Falling aprons at circular piers under currents

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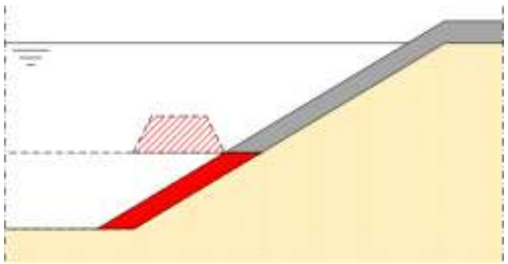
Introduction

- Scour is a critical threat to infrastructure (bridge piers, monopiles)

- Well-designed scour protection can provide protection against all failure mechanisms (e.g. Chiew, 1999, 2004)
  - > shear failure
  - > winnowing failure
  - > edge failure
  - > bed-form induced failure
  - > <u>bed degradation failure</u>

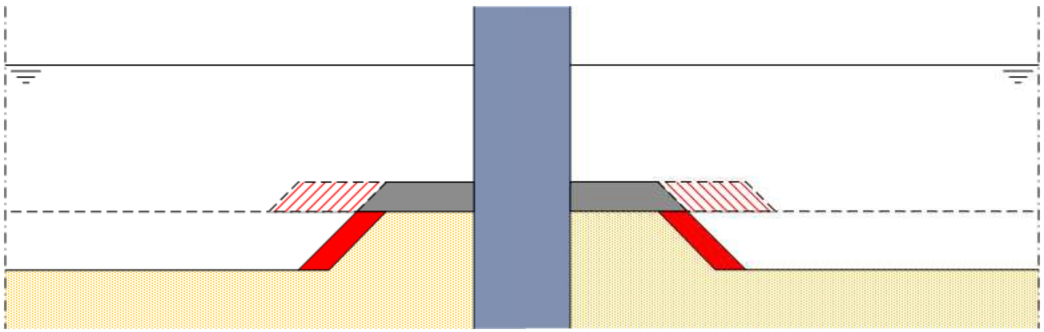


- No guidelines to account for bed lowering at pile

Research objectives

- Investigate behaviour of falling aprons at circular piers under currents

- Develop a guideline to quantify the stone volume required to account for a given bed level degradation



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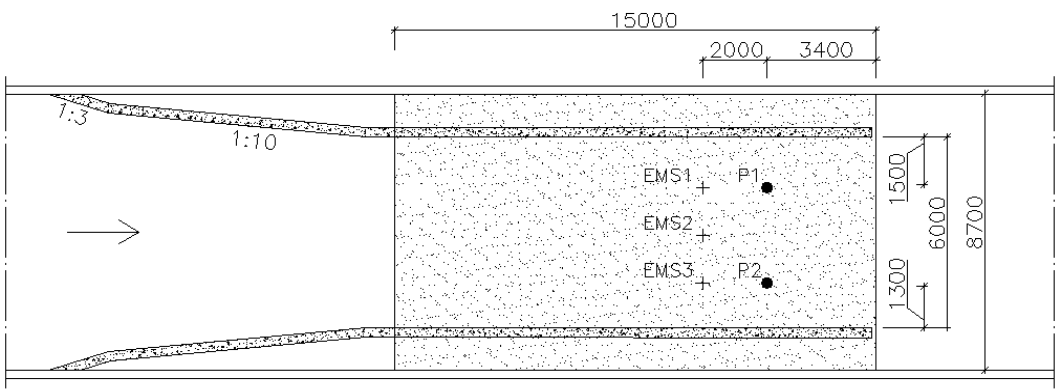
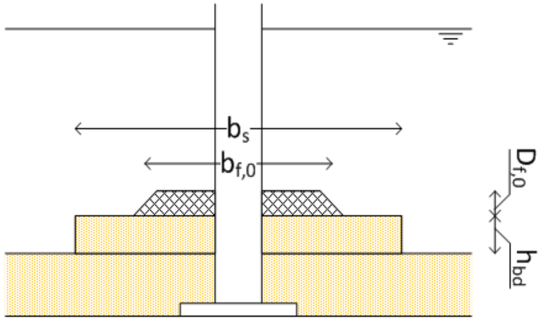
Set-up of physical model experiments

