Bucket Foundation, a status
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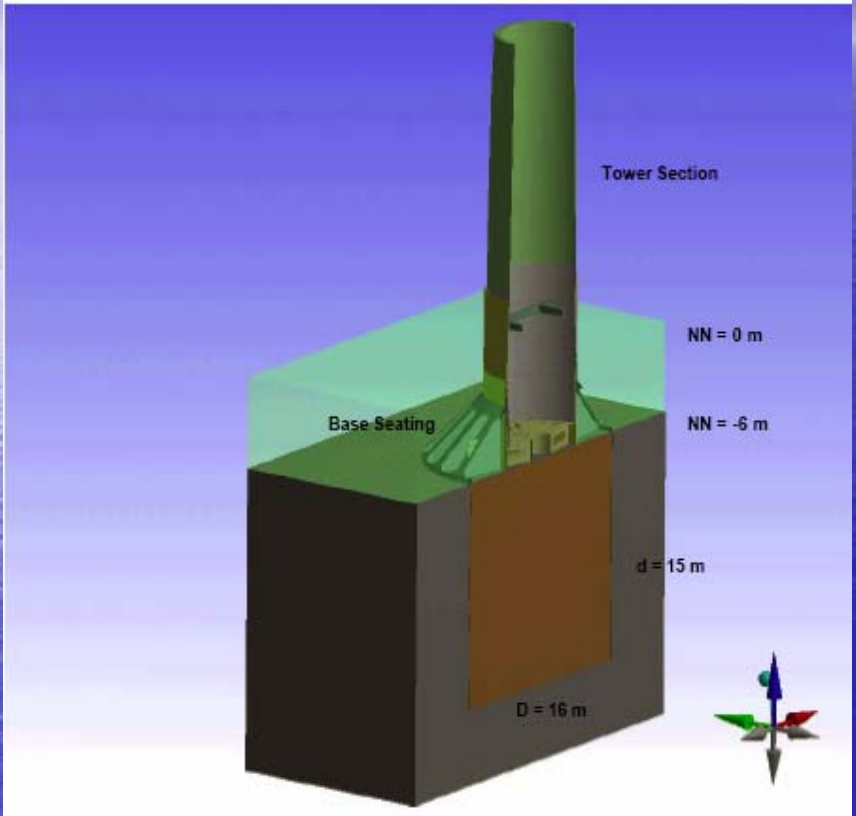
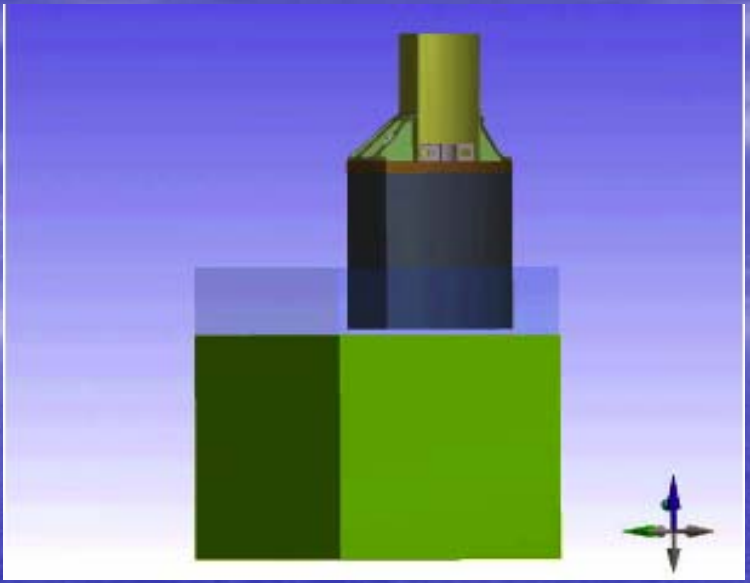
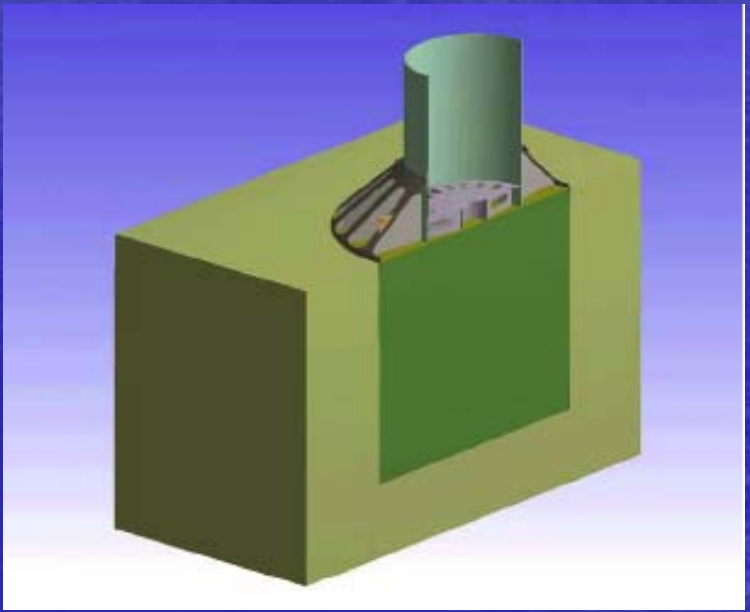
Test site for offshore wind turbine in Frederikshavn

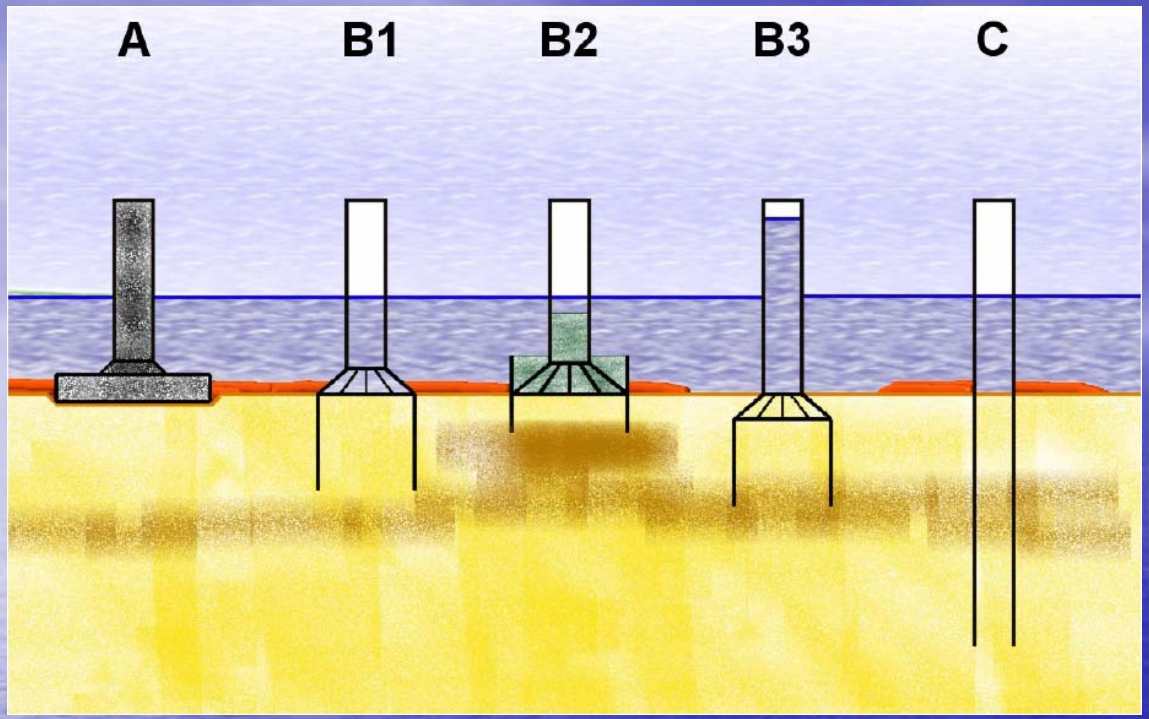
- MBD and Elsam have establish the test site for offshore wind turbine in cooperation with University of Aalborg August 2002
- Elsam builds the 4 wind turbines in Frederikshavn using Tech-wise as consultant.
- The first project is to develop an innovative foundation solution for offshore wind farms. “Bucket Foundation”

Construction stage
Bucket foundation









	A	B	C
Deadload V	X	X	
Diameter D	X	X	(X)
Foundation depth d		X	X
Foundation level h		X	

Demands to the prototype

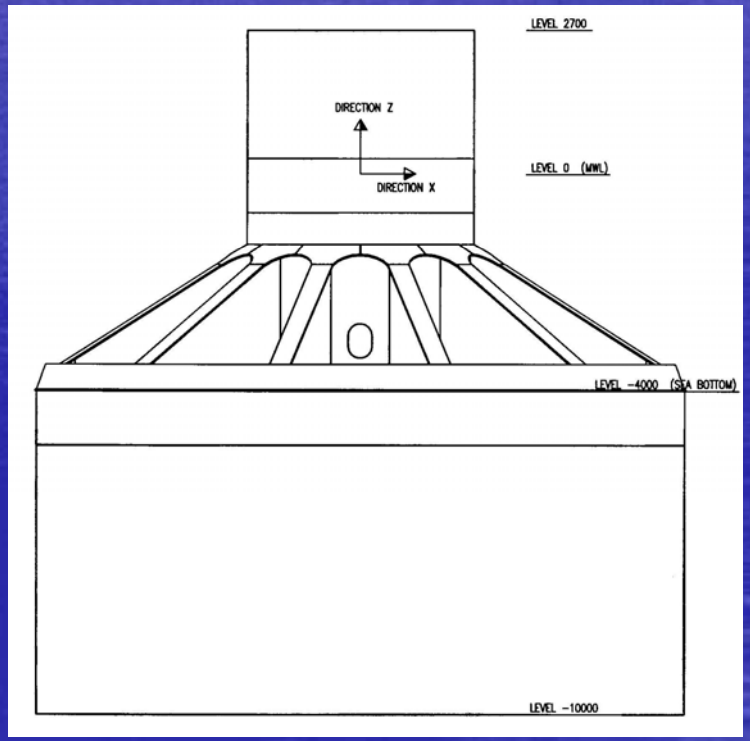
Bucket Foundation

- Flang: Welded on the center column
- Allowable deformatuon: 0,5 deg in 20 year

  After instalation: 0,25 deg

  Plastic deformations: 0,25 deg
- The stifness:

  First resonance frequency ω_1>0.295 HZ



Objective for the research

- Develop a design procedure:

