International
Progress Report

IPR-07-16

Äspö Hard Rock Laboratory

Canister Retrieval Test

Dismantling and sampling of the buffer and determination of density and water ratio

Lars-Erik Johannesson

Clay Technology AB

June 2007

Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

Äspö Hard Rock
Laboratory

Report no.
IPR-07-16

No.
F69K

Author
Lars-Erik Johannesson

Date
June 2007

Checked by
David Dixon

Date
November 2007

Approved
Anders Sjöland

Date
2008-05-21

Äspö Hard Rock Laboratory

Canister Retrieval Test

Dismantling and sampling of the buffer and determination of density and water ratio

Lars-Erik Johannesson

Clay Technology AB

June 2007

Keywords: Buffer, Bentonite, Sampling, Dismantling, Retrieval, Core, Saturation, Water ratio, Density, Temperature, Measurements, Swelling, Full scale, In-situ, Power cables

Abstract

A full size canister with a bentonite buffer was installed in the deposition hole in the autumn of 1999 at the Äspö Hard Rock Laboratory. The bentonite buffer consisted of highly compacted blocks and with an outer slot between the blocks and the wall of the deposition hole (~ 5 cm width) filled with bentonite pellets. The bentonite surrounding the canister was saturated through filters installed on the wall of the deposition hole. This test, Canister Retrieval Test (CRT), was primarily designed to test the technique to retrieve canisters from a water saturated buffer. One such technique has been tested in the lower part of the buffer in the CRT. In this test the buffer was pumped out of the borehole after having been slurred by a salt solution. The upper part of the buffer was removed by mechanical means before the retrieval test was started so that water and density samples could be recovered. This report describes the work with the sampling in the upper part of the buffer and the determination of the water ratio and the density of the taken samples.

Most of the samples were taken from the upper portion of the buffer by core drilling from the upper surface of each installed bentonite block. The cores had a diameter of about 50 mm and a maximum length equal to the original height of the bentonite blocks (about 500 mm). The drilling occurred from the tunnel floor using a rig designed for taking geotechnical soil samples.

The water ratio of the buffer was determined by drying a sample at a temperature of 105°C for 24 h and the bulk density was determined by weighing a sample both in the air and immerged in paraffin oil with known density.

The water ratio, degree of saturation and dry density of the buffer were then plotted. The plots show that the buffer was far from saturated above the canister lid, while the buffer at the canister level was fully saturated. The data is also showing that the initial large variation in dry density for different part of the buffer has been reduced during the saturation although there are still noticeable differences in the density at the dismantling (see Figure 1).

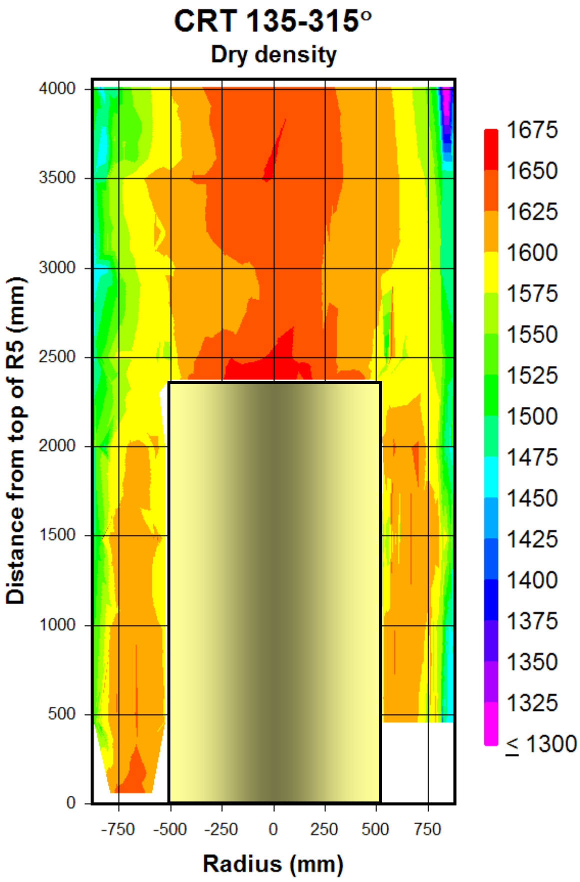


Figure 1. *The contour plot of the dry density in direction 135-315° for the buffer.*

