OTC2014
2014 Offshore Technology Conference
5-8 May • Houston, Texas USA

Paper No. OTC-25197-MS
Significant ageing effects for axially loaded piles in sand and clay verified by new field load tests

Kjell Karlsrud, Tor Georg Jensen, Ellen Katrine Wensaas Lied and Fritz Nowacki (Norwegian Geotechnical Institute, Oslo, Norway), and Arne Schram Simonsen (Multiconsult AS, Oslo, Norway)

The JIP project "Time effects piles"

Initiated and executed by the Norwegian Geotechnical Institute (NGI), 2008-2013

Other partners and participants:

- The Norwegian Research Council
- JIP partners: (Femern AS, Kværner, Total E&P, Petronas Carigali, Saudi Aramco, Statoil)
- Industry participants: (Multiconsult, Kynningsrud, RautarrRuukkii Oyi, Skanska/Entreprenørservice, The Norw. Dep. of Public Roads)

Motivation

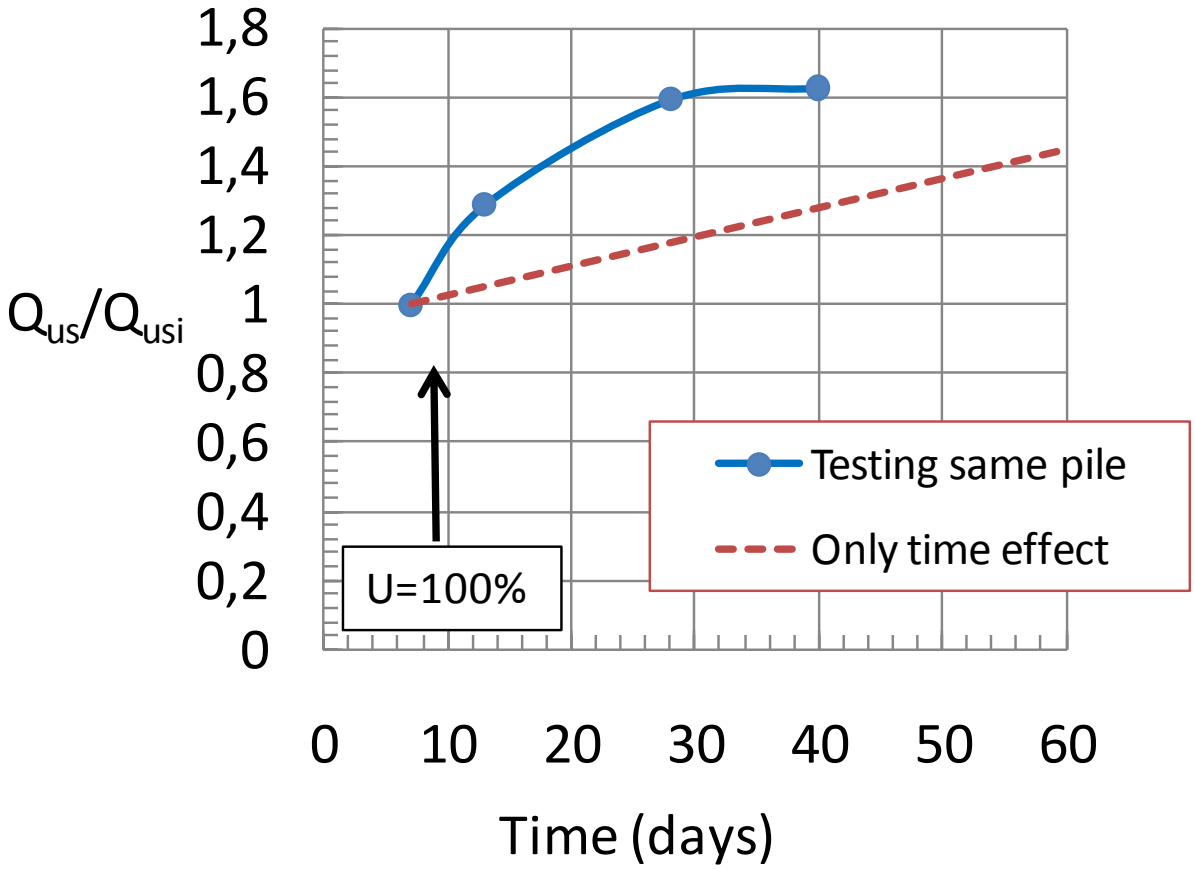
- Past studies suggest that time or ageing effects can be very significant in both clays and sands

  ⟹ Potenially large cost savings

  - For clays ageing effects are gains in capacity after the installation induced excess pore pressures are fully dissipated
- Much of exisiting data were based on repeated loading of the same pile or re-strike tests

  ⟹ Can give wrong impression of ageing effects

Example of effect of time and repeated load tests on capacity of Haga piles (based on Karksrud & Haugen, 1985)



The ageing formula first proposed by Skov and Denver (1988)