  Design Basis
  Conceptural Design
  Detailed Design

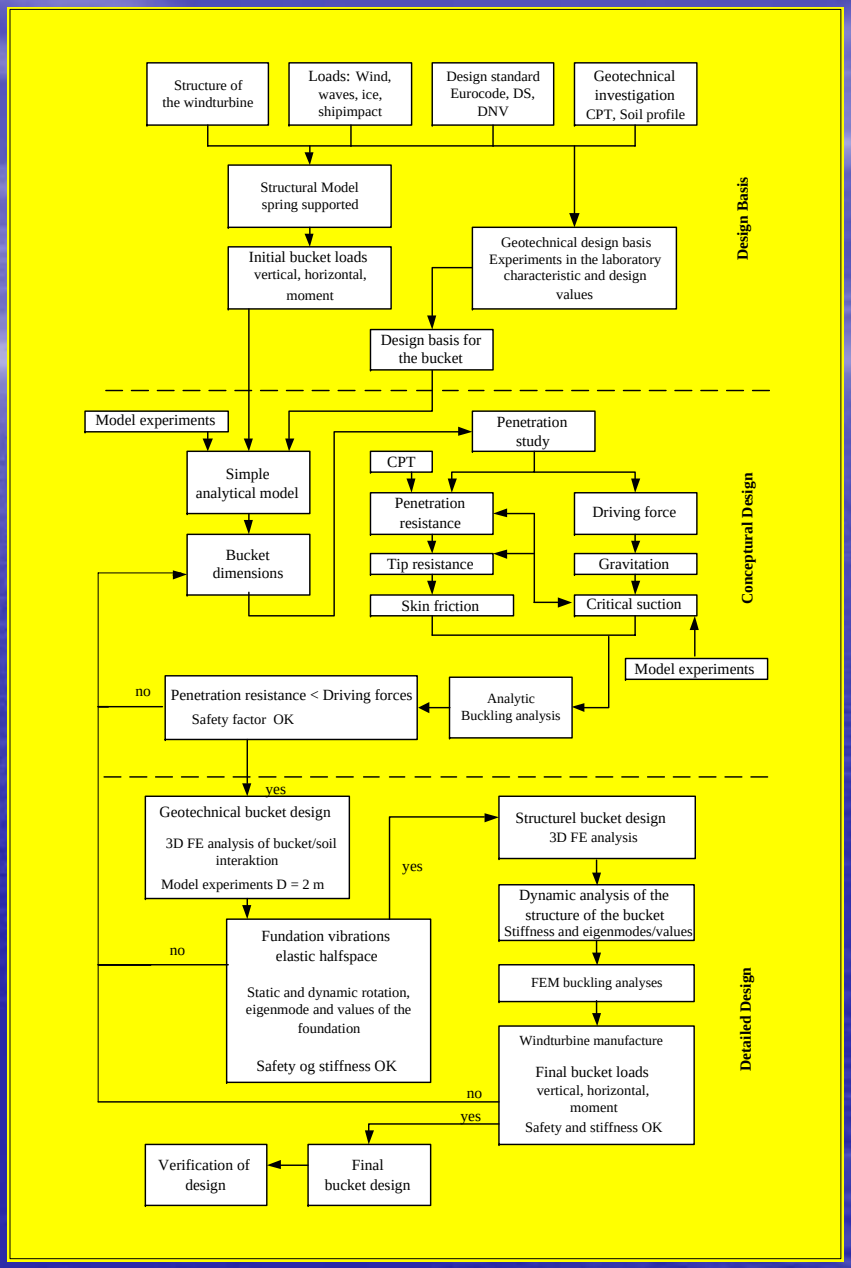
  - In cooperation with certifying party DNV
  - Approval procedure in future projects

- Reduce the uncertanties in the new design

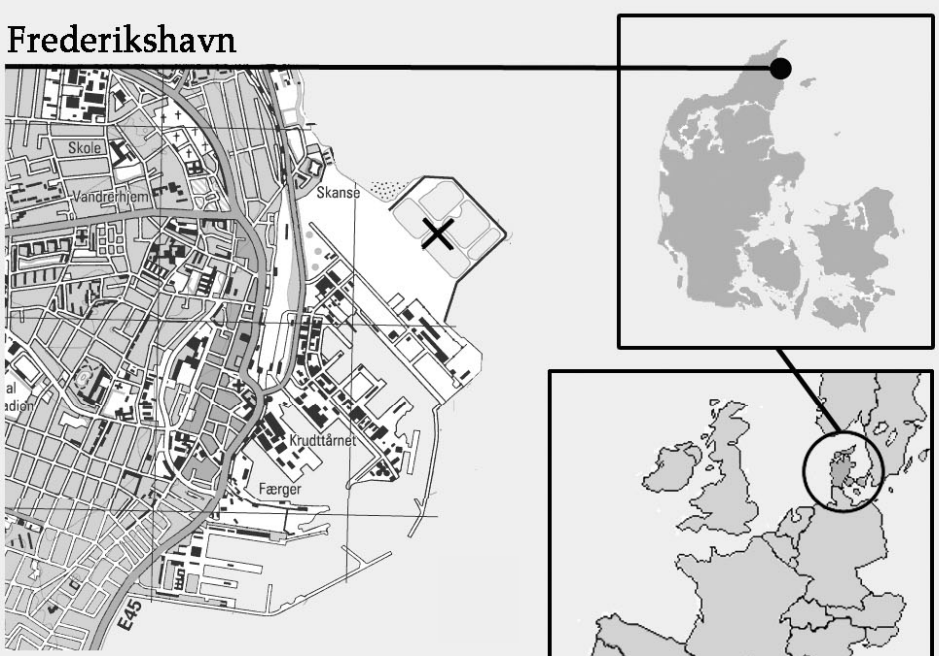
  - Laboratory model test
  - Field trials at reduced scale
  - Full-scale tests

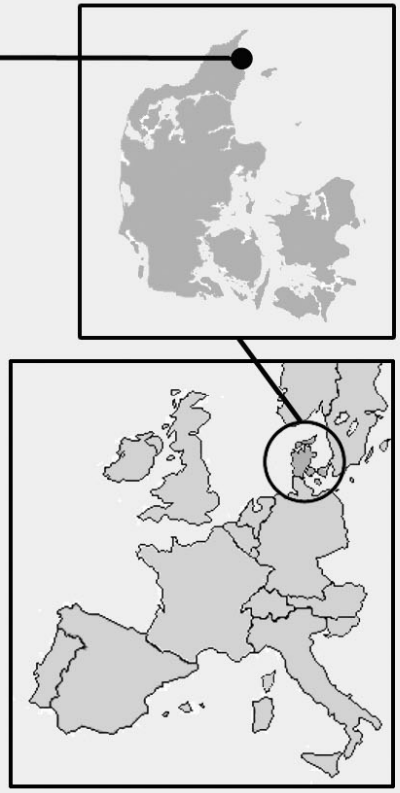
- Focus on:

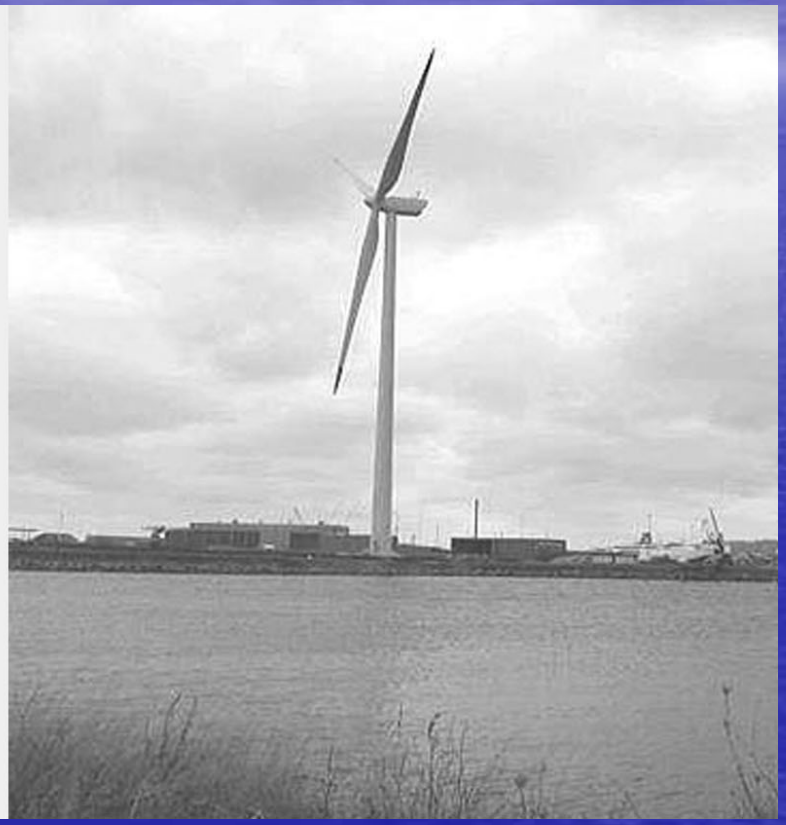
  - Installation
  - Performance at static loads
  - In service performance



