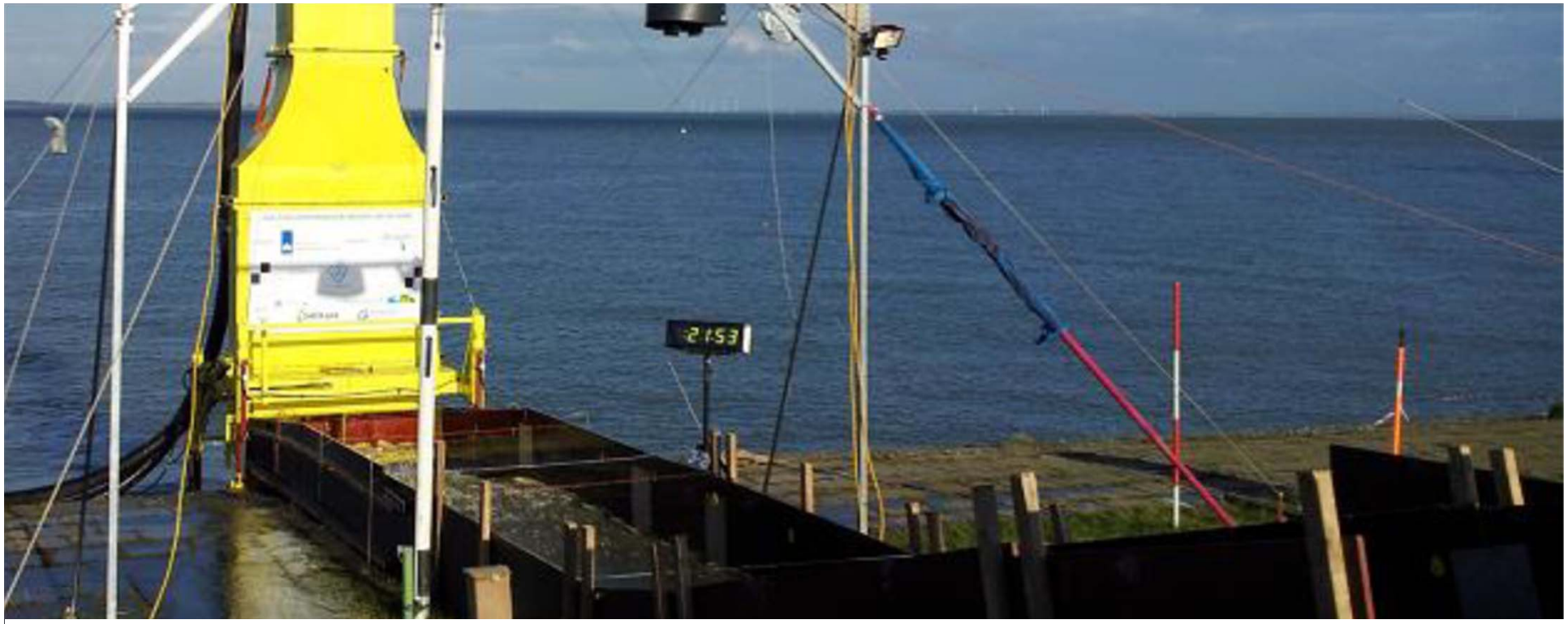

WAVE RUN-UP SIMULATION ON REAL DIKES

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WAVE RUN-UP SIMULATION ON REAL DIKES

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- André van Hoven - Deltares

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Contents

- Main features new wave run-up simulator
- Cumulative overload method
- Tests and Hydraulic measurements
- Grass pull tests
- Conclusions

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Overtopping simulator: Pilot on Run-up

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Results of pilot test on run-up

- Up-rushing wave simulated well
- Release of water after run-up needs to be taken care off
- Down-rush not simulated; too much water
- Large pressures on the side wall: too much water

Recommendation:

- New Wave Run-up Simulator
  - Slender – less water
  - Quick release of water (higher velocities)

