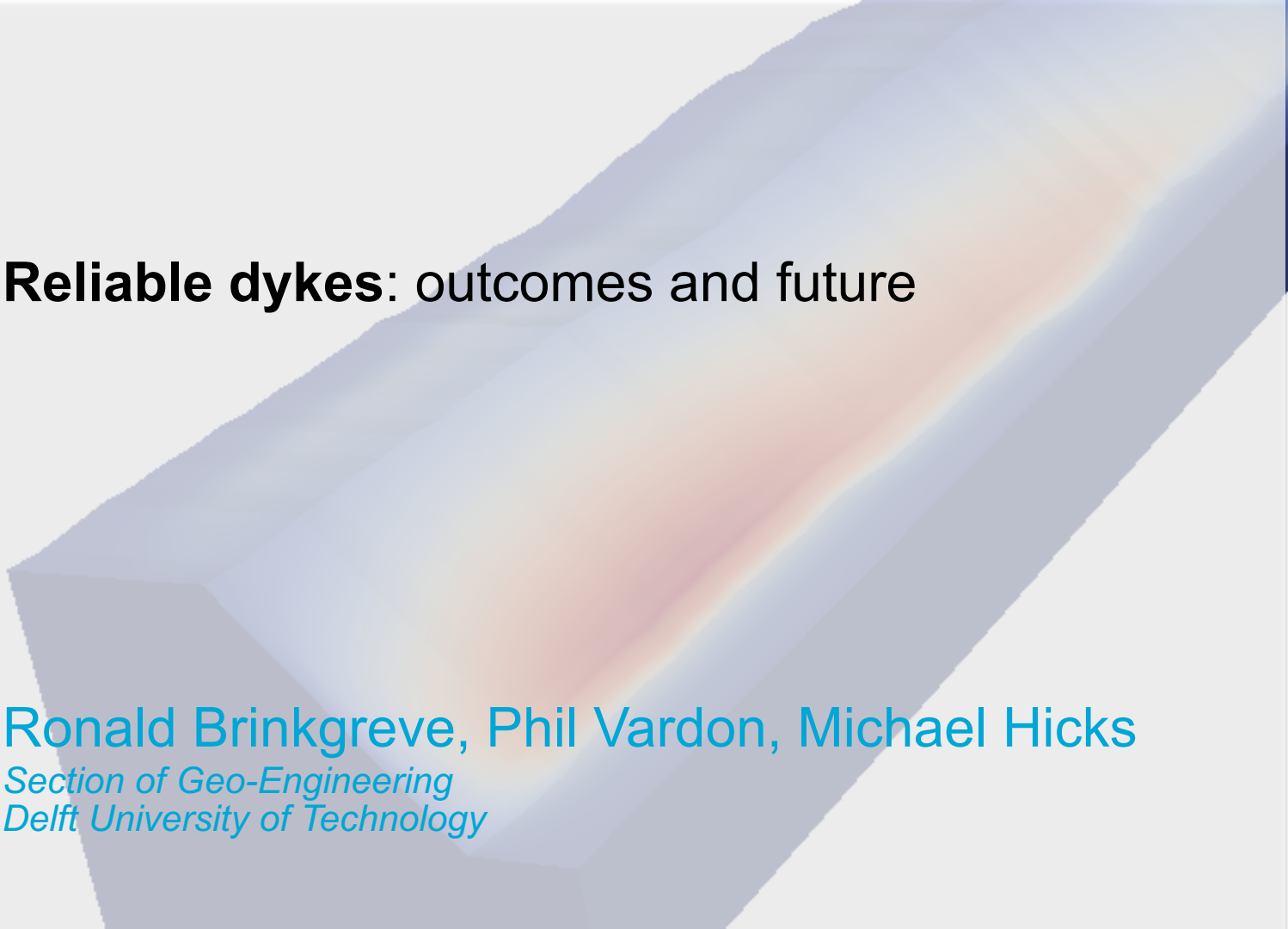
Reliable dykes: outcomes and future



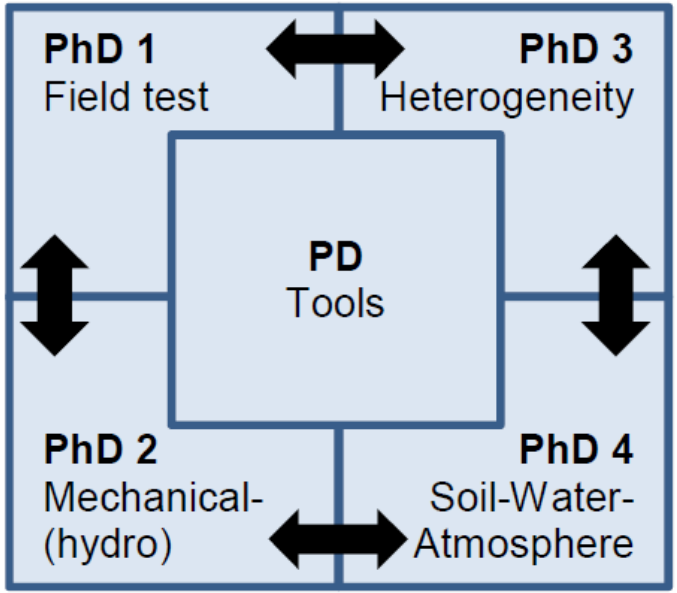
Ronald Brinkgreve, Phil Vardon, Michael Hicks

