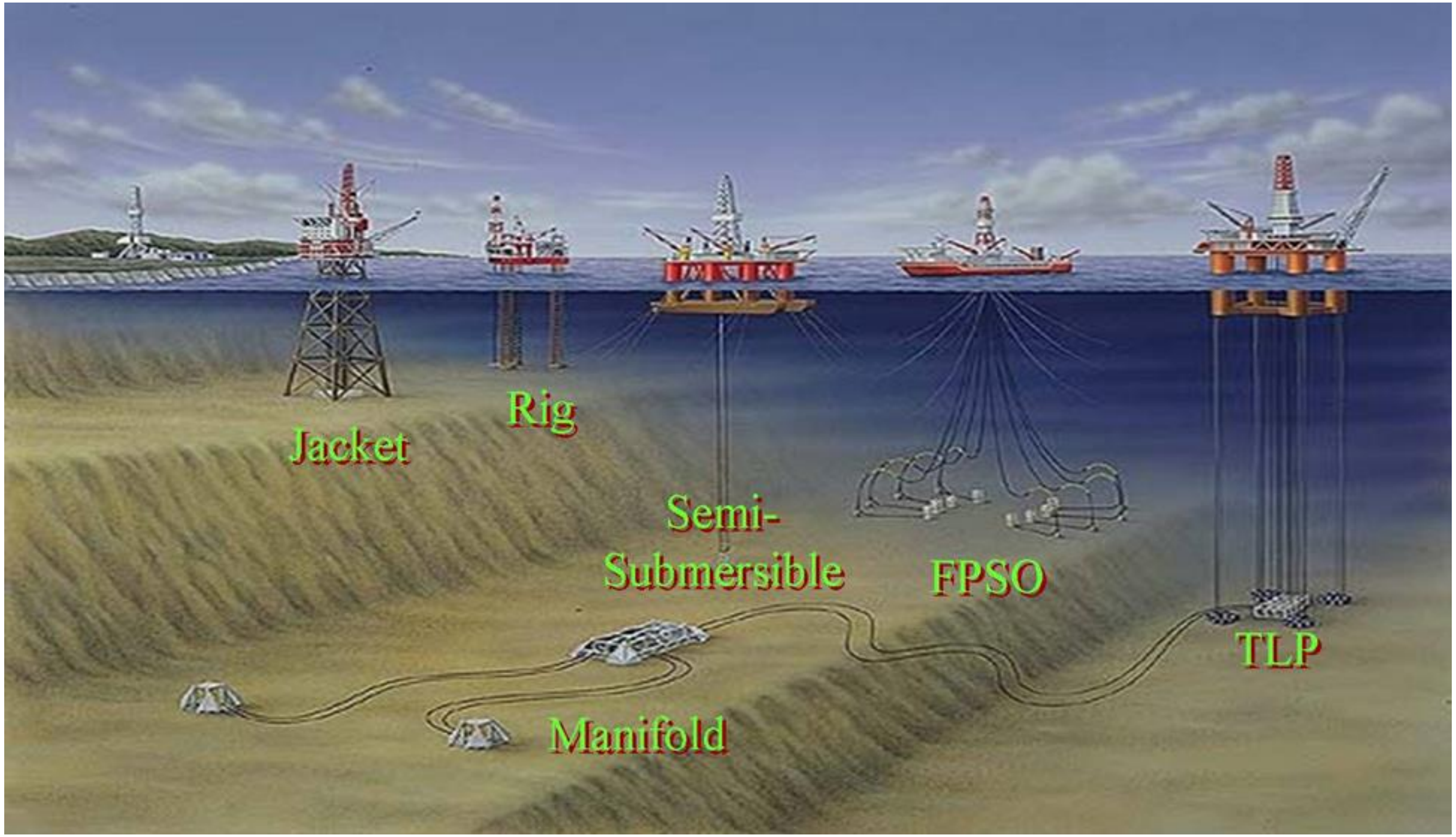
OFFSHORE FOUNDATIONS



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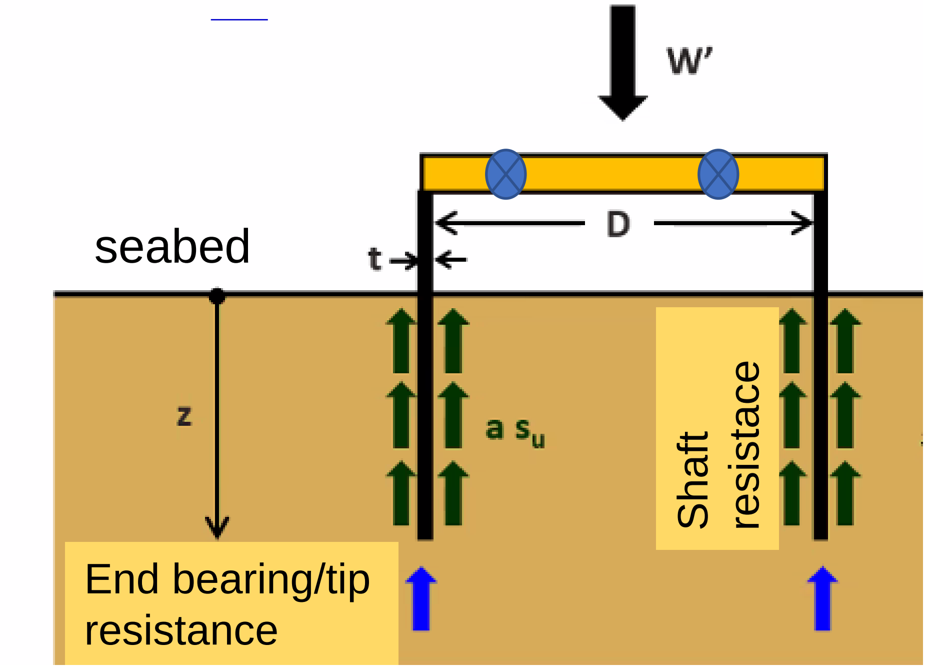
mudmat

- Suction buckets/κάδοι αναρρόφησης

1. Sinking due to self weight
W=shaft+tip resistance



2. By sucking water from within the cylinder above the seabed(⊗ pumps) the hydrostatic pressure on the top surface >> pore water pressure within the cylinder above the seabed, hence it sinks further than due to self weight

1. MUDMAT FOUNDATIONS

Floating platforms are held in place with a system of anchors (Fig. 1). There are mainly various types of