WP 2.3 – WP 2.4
Results of 3D stability tests

- Morten Kramer -

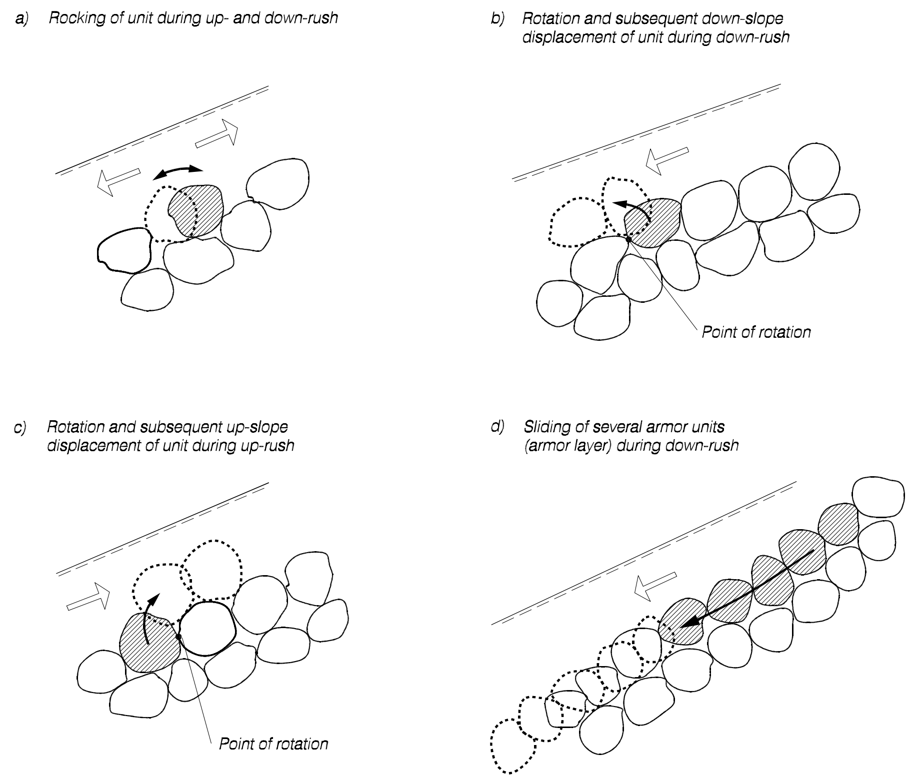
- Introduction with description of the “stability concept”
- What kind of information exist?
- Tests at AAU
- Conclusion and discussion. Do we need additional tests?

Introduction

- Wave forces acting on a rubble-mound slope can cause armor unit movement. This is called hydraulic instability.

• Breakage of armor units is another type of instability which is not discussed here.

• Armor unit movements can be rocking, displacement of units out of the armor layer, sliding of a blanket of armor units, and settlement due to compaction of the armor layer.



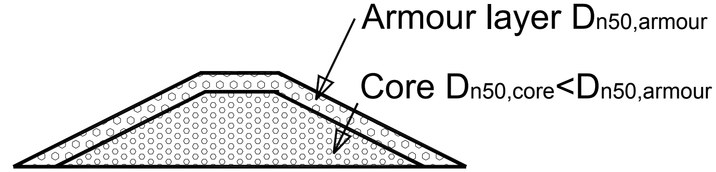
Why do we perform laboratory tests?

The complicated flow of waves impacting armor layers makes it impossible to calculate the flow forces acting on armor units. Moreover, the complex shape of units together with their random placement makes calculation of the reaction forces between adjacent armor units impossible. Consequently, deterministic calculations of the instantaneous armor unit stability conditions cannot be performed, which is why stability formulae are based on hydraulic model tests. The response of the armor units in terms of movements are related directly to parameters of the incident waves, while treating the actual forces as a "black box" transfer function.

Parameters influencing armour layer stability

- Sea state parameters
  - Characteristics of waves
  - Number of waves
  - Water depth
  - Mass density of water

- Structural parameters
  - Shape of profile
  - Characteristics of materials



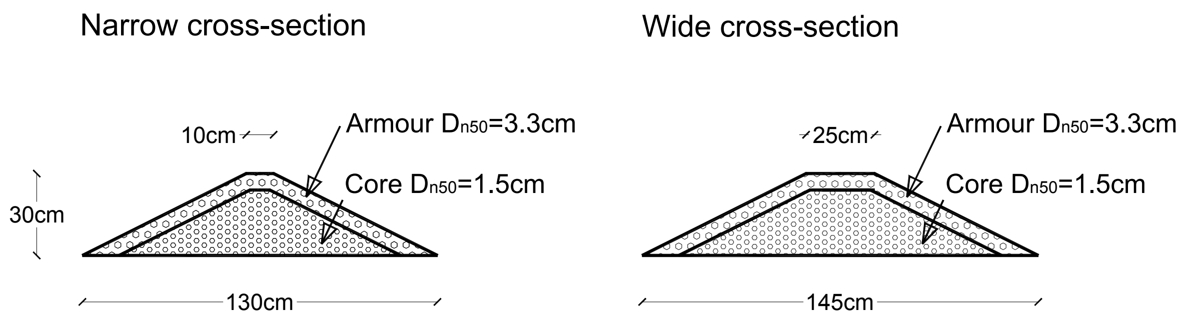
Existing tests on LCS

- 2D
  - Ahrens 1987
  - Van der Meer 1990/1996
  - Loveless and Debski 1997
  - ...
- 3D
  - Vidal et al. 1992
    - Tests were carried out in the wave basin at NRC, Canada, 1991-1992.