Section of Geo-Engineering
Delft University of Technology

TU Delft

Reliable Dykes: NWO project 13864

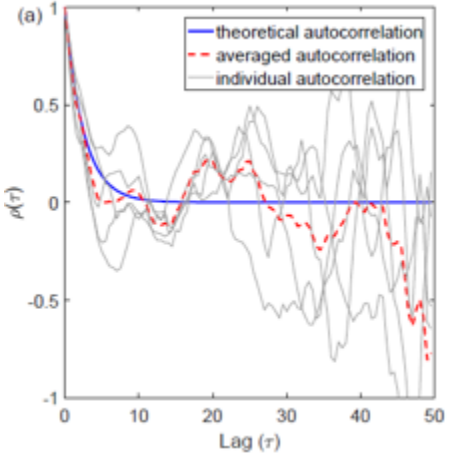
- Reliability-based geomechanical assessment tools for dykes and embankments in delta areas



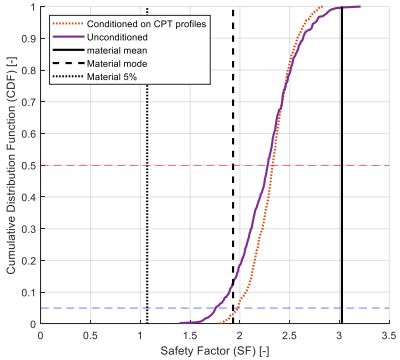
PhD 1: Tom de Gast

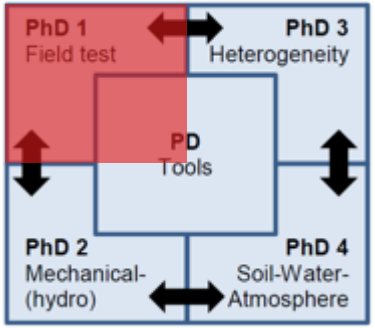
Field test

Measuring heterogeneity



Practical RFEM (conditioned)





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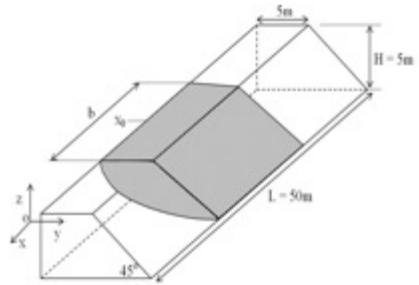
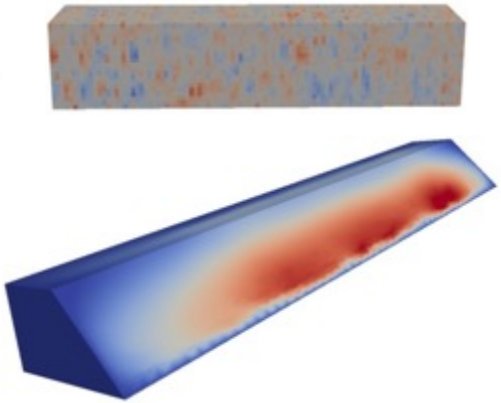
PhD 3: Divya Varkey

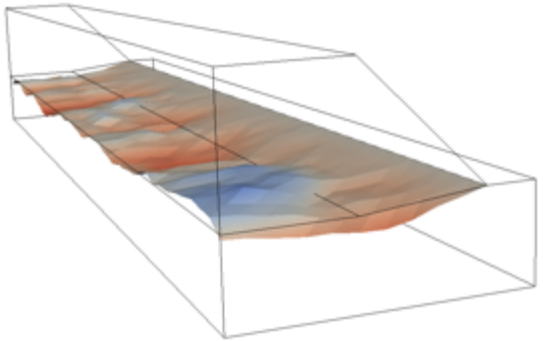
Improving Analytical methods

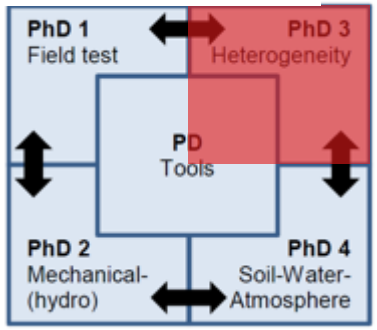


RFEM



Geometric uncertainty





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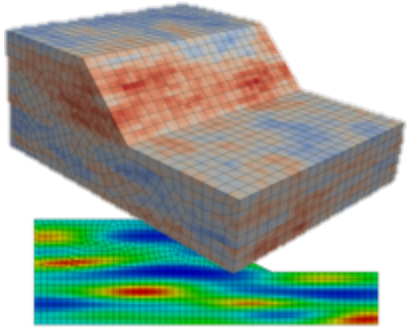
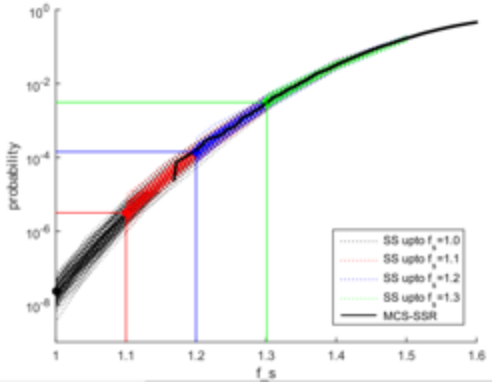
PD: Bram van den Eijnden