Test site for offshore wind turbine research in Frederikshavn





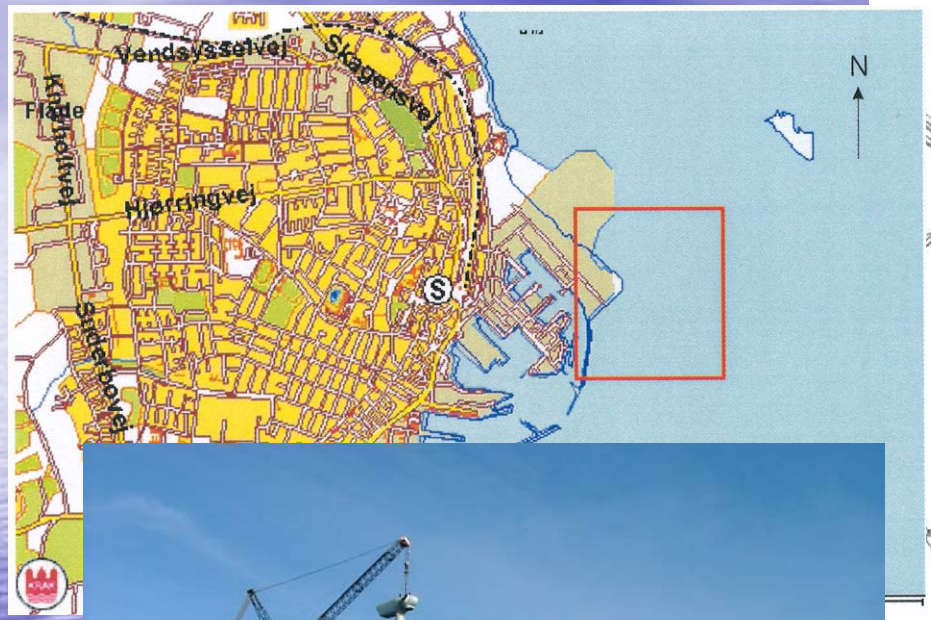


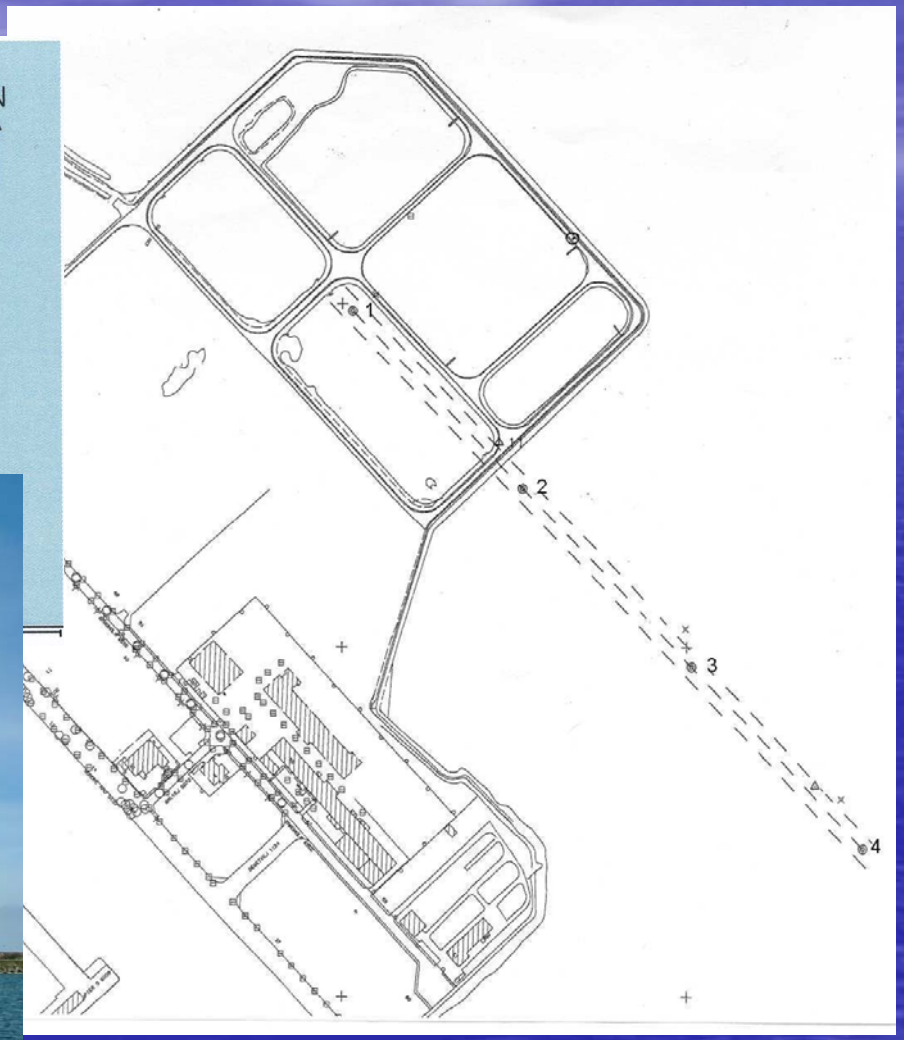
Bucket location

Latitude: 57°26,89′

Longitude: 10°33,4′

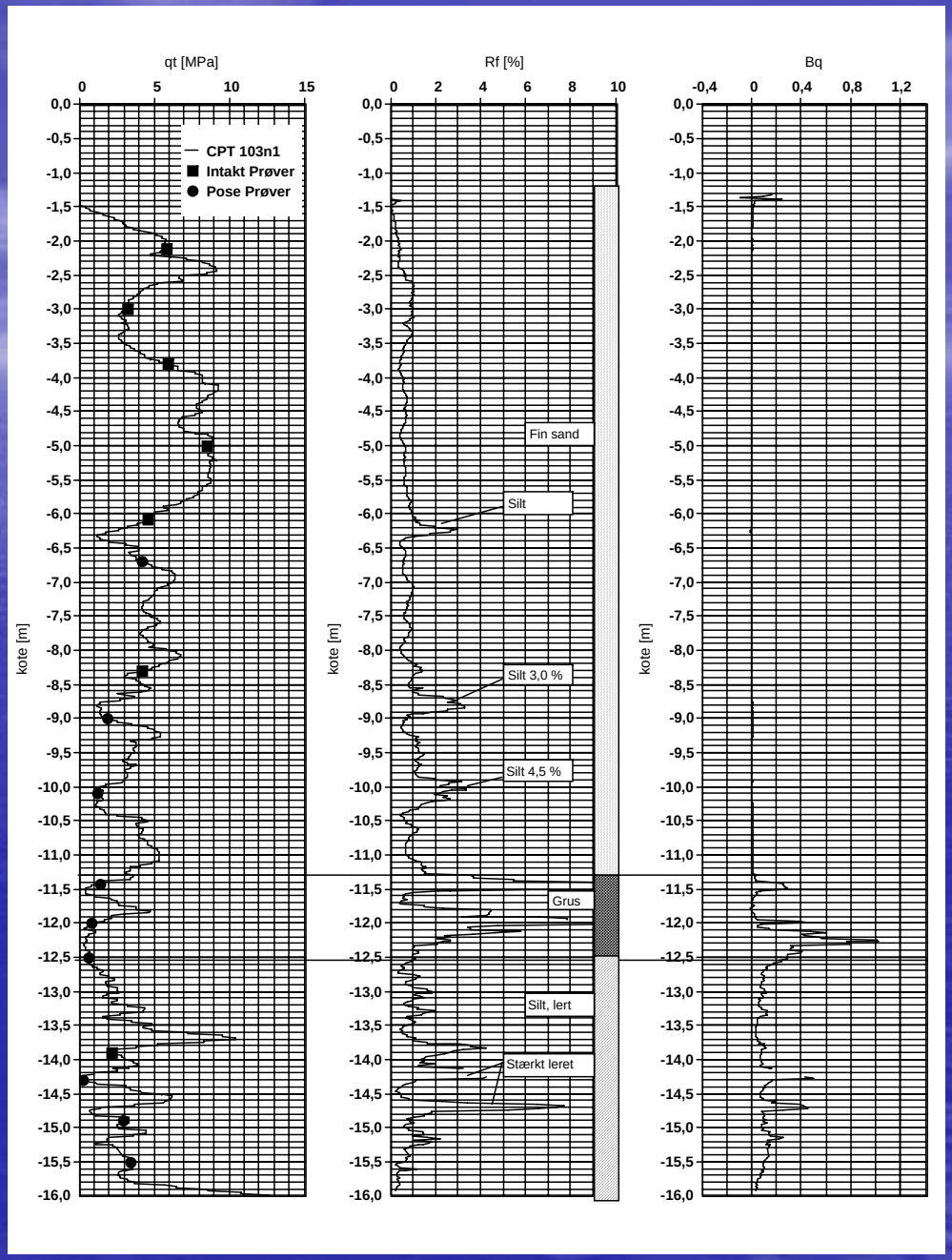
Test site for offshore wind turbine research in Frederikshavn



