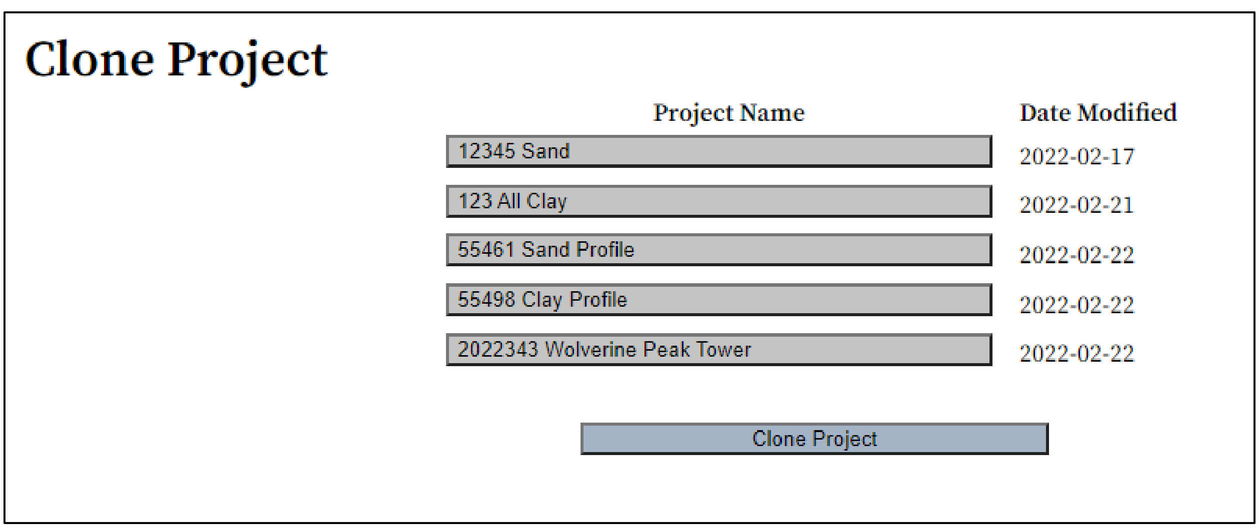
Create New Project

Opens a new view that allows the user to create a new project. New projects only require the "Project Name/Number" field to be filled in. Project details supports alphanumeric values with spaces only. Special characters are not allowed. Additionally, you cannot have two projects with the same name, so you will not be allowed to proceed with a duplicate project name. After clicking "Create Project", you will be redirected to the Project Edit View for the new project where you will be able to input your soil and foundation parameters.



Clone Project

Opens a new view that allows the user to clone an existing project to facilitate sensitivity analysis or testing different foundation types on the same soil profile without modifying the original project. This creates a copy of an existing project with a different automatically generated unique name (this can be changed later). The clone will have the same project details, soil data, and foundation data as the cloned project.



View Demo Video

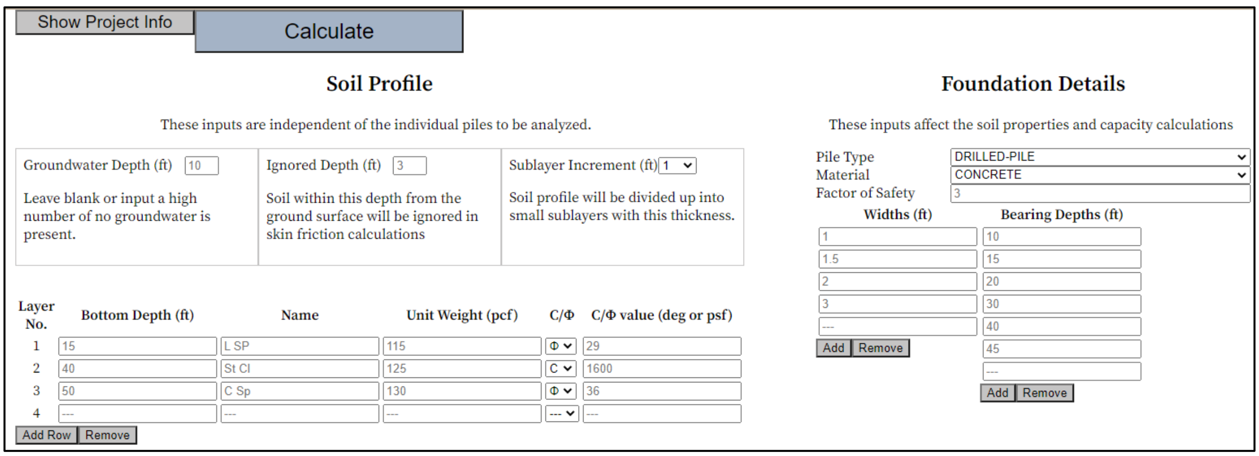
Opens a link in a new browser tab to a YouTube video demonstration of the NAVFAC Deep Foundation Design application.

