

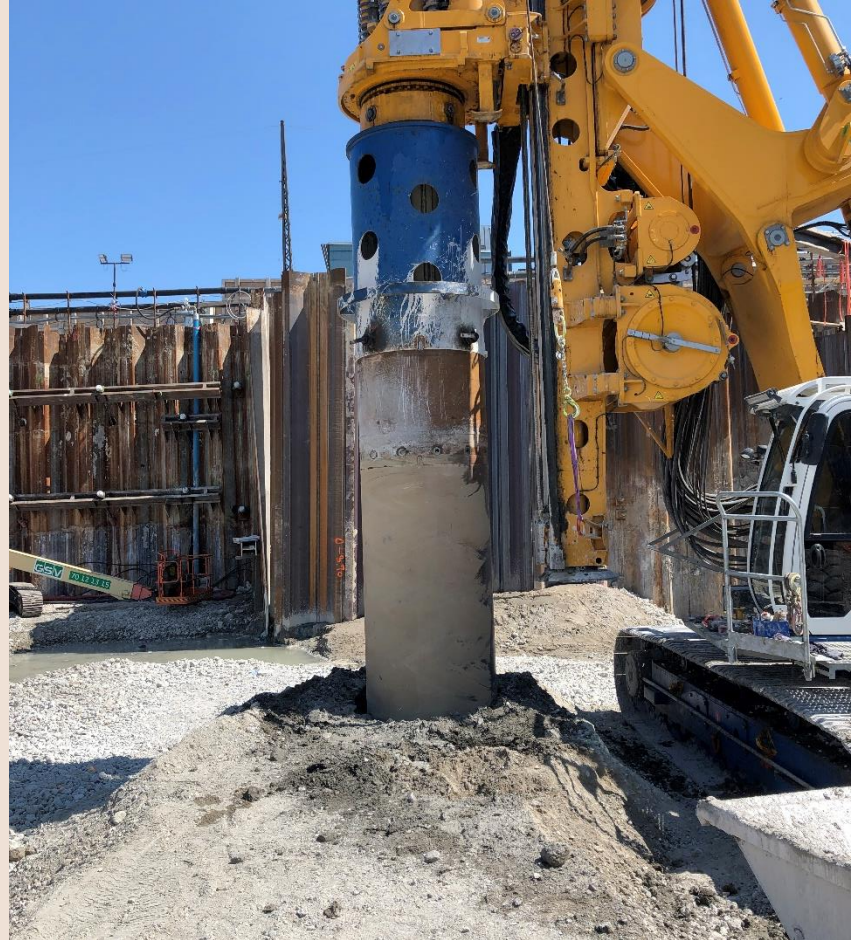


Verifikation af borede pæle og udnyttelse af spidsmodstand med Flatjacks



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- Intro
- Baggrund og lidt teori
- Beregningseksempel
- Udførelsesafhængighed af borede pæle
- Flatjacks – hvad er det, og hvorfor?
- Projekteksempler
- Afrunding



Normbaggrund og lidt teori 1/2

- Som det er nu:

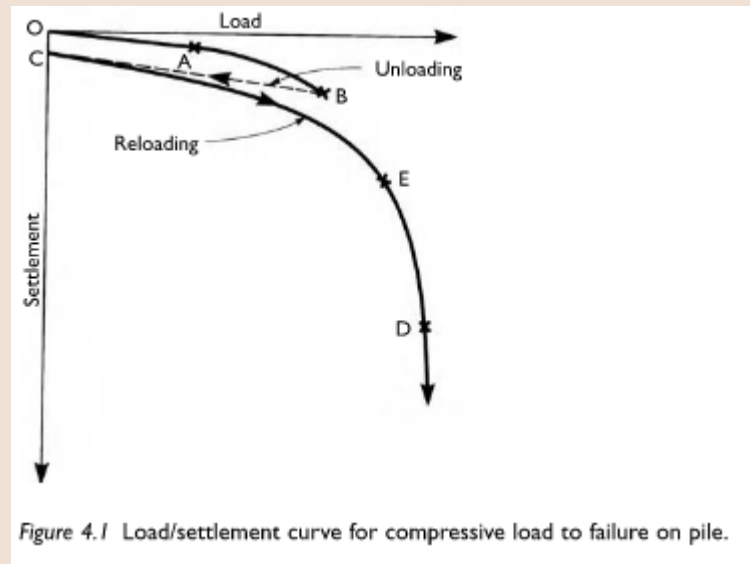
*For borede, in situ-støbte pæle kan bæreevnen være væsentligt mindre end for tilsvarende rammede pæle. Der må ikke påregnes positiv overflademodstand på mere end **30 %** af den tilsvarende rammede pæls overflademodstand eller større regningsmæssig spidsmodstand end 1000 kN/m² , **medmindre der foreligger anerkendt dokumentation for at tage en større bæreevne i regning.***

Men hvad er så anerkendt dokumentation?

Ofte anvendes (1 stk) O-celleforsøg/statisk belastningsforsøg – Statistisk grundlag?