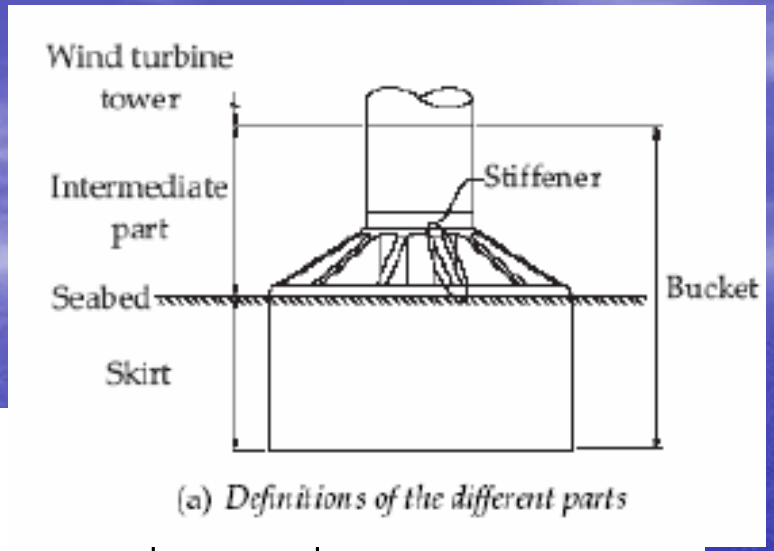


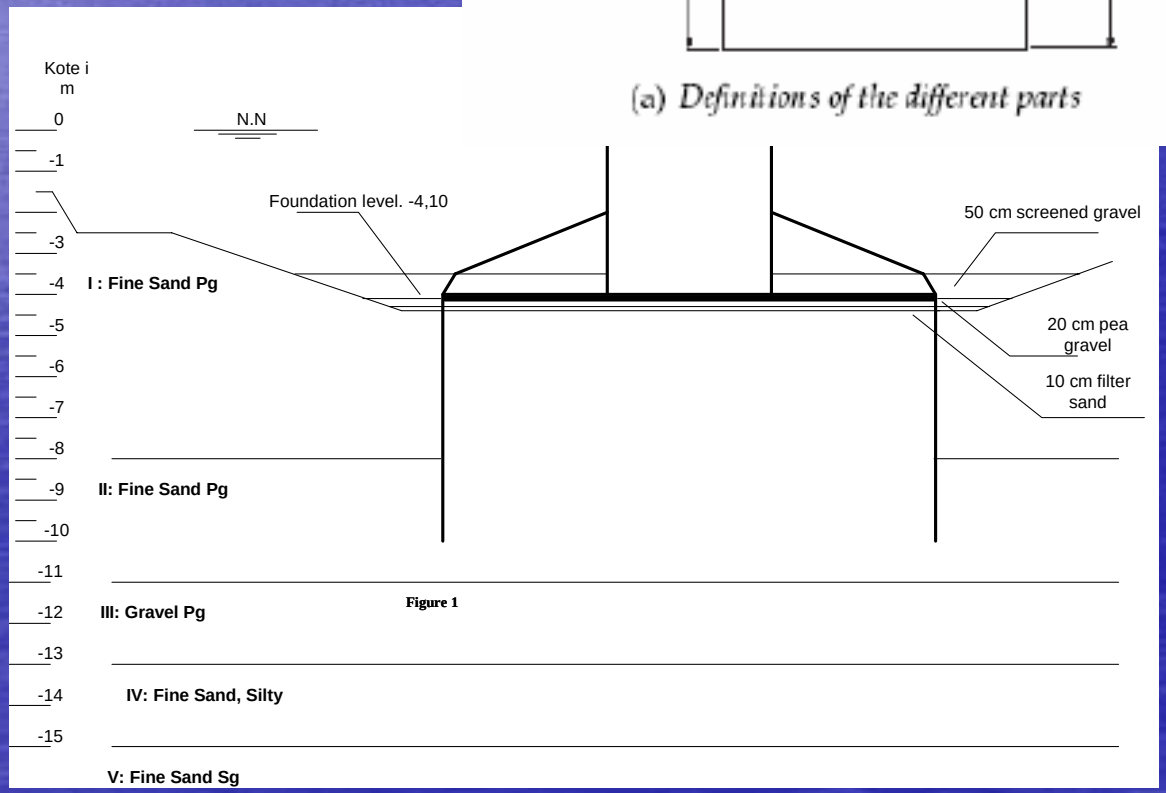
Geotechnical investigations

CPT and Borings

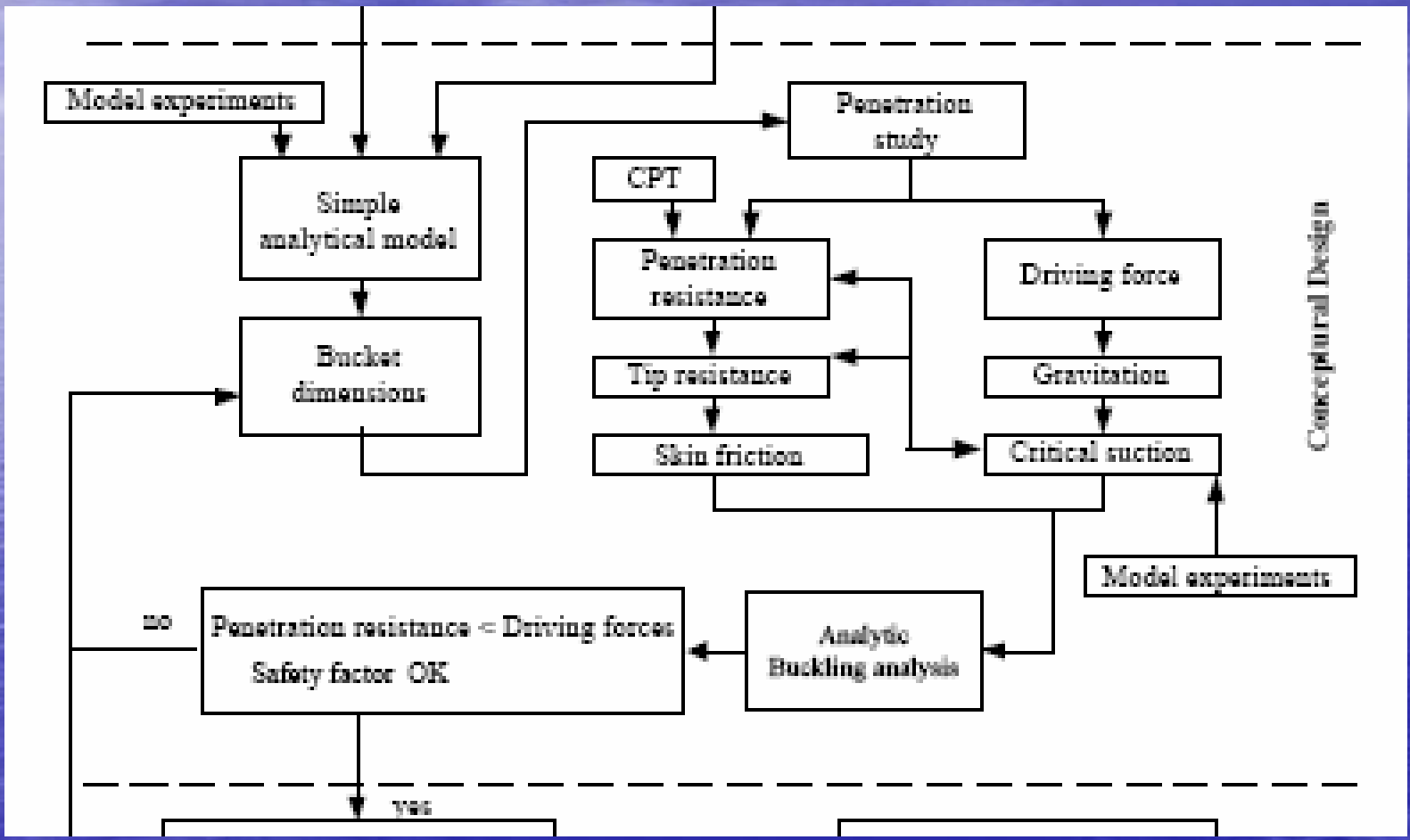


Bucket Foundation Frederikshavn





Conceptural Design



Laboratory Tests

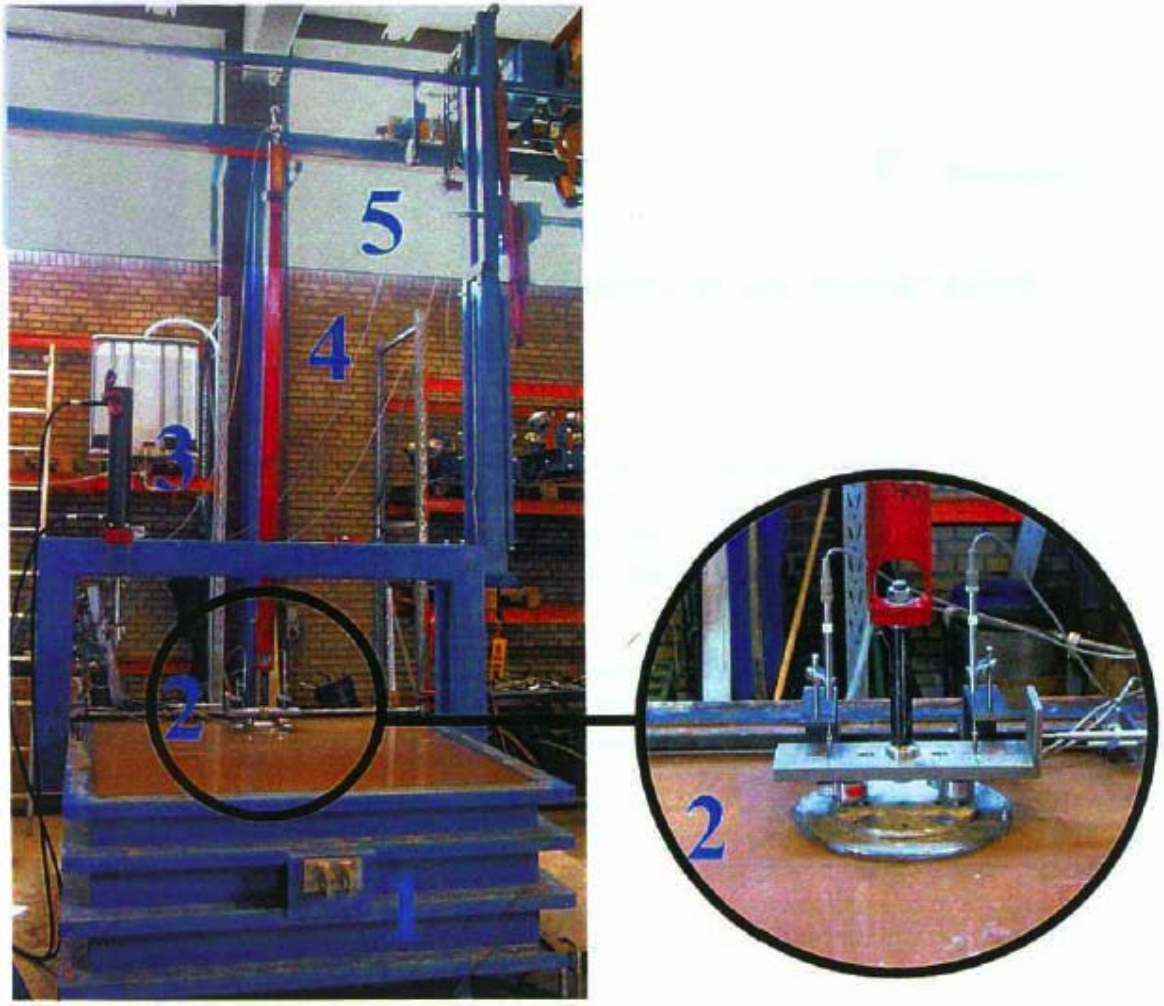


Figure 5.1. Test set-up used at the experiments with bucket foundations.

Failure Mechanisms

Combined loading

Foundation Concept

Field Model Tests

Prototype	Laboratory Model			Field Model
$D^p = 12m$	$D^m = 0.2m$	$D^m = 0.3m$	$D^m = 0.4m$	$D^m = 2m$
h^p_{lwp} [m]	h^p_{lwp} [m]			h^p_{lwp} [m]
104.4	1.74	2.61	3.48	17.40
69.6	1.16	1.74	2.32	11.60
38.0	0.63	0.95	1.27	6.33
20.0	0.33	0.50	0.67	3.33
10.0	0.17	0.25	0.33	1.67

Plastic strain increments

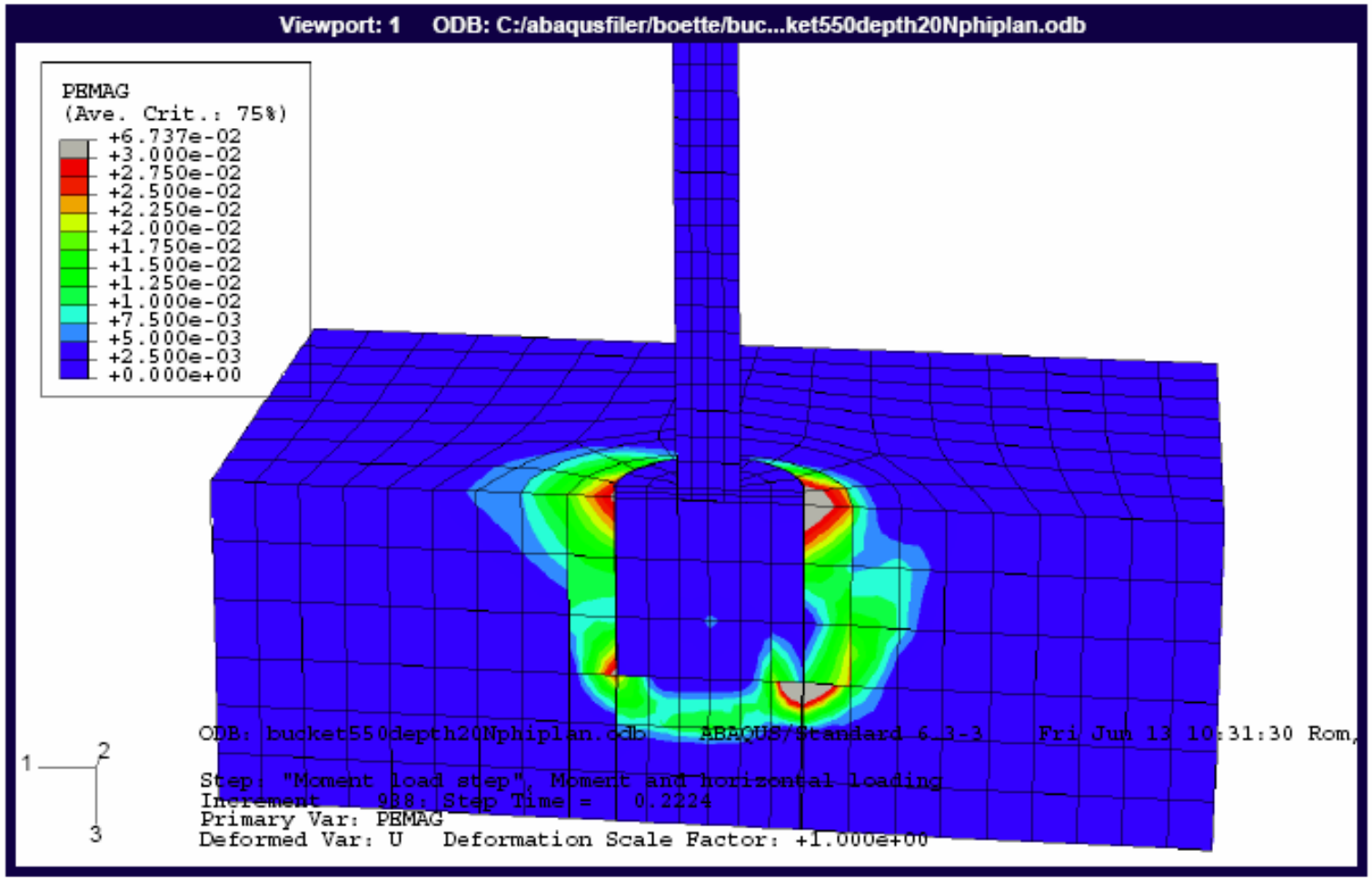


Figure 5.14 Magnitude of the plastic strain increments around the bucket at failure.