About

Opens a link in a new browser tab the GitHub repository for the NAVFAC Deep Foundation Design application. From here, users can find the source code for the application as well as links to the code documentation.

Editing a Project

After loading a project, the user is presented with a view that allows them to input all the necessary parameters required to perform their foundation analysis. In this section, we will walk through how to use each input parameter.



Groundwater Depth

This is the depth in feet from the ground surface the groundwater table. If no groundwater is present within soil profile, you can input any number deeper that the full depth of the soil profile, and the groundwater will not be considered in the analysis.

Note: Groundwater Depth must be evenly divisible by Sublayer Increment. For example, if Sublayer Increment is equal to 0.5, Groundwater Depth may be 2.0 or 5.5, but not 5.3.

Ignored Depth

This is the depth in feet from the ground surface that will be ignored in skin friction calculations. This can vary depending on the type of soil at the ground surface, but a typical value to use is about 3 feet.

Note: Ignored Depth must be evenly divisible by Sublayer Increment. For example, if Sublayer Increment is equal to 0.5, Groundwater Depth may be 3.0 or 5.5, but not 5.3.

Sublayer Increment

This is the thickness in feet that each sublayer will be after dividing the raw soil profile into several layers. This subdivision allows the calculation to be more accurate and to handle more complex soil profiles.

Note: Sublayer Increment must be selected as either 0.5 or 1.0 from the dropdown menu.

Soil Layers

Each soil layer must include all of the following:

Bottom Depth

The depth from the ground surface in feet to the bottom of the layer. Each layer must be deeper than the layer above, and each bottom depth must be evenly divisible by Sublayer Increment.

Name

The name of the soil layer. This does not affect the analysis, but the layer name shows up in the calculations for your reference.

Unit Weight

The unit weight in pounds per cubic feet of the soil layer. This is NOT the submerged unit weight. If there is groundwater in the soil layer, the submerged unit weight will be calculated as:

$$submerged\ unit\ weigiht = unit\ weight - unit\ weight\ of\ water$$

C/ Φ

A dropdown selector to indicate if the layer is cohesive (C) or granular (Φ). This application does not support combined granular/cohesive layers.

C/ Φ Value

The cohesion value in pounds per square foot, or the soil internal friction angle in degrees. Cohesion values can be any non-negative number, but friction angles provided must be integers between 26 and 40.

Foundation Details

This application supports all pile types indicated in the NAVFAC Foundations & Earth Structures Design Manual. Pile Type and Material are selected using dropdown menus.

Pile Type

This application supports each of the following pile types. The selection of the pile type and material affects the skin friction analyses by way of the contact friction angle with the soil and the horizontal earth pressure coefficient. Pile Type can take on any of the below values, named as they are within the NAVFAC manual:

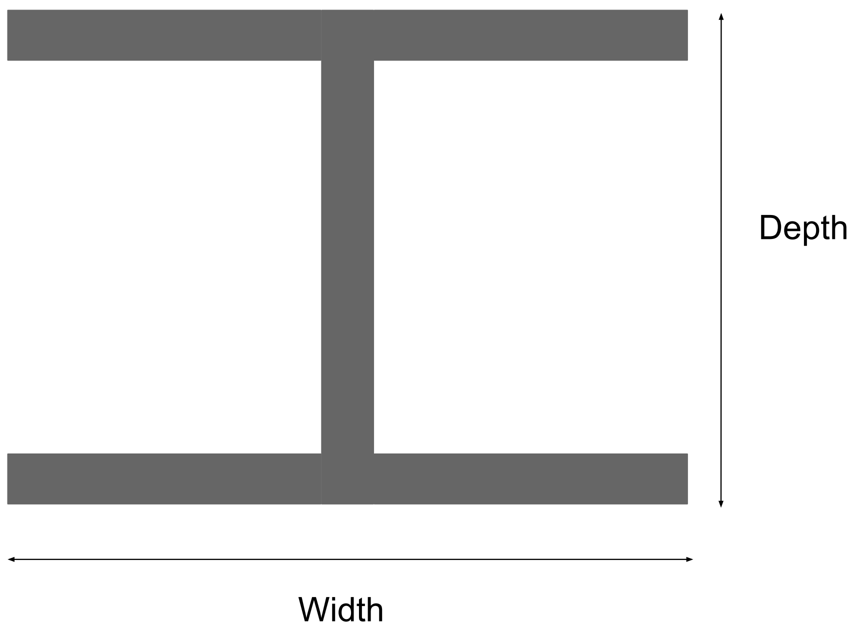
- DRIVEN-SINGLE-H-PILE
- DRIVEN-SINGLE-DISPLACEMENT-PILE
- DRIVEN-SINGLE-DISPLACEMENT-TAPERED-PILE
- DRIVEN-JETTED-PILE
- DRILLED-PILE