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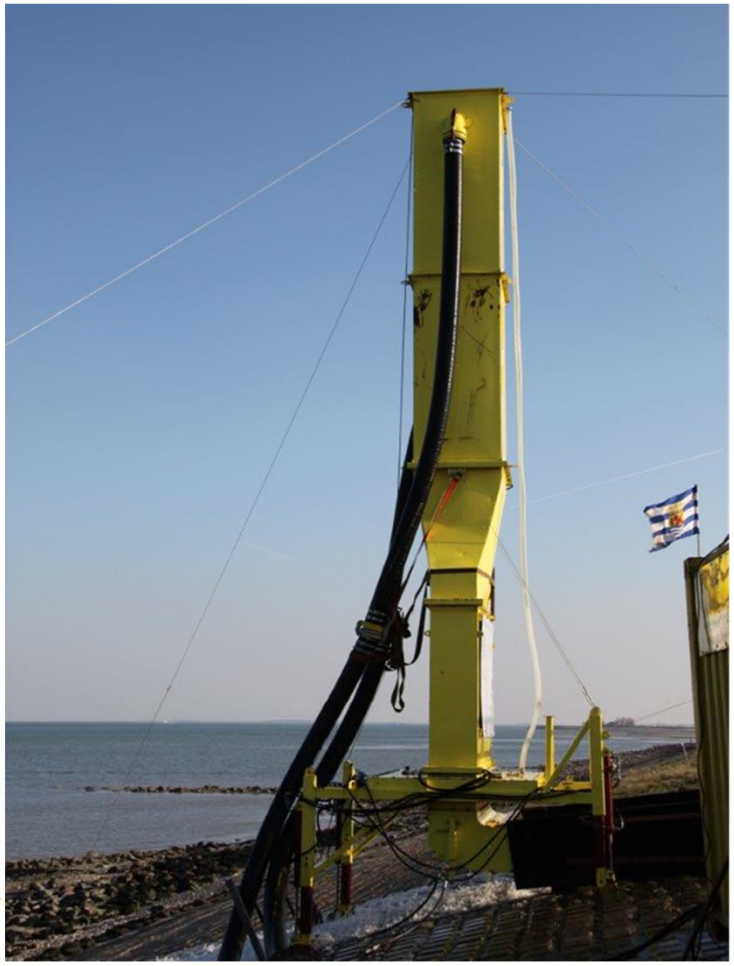

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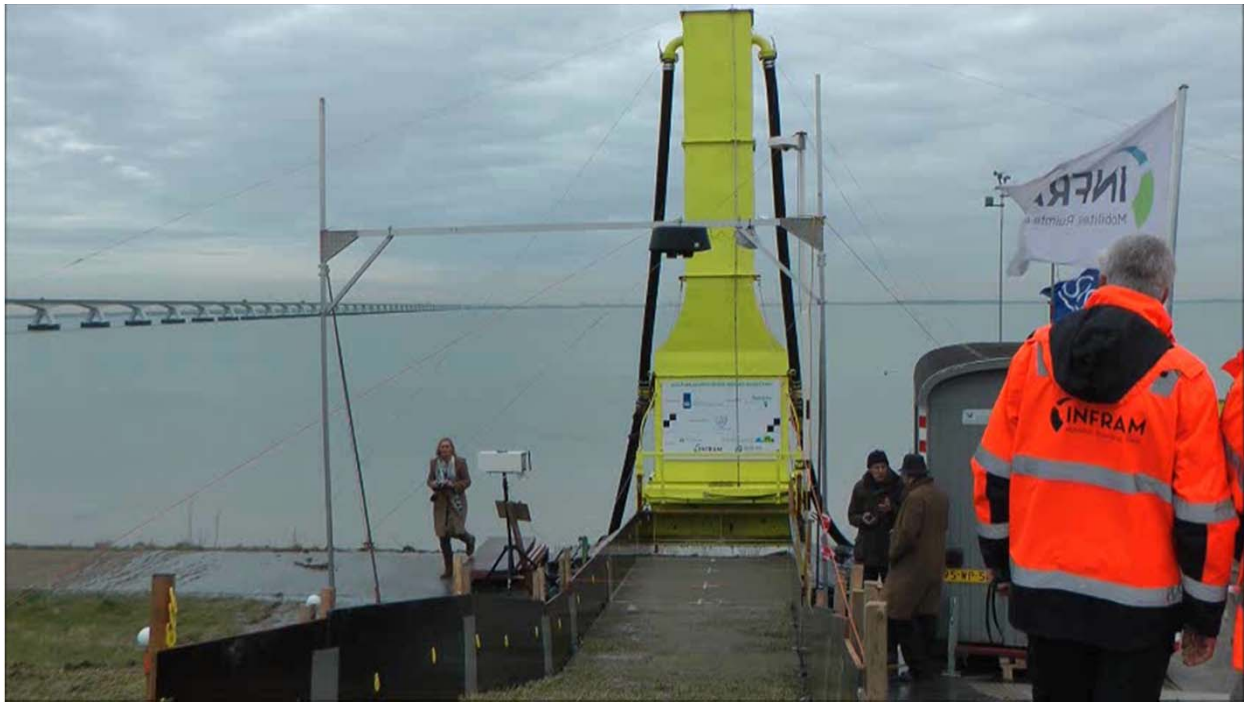
Features

- 2 m wide
- 2.8 m^3 per m
- 7 m water column
- quick release drawer type valve
- max velocity 8 m/s
- max run-up height 4 m on 1:3 slope (13 m along slope)



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Cumulative overload method

$$\boldsymbol{D} = \sum_{i=1}^{N} \left(\alpha_1 U_i^2 - \alpha_2 U_c^2\right) \qquad \text{for } \alpha_1 U_i^2 > \alpha_2 U_c^2 \qquad [m^2/s^2]$$

