Pile Design and Pile Load Tests in The Netherlands

Adriaan van Seters

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- Safety of pile foundations
  - CUR-committee 229 – Van Tol
  - Investigations 2011 – 2014
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- Pile load tests
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- Discussion

CUR 229 – Axial pile bearing capacity - 2010

Purpose of committee:

- Determine pile factors α_p en α_s
- Evaluation of pile load tests
- (new calculation model with Belgium and France)

Actually:

- No damage in The Netherlands
- Only sufficient tests for precast concrete and closed ended steel pipe piles
- Other piles → no evaluation

Problem:

- Conclusions valid for other piles?
- Many new pile types, too little tests
- "My looks like a … pile" Same pile factors?

CUR 229 – Axial bearing capacity - 2010

- Displacement piles
- Evaluation of pile tip in sand (norm α_p = 1,0)

Pile tip in deep sand layer [* diameter]	No of tests	Average α_p - value	Variation Coëfficiënt
0 – 8	8	0,99	0,28
8 - 22	7	0,63	0,14

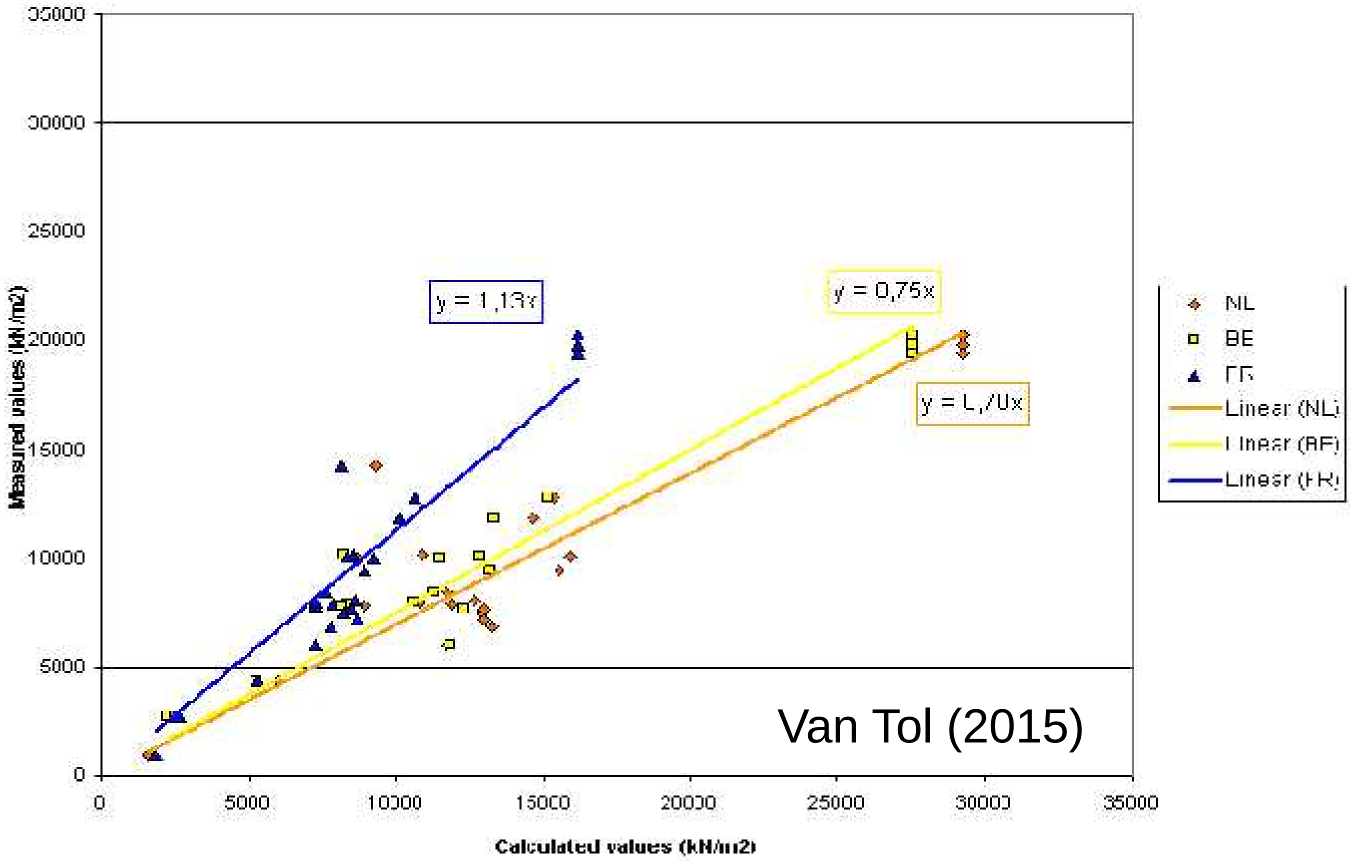
- Evaluation of shaft friction - α_s in sand (norm α_s = 0,01)