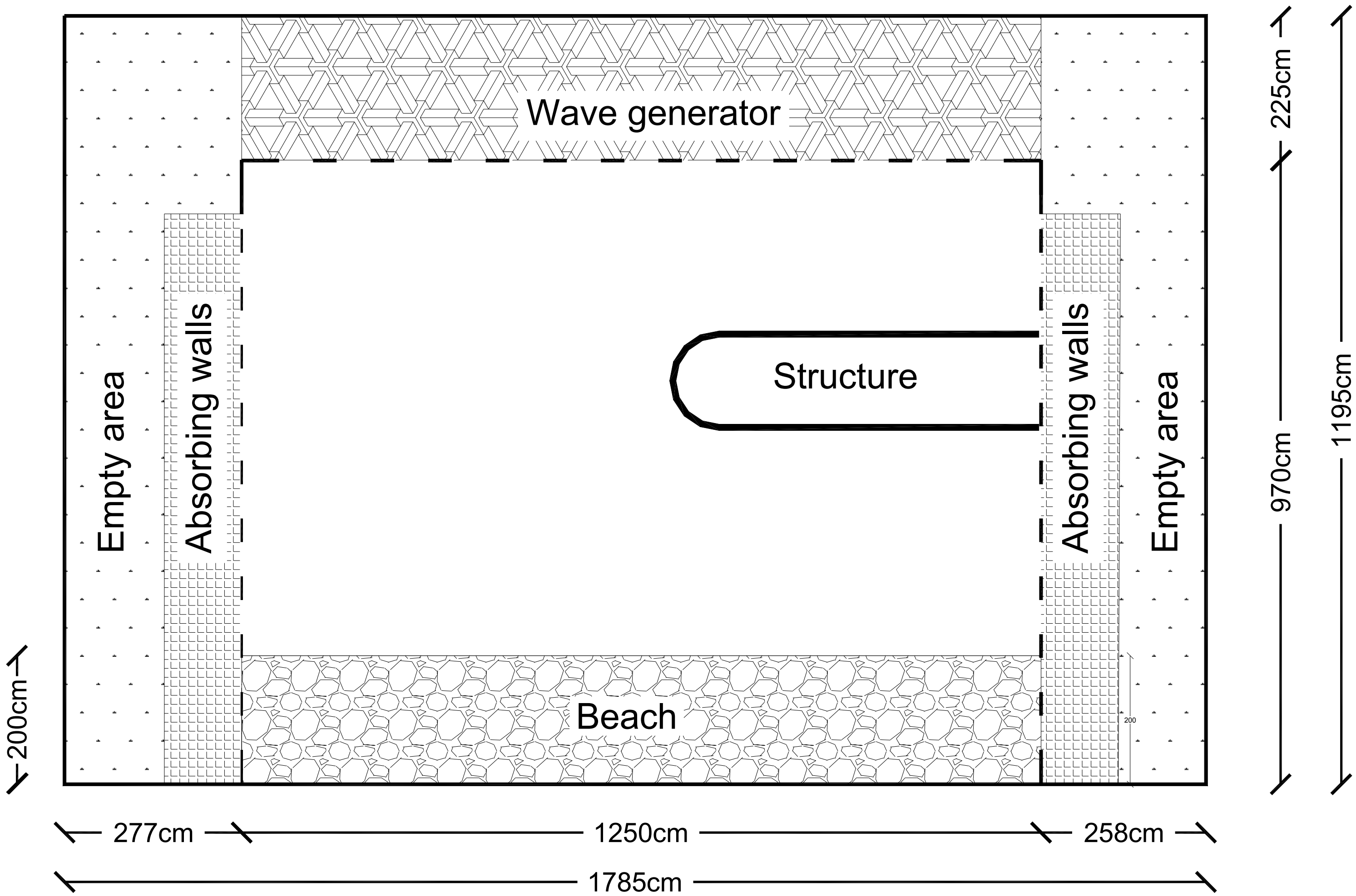
Task for the new 3D stability tests at AAU

Influence of:

1) Obliquity of short crested waves
2) Wave height and steepness
3) Crest width — Two crest widths were tested
4) Freeboard — By varying water level (one crest height was tested)
5) Structure slope — By trying to compare with NRC tests