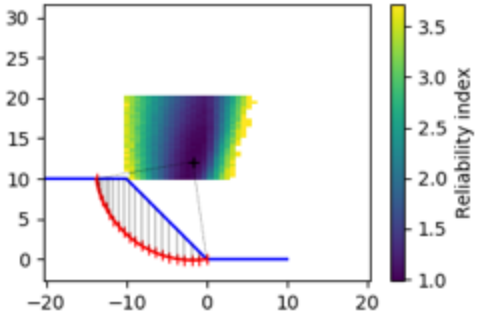
RFEM tools

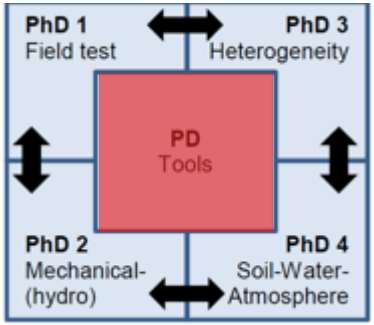


Subset simulation



Random LEM





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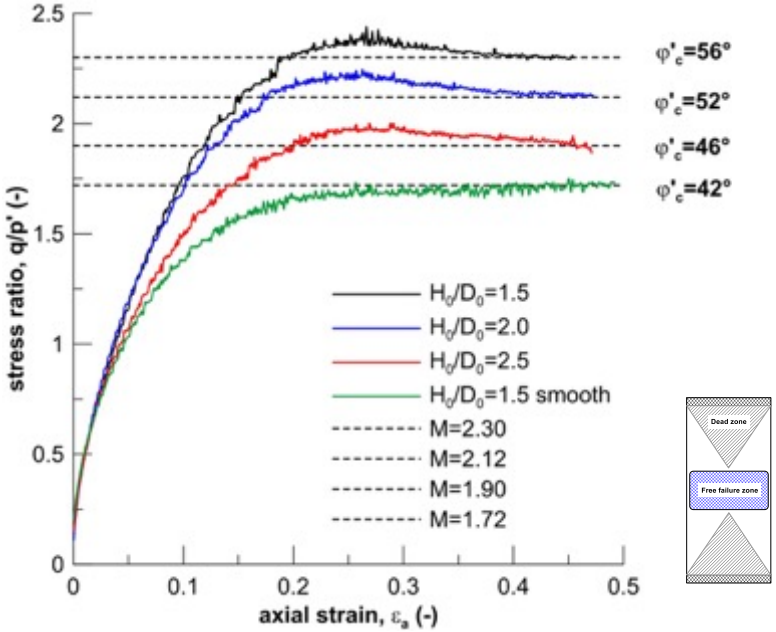
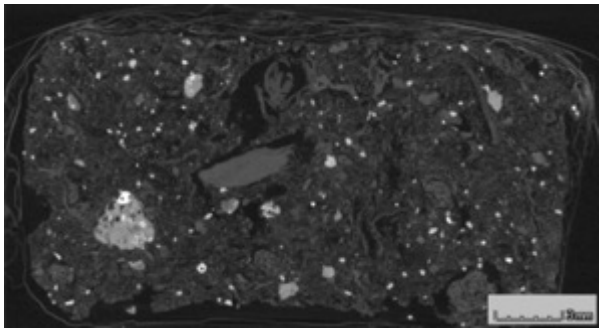
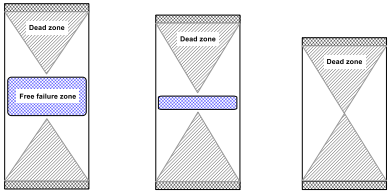
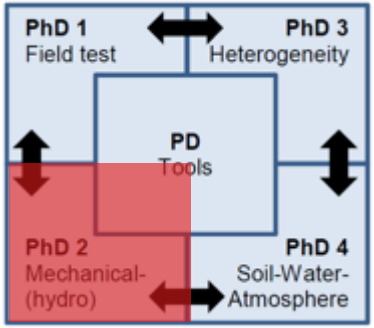
PhD 2: Stefano Murano





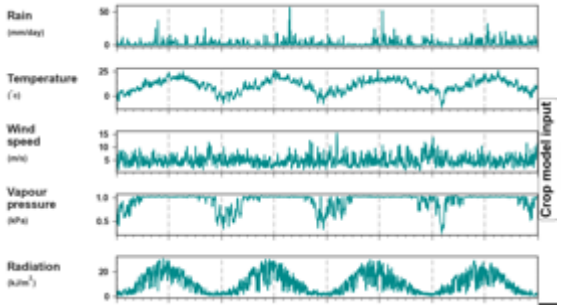


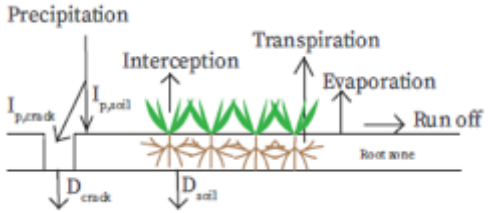


PhD 4: Elahe Jamalinia

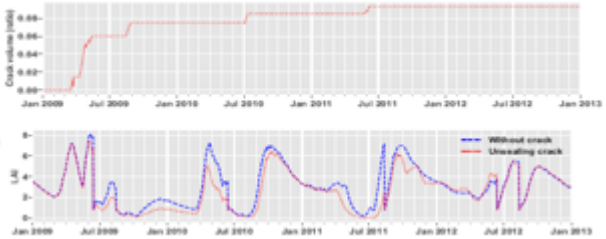
- Ongoing…

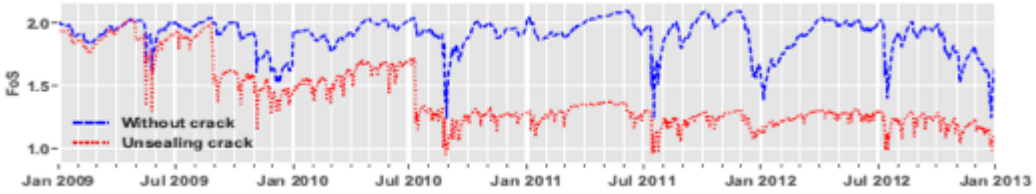
weather



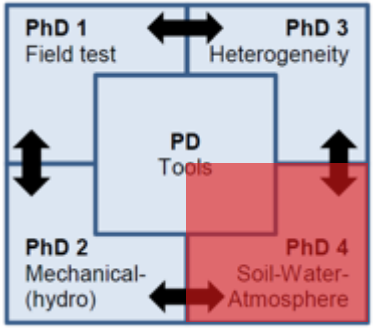


Dyke and vegetation state





Safety



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Main findings (so far)