D = cumulative overload [m^2/s^2]
N = number of overtopping waves [-]
i = number of the overtopping wave [-]
U_i = a characteristic value of the front velocity of the overtopping wave [m/s]
U_c = critical velocity of the grass slope (=strength) [m/s]
α_1 = influence factor on the velocity U_i by transitions or obstacles [-]
α_2 = influence factor on the critical velocity U_c by transitions or obstacles [-]

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Damage values

Start of damage	$D = 1000\ m^2/s^2$
Several open spots	$D = 4000\ m^2/s^2$
Failure	$D = 7000\ m^2/s^2$

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Results on U_c from overtopping tests

Grass on clay

▪ Delfzijl	U_c = 8 m/s	
▪ Boonweg	U_c = 8-9 m/s	
▪ St Philipsland	U_c = 6 m/s	grass with open spots
▪ Afsluitdijk	U_c = 8 m/s	
▪ Nijmegen	U_c = 6.5 m/s	river dike with open spots
▪ Millingen	U_c = 7 m/s	river dike

Grass on 100% sand

- Vechtdijk U_c = 3.5 m/s

Bad or no maintenance with relatively poor soil

- Tielrode, ruderal vegetation U_c = 0 m/s
- Tholen, inadequate maintenance U_c = 0 m/s

Bare clay

- Delfzijl, good quality erosion resistant bare clay U_c = 3-4 m/s

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New classes (Dutch grass and situations!)

- Well maintained grass on clay — U_c=8 m/s σ=1.0 m/s
- Maintained grass, open spots, on clay — U_c=6 m/s σ=0.75 m/s
- Well maintained grass on sand — U_c=3,5 m/s σ=0,5 m/s
- Bad coverage, no maintenance, poor soil — U_c=0 m/s

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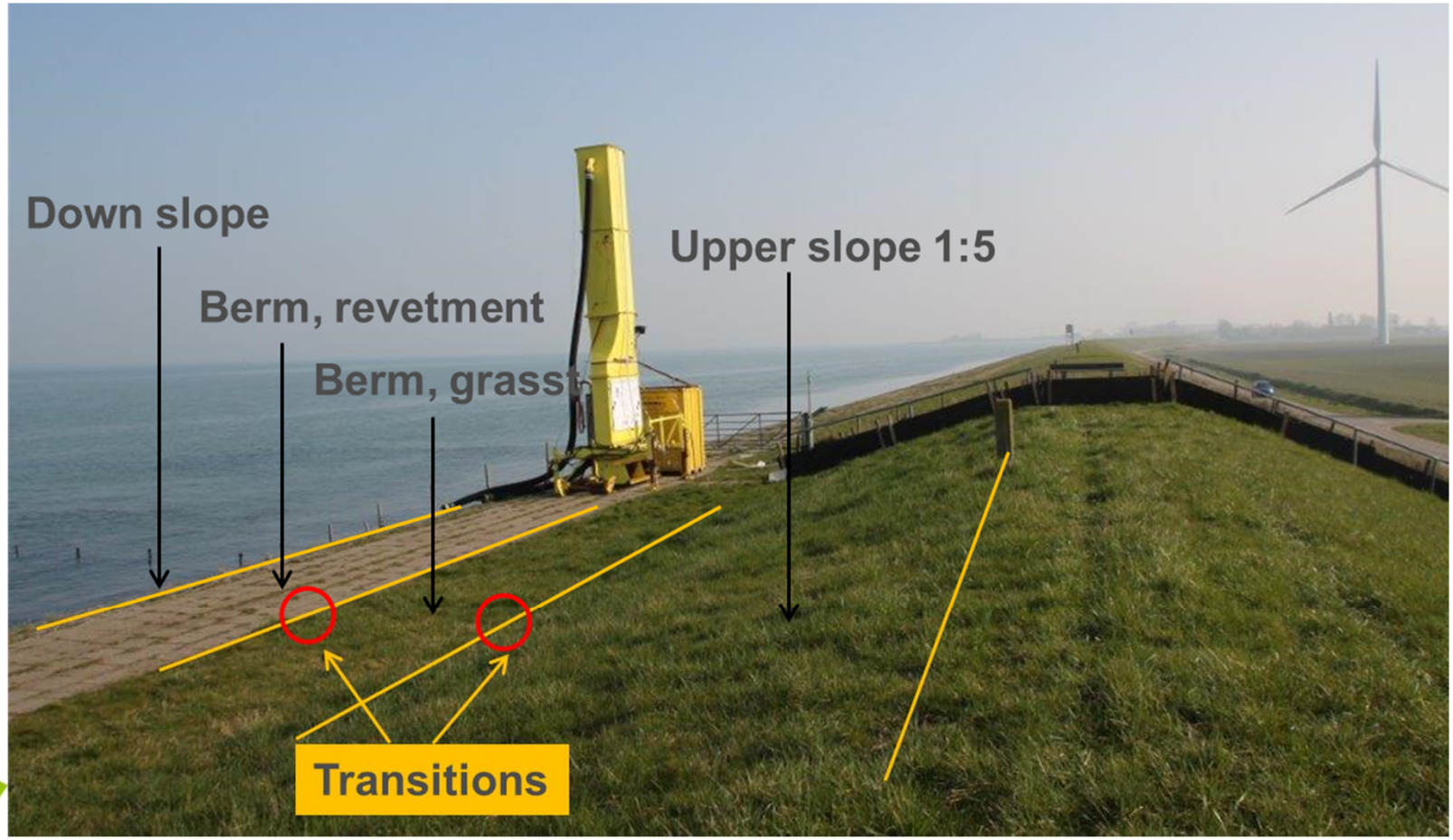