No of tests	Average α_s – value	Variation coëfficiënt
10	0,0099	0,36

Investigation University Western Australia

- 28 pile tests
- α_p = 0,834, variation coefficient = 0,32

CUR 229 – Conclusion



International Investigations:

→ In NL Pile TIP bearing capacity is overestimated

CUR 229 – Conclusions

Conclusies CUR 229 for precast concrete and closed ended steel piles:

- Calculation model shaft (α_s = 0,01) is OK
- Shallow founded piles (< 8D in sand layer): Calculation pile bearing capacity is OK (α_p = 1,0)
- Deep founded piles (> 8D in sand): Calculation model is not OK

→ $\sim_p$ tussen 0,6 en 0,7

Conclusie CUR 229 – other pile types (o.a. Vibro)

- Too less tests, no conclusion

CUR-committee C193

Purpose CUR-committee:

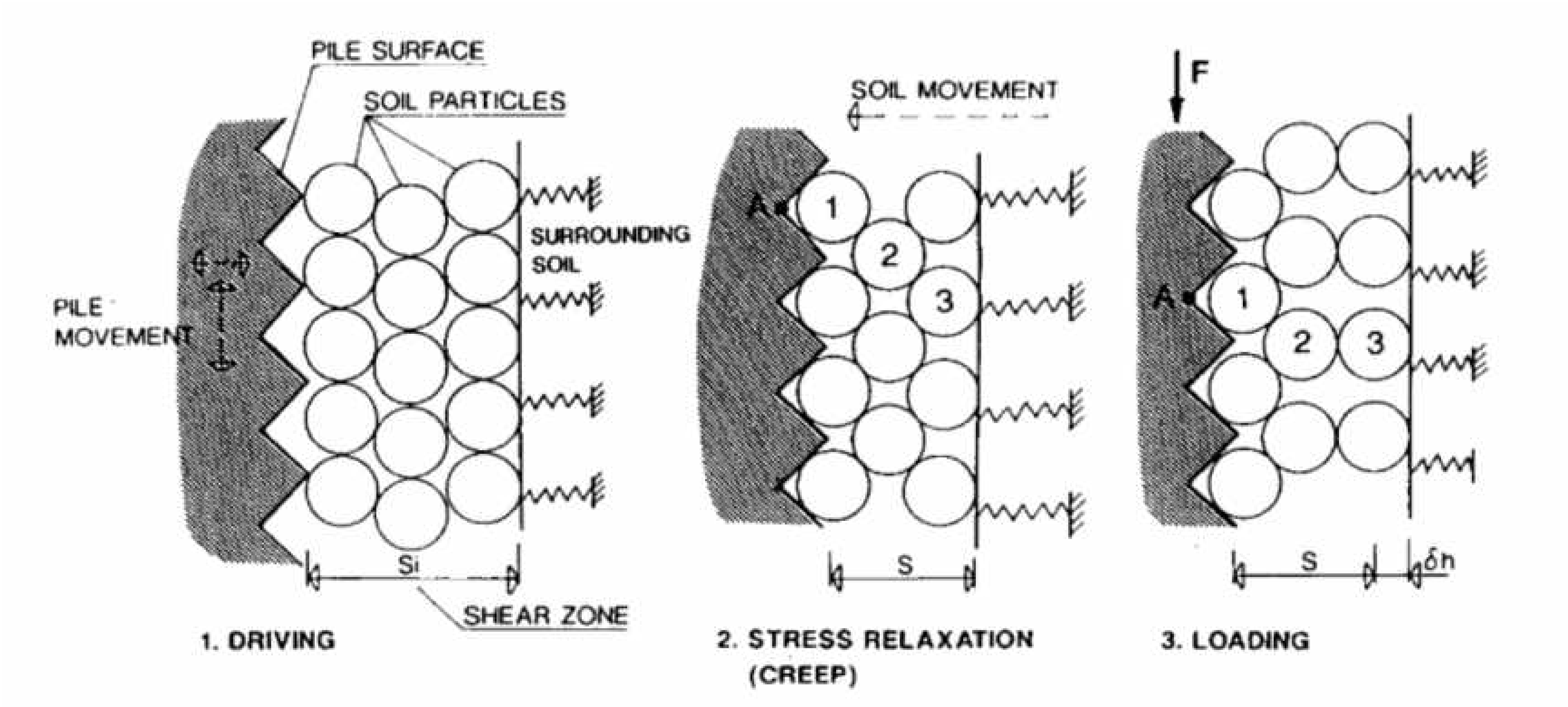
- Why is there no damage at the moment → Hidden safety?
- How to deal with α-factors
- What happens for other pile types?
- How to facilitate pile testing?

CUR193 – Literature investigation – Hidden Safety

Number of aspects from literature (Deltares, Fugro, R'dam, 2013):

1. Increase of bearing capacity in time – ageing
2. Remaining stresses in the pileafter driving – Effects on the pile load tests? Underestimating pile tip bearing, Overestimating friction?
3. Limit values of cone resistance → too low?
4. Pile group effects – densification?
5. Influence positive shaft friction – base effect
6. Influence of reaction piles on the pile load tests
7. Windload: does act completely on the foundation?