New data

- Full-scale field test and dataset

New knowledge

- Insights into behaviour and modelling of peat
- Insights into characteristics of spatial variability
- Insights into the processes and impact of soil-water-atmosphere interaction

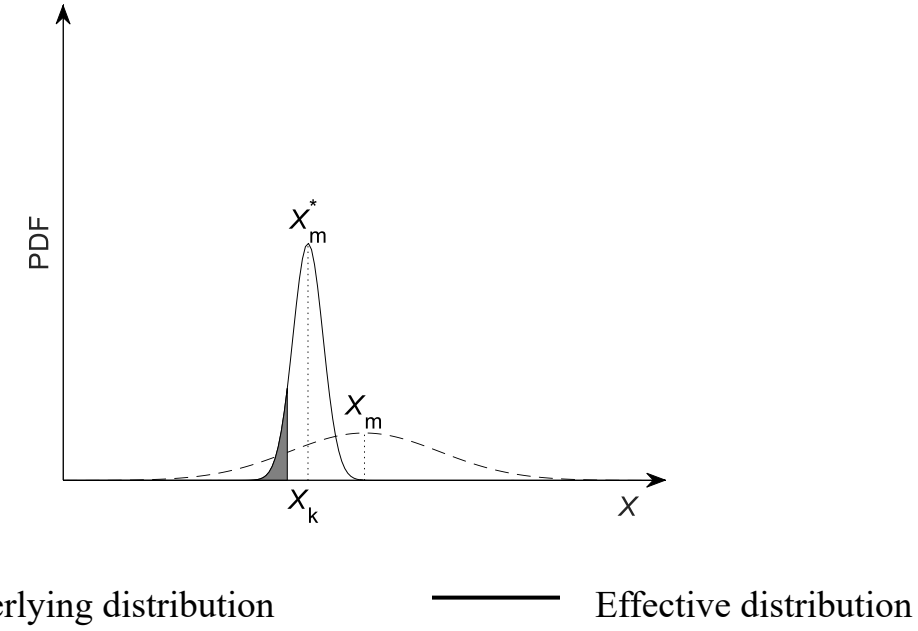
New techniques

- Protocols for field and laboratory testing
- Development of simplified reliability-based frameworks for 2D and 3D assessments
- Validation of an RFEM reliability-based assessment approach and its application in practice

RFEM reliability-based assessment approach

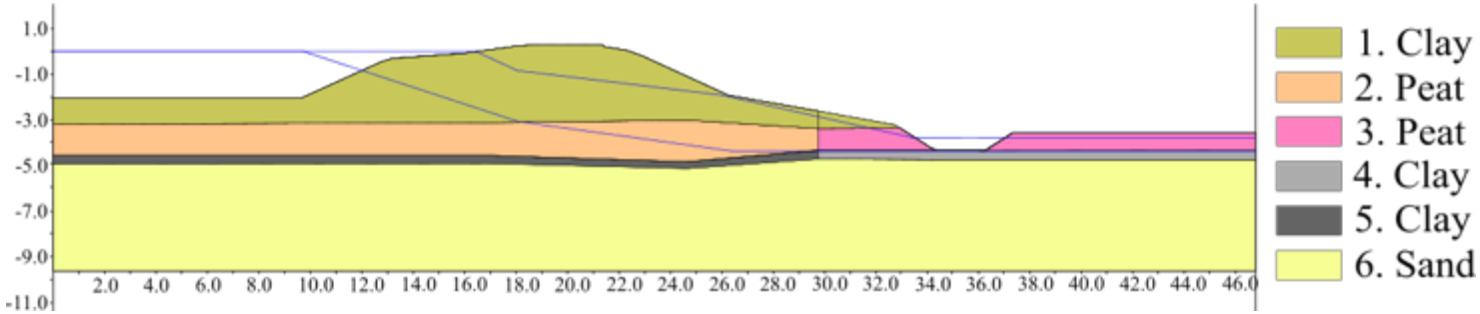
- Also sometimes called ‘modified distribution’
- Most codes target ‘the occurrence of the limit state under consideration is not greater than 5%’.
- Interpreted mostly as using a 5% material parameter confidence.
- This ignores any spatial correlations or averaging.

