Semi Probabilistic approach to reduce maintenance costs of wooden pile foundations

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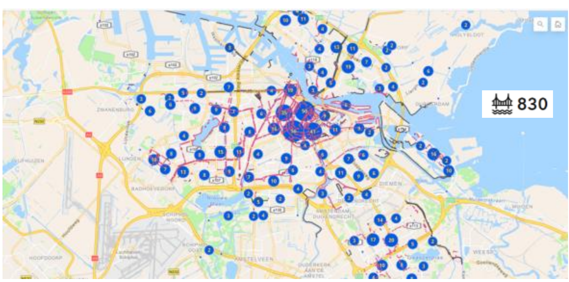
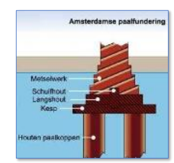
Outline

- Problem: Reduce costs for maintenance of (historic) bridges in Amsterdam
- Previous solution: Based on calculation values
- New solution: Based on probabilistic approach
- Challenges: Obtain data for probabilistic approach
- Conclusion: What are the benefits

Amsterdam bridges

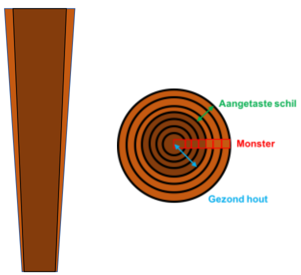


Bridges in Amsterdam



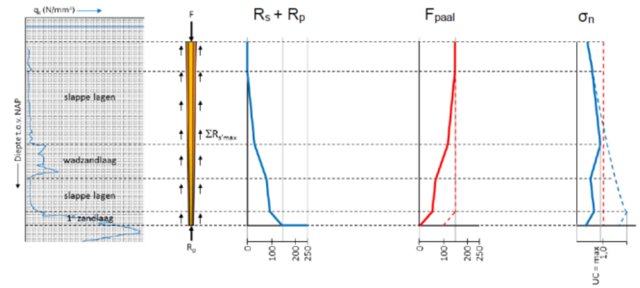
- wooden piles under historic bridges (> 200)
- limited possibility for inspection
- bacterial degradation

Pile geometry

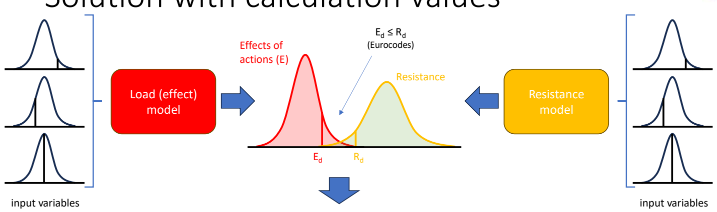


- Pile properties:
  - Bacterial degradation ->
    - Skin does not contribute to strength
  - Top diameter
  - Tapering
  - Timber strength
  - Top load
  - Redistribution
- Structural assessment:
  - Check timber strength (f_{timber}) is sufficient to carry stress (f_{pile}) due to top load
- Geotechnical assessment
  - Check whether pile-soil interaction is enough to carry top load

Pile-soil interaction



Solution with calculation values



$$UC = \frac{E_d}{R_d}$$

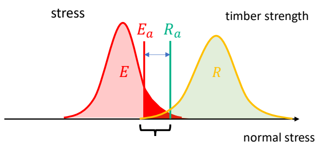
UC < 1: approved
UC > 1: failing

Towards a (semi-)probabilistic solution

- Probability distribution of strength and resistance
- Use calculation values for some parameters:
  - Timber strength (α_E)
  - Pile-soil interaction (α_R)
- Safety class prescribe accepted probability of failure

Safety cl.	β	$\alpha_{E(STR)}$	$\alpha_{R(GEO)}$	$P_{exc\ str}$	$P_{exc\ GEO}$
CC1	1.8			0.104	0.075
CC2	2.5	-0.7	0.8	0.040	0.023
CC3	3.3			0.010	0.004

- Leads to assessment values (E_a and R_a), corresponding with probability of exceedance



$$UC = \frac{E_a}{R_a}$$

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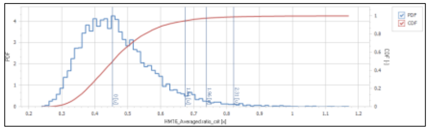
Monte Carlo analysis