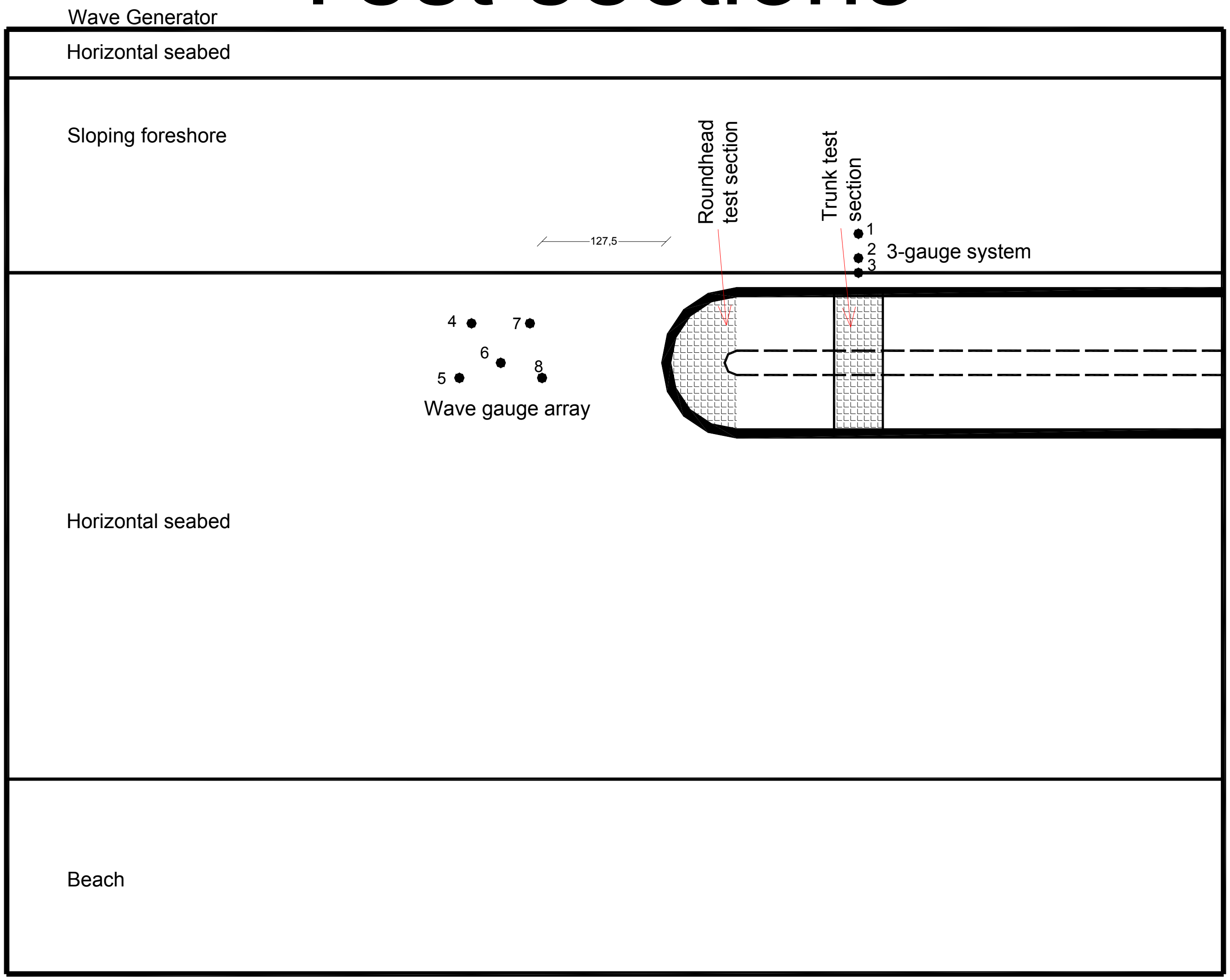


Layout

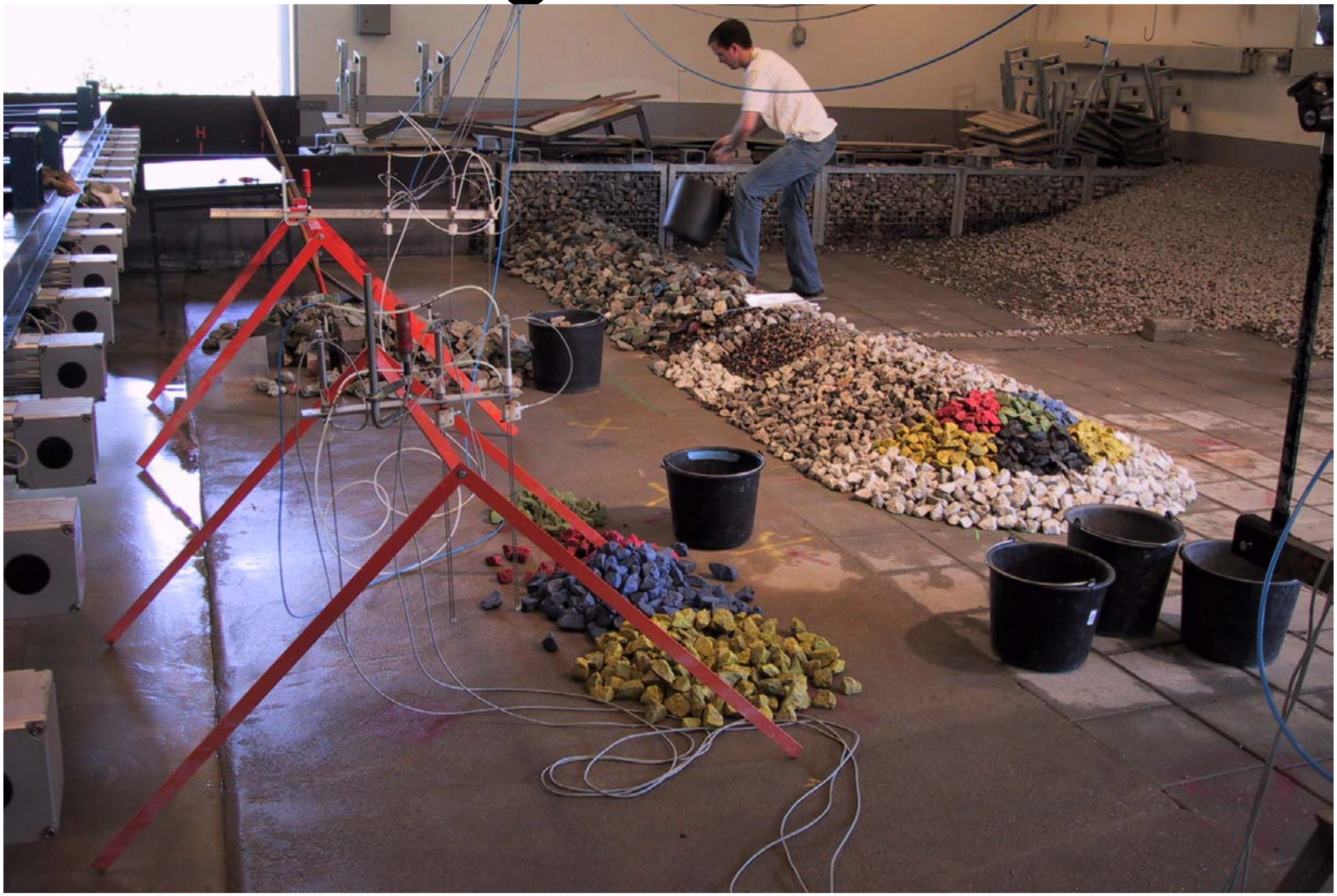


Wave generator
Structure
Beach
Empty area
Absorbing walls
Absorbing walls
Empty area
225cm
970cm
1195cm
200cm
277cm
1250cm
258cm
1785cm

