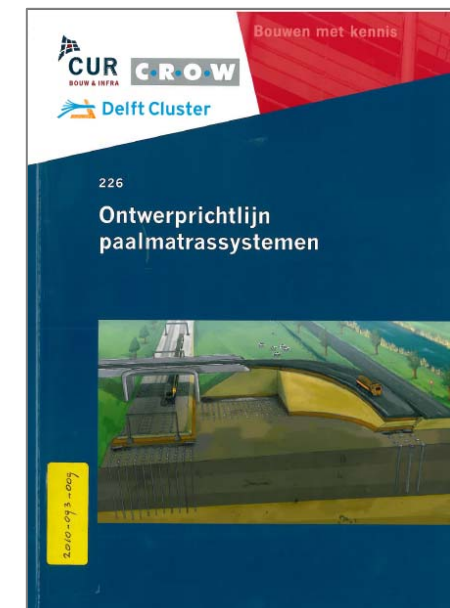


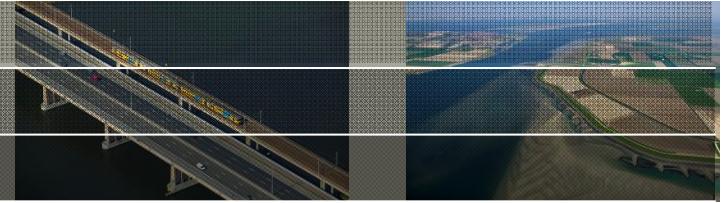
## Kan de CUR226-ontwerprichtlijn paalmatrassen beter?

Suzanne van Eekelen

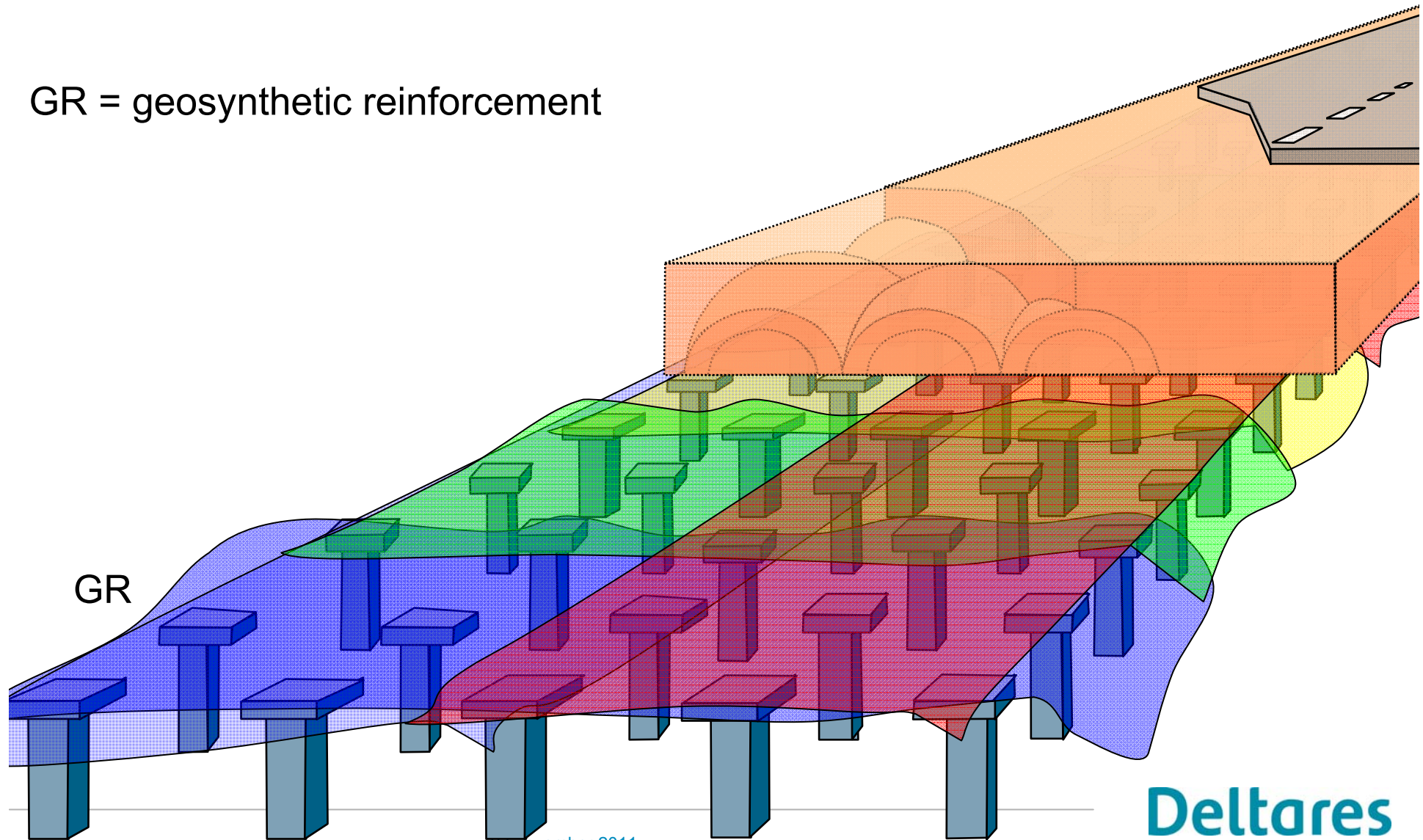
Deltares, Delft University of Technology, NGO-I&K



# Wat is een paalmatras?

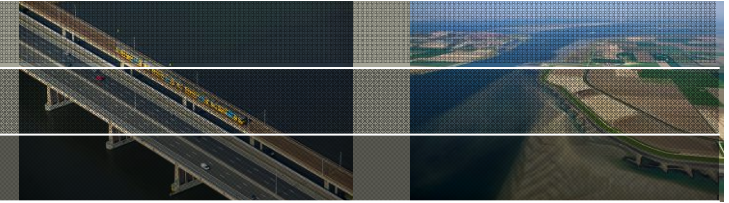


GR = geosynthetic reinforcement



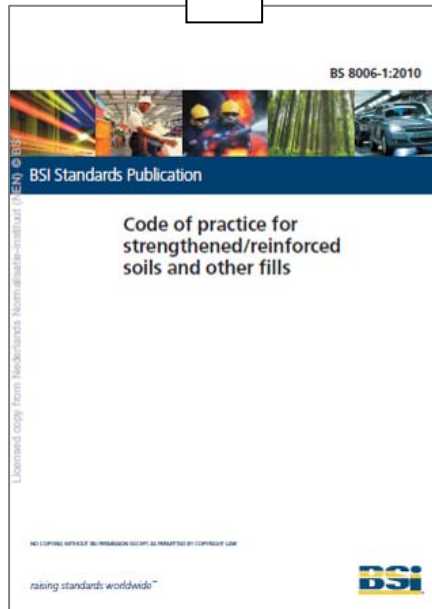
GR

# Ontwerprichtlijnen

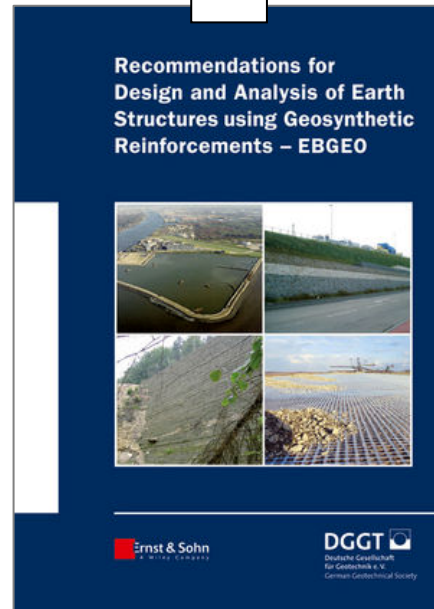


1. Britse BS8006 (1995, update 2010, Engels)
2. Duitse EBGEO (2004, updated 2010, Duits en Engels)
3. Nederlandse CUR design guideline (2010, Nederlands)

1

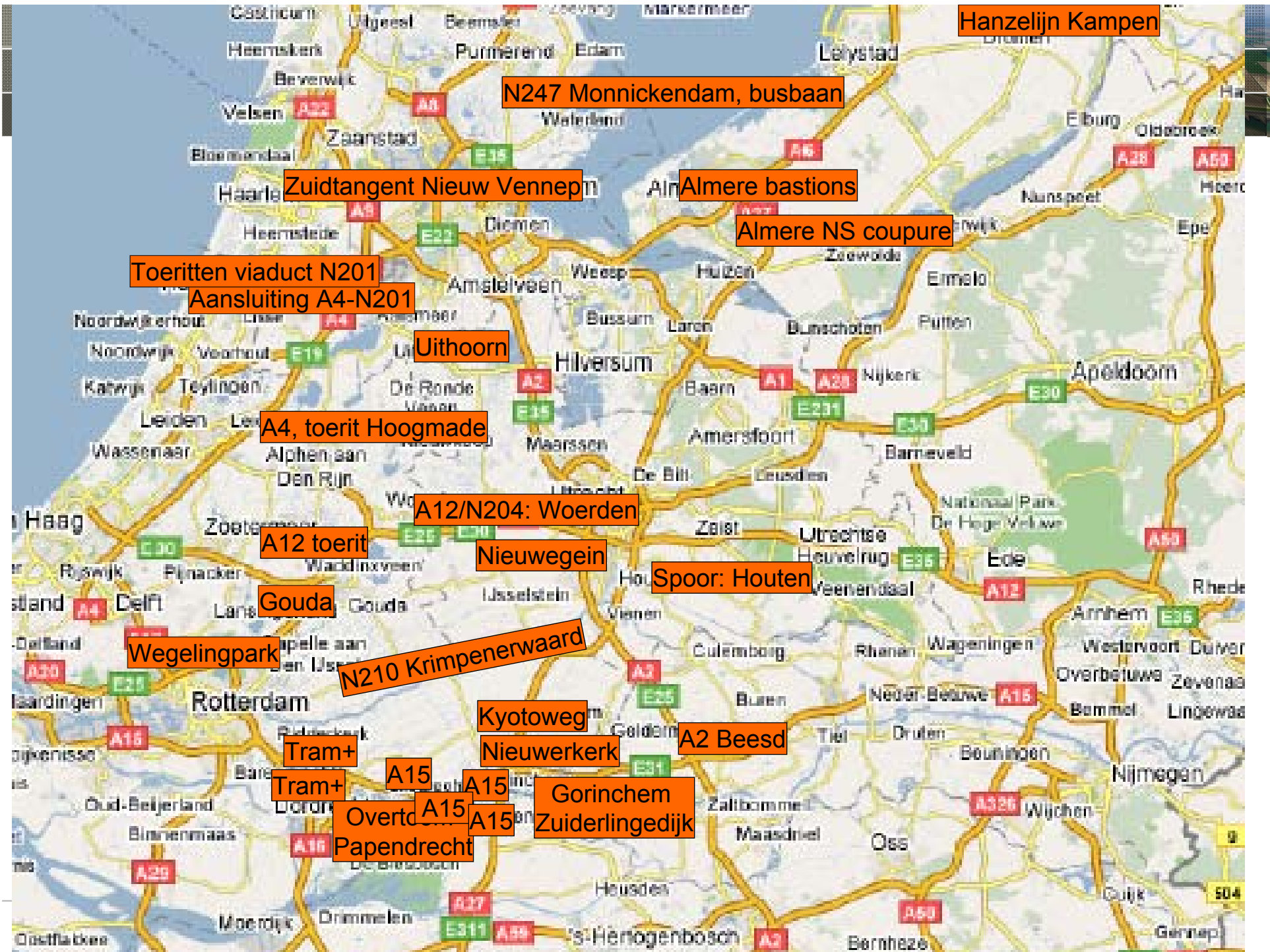


2



3





# Kan de CUR-ontwerprichtlijn paalmatrassen beter?

Samenvatting ontwerpregels

Veldmetingen

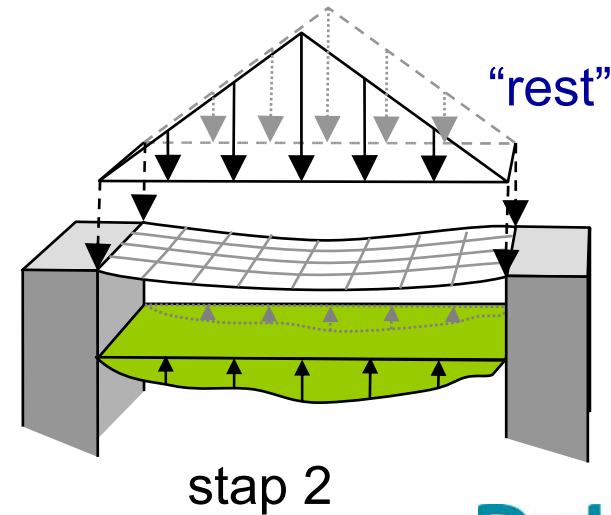
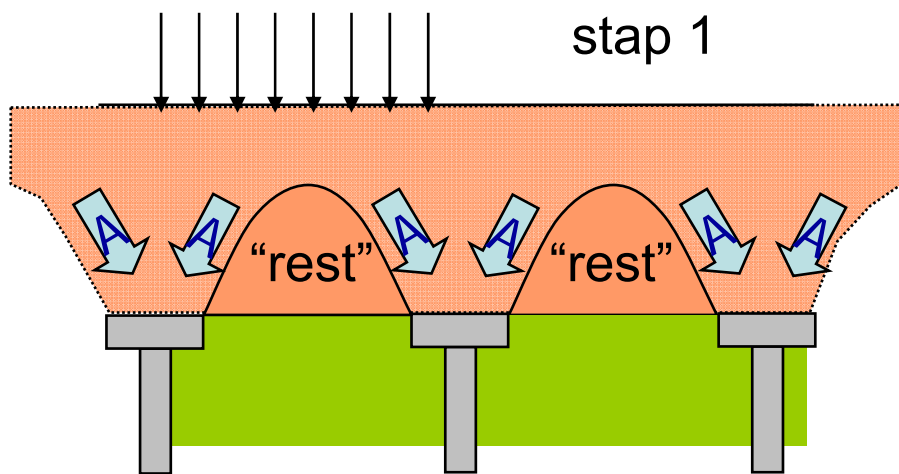
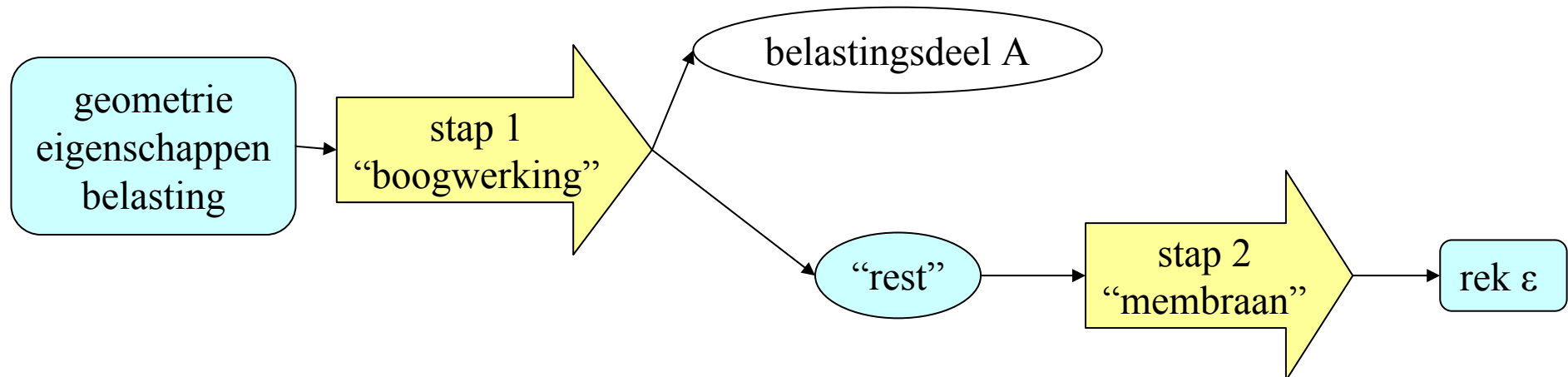
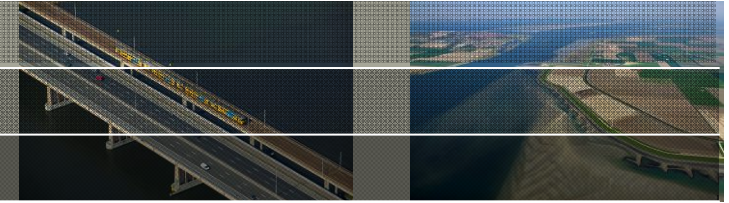
Doel labproeven