Safety class	β	$\alpha_{E(STR)}$	$\alpha_{R(GEO)}$	$P_{exc\ str}$	$P_{exc\ GEO}$	Required samples
CC1	1.8			0.104	0.075	300
CC2	2.5	-0.7	0.8	0.040	0.023	1000
CC3	3.3			0.010	0.004	5000



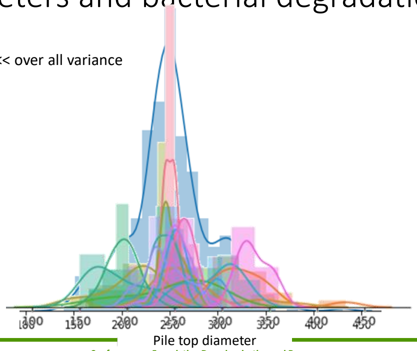
$$UC = \frac{E_a}{R_a}$$

Applying a probabilistic model

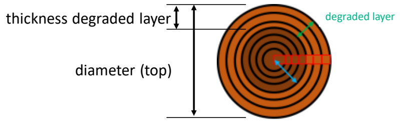
- Get enough data
  - Perform measurements on extracted piles
  - Send divers to inpect piles on site

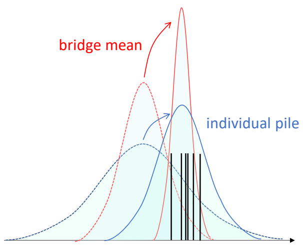
Pile diameters and bacterial degradation

Variance within bridge << over all variance



Bayesian model



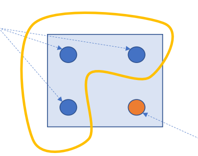


Bayesian updating:

Bridge data "+" Amsterdam data =>
data per pile in bridge incl. std. dev.

Samples and unsampled piles

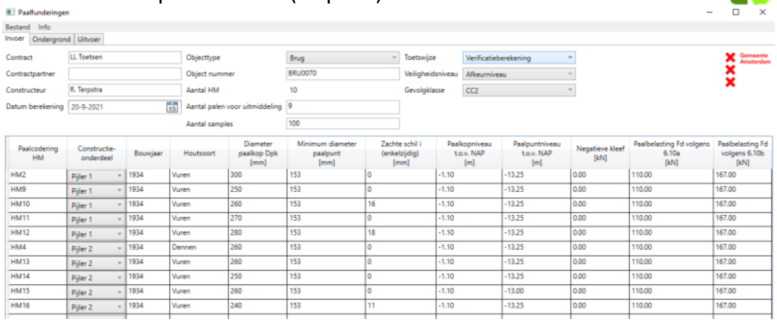
Unsampled piles:
Apply Bayesian updated distribution of diameter and bacterial degradation



Redistribution:
Redistribute top load so that maximum stress in all piles is equal

Sampled pile:
Apply measured diameter and bacterial degradation

GUI impression (input)



Paalfunderingen

Bestand Info

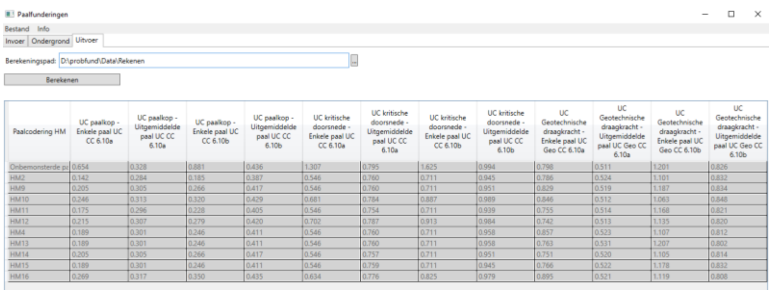
Invoer | Ondergrond | Uitvoer

Contract: LL Toetsen
Contractpartner:
Constructeur: R. Terpstra
Datum berekening: 20-9-2021
Objecttype: Brug
Object nummer: BRU0070
Aantal HM: 10
Aantal palen voor uitmiddeling: 9
Aantal samples: 100
Toetswijze: Verificatieberekening
Veiligheidsniveau: Afkeurniveau
Gevolgklasse: CC2