- Physical model tests in Atlantic Basin at Deltares
- Two transparent model piers with various scour protection layouts in sandy test section (d_{50} = 0.16mm)
- Bed degradation represented by eroding sill
- Monitoring by internal & external camera’s
- Stereo photography for 3D bathymetry





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Test program

- 7 tests x 2 models; L03 reference layout

Test	Layout name	Extent $b_{f,0}$ [-]	Thickness $D_{f,0}$ [mm]	Sill height h_{bd} [mm]	Water depth h_w [m]	D.a. current velocity u_c [m/s]	Duration T [hr]
T-01	L01	6D	100	0.25D	1.0	0.50	3
	L02	6D	100	0.25D	1.0	0.50	3
T-02	L03	4D	100	0.50D	1.0	0.50	3
	L04	4D	100	-	1.0	0.50	3
T-03	L05	4D	100	1.00D	1.0	0.50	3
	L06	3D	100	0.50D	1.0	0.50	3
T-04	L05	4D	100	1.00D	1.0	0.50	3
	L07	2D	100	0.50D	1.0	0.50	3
T-05	L05	4D	100	1.00D	1.0	0.50	6
	L07	2D	100	0.50D	1.0	0.50	6
T-06	L08	4D	50	0.50D	1.0	0.50	3
	L03	4D	100	0.50D	1.0	0.50	3
T-07	L08	4D	50	0.50D	1.0	0.50	6
	L03	4D	100	0.50D	1.0	0.50	6

Test results

- Filling the basin

- Reference case: extent of 4D with sill height of 0.5D

Test results

- Effects of sill height, extent and layer thickness


reference


reduced extent


larger sill height


lower thickness

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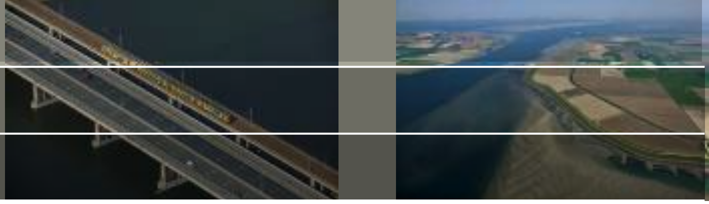
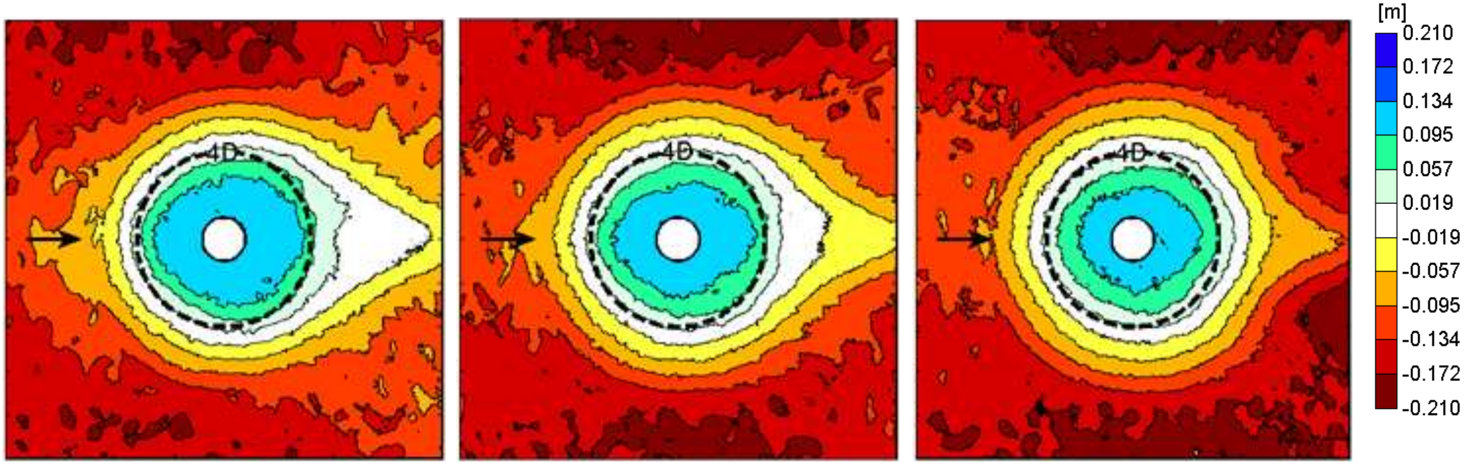


