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Field tests on geocontainers

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ABSTRACT: Two Instrumented geocontainers have been dumped in a field test. Pore pressure transducers, total stress transducers and strain gauges were installed. Measurement results are presented for these containers. It appeared that the dumping is the maximum loading for a container. When another container is dumped on top of an instrumented container the loading is considerably lower. Falling velocities reached up to 8 m/s. The degree of saturation appears to have quite some influence on the loading on the geotextile. Furthermore the falling conditions have a large influence on the loading. Both containers fell with an angle compared to the horizontal starting position, although for different reasons.

1 INTRODUCTION

A research programme was set-up to investigate the possibilities to use geocontainers as an alternative for a rockfill core in breakwaters for an enlargement of the Rotterdam harbour. The Ministry of Transport and Public works and the research organisation Delft Cluster co-operate in this programme. The research programme incorporates theoretical studies, small scale model tests on hydraulic and geotechnical aspects and full scale field investigations. Results of the theoretical studies have been published before (Bezuijen et al, 2000, Groot de et al, 2000). The model tests on hydraulic and geotechnical aspects will be dealt with in another paper at this conference (Bezuijen et al. 2002).

This paper concentrate on the field tests. Near Arnhem in the Netherlands a dam is constructed in an old sand exploitation pit. This pit is up to 20 m deep. The dam is necessary for the construction of a tunnel that also crosses the nearby river, see Figure 1. Geocontainers are used to construct a dam with a steeper slope than would be possible with traditional methods. The geocontainers have a length of 28.8 m, a width of 7.1 m (in the split barge) and a volume of approx. 450 m^3 each. The containers are placed by means of a split barge.

Two containers have been instrumented with pore pressure, total pressure and strain gauges to determine the pressures in the geocontainer and strains in the textile during dumping and impact.

Field tests have been performed before (see for example Fowler et al, 1994, Fowler et al, 1995 and Van Oord ACZ 1995). However, the tests described here were performed at larger water depth and total stress transducers were installed, which was not the case at earlier tests.

The paper will present the results of the measurements and consequences for loading on the geotextile of a geocontainer.

2 DESCRIPTION PROJECT

An old sand exploitation pit is partly refilled with sand, for the construction of a railway tunnel underneath the adjacent river. The plan was to construct the sand dam in the pit with geocontainers and sand. After each layer of geocontainers was dumped, the area in between is filled with sand by means of hydraulic fill. A cross-section of the dam is shown in Figure 1. (The dam is only constructed partly in this way. Due to a change of plans the last part of the dam was constructed by hydraulic fill only).

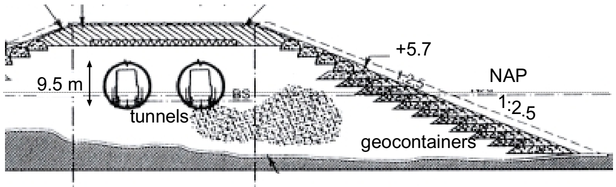

Figure 1. Original plan to construct dam with geocontainers.

Figure 1 shows only one slope of the planned dam. A comparable slope was planned to the other side.

The maximum water depth is approximately 20 m. The relative large water depth makes this project suitable for a field test, because this will also be the situation when using geocontainers for the enlargement of the Rotterdam harbour, as mentioned in the introduction. The dimensions of the geocontainers used are presented in Figure 2.

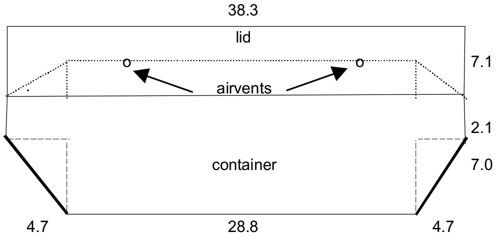

Figure 2. Dimensions geocontainer, dimensions in metres.

3 MEASUREMENTS

Two containers have been instrumented and 3 tests were performed between September and November 2001. Initially, one of the instrumented containers was dumped in place and the instrumentation recorded the pressures and strains during the dumping process. After the end of this test, the instrumentation cables were disconnected from the data logging system, placed in a watertight PVC cylinder and left to float. A few days later, during dumping of the next layer above the layer with the instrumented container (test 2- noninstrumented geocontainer on top of the instrumented geocontainer), the instrumentation was reconnected to the data logging system, to measure the impact of the dumping of this layer on the bottom geocontainer. The field tetsts ended with the dumping of a second instrumented container. The results of the last container were the most interesting, because the first container was damaged during the fall. Therefore the paper will concentrate on the results of this last measurement. Only the reason why the first container failed will be shown.