CUR193 - Ageing



Axelsson (2012), Karlsrud (2014), Gavin (2015)

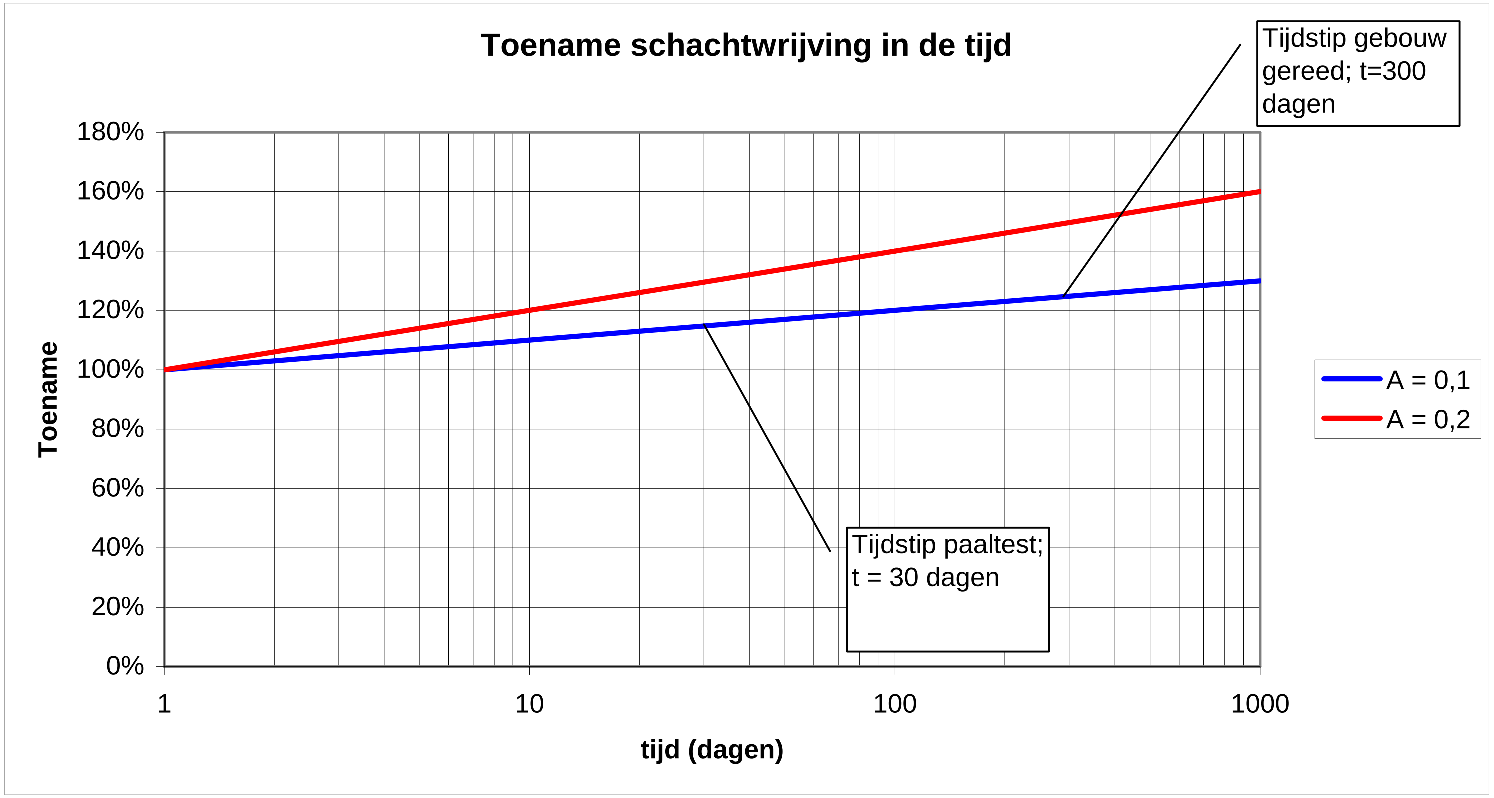
Only displacement piles.

1. Increase of horizontal stress

2. Increase of dilatantie

3. Higher stiffness of the sand by ageing

CUR193 - Ageing



Increase of friction in sand - factor α_s – by ageing (logarithmic process?)

Pile test at 30 days after installing the pile

Pile load at 300 days after installing the pile

Increase 10 – 15 %

CUR193 – Limitation of cone resistance too low?

