Deltares

Advanced pile integrity tests

Experimental results from Horstwald site

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Deltares

Titel
Advanced pile integrity tests

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Summary
This report describes two tests to get better understanding of two new acoustic methods to check the integrity of in situ constructed piles:

- The single hole sonic logging equipment (SHSL) is tested in a laboratory test, in order to get insight in the signal that is emitted.
- The SHSL equipment and the newly developed deep acoustic check (DAC) equipment are applied in a field test at Horstwald (near Berlin)

References
This report is part of

- 1204442.003 SR2011 EUREKA Diepe controle in de grond gevormde palen
- 1202249.005 Geo-Impuls working group 4: verbeteren kwaliteitscontrole IGGE 2010 subproject GI-4.10 Single hole sonic logging

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draft
This is a draft report, intended for discussion purposes only. No part of this report may be relied upon by either principals or third parties.

Contents

1 Introduction

This report describes the purpose, set-up and execution of several tests in order to improve the Pile Integrity Testing.

Deltares propose two acoustic methods, which might improve the acoustic testing of foundation piles:
Deep Acoustic Testing (DAC): this is the extension of the well-known Pile Integrity Testing by a second lost transducer at the pile tip
Single Hole Sonic Logging (SHSL): where the reflections from an acoustic sender from the pile are evaluated.

Most test were carried out at the test site at Horstwald of the BAM (Bündes Anstalt für MaterialüberPrüfung in Berlin), one test was carried out in the laboratory of Deltares (Stieltjesweg, Delft). At the test site in Horstwald three pile with prepared holes are available from earlier test.

Acknowledgements
The offer of the BAM to use their test facility at Horstwald is acknowledged. The indispensable cooperation of dr. E. Niederleithinger of BAM is acknowledged. The SHSL equipment is put at our disposal by Brem Funderingsexpertise in Reeuwijk.

2 Test of source signal

2.1 Summary

The SHSL equipment is tested in a bin, filled with water. It is concluded that the source signal exists of a long train of pulses, which does not end before the end of the measurements.

2.2 Measurement set-up

A plastic bin (length L = 0.70 m and width B = 0.50 m) had been filled with water. The water level was 0.26 m. The receiver was placed in the water with the lower level about 0.10 m above the bottom; the top of the receiver was just above the water table. Figure 2.1 shows a sketch of the set up.

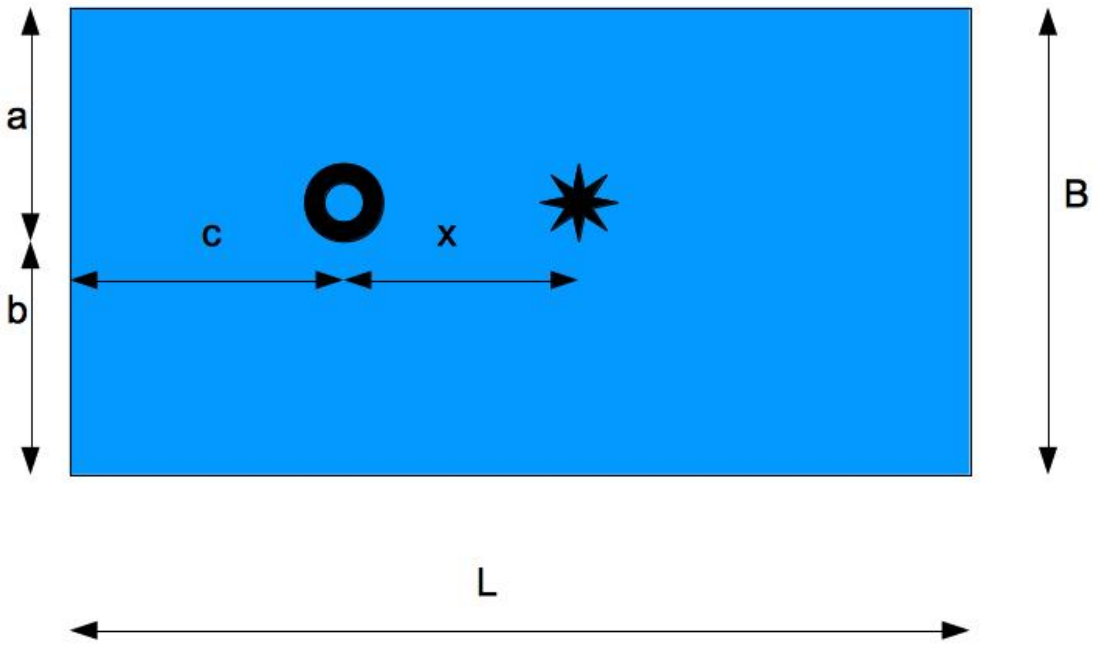


Figure 2.1 Topview pf test set-up in laboratory for source determination

The source was placed at several positions in the bin. The measurements were carried out by moving the height wheel, but in general, the receiver was not attached with the wheel. The signals in the receiver are stored.