- $Q(t) = Q(t_0) \cdot [1 + \Delta_{10} \cdot \log_{10} (t/t_0]$
- t= time in days after pile installation in days
- t_0 = a reference
- $Q(t_0)$= capacity of the pile after a reference time t_0
- Q(t) = capacity at a later time

Test sites

Site	Soil type	w (%)	I_p (%)	OCR (clay)	q_c (MPa)	D_r (%)
Stjørdal	NC Clay, low I_p	28-32	12-16	1.4-1.6		-
Onsøy	NC Clay, medium I_p	48-70	22-40	1.3-1.6		-
Cowden, UK	OC glacial Clay till	16-17	17-19	4-10		-
Femern, Germany	OC Clay, high I_p	35-40	70-170	3 - 8		-
Larvik	Loose fine silty Sand	20-31	-	-	2.9 to 5.3	20-40
Ryggkollen	Medium Sand	?	-	-	20 to 30	50-80

Testing arrangement

Pile dimensions:
L= 20-25 m (9m Cow.)
D = 406-508 mm
All open-ended

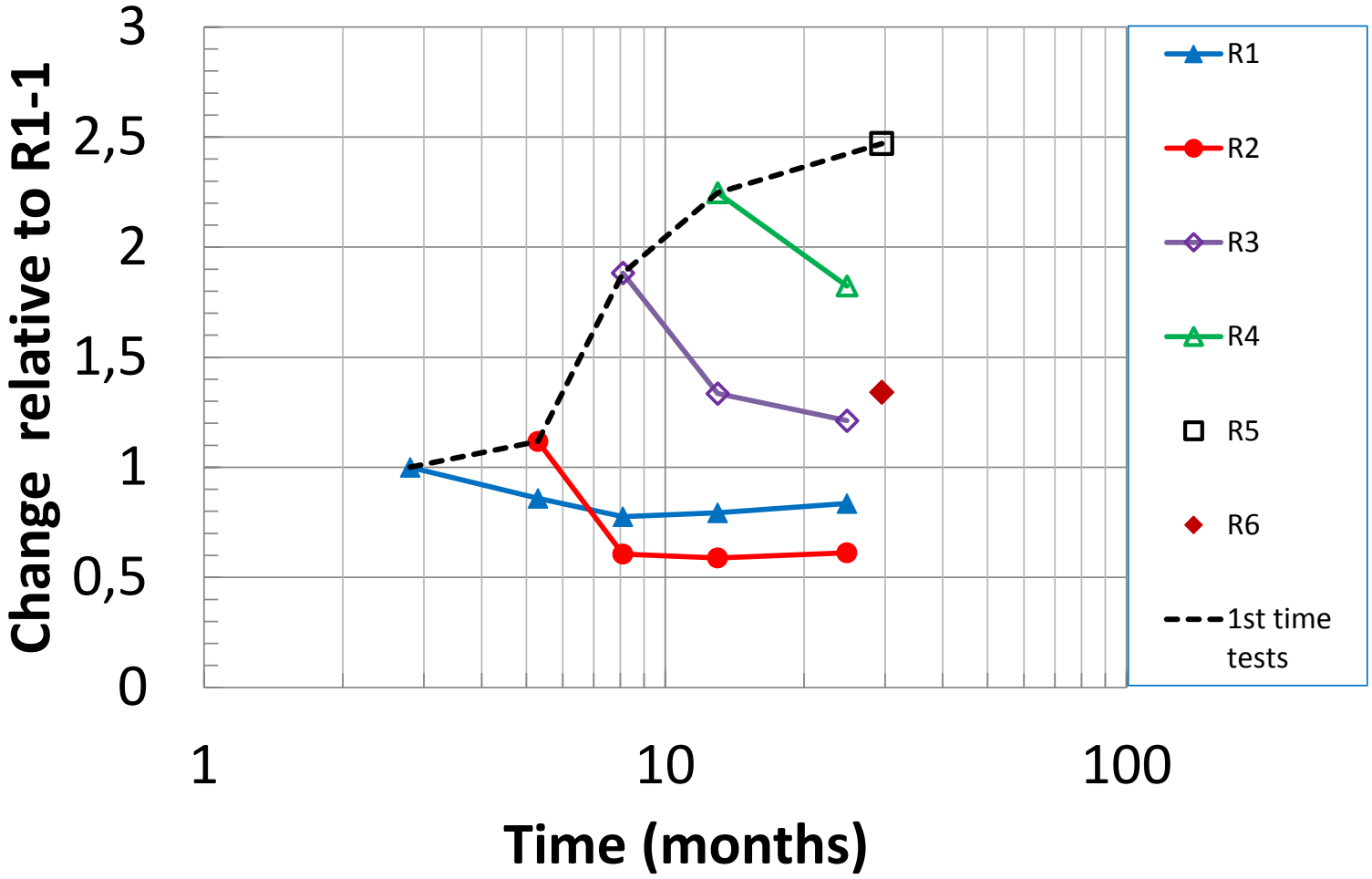
- All piles were loaded in tension
- Loads were applied by hydraulic jacks using a specially designed actuator for maintaining load over long time