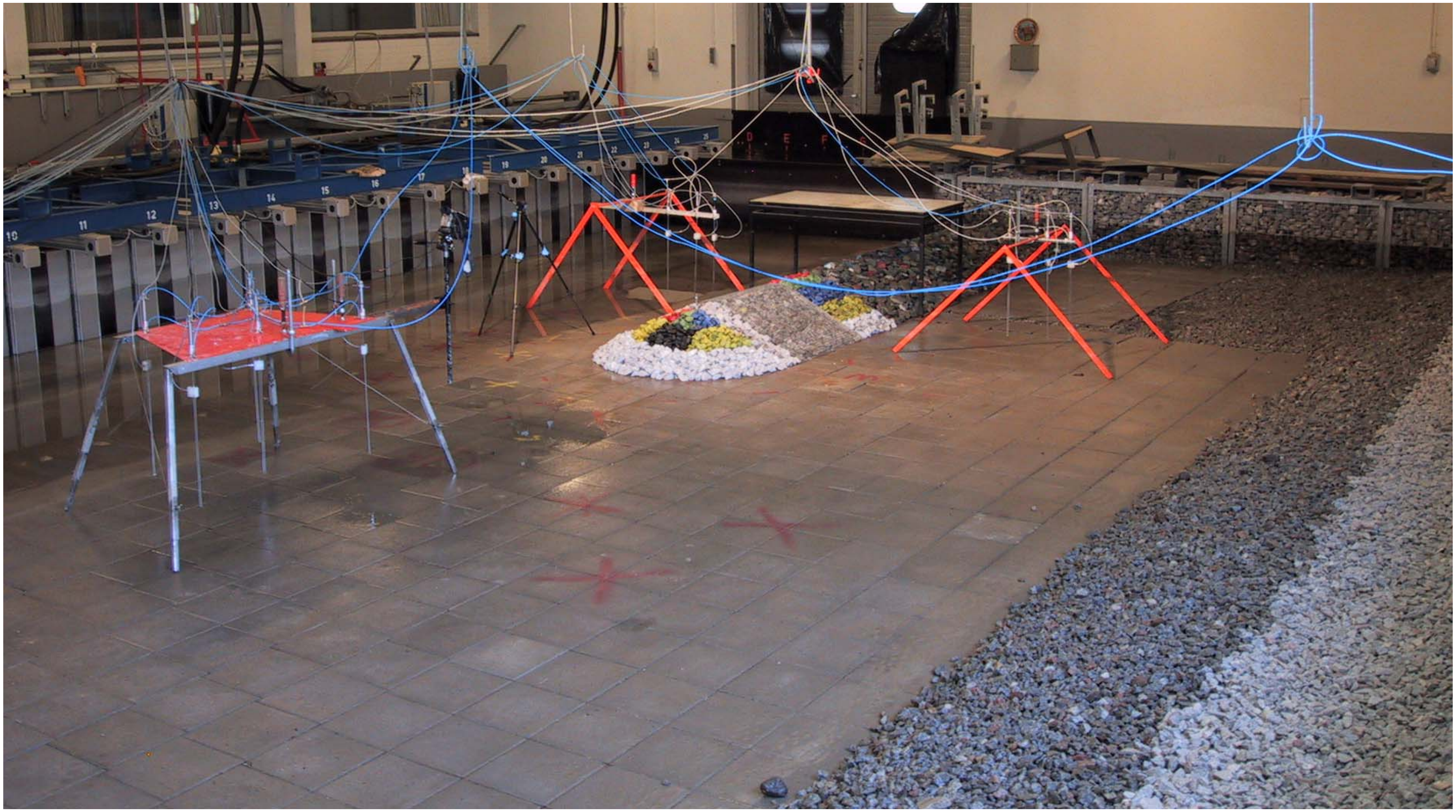
Test sections



Building the structure



Picture of layout



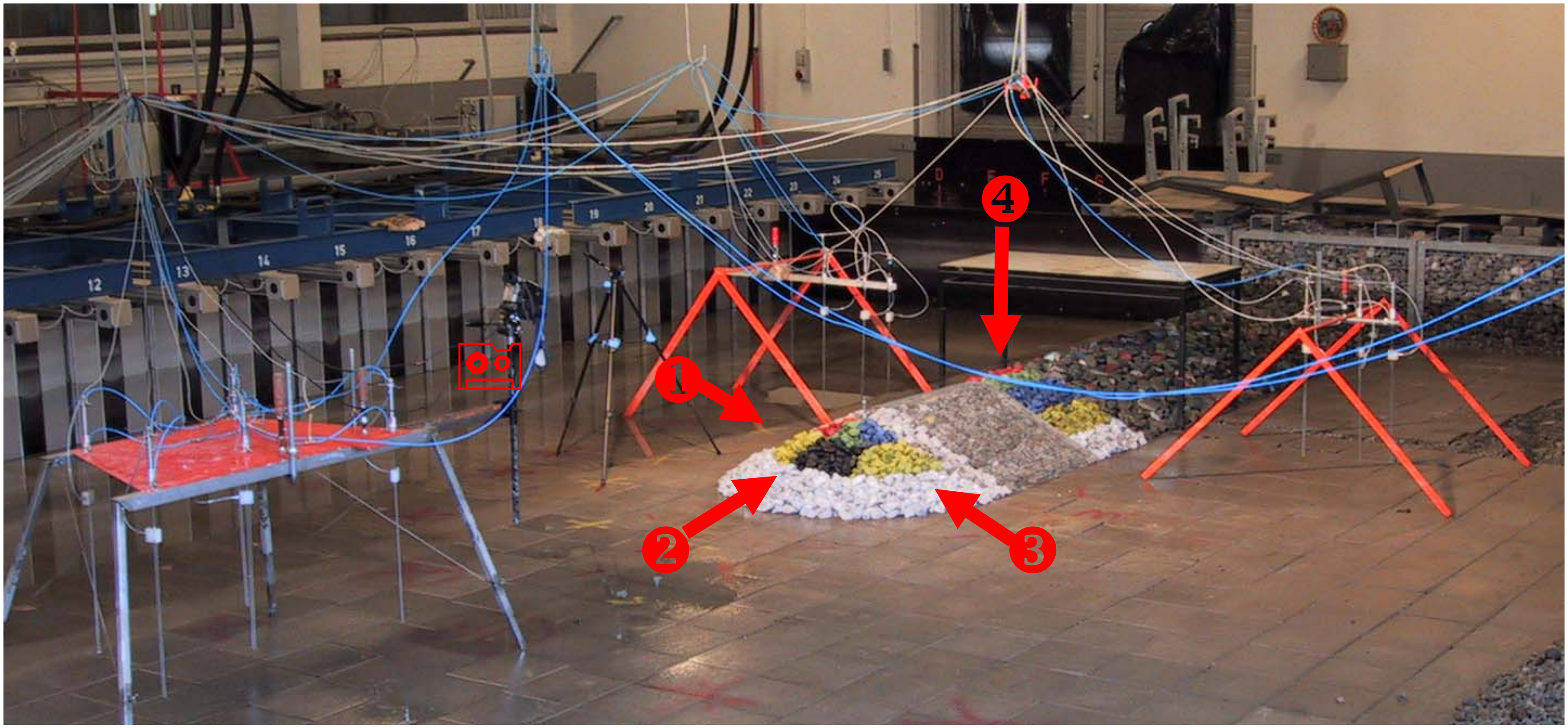
Test procedure

- Built/rebuilt the structure
- Fix water level, wave direction, steepness and spreading
- Perform test with 1000 waves with small wave height
- Measure damage
- Increase significant wave height and run 1000 waves
- Measure damage
- ...continue to increase the wave height and measure damage until severe damage was observed

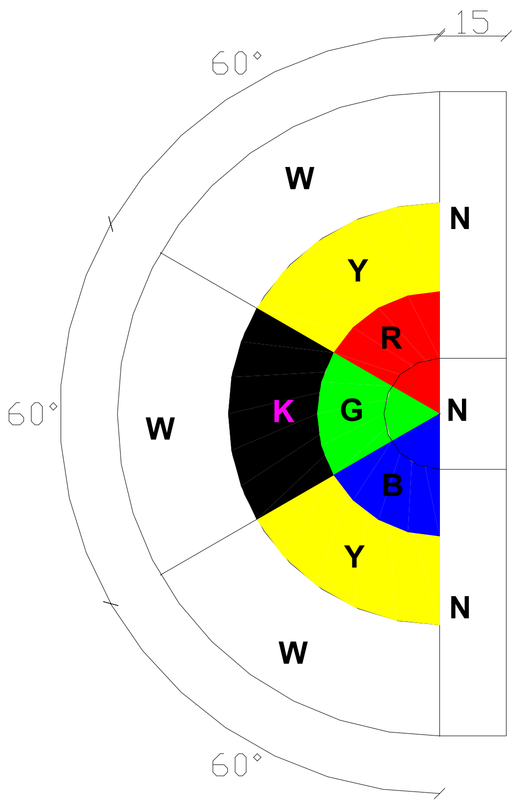
Measurements

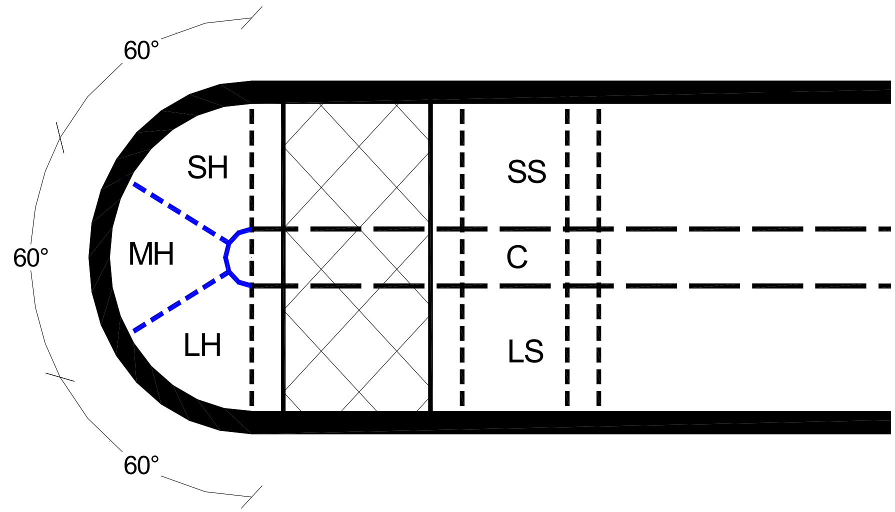
- Waves were recorded continuous during the tests.
- Wave breaking was described from visual observations.
- Damage in terms of displacement of stones was measured after each test by use of digital photos. Damage was classified in categories. Digital video recordings were taken during a few tests of special interest.