Four test runs are done. Table 2.1 shows the essential dimensions (referring to Figure 2.1).

name	a	b	c	depth z	distance x	description
meting40cm	0.22	0.28	0.23	same	0.26, 0.18, 0.10	at three distances
meting3	0.22	0.28	0.23	same	0.10, 0.20, 0.30, 0.40	at four large distances
meting4	0.24	0.26	0.3	same	0.04, 0.08, 0.12, 0.16	at four short distances
meting5	0.24	0.26	0.3	wheel from bottom to water table	0.05, 0.10	vertical distribution

Table 2.1 Overview tests for source determination

2.3 Results

The measured signals are stored as csv-file without any processing. These results are presented here. The time in the measurements run in negative z direction.

The results are presented in seismograms, where position and signal are integrated shown. Each third measurement is shown

The wave speed in the water is about 1530 m/s, calculated from afstand40cm for the distance 0.26 m in $0.17*10^{-3}$ s (=0.17 ms). This is a reasonable value.

The reflections of the walls are expected after travelling two times the distance to the wall. For the measurement afstand40cm, the travel distance is about .22*2 = 0.44 m, so the duration is 0.29 ms. This might explain the signal change at approximately 0.27 ms.

2.4 Conclusion

The measurements strongly suggest that the signal is a train of pulses that endures longer than the measurements.

2.5 Discussion

The choice for a long train of pulses is not a useful one. It means that al reflections are always drunk in the other signals. It is suggested to use a finite train of pulses, e.g. 8 pulses.

3 Site description Horstwald

The BAM-test site 'Horstwald' is located near the village of Sperenberg and Kummersdorf-Gut, about 60 km south of Berlin (BRD). At the site three piles with holes lined with plastic tubes are available.

Table 3.1 shows the properties of the three piles that are not equal for all piles. The diameter of the piles is 0.60 m and the diameter of the tubes is ?? mm. Figure 3.1 shows the position of the tubes, seen from the small office cabin. Appendix B shows photographs of the piles.

property	pile B1	pile B4	pile B5	unit/remark
length of pile	11.85	9.35	9.75	
number of tubes	2	3	3	
height of tube above pile head	0.11	0.57	0.15	

Table 3.1 Overview of properties of the test piles

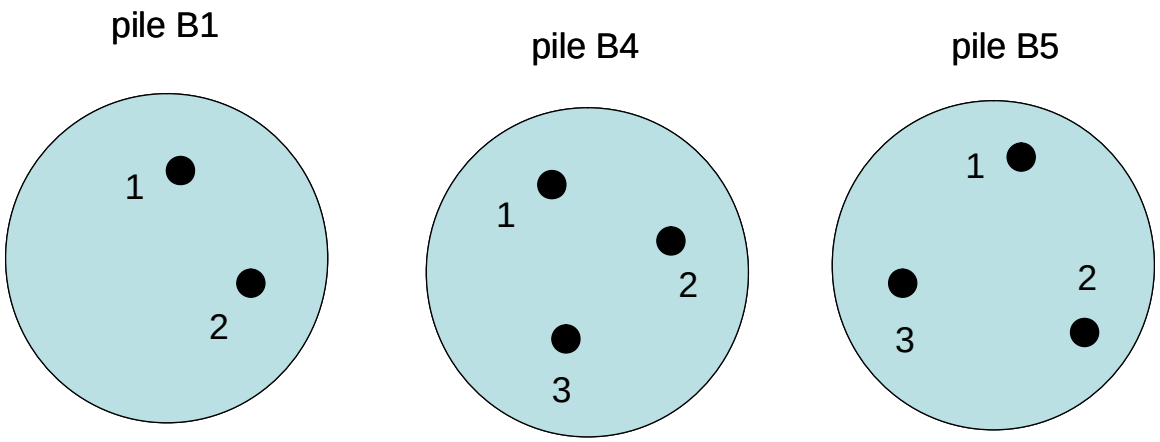


Figure 3.1 Overview of position from the tubes (not to scale)

4 Results of SHSL tests

4.1 Summary

For all three piles (in total 8 holes) the SHSL measurements are carried out for sender receiver distance 40, 60 and 80 cm. For pile B1 (two holes) also measurements with 30, 40, 100 and 120 cm are carried out.
The quality seems reasonable.