Material

This application supports each of the following materials. The selection of the pile type and material affects the skin friction analyses by way of the contact friction angle with the soil and the horizontal earth pressure coefficient. Material can take on any of the below values, named as they are within the NAVFAC manual:

- CONCRETE
- TIMBER
- STEEL

Widths
For all pile types except “DRIVEN-SINGLE-H-PILE”, this is the diameter of the circular pile in feet. For “DRIVEN-SINGLE-H-PILE”, width will require two values corresponding the depth and width of the pile section. The pile area and perimeter are then calculated as a rectangle, assuming the presence of a soil plug.



Bearing Depths
The bearing depths of the foundation in feet. The bearing depth must be evenly divisible by the Sublayer Increment and must be shallower than the bottom depth of the full soil profile.

Factor of Safety
The factor of safety applied to the ultimate capacity to determine the allowable capacity of the pile. It is recommended to use a value of 3.

Project Info
The basic project info, which was initially input at the time of project creation, can be edited by clicking “Show Project Info”. The project info includes the following. Each field accepts alphanumeric values and spaces.

- Project Name/Number

- Client
- Engineer
- Notes

Data Validation/Saving the project

After entering all the project data and clicking “Calculate”, the program will check all of your inputs to make sure they are valid before running the analysis. If any errors are found, you will be presented with a list of errors found and tips on how to resolve them.

If no errors were found, the project will be saved and you will be redirected to the calculation view.

Note: If you click “logout”, “Home”, or reload the page, your project will not be saved.

Analysis View

After clicking “Calculate” from the Project Edit View, if the data entered is valid, the application will then perform axial capacity analysis on each combination of width and depth you entered for the project. The calculation will be performed in both tension and compression.

The calculation should only take a few seconds to run. After the calculation runs, you are presented with a detailed analysis page containing the following sections. This analysis page is designed with Print to PDF in mind, so the output will be well-formatted when saving as a pdf or printing.

To make changes to your project or to open a new project, we recommend using the “Back to Edit View” or “Home” buttons for navigation.

Project Meta Data

This is a header that contains the project name, client, engineer, and the date and time of calculation.

NAVFAC Deep Foundation Axial Analysis

Project Name:	example mixed profile
Client:	You
Engineer:	RPC
Date Calculated:	Tue Feb 22 2022 09:33:01 GMT-0500 (Eastern Standard Time)

Summary of Allowable Axial Capacity

Two tables presenting the allowable axial capacity for each embedment depth and width combination in compression and tension modes.

Summary of Allowable Axial Capacity

Allowable Capacity (kips) - Compression

	Width (ft)			
Embedment Depth (ft)	**1**	**1.5**	**2**	**3**
10	4.2	8.4	13.9	29.0
15	7.2	13.6	21.9	44.1
20	11.7	20.4	31.0	57.8
30	20.8	34.1	49.2	85.1
40	39.7	80.8	145.9	289.0
45	42.9	87.3	156.9	330.6

Allowable Capacity (kips) - Tension

	Width (ft)			
Embedment Depth (ft)	**1**	**1.5**	**2**	**3**
10	2.1	4.0	6.5	13.2
15	3.7	6.9	11.0	21.7
20	8.9	15.1	22.4	40.7
30	19.1	31.4	45.4	78.6
40	29.4	47.7	68.3	116.6
45	31.8	52.7	76.9	132.0

Summary of Ultimate Axial Capacity

Two tables presenting the ultimate axial capacity for each embedment depth and width combination in compression and tension modes.

Summary of Ultimate Axial Capacity

Ultimate Capacity (kips) - Compression

	Width (ft)			
Embedment Depth (ft)	**1**	**1.5**	**2**	**3**
10	12.7	25.2	41.7	86.9
15	21.5	40.8	65.7	132.4
20	35.2	61.3	93.0	173.4
30	62.5	102.3	147.7	255.4
40	119.2	242.5	437.8	867.1
45	128.7	262.0	470.8	991.7

Ultimate Capacity (kips) - Tension

	Width (ft)			
Embedment Depth (ft)	**1**	**1.5**	**2**	**3**
10	3.8	6.6	10.0	18.5
15	7.6	12.7	18.7	33.4
20	21.9	34.6	48.4	79.7
30	50.4	78.2	107.8	172.3
40	78.9	121.9	167.2	264.9
45	84.9	134.3	188.4	300.4

Summary of Soil Properties

This is a table showing the input soil profile divided into sublayers of thickness equal to the sublayer thickness. Additionally, the effective stress (psf) at the midpoint and at the bottom of each sublayer is presented.