The instrumented containers had 4 pore pressure transducers (PPTs) placed next to the geotextile just inside of the container, two on top of the container and two on the bottom of the container, see Figure 3. The PPTs were mounted on the geocontainer to determine its shape and position during the dumping. The sensors worked within an output range between 0 and 2.5 bar. Two total stress transducers (TSTs) and two PPTs were mounted in the centre of the geocontainers at the indicated positions.

The pore pressures and total stresses in the geocontainer material were measured with piezo-resistive sensors. Prior to placing in the geocontainer, the sensors were attached to heavy brick stones, preventing the sensors from moving during filling the geocontainer with sand. The TSTs were a field version of the transducers used for the small scale model tests described in another paper for this conference (Bezuijen et al, 2002). The sensor worked within an output range between 0 and 5.0 bar. A latex membrane, filled with water between the latex membrane and the membrane of the transducer, was used to transmit the pore pressures and grain stresses, see Figure 4.

In total 8 strain gauges were mounted at the positions indicated in Figure 3. The strain gauges 1 to 4 were mounted on top if the container, on the outside of the geocontainer and the remaining were mounted on the inside. Prior to the field testing, the two ends of the strain gauges were glued to 5mm brass pins. The strain gauges were made waterproof by encasing them in silicon gel. The strain gages were attached in place by gluing the other end of the brass pins to the geotextile.

All instruments were equipped with 50 meters of cable. Readings from the instrumentation were taken at a rate of 50 samples per second.

Figure 5 shows the geocontainer in the split barge during filling and mounting of the instrumentation. Figure 6 shows the geocontainer as it disappears trough the opening of the split barge. The cable that connects the instrumentation on the computer can be seen on the left hand side of the barge. The container dumping started rather flat. As can be seen on the figure, the bow end fell a bit earlier than the rear side from with the picture was taken, but the difference was only small (approximately 0.5 s).

4 MEASUREMENT RESULTS

4.1 *Falling of containers*

First container

The first container did not fell level from the split barge. This is demonstrated in the left plot of Figure 7. Pressure gauges were mounted at the same position in this test compared with last test, see Figure 3. In this figure the horizontal and vertical axis are plotted on the same scale. The figure shows the pressures measured with D1 and D3 at different times. The angle in the plot is the real angle the container fell between D1 and D3. The actual length of the geocontainer is approximately 3 times more, but as can be seen from Figure 3 there were no pressure gauges outside D1 and D3, thus the movement of those parts is not recorded. It is clear from the plot that the maximum angle is nearly 45 degrees. The angle only decreases when the container hits the bottom.

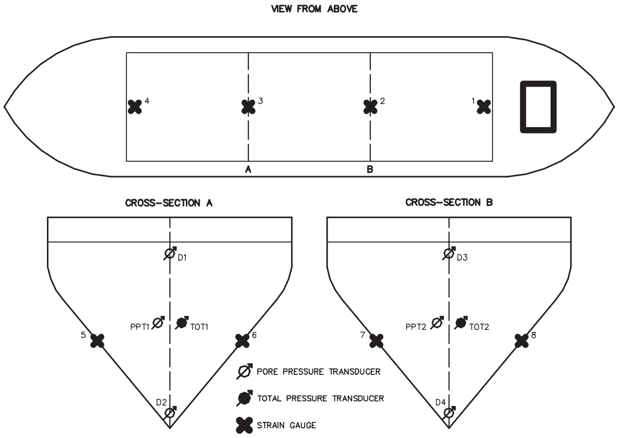

Figure 3. Instrumentation used for the last instrumented container.

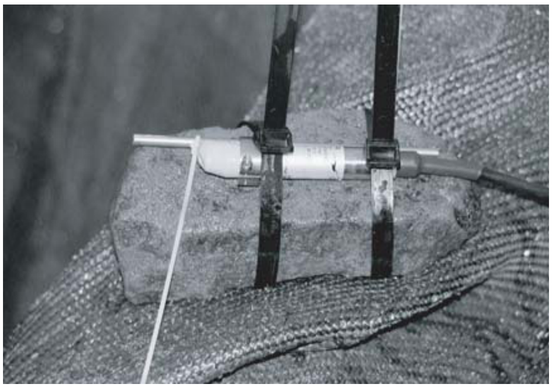

Figure 4. Total pressure transducer used in field tests.