Normbaggrund og lidt teori 2/2

- Aktivering af spidsmodstand
- *The base resistance of the pile requires a greater downward movement for its full mobilization, and the amount of movement depends on the diameter of the pile. It may be in the range of **10% to 20% of the base diameter**. When the stage of full mobilization of the base resistance is reached (point D in Figure 4.1) the pile plunges downwards with-out any further increase of load, or small increases in load produce increasingly large settlements.*
(Pile design and construction practice, 5th ed., Tomlinson et.al.)
- Opblødning ved spidsen
- 10% af pælediameter på en Ø880 mm pæl er 88 mm (!)



Beregningseksempel

- Antagelser:
- Ø1000 mm pæl 15 m lang
- Homogene jordbundsforhold
- 3 tilfælde
 - 30% overflademodstand ift. rammet pæl, ingen spidsmodstand
 - Overflademodstand med $\alpha = 0,3$, ingen spidsmodstand
 - Overflademodstand med $\alpha = 0,3$, spidsmodstand som: (max 1000 kPa)

Bæredygtighed?

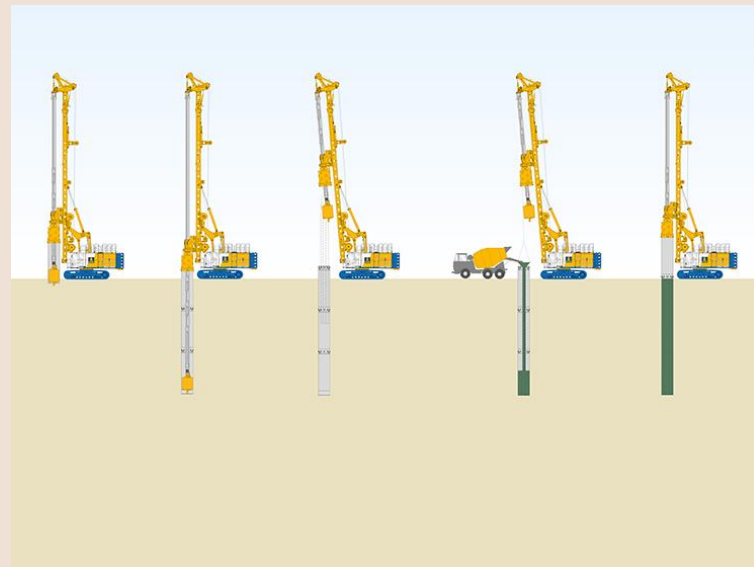
CC2	Sand	Ler
Tilfælde 1	326 kN	435 kN
Tilfælde 2	544 kN	1087 kN
Tilfælde 3	1329 kN	1631 kN

Jordart	Rumvægt	Φ'_{crit}	c_{uk}
Sand	10 kN/m ³	30 deg	-
Ler	11 kN/m ³	-	150 kPa

Spidsmodstand kohæsion	Spidsmodstand friktion
$R_{b;ber} = 9 c_{u,k} A_b$	$R_{b;ber} = 1,20 N_q q'_b A_b$ $N_q = \exp(\pi \tan \varphi') \tan^2 \left(45 + \frac{\varphi'}{2} \right), \varphi' = 30^\circ$

Udførelse og kontrol?

- Kvalitet yderst udførelsesafhængig
 - Oprensning
 - Indstrømning af vand
 - Udstøbning
- Kontrol af udførelse?
 - Betonmængde, men ellers?
 - PDA/CAPWAP ikke muligt



Kelly-boring, kilde: Bauer.co.id

Diskussion

- Bæreevne af borede pæle varierer voldsomt, faktor 3 – 4 (som eksemplet)
 - Normbegrænsning kræver yderligere dokumentation, men 1 forsøg giver stor statistisk usikkerhed
 - Udførelsesafhængighed, kontrol?
-
- Så hvad gør vi? Flatjacks!

Flatjacks – koncept 1/2

- Kontrolleret efterinjicering ved pælespids
- Etablering af fuld kontakt og forbelastning ved pælespidsen
- Mulighed for aktivering af spidsmodstand ved flytninger lig overflademodstand
- In-situ verifikation af pælens opførsel analog til test af f.eks. jordankre
- Øget robusthed og sikkerhedsniveau



Flatjacks – koncept 2/2

- Der findes efterhånden en god håndfuld af eksempel på flatjacks både skræddersyede til projekter og kommercielle
- Konceptet er ikke nyt, der findes eksempler tilbage fra 60'erne
- Metode:
 - Injicering af grout over en kendt del af spidsarealet med et fastlagt tryk, typisk i en lukket beholder der tilpasser sig bunden



Flatjacks – funktionsbeskrivelse

- Krav til hvad flatjack skal kunne – entreprenøren vælger løsningen
- Eksempel:
 - Fastgøres centreret på armeringskurven
 - Dækker min 80% af spidsarealet
 - Injiceringstryk op til xx bar (afhængig af jordbundsforhold/lastforhold ~5-100 bar)
 - Injiceringssystem med redundans
 - Udvidelse på x % af pælediameter (afhængig af jordbundsforhold)
 - Monitorering ved injicering (typisk tryk + flytning af pæletop)