Summary of Soil Properties

Groundwater Depth (ft): 10 Ignored Depth (ft): 3 Sublayer Thickness (ft): 1

Layer No.	Bottom Depth (ft)	Name	Unit Weight (pcf)	C (psf)	Φ (deg)	Eff. Stress at Mid.	Eff. Stress at Bot.
1	1	L SP	115	0	29	58	115
2	2	L SP	115	0	29	173	230
3	3	L SP	115	0	29	288	345
4	4	L SP	115	0	29	403	460
5	5	L SP	115	0	29	518	575
6	6	L SP	115	0	29	633	690
7	7	L SP	115	0	29	748	805
8	8	L SP	115	0	29	863	920
9	9	L SP	115	0	29	978	1035
10	10	L SP	115	0	29	1093	1150
11	11	L SP	115	0	29	1176	1203
12	12	L SP	115	0	29	1229	1255
13	13	L SP	115	0	29	1281	1308
14	14	L SP	115	0	29	1334	1360
15	15	L SP	115	0	29	1387	1413
16	16	St Cl	125	1600	0	1444	1476
17	17	St Cl	125	1600	0	1507	1538
18	18	St Cl	125	1600	0	1569	1601
19	19	St Cl	125	1600	0	1632	1663
20	20	St Cl	125	1600	0	1695	1726

Individual Pile Analyses

The analysis out put includes a page for each individual pile that was analyzed. Here, we will discuss what each part of an Individual Pile Analysis means. Within each Individual Pile Analysis, the soil properties for each sublayer up to the first sublayer below the bearing elevation are shown.

Individual Pile Analysis

Material	CONCRETE	Pile Type	DRILLED-PILE	Load Direction	Compression
Kh	0.7	Pile Area (sf)	0.785	Pile Perimeter (ft)	3.142
Width (ft)	1	Bearing Depth (ft)	10	FS	3
Allowable Capacity (kip)	4.24	Ultimate Capacity (kip)	12.72		
Bearing Mode	GRANULAR	Nq	9	Effective Stress Limited?	yes
Pile Weight (kip)	1.18	Total Skin Friction (kip)	4.59	End Bearing (kip)	8.13
Groundwater Depth (ft)	10	Ignored Depth (ft)	3	Sublayer Thickness (ft)	1

Layer No.	Bottom Depth (ft)	Name	Unit Weight (pcf)	Phi (deg)	C (psf)	Eff. Stress at Mid. (psf)	Eff. Stress at Bot. (psf)	contact friction angle δ	Adhesion α (psf)	Skin Friction (psf)
1	1	L SP	115	29	0	58	115	21.75	0	0.00
2	2	L SP	115	29	0	173	230	21.75	0	0.00
3	3	L SP	115	29	0	288	345	21.75	0	0.00
4	4	L SP	115	29	0	403	460	21.75	0	353.14
5	5	L SP	115	29	0	518	575	21.75	0	454.03
6	6	L SP	115	29	0	633	690	21.75	0	554.93
7	7	L SP	115	29	0	748	805	21.75	0	655.83
8	8	L SP	115	29	0	863	920	21.75	0	756.72
9	9	L SP	115	29	0	978	1035	21.75	0	857.62
10	10	L SP	115	29	0	1093	1150	21.75	0	958.51
11	11	L SP	115	29	0	1176	1203	21.75	0	0.00

Material

The foundation material, taken directly from the user input.

Pile Type

The pile type, taken directly from the user input.

Load Direction

The direction of the applied load. This is either compression or tension.

Kh

The horizontal coefficient of earth pressure. This is determined by both the Pile Type and the Load Direction.

Pile Area (sf)

The area of the pile section in square feet. This is calculated as either the area of a circle or the area of a rectangle depending on the Pile Type.

Pile Perimeter (ft)
The perimeter of the pile section in feet. This is calculated as the circumference of a circle or the perimeter of a rectangle depending on the Pile Type.

Width (ft)
The pile width, taken directly from the user input.

Bearing Depth (ft)
The bearing depth, taken directly from the user input.

FS
The factor of safety, taken directly from the user input.