Gemeente Amsterdam

Paalcodering HM	Constructie-onderdeel	Bouwjaar	Houtsoort	Diameter paalkop Dpk [mm]	Minimum diameter paalpunt [mm]	Zachte schil i (enkelzijdig) [mm]	Paalkopniveau t.o.v. NAP [m]	Paalpuntniveau t.o.v. NAP [m]	Negatieve kleef [kN]	Paalbelasting Fd volgens 6.10a [kN]	Paalbelasting Fd volgens 6.10b [kN]
HM2	Pijler 1	1934	Vuren	300	153	0	-1.10	-13.25	0.00	110.00	167.00
HM9	Pijler 1	1934	Vuren	250	153	0	-1.10	-13.25	0.00	110.00	167.00
HM10	Pijler 1	1934	Vuren	260	153	16	-1.10	-13.25	0.00	110.00	167.00
HM11	Pijler 1	1934	Vuren	270	153	0	-1.10	-13.25	0.00	110.00	167.00
HM12	Pijler 1	1934	Vuren	280	153	18	-1.10	-13.25	0.00	110.00	167.00
HM4	Pijler 2	1934	Dennen	260	153	0	-1.10	-13.25	0.00	110.00	167.00
HM13	Pijler 2	1934	Vuren	260	153	0	-1.10	-13.25	0.00	110.00	167.00
HM14	Pijler 2	1934	Vuren	250	153	0	-1.10	-13.25	0.00	110.00	167.00
HM15	Pijler 2	1934	Vuren	260	153	0	-1.10	-13.00	0.00	110.00	167.00
HM16	Pijler 2	1934	Vuren	240	153	11	-1.10	-13.25	0.00	110.00	167.00

GUI impression (results)



Paalfunderingen

Bestand Info

Invoer | Ondergrond | Uitvoer

Berekeningspad: D:\probfund\Data\Rekenen

Berekenen

Paalcodering HM	UC paalkop - Enkele paal UC CC 6.10a	UC paalkop - Uitgemiddelde paal UC CC 6.10a	UC paalkop - Enkele paal UC CC 6.10b	UC paalkop - Uitgemiddelde paal UC CC 6.10b	UC kritische doorsnede - Enkele paal UC CC 6.10a	UC kritische doorsnede - Uitgemiddelde paal UC CC 6.10a	UC kritische doorsnede - Enkele paal UC CC 6.10b	UC kritische doorsnede - Uitgemiddelde paal UC CC 6.10b	UC Geotechnische draagkracht - Enkele paal UC Geo CC 6.10a	UC Geotechnische draagkracht - Uitgemiddelde paal UC Geo CC 6.10a	UC Geotechnische draagkracht - Enkele paal UC Geo CC 6.10b	UC Geotechnische draagkracht - Uitgemiddelde paal UC Geo CC 6.10b
Onbemonsterde pa	0.654	0.328	0.881	0.436	1.307	0.795	1.625	0.994	0.798	0.511	1.201	0.826
HM2	0.142	0.284	0.185	0.387	0.546	0.760	0.711	0.945	0.786	0.524	1.101	0.832
HM9	0.205	0.305	0.266	0.417	0.546	0.760	0.711	0.951	0.829	0.519	1.187	0.834
HM10	0.246	0.313	0.320	0.429	0.681	0.784	0.887	0.989	0.846	0.512	1.063	0.848
HM11	0.175	0.296	0.228	0.405	0.546	0.754	0.711	0.939	0.755	0.514	1.168	0.821
HM12	0.215	0.307	0.279	0.420	0.702	0.787	0.913	0.984	0.742	0.513	1.135	0.820
HM4	0.189	0.301	0.246	0.411	0.546	0.760	0.711	0.958	0.857	0.523	1.107	0.812
HM13	0.189	0.301	0.246	0.411	0.546	0.760	0.711	0.958	0.763	0.531	1.207	0.802
HM14	0.205	0.305	0.266	0.417	0.546	0.757	0.711	0.951	0.751	0.520	1.105	0.814
HM15	0.189	0.301	0.246	0.411	0.546	0.759	0.711	0.945	0.766	0.522	1.178	0.832
HM16	0.269	0.317	0.350	0.435	0.634	0.776	0.825	0.979	0.895	0.521	1.119	0.808

Why probabilistic assessment?

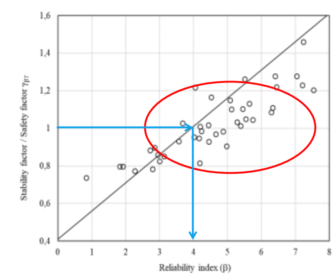
Less conservatism in probabilistic approach than by using calculation values

=>

Less bridges need maintenance

=>

Reuse wooden piles by not replacing them



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