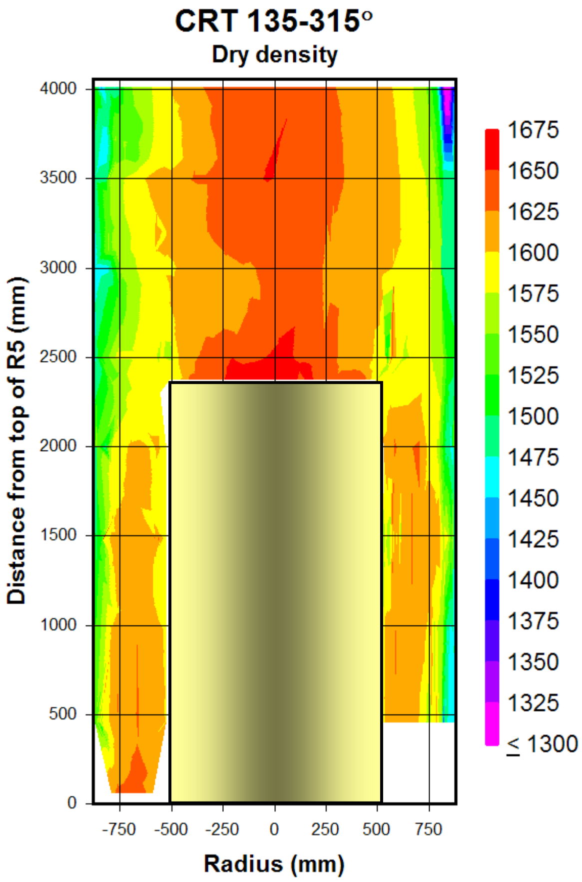
Sammanfattning

En kapsel i full skala omgiven av en bentonitbuffert installerades i ett deponeringshål under hösten 1999 vid Äspölaboratoriet. Bufferten bestod av högkompakterade bentonit block. Dessutom var den yttre spalten mellan blocken och deponeringshålets vägg (~5 cm bred) fyll med bentonitpellets. Bentoniten i deponeringshålet vattenmättades via filter som installerats på deponeringshålets vägg . Försöket (Canister Retrieval Test) var ursprungligen designat för att tests en teknik för att kunna återta kapseln från en vattenmättad buffert. En sådan teknik har testats i den nedre delen av bufferten i deponeringshålet. Den teknik som användes vid testen innebar att bufferten pumpades upp efter att den blivit upplöst i en saltlösning. Den övre delen av bufferten bröts upp mekaniskt innan ”återtagsförsöket” startade. Under brytningen av den övre delen av bufferten togs prover på vilka vattenkvot och densitet bestämdes. Denna rapport beskriver arbetet med provtagningen och bestämningarna av vattenkvot och densitet på de tagna proverna.

De flesta proverna från buffertens övre del togs genom att kärnor borrades från överytan av varje installerat bentonitblock. Kärnorna hade en diameter på ca 50 mm och en maximal längd lika med blockens höjd (ca 500 mm). Uttaget av kärnorna gjordes från tunnels golv med hjälp av en borrvagn som normalt används för geoteknisk provtagning i jord.

Vattenkvoten på bufferten bestämdes genom att prover torkades i en temperatur på 105°C under 24 h. Skrymdensiteten bestämdes genom att prover vägdes dels i luft och dels nedsänkta i paraffinolja med känd densitet.

Vattenkvoten, torrdensitet och vattenmättnadsgrad beräknades för proverna och resultaten pressenterades i kurvor och figurer. Resultaten visar att bufferten var långt ifrån vattenmättad ovanför kapselns topp medan bufferten runt kapseln var vattenmättad. Resultaten visar också att den stora skillnaden i torrdensitet för olika delar av bufferten vid installationen har minskat under vattenmättnaden även om märkbara skillnader i densitet kunde observeras också efter brytningen (se Figur 1)



***Figur 1**. Torrdensiteten i övre delen av bufferten i snittet 135-315°.*

Contents

1 Introduction

The Canister Retrieval Test (CRT) was primarily designed to test the technique to retrieve canisters from a water saturated buffer. One such technique has been tested in the lower part of the buffer in the CRT. In this test the buffer was pumped out of the borehole after having been slurred a salt solution. The upper part of the buffer was removed by mechanical means before the retrieval test was started so that water and density samples could be recovered.