Allowable Capacity (kip)
The calculated allowable capacity in kips for the pile.

Ultimate Capacity (kip)
The calculated ultimate capacity in kips for the pile.

Bearing Mode
Indicates if the pile is bearing in a cohesive layer or a granular layer. This determines the end bearing calculation used.

Nc or Nq
The value of either the cohesive bearing capacity factor or the granular bearing capacity factor, depending on the Bearing Mode and the soil properties directly below the bearing elevation.

Effective Stress Limited?
Indicates whether the effective stress within the soil profile has been limited to that stress located at a depth of 20B.

Note: This considers whether the width of the pile would limit the effective stress at some point within the entire soil profile, relatively shallow piles may not actually be affected by this restriction. You can tell if the effective stress has been limited for that particular pile by inspection of the effective stress columns.

Pile Weight (kip)
The weight of the pile in kips. This is determined by the Bearing Depth, Pile Area, and Material.

Total Skin Friction (kip)
The sum of the skin frictions within each individual sublayer, found by taking the sum of the Skin Friction column.

End Bearing (kip)
The calculated ultimate end bearing value in kips.

Groundwater Depth (ft)
The groundwater depth, taken directly from the user input.

Ignored Depth (ft)
The ignored depth, taken directly from the user input

Sublayer Thickness (ft)
The sublayer thickness, taken directly from the user input.

Bottom Depth (ft)
The depth in feet to the bottom of the sublayer.

Name
The name of the sublayer.

Unit Weight (pcf)
The unit weight of the sublayer in pounds per cubic foot.

Phi (deg)
The soil friction angle of the sublayer. This is equal to 0 for cohesion layers.

C (psf)
The soil cohesion of the sublayer. This is equal to 0 for granular layers.

Eff. Stress at Mid. (psf)
The effective stress at the midpoint of the sublayer. The is the effective stress value used in the skin friction calculation.

Eff. Stress at Bot. (psf)
The effective stress at the bottom of the sublayer. This is the effective stress value used in the end bearing calculation.

Contact Friction Angle δ
The contact friction angle between the pile and the soil. This is determined by the internal soil friction angle and the pile material.

Adhesion α (psf)
The adhesion between the soil and the pile. This is determined by the soil cohesion and the pile material.

Skin Friction (psf)
The incremental skin friction value for the sublayer. This is determined by adhesion, perimeter, and sublayer thickness for cohesive soils, and by horizontal earth pressure coefficient, effective stress, contact friction angle, perimeter, and sublayer thickness for granular soils.

Calculation Methodology

In this section, we provide the logic behind each individual calculation made behind the scenes, from the time you submit your project for analysis to the final allowable capacity result.

Horizontal Earth Pressure Coefficient (Kh)

The horizontal earth pressure coefficient is a function of the pile type and load direction. The values for Kh used in this program are the averages from the potential ranges given on page 216 of the NAVFAC Foundations & Earth Structures Design Manual 7.02, last edited September 1986.

Pile Type	compression	Tension
DRIVEN-SINGLE-H-PILE	0.75	0.4
DRIVEN-SINGLE-DISPLACEMENT-PILE	1.25	0.8
DRIVEN-SINGLE-DISPLACEMENT-TAPERED-PILE	1.75	1.15
DRIVEN-JETTED-PILE	0.65	0.45
DRILLED-PILE	0.7	0.4

Granular Bearing Capacity Factor (Nq)

The granular bearing capacity factor is a function of the soil internal friction angle and the pile type. The values for Nq used in this program are taken from page 216 of the NAVFAC Foundations & Earth Structures Design Manual 7.02, last edited September 1986. Because Nq for phi of 27 and 29 is not given in the NAVFAC manual, we have determined them using linear interpolation of the surrounding values.

Phi	DRILLED-PILE	Driven pile types
26	5	10
27	6.5	12.5
28	8	15
29	9	18
30	10	21
31	12	24
32	14	29
33	17	35
34	21	42
35	25	50
36	30	62
37	38	77
38	43	86
39	60	120
40	72	145

Unit Weight of Water

The unit weight of water is taken to be 62.4 pounds per cubic feet.

Adhesion

Soil adhesion is determined by the soil cohesion and the pile material by linearly interpolating based on the following table. The values used are taken from page 219 of the NAVFAC Foundations & Earth Structures Design Manual 7.02, last edited September 1986.