Opzet proeven

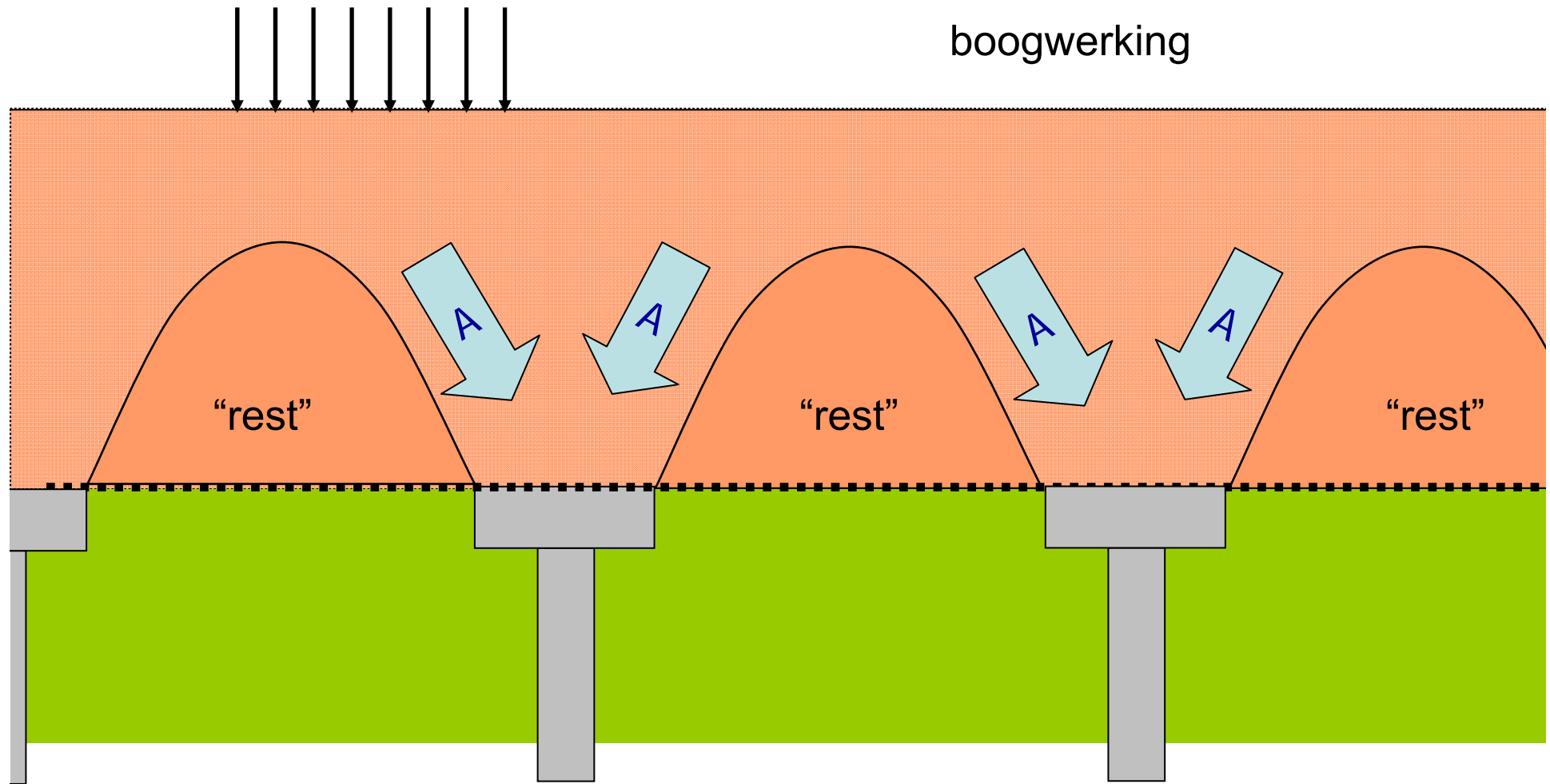
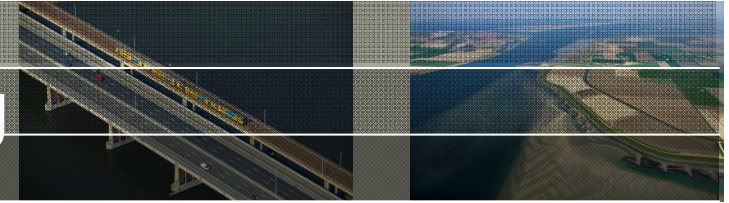
Resultaten

Aanpassen ontwerpregels

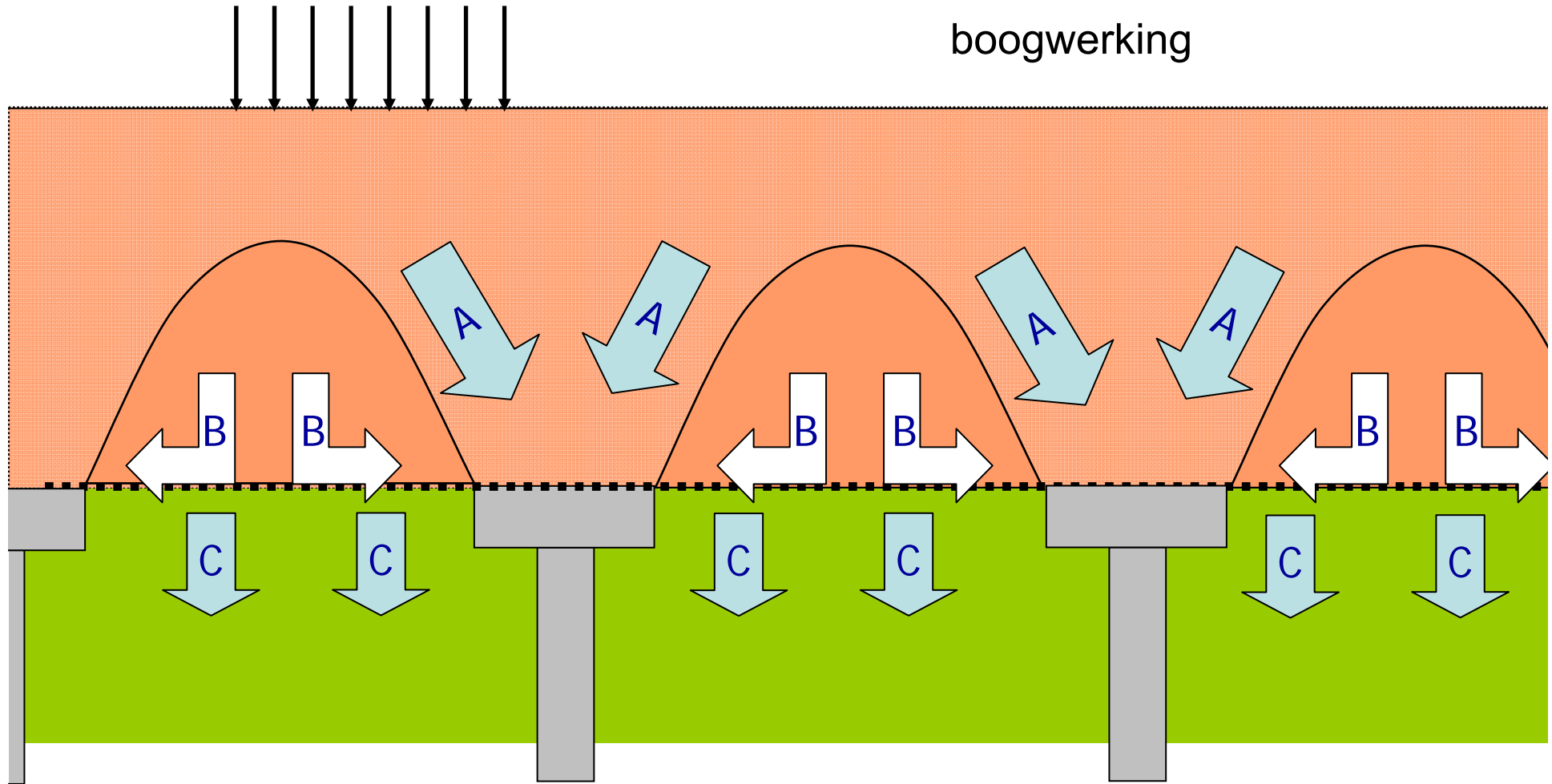
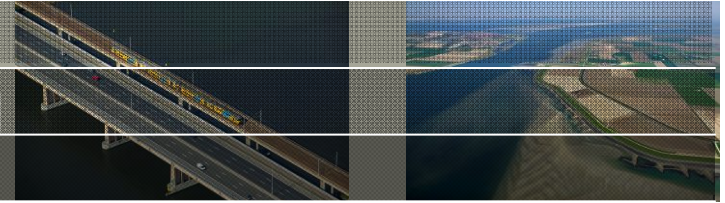
# Verticale belasting: 2 stappen



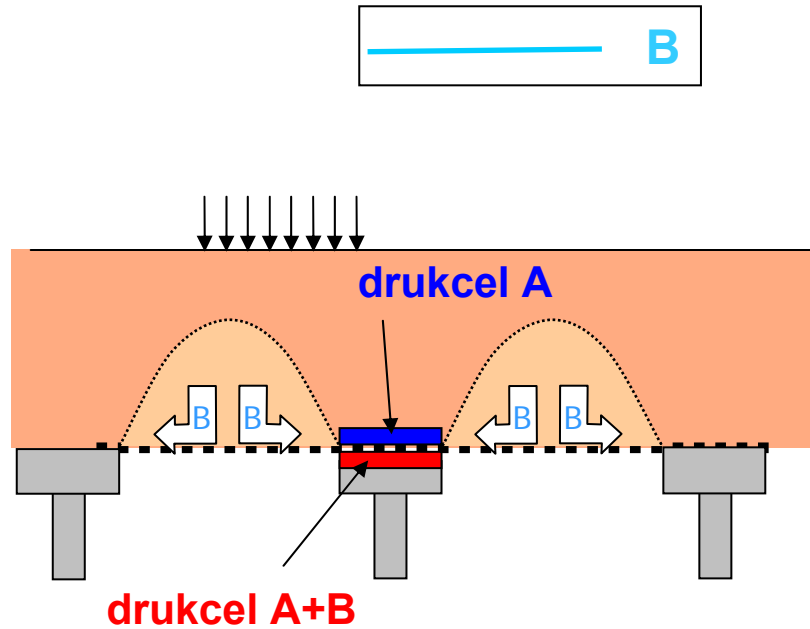
# Definities belastingsverdeling



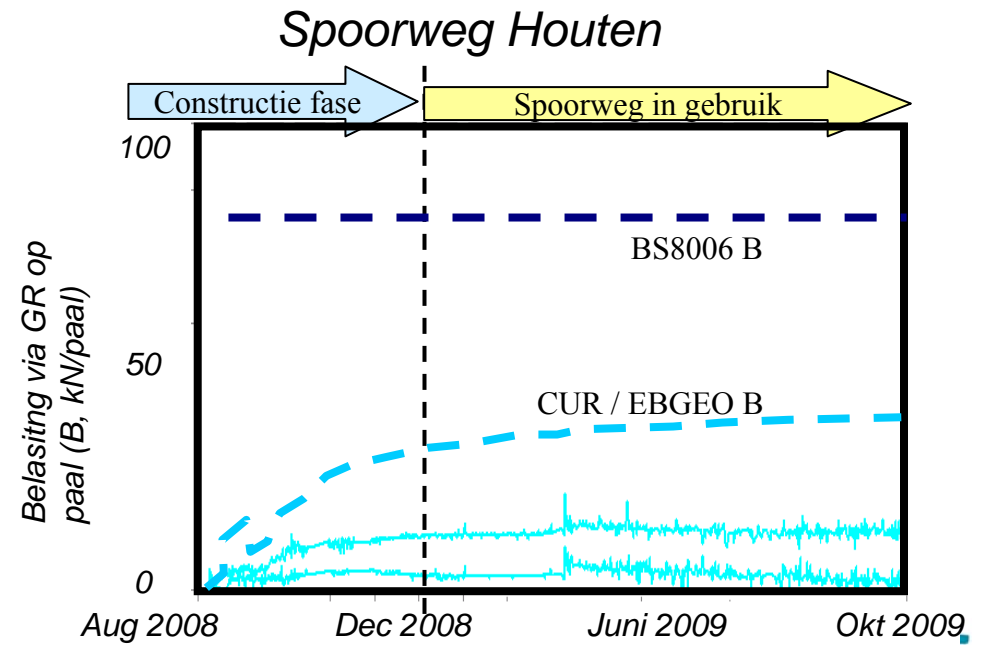
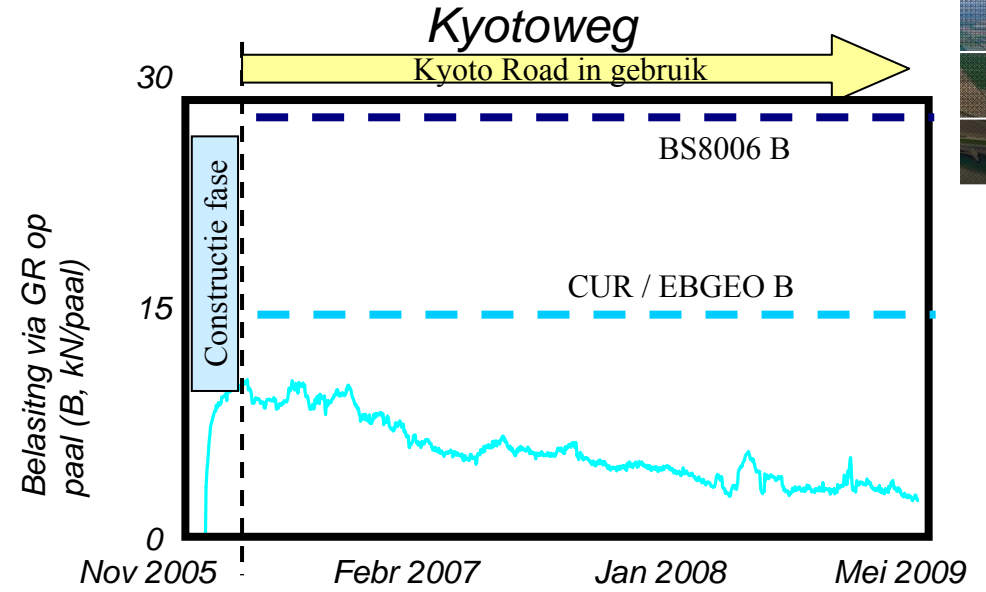
# Definities belastingsverdeling