Test program

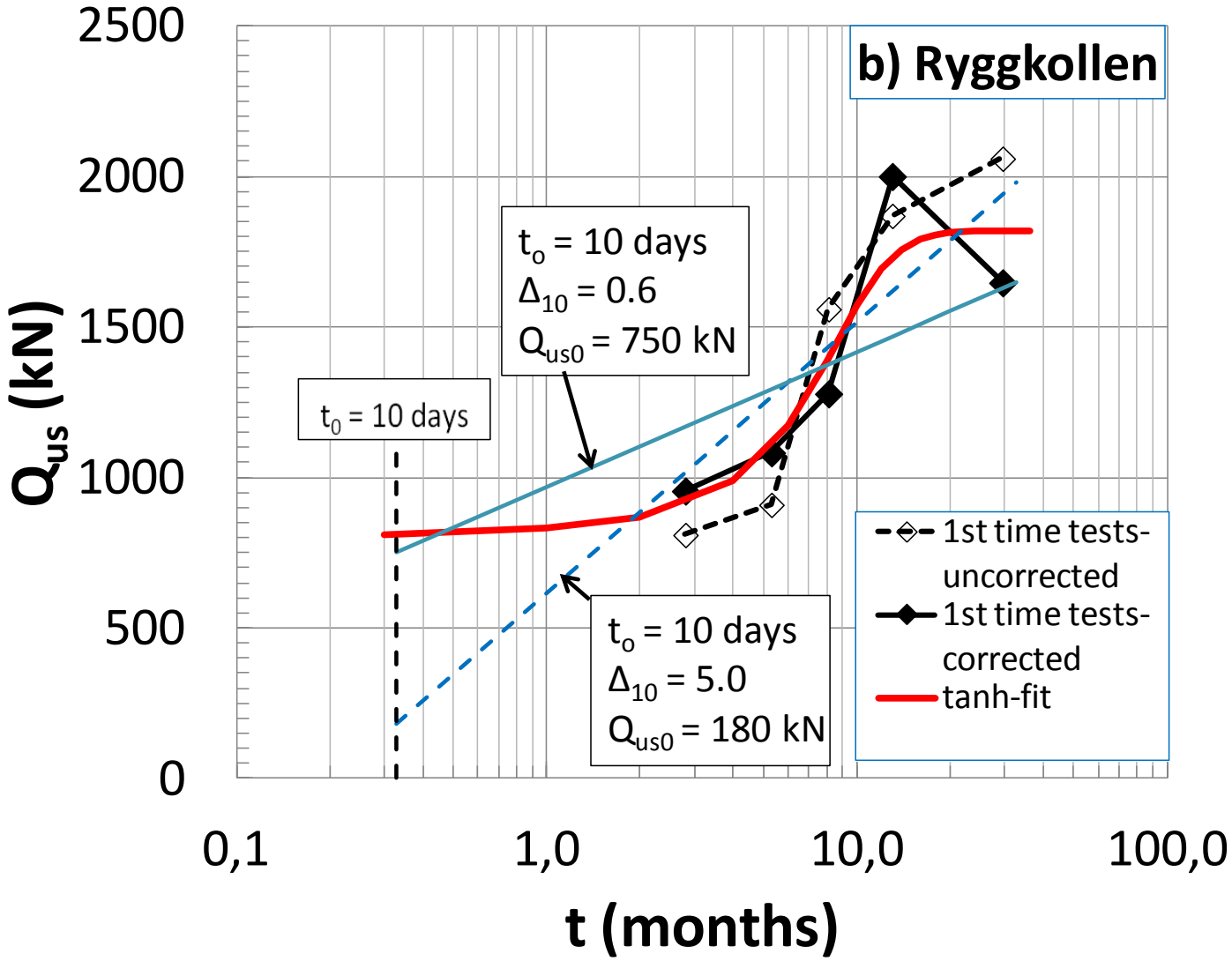
Test pile No.	Time of testing after pile installation (months)				
	1(2)	3(4)	6	12	24
1	X	X	X	X	X
2		X	X	X	X
3			X	X	X
4				X	X
5					X
6			Sust.	Sust.	X