4.2 Measurement execution

The measurements are executed using the standard procedure prescribed by the equipment. The duration of the measurements is chosen according the suggestion from the equipment. Transducer number 992 is used as emitter; transducer 993 is used as receiver.

For each pile several distances between the sender and the transducer is used. ?? shows the overview of all distances applied per pile.

distance [cm]	pile B1	pile B4	pile B5
30	X		
40	X	X	
60	X	X	X
80	X		X
100	X		
120	X		

Table 4.1 Overview of distances applied per pile

The file names are structured:

- first the pile name
- then the hole name preceded by an H
- finally the distance

4.3 Results

Appendix C shows the result of the measurements. These are synthetic seismograms, where the measured signals are shown on the depth where these are measured. Only one of each 10 measurements is shown, in order to increase visibility.

4.4 Some remarks on the results

The measurements in pile B1 are done with a range of distances between source and receiver from 30 cm to 120 cm. Figure 4.1 shows the estimated first arrivals of the measurements. These show a good relation with the distance between the two transducers. This means that the analysis of first arrivals is not the most obvious approach. However, the results in hole one (B1H1) with distance 60 and 80 cm, show anomalous behaviour. At some depths the signals arrive relatively early. The reason of this anomaly is unknown.

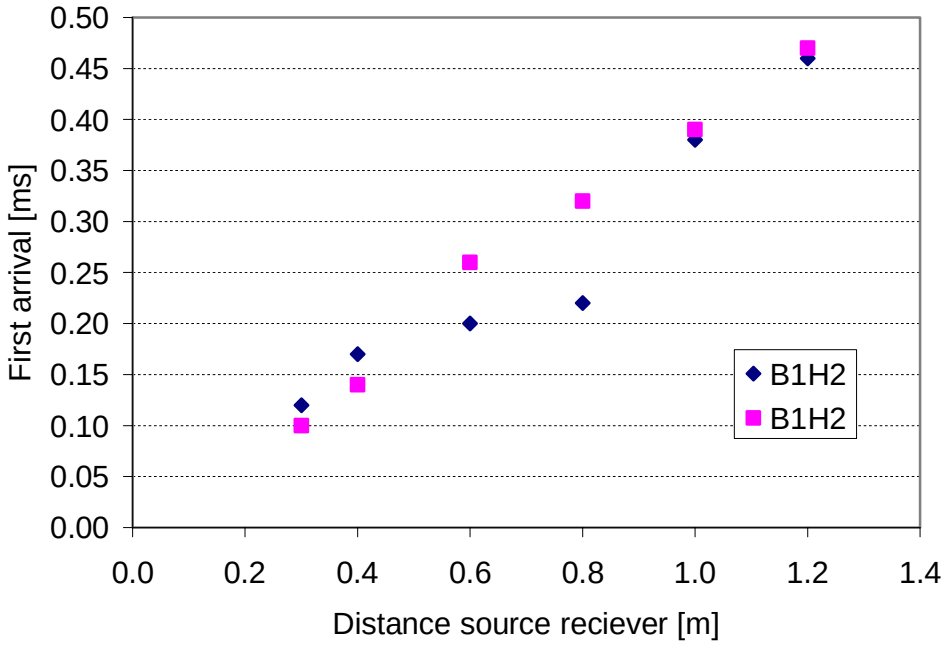


Figure 4.1 Approximate first arrivals for the two holes in pile B1

Table 4.2 shows the length of the measured interval and the expected pile length. This shows a reasonable agreement.

pile	B1	B4	B5
measured interval	9.0-10.0	8.1-9.0	8.1-8.4
expected length	11.85	9.35	9.75

Table 4.2 Comparison measurement interval and expected pile length

Sometimes the signals vanish after some time, *e.g.* measurement B1H1-1000cm (see appendix C0001). This may be due to the interference of the all waves. However, if that occurs often, one should also expect resonances that intensify the measured signals later on. That is not seen at all.