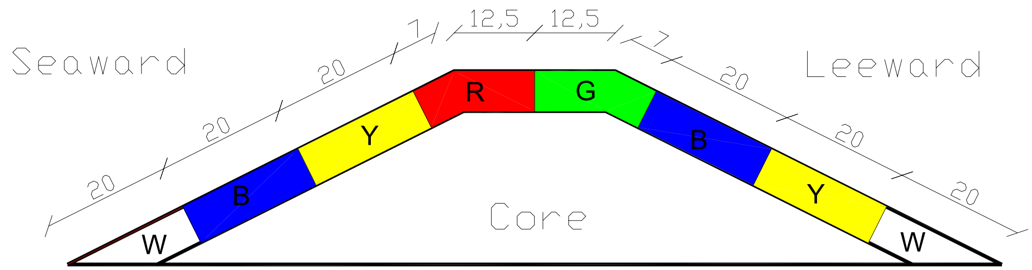
Measurement of damage



Colouring of sections



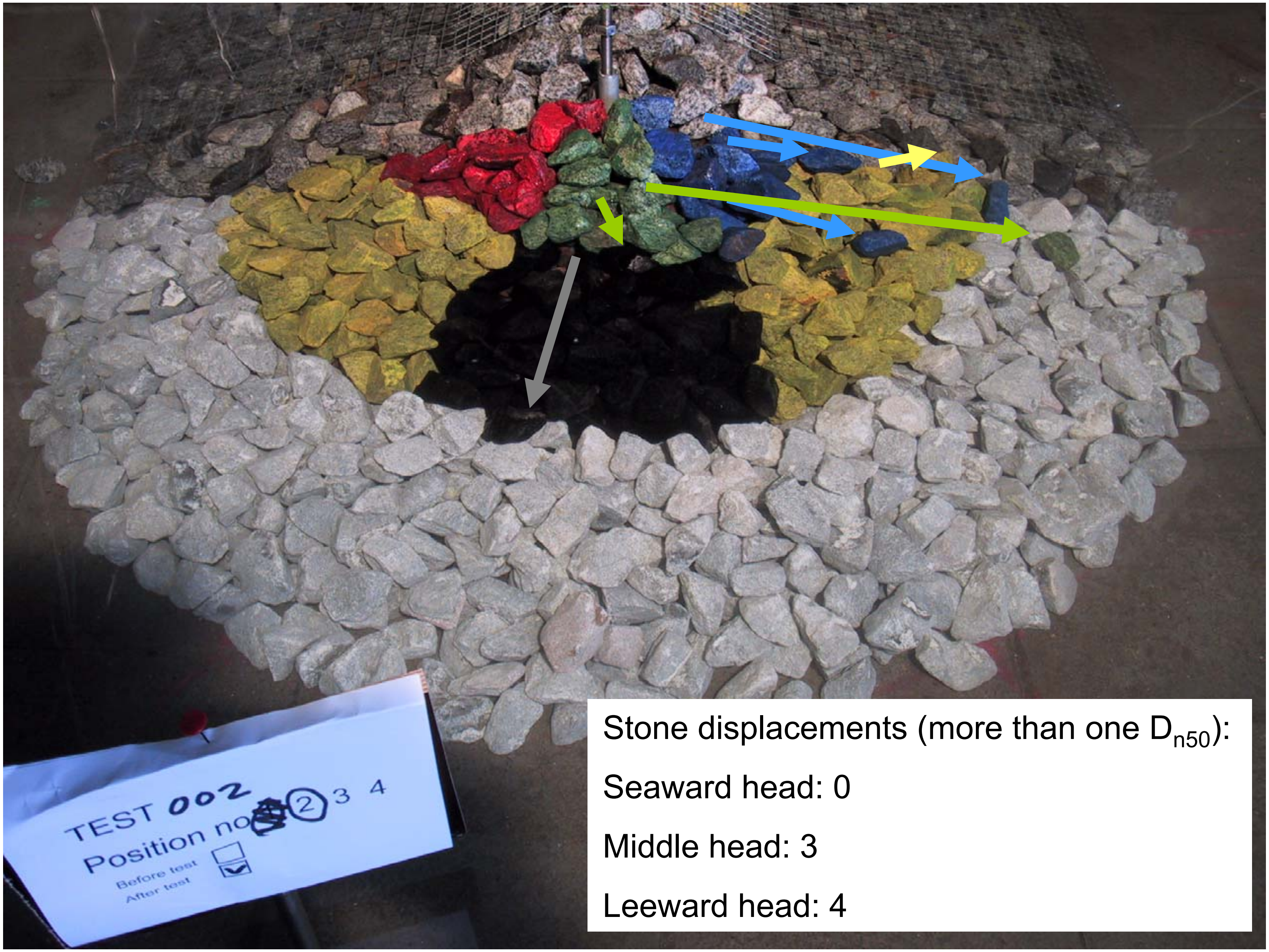




Example

- Test no. 1-4, position 2 (roundhead from gap)
  - Main wave direction perpendicular to structure
  - Crest width = 0.1m (narrow crest with)
  - Freeboard = +0.05m
  - Wave steepness = 0.02


TEST 001
Position no 1 2 3 4
Before test
After test



Stone displacements (more than one D_{n50}):

Seaward head: 0

Middle head: 3

Leeward head: 4

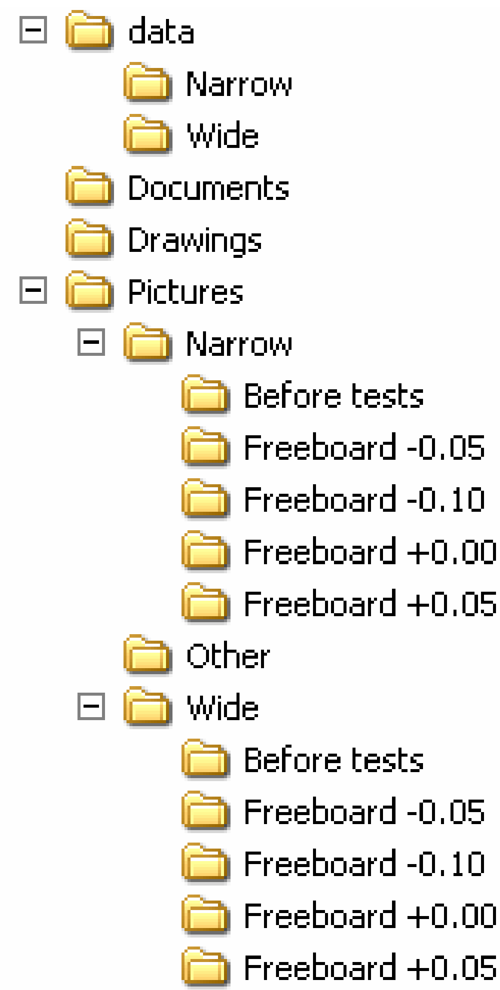

TEST 003
Position no 1 2 3 4
Before test
After test


TEST 004
Position no 1 2 3 4
Before test
After test

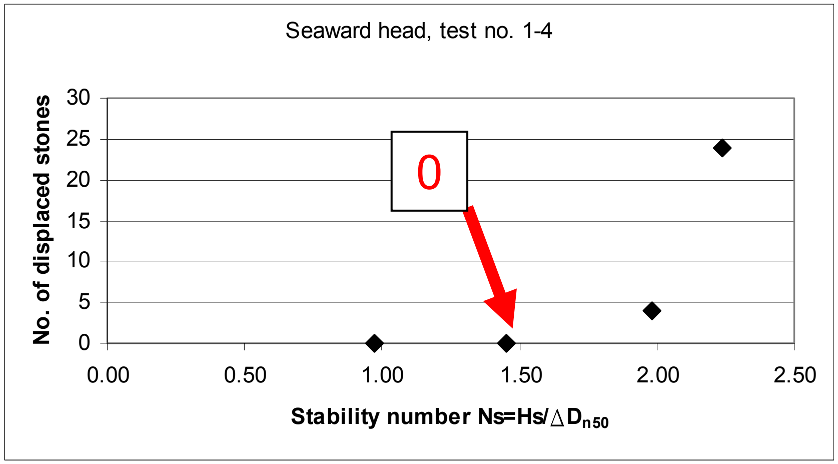
Databank on CD

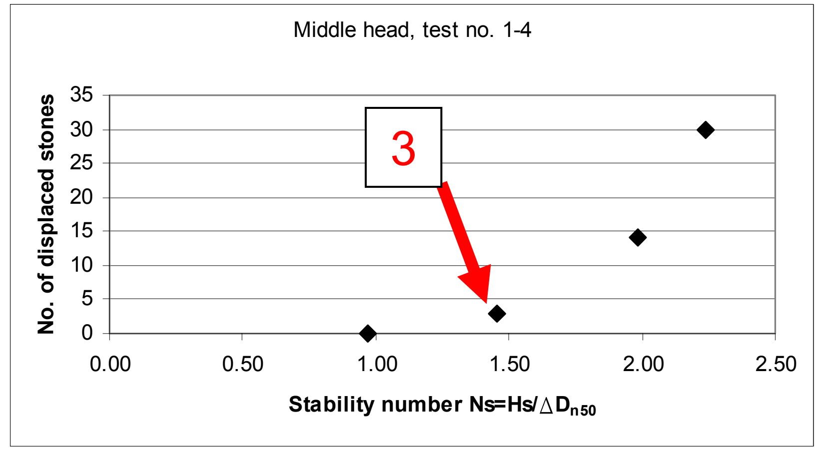
The CD with the measurements will be delivered together with the report describing the tests in detail. This report is a part of DELOS delivery D31 to be completed within March 2003.