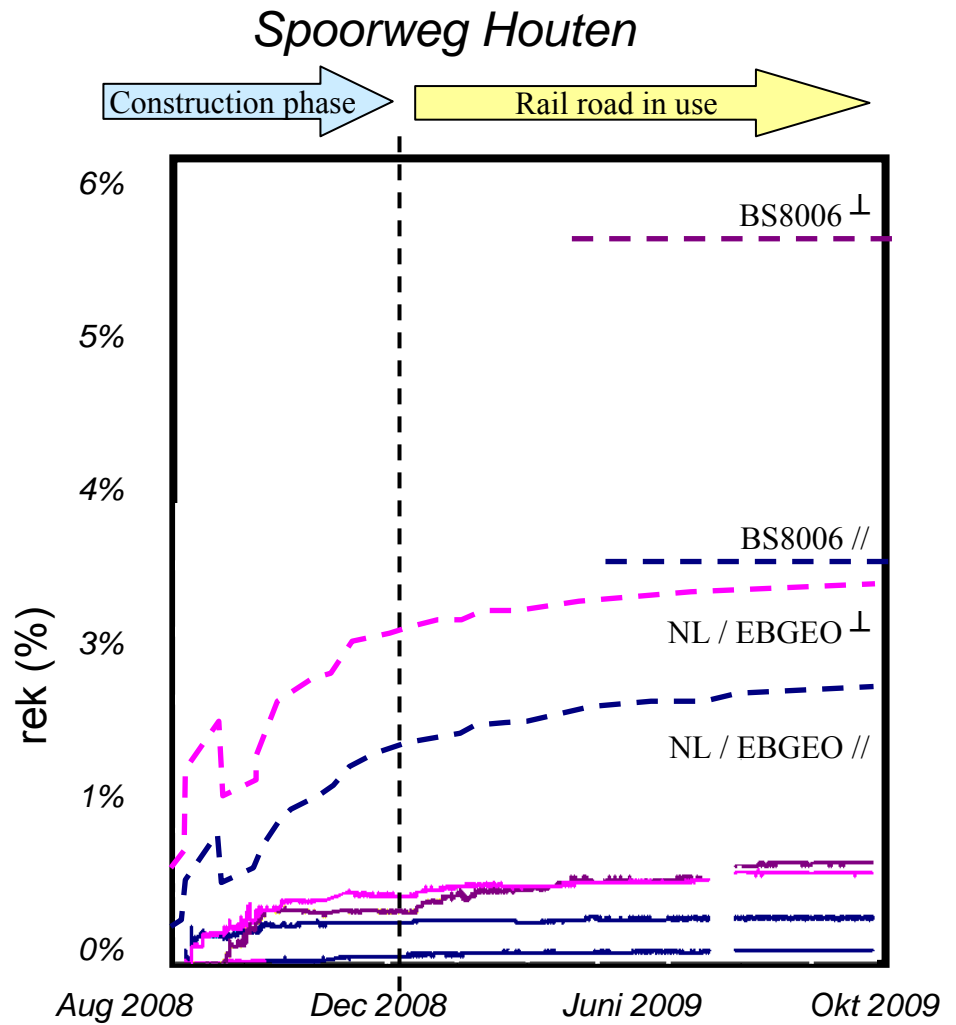
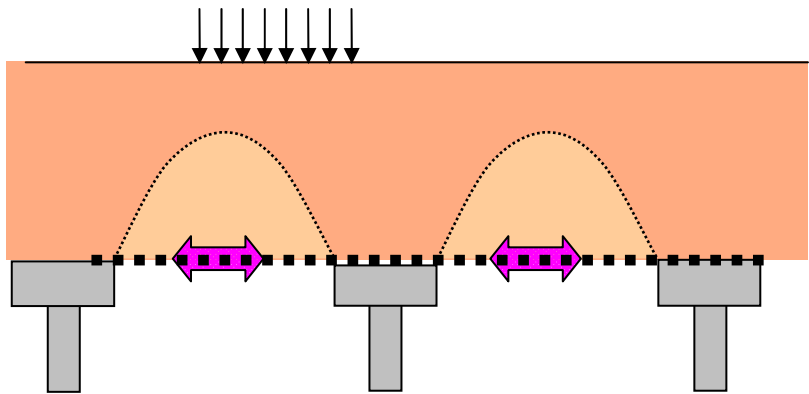




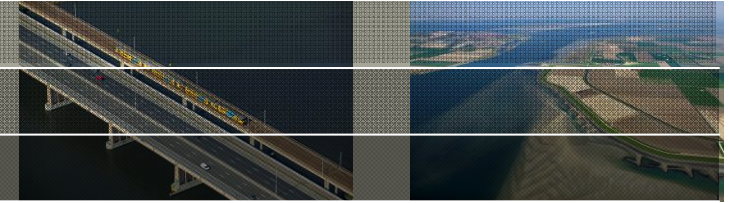
$$B = (A+B) - A$$



— rek  $\perp$  wegas  
— rek // wegas



# Proevenserie paalmatrassen



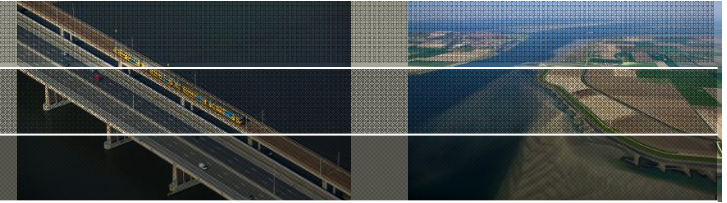
Doel experimenten:

**Het verschil verklaren tussen gemeten en berekende rekken**

1. 3D proeven met granulaat, geokunststof en realistische spanningen
2. Stap 1 en 2 apart valideren
3. Variaties

Noodzakelijk: A, B en C apart meten

# Paalmatrasproeven



Samenvatting ontwerp

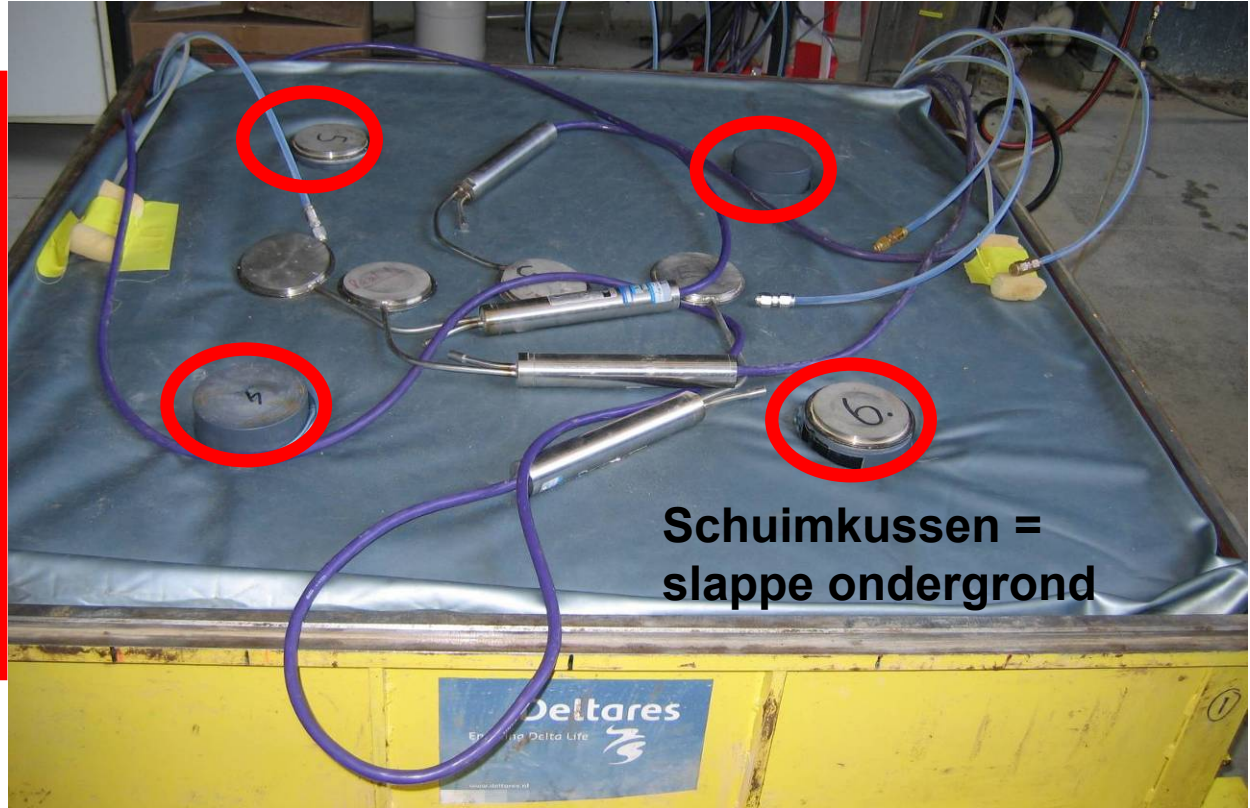
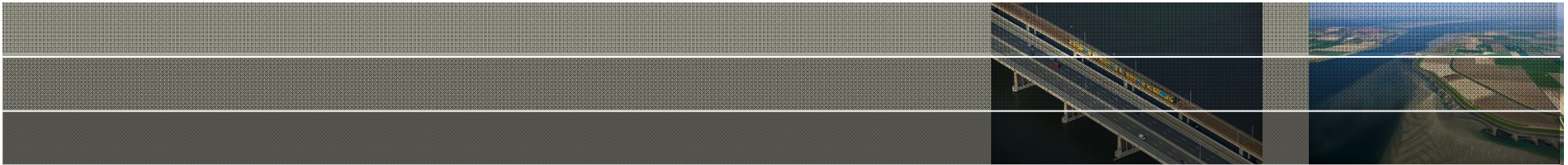
Veldmetingen

Doel labproeven

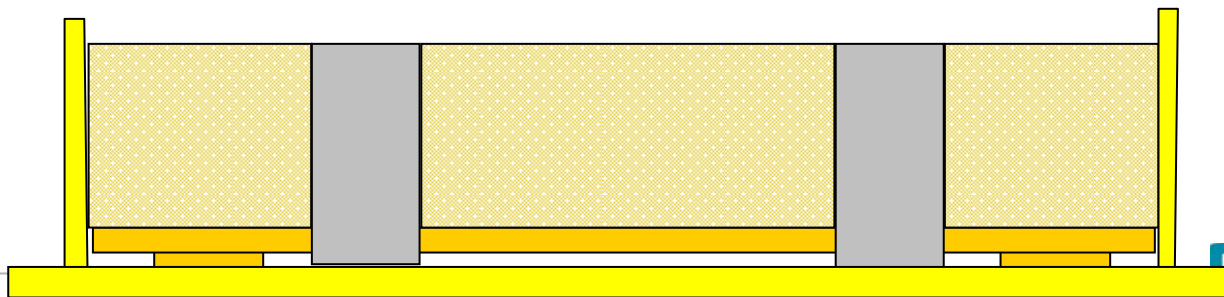
Opzet proeven

Resultaten

Aanpassen model

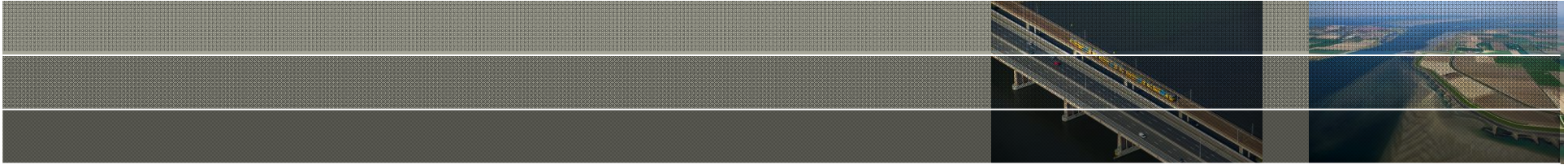


Schuimkussen =  
slappe ondergrond



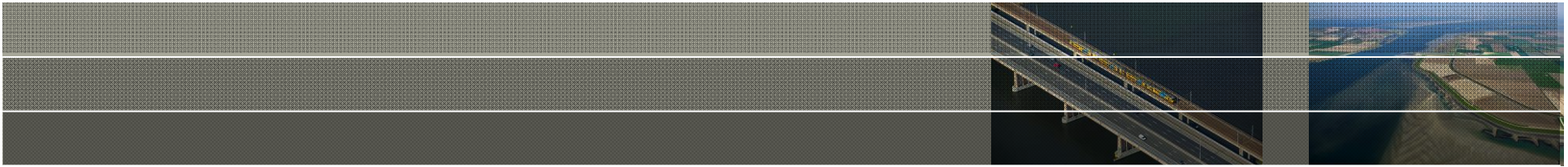
Deltares

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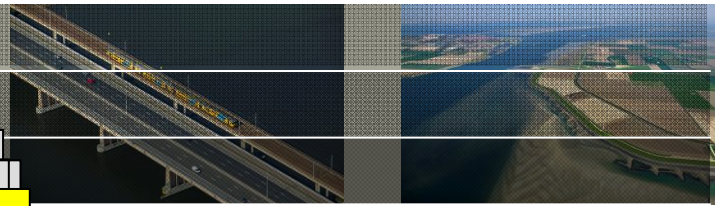
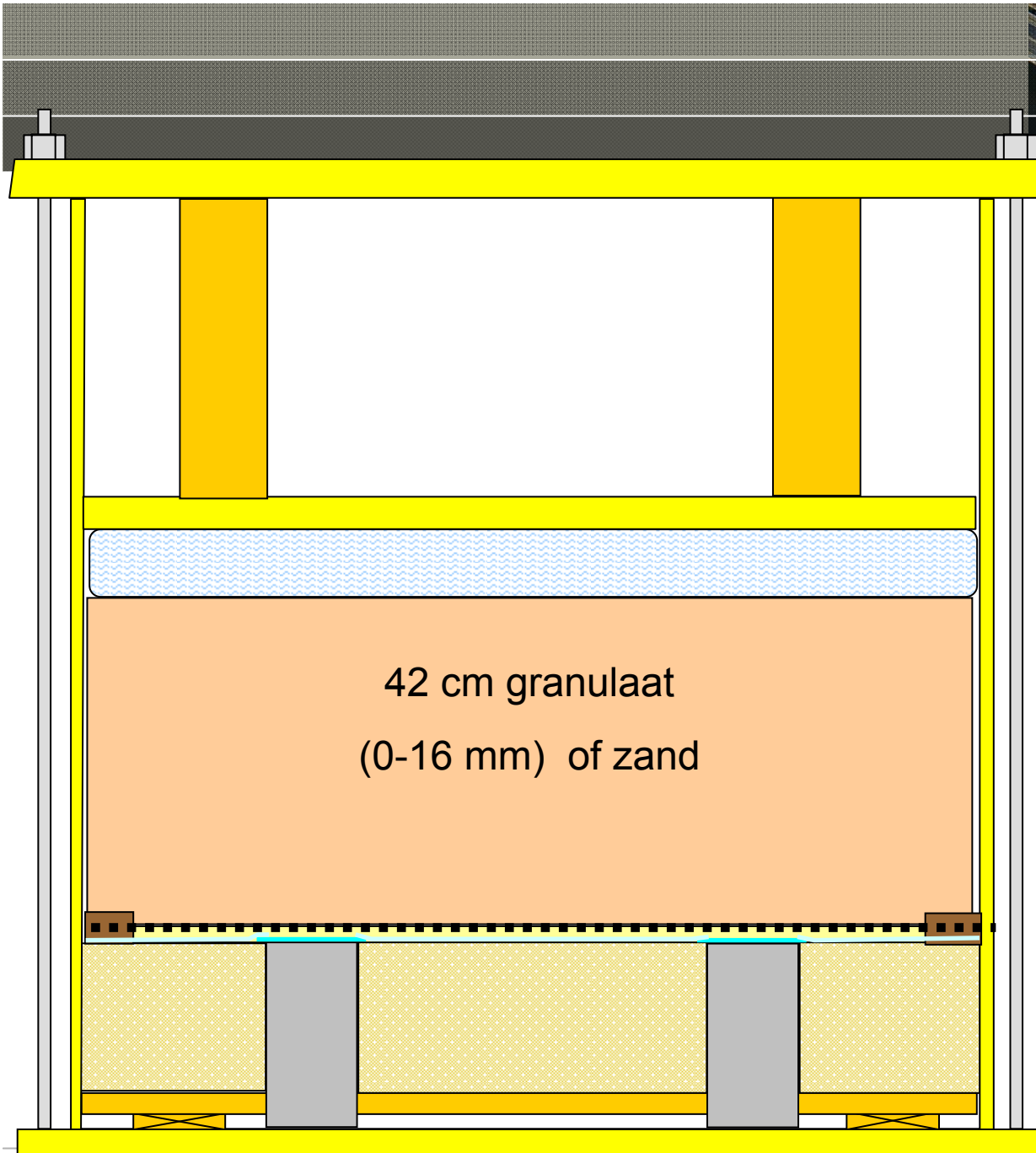