Material	Cohesion (psf)		Adhesion	
	Lower Bound	Upper Bound	Lower Bound	Upper Bound
Timber or Concrete	0	250	0	250
	250	500	250	480
	500	1000	480	750
	1000	2000	750	950
	1000	2000	950	1300
	2000	---	---	1300
Steel	0	250	0	250
	250	500	250	460
	500	1000	460	700
	1000	2000	700	720
	1000	2000	720	750
	2000	---	---	750

Area

Area is calculated as the area of a circle or the area of a rectangle.

For circles: $A = \pi r^2$

For rectangle: $A = wd$

Cohesive Bearing Capacity Factor (Nc)

The cohesive bearing capacity factor is determined based on the depth and width of the foundation using a 4th order approximation of the curve shown on page 219 of the NAVFAC Foundations & Earth Structures Design Manual 7.02, last edited September 1986. Values range from 6.29 to 9, but in most cases Nc will be 9 because the depth is typically greater than 4 time the width.

For $x = depth/width$

When $x < 4$, $Nc = 6.29 + 1.88x - 0.506x^2 + 0.0632x^3 - 0.0031x^4$

When $x \geq 4$, $Nc = 9$

Cohesive End Bearing

The cohesive end bearing value is determined by the soil cohesion, pile area, and bearing capacity factor as given on page 219 of the NAVFAC Foundations & Earth Structures Design Manual 7.02, last edited September 1986.

$$End\ Bearing = c \times A \times Nc$$

Effective Stress at Bottom

The effective stress at the bottom of a soil layer is calculated as follows:

$$Eff.Stress\ (mid)_i = Eff.Stress(bot)_{i-1} + (incremental\ vertical\ stress)_i$$

If no groundwater is present at the depth of layer i,

$$(incremental\ vertical\ stress)_i = unit\ weight \times sublayer\ thickness \text{ (no groundwater)}$$

If groundwater is present at the depth of layer i,

$$(incremental\ vertical\ stress)_i = (unit\ weight - unit\ weight\ water) \times sublayer\ thickness$$

Note: If the layer depth is greater than 20 times the width of the foundation, the effective stress will be limited to the effective stress present at a depth of 20 times the depth.

Effective Stress at Midpoint

The effective stress at the midpoint of a soil layer is calculated as follows:

$$Eff.Stress\ (mid)_i = Eff.Stress(bot)_{i-1} + \frac{1}{2}(incremental\ vertical\ stress)_i$$

If no groundwater is present at the depth of layer i,

$$(incremental\ vertical\ stress)_i = unit\ weight \times sublayer\ thickness \text{ (no groundwater)}$$

If groundwater is present at the depth of layer i,

$$(incremental\ vertical\ stress)_i = (unit\ weight - unit\ weight\ water) \times sublayer\ thicknes$$

Note: If the layer depth is greater than 20 times the width of the foundation, the effective stress will be limited to the effective stress present at a depth of 20 times the depth.

Cohesive Skin Friction

The skin friction for a cohesive sublayer is calculated based on the adhesion, perimeter, and sublayer thickness as given on page 219 of the NAVFAC Foundations & Earth Structures Design Manual 7.02, last edited September 1986.

$$cohesive\ skin\ friction = adhesion \times perimeter \times sublayer\ thickness$$

Contact Friction Angle δ

The contact friction angle of a granular layer is calculated based on the internal soil friction angle and the pile material as given on page 216 of the NAVFAC Foundations & Earth Structures Design Manual 7.02, last edited September 1986.

Material	**Contact Friction Angle δ**
Timber or Concrete	0.75 * Phi
Steel	20

Granular End Bearing Capacity

The end bearing capacity of a pile bearing within a granular layer is based on the effective stress at the bearing elevation, the granular bearing capacity factor, and the area of the pile section, as given on page 215 of the NAVFAC Foundations & Earth Structures Design Manual 7.02, last edited September 1986.

$$End\ bearing = Eff.Stress \times Nq \times Area$$

Granular Skin Friction

The skin friction of a granular sublayer is based on the horizontal earth pressure coefficient, the effective stress at the midpoint of the soil layer, the contact friction angle, and the surface area, as given on page 215 of the NAVFAC Foundations & Earth Structures Design Manual 7.02, last edited September 1986.

$$granular\ skin\ friction = Kh \times Eff.Stress \times \tan\delta \times perimeter \times sublayer\ thickness$$

Perimeter

The perimeter is calculated as the circumference of a circle or the perimeter of a rectangle.

For circles, $perimeter = pi \times D$

For rectangles, $perimeter = 2(H + W)$

Pile Weight

The pile weight is determined based on the volume of the pile and the material.