anchors, namely, conventional drag embedment anchors (DEAs) chained to the platform, suction caisson anchors, gravity anchors, anchored piles etc..

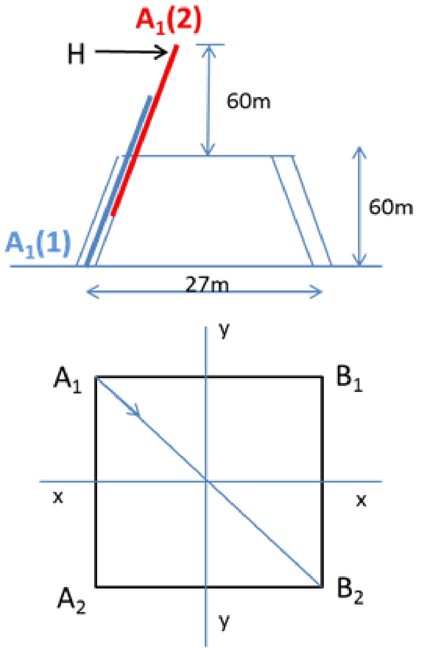
The offshore foundation (Jacket Mudmat) shown in the figure has a square cross section 27mx27m and height of 60m. Four hollow cylindrical piles 60’’ in diameter, 2’’ thick and 70m high are pushed in the seabed at the corners of the foundation. The weight of the foundation is 700ton and the strength at the seabed is Su=3kPa. Calculate the average stress applied by the foundation and the bearing capacity of the ground:

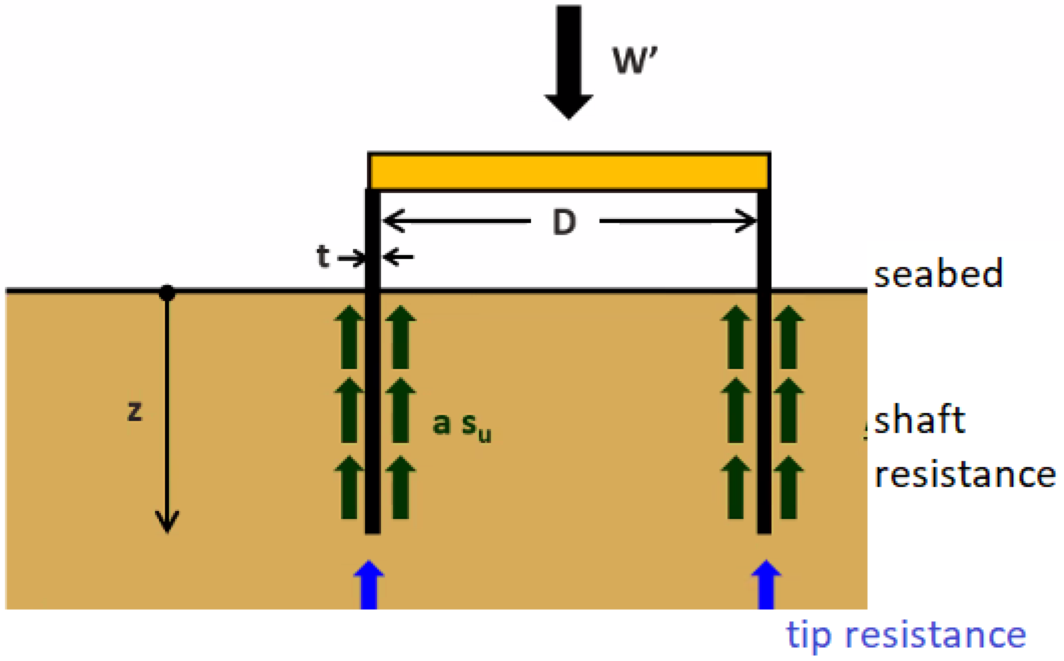
- Due to the weight of the foundation
- When only piles A_1 & A_2 have been inserted at $A_1(1)$ και $A_2(1)$
- When pile A_1 is being inserted (position $A_1(2)$ in figure) and during insertion a horizontal force H=250kN is applied in the direction A_1B_2

Note:

For eccentric loading: $B' = B - 2e_{yy}$, $L' = L - 2e_{xx}$
Effective loading area: B’*L’
1ton=10kN, 1’’=0.0254m, $\gamma_{pile.} = 75 kN/m^3$

$$q_u = (2+\pi) S_u S_c i_c$$
$$S_c = 1 + 0.2\frac{B}{L}$$
$$i_c = \frac{1}{2}\left(1 + \sqrt{1 - \frac{H}{BLS_u}}\right)$$





2. Suction Caissons (Buckets)

Partial insertion due to self-weight
Draw the load (kN) against depth of insertion (m) curve and calculate the depth required to equilibrate the weight of the platform and foundation W'=15MN. The seabed is a clay with Su=50kPa and γ=20kN/m3 and the dimensions of the bucket are D=14m, L=14m, t=5cm.

Shaft resistance: Qs=2*(α*Su)*(πDz), α=0.6

Tip resistanxe: Qt=(Nc*Sc*Su+γ*z)*(area(t))

Total resistance: Qu=Qs+Qt

Suction Buckets

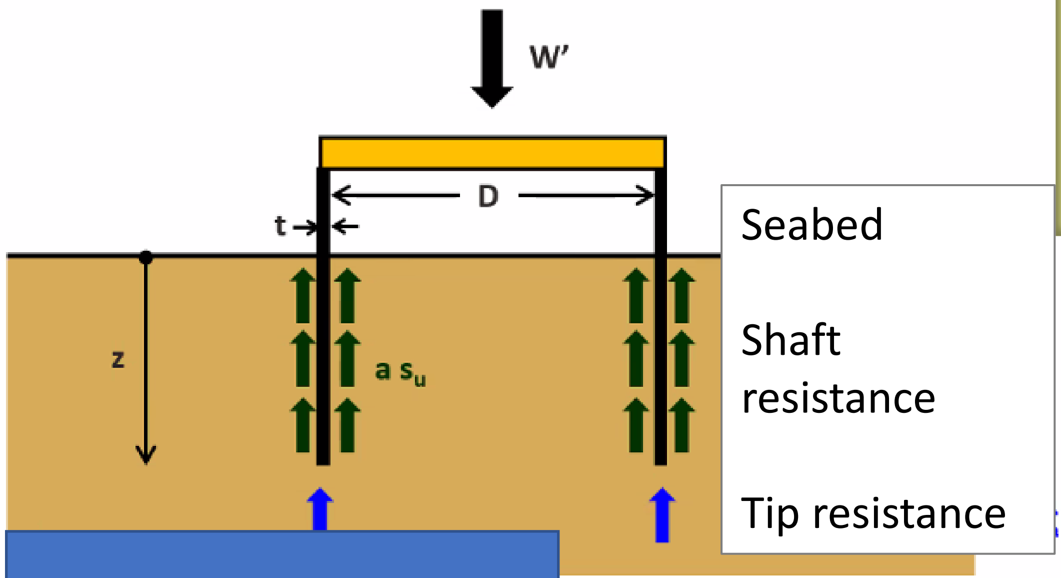
partial insertion due to self weight

Shaft resistance: Qs=2*(α*Su)*(πDz)=2x0.6x50xπx14z=2639z

Tip resistanxe:

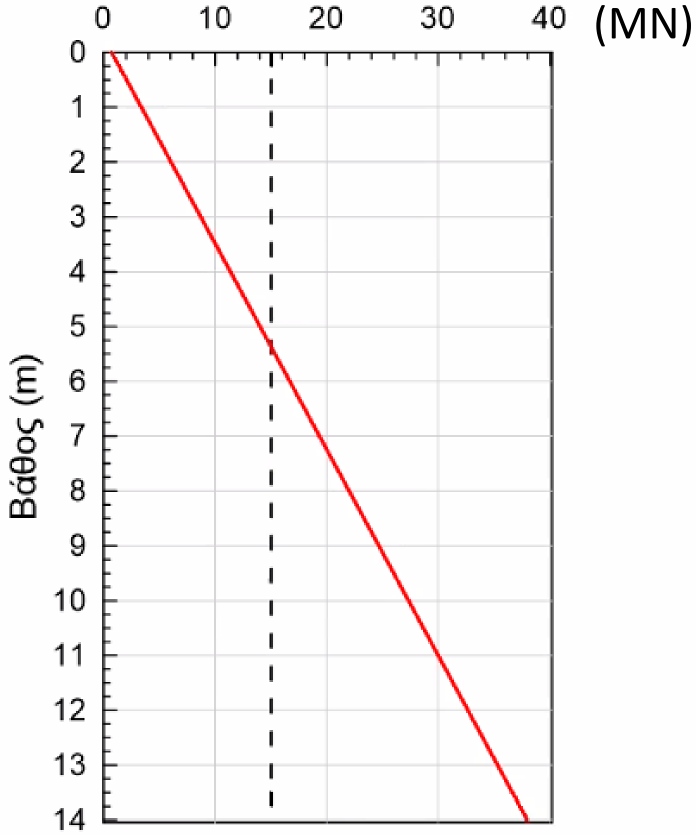
Qt=(Nc*Sc*Su+γ*z)*Area(t)=[(2+π)x(1+0.2xt=0.05m/1m)x50 +20z]*0.35m2