Overall, the quality of the measurements seems reasonable.
Further study seems useful.

5 Results of DAC tests

5.1 Summary

The application of the equipment was seriously hindered by noise when it was placed in the water-filled tubes. However, the measurements show that the equipment is applicable in the sense foreseen in the Eureka proposal.

5.2 Target of these tests

These test had two targets

- gathering good signals on piles with known flaws, which might be used to show the possible use of the second sensor in the pile;
- showing that the low budget equipment is good enough to reach the required results.

5.3 Description of the tests and equipments

Two combined tests were foreseen. During a test a high accuracy transducer was lowered in one hole, and a low budget transducer lowered in another hole. A third high quality transducer was located at the pile tip. Each time the pile was repeatedly loaded by several hammer blows. Afterwards the transducers were changed from holes and the test was repeated.

5.3.1 Short description of the results for high accuracy equipment

Due to an erroneous given cross-section of the pipes, it was not possible to lower the high accuracy equipment into the holes. This part of the test had to been skipped. The high accuracy transducer at the pile head was used continuously.

5.3.2 Short description of the results for low budget equipment

The equipment turned out to be very sensitive to noise. This could be removed in the laboratory, but unfortunately strengthens when the transducer was lowered into the water-filled hole. We had no possibility to remove the water completely on this short term. Nor could we find a solution for this quandary in the filed. Therefore, some measurements drunk in noise were made, hoping that we could remover the noise later.

5.4 Overview of the tests carried out

Table 5.1 gives an overview of the measurements. The sample rate was 2 kHz. Due to the noise problems, I forget to increase the sample rate for the final measurements.

file number	location equipment	remarks
test voor berlijn001.asc	in laboratory	
test voor berlijn002.asc	in laboratory	
test voor berlijn003.asc	in laboratory	
test voor berlijn004.asc	outside pile	
test voor berlijn005.asc	top of pile S1	lowering into water; not reliable, adjustment devices wrong
test voor berlijn006.asc	top of pile S2	lowering into water; not reliable, adjustment devices wrong
test voor berlijn007.asc	outside pile moving together	not reliable, adjustment devices wrong

test voor berlijn008.asc	outside pile moving together	
test voor berlijn009.asc	top of pile S2	lowering into water-filled hole
test voor berlijn010.asc	B5H1	heavy hammer
test voor berlijn011.asc	B5H2	heavy hammer
test voor berlijn012.asc	B5H3	heavy hammer, transducer at pile head dropped
test voor berlijn013.asc	B4H1	heavy hammer
test voor berlijn014.asc	B4H2	heavy hammer
test voor berlijn015.asc	B4H3	heavy hammer
test voor berlijn016.asc	B1H2	heavy hammer; noise increased suddenly
test voor berlijn017.asc	unknown	heavy hammer

Table 5.1 Overview of DAC files

5.5 Noise reduction of the signals

One signal is processed. Figure 5.1 shows the original measured signals at pile head and pile toe respectively. At the pile toe the 50 Hz noise is clearly visible. However, the signal at 6278 ms is visible.