A full size canister with a bentonite buffer was installed in the deposition hole in the autumn of 1999 at the Äspö Hard Rock Laboratory. The bentonite surrounding the canister was saturated through filters installed on the wall of the deposition hole. Sensors to measuring temperature, total pressure, pore pressure and relative humidity were installed in the buffer. The data from the sensors was collected continuously during the saturation phase.

The test has been and will be further used for verification of models for predicting the saturation and homogenisation of the buffer. For this work it is important to have access to samples taken from different locations in the buffer. The samples can be used for determining the density and water ratio of the buffer. They can also be used to determine if the bentonite has been affected during the test period, especially close to the canister and the rock wall. The biological activity in the buffer is also of interest. It is also important to be able to recalibrate sensors installed in the buffer.

This report describes the work with the sampling in the upper part of the buffer. The results of the measurements of water ratio and density are also reported here.

When the samples had been taken on block R10 the upper lid of the canister was removed and the cables from the heaters were also removed. Since this part differ from the rest of work done with the dismantling of the test it is described in a separate section of the report (Section 6).

Other activities associated with the dismantling of the CRT are the removal of the wires, which anchored the concrete plug placed above the buffer and the removal of the steel lid and the concrete plug from the deposition hole. This part of the work is not described in this report.

The core drilling of the samples were done by Kjell Hidsjö at FMGeo AB and Markus Karlsson at BGK AB. The handling of the samples at the site was done by Stefan Grandin-Svärd at SKANSKA and Fredrik Rudklint at GEOSIGMA AB.

2 Execution

2.1 Introduction

The Canister Retrieval Test, see Figure 2-1 was installed in 1999 in order to demonstrate the feasibility of retrieving a canister from a water saturated buffer. The upper part of the test was mechanically excavated and sampled in order to get information about the saturation phase and possible changes in the properties of the buffer material. The lower part of the buffer was used for testing a canister retrieval technique.