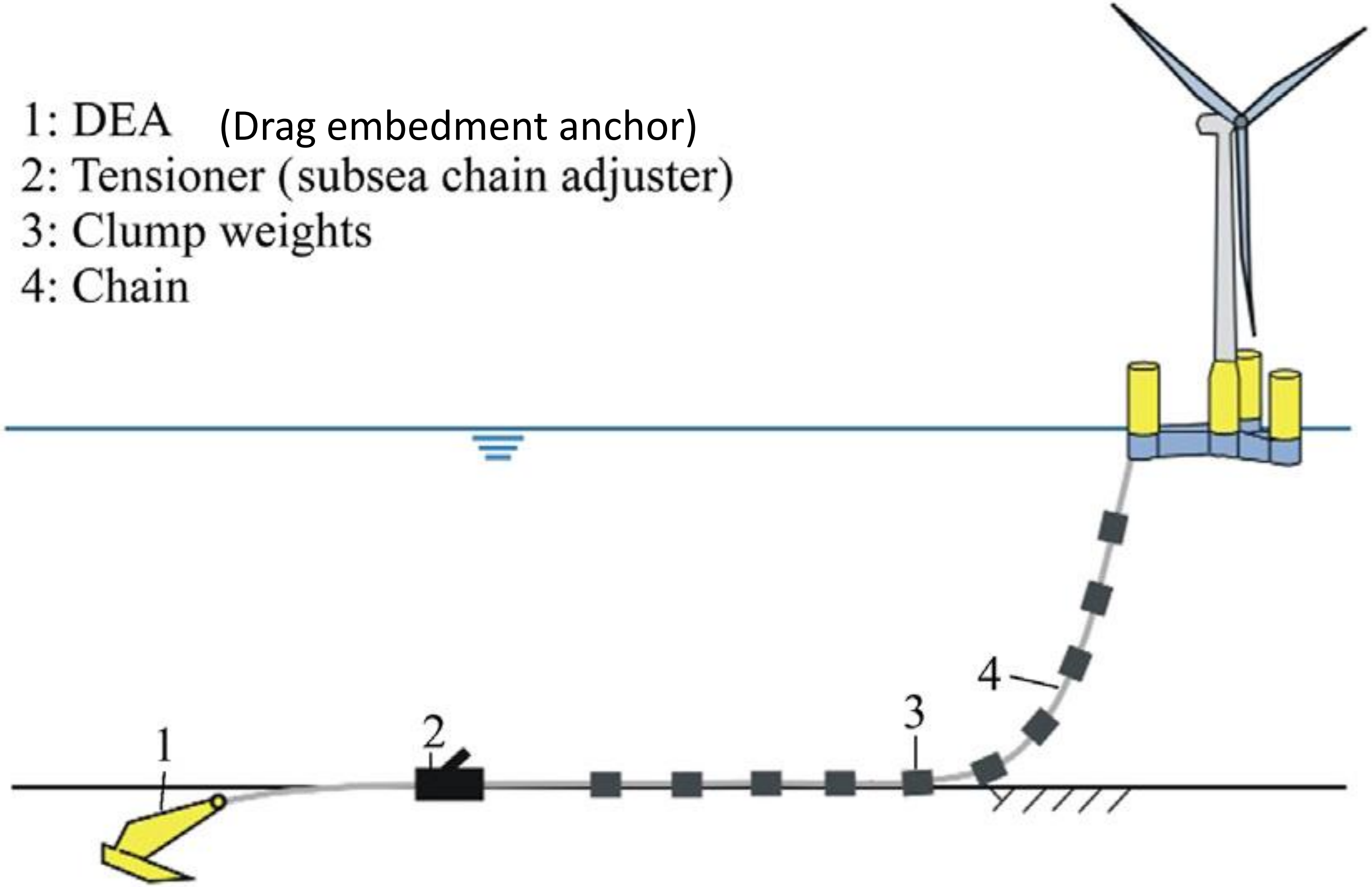
Total resistance: Qu=Qs+Qt



Clay: $\gamma=20kN/m^3$, $Su=50kN/m^2$, $\alpha=0.6$
bucket: D=14m, L=14m,
t=5cm, W'=15MN

z=5.6m





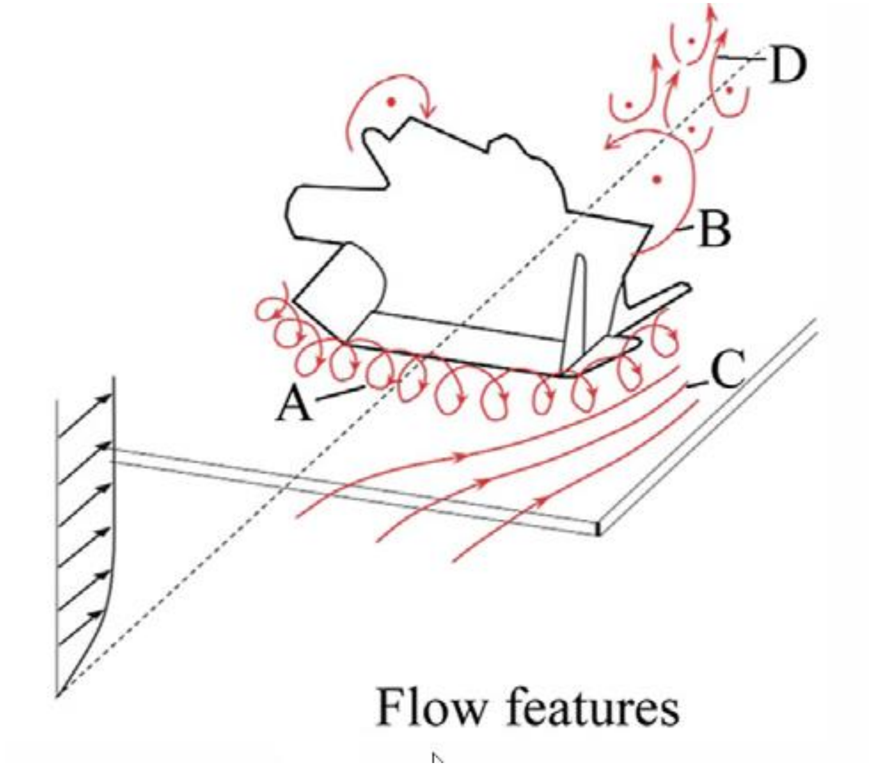
1: DEA (Drag embedment anchor)
2: Tensioner (subsea chain adjuster)
3: Clump weights
4: Chain