Figure 5. Overview split barge during installation of instrumentation. The arrows indicate the positions of the already installed strain gauges.

Figure 6. Geocontainer at the moment of dumping.

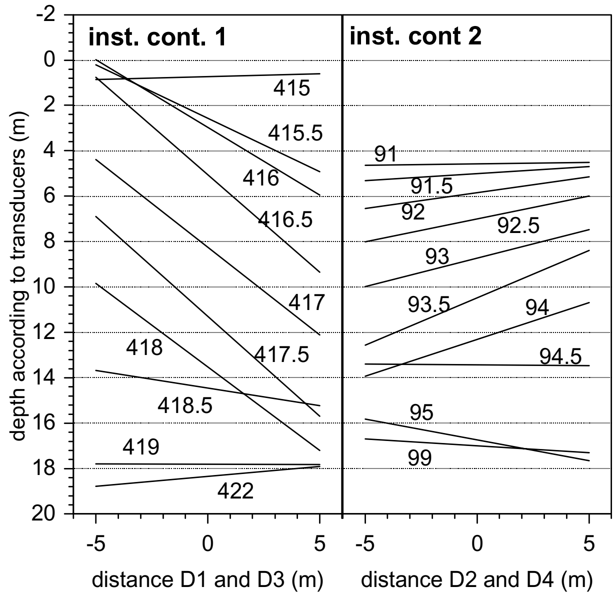

Figure 7. Depth recorded with pressure transducers at different times for both instrumented containers. Transducer located at 1/3 and 2/3 of the length of the container (transducers on top of container for instrumented container 1 and on the bottom for container 2, see also text).

The velocity plot shows what happened, see Figure 8. The velocities have been derived from the measured pressures with PPT D1 and D2 by differentiating the results and taking a moving average over 25 points to reduce noise. The falling velocity started to increase at location D3. However, it appears that the container was still 'locked' near location D1 and therefore at that location the velocity remained more or less zero. This locking even hampered the falling at D3, leading to a decrease in velocity (at t=416 s). This decrease in velocity at D3 is of a very short duration. Directly after that the container is released also in the neighbourhood of D1 and it falls to the bottom. It was noted however, that the split barge moved horizontally during dumping, because of the forces acting on it, most likely at around t=416 s.

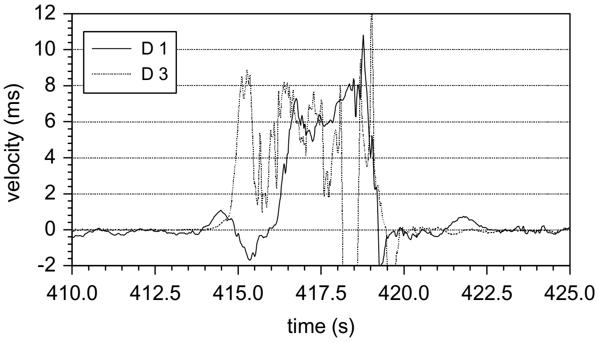

Figure 8. Container 1. Measured falling velocities, see text.

The forces when the container was at one side more or less stuck in the split barge or later on when only one side hits the bottom led to damage of the container. It could not be determined what was the real reason for the damage.

Second container

The right part of Figure 7 shows the falling of the second container. In this case the depth pressure gauges underneath the container D2 and D4 have been used, because the gauges on the top were located in unsaturated sand and the results were not suitable to determine the depth. This is of course a general shortcoming of using measured pressures to determine depth. The water movement around the container also influences the measured pressures as well as the impact forces, especially for the gauges underneath the container. In Figure 7 the peak pressures measured during impact are omitted, and the results as presented in that figure seems reasonable for both containers.

The 2^nd^ container started level, see also Figure 6, but during the fall it fell more and more on an angle, up to 93.5 s, after that it got a more level position. It never reached the angles measured during the dumping of the first container. It is possible that between 93.5 and 94 s one side of the container hit the bottom (it should be realized that the ends of the container were at –15 and 15 m in the coordinates of the x-axis from Figure 7). If that is the case, it is realistic to assume that the pressures measured at 94.5 and 95 s are not very suitable as depth measurement, because of dynamic effects. It seems however, if the container rotates back to end up in a level position at t=99 s.

The vertical velocities determined from the gauges D2 and D4, again with an averaging over 25 points are shown in Figure 9. The vertical velocities were a bit lower than for the first container, up to 6 m (the peak for D4 is caused by the impact and not realistic) and there are no sharp decreases in velocities before the container hits the bottom. This container survived the dumping.