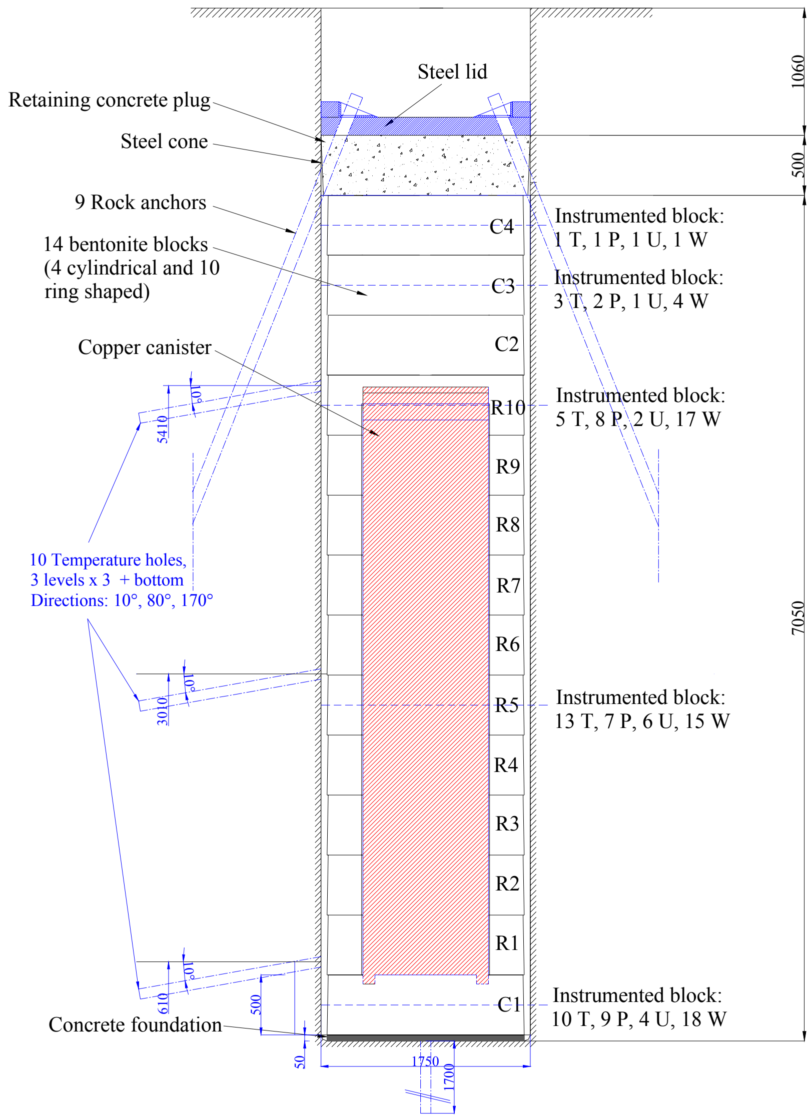


Figure 2-1. Schematic drawing of the Canister Retrieval Test. Sampling of the bentonite occurred down to the level of the upper surface of block R5. The bentonite below this level was removed using a non-mechanical retrieval technique. The drawing also shows the number and positions of the installed sensors (T=temperature, P=total pressure, U=pore pressure and W=relative humidity).

There are two phases in the analyses of the samples taken from the buffer.

1. The water ratio and the density were determined at the Äspö Hard Rock Laboratory just after the samples were taken from the buffer, which minimized the risk of drying and redistribution of the water in the samples. About 1500 samples were taken from the buffer.

2. More advanced investigations of the buffer will be made at Clay Technology AB in Lund, such as determination of hydraulic conductivity and swelling pressure, mineralogical changes etc. These tests do not require immediate handling of the samples and will be reported separately.

The first phase is described in this report. The most important events during sampling are listed in Table 5-1. The sampling and investigation techniques are described in this document.

Table 2-1. Events during dismantling of the upper part of the buffer in the CRT.

Activity	Date	Comments
The power to the canister was switched of.	2005-10-11	The power was switched off about 3 months before the first samples of the buffer were taken
The plug was removed	2006-01-16—01-18	The rock anchors were removed and the steel lid and concrete plug was lifted up from the deposition hole
Samples were taken from block C4	2006-01-18—01-23	
Samples were taken from block C3	2006-01-24—01-30	
Samples were taken from block C2	2006-01-30—02-02	
Samples were taken from block R10	2006-02-06—02-10	Samples were taken from both the ring shaped block and the bricks placed on top of the canister lid. The thickness of the bricks-filled regime was about 220 mm.
Removal of the upper lid of the canister	2006-02-13—02-14	The upper lid of the canister was removed.Samples were recovered from the filling between the lids of the canister. The power cables were removed from the deposition hole
Samples were taken from block R9	2006-02-14—02-20	
Samples were taken from block R8	2006-02-22—03-01	
Samples were taken from block R7	2006-03-02—03-09	
Samples were taken from block R6	2006-03-13—03-21	

2.2 Methods used for taking the samples

Most of the samples were taken by core drilling from the upper surface of each installed bentonite block (Figure 2-1). The cores had a diameter of about 50 mm and a maximum length equal to the original height of the bentonite blocks (about 500 mm). The drilling occurred from the tunnel floor using a rig designed for taking geotechnical soil samples (Figure 2-2). Samples close to the canister and the rock wall were taken by braking pieces from the blocks by hand. Additional samples were taken close to the installed sensors. Larger pieces (up to ¼ of a block) were also sawn out from the blocks and stored. The rest of the buffer material was removed and discarded.

Figure 2-2. *Type 705 DD drilling rig placed over the deposition hole.*

2.3 The position of the samples

A coordinate system for the deposition hole was established when the buffer was installed in order to locate installed sensors. This coordinate system was also used to locate samples recovered at the end of the test. The position of each sample is defined by three coordinates

1. r-coordinate. The horizontal distance from the centre of the deposition hole.
2. z-coordinate. The distance from the bottom of the deposition hole to the position of the sample.
3. α-coordinate. The horizontal direction where the 0° direction is defined in Figure 2-3.