Deltares

27 november 2011



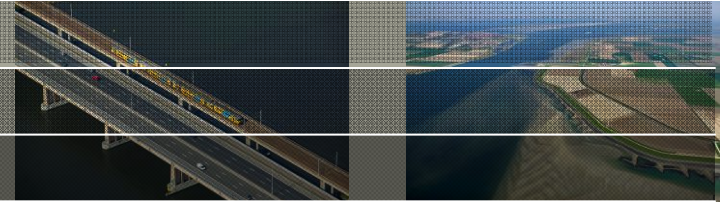
**Deltares**



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# Test procedure



Consolidatie

Bovenbelasting → 25 kPa

Consolidatie

Consolidatie

Consolidatie

Bovenbelasting → 50 kPa

Consolidatie

Consolidatie

Consolidatie

Bovenbelasting → 75 kPa

Consolidatie

Consolidatie

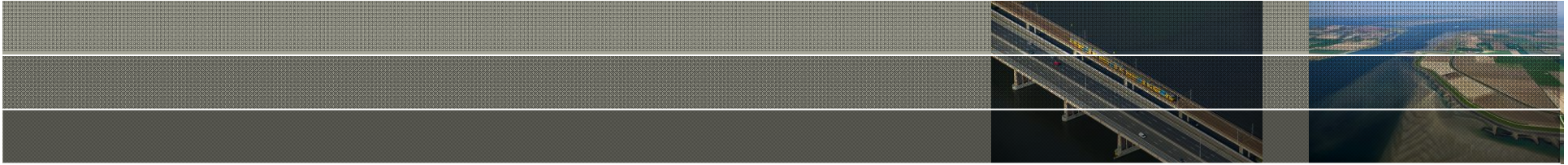
Consolidatie

Bovenbelasting → 100 kPa

Consolidatie

Consolidatie

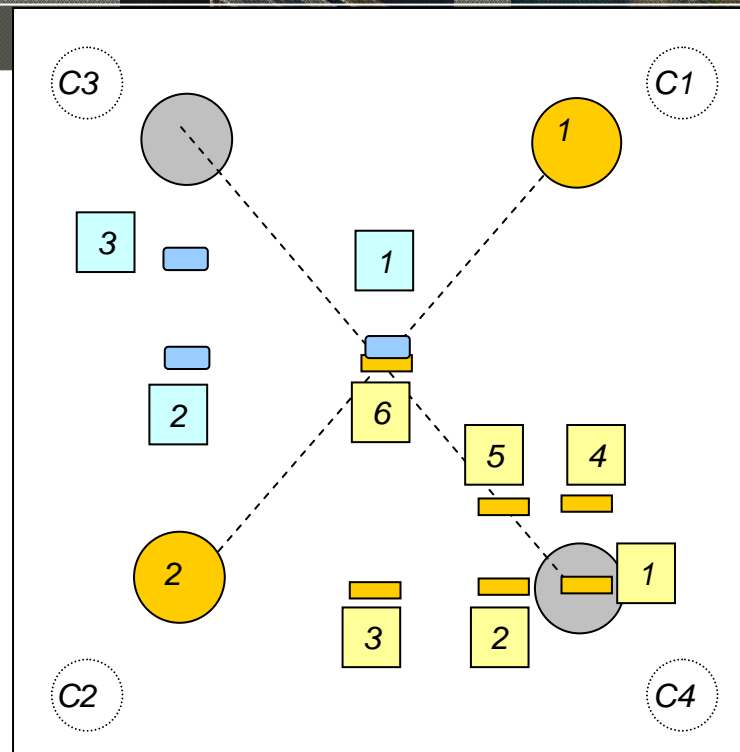
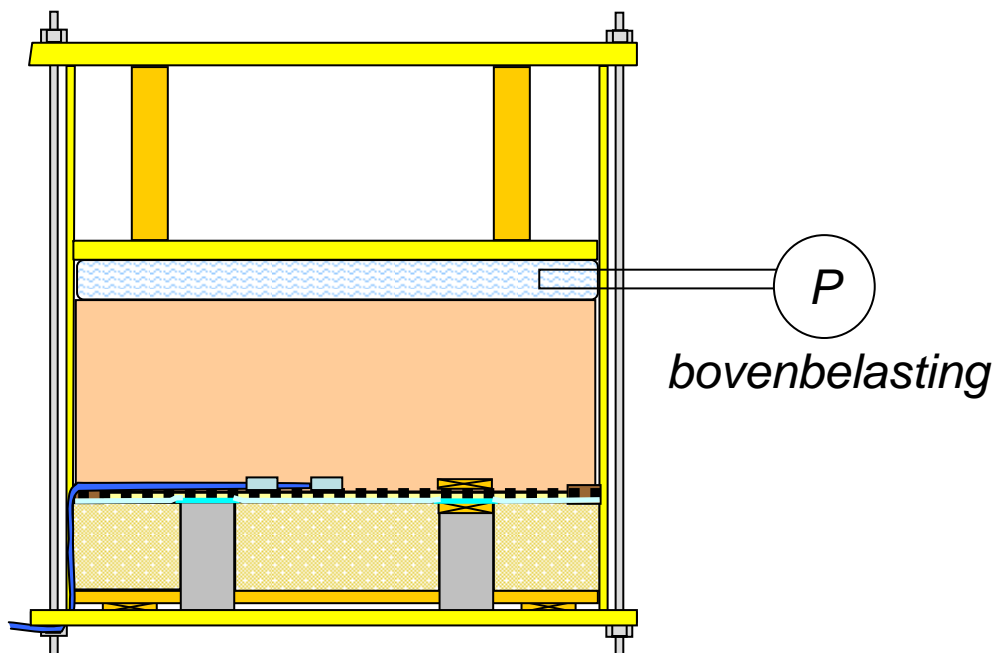
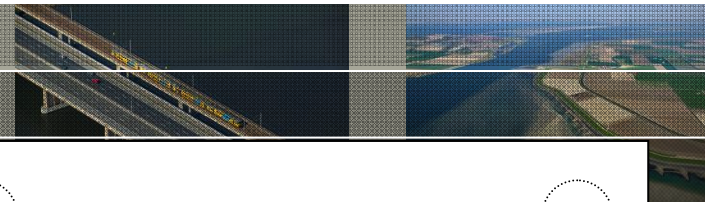
Vacuum



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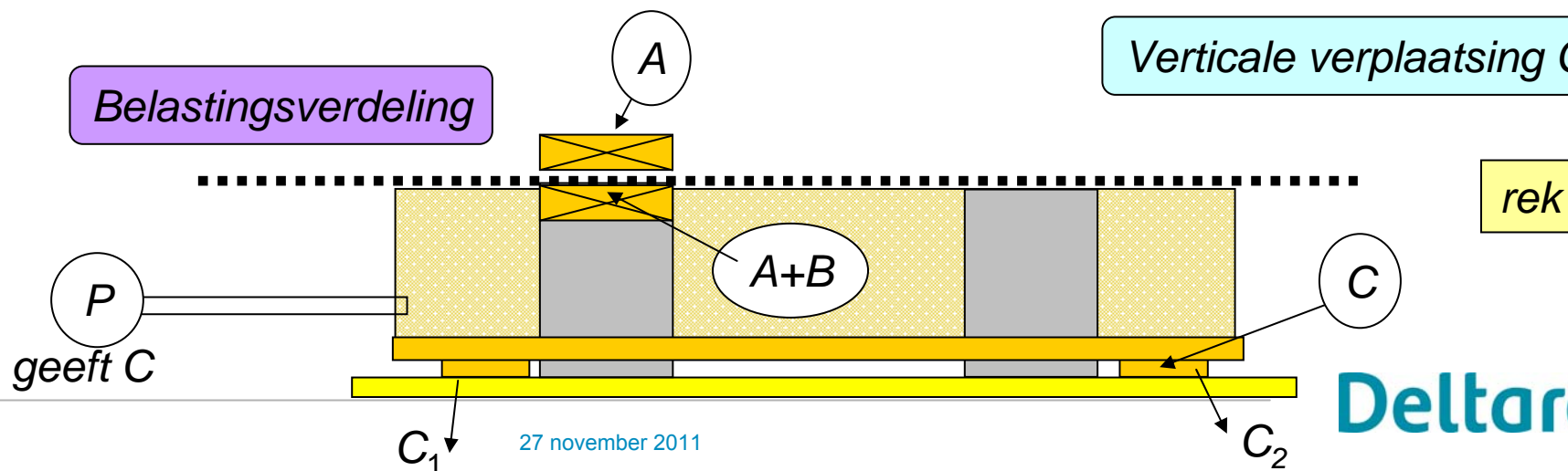
**Deltares**

# Metingen



Belastingsverdeling

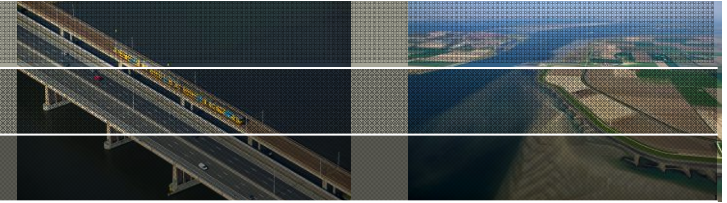
Verticale verplaatsing GR



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Deltares

# Paalmatrasproeven



Samenvatting ontwerp

Veldmetingen

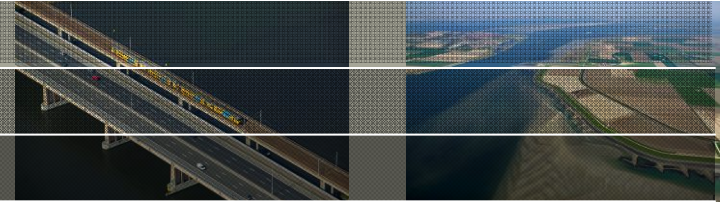
Doel labproeven

Opzet proeven

Resultaten

Aanpassen model

# Resultaten



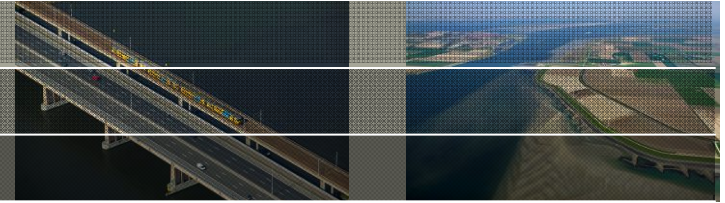
Karakteristieke resultaten

Vergelijking met het CUR/EBGEO ontwerpmodel

1. Stap 1 (boogwerking)
2. Stap 2 (membraan)

Suggesties voor aanpassingen ontwerpmodel

# Resultaten



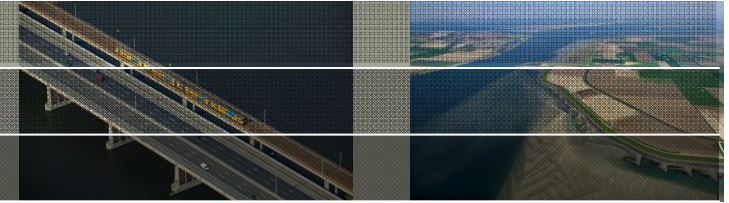
Karakteristieke resultaten

Vergelijking met het CUR/EBGEO ontwerpmodel

1. Stap 1 (boogwerking)
2. Stap 2 (membraan)

Suggesties voor aanpassingen ontwerpmodel

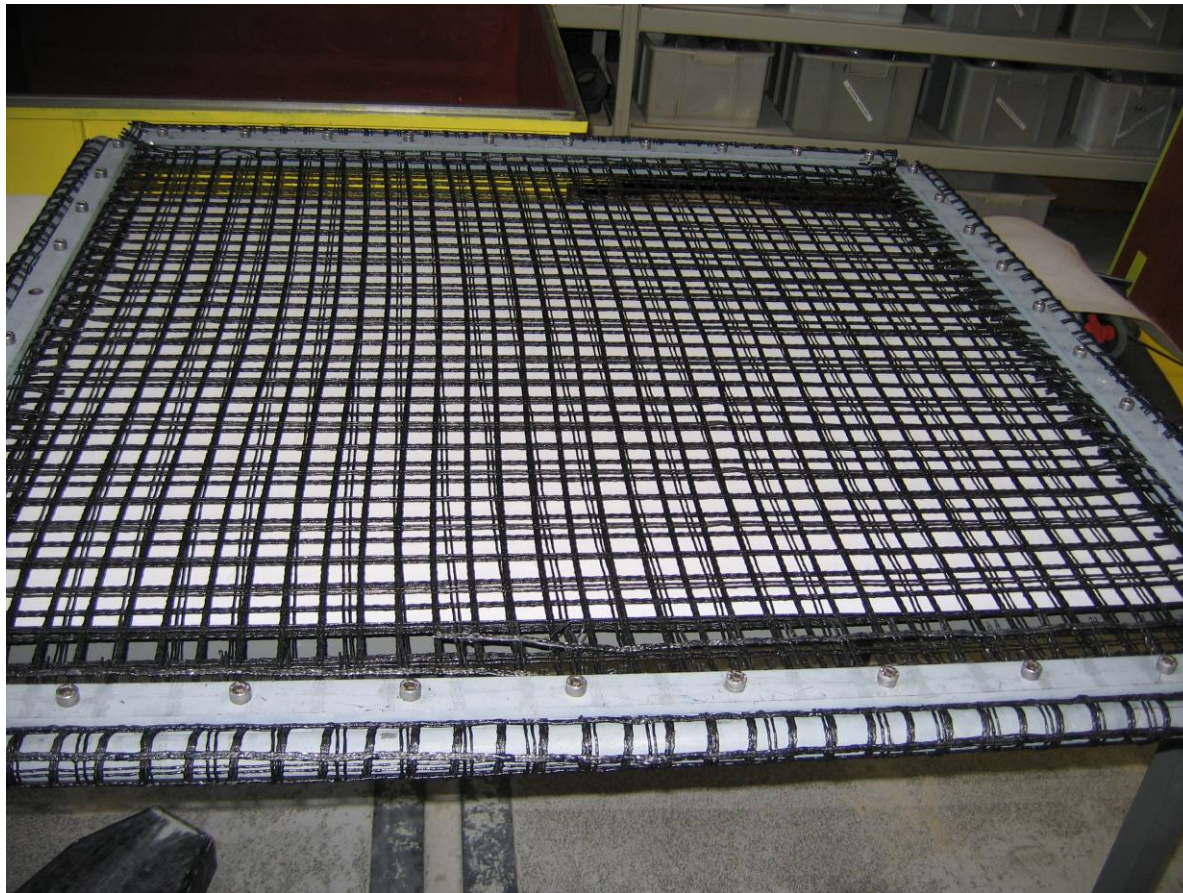
# Karakteristieke resultaten



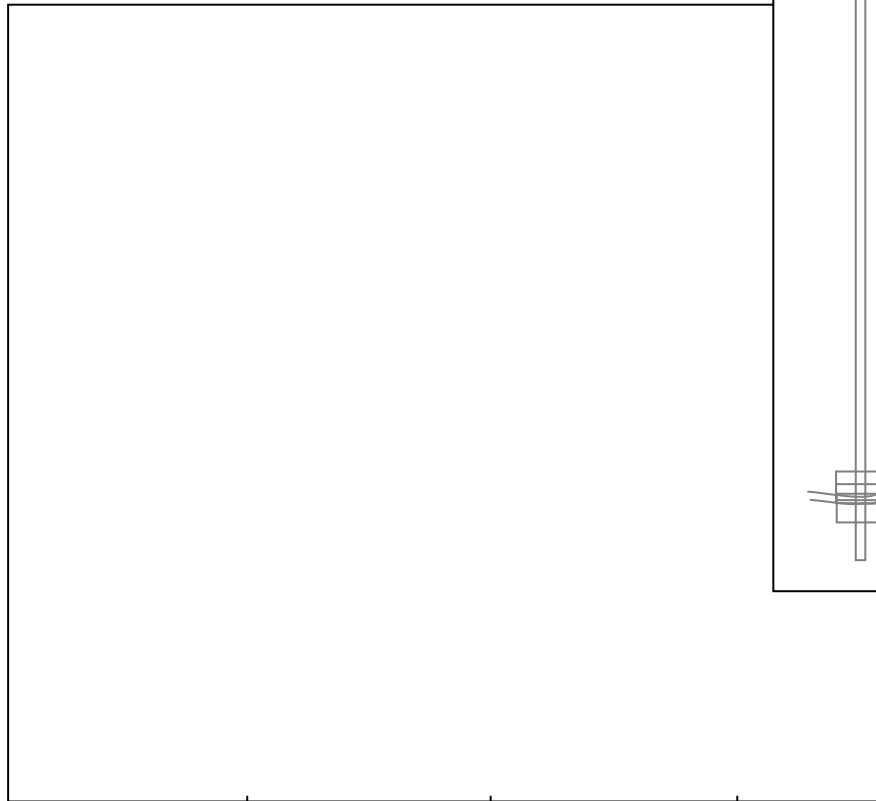
Representatieve proef:

(1 GR laag:  
2 lagen of Huesker  
Fortrac 110/25MP  
op 1 frame)