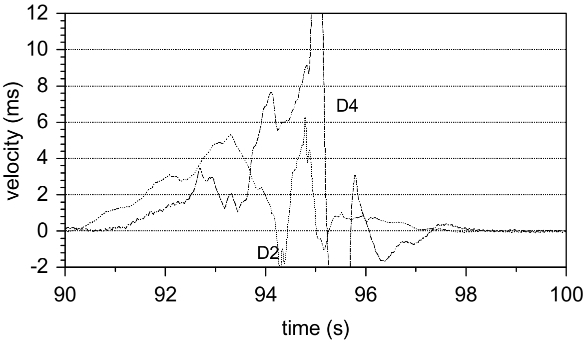

Figure 9. Container 2. Measured velocities, determined from pore pressure transducer measurements.

4.2 *Pressures 2nd container*

Figure 10 shows the whole registration of the gauges D1 until D4 of the second container during the dropping. The gauges D1 and D3 were located at the top of the container, but they were located in the sand underneath the geotextile. The lower part of the sand in the container was saturated, due to water coming into the split barge from underneath. The upper part was not saturated (In the first instrumented container the sand was to some degree saturated because wet filling sand was used there instead of initially dry sand in the second container). The results clearly show the influence: D1 and D3 rise much slower than D2 and D4. However, that also means that there will be a grain stress present in that part of the container and this will reduce the loading on the geotextile (Bezuijen et al , 2000).

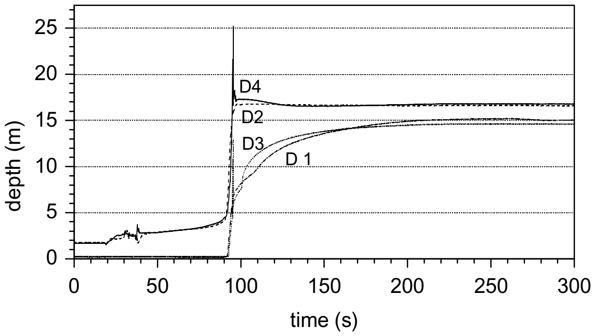

Figure 10. Measured depths at various positions on the container.

Figure 11 shows the pressures D1 until D4 during dumping. Remarkable is the dip in the pressures measured in D2 at 95 s. in the dumping process. As mentioned before this was probably the time the bow end of the container hits the bottom.

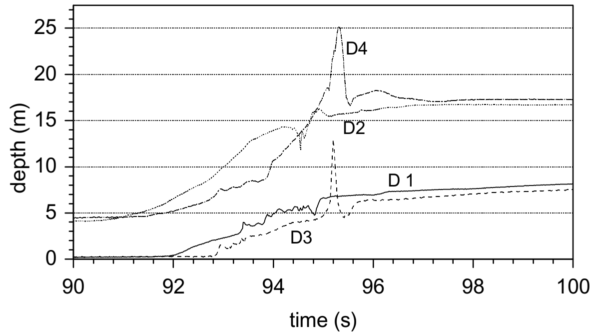

Figure 11. Detail of Figure 10 during dumping.

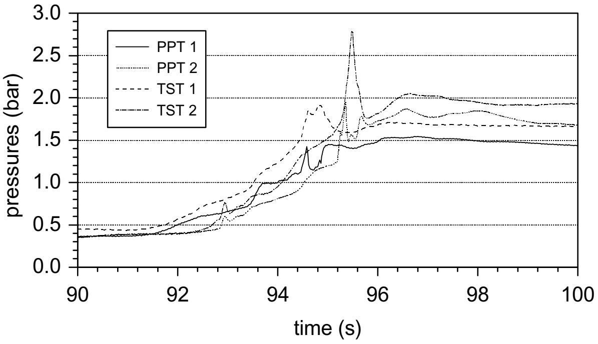

Figure 12. Measured total pressure and pore pressures.

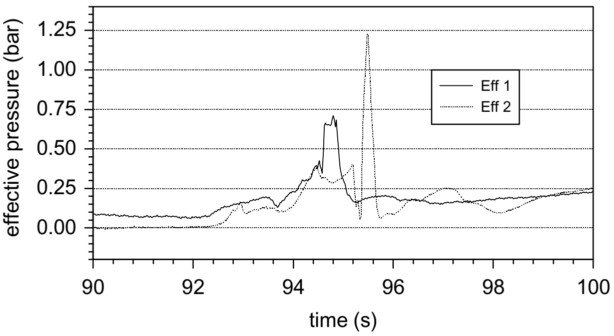

Figure 13. Effective stresses calculated from the total and pore pressures.