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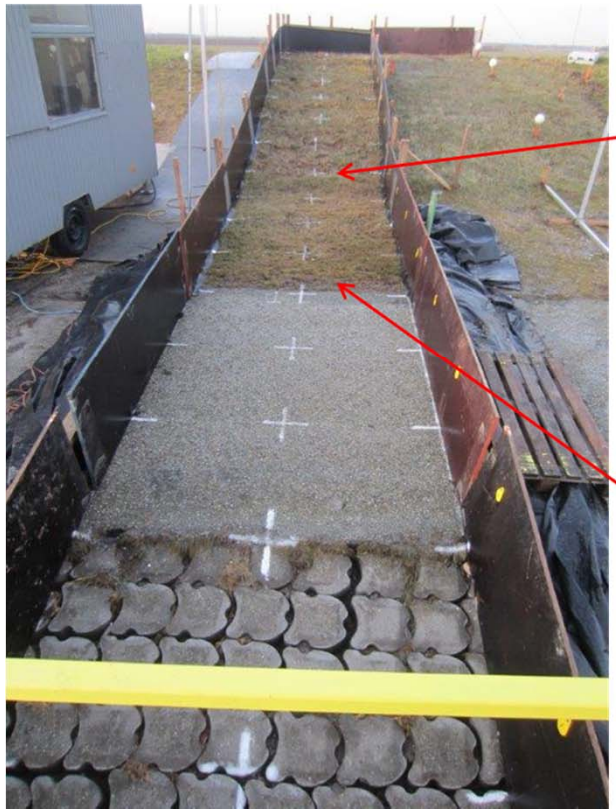
Test 1

Just start of damage



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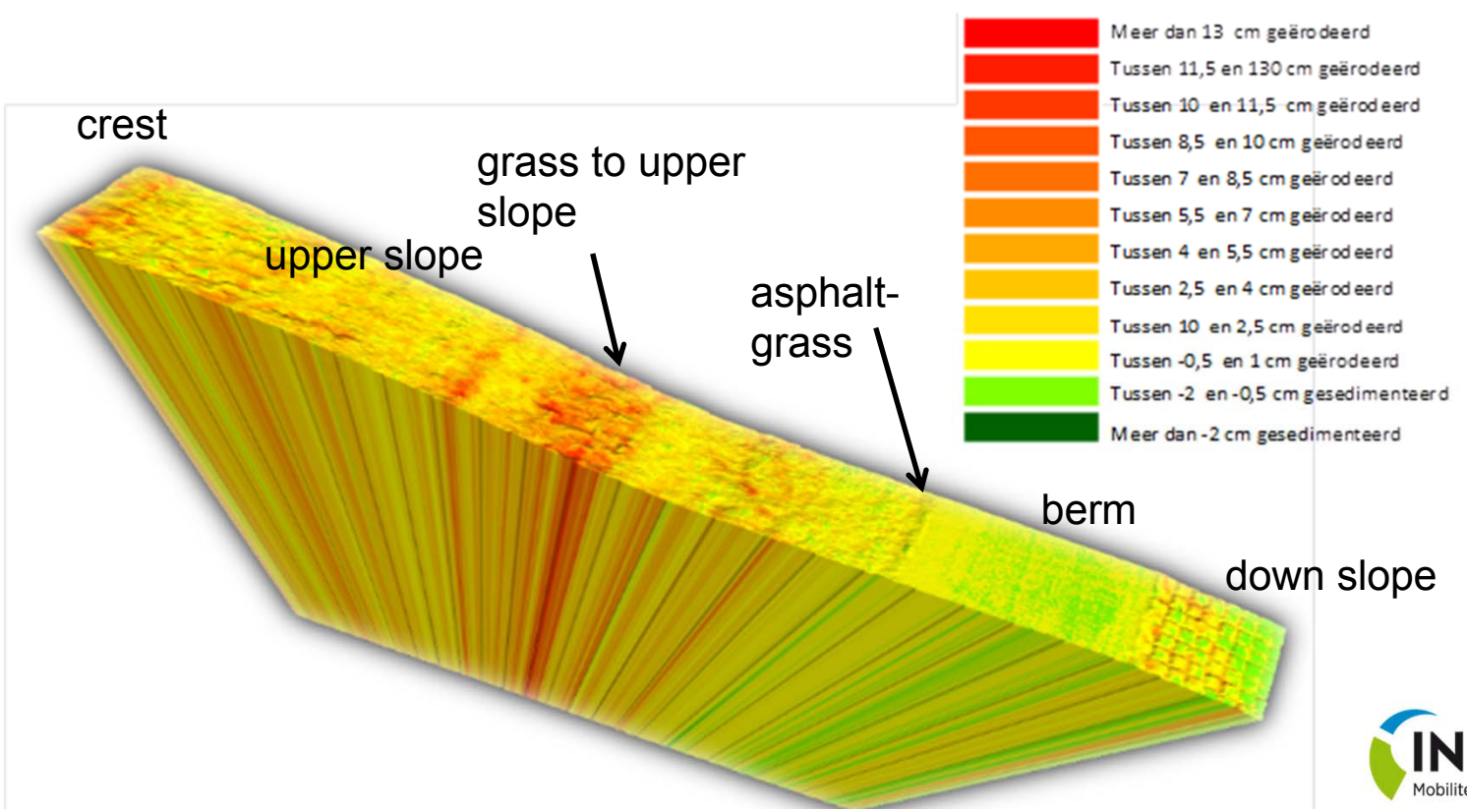
Measurement erosion by laser