In teh calculation model for pile bearing in sand → LIMIT on q_c

NEN-standard:

Limit on pile tip resistance: 15 MPa

Limit on shaft friction: 120 kPa á 150 kPa

Literature:

Limit on pile tip resistance around15 MPa (some 16 MPa)

Shaft friction just above pile tip → sometimes 300 á 600 kPa

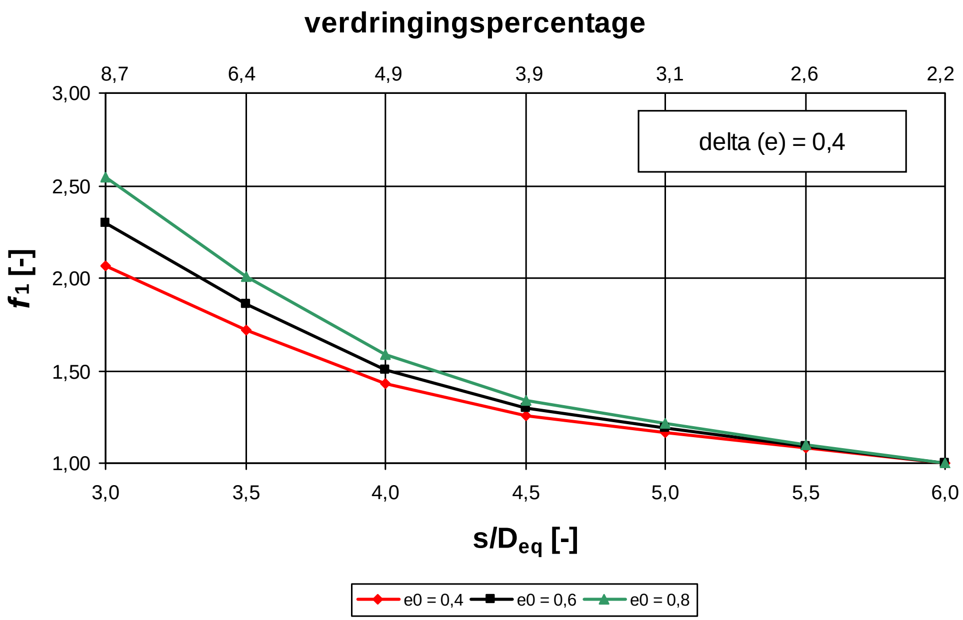
Conclusion:

Pile tip bearing capacity limit: seems OK

Shaft friction: present limit is at the low side

CUR193 – Pile groups - effects of densification

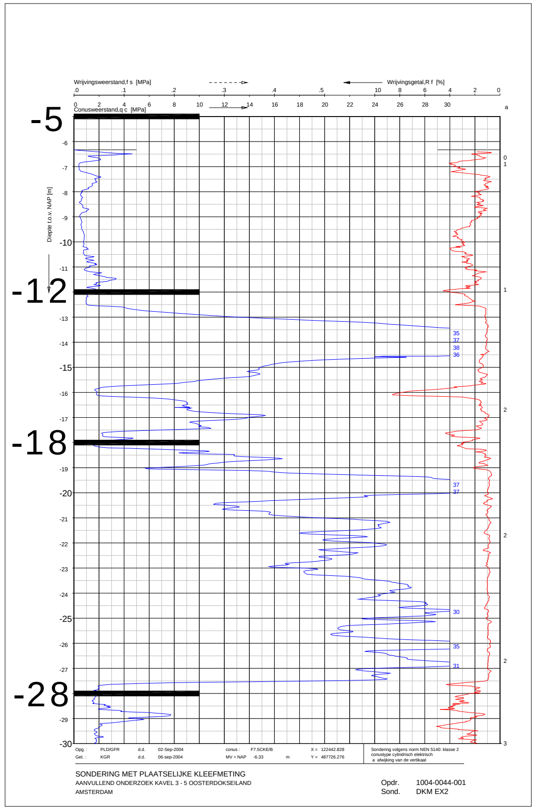
- Displacement piles in sand:
  - Increase of cone resistance in a dense pile group f1 x q_c
  - For a 9-piles groep:

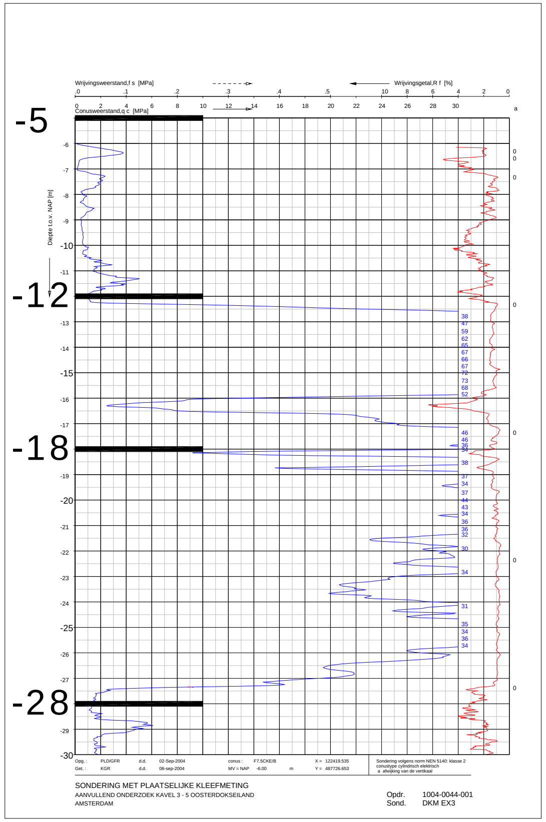


- For pile group at 3D distance → f1 = 2,3
- For row of piles 3D distance → f1 = 1,3

CUR193 – Pile groups - effects of densification

Oosterdokseiland – Amsterdam (2004)





Palen 450 mm

Distance 4 D 1,8 m

Increase cone resistance after drivinga :

f1 = 1,5 a 2!