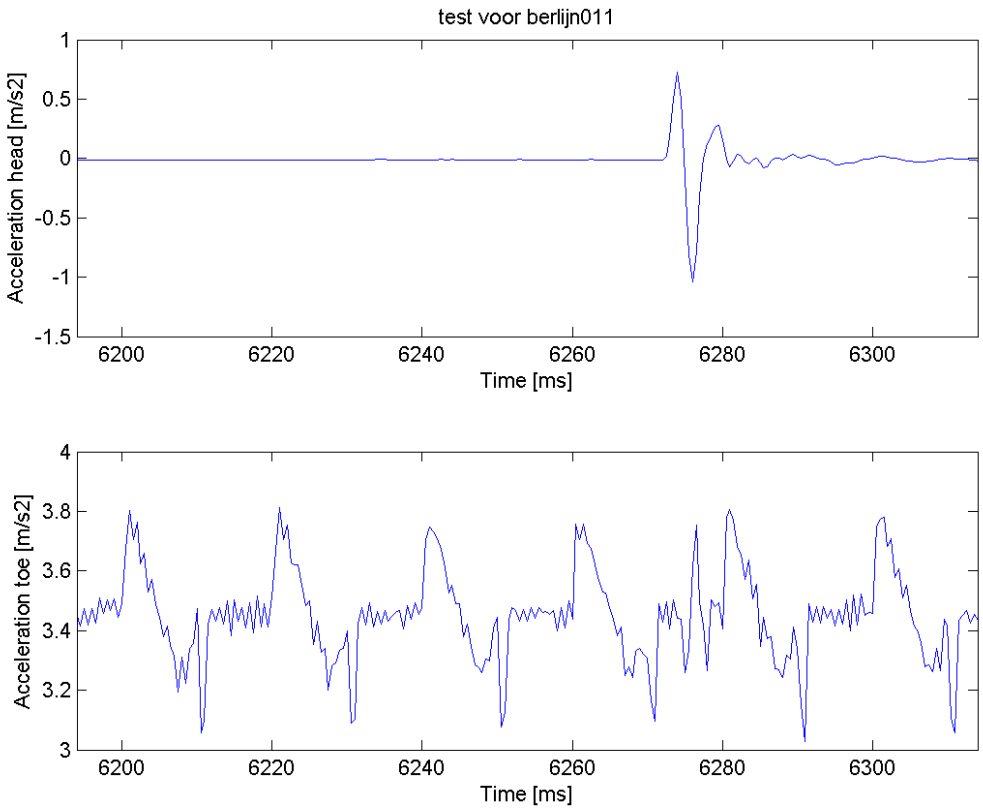


Figure 5.1 Measured acceleration at pile head (top) and pile toe (bottom)

Figure 5.2 shows the signal at another moment, after filtering away the noise of 50 Hz and higher harmonics (100, 150 Hz etc.). The figure shows again a clear signal, which is above the remaining white noise. The signal has a reasonable strength and form.

Due to the filtering there seems to be some distortion of the signal. Next test should be done with similar transducer on the pile head and at the pile toe.

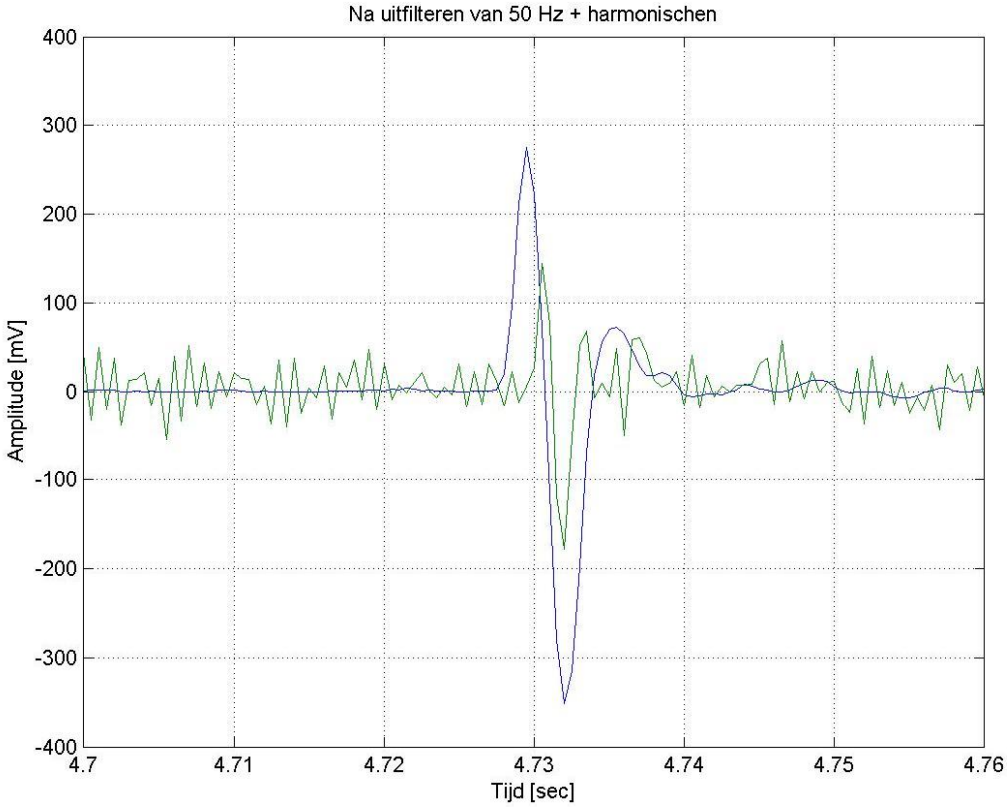


Figure 5.2 Processed result at pile head (blue, straight line) and pile toe (green noisy line)

This shows that the equipment is able to measured the required signal.