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Test 2

Hardly start of damage

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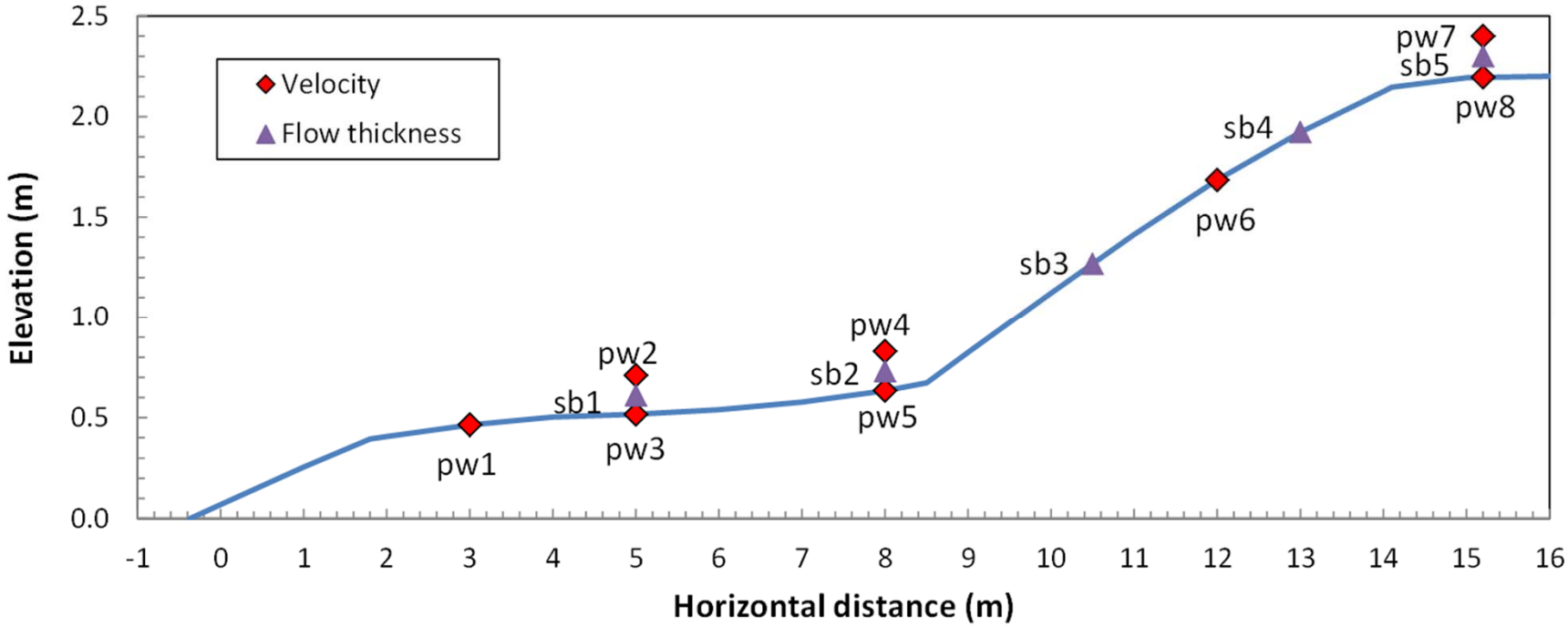
Measurements of velocity and flow thickness