CUR193 – Pile groups - effects of densification

Result:

- Factor f1 can go up to 1,5 á 2
- Limit of cone resistance is 15 MPa
- So limited effect???

In practice :

- Increase bearing capacity by group effect: approx. 10 %

CUR193 – Windloading – safety at load side?

Due to wind loading

→ piles get a axial compression load

→ piles displace vertically

→ Reduction of neg shaft friction

Example calculation

Total load = 1000 (permanent) + 600 (neg shaft) + 600 (wind) = 2200 kN

Interaction-calculation: Actual load is 1900 kN

Possibly: 50 % of wind load taken by neg shaft friction

If no negative shaft friction

- Full wind load on the piles!

Note:

- Wind load is significant when highrise > 40 m.

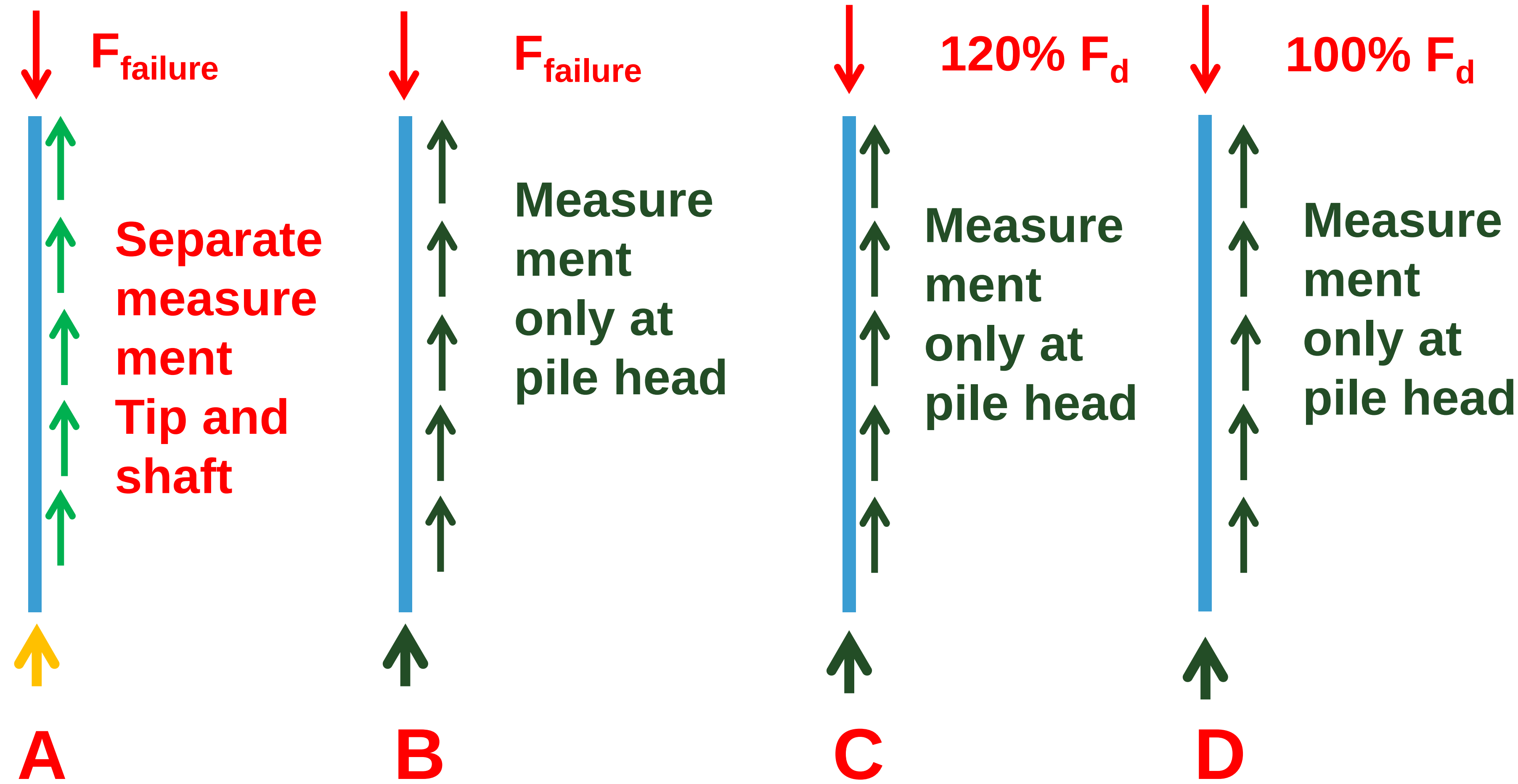
Decision Standards committee 2015

- Reduction of tip resistance α_p with 30 %
- Values for shaft α_s remain unchanged
- Stimulate pile load tests
  - New value α_p maybe too low for other piles
  - Prove the present pile factors (from 1950 – 1980)