Results sand sites

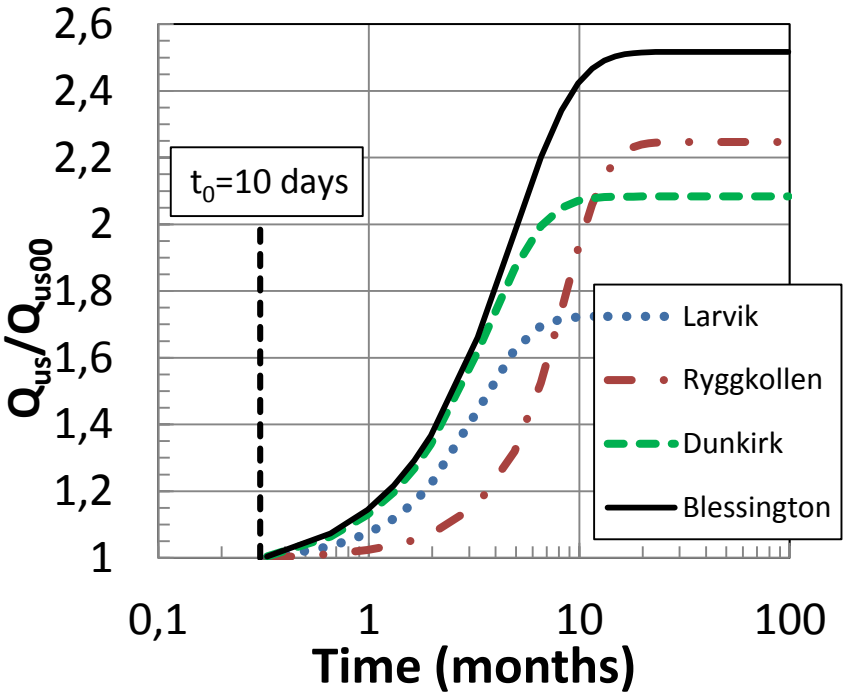
Relative capacities- all tests Ryggkollen