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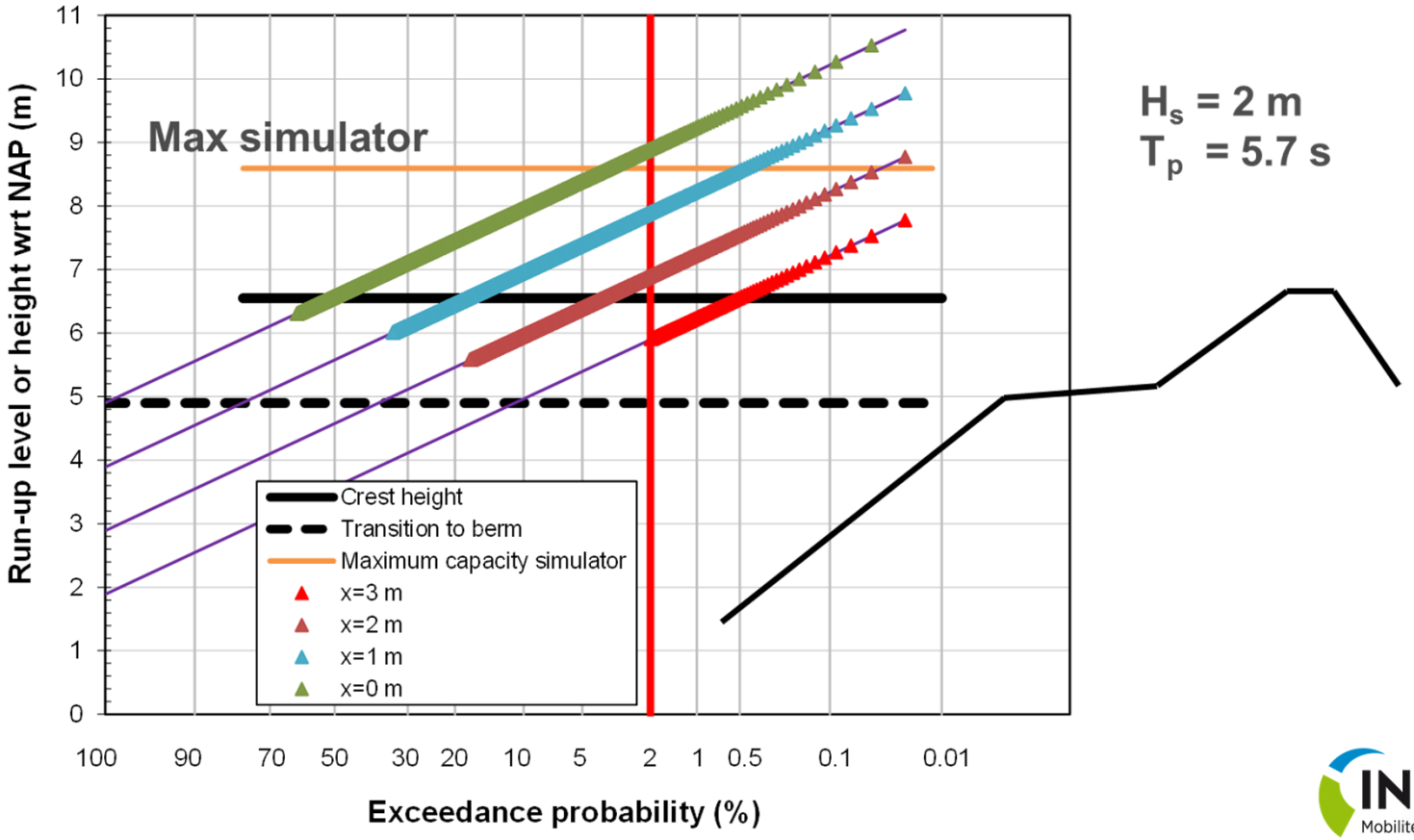
Run-up distributions per test



