Suction Installed Caisson Foundation and Anchor Tool Design

Notes:

Document is heavily based on OWA Suction Installed Caisson Foundations for Offshore Wind: Design Guidelines February 2019

Table

Description automatically generated

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for effective stress parameter

Load convention, downwards positive, upwards negative i.e.Mooring uplift force is negative, self weight is positive.

# User Inputs

Water depth d d

Outer Diameter Do

Outer Diameter Min Domin

Outer Diameter Max Domax

Outer Diameter Delta Dodelta

Skirt Length L

Skirt Length Min Lmin

Skirt Length Min Lmax

Skirt Length Delta Ldelta

Steel Density ρs rhosteel 8050

Water Density ρw rhowater 1025

Steel Youngs Modulus E 210000000

Vertical Load Ref Point V\_LRP V\_LRP

Horizontal Load Ref Point H\_LRP H\_LRP

Moment Load Ref Point M\_LRP M\_LRP

Anchor or Foundation Type Type Anchor/Foundation

Soil Type Type\_Soil Sand/Clay

Soil Class Class\_Soil Verysoft/Firm/Stiff etc.

# Fixed Values

Gravity g g 9.81

K K K 0.5

Poisson Ratio v 0.3

Safety Factor Material

Favorable Safety Factor Load Factor = 0.9

Unfavorable Safety Factor Load Factor = 1.1

# Pre-calculations

Wall Thickness (should be a percentage – 2% of Do)

Installed depth h=L-0.5

Inner Diameter

Caisson diameter

Area Caisson =

Mass of Caisson ρs

Buoyancy Mass of Caisson ρw

Effective Mass of Caisson -

Weight of Caisson

Effective vertical load

Hydrostatic Pressure ρw.g.d

Suction limit if d > 50m, SL = 500,000 N/m2 (Pump Limit)

If d <= 50m, SL = + 50,000 N/m2 (Cavitation limit)

## Load capacity conversions

Clay (undrained) Vertical Capacity on outside of caisson

Sand Vertical Capacity on outside of caisson

Horizontal Capacity on outside of caisson (Clay)

Horizontal Capacity on outside of caisson (Sand)

Horizontal Capacity on base of caisson

Vertical Capacity on base of caisson

Position of effective depth of action of horizontal load

Moment capacity on base of caisson

# Soil Parameters

Soil are classified by type and subtype, i.e. Clay (very soft) or Clay (very stiff)

## Clay, 𝜙′ = 0

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
|  |  | Very soft clay | Soft Clay | Firm Clay | Stiff Clay | Very Stiff Clay | Hard Clay |
| Undrained Strength | s\_u | 1.00E+04 | 2.00E+04 | 3.30E+04 | 7.50E+04 | 1.50E+05 | 2.00E+05 |
| Soil sensitivity | S\_t | 12 | 12 | 12 | 12 | 12 | 12 |
| Adhesion factor | alpha | 1/S\_t | 1/S\_t | 1/S\_t | 1/S\_t | 1/S\_t | 1/S\_t |
| Effective (Buoyant) Unit Weight of the soil | gamma | 720 | 720 | 720 | 980 | 980 | 980 |
| Bearing Capacity Factor (Cohesion) | Nc | 5.141592654 | 5.14159265 | 5.14159265 | 5.14159265 | 5.141592654 | 5.141592654 |

## Sand

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  |  | very loose sand | Loose sand | Medium dense sand | Dense sand | very dense sand |
| Effective (Buoyant) Unit Weight of the soil |  | 870 | 870 | 870 | 1060 | 1060 |
| Angle of Friction | 𝜙′ | 25 | 30 | 32 | 35 | 38 |
| Relative density index | | 0.1 | 0.25 | 0.45 | 0.75 | 0.85 |
| Interface friction angle | 𝛿 | 𝜙′-5 | 𝜙′-5 | 𝜙′-5 | 𝜙′-5 | 𝜙′-5 |
| Bearing capacity factor (overburden) | Nq | 10.66214239 | 18.40112222 | 23.17677621 | 33.29609149 | 48.9332527 |

# Installation

## Installation Clay

Note 1: First find penetration depth under self weight only. Solve for “h\_sw” in Eqn. I\_C\_1, under self weight only so setting s = 0

Note 2: assume

Note 3: Second calculate required suction pressure to ensure h is achieved. Check if required suction pressure (SR) is greater than suction limit (SL)

Eqn. I\_C\_1

=

Where:

Installed depth of caisson. First solve for “h” in Eqn. I\_C\_1, under self weight only so setting s = 0

Bearing capacity factor (cohesion)

Undrained strength of the soil

Average undrained strength of the soil over the depth of the SICF skirt

Undrained strength of the soil at the SICF skirt tip

Caisson skirt wall thickness

Adhesion factor (sometimes estimated as , where is the clay sensitivity)

Effective unit weight of soil

R Resistance

Suction applied during SICF installation (pressure outside caisson minus pressure inside caisson) = Suction Limit SL

## Installation Sand

Same procedure as clay, first solve for self-weight installed depth, then check if possible to install to required depth before suction limit is reached

Eqn. I\_S\_1

Where:

, c0 = 0.45, C1 = 0.36, c2 = 0.48

## Buckling Check

Check if s\*, if it is fail installation check

# Bearing Capacity

## Bearing Capacity

If type = anchor or M\_LRP ==0

If type = foundation or M\_LRP >0

and

## Bearing capacity undrained

/

## Bearing capacity drained (sand)

(Need to confirm this with Stefan)

h (Need to confirm this with Stefan)

dγ = 1 ???(need to get formula/value for this from Stefan, not in OWA doc)

/

## Sliding

* Clay

* Sand

Sliding check:

## Uplift (tension on anchors)

## Clays

Take the smaller of the following

(undrained analysis)

Clay (cavitation at the caisson base)

Clay (cavitation under the lid)

assumed full vacuum in the void (i.e. no flow of water).

# sands

rapid (undrained) loading.

For cavitation at footing base:

For cavitation below caisson lid:

slow (drained) loading

For cavitation at footing base:

For cavitation below caisson lid:

For slow loading the tensile capacity arises only from friction on the sides of the caisson and is calculated as:

sands

clays

Compare the smallest from above equations against any uplift force from mooring tensions

Output values

* Mass of Caisson
* Dimensions

Output figure

Scatter chart of design regions. Bearing sufficient if ALL of: Bearing capacity, sliding and uplift checks are passed