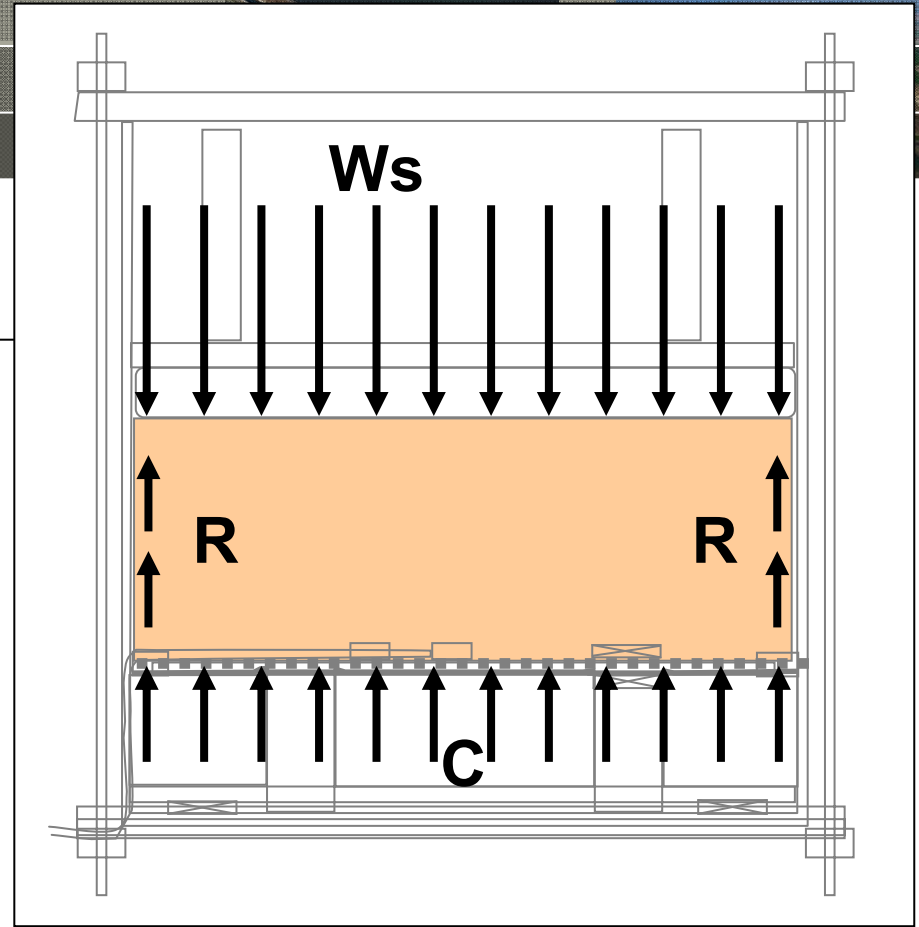
42 cm granulaat  
(0-16.5 mm),  
 $\varphi_{\text{peak}} = 49.0^\circ$ ,  
 $\psi = 9^\circ$



# Stap 1



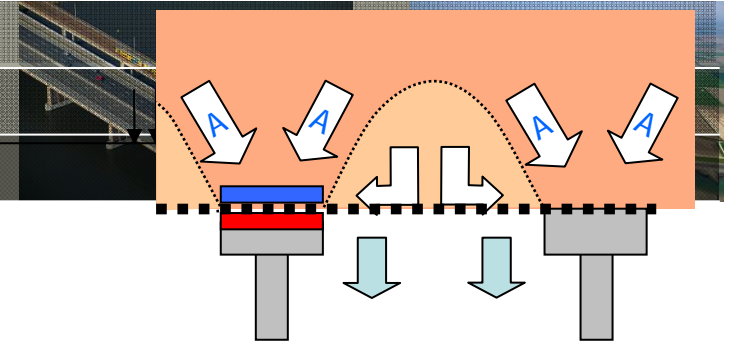
5 10 15



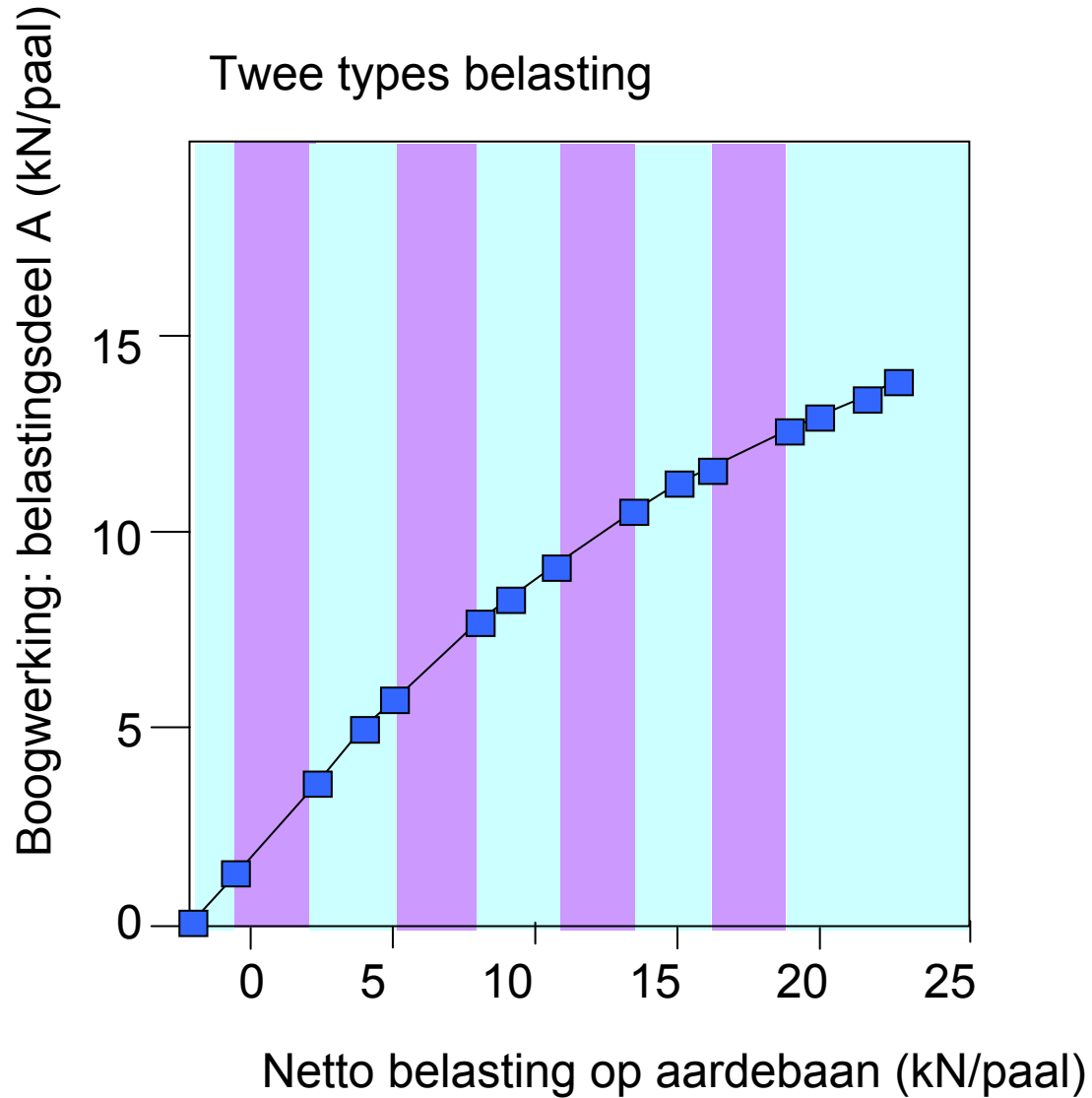
Netto belasting op aardebaan (kN/paal) =  $W_s - R - C$



# Stap 1



Twee types belasting



Consolidatie  
schuimkussen  
(ondergrond)

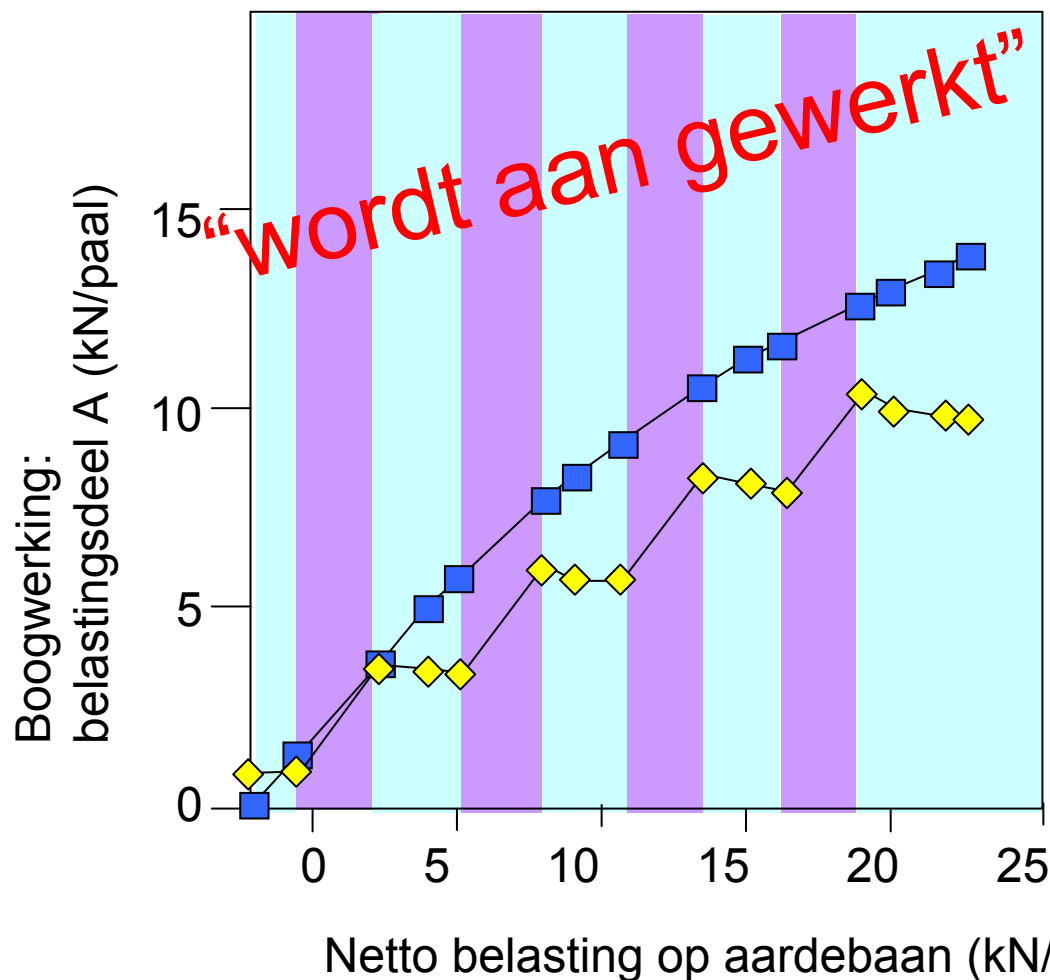
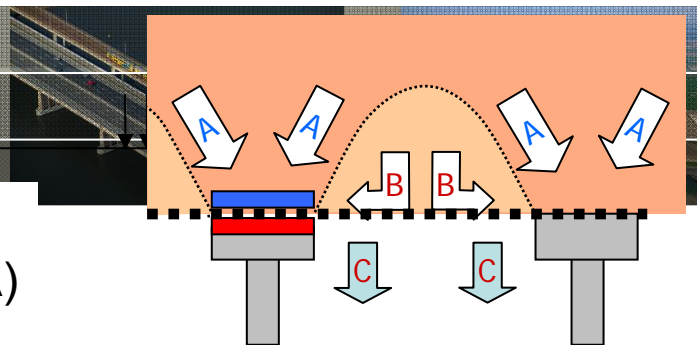
Toename  
bovenbelasting

duidelijke relatie  
netto belasting en A

consolidatie =  
toename boogwerking

# Stap 1

- ✗ Relatie netto belasting en A
- ✗ Consolidatie geeft toename boogwerking (toename A)

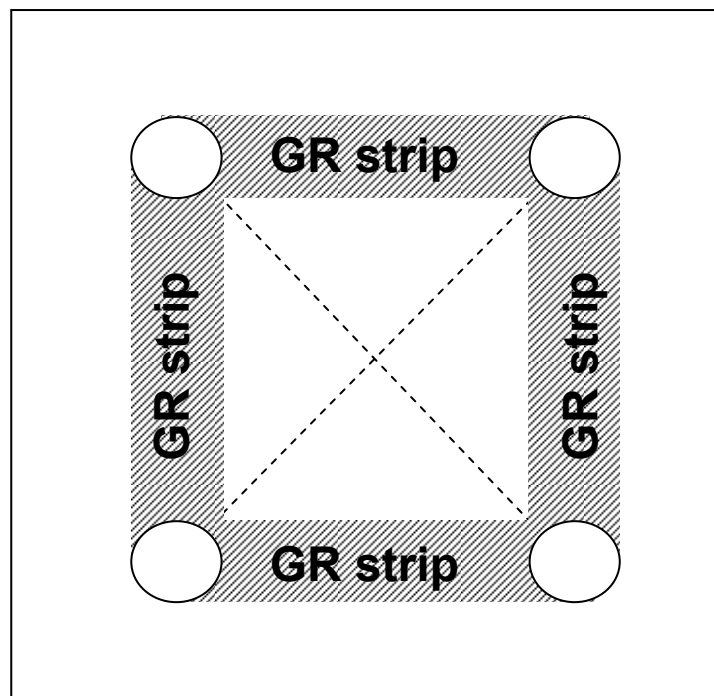
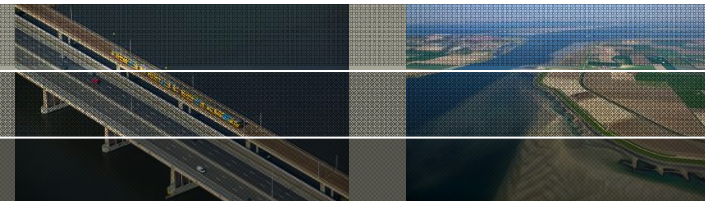


Consolidatie  
schuimkussen  
(ondergrond)