Interface friction

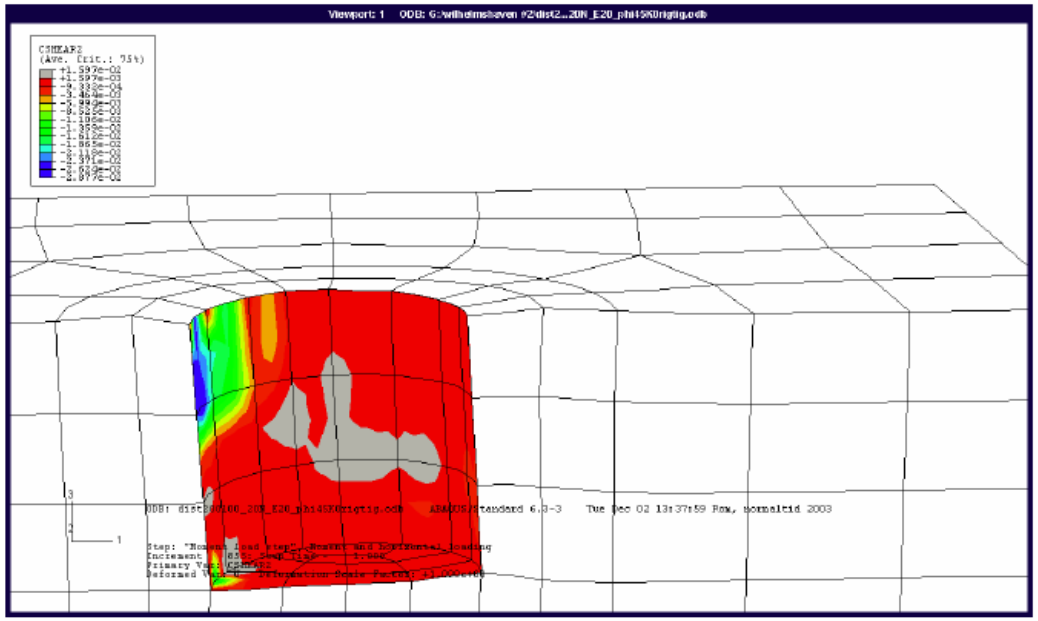
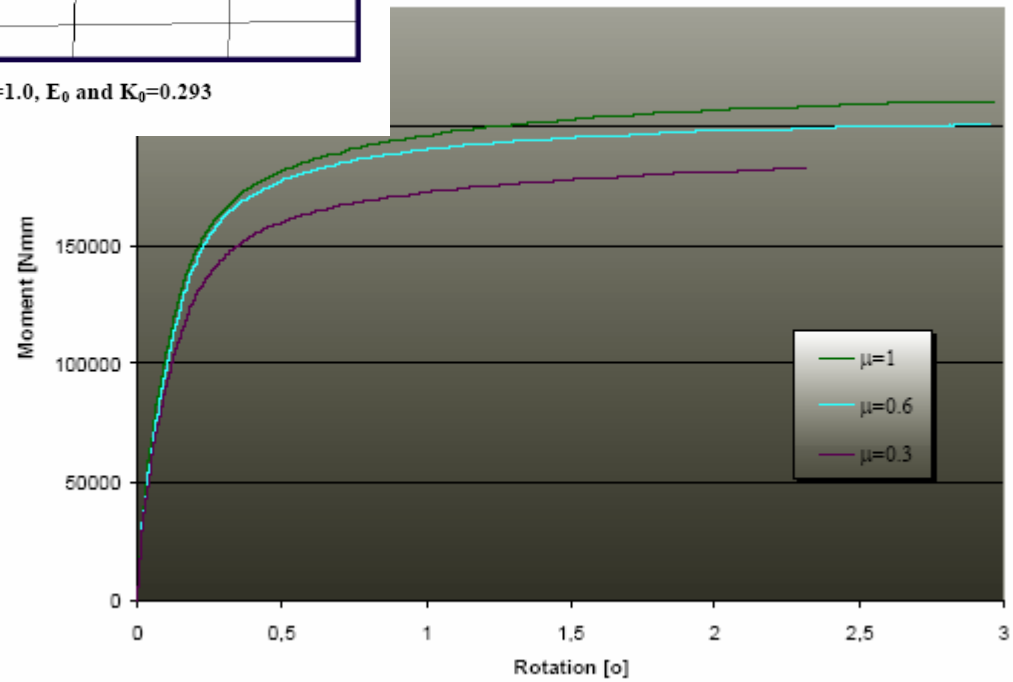
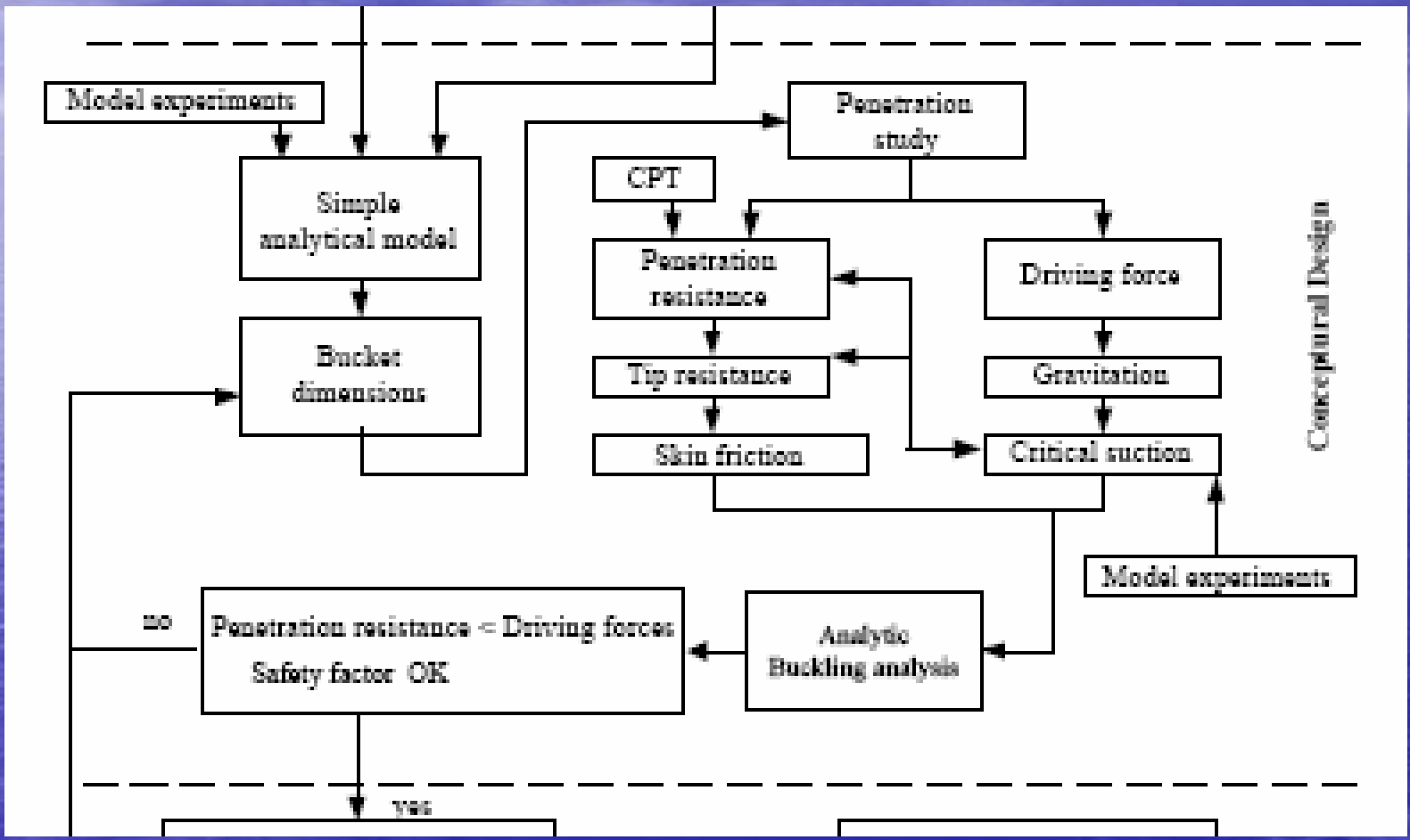


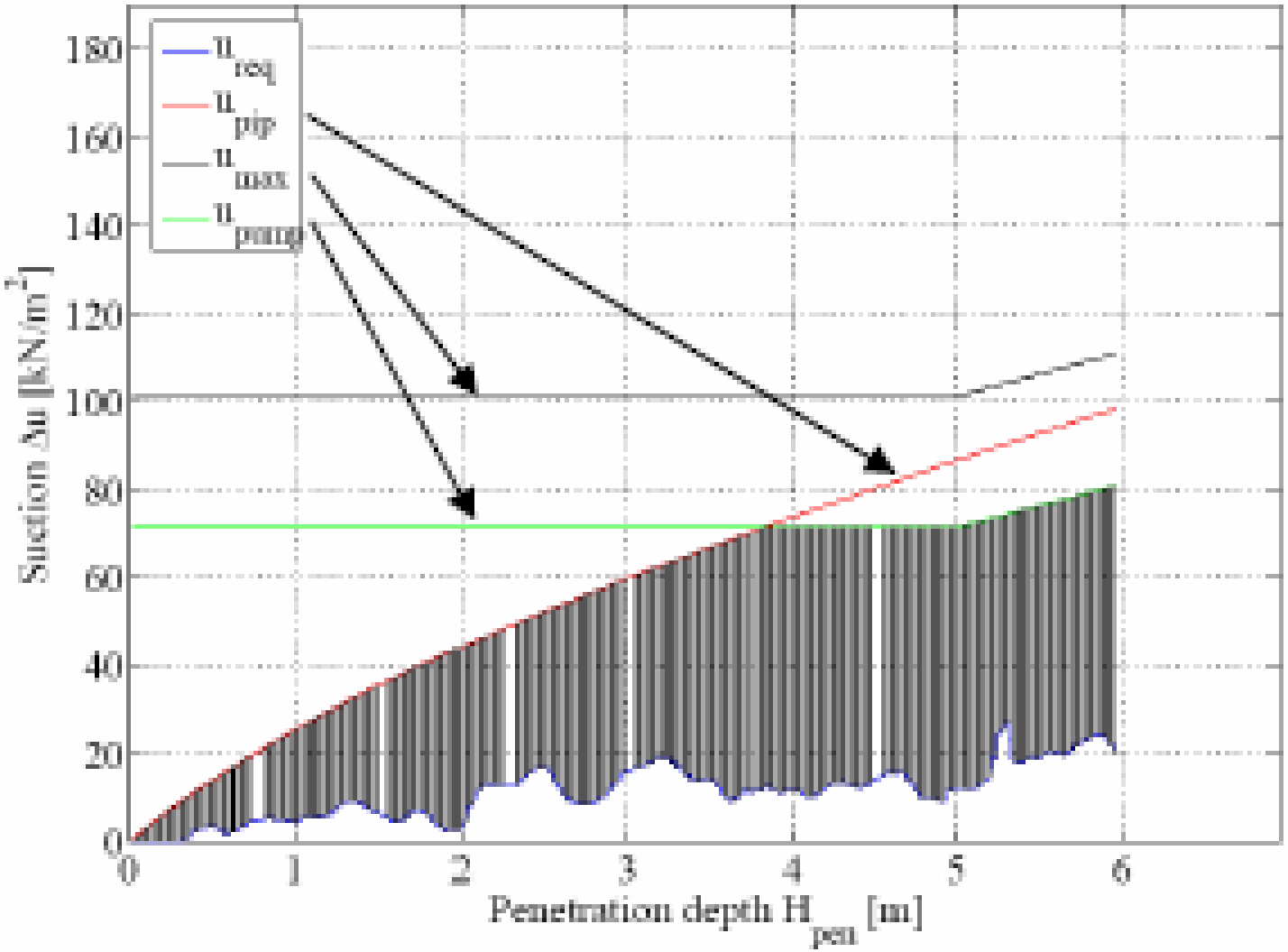
Figure 5.11 The variation of the interface friction around the bucket μ=1.0, E_0 and K_0=0.293