For concrete or steel foundations, $weight(lb) = 150 \times embedment\ depth \times area$

For timber foundations, $weight(lb) = 30 \times embedment\ depth \times area$

Ultimate Load Capacity

The ultimate load capacity depends on the sum of the incremental skin friction values, end bearing value, and if the pile is in tension, the weight of the pile.

$$Ultimate\ load\ capacity\ (compression) = \sum Skin\ Friction + End\ Bearing$$

$$Ultimate\ load\ capacity\ (tension) = \sum Skin\ Friction + End\ Bearing + Pile\ Weight$$

Allowable Load Capacity

The allowable load capacity is determined by dividing the sum of the skin frictions and end bearing by the factor of safety, and adding the weigh of the pile if the load in in tension.

$$Allowable\ load\ capacity\ (compression) = \frac{\sum Skin\ Friction + End\ Bearing}{FS}$$

$$Allowable\ load\ capacity\ (tension) = \frac{\sum Skin\ Friction + End\ Bearing}{FS} + Pile\ Weight$$

Example Calculations

In this section, we provide a few example calculations performed by hand and calculated using the NAVFAC Deep Foundations design application.

The slight discrepancy in the load capacities calculated by hand and by the web application is likely only due to rounding differences between the hand calculations and web application. With a 0.50% maximum difference between the hand calculations and automated results, it is clear that the results are effectively the same.

Example 1: Single Layer Granular Soil Profile with a Driven Timber Pile

Inputs	
Soil type	Medium Compact Sand
Unit Weight	120 pcf
Phi	32
Groundwater Depth	15 ft
Ignored Depth	3 ft
Pile Type	Driven single displacement pile
Material	Timber
Factor of Safety	3
Pile Width	1.5 ft
Bearing Depth	25 ft

Hand Calculations	
Area	$\pi \times (1.5/2)^2 = 1.77\ sf$
weight	$30pcf \times 25ft \times 1.77sf = 1.33kip$
Perimeter	$\pi \times 1.5 = 4.7ft$
Contact friction angle	$0.75 \times 32deg = 24deg$
Horizontal earth pressure coefficient	1.25 (comp) or 0.8(tension)
Layer 1 (Dry)	
Eff. Stress Mid	$120pcf \times 3ft + 120pcf \times 12ft/2 = 1080psf$
Skin friction (comp)	$1.25 \times 1080psf \times \tan 24 \times 4.7ft \times (12ft) = 33.90kip$
Skin friction (tension)	$0.8 \times 1080psf \times \tan 24 \times 4.7ft \times (12ft) = 21.70kip$
Layer 2 (Saturated)	
Eff Stress Mid	$(120pcf \times 15ft) + [(120pcf - 62.4pcf) \times 10ft]/2 = 2088psf$
Eff Stress Bottom	$(120pcf \times 15ft) + [(120pcf - 62.4pcf) \times 10ft] = 2376psf$
Skin friction (comp)	$1.25 \times 2088psf \times \tan 24 \times 4.7ft \times 10ft = 54.62kip$
Skin friction (tension)	$0.8 \times 2088psf \times \tan 24 \times 4.7ft \times 10ft = 34.95kip$
Nq	29
End bearing	$2376psf \times 29 \times 1.77sf = 121.96kip$
Axial Capacity	
Ultimate Compression Capacity	$33.90kip + 54.62kip + 121.96kip = \mathbf{210.5}kip$
Ultimate Tension Capacity	$18.08kip + 34.95kip + 1.33kip = \mathbf{58.0}kip$
Allowable Compression Capacity	$\frac{210.48kip}{3} = \mathbf{70.2}kip$
Allowable Tension Capacity	$\frac{21.70kip + 34.95kip}{3} + 1.33kip = \mathbf{20.2}kip$

Comparison Between Hand Calculations and Web Application

	Hand Calc.	Web Application	Total difference	Percentage difference
Ultimate Compression Capacity	210.5	210.5	0	0.00%
Ultimate Tension Capacity	58.0	58.1	0.1	0.17%
Allowable Compression Capacity	70.2	70.2	0	0.00%
Allowable Tension Capacity	20.2	20.3	0.1	0.50%

Example 2: Driven Single H-Pile in Saturated Clay

Inputs	
Soil type	Stiff Clay
Unit Weight	130 pcf
Cohesion	1800 psf
Groundwater Depth	0 ft
Ignored Depth	3 ft
Pile Type	Driven Single H-Pile
Material	Steel
Factor of Safety	3
Pile Width	1.0 ft x 1.0 ft
Bearing Depth	10 ft