5.6 Final conclusion and continuation

The low budget equipment is able to measure the required signals.

The noise signal must be removed from the device.
The sample frequency must be higher, presumably even higher then the 4 kHz foreseen, maybe up to 10 or 20 kHz.
Both the transducer on the head and in the pile must be of the same type and have similar wire length in order to find the wave speed in the pile accurately.

It seems not that hard to redo the test. The data acquisition equipment (laptop and conditioner) can be easily transported by hand luggage, three or four transducers with wires, the power supply and a hammer (if not locally available) can be carried as handled luggage in the airport or send before hand by DHL. After hiring a car at the airport a single day trip is enough to redo this test with the improved equipment.

6 Conclusions and recommendations

6.1 Conclusions

The SHSL sender emits a continuous 50 kHz signal.

The SHSL equipment is applied in the test piles in Horstwald (near Berlin) and the measurements are available for further interpretation. First arrival times are determined by the distance between the transducers and is not seen as a useful parameter for interpretation

The new DAC equipment did function, but showed a lot of noise. The results show that the equipment is able to measure the signals. Due to noise and the low sample rate applied, the possibility to use the measurement for further analysis seems limited.

6.2 Recommendations

6.2.1 SHSL system

It is recommended to

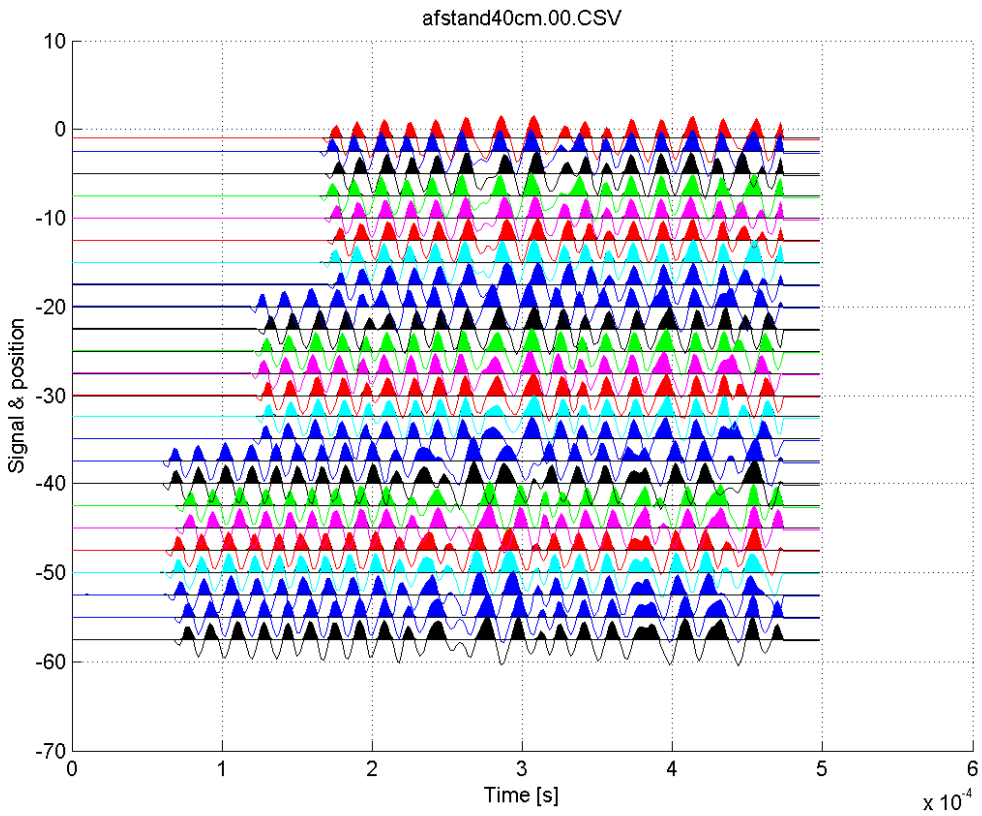
1. study the possibility of the system to change to a limited number of sinuses per measurements
2. analyse the measurements with more advanced techniques