RFEM reliability-based assessment approach



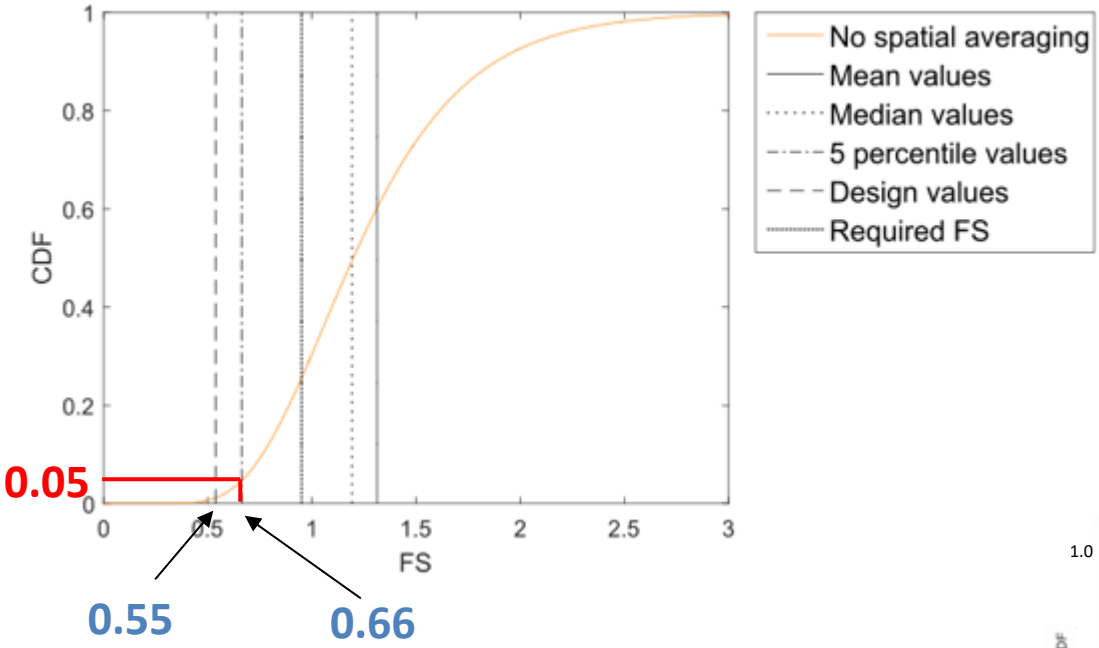
RFEM reliability-based assessment approach

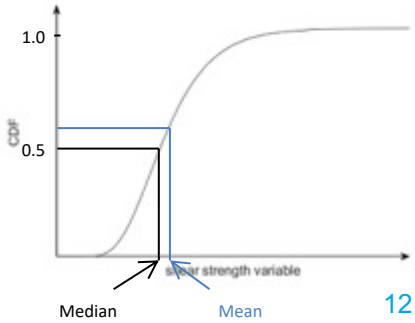
- Case study



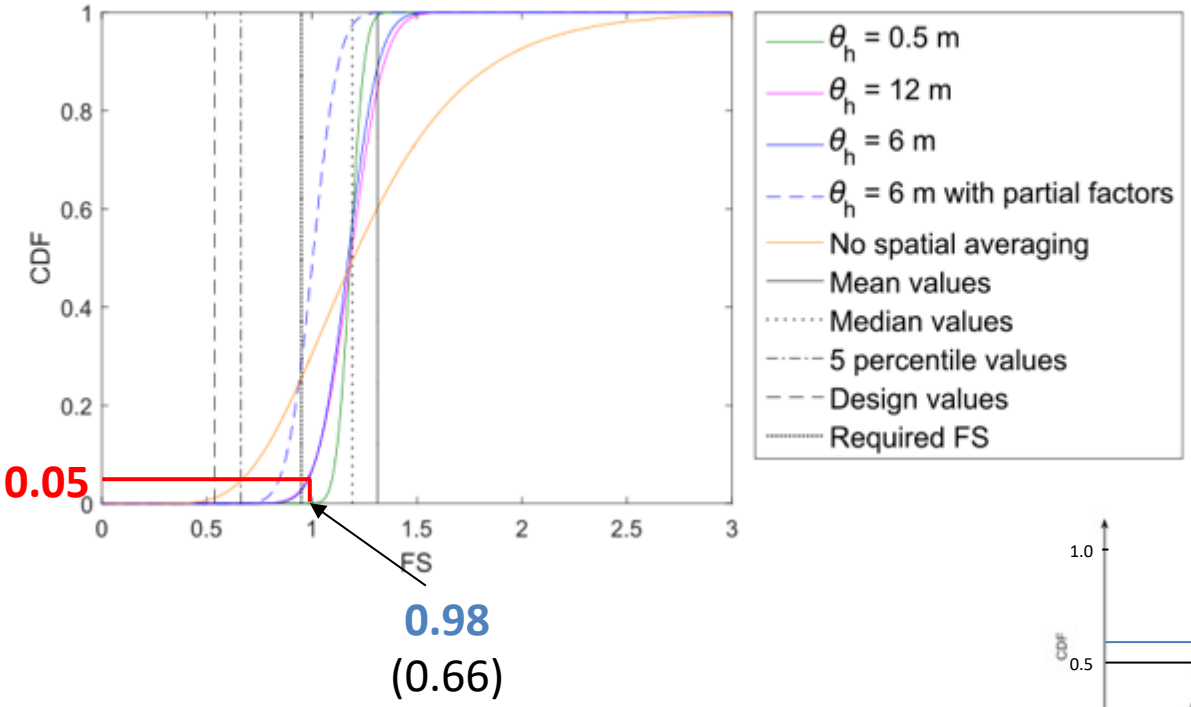
- Using standard approach and design values: FOS=0.55 (with partial factors), FOS=0.66 (without)

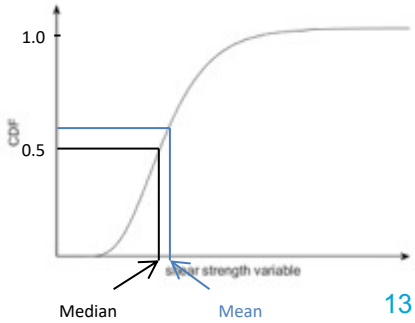
RFEM reliability-based assessment approach