- Liquefaction
- Sinking

- Scour
- Liquefaction
- Sinking (scour)
- Sinking (liquefaction)

- Scour
- Liquefaction
- Sinking (scour)
- Sinking (liquefaction)

tensioner



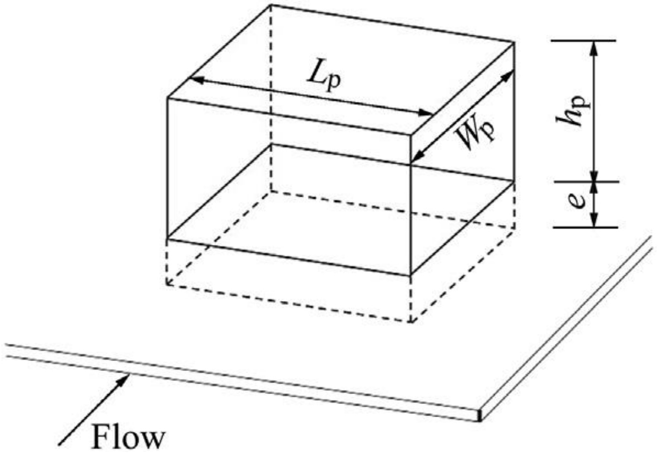
Flow features

the horseshoe vortex in front of the tensioner (“A”), the vortex shedding behind the tensioner (“B”), the flow contraction around the tensioner (“C”), and the counter-rotating streamwise vortices in the lee-wake (“D”).

These flow features cause an increase in the local sediment transport capacity and thus lead to scouring/piping around the object.

After B. Mutlu Sumer, Veysel Sadan Ozgur Kirca / Water Science and Engineering 2022, 15(1): 3-14

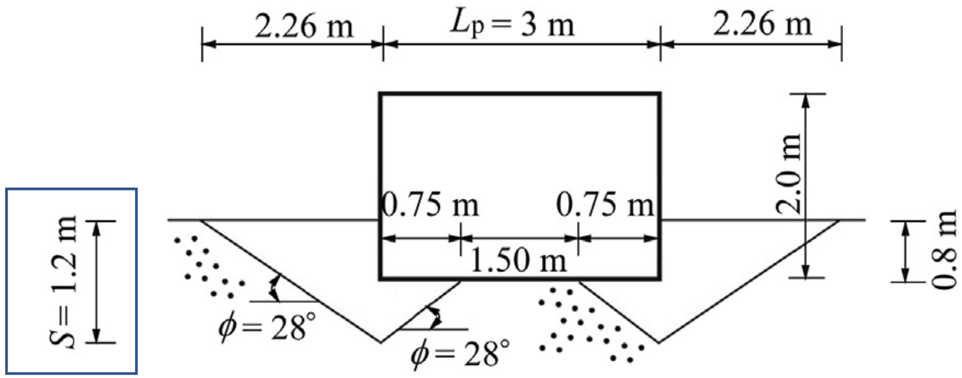
Scour depth



This is reflected in the following expression to predict the scour depth (live-bed scour) (Sumer and Fredsøe, 2002):
$S/S_0=1-\exp(-0.55\ h_P/L_P)$
where S is the maximum equilibrium scour depth; S_0 is the maximum equilibrium scour depth corresponding to a surface-piercing pile; h_p is the height of the submerged pile measured from the bed, and L_P is the pile size defined in the surface. The scour depth for a surface-piercing pile, S_0, is taken equal to that around a square cross-section pile (Sumer and Fredsøe, 2002): $S_0/L_p=2$

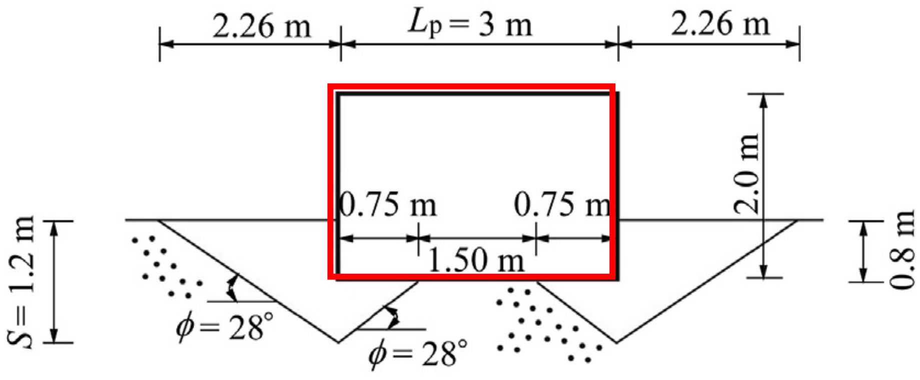
a submerged
pile with a length of $L_P=3$ m, a width of $W_P=2.5$ m, and a height of $h_P+e=2$ m (e is 0.8 m, and thus $h_P=1.2$ m)

$h_P=1.2$ m and $L_P=3$ m,
the potential scour depth is found to be S =1.18 m ~ 1.2 m.