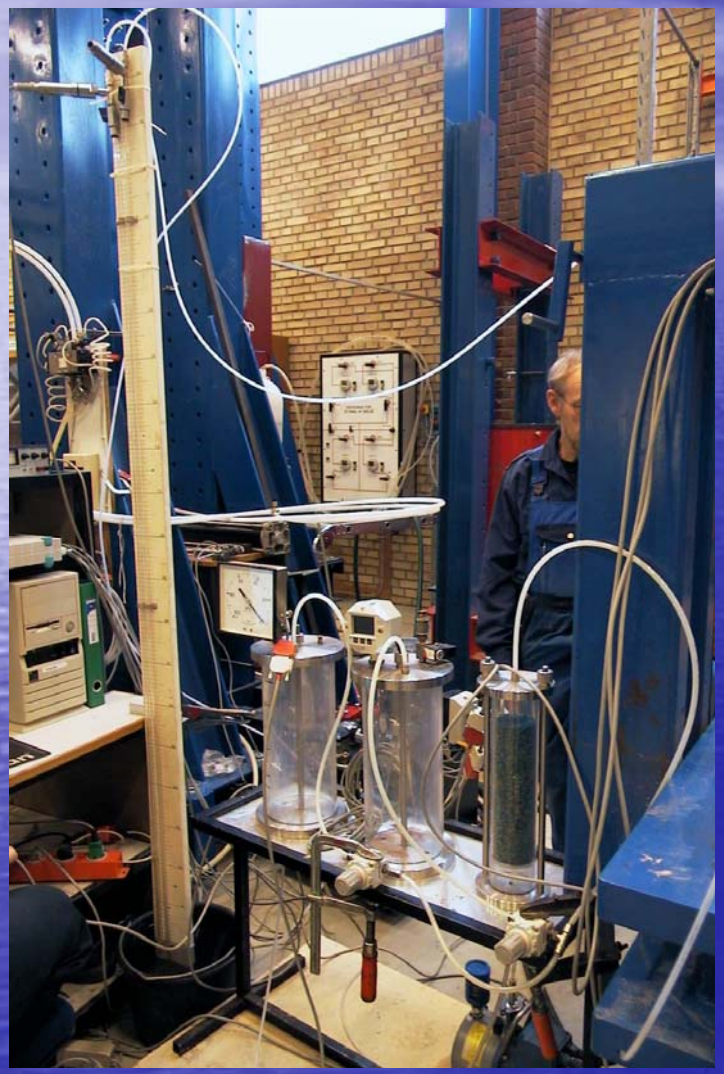
Conceptural Design



Penetration



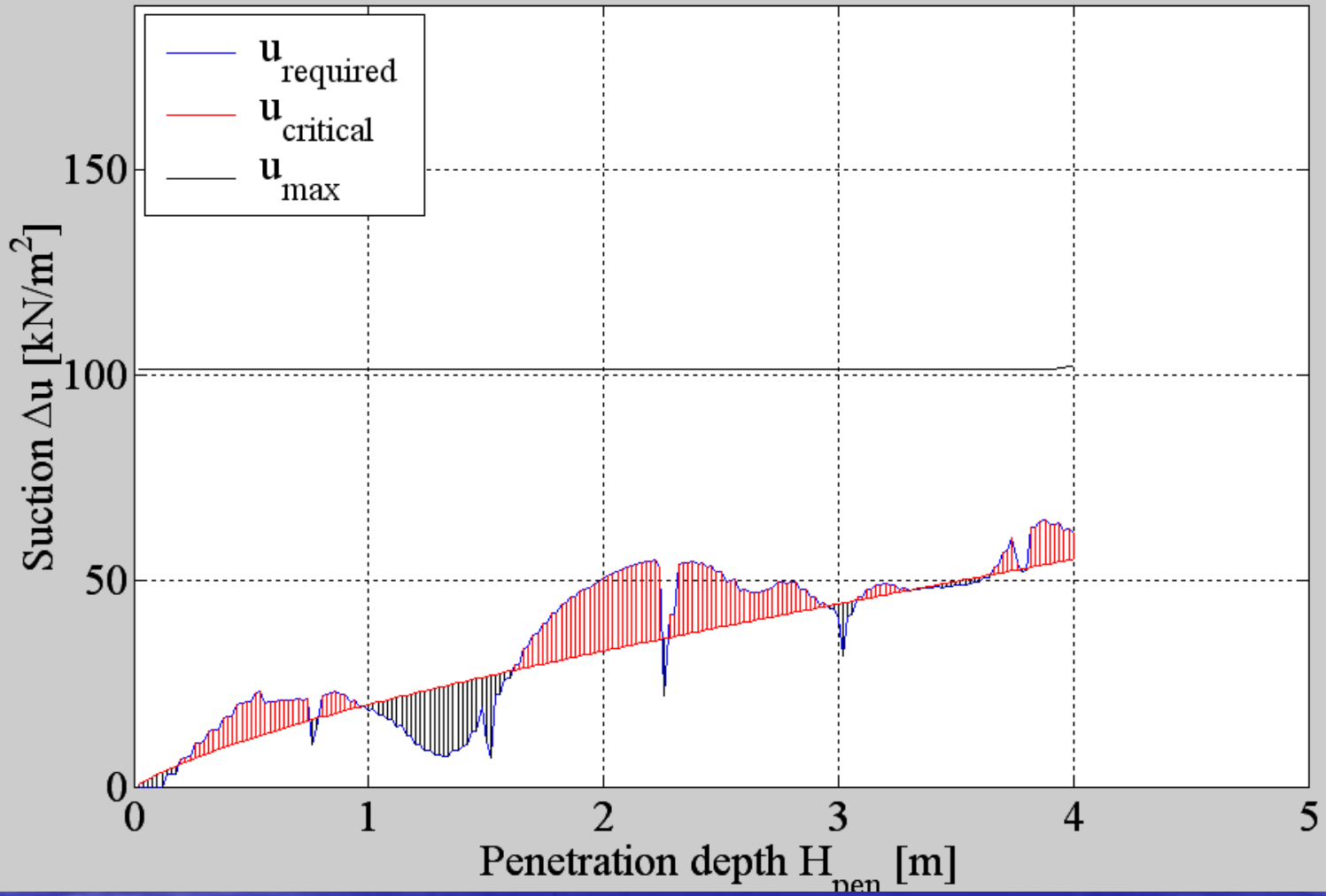
Critical suction



Test field
Penetration tests

4 x 4m test Bucket

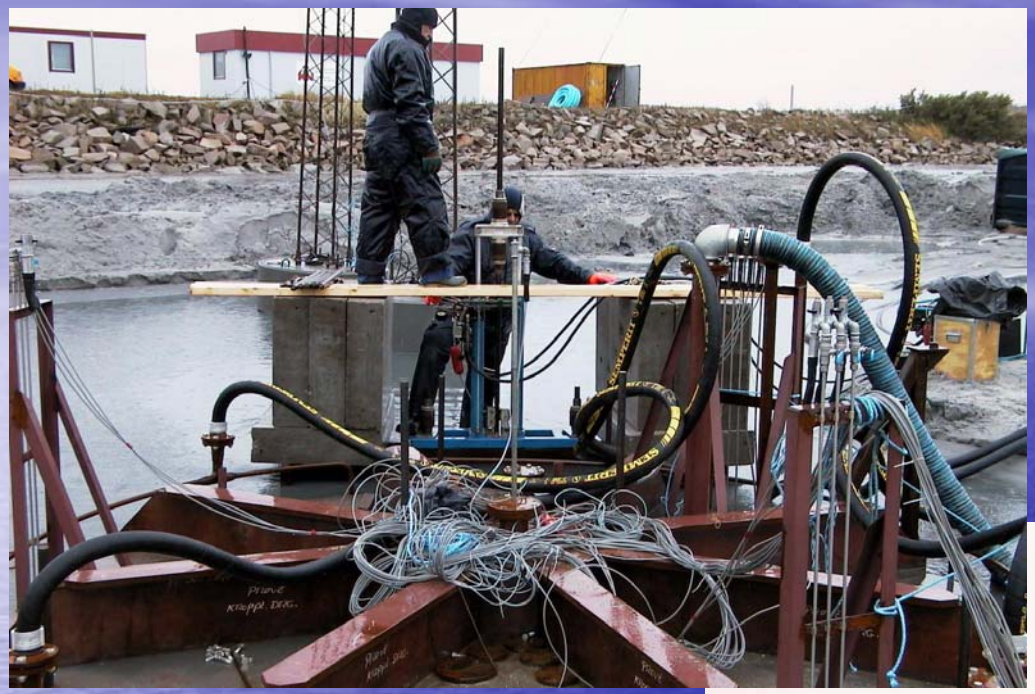
Penetration study 4x4m Bucket



Soil Failure

Critical Suction

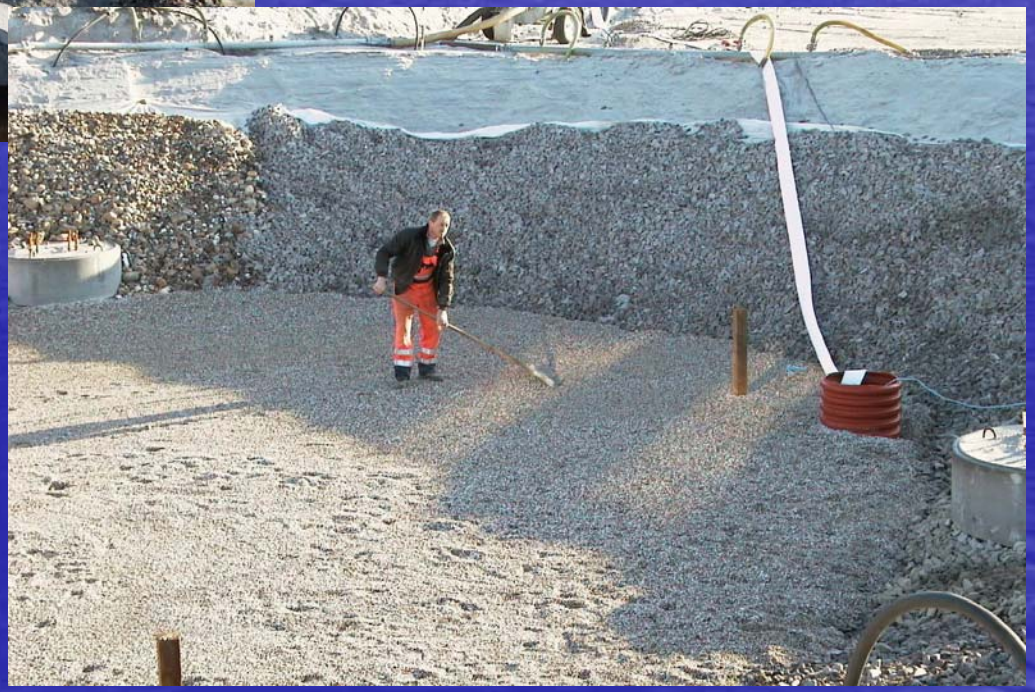
Successful instalation



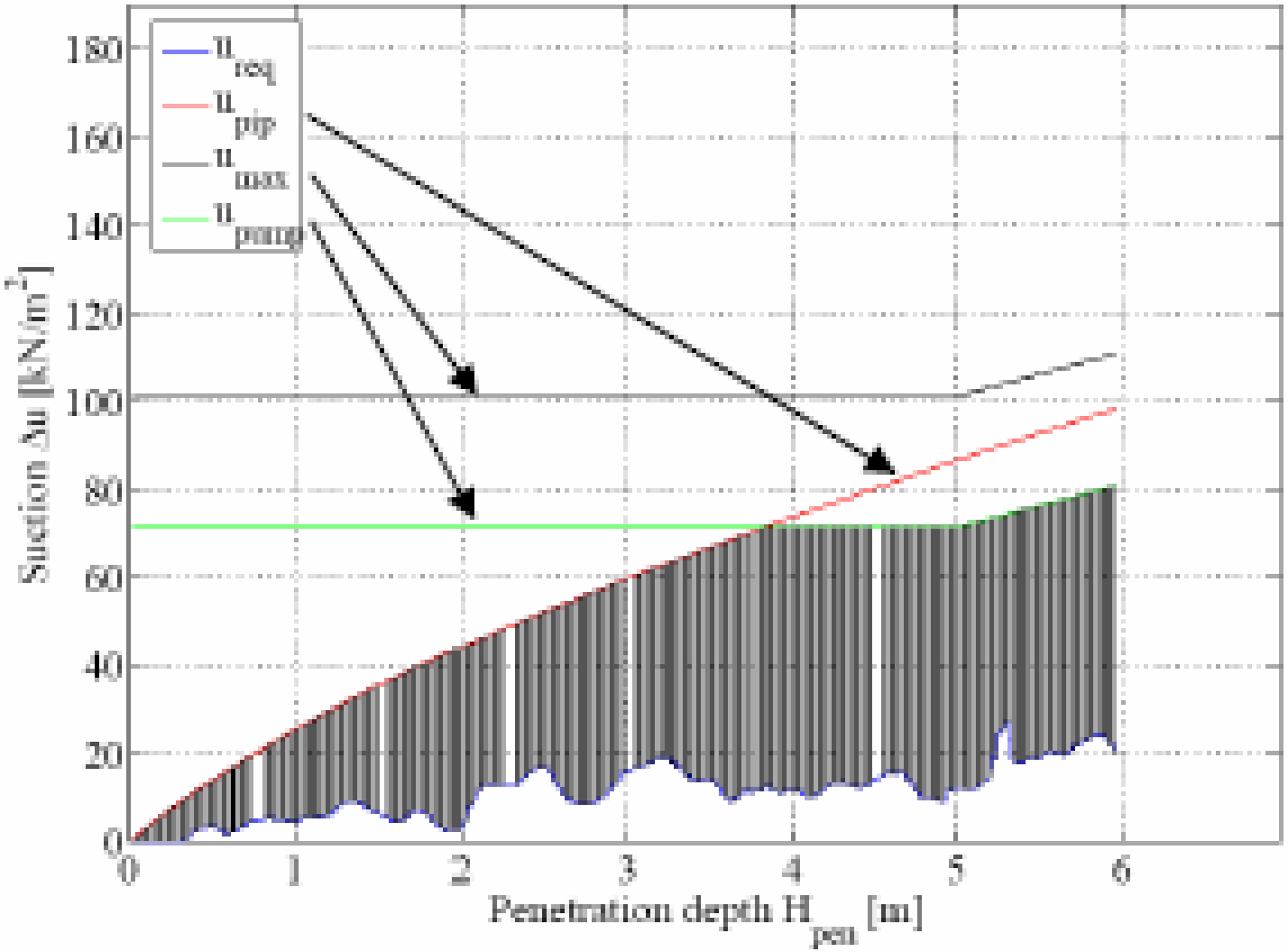
REMOTE OPERATED OFFLIN

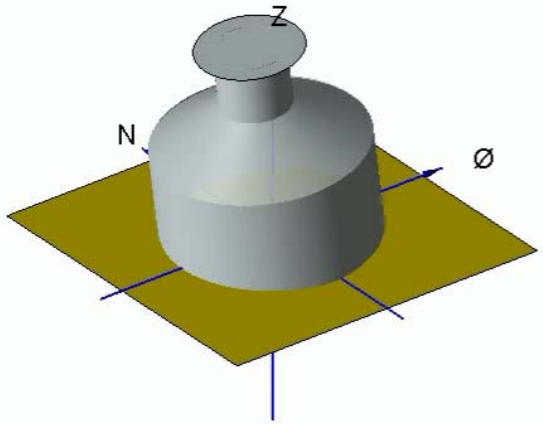
Test field Prototype

12 x 6m Bucket

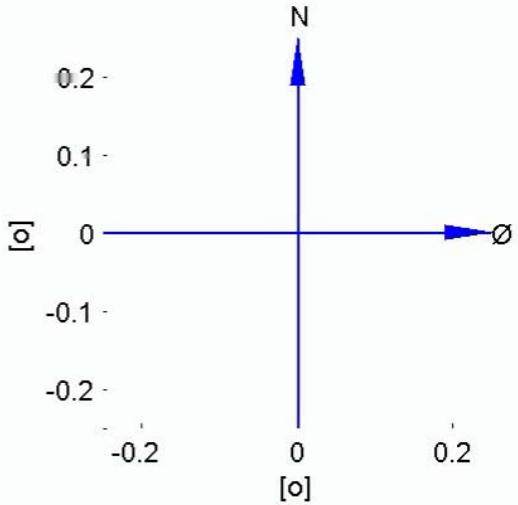