The report will also contain analysed results.



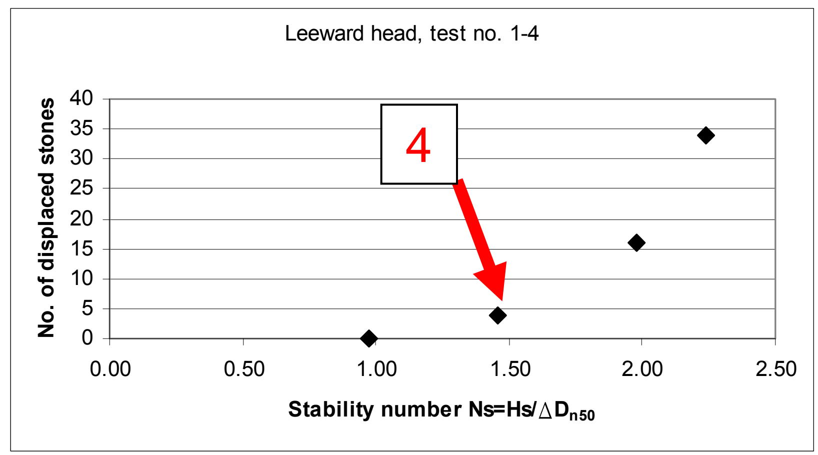
Test 1-4 for roundhead





Number of displaced stones in % =

$$\frac{\text{Number of displaced stones in section}}{\text{Total number of armour stones in the section}} *100$$



Degree of damage

- ND: No damage
- ID: Initiation of damage

  Displaced stones >1% ~ 2 stones for narrow roundhead

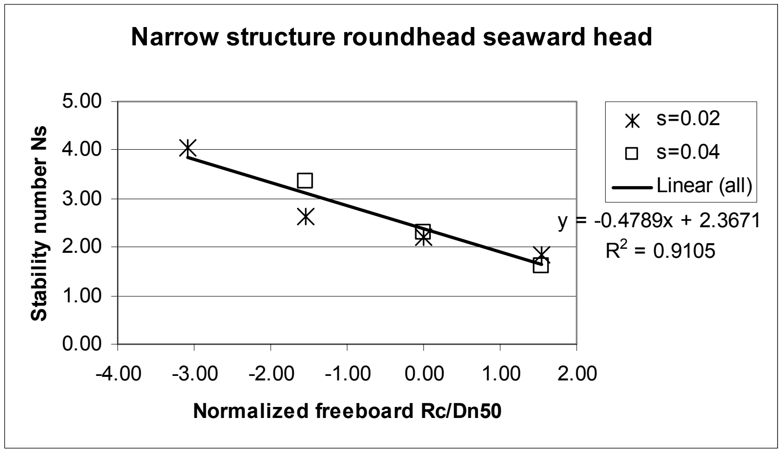
- IR: Iribarren damage

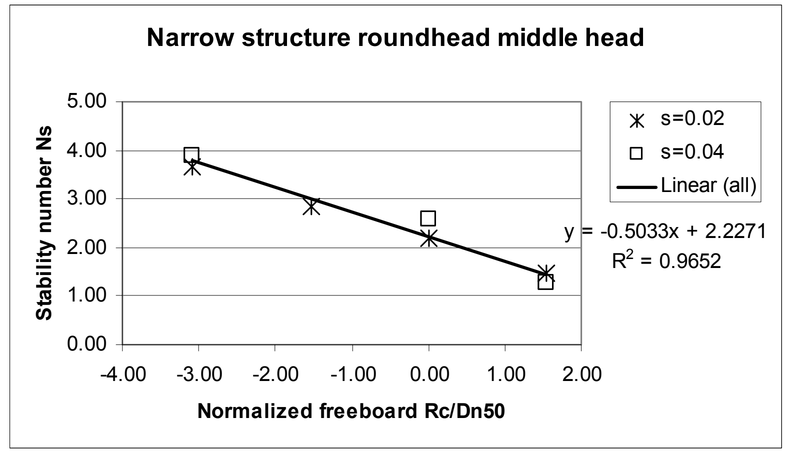
  Big holes in outer armour layer

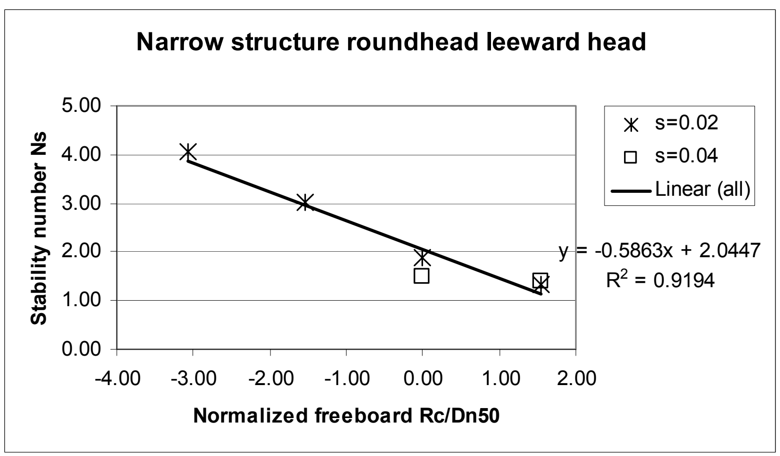
- D: Destruction

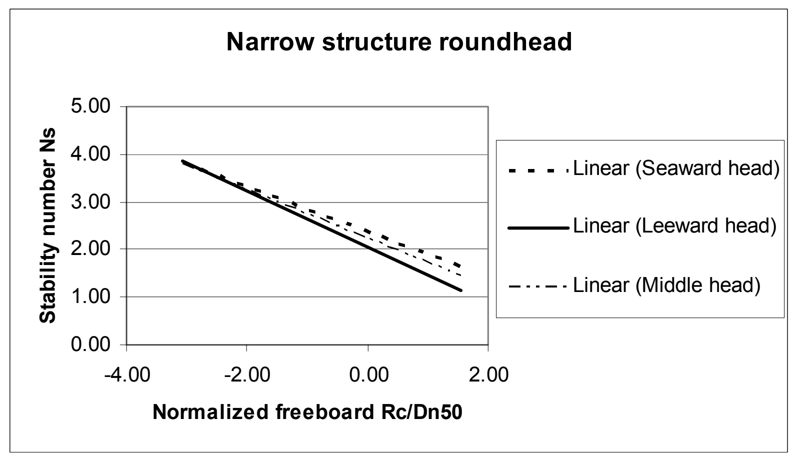
Influence of freeboard

Example: Initiation of damage for roundhead. Preliminary results.