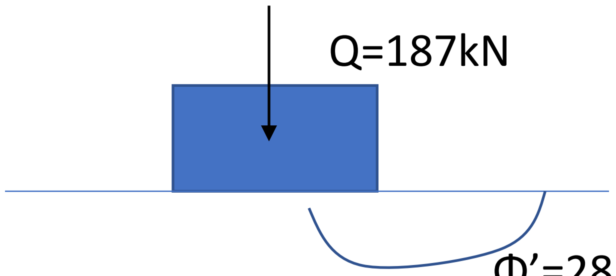


As the scour process continues, the scour hole around the tensioner deepens, and when the scour depth reaches the bottom of the tensioner, a new process is initiated as the bearing area of the tensioner gets smaller, causing a larger stress to be exerted on the soil. With this, the bearing capacity of the soil might ultimately be exceeded, and the soil in this case fails, under general shear failure in which the soil failure occurs by
sliding in an outward direction.
As a result the tensioner sinks/settles a process interrupted only when it sinks to a depth not affected by scouring.

SCOURED BED (1):Equilibrium scour hole around the tensioner approximated to a rectangular cross-section pile



Bearing capacity calculations for tensioner undermined by scour



Φ'=28
γ=18kN/m3
γ(material)=1.25

NO SCOUR

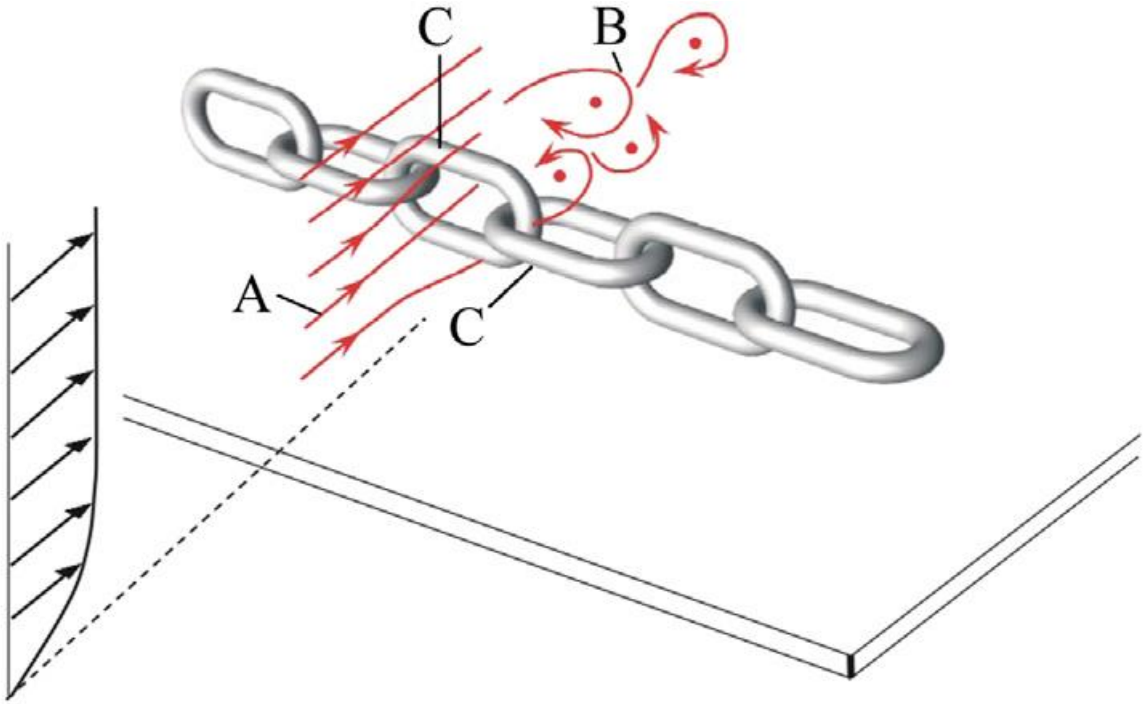
$q_u = 1/2\gamma' B' N_\gamma S_\gamma i_\gamma + \gamma' D N_q S_q i_q = 123.3 kN/m2 >>$
$q_{applied} = Q/B'L' = 24.9 kN/m2$