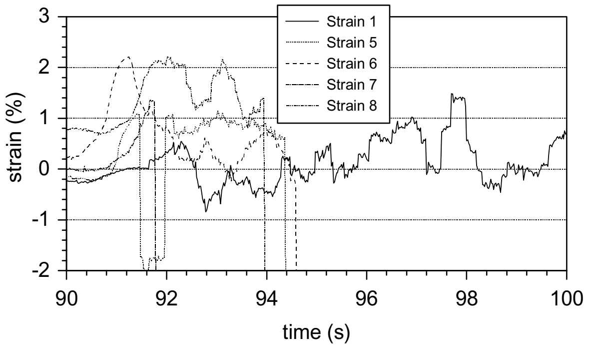

Figure 14. Measured strains. The instruments outside the container (1, 2, 3 and 4) survived, but showed a large noise after dumping. The other instruments broke down at different moments.

The pressure peak during impact is only present for D4. It is assumed that the part left of D2 (see Figure 3) hits the bottom first and then the rest of the container hits the bottom. It is remarkable that the pressure peak measured with D4, is also visible in D2 indicating an increased pressure in the whole cross-section of D2 and D4. This peak is also recorded with the total pressure gauge TST2 in Figure 12, but not with the PPT2. The most likely reason that it is not measured with PPT2 is dilatancy of the sand in the container, which will lead to a reduction of the pore pressure especially in the center of the container where PPT2 and TST2 were located.

The effective stresses, as shown in Figure 13, affirm the idea that first the end of the container near PPT1 and TOT1 touches the bottom. The peak in the grain stress is earlier at that side (Eff 1, cross-section A) than at the other side (Eff 2, cross-section B).

4.3 *Loading on second container*

It was tried to measure the loading on the geotextile by measuring the strain of the geotextile during impact by strain gauges. This appeared to be not very successful, see Figure 14. The gauges inside the container broke down before the real impact, indicating only a few percent strain. The gauges outside the container (on top) could not be used due to noise. To get an indication of the maximum loading during impact the pressure measurements have been be used. The results shown in Figure 11 (D2 and D4) showed a pressure peak of approximately 0.8 bar. With the equation P=T/R with P the maximum pressure, R the radius of the container (the smallest radius because that corresponds with the highest pressures) and T the tensile force (Bezuijen et al, 2000). In this case the radius is approximately 1 m and therefore the measured pressure peaks correspond with a considerable load of 80 kN/m.

5 CONCLUSIONS

The field tests lead to the following conclusions:

The impact of the container on the bottom was in this test the most important regular loading condition. Estimated loading was as high as 80 kN/m on the geotextile.

In case the release from the barge is obstructed, this can be an even more sever loading condition. Normally the geotextile will not survive such a loading and therefore a smooth release is of great importance.

Pore pressure transducers and total stress transducers worked well during these tests, but the developed strain gauges were not suitable for these field conditions.

Even if the container leaves the barge in a horizontal position, it is not necessary that it remains horizontal. From these tests an angled impact seems not an exception, although 2 instrumented containers is a rather low number to perform statistics.

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REFERENCES

Bezuijen A., Adel H. den, Groot M.B. de, Pilarczyk K.W. 2000. Research on geocontainers and its application in practice. *Proc. 27th ICCE, Sydney.*

Bezuijen A., Oung O., Klein Breteler M., Berendesen E., Pilarczyk K.W. 2002. Model tests on geocontainers, placing accuracy and geotechnical aspects. *Proc. 7th Int. Conf. on Geosynthetics, Nice.*

Groot M.B. de, Bezuijen A., Pilarczyk K.W. 2000, Forces in Geocontainer geotextile during dumping from barge. *Proc. Eurogeo 2, Bologna, October 2000.*

Fowler J., Toups D., Duarte F., Gilbert P. 1994. Geotextile contained dredged material. Red Eye Crossing, Baton Rouge, Louisiana.

Fowler J., Toups D. and Gilbert P. 1995. Geotextile contained contaminated-dredged material, Marina Del Rey, Los Angeles and Port of Oakland, California, *14th World Dredging Congress, Amsterdam, the Netherlands.*

Van Oord ACZ BV. 1995. *Test programme of geocontainers* not publicly available research report.