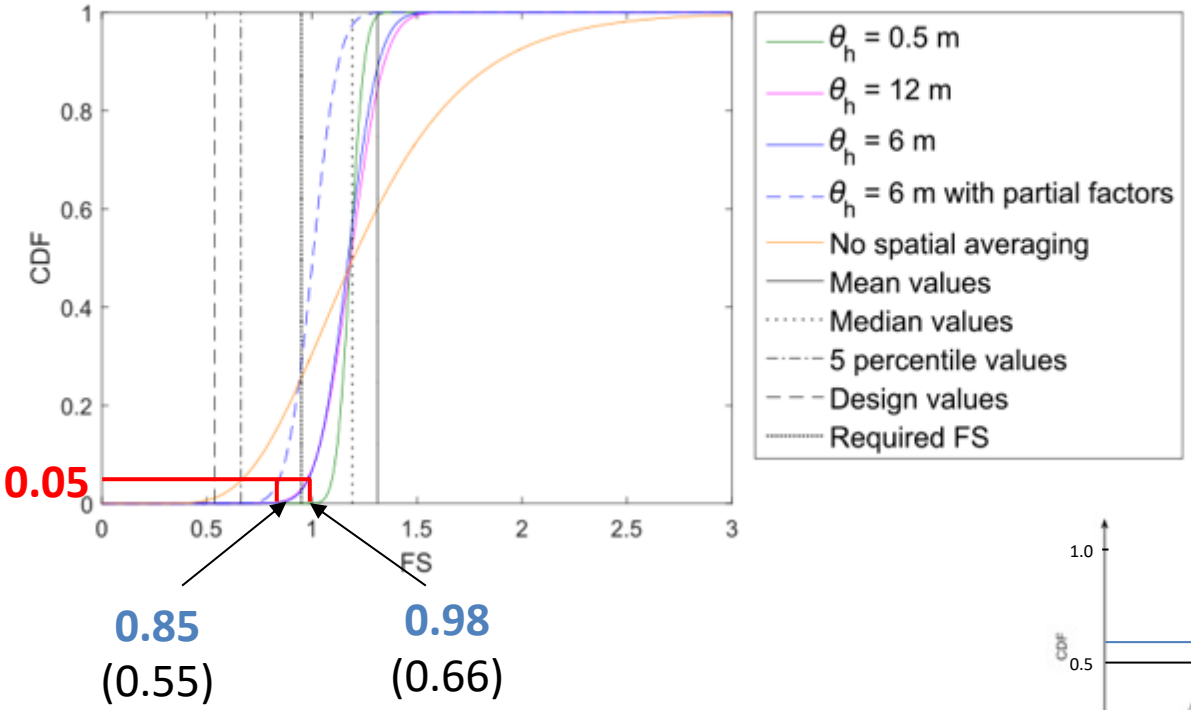


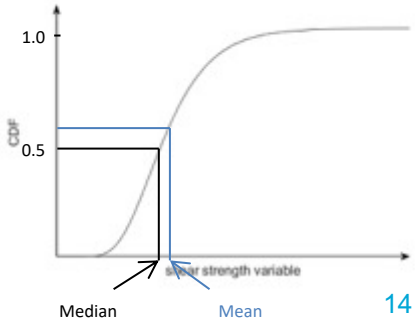
RFEM reliability-based assessment approach