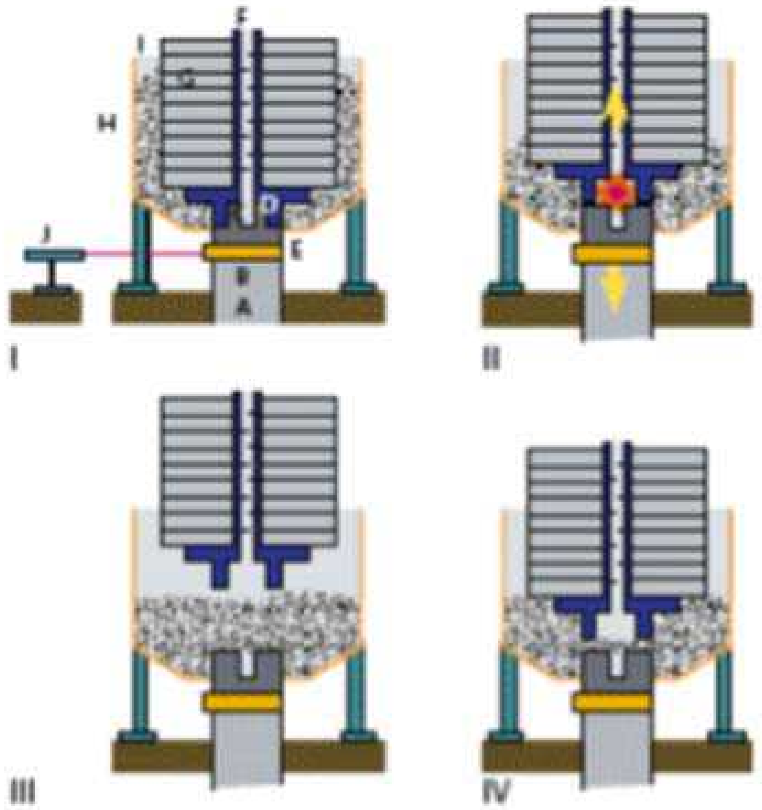
Static Pile load tests

NPR - standard

STATIC LOAD TESTS – 4 CLASSES:



RAPID LOAD TEST / STATNAMIC



Four stages of a Statnamic test with gravel catch system.

A = pile to be tested
B = load cell
C = cylinder & pressure chamber
D = piston
E = platform
F = silencer
G = reaction mass
H = gravel container
I = gravel chamber
J = optical measuring system

Statnamic:

- Explosives
- Gravel container?

Statrapid:

- Block falls from determined heigth
- Springs between block and pile

RAPID LOAD TEST / STATNAMIC

- Procedure – Unloading Point Method
- Alternative for Class B en D Pile load tests
- 3 tests per pile (class B – investigation tests)
- Failure load and load-displacement diagram
- 1 test per pile (classe D – Control tests)
- Only for piles in sand