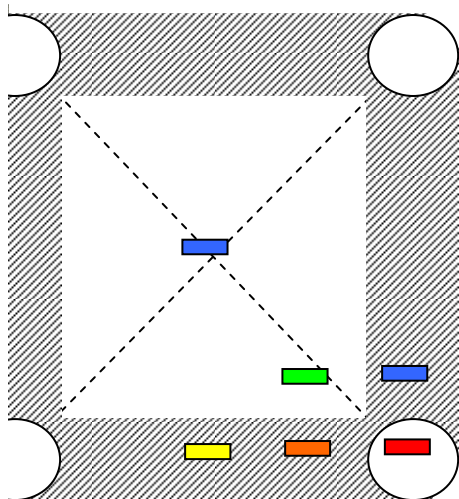
Toename  
bovenbelasting

■ gemeten A kN/paal  
◆ berekende A kN/paal

## Stap 2

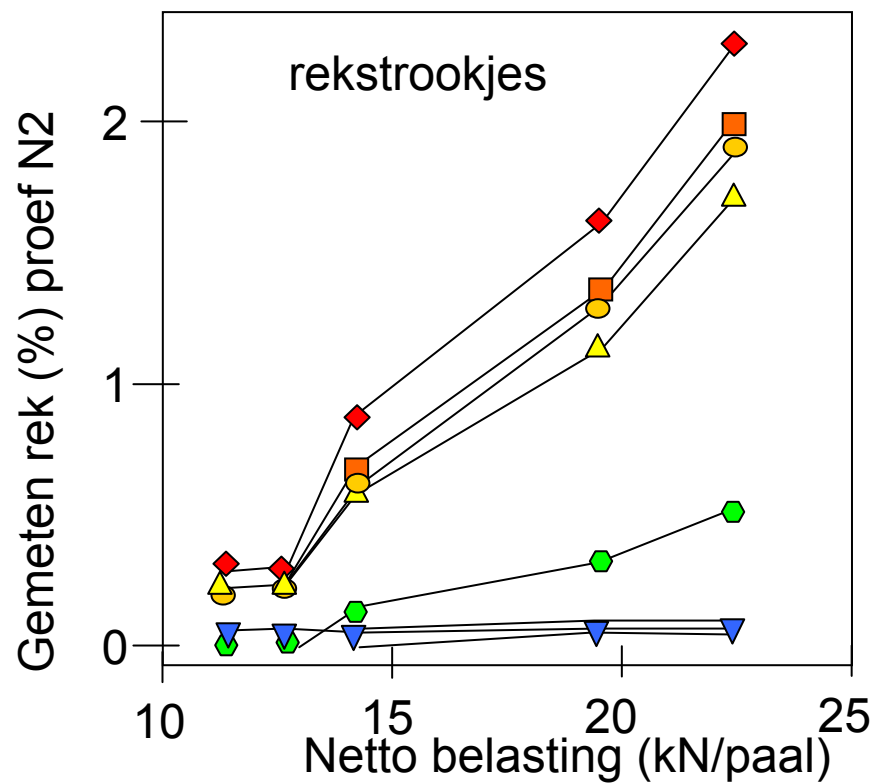
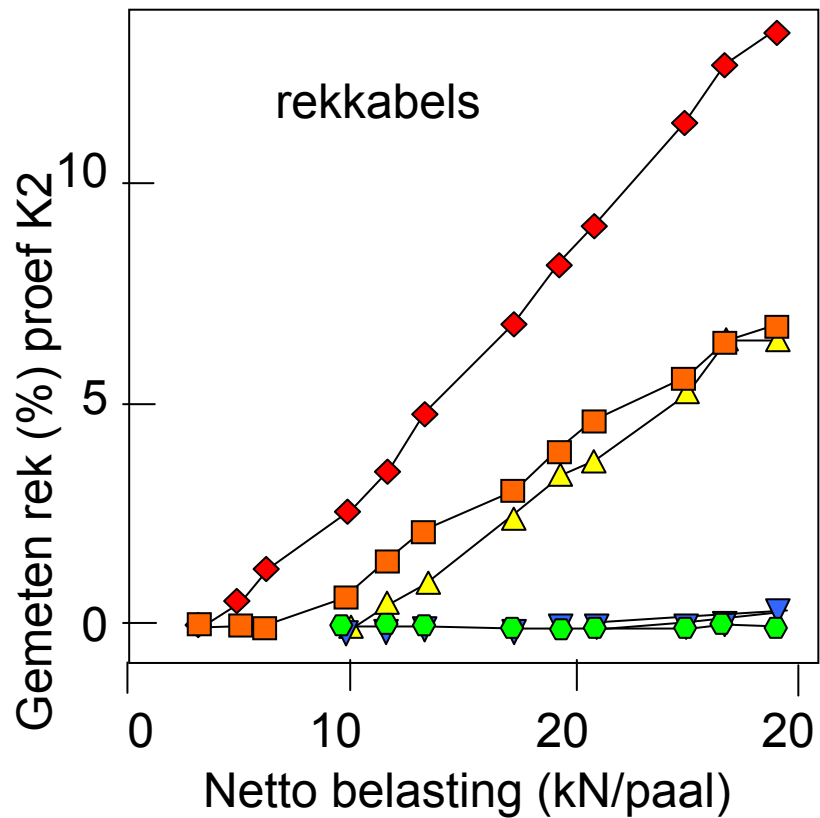
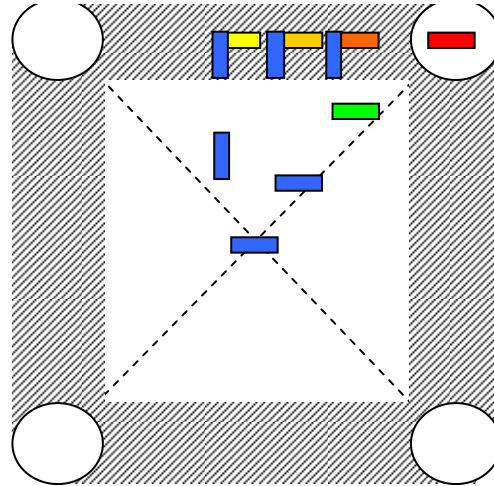


Rekken hoofdzakelijk in de GR strippen

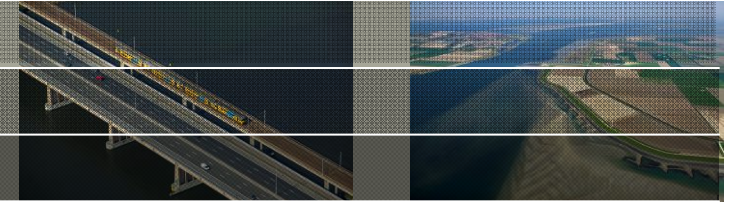


## Stap 2

Rekken hoofdzakelijk in GR strippen



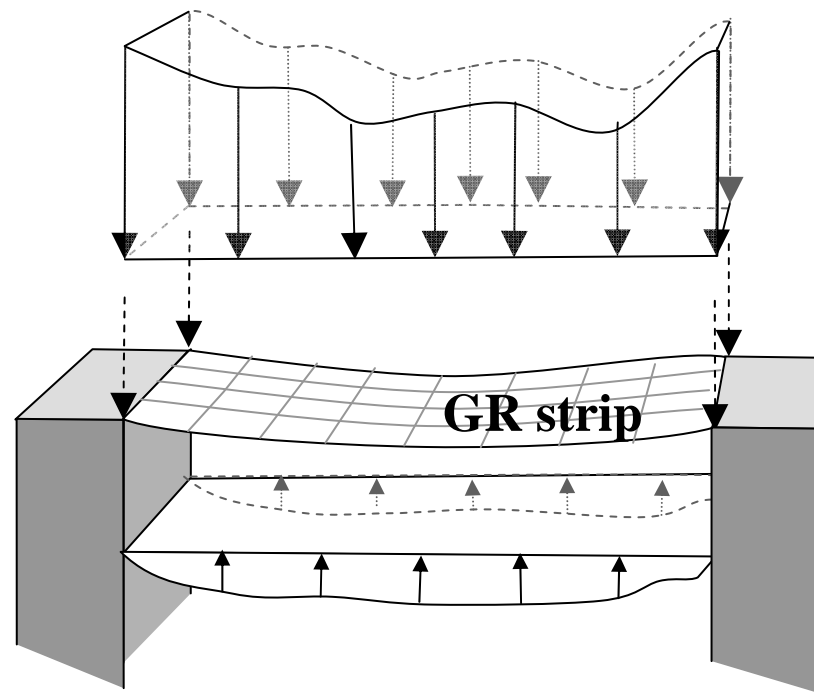
## Stap 2



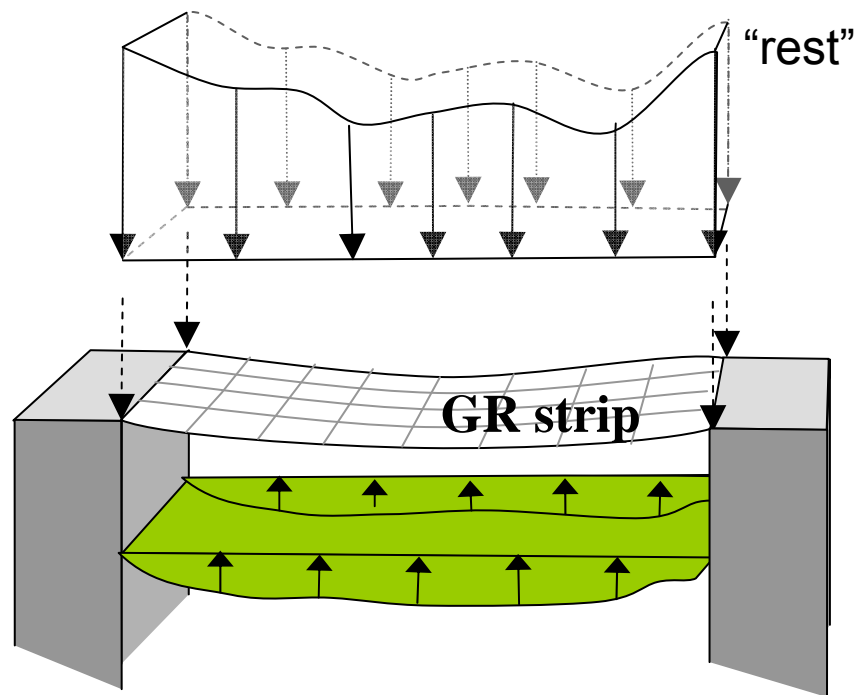
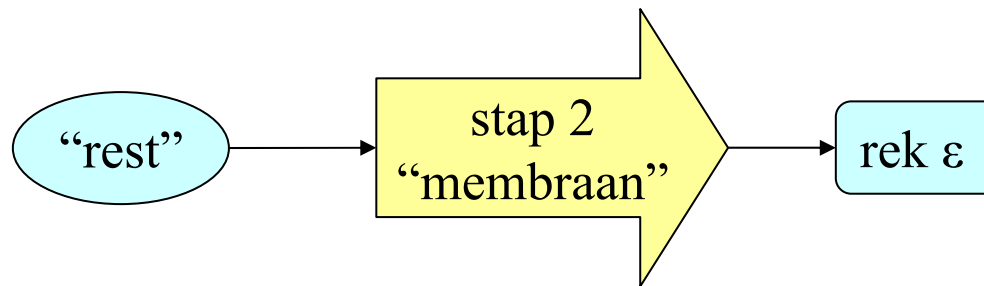
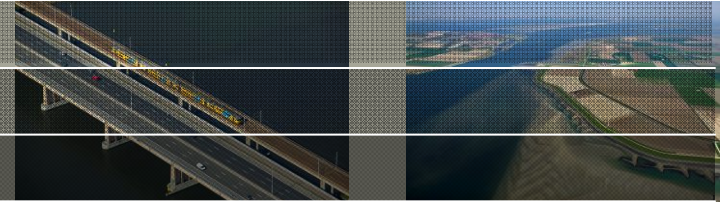
Grootste rekken: op paal

→ voor deze gladde, kleine diameter palen

Op een na grootste rekken: in GR strippen



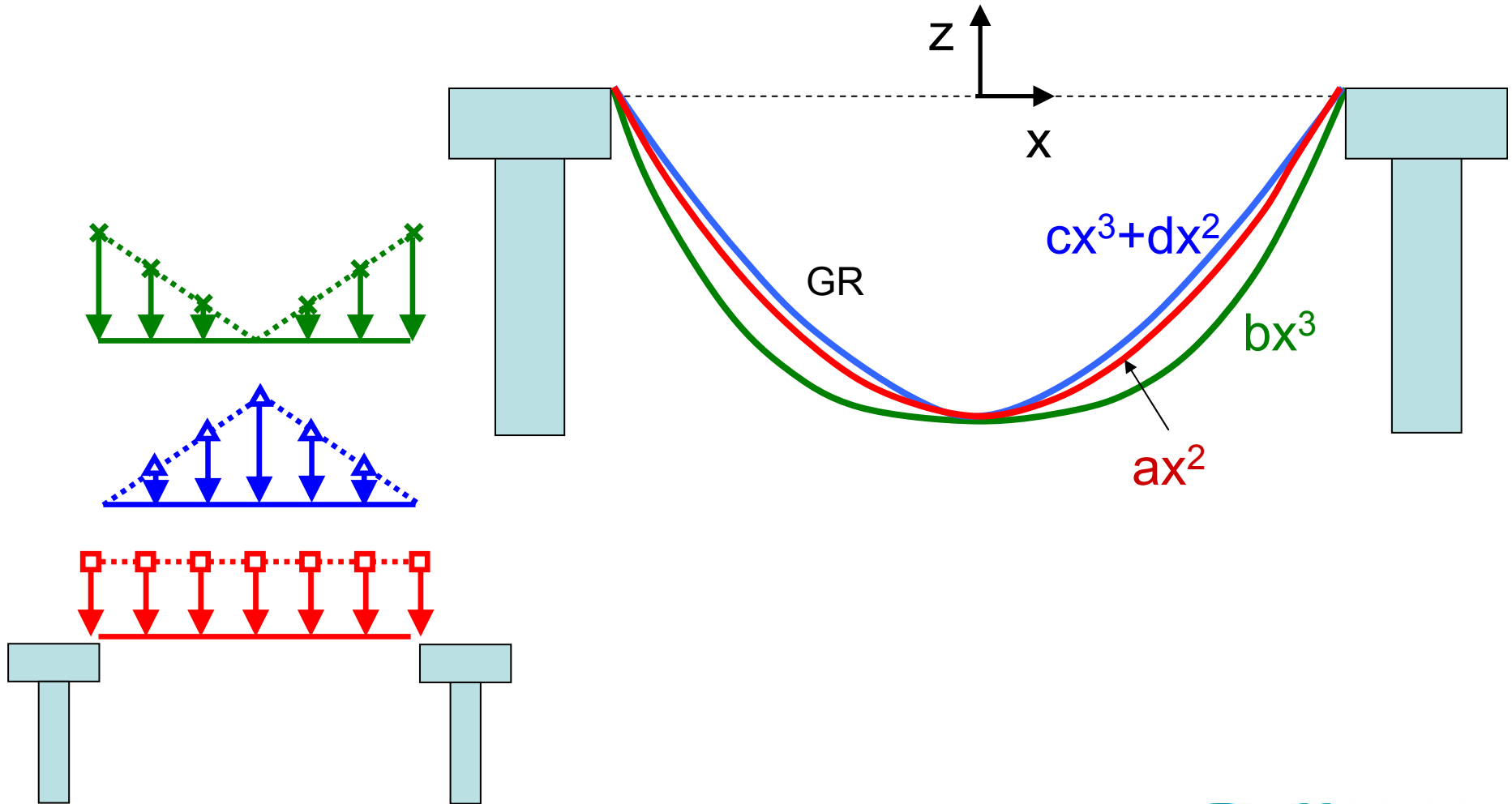
# Stap 2

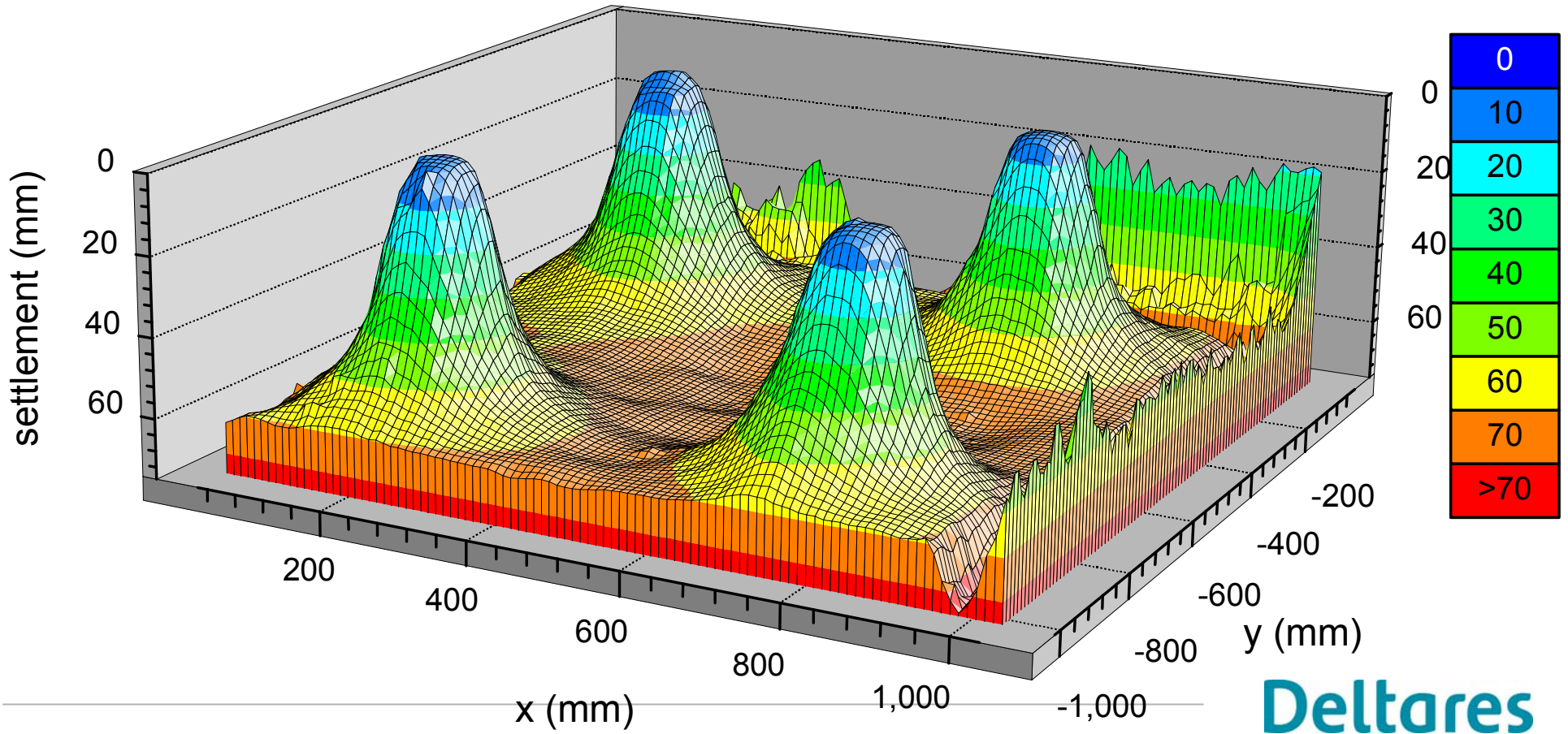
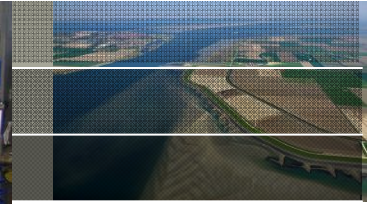