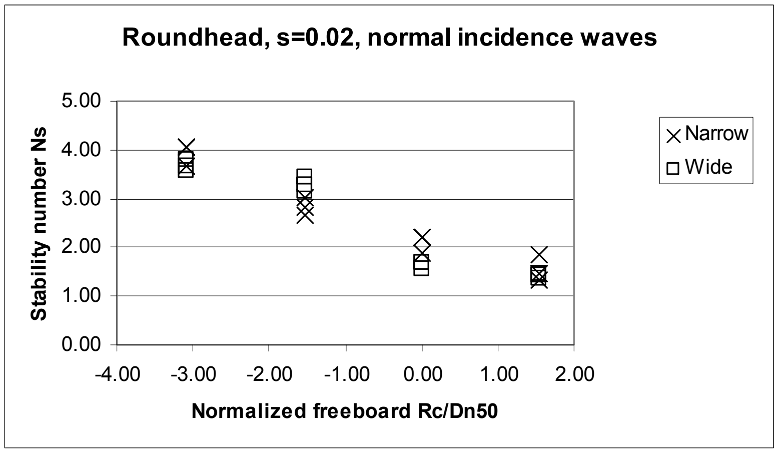


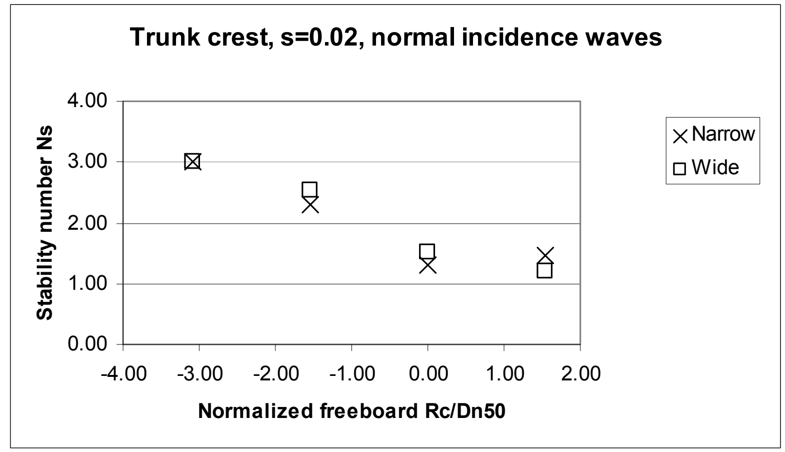


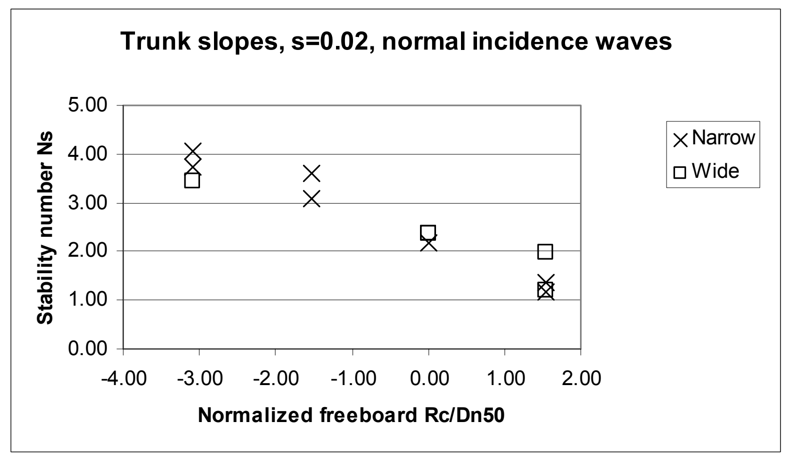


Influence of crest width

Example: Initiation of damage. Preliminary results.







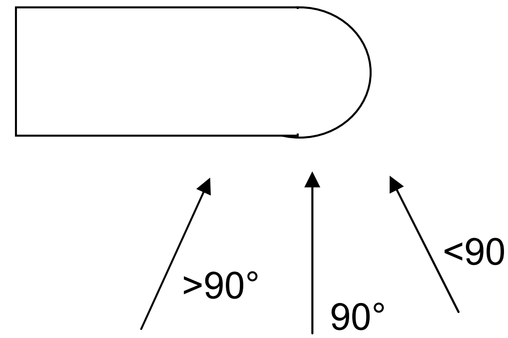
Crest widths:

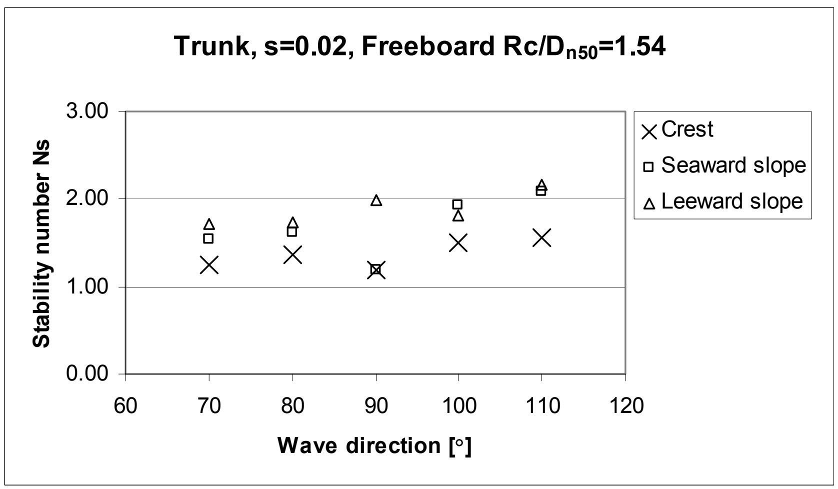
Narrow structure: $3D_{n50}$

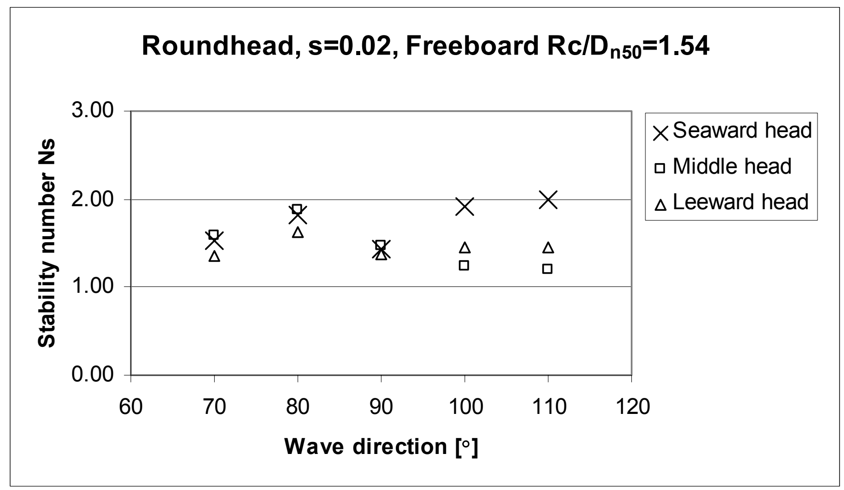
Wide structure: $8D_{n50}$

Stability related to obliquity

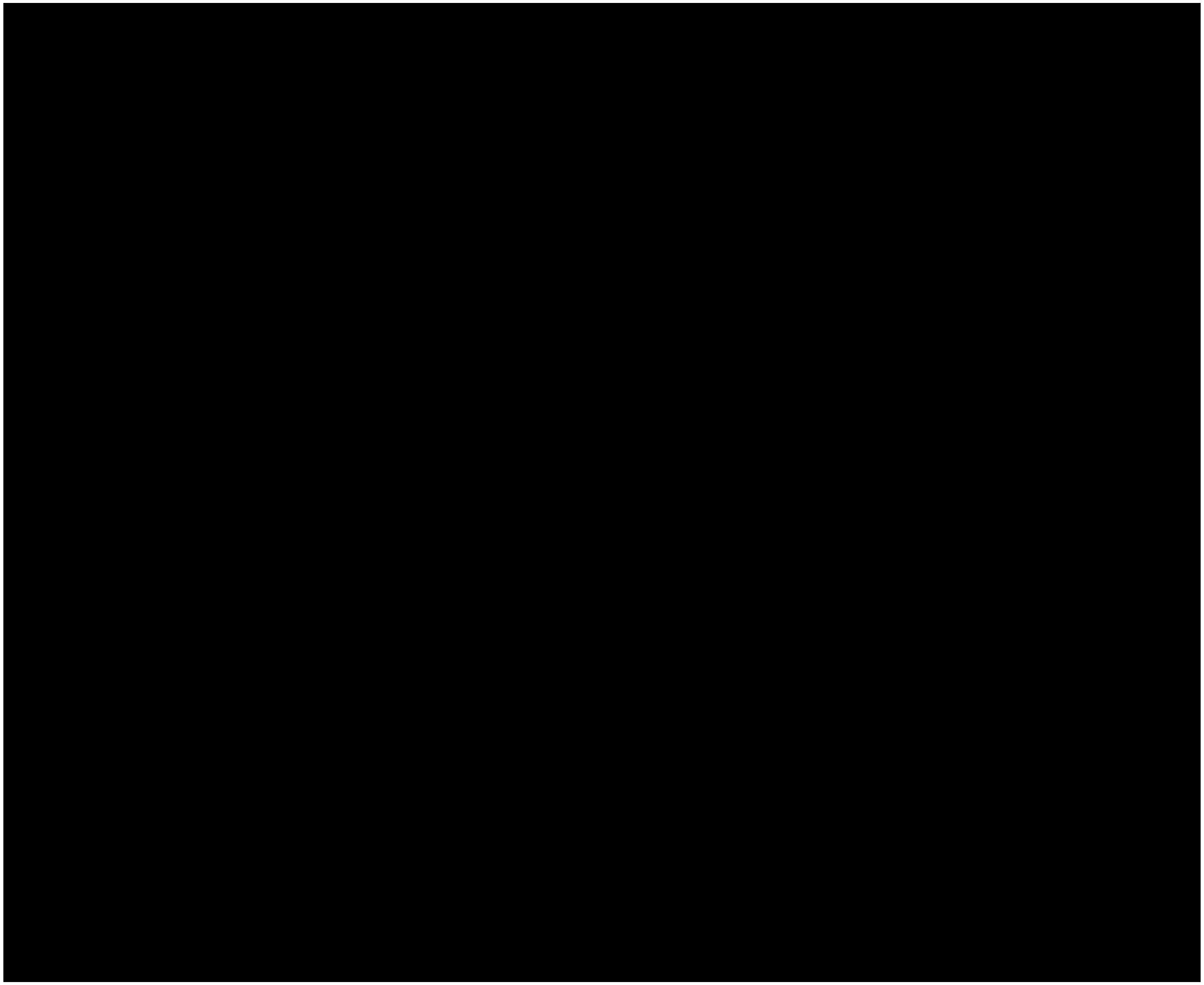
Example: Initiation of damage. Preliminary results.





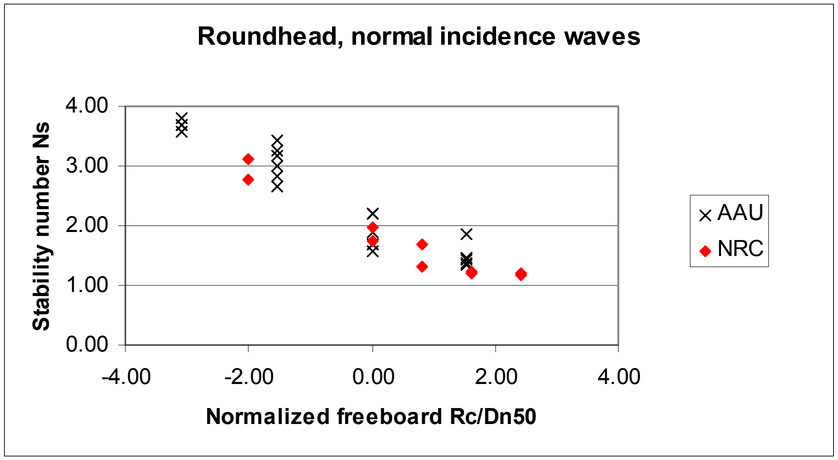


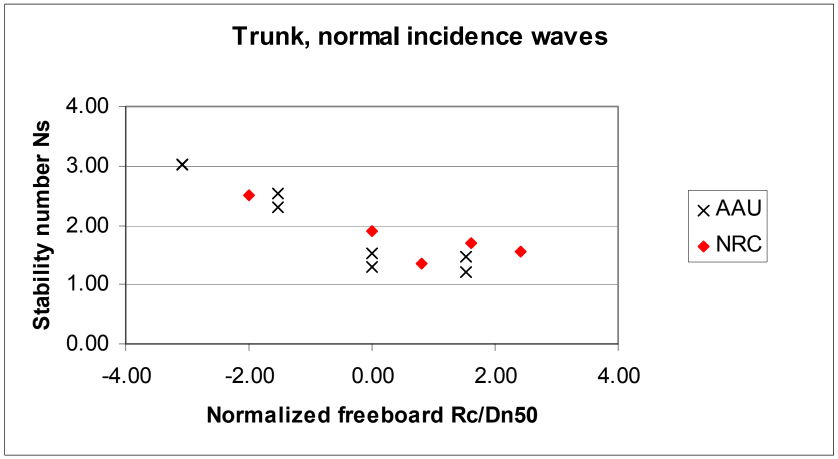
Oblique wave attack, test no. 54



Influence of structure slope

Example: Initiation of damage. Preliminary results.





The most important differences in the two test series:

- Structure slopes were 1:1.5 in NRC tests (1:2 in AAU tests)
- No foreshore slope was present in NRC tests
- 2D irregular waves were generated in NRC tests (3D in AAU tests)
- Damage level description is subjective

Test schedule

Narrow crest width

Test no.	[°]	Crest width [m]	Free-board [m]	Wave steepness
1-4	90	0.1	0.05	0.02
5-8	90	0.1	0.05	0.04
9-12	90	0.1	0	0.02
13-17	90	0.1	0	0.04
18-22	90	0.1	-0.05	0.02
23-27	90	0.1	-0.05	0.04
28-31	90	0.1	-0.1	0.02
32-36	90	0.1	-0.1	0.04

Wide crest width

Test no.	[°]	Crest width [m]	Free-board [m]	Wave steepness
37-40	90	0.25	0.05	0.02
41-44	70	0.25	0.05	0.02
45-48	80	0.25	0.05	0.02
49-51	100	0.25	0.05	0.02
52-55	110	0.25	0.05	0.02
56-59	60	0.25	0.05	0.02
60-63	90	0.25	0	0.02
64-66	90	0.25	-0.05	0.02
67-69	90	0.25	-0.1	0.02

Test 1-36: Influence of wave-steepness and freeboard

Test 37-59: Influence of wave obliquity

Test 1-40, 60-69: Influence of crest width

Conclusion & discussion

- Two structures with different crest width was tested in irregular 3D waves. From the results it is directly possible to describe the influence of:
  - Obliquity of short crested waves
  - wave height and steepness
  - Crest width in the tested range
  - Freeboard

- Limitations of the present data bank / task for supplementary tests:

What is the influence of structure permeability on roundhead damage for LCS's?

How does long crested waves affect the stability compared to short crested waves?

Etc.