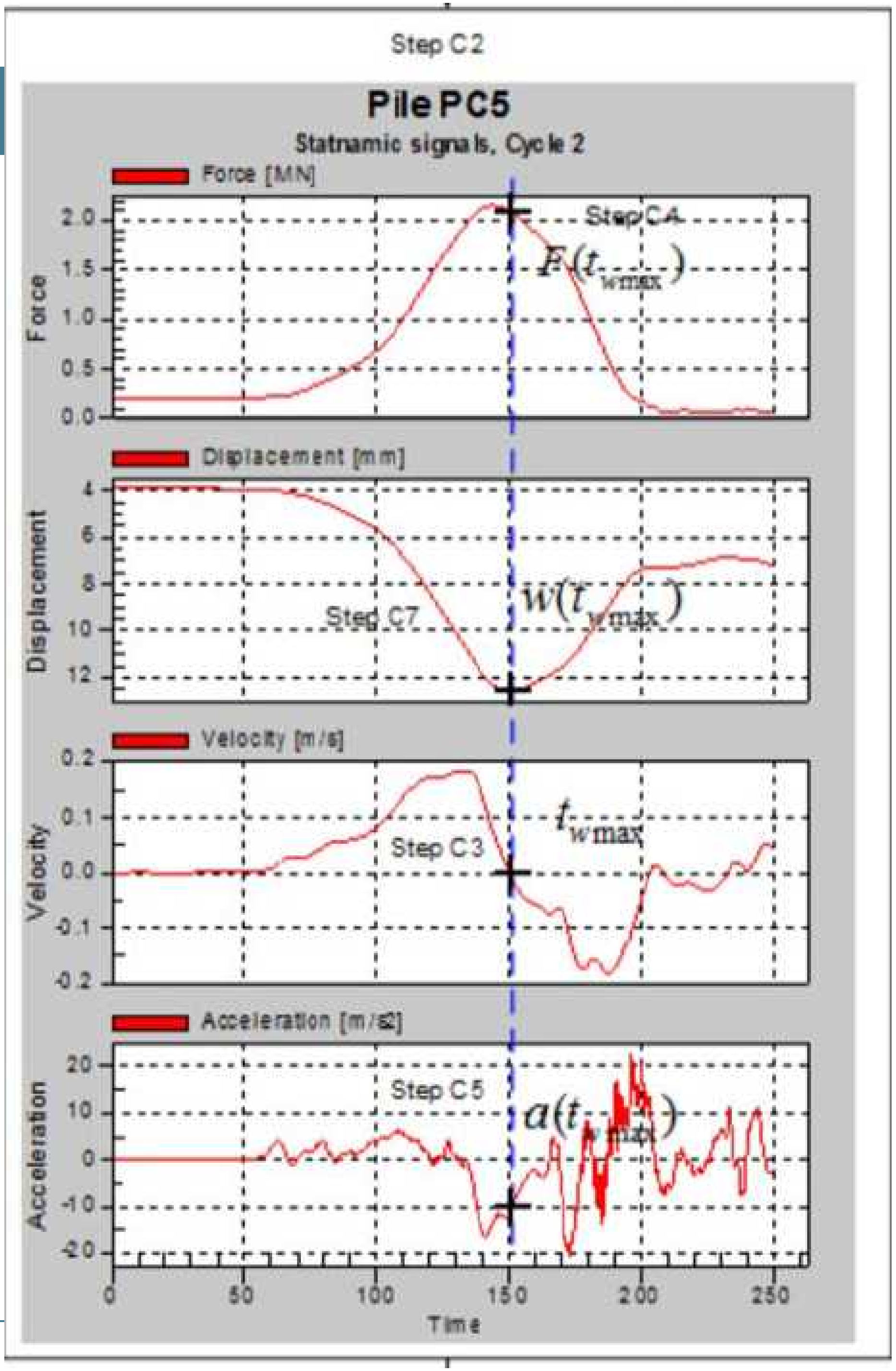
- Piles in clay → together with static test
- (Take friction in upper soft layers into account)