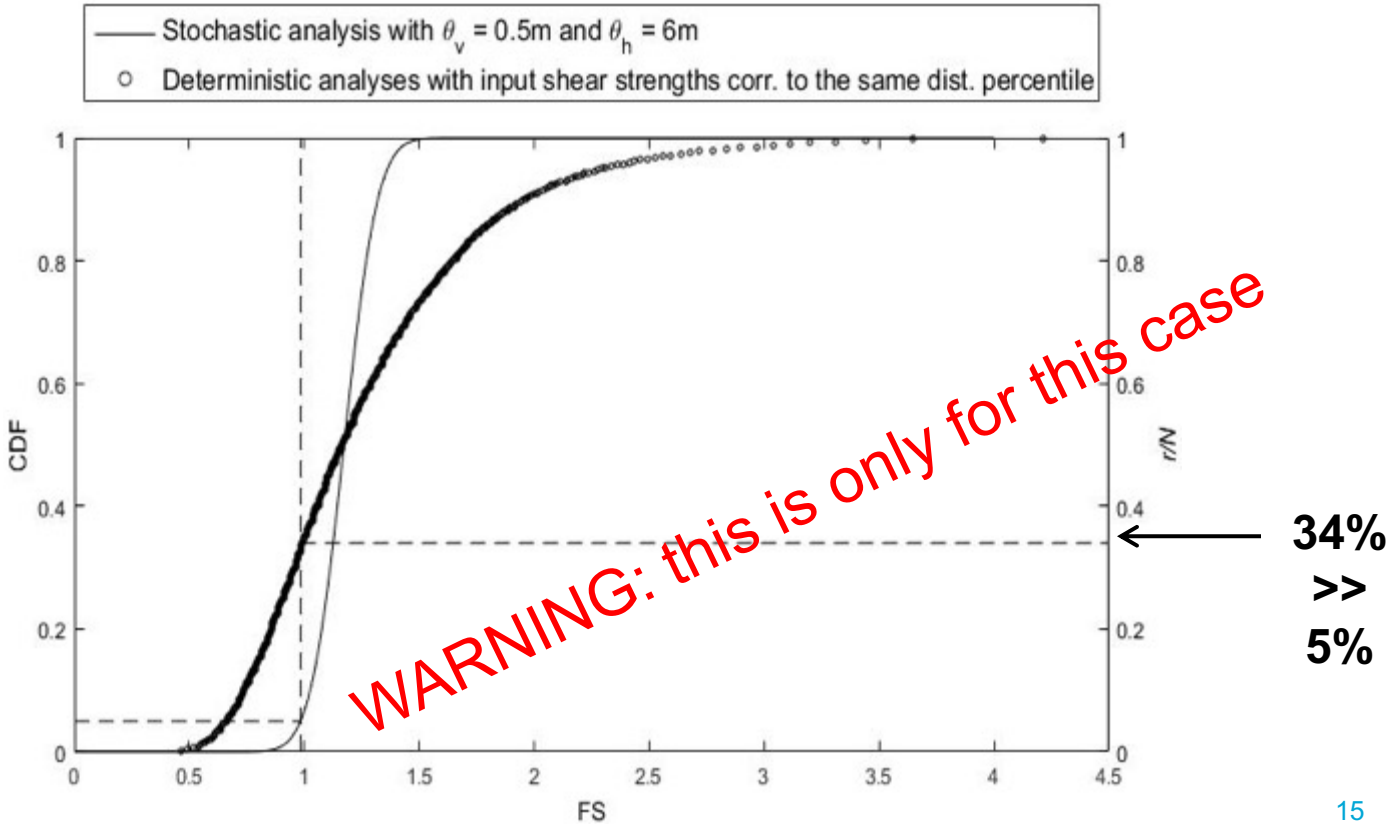


RFEM reliability-based assessment approach

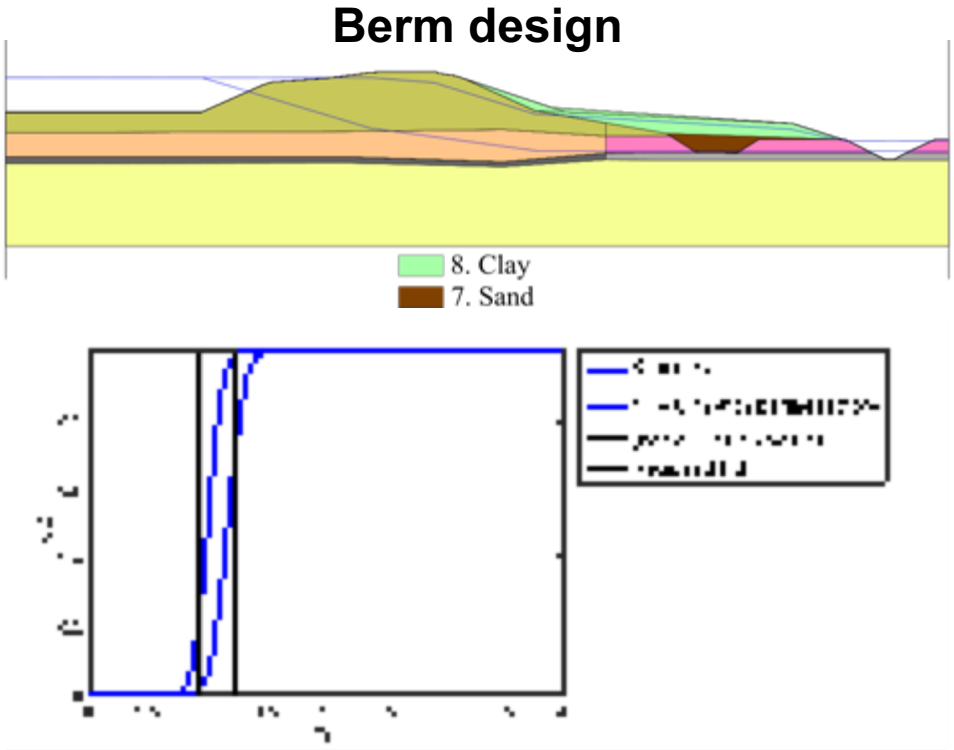




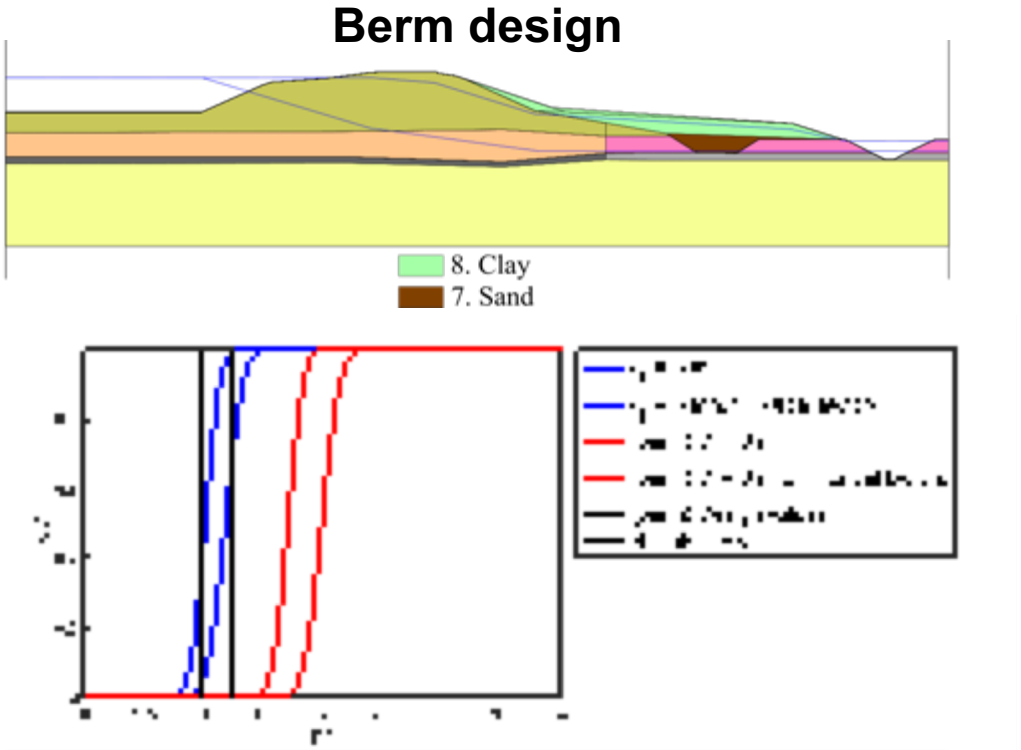
RFEM reliability-based assessment approach