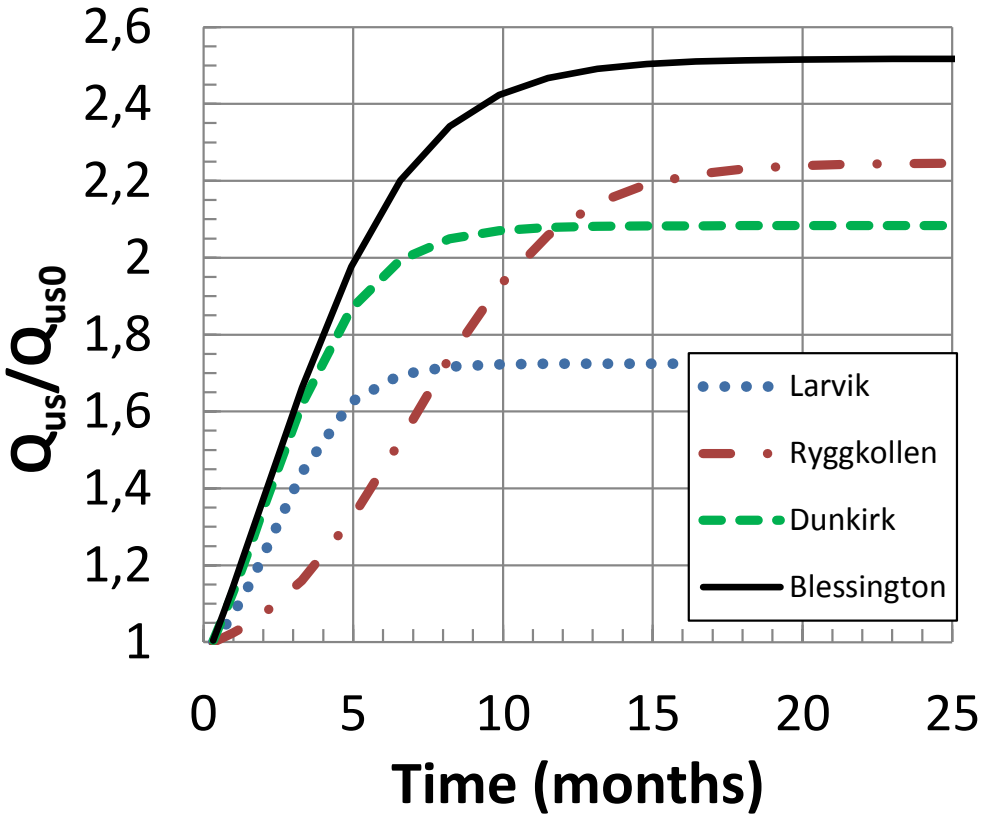


Shaft capacity vs time- Sand,Ryggkollen