H_s = 2 m
T_p = 5.7 s

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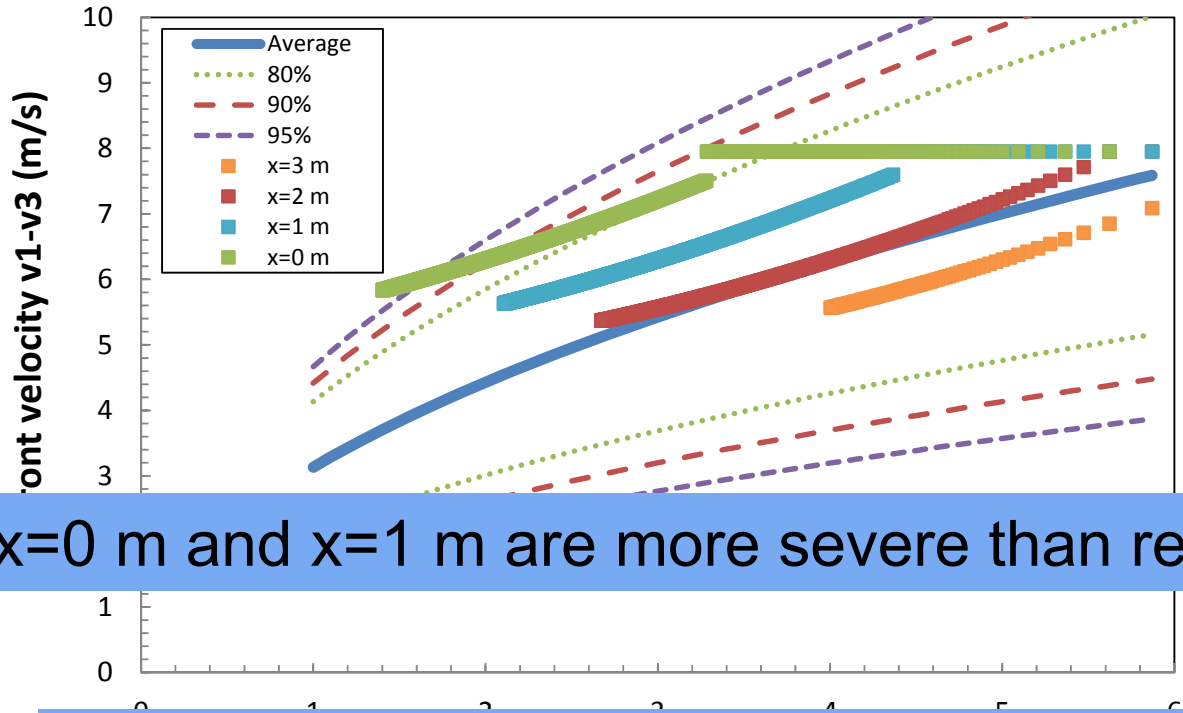
Simulated run-up front velocities



x=0 m and x=1 m are more severe than reality

All velocities between 5.5 and 7.95 m/s

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Cumulative overload

α_1	α_2	U_c=7 m/s	U_c=8 m/s	U_c=9 m/s
1.00	1.00	6773	0	0
1.05	1.00	9440	869	0
1.10	1.00	12710	2034	0
1.15	1.00	16641	3228	0
1.20	1.00	21285	4658	0
1.30	1.00	32895	8558	428
1.40	1.00	47842	14097	2756
1.50	1.00	66014	21561	5317
1.60	1.00	85969	31203	8844

D=1000 m^2/s^2

Limits:

500-4000 m^2/s^2

U_c= 8 m/s

with
a_1=1.1 and
a_2=1.0

Validation is thin as only based on start of damage!

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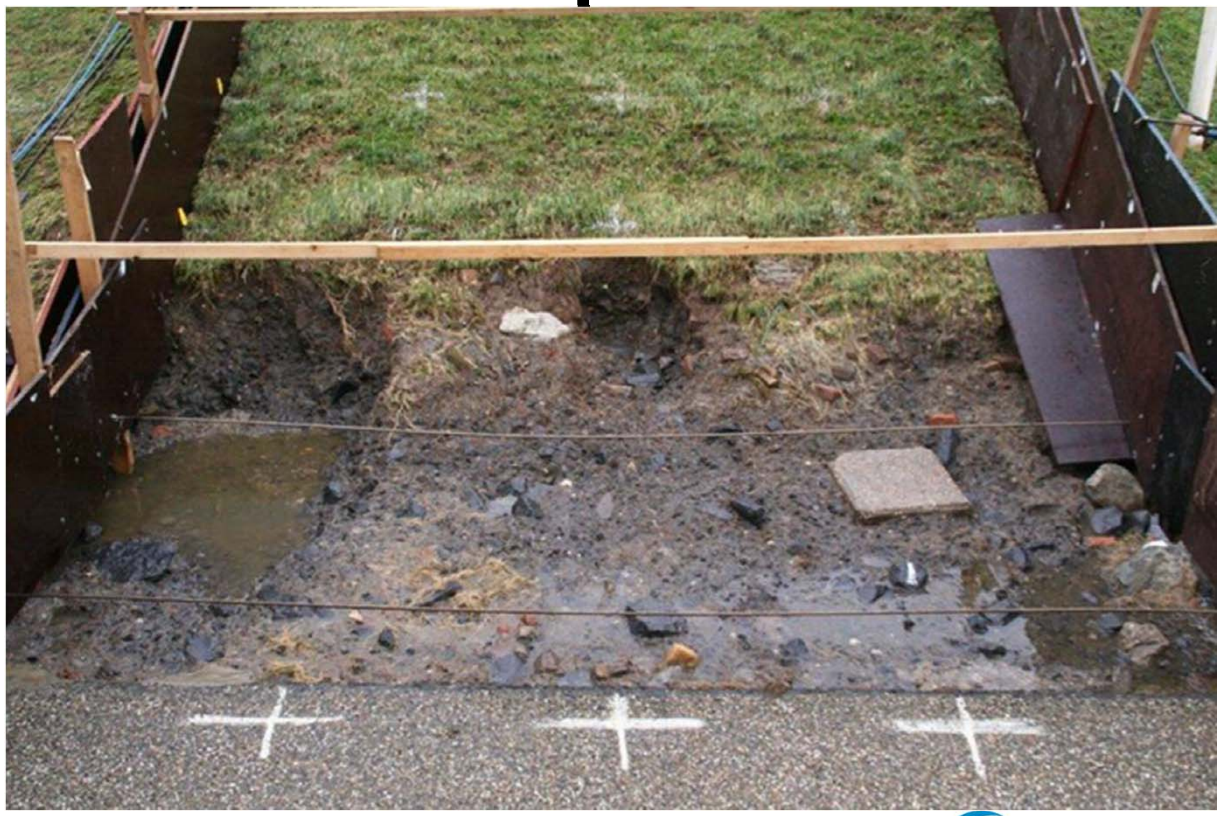
Cumulative overload pilot test