belastingsverdeling



vervorming GR

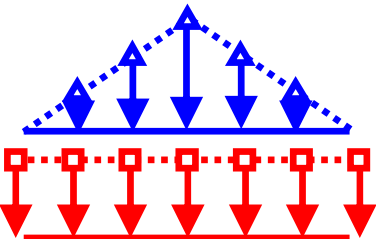
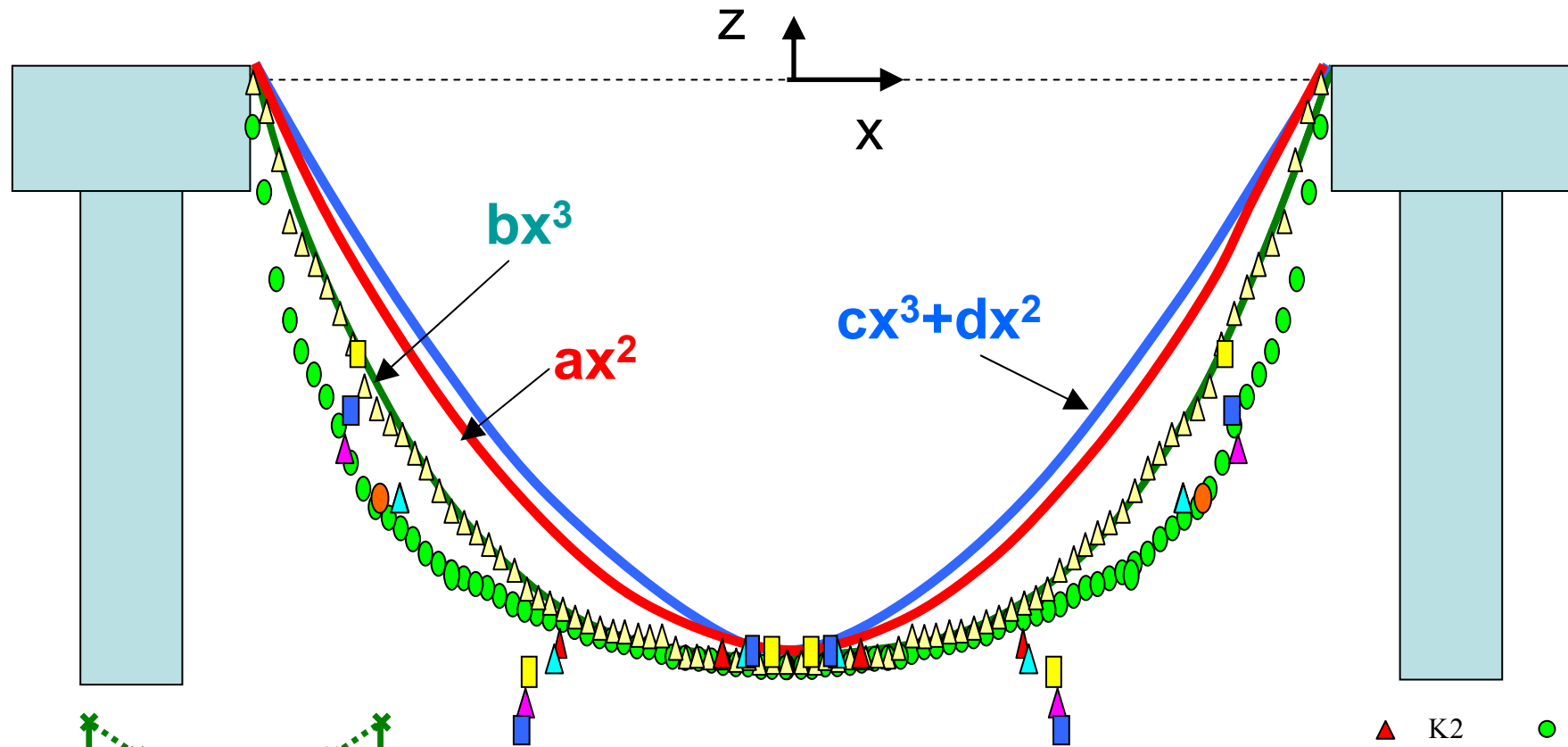




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Deltares

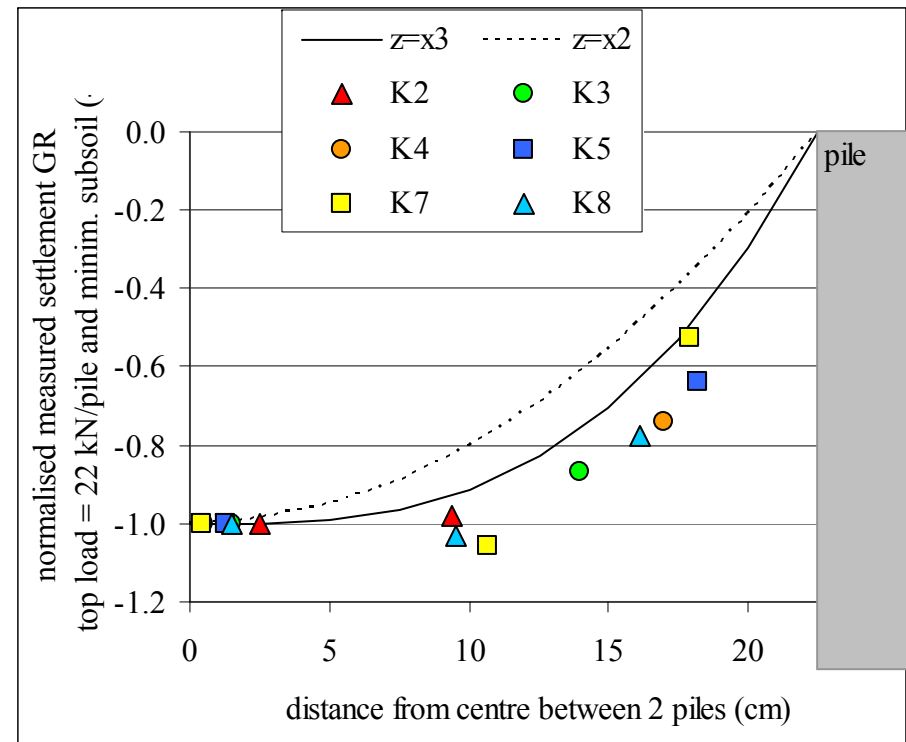
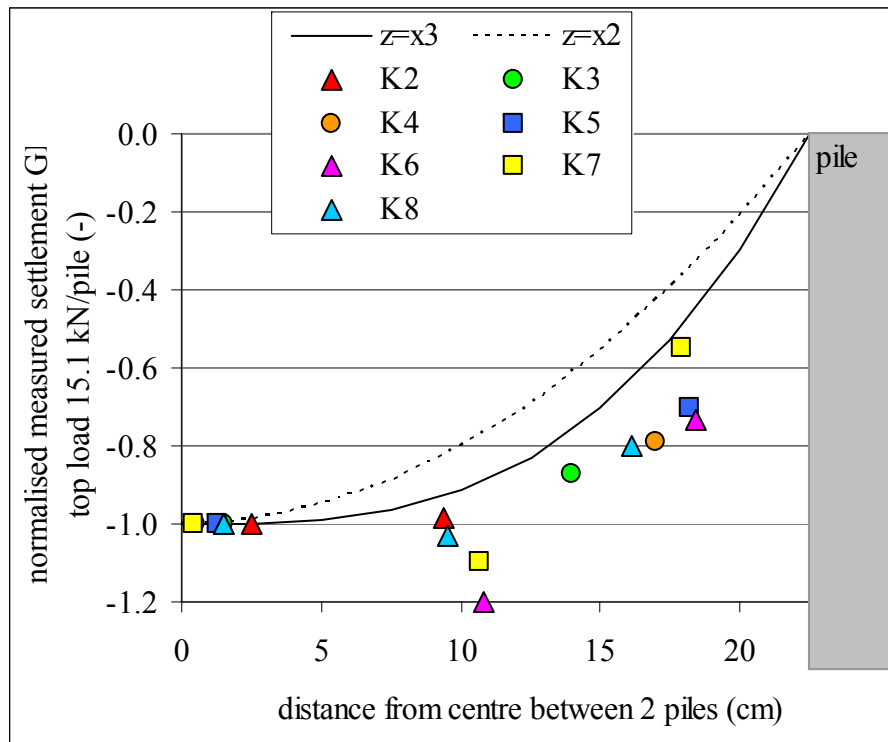


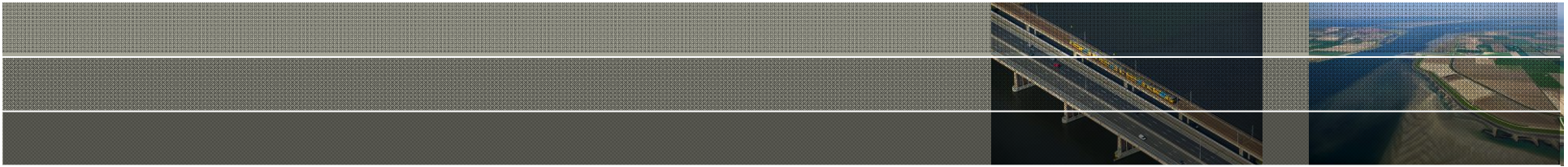


- ▲ K2
- K3
- K4
- K5
- ▲ K6
- K7
- ▲ K8

(eind situatie,  
minimale of geen  
ondersteuning  
ondergrond)

# Situaties voor het einde van de proeven

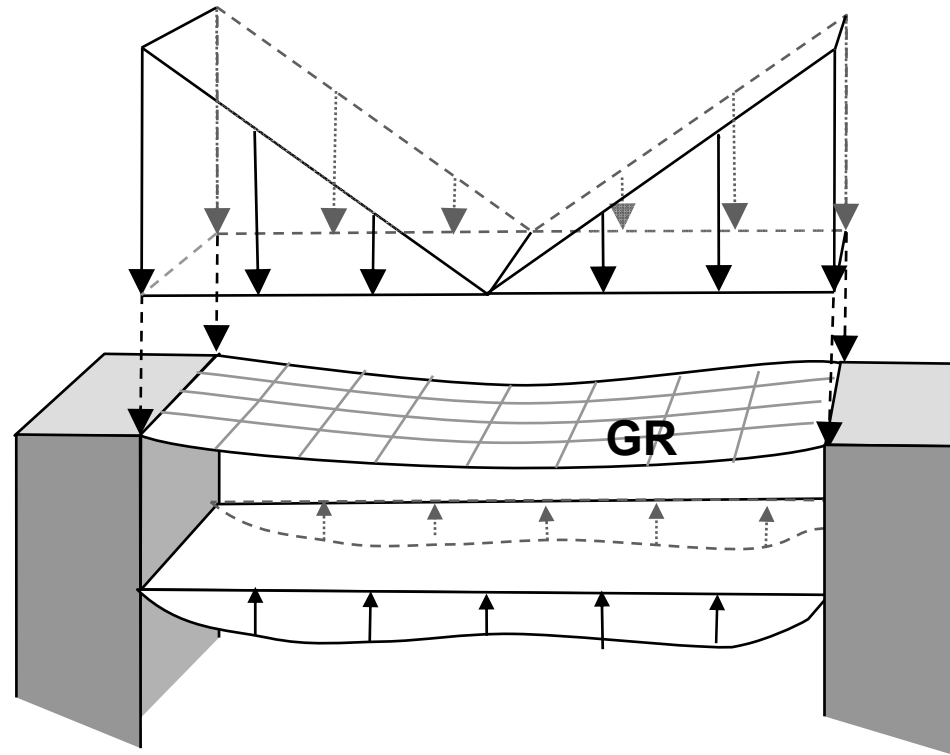




## Conclusie:

Vervormd GR is minstens  $GR = ax^3$  (derde orde polynoom of meer)

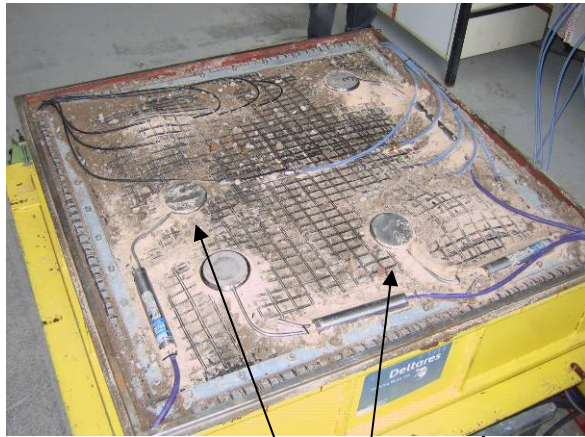
En dus is de belastingsverdeling minstens een inverse driehoek)



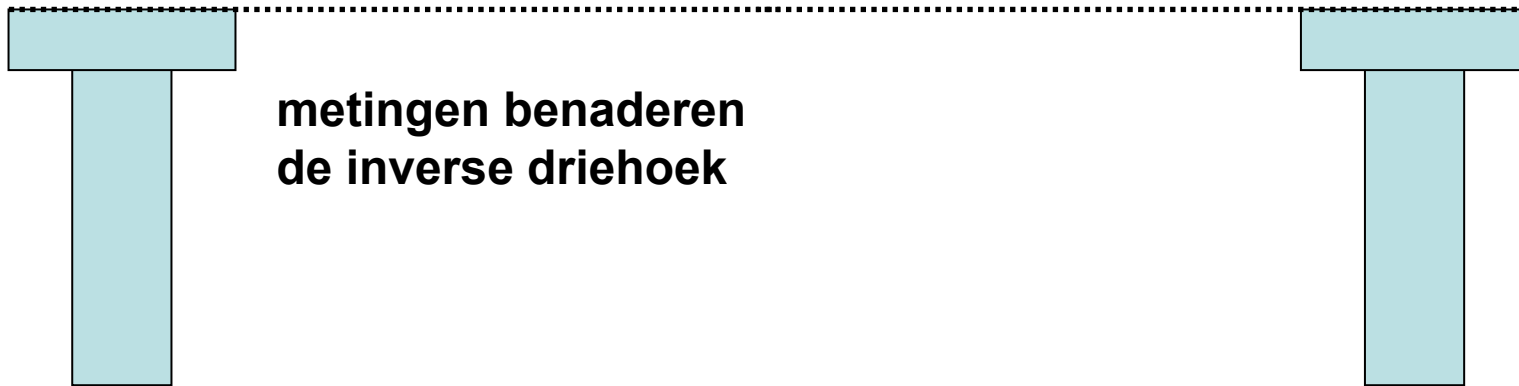
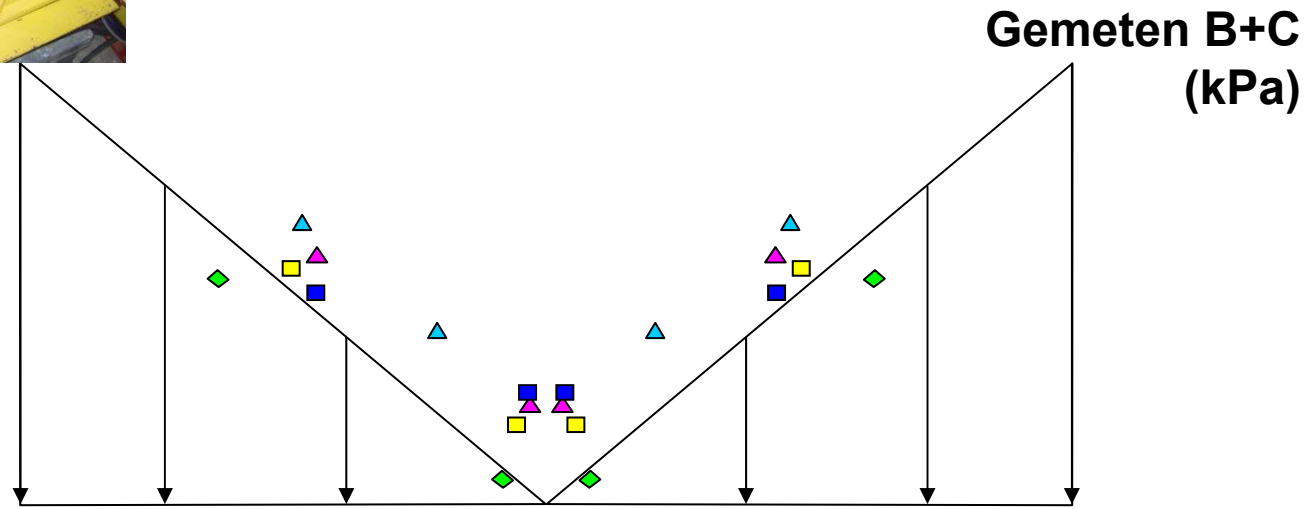
Geconcludeerd uit  
vervorming GR.