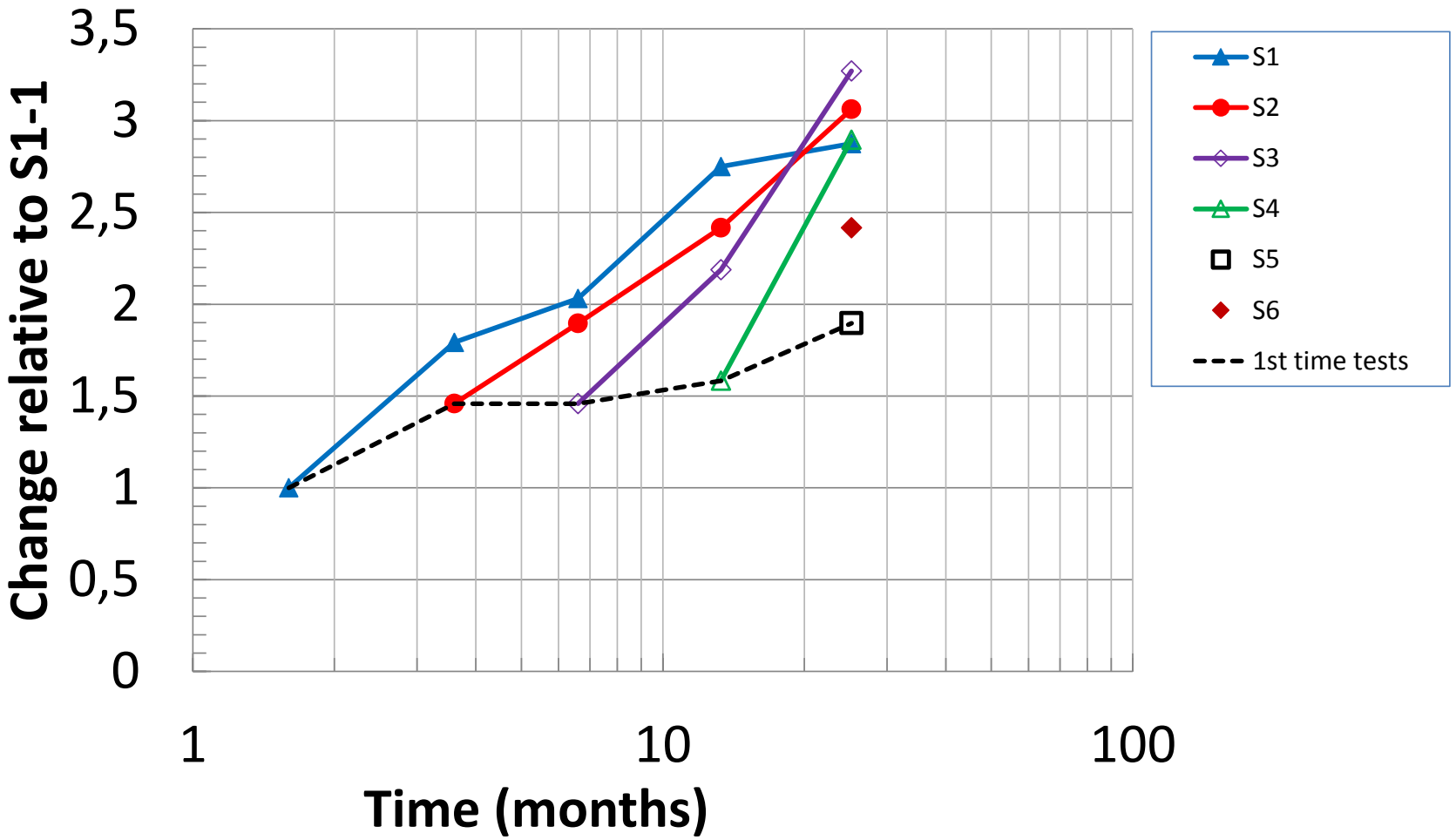
Ageing effects- 1st time tests sand



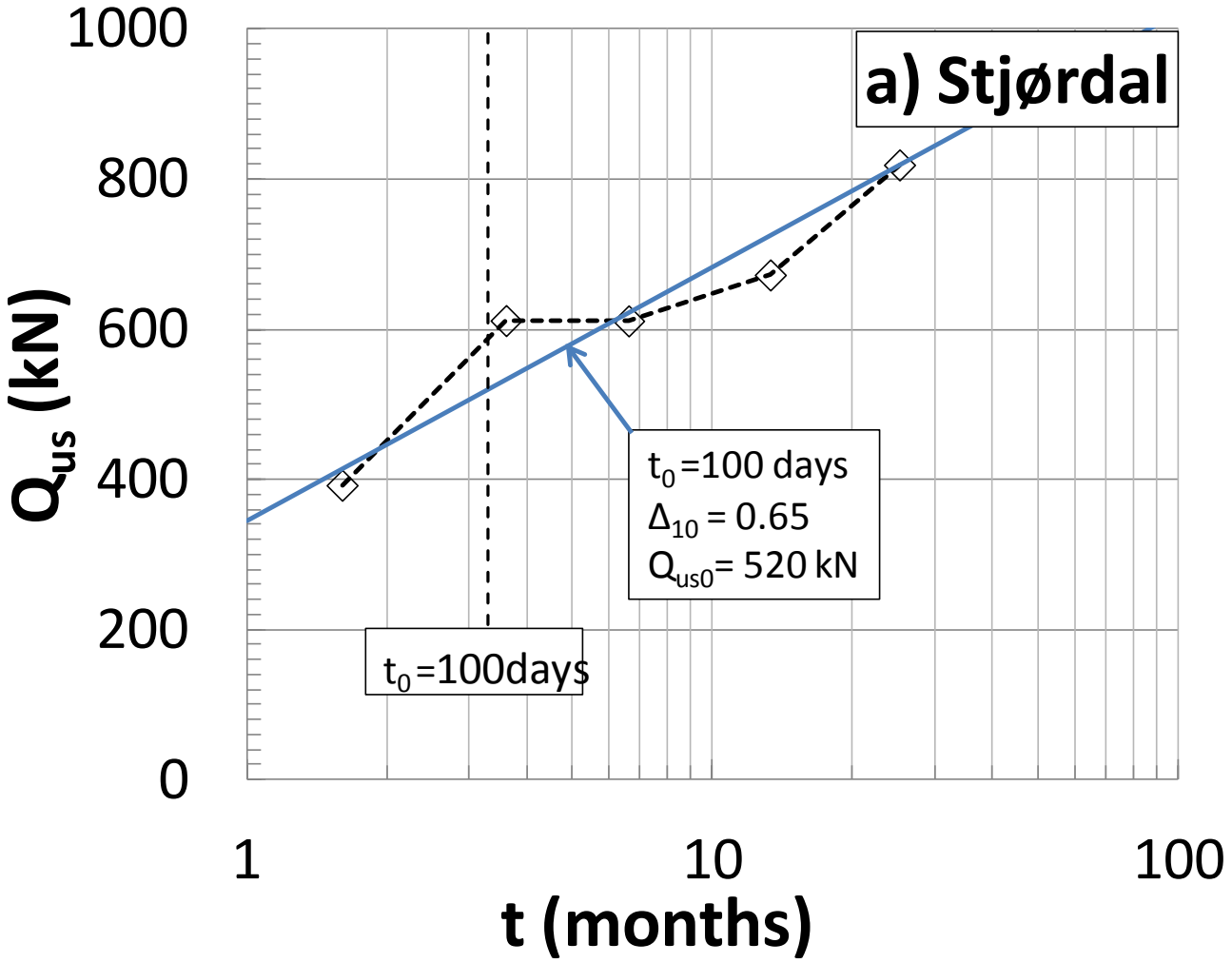