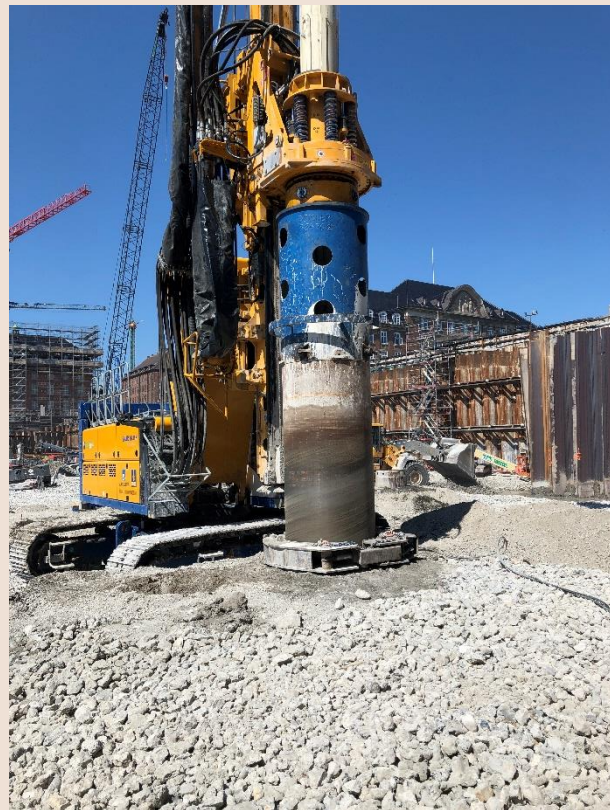
Projekteksempel 1

- Nordskovvej ved Silkeborg, bro over Remstrup Å
- Statisk belastningsforsøg + flatjack ved spids
- Ø880 mm boret pæl
- Bæreevneestimat kar. (middelværdier): 2500 kN
- Testet til 3750 kN (max testlast muligt) uden brud!
- Max flytning ca. 25 mm
- Designbæreevne ca. 1900 kN



Projekteksempel 2

- "Posten" i indre København
- CC3+ byggeri, borede pæle i København Kalk (rock sockets)
- Laster på ~10-15 MN
- Flatjacks anvendt primært for:
 - Forspænding af pæl og dermed stivere respons
 - Verifikation af pæl for overholdelse af norm (foruden O-celle forsøg)
- Injiceringstryk op til 100 bar (10 MPa)



Afrunding

- Flatjack er en relativ billig måde at opnå Udnyttelse af spidsmodstand Overholdelse af normkrav og in-situ verifikation Optimering af pæleprojekt
- Det virker – talrige eksempler i litteraturen
- Projekteksempel fra Nordskovvej er udgivet som artikel fra NGM 2020

Full-scale static compression pile load test in sand with post installation pre-stressing to engage toe resistance

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Abstract. A full-scale static compression pile load test was conducted in connection with construction of a new road bridge in Silkeborg, Denmark. The new road bridge crosses a river between two existing bridges, one for pedestrians and one for an existing rail way. An existing pedestrian bridge was moved five meters to the north to give space for the new road bridge. The western part of the existing bridge was therefore to be founded partly on the existing footing of the pedestrian bridge and partly on a new pile-based footing. Bored cast-in-place piles were chosen to minimize vibrations during construction. The pile load test was necessary to document the bearing capacity of the bored piles because the Danish National Annex to the Eurocode 7, part 1 (2015), Annex L (DS/EN 1997-1 DK:NA) obligates the designer only to regard 30 % of the shaft resistance determined by geostatic calculation for the corresponding driven pile. Furthermore, it is a common design practise to disregard the toe resistance, as mobilization only occurs after deformations larger than normally acceptable for the superstructure. To overcome the latter, the test pile was constructed with a flat-jack device to allow post installation pre-stressing by grouting underneath the pile toe. Hence, it was possible to include toe resistance with only minimal displacements of the pile toe, as the grouting was conducted successfully, and post installation pre-stressing was obtained. The results of the pile load test show a bearing capacity up to 50% larger than estimated by geostatic calculation, even when including toe resistance and disregarding the 70 % shaft reduction in the geostatic calculation for the corresponding driven pile. An estimate of the displacement of the new pile-based footing was made based on load-displacement curves for the test pile, and the subsequent production piles were installed using the same principles due to the flat-jack device's effective post installation pre-stressing.

1. Introduction

Due to the increase of traffic in the city centre of Silkeborg, the city council had decided to construct a new road into the city centre. The purpose of the new road was to ease the traffic on the current roads as well as guide the traffic faster into and away from the city centre.

The road was constructed through the forest Nordskov in the alignment of the old railway track from Silkeborg to Långaa. The road had to cross Remstrup River where the old ferry boats sail, e.g. Hjejlen, which is the oldest coal-fired paddle steamer in the world still in operation and which places some practical bindings on the execution of the project. The road crosses the river on a new bridge between two old railway bridges which were constructed in the beginning of the 19th century. The northern bridge now serves as a pedestrian bridge, while the southern bridge still serves as a railway bridge. However, the space between the bridges did not allow for the new road bridge, and therefore the

Spørgsmål?