Results Rapid Load Test

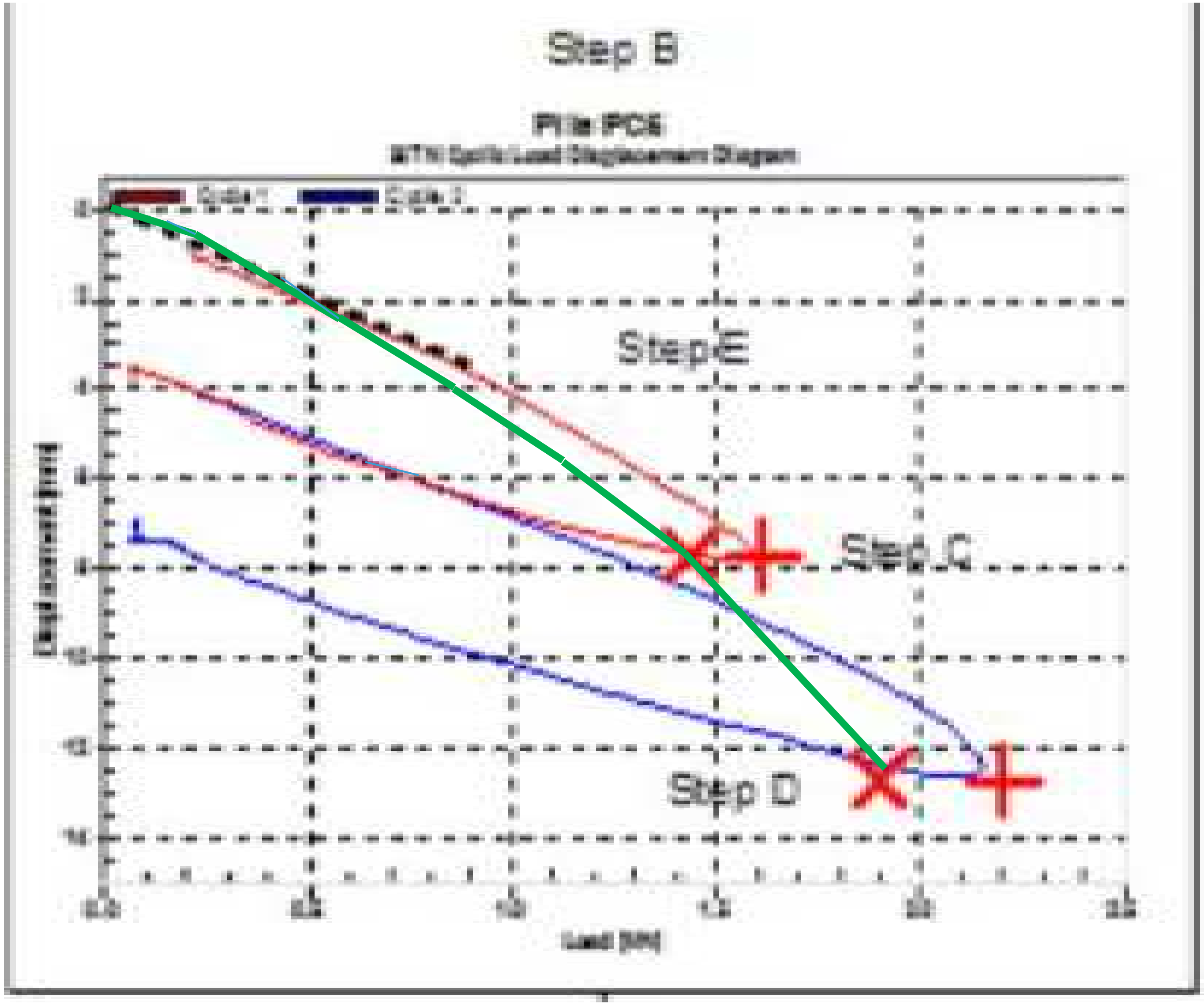
Unloading Point Method

- Load depends of dynamic effects
- Dynamisch effect = 0,

  when velocity = 0



Resultaat Rapid Load Test – Load - displacement



Discussion

CUR 229 – 2010 - Pile load tests show lower safety than expected

No damage → Hidden safety???

- Ageing
- Densification - Group effects
- Other?

Feasibility of Pile load tests:

- Static Pile load tests not going to failure (120 % F_{design})
- Rapid Load Tests

Thank you for your attention

a.vanseters@fugro.com

Planning – NEN9997-1/NPR

NEN9997-1/EN1997-1

1 juli 2016 – norm gereed

Aanwijzing door Bouwbesluit per 1/1/2017

NPR – PROEFBELASTINGEN

2016 - “groen” ter commentaar

Eind 2016 – Richtlijn gereed

a.vanseters@fugro.com

Besluit Normcommissie 2011

NEN-COMMISSIE

- Beeld is niet compleet (**alleen** geheide palen in CUR 229)
- Schade gevallen niet bekend (verborgen veiligheid)
- Alleen geheide palen → marktverstoring
- Veel “nieuwe paalsystemen” zonder proefbelastingen

BESLUIT

- Paalklassefactoren α_p, α_s, en α_t ongewijzigd t.o.v. NEN 6743
- Maximale geldigheidsduur tot 1/1/2016
- Binnen 5 jaar nieuwe α_p, α_s, en α_t uit proefbelastingen
- α-factoren + beschrijving van paalsysteem deponeren bij NEN
- Indien geen proeven → reductie α-factoren per 1/1/2016 met 33 %

Periode 2011 - 2016

AFGELOPEN 5 JAAR

- Onderzoek naar verborgen veiligheid (CUR 193)→
  - Literatuurstudie
  - Pilot groepswerking en ageing uitgevoerd in centrifuge
  - Resultaat: Mogelijk hogere schachtwrijving door "ageing" (tijdseffecten) en groepswerking bij geheide palen

- Geen middelen voor prototype testen
- Geen geld voor verder onderzoek
- Geen proefbelastingen beschikbaar gekomen

Gevolgen voor Praktijk na 1/1/17

NIEUWBOUW

- Lagere α_p
- Zwaardere en/of langere palen
- Proefbelasten → hogere α_p?

BESTAANDE BOUW → NEN8707-ontwerp

- Bestaande situatie → huidige factoren
- Belastingsverhoging bij Verbouw
  → nieuwe factoren

NIEUWE NORM (TABEL 7C, VOETNOOT A) ONDERSCHEIDT:

- Projectgebonden proefbelastingen
- Algemeen geldige proefbelastingen:
  - Instrumentatie – scheiding tussen punt en schacht
  - Minimaal 2 terreinen
  - Beschrijving van het paalsysteem en installatieproces
  - Paalklassefactoren α_p, α_s of α_t voor specifieke beproefde paalsysteem van de betreffende leverancier

⇒ NPR - PROEFBELASTINGEN

STATISCH PROEFBELASTEN – 4 KLASSEN

	Test belasting	Meting	Resultaat	Type paal	Aantal proeven
Klasse A	Bezwijken	Scheiding schacht/punt	α-factoren	Test paal	> 2 terreinen x 3 palen
Klasse B	Bezwijken Eurocode 7	Last + zakking paalkop	Bezwijkdraag-kracht project	Test paal	> 3?
Klasse C	120 % F_d	Last + zakking paalkop	Bezwijkdraag-kracht project	Paal in werk	????
Klasse D	100 % F_d	Last + zakking paalkop	Controleproef – specifieke paal	Paal in werk	1

REGISTRATIE VAN ~ -FACTOREN

- Aanmelding belastingsproef bij NEN **met beschrijving paalsysteem en paalinstallatie**
- (Aparte) NEN-commissie beoordeelt draaiboek
- Proef wordt uitgevoerd met onafhankelijk toezicht
- Rapportage wordt door NEN-commissie beoordeeld
- α-factoren en beschrijving worden bij NEN vastgelegd
- α-factoren **alleen** geldig voor **betreffende leverancier**