Results clay sites

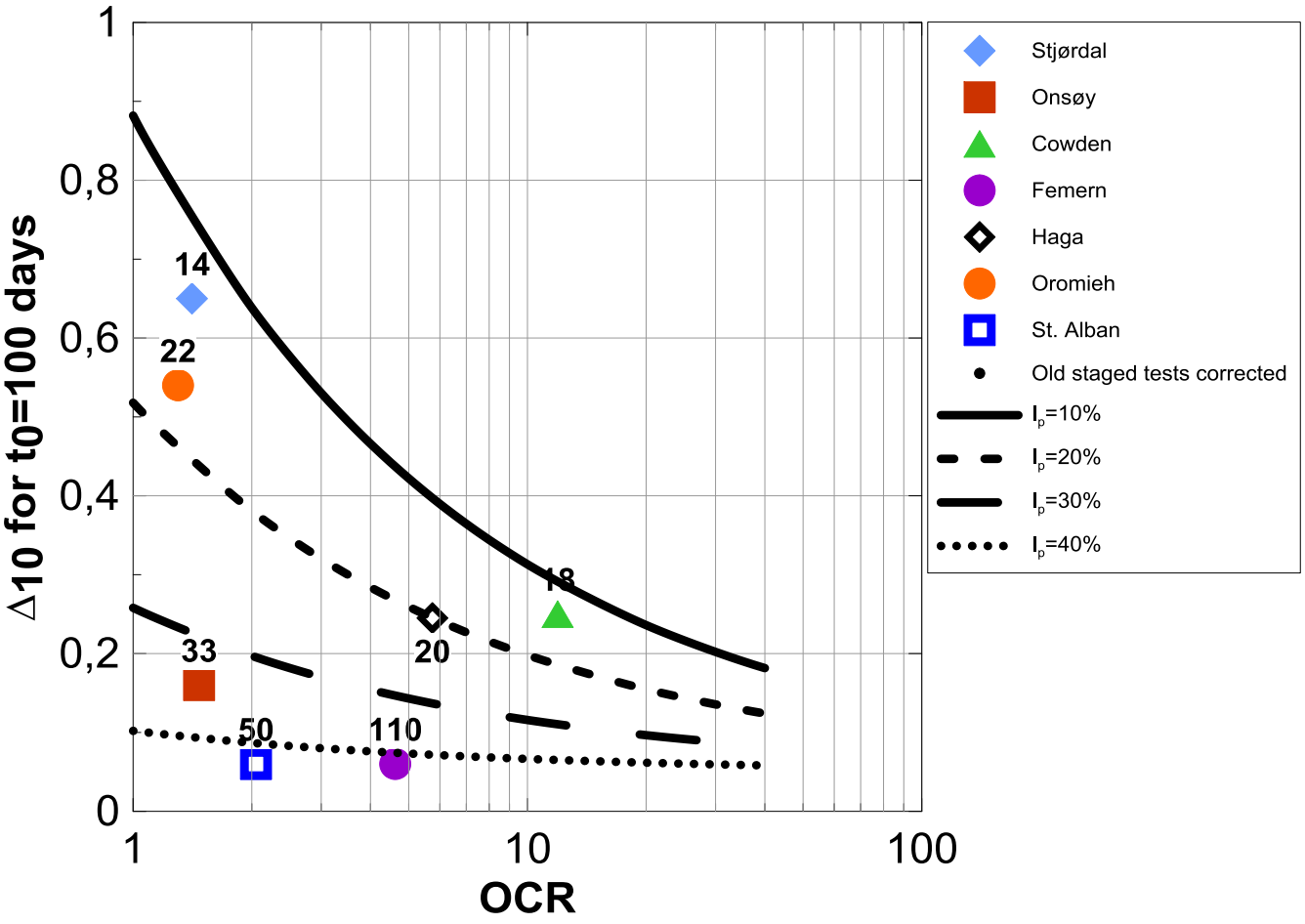
Relative capacities- all tests- Stjørdal