RFEM reliability-based assessment approach



RFEM reliability-based assessment approach



RFEM reliability-based assessment approach

Berm redesign

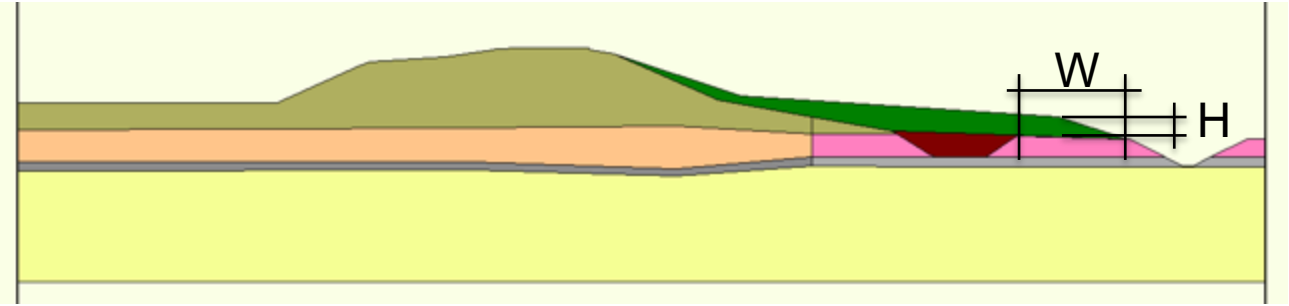
FS corresponding to 0.05 CDF

	H	***2/3 H***	***3/5 H***		***1/2 H***		***0 H***	
	w/o partial factors	w/o partial factors	w/o partial factors	with partial factors	w/o partial factors	with partial factors	w/o partial factors	with partial factors
W	1.789	1.461	1.268	1.083	1.197	1.027	0.968	0.826
2/3 W	1.736	1.377	1.265	1.08	1.193	1.021	-	-
1/2 W	1.724	1.375	1.259	1.079	1.186	1.016	-	-
1/3 W	1.647	1.36	1.249	1.071	1.181	**1.015**	-	-

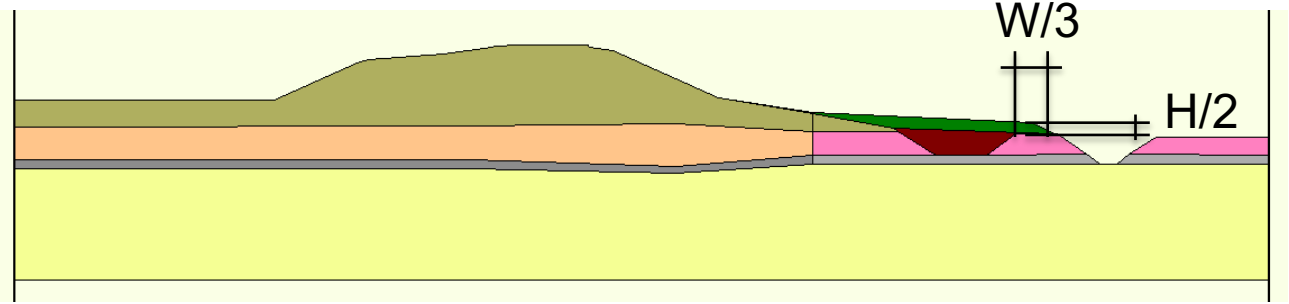
> Required FS (0.95)

RFEM reliability-based assessment approach

Berm original design



Berm redesign: 75% saving on material



RFEM reliability-based assessment approach

- Calculates more accurate reliability
- Usually increases calculated reliability:
  - Eliminate or reduce required remedial work

- RFEM is not a ‘product’ you can use yourself
  - Combination of 3+ pieces of software
  - Utilises grid computing
  - Alternative: Updated Vanmarcke’s simplified method

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Concrete results from current research project:

- Optimised CPT testing locations
- Tests on peat require bigger samples
- Practical tool for reliability analysis
- Reduced cost of dyke reinforcement
- More favourable choice of parameters

Future perspectives

Reliable dykes

- RFEM
- Lab protocols

Future perspectives - RFEM

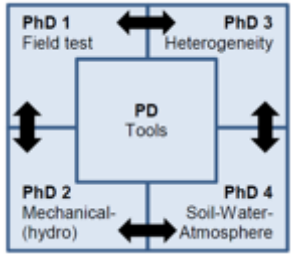
- Turn into product → Cost and time now
  - Development work required
- Have as a service → Ongoing costs, lower now
  - TU Delft / other company
- Collect database of x% values → Limited costs, Need one of the others too
  - Can continue using deterministic analysis
  - Long term / cheap

Future perspectives - RFEM

- Value proven

NWO / STOWA
€750k / €300

Reliable dykes



Prototype products
Savings in reduced costs, €m

New knowledge, still development needed

Future perspectives

- Quantify uncertainties
- New prototype products
  - Random LEM
  - Big data
  - Inverse analysis, data assimilation, Bayesian networks
  - Soil-vegetation-atmosphere monitoring

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RFEM reliability-based assessment approach

Recipe

Required information (Stage 1)

1. Lab test data.
2. Water levels and phreatic lines.
3. External loads, if any.
4. Analysis type.
5. Drawing of the cross-section with clear markings for the different geological layers.
6. CPT data.

Pre-analysis (Stage 2)

1. Distribution statistics.
2. Scale of fluctuations.
3. Cross-correlation coefficients.
4. Input file for the analysis.

Analysis and processing results (Stage 3)

1. Scaling down shear strength distributions by respective partial factors.
2. RFEM analysis.
3. Plot a histogram of the FS from all the realisations and fit a curve.
4. Find the value corresponding to a reliability of 95% (CDF of 0.05) based on the design values.

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