Hand Calculations	
Area	$1.0ft \times 1.0ft = 1.0\ sf$
weight	$150pcf \times 10ft \times 1.0sf = 1.50kip$
Perimeter	$1.0ft \times 4 = 4.0ft$
Contact friction angle	$20deg$
Horizontal earth pressure coefficient	0.75 (comp) or 0.4(tension)
adhesion	$700 + (1800 - 1000)\dfrac{720 - 700}{2000 - 1000} = 716psf$
Bearing Capacity Factor Nc	$\dfrac{10}{1} > 4 => Nc = 9$
Skin Friction (comp or tension)	$716psf \times 4.0ft \times (10 - 3)ft = 20.05kip$
End bearing	$1800psf \times 1sf \times 9 = 16.20kip$
Axial Capacity	
Ultimate Compression Capacity	$20.05kip + 16.20kip = \mathbf{36.3}kip$
Ultimate Tension Capacity	$20.05kip + 1.50kip = \mathbf{21.6}kip$
Allowable Compression Capacity	$\dfrac{36.3kip}{3} = \mathbf{12.1}kip$
Allowable Tension Capacity	$\dfrac{20.05kip}{3} + 1.50kip = \mathbf{8.2}kip$

	Hand Calc.	Web Application	Total difference	Percentage difference
Ultimate Compression Capacity	36.3	36.2	0.1	0.27%
Ultimate Tension Capacity	21.6	21.5	0.1	0.45%
Allowable Compression Capacity	12.1	12.1	0	0.00%
Allowable Tension Capacity	8.2	8.2	0.0	0.00%

Example 3: Drilled Pile in Layered Soil Profile

Inputs	
Overall	
Groundwater Depth	10 ft
Ignored Depth	3 ft
Pile Type	Drilled Pile
Material	Concrete
Factor of Safety	3
Pile Width	2 ft
Bearing Depth	30 ft
Layer 1	
Name	Loose Sand
Bottom Depth	15 ft
Unit Weight	110 pcf
Phi	27
Layer 2	
Name	Soft Clay
Bottom Depth	31 ft
Unit Weight	110 pcf
C	600 psf

Hand Calculations	
Area	$\pi \times (2/2)^2 = 3.14\ sf$
weight	$150pcf \times 30ft \times 3.14sf = 14.13kip$
Perimeter	$\pi \times 2ft = 6.28ft$
Horizontal earth pressure coefficient	0.7 (compression) or 0.4 (tension)
Layer 1 – Dry Sand	
Contact friction angle	$0.75 \times 27 = 20.25$
Horizontal earth pressure coefficient	0.7 (comp) or 0.4(tension)
Eff. Stress Mid	$110pcf \times 3ft + 110pcf \times 7ft/2 = 715psf$
Skin friction (comp)	$0.7 \times 715psf \times \tan 20.25 \times 6.28ft \times 7ft = 8.12kip$
Skin friction (tension)	$0.4 \times 715psf \times \tan 20.25 \times 6.28ft \times 7ft = 4.64kip$
Layer 2 – Saturated Sand	
Eff Stress Mid	$10ft \times 110pcf + (110pcf - 62.4pcf) \times 5ft/2 = 1219psf$
Skin friction (comp)	$0.7 \times 1219psf \times \tan 20.25 \times 6.28sf \times 5ft = 9.88kip$
Skin friction (tension)	$0.4 \times 1219psf \times \tan 20.25 \times 6.28sf \times 5ft = 5.65kip$
Layer 3—Saturated Clay	
adhesion	$480 + (600 - 500)\dfrac{750 - 480}{1000 - 500} = 534psf$
Bearing Capacity Factor Nc	$\dfrac{30}{2} > 4 => Nc = 9$
Skin Friction (comp or tension)	$534psf \times 6.28ft \times 15ft = 50.30kip$
End bearing	$600psf \times 3.14sf \times 9 = 16.96kip$

Axial Capacity	
Ultimate Compression Capacity	$8.12kip + 9.88kip + 50.30kip + 16.96kip = \mathbf{85.3}kip$
Ultimate Tension Capacity	$4.64kip + 5.65kip + 50.30kip + 14.13kip = \mathbf{74.7}kip$
Allowable Compression Capacity	$\frac{85.3kip}{3} = \mathbf{28.4}kip$
Allowable Tension Capacity	$\frac{4.64kip + 5.65kip + 50.30kip}{3} + 14.13kip = \mathbf{34.3}kip$

	Hand Calc.	**Web Application**	**Total difference**	**Percentage difference**
Ultimate Compression Capacity	85.3	85.3	0.0	0.00%
Ultimate Tension Capacity	74.7	74.8	0.1	0.13%
Allowable Compression Capacity	28.4	28.4	0	0.00%
Allowable Tension Capacity	34.3	34.3	0.0	0.00%