Shaft capacity vs time- Stjørdal

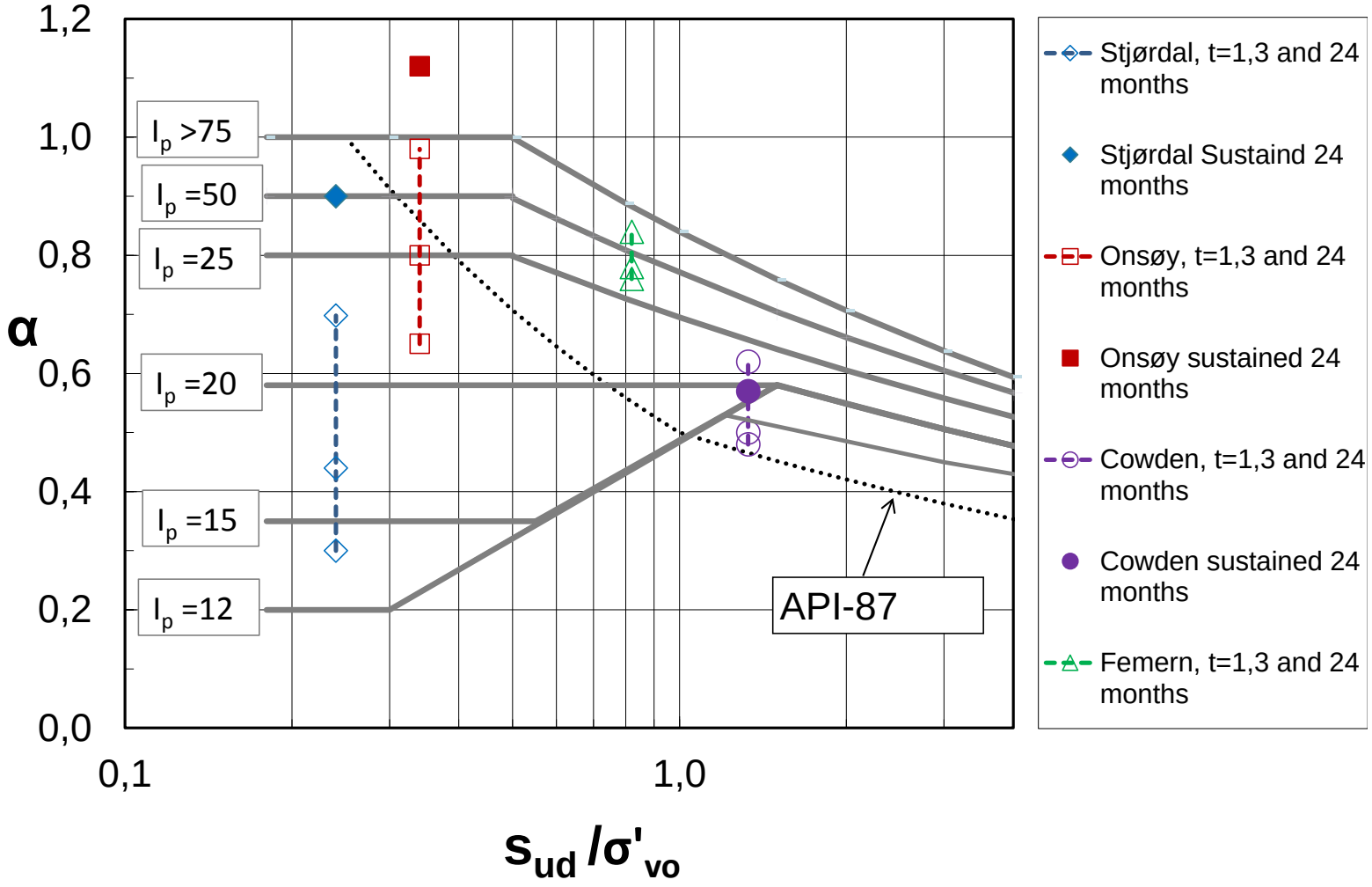


Summary of Δ_{10} ageing factors- Clay

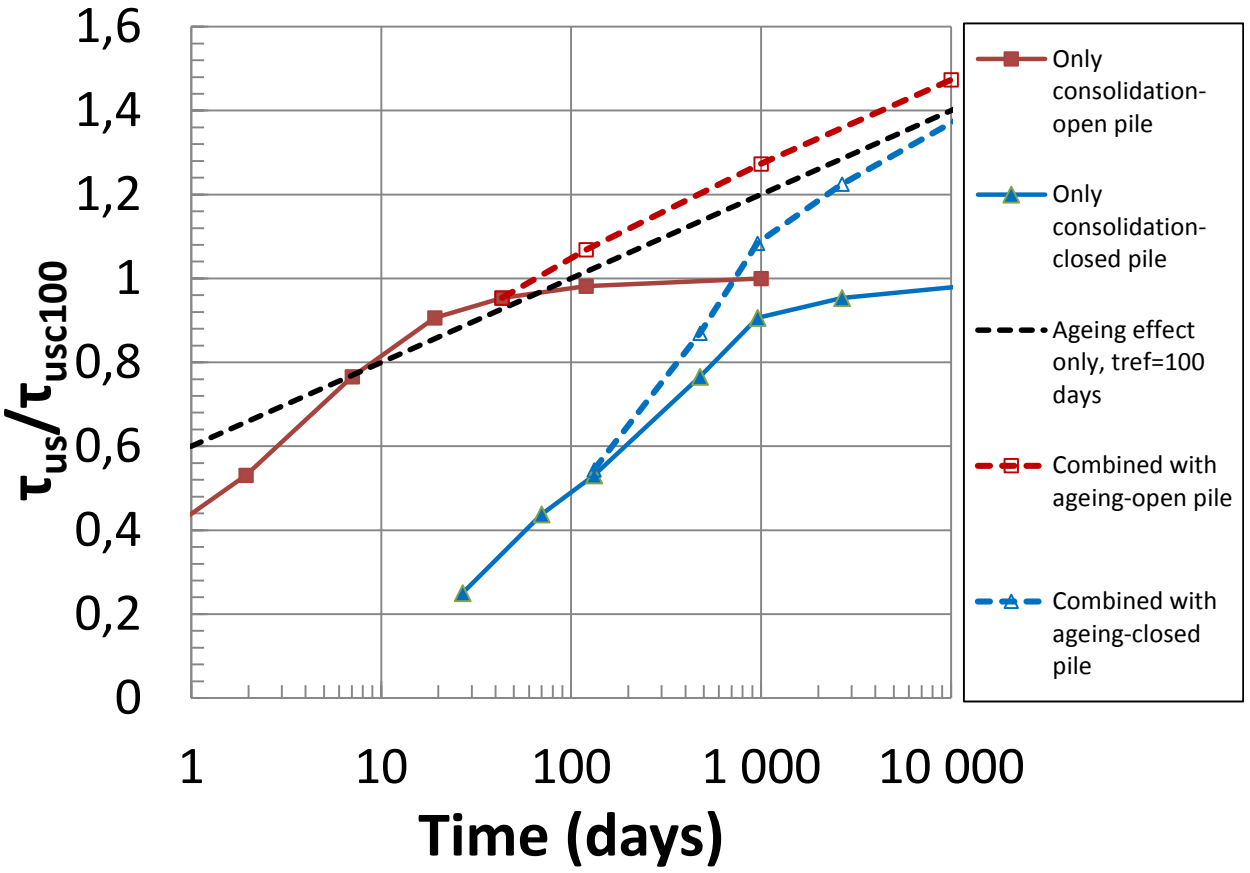


Impact of time effect on α-value

(plotted in Karlsrud, 2012 diagram)



Combining effects of aging and consolidation



Conclusions

- Very significant ageing effects for sand and and clay are verified
- In sands the effect seems to level off after 1-2 yrs
- In clays the effect follows log(t) but depends I_p and OCR
- Sustained and staged loading improves capacity in clay, reduces in sand

IT IS TIME TO ACCOUNT FOR AGEING EFFECTS IN DESIGN PRACTICE!

Great thanks to all participants!

Name	Category	Comment
RCN	Main sponsor	
Saudi Aramco	JIP- partner	
Total E&P	JIP- partner	
Statoil	JIP- partner	
Femern Belt	JIP- partner	Provided also tests at their own site
Petronas Carigali SDN	JIP- partner	
Kværner	Industry- partner	Provided funding + work
Ruukki	Industry- partner	Provided pile materials
Entreprenørservice	Industry- partner	Provided some equipment and site work
Kynningsrud	Industry- partner	Provided some site work
SKANSKA	Industry- partner	Provided mainly data
Multiconsult	Main contract partner RCN	Provided work, data and funding
NGI	Responsible techn. org.	Provided work, data and funding
BRE	Research partner	Provided work (Cowden) and data
Norw. Dir. of Public Roads	Government	Provided work, data and funding