Development in time

- Largest development within first 3h.
- Hereafter, gradual erosion at upstream and downstream side

after 3h after 6h after 12h



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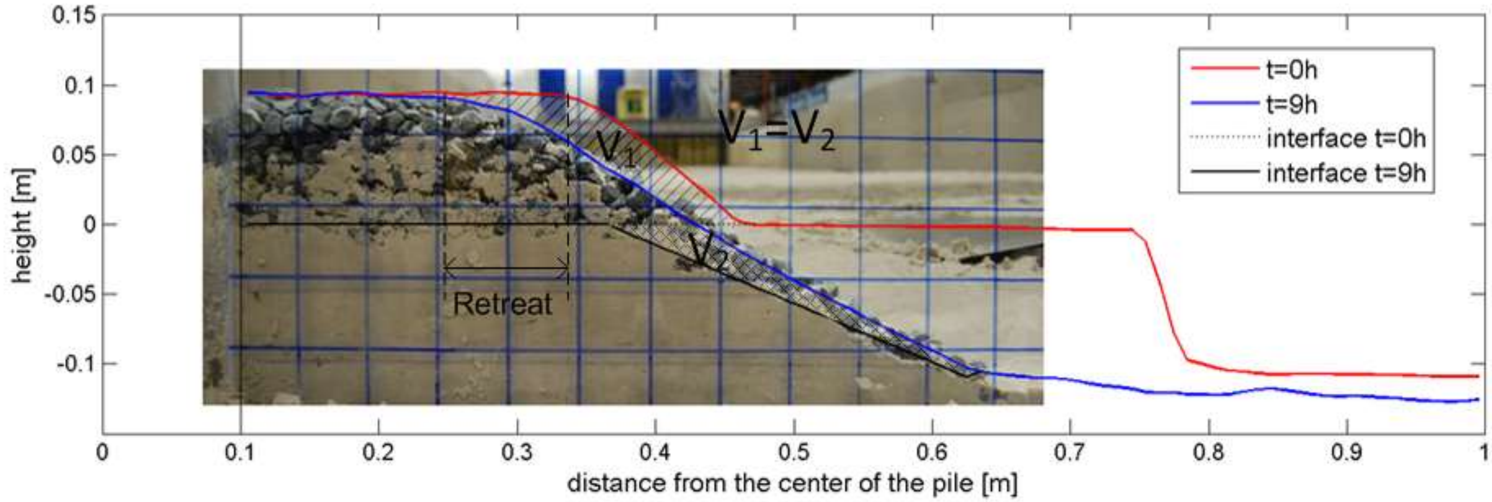
Analysis

- Consistent behaviour in tests:
  - > layer thickness gradually decreases towards outside
  - > similar slope angles (1:2 outer slope; 1:2.5 inner slope)
  - > no scour occurred where an extent of 3D was maintained