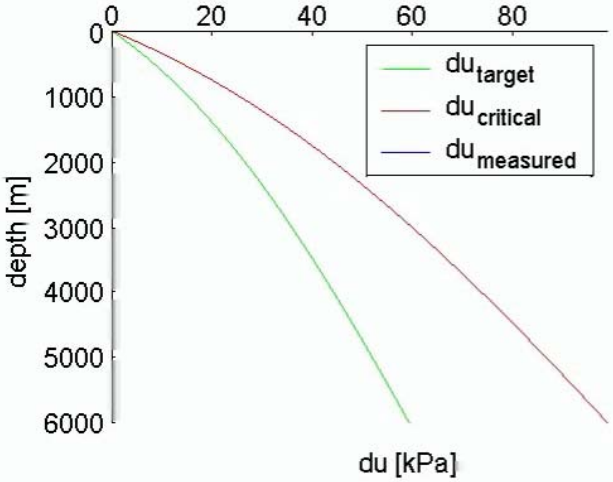
Penetration

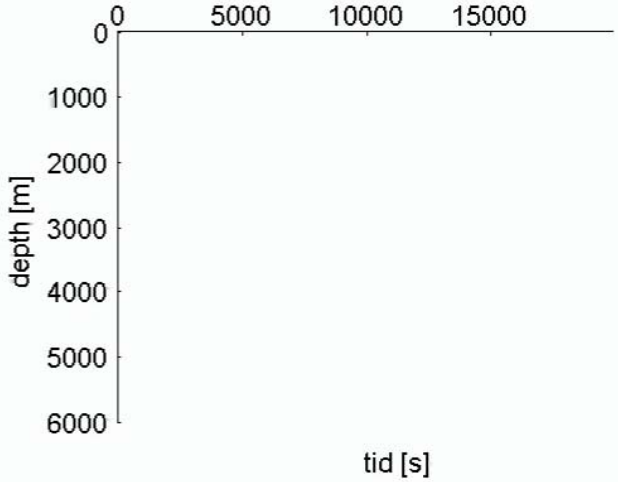




The rotation of the bucket is scaled by a factor = 20

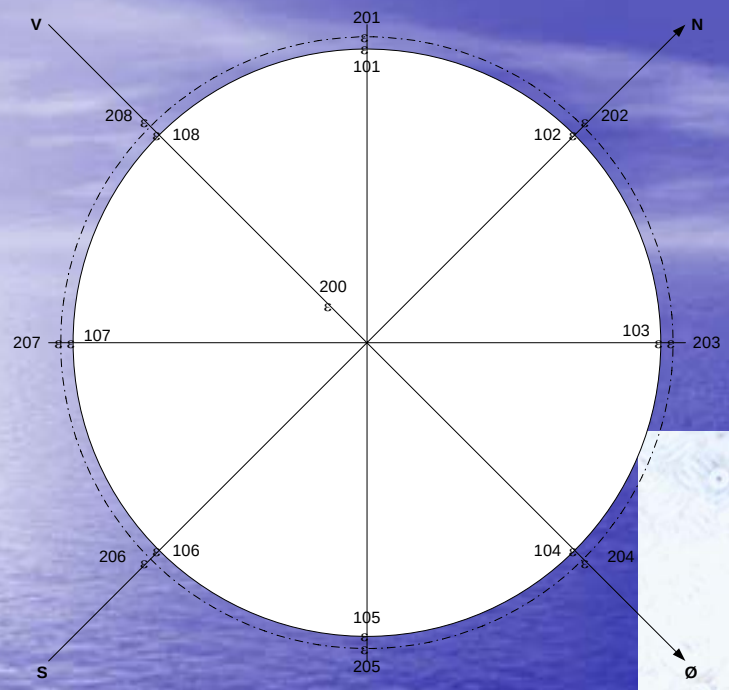




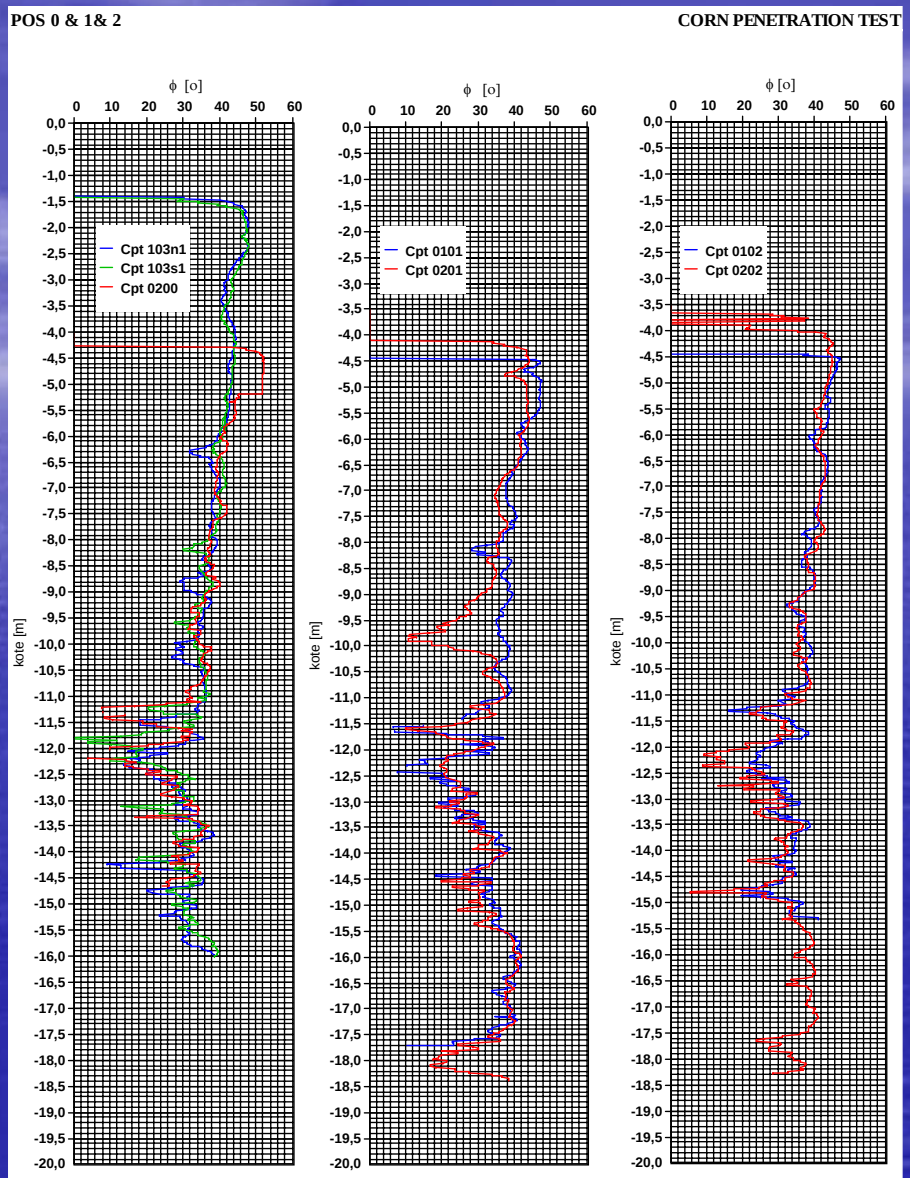


Grouting

Investigating of soil strength after bucket instalation



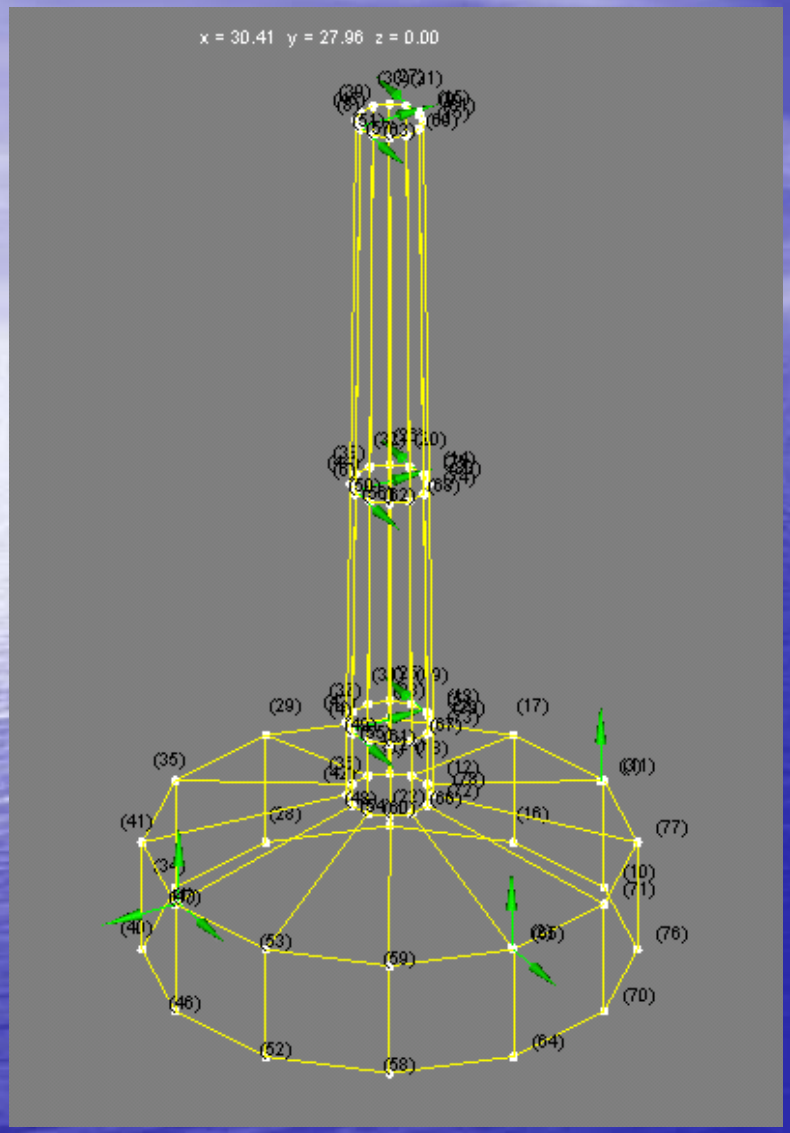
Results of CPT before and after installation



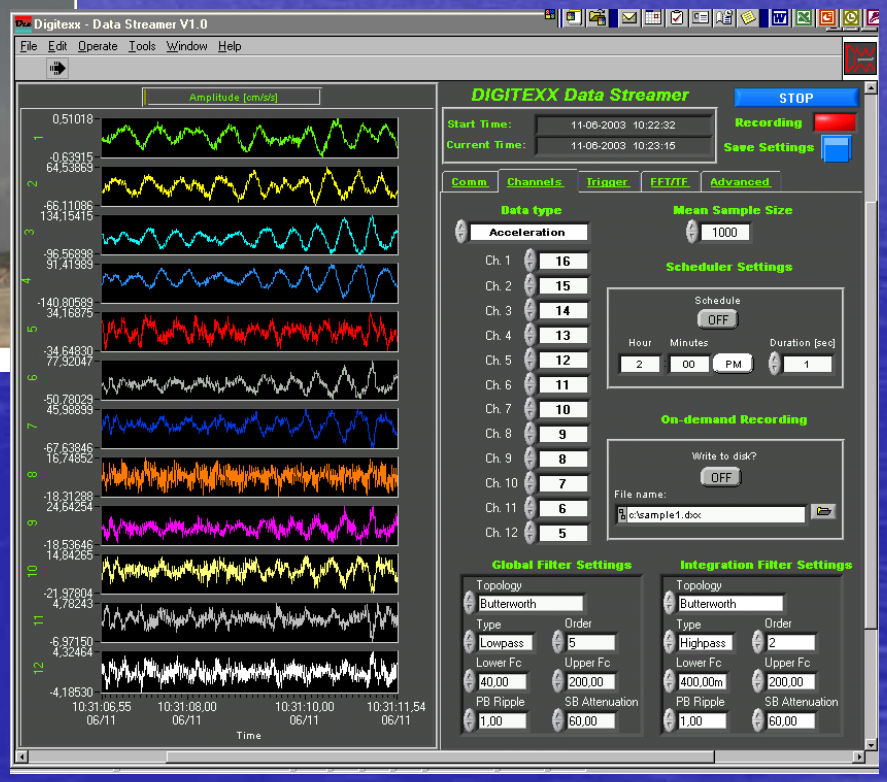
GEG - Aalborg University			Page 1
Job:	Frederikshavn forsøgspark Bassin 3		
Executed :	JCI	Encl.No.	1
Evaluated :	LBI	Cheked :	LBI