$S_q = 1 + (B'/L') \sin\phi = 1 + (2.5/3) \sin 23 = 1.326$
$S_\gamma = 1 - 0.3B'/L' = 0.75$

$\tan\phi / \tan\phi(mob) = 1.25 \rightarrow \phi(mob) = 23$
$N_q = 8.71$, $N_\gamma = 6.59$

$S_q = 1 + (1.5/2.5) \sin 23 = 1.23$, $S_\gamma = 0.82$
$q_u = 21 kPa < < q(applied) = 49.8 kPa$ hence sinking well before the scour depth reaches
its potential equilibrium value (1.2 m)

Regarding scour below chains, a subsea structure entirely different from the tensioners and clump weights (slide 2), the flow features responsible for scour are somewhat similar to those below a pipeline. We consider a chain placed at a distance from the seabed (a non-zero clearance) and subject to a current. The flow features around the chain are illustrated in the sketch:



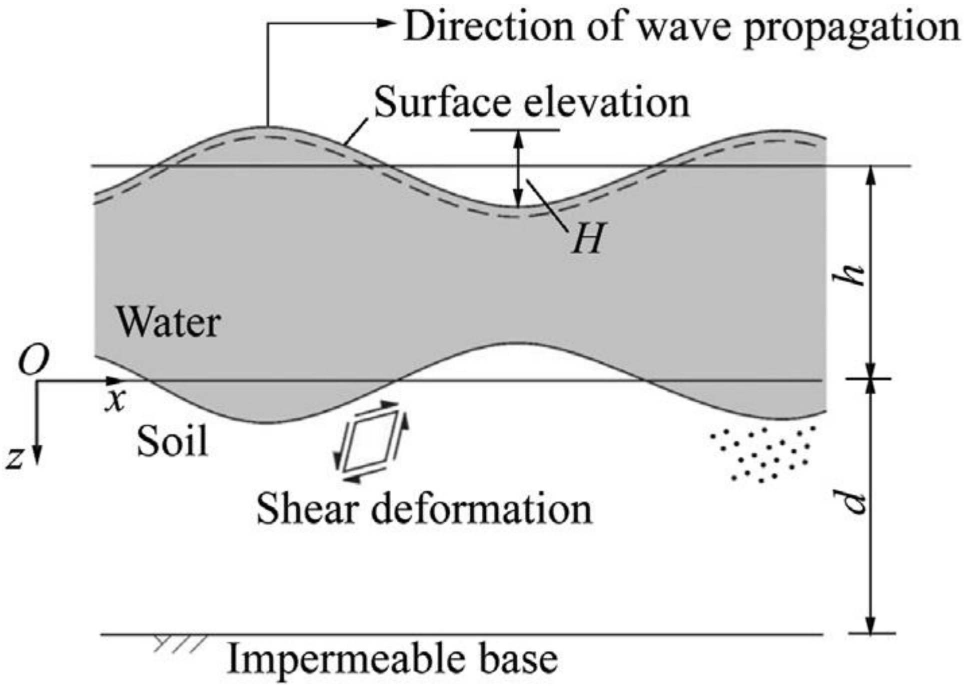
From the analogy to scour below pipelines, the scour depth and time scale can be calculated by use of the formulae given for pipelines (Sumer and Fredsøe, 2002):

$S/D=0.625$

where D is the diameter of the pipeline, which can be taken in the present chain problem as the small dimension of the chain link.

LIQUEFACTION

h/L>1/2 where L the wave length the excess pore pressure does not penetrate down the seabed.



With the introduction of waves (height H, Period Tw) pore pressure builds up due to the cyclic wave action. Subsequently this pressure dissipates.

The anchor sinks (Gs liquefied soil=1.8-2 cf metal Gs=7.5) with the onset of liquefaction and sinking is arrested at the compacted/densified soil. Liquefaction is followed by compaction starting at the bottom of the liquefiable layer and moving upwards.

Force balance: Weight-Buoyancy=Drag force due to the sinking motion within the liquefied soil. Used to define the sinking velocity.

Sumer's compaction model (Sumer, 2014a) gives the expression for the compaction front velocity Uc (see details in Kirca and Sumer (2019)).