- Behaviour can be schematized with volume balance



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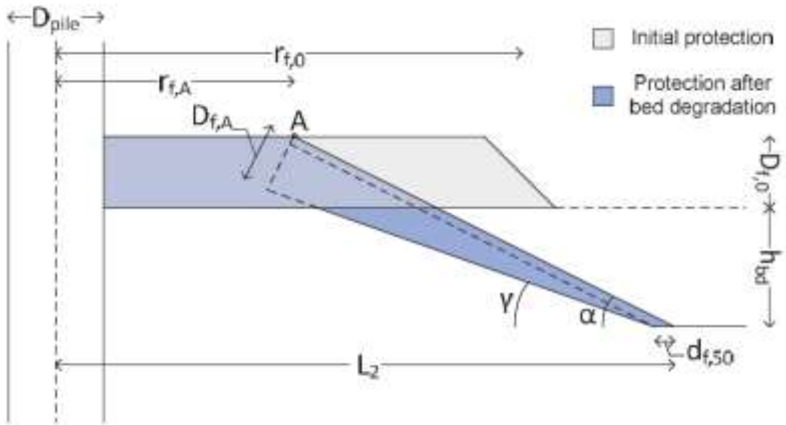
Analysis

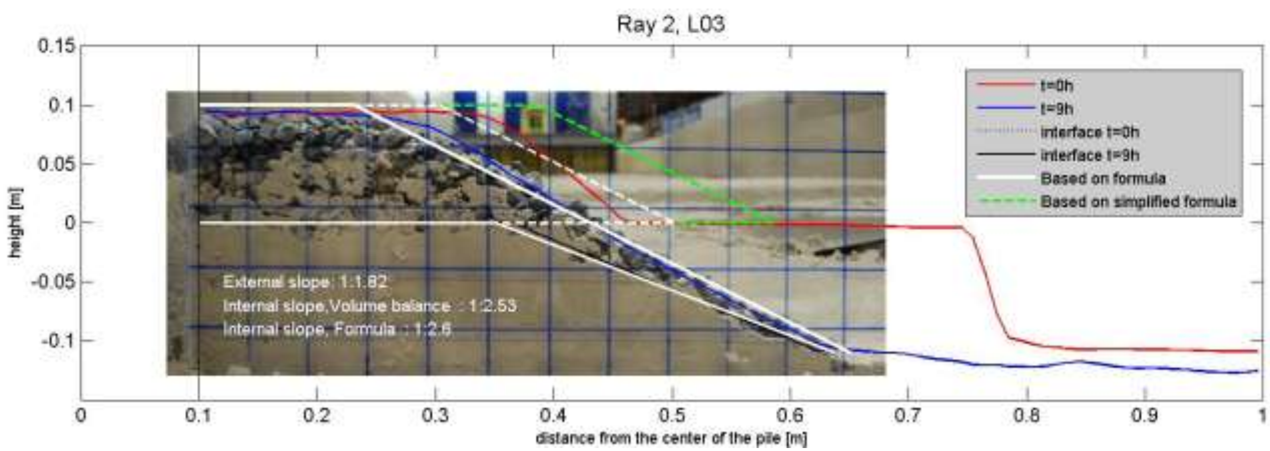
- Design formula for falling apron



$$r_{f,0}=\sqrt{\frac{\frac{\pi}{6}\left(L_2^3-r_{f,A}^3\right)-\frac{\pi}{3}\tan\gamma\left(\left(L_2-d_{f,50}\right)^3-\left(L_2-d_{f,50}-\frac{h_{bd}}{\tan\gamma}\right)^3\right)}{\pi D_{f,0}}}$$

Or simplified: $r_{f,0}-r_{f,A}=1.4\times h_{bd}$

- Validation



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Conclusions

- Falling apron process at pier
  - > starts upon being undermined
  - > initial stone redistribution by rolling, later sliding and sinking
  - > protective mound formed (with external slopes of 1:2)
- Scour prevented for tests in which extent of 3D was maintained
- Bed degradation can be accounted for by designing a falling apron
- Design rule derived to estimate stone volume needed for falling apron at pile

Thank you for your attention

B. de Sonneville, G. van Velzen, H. Verheij and K. Dorst (2012).
Falling aprons at circular piers under currents.
ICSE 6 Paris. August 2012

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