Nieuwe serie proeven:  
meting van  
belastingsverdeling

# Gemeten *belastingsverdeling* in aanvullende proeven



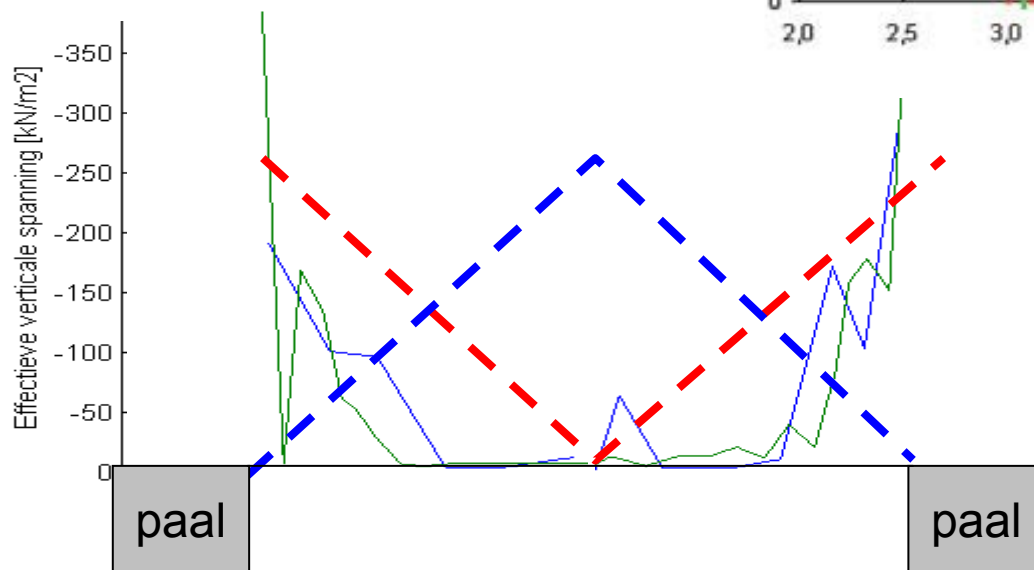
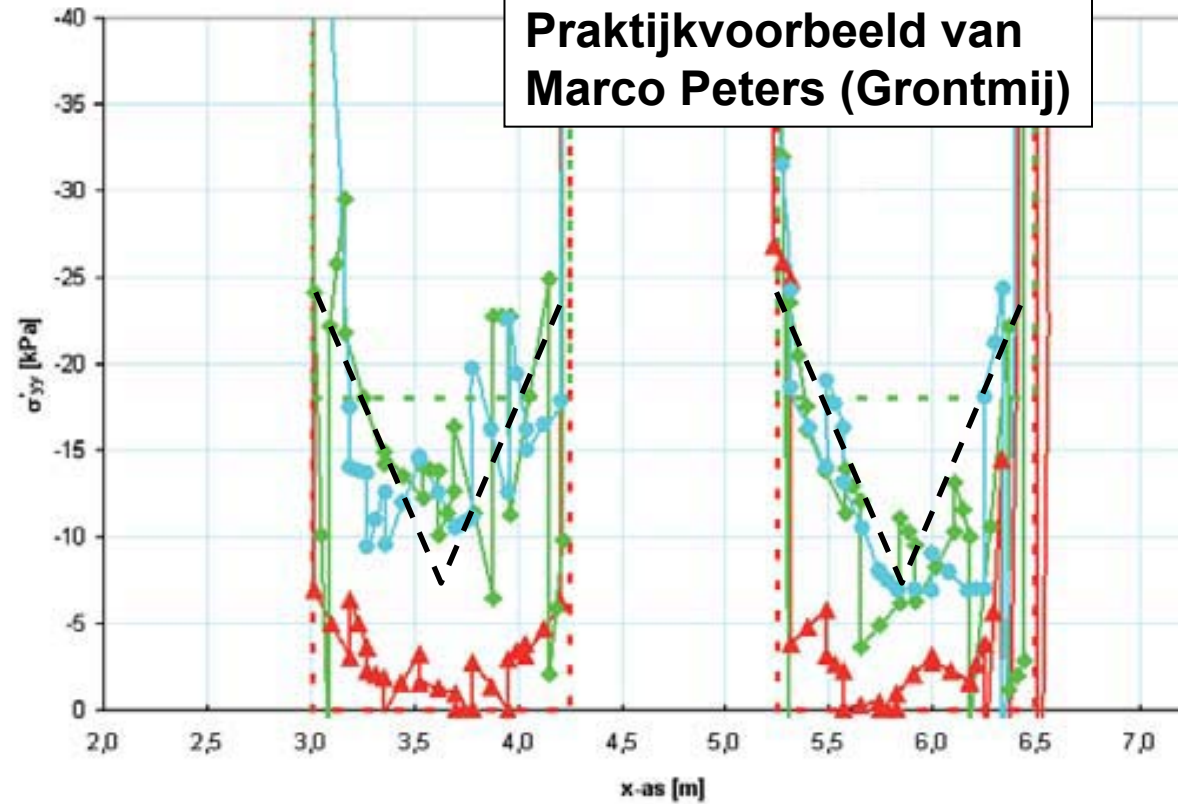
extra  
opnemers

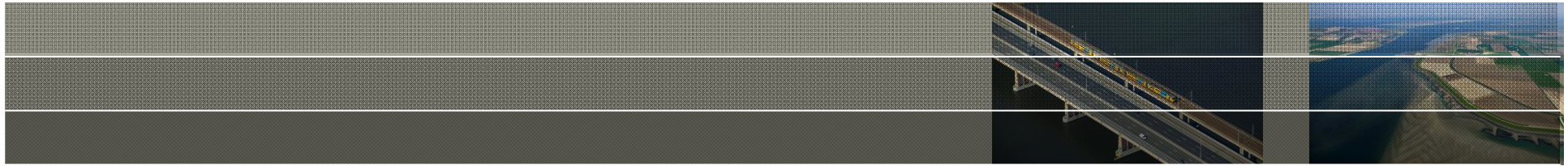


# Eindige elementen

Narekenen proef met  
Plaxis 3D Tunnel  
(Theresa den Boogert,  
nu Mobilis)

Praktijkvoorbeeld van  
Marco Peters (Grontmij)

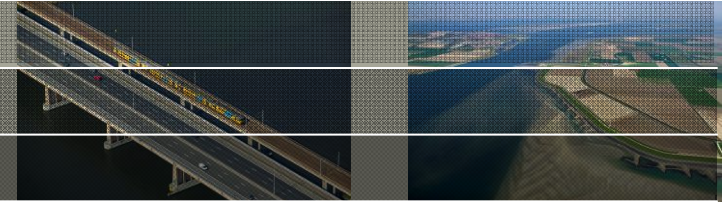




Conclusies tot nu toe (stap 2):

4. Rekken vooral in GR strippen
5. Belastingsverdeling: inverse driehoek

# Paalmatrasproeven



Samenvatting ontwerp

Veldmetingen

Doel labproeven

Opzet proeven

Resultaten

**Aanpassen model**

# Vergelijking rekenmodel en metingen



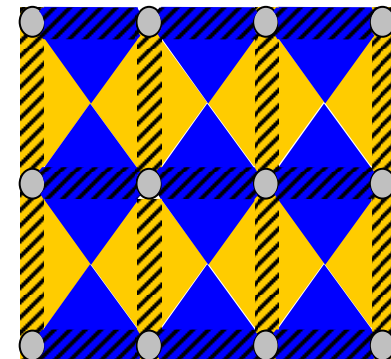
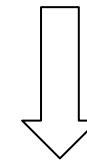
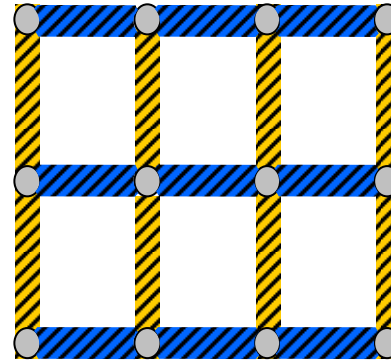
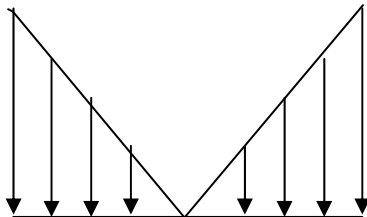
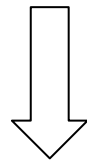
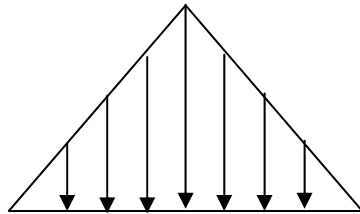
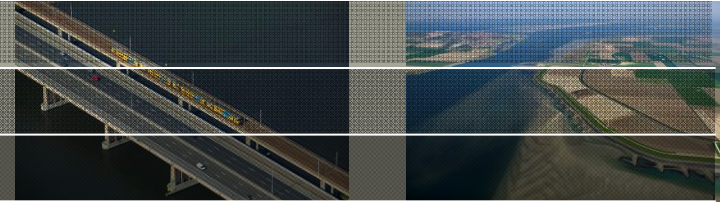
Stap 2:

Twee aanpassingen:

- belastingsverdeling
- ondergrond

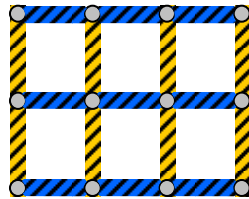
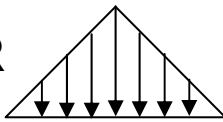


# Het effect van:

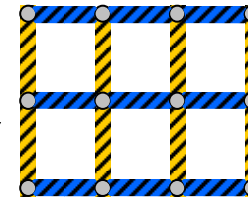
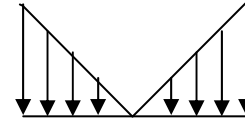


Herman-Jaap  
Lodder

◆ EBGEO/CUR

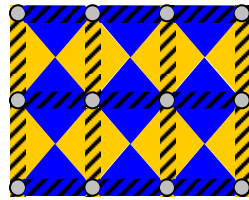
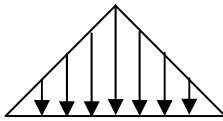


▼

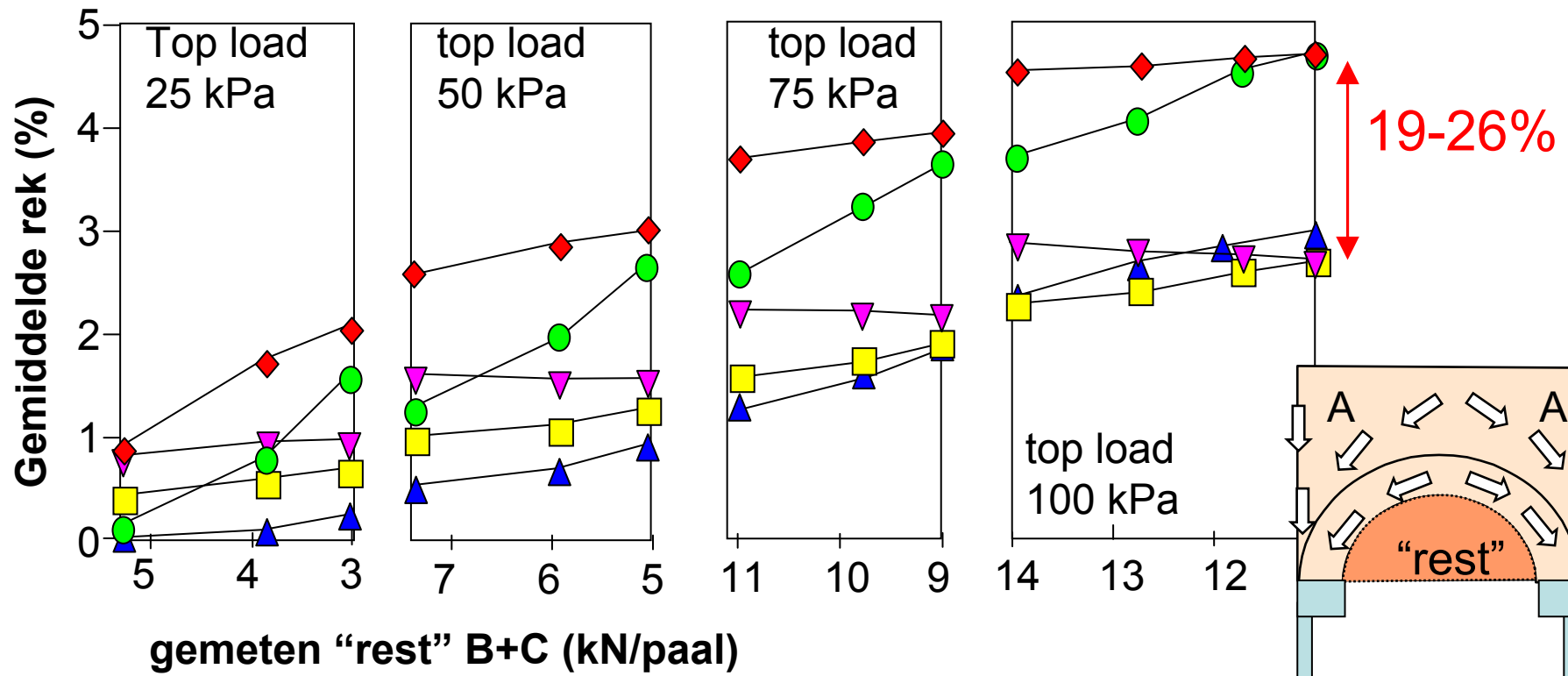
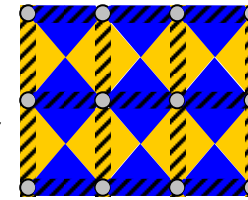
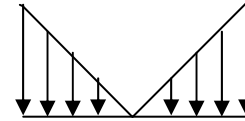


▲ gemeten

●

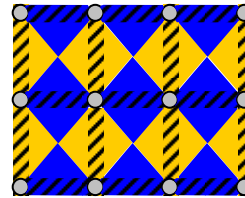
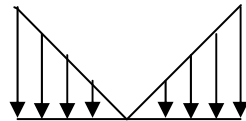


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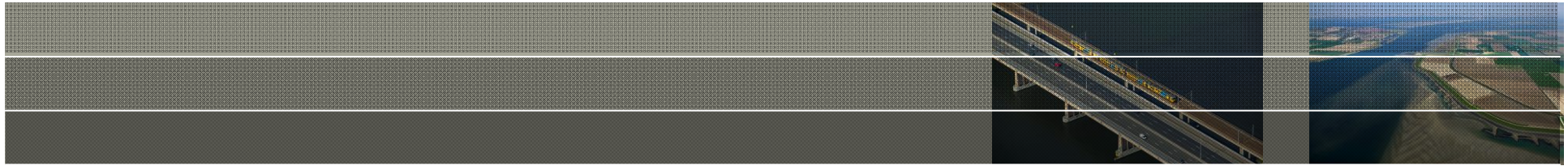


# Conclusies

- EBGEO/CUR berekent hogere rekken dan we meten.



- Stap 2: inverse driehoek en aangepaste ondergrondmodel geven betere overeenstemming met metingen
- Deze aanpassingen geven (voor dit geval) een besparing in de benodigde GR sterkte van 19-26%.
- Aanpassingen stap 1: wordt aan gewerkt

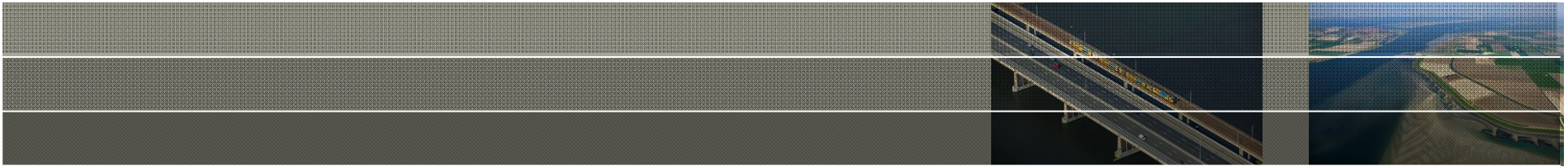


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Deltares, Delft Cluster



Bedankt voor de aandacht!