D=4000-5000 m^2/s^2



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Cumulative overload pilot test

α_1	α_2	U_c=5 m/s	U_c=6.5 m/s	U_c=8 m/s
1.00	0.90	6226	944	0
1.05	0.90	7295	1274	33
1.10	0.90	8426	1663	93
1.15	0.90	9833	2114	157
1.20	0.90	11331	2626	237
1.30	0.90	14386	3826	476
1.40	0.90	17512	5254	838
1.50	0.90	20700	6892	1342

U_c=6 m/s

with
α_1=1.2 and
α_2=0.9

Only one test,
a pilot test

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Grass pull tests

- Strength of grass roots: grass sod strength puller

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MSc Roel Bijlard: critical grass tensile stress

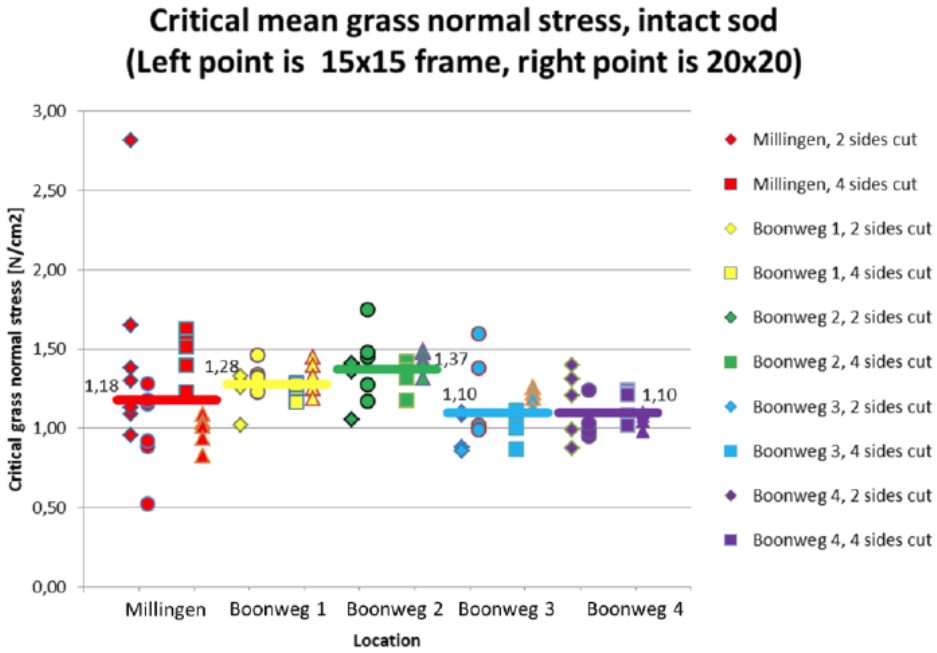

Table 1 - Critical velocity per location estimated from the sod pulling tests (calculated values) and wave overtopping simulator tests (determined values)

	Critical grass tensile stress [N/cm2]			Critical Velocity [m/s]		
Location	μ	σ	2.5 % limit	Calculated	Determined	Difference
Millingen	1,18	0,27	0,65	7,23	7	3%
Boonweg 1	1,28	0,10	1,08	9,33	8 - 9.5	2 - 16%
Boonweg 2	1,37	0,14	1,10	9,38	8 - 9.5	1 - 17%
Boonweg 3	1,10	0,17	0,77	7,85	8	-2%
Boonweg 4	1,10	0,14	0,83	8,14	8	2%

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Conclusions

- We got a very nice working wave run-up simulator;
- The grass cover was strong and transitions not significant;
- Only the stage of start of damage was reached, a small basis for validation;
- The cumulative overload method, developed for wave overtopping seems to work for wave run-up. But validation is not conclusive;
- More tests are needed, preferably on a structure where failure of the grass cover is reached;
- Grass pull tests are a promising technique

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