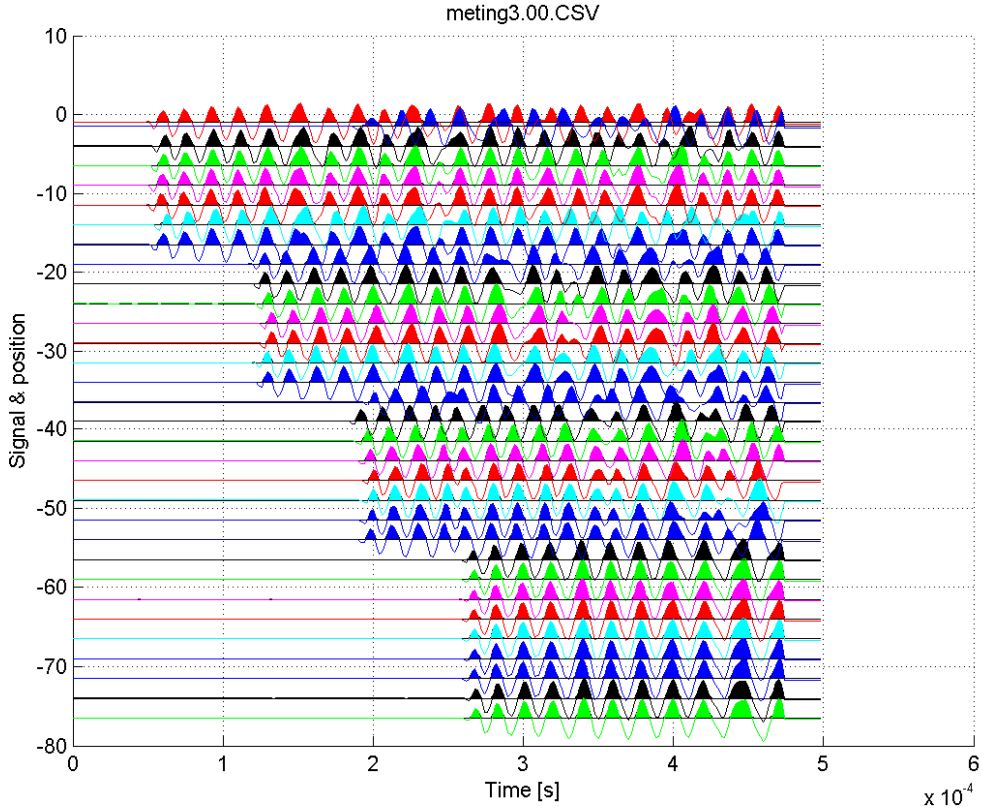
6.2.2 DAC system

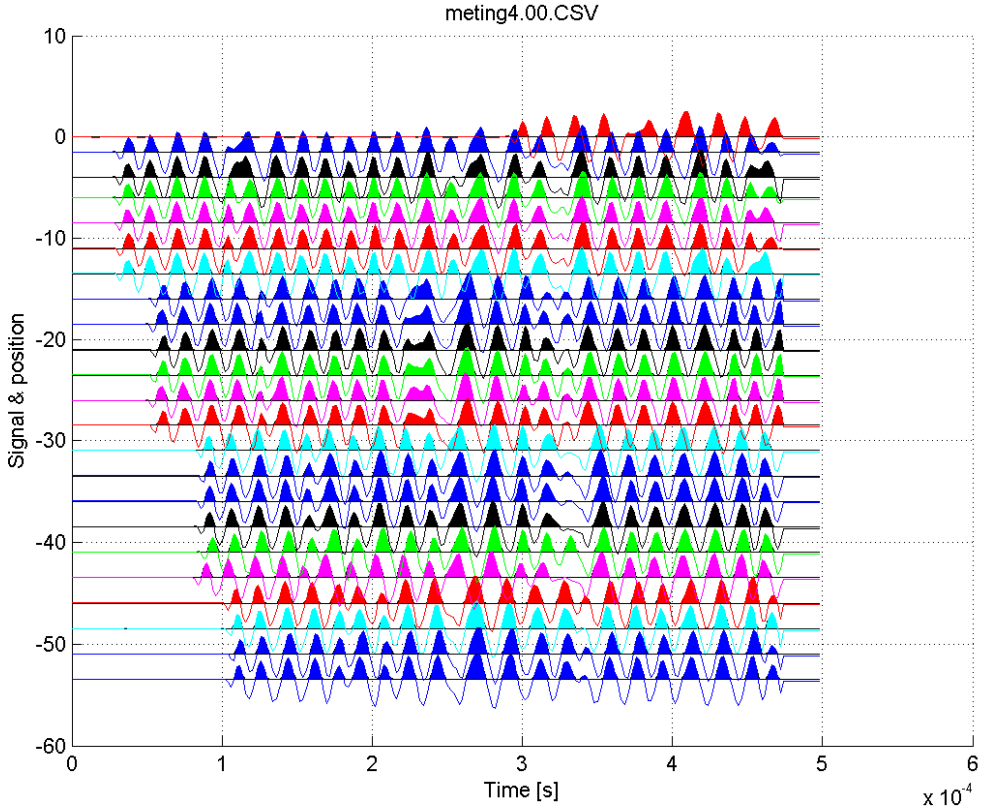
It is recommended to

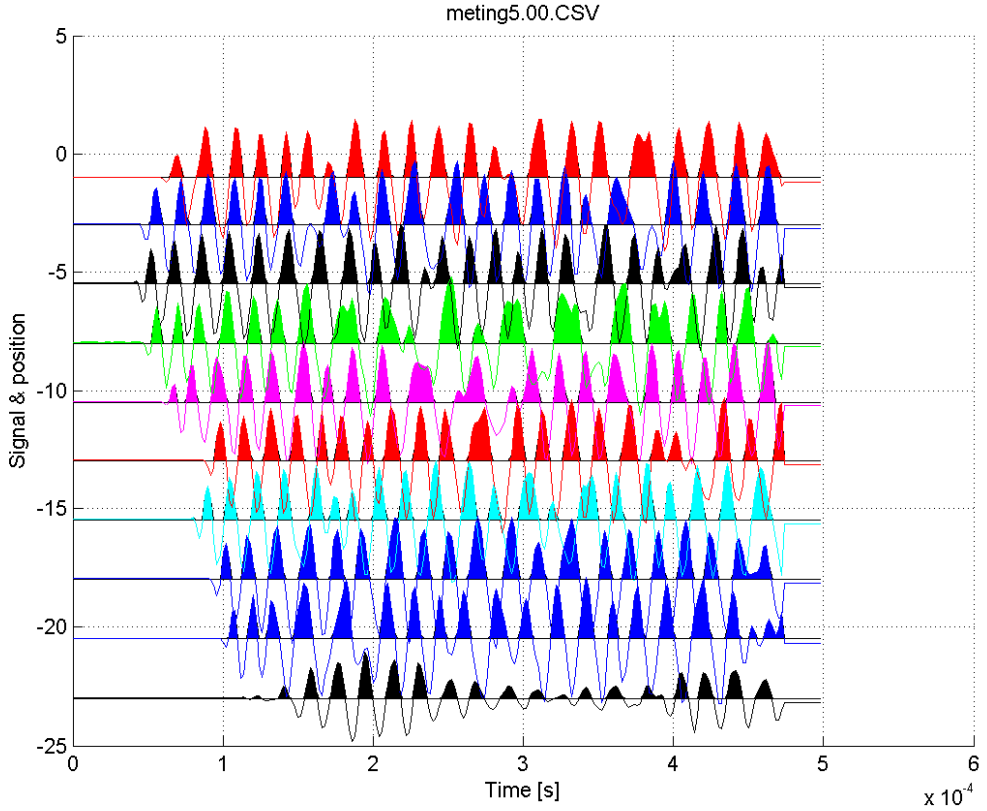
1. reduce the noise from the transducer when it is applied in the water
2. repeat this type of measurement for a test

A Bijlage Meetresultaten in de waterbak bij Deltares


afstand40cm.00.CSV
Signal & position
10
0
-10
-20
-30
-40
-50
-60
-70
0
1
2
3
4
5
6
Time [s]
x 10^-4


meting3.00.CSV
Signal & position
Time [s]
x 10^-4
10
0
-10
-20
-30
-40
-50
-60
-70
-80
0
1
2
3
4
5
6


meting4.00.CSV
Signal & position
10
0
-10
-20
-30
-40
-50
-60
0
1
2
3
4
5
6
Time [s]
x 10^-4


meting5.00.CSV
Signal & position
5
0
-5
-10
-15
-20
-25
0
1
2
3
4
5
6
Time [s]
x 10^-4

B Photographs of the test piles at Horstwald

B.1 Pile B1

B.2 Pile B4


1
2
3

B.3 Pile B5


1
2
3

C SHSL measurements