In Service performance

In Service performance

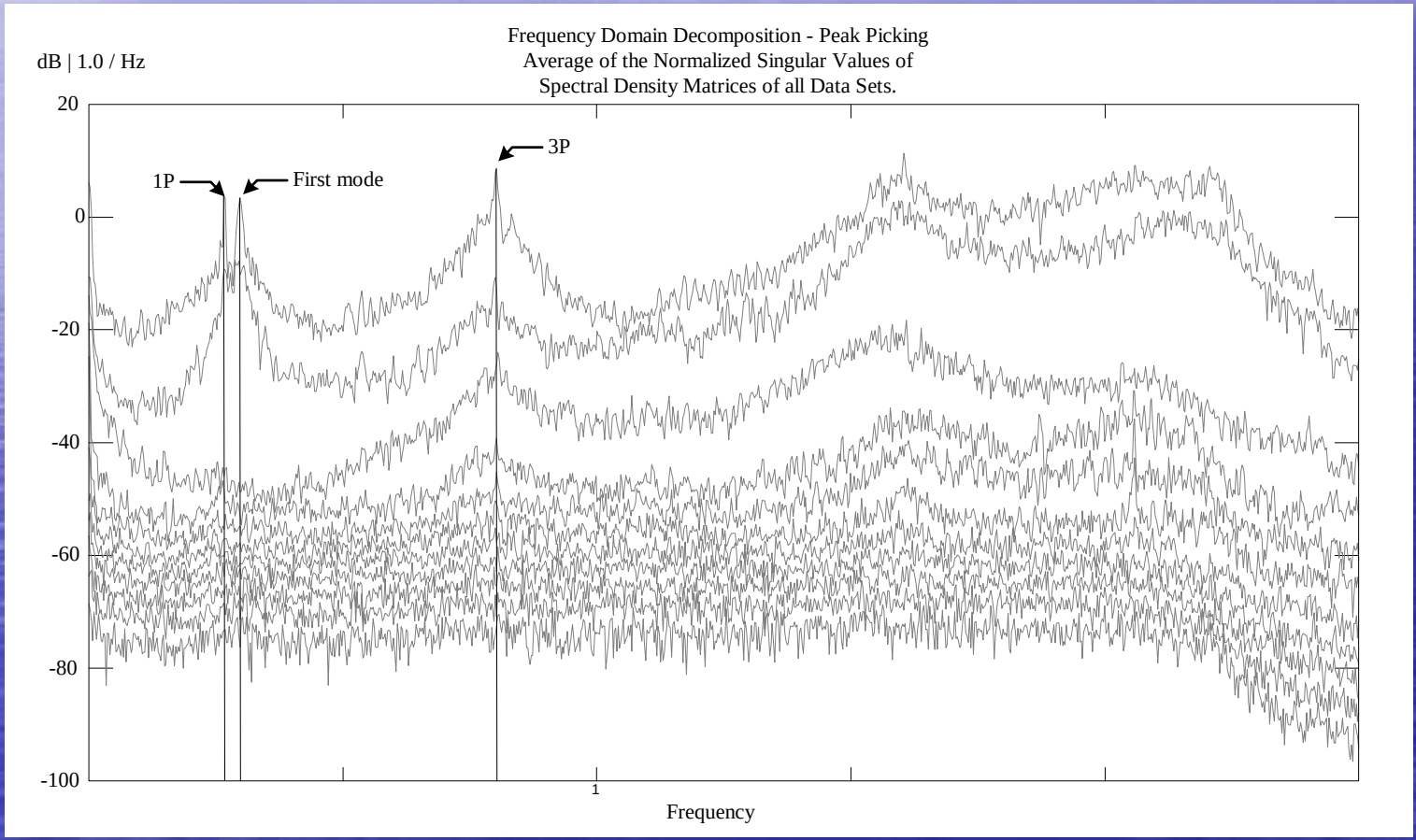


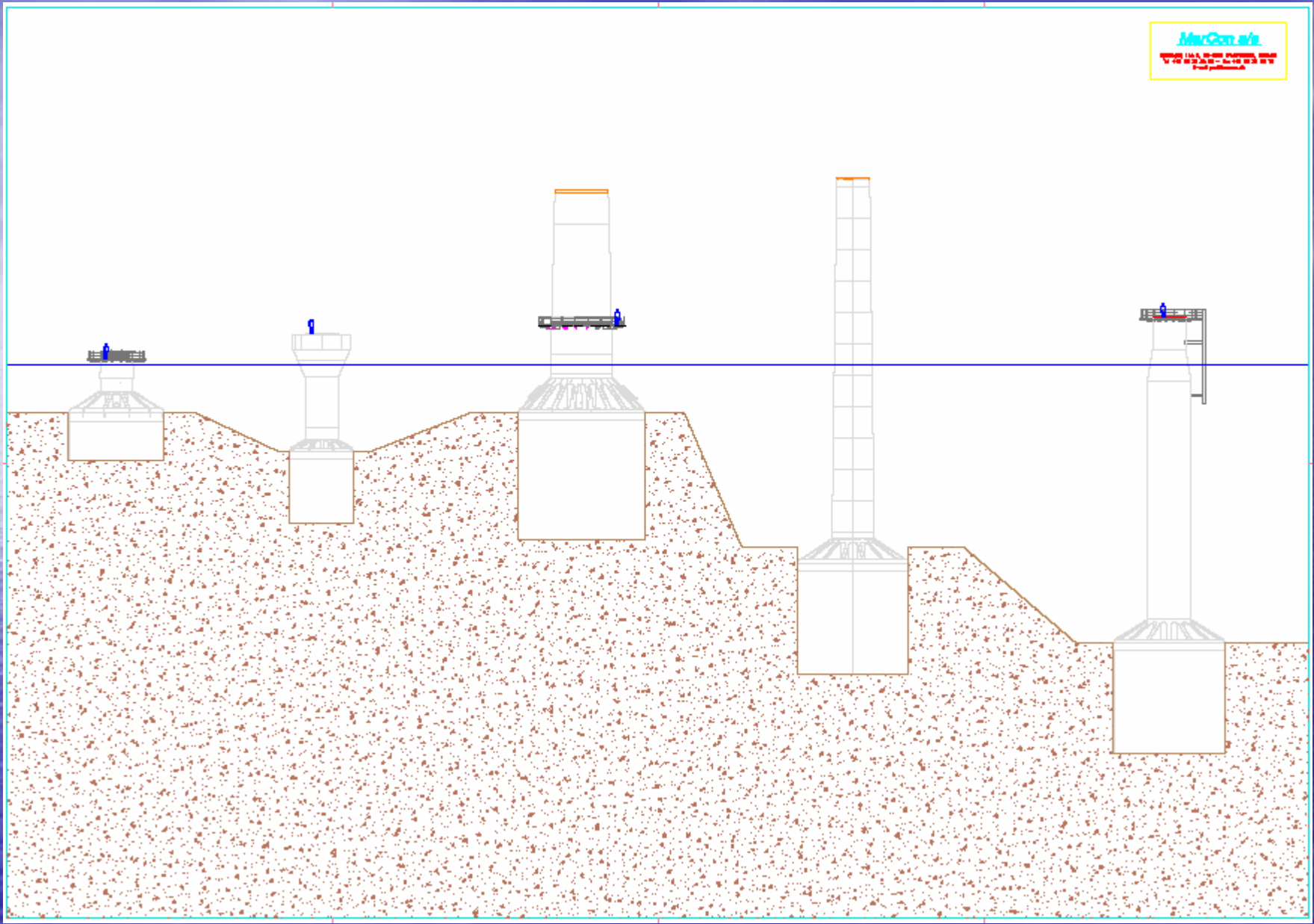
Online monitoring of foundation/tower



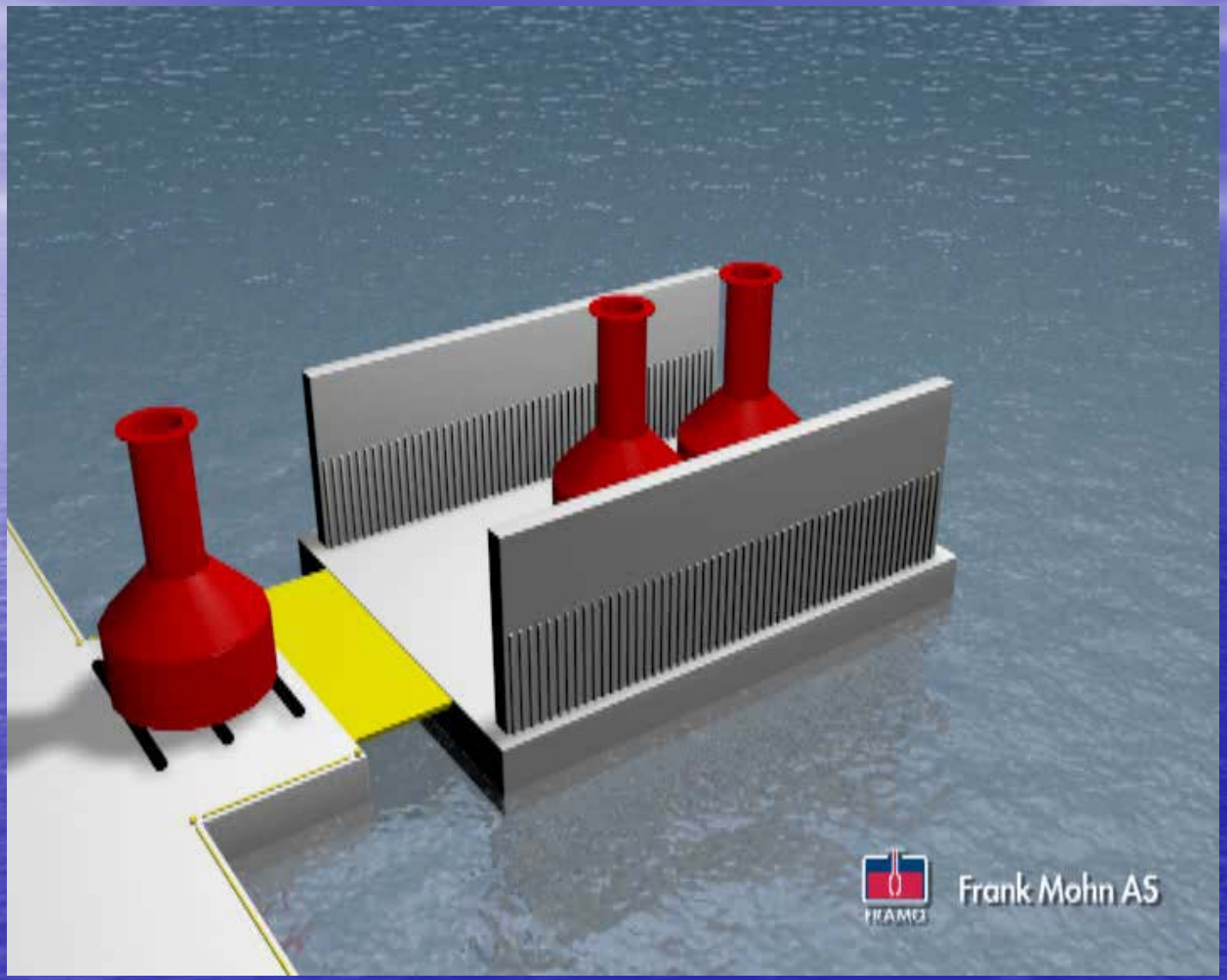
Frequency plot

- Measured performens of the wind turbine in Frederikshavn.
- Operational mode





Installation



Conclusions