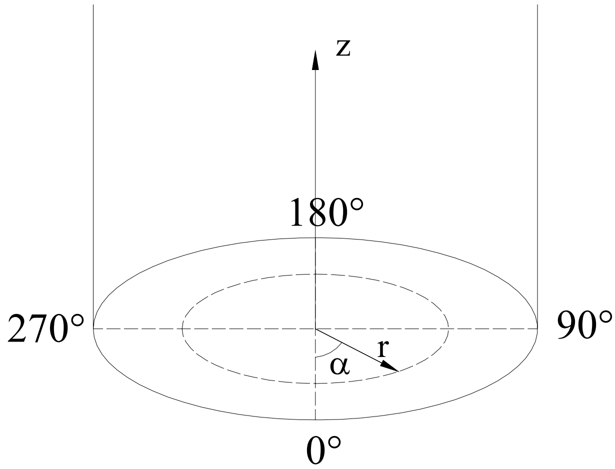


***Figure 2-3**. The coordinate system used for describing the position samples. 0°is the direction towards the end of the drift and 180° is the direction almost to the north.*

The angle α was marked in advance by installing small bolts into the wall at the upper part of the deposition hole (on every tenth degree). The bolts were used for determining the α- coordinate of the samples. The accuracy of the determination is approximately 2°.

The z-coordinate was determined with a laser levelling instrument. The accuracy of this measurement is approximately 1 mm.

The r-coordinate was determined by measuring the distance to the canister and/or to the wall of the deposition hole. The accuracy of this measurement is approximately 5 mm.

2.4 Selection of samples

The sampling of the buffer was mainly made according to the following principles:

1. The samples were taken block layer by block layer. The intention was to take the samples from one layer and than remove the rest of the block to the level of the next lower block.
2. Most of the samples were taken along the four directions, 45°, 135°, 225° and 315°. These angles are intermediate to the lines of instrumentation , see Figure 2-3. Samples were also taken between the four main directions in the four block layers that were installed without instruments (R6 - R9), see appendix 1-5.
3. The sampling in the 45° direction was to determine the density and water ratio every 2,5 cm in radial direction
4. The purpose of sampling in the other three directions was to determine the water ratio and the density every 5 cm in radial direction.
5. In the samples taken between the four main directions in the four blocks without any installed sensors the water ratio and the density were determined on only one level close to the upper surface of the block.
6. In the direction 135° samples from 5 levels were used in each core to get information of the variation of water ratio and density with depth.
7. Beside the above mentioned locations, samples were also taken at places of special interest, such as the interface between the canister and the buffer, the interface between the bentonite and the rock surface and close to the installed sensors.
8. A large piece of each investigated block was also recoverd and saved. Smaller samples can be taken from these pieces.

***Figure 2-4**. Cores taken from block C3.*

About 430 cores were taken from the blocks and about 1200 determinations of water ratio and density were made on samples taken from the cores. In addition samples were taken close to installed sensors, close to the surface of the wall of the deposition hole and close to the canister. The material from the cores and other samples taken from the buffer which was not used for determination of water ratio and density, was wrapped in plastic and stored for planned future laboratory tests.

2.5 Sensors and cables

Sensors were located in five buffer blocks, see Figure 2-1. A cable was led from each sensor along the upper surface of the block to the periphery of the deposition hole and then further on to the floor of the tunnel in grooves in the rock wall. Furthermore some cables, coming from the canister, were placed in block R10.

It was important to avoid damage to the installed sensors and cables during sampling of the buffer so that a recalibration of as many of the installed sensors as possible could be accomplished. The handling of sensors and cables was therefore made as follows:

1. The sensor was identified and its position in the buffer was measured and noted in a protocol.
2. The sensor was removed from the buffer and a sample of the buffer was taken at the position of the sensor.
3. If possible, the sensor was removed from the deposition hole by pulling it from the groove in the rock wall and then putting it aside for future attention.

The outcome from the recalibration of the sensors will be presented in a separate report.

2.6 Handling, packeting and marking of the samples

The samples, both cores and other types of samples, were wrapped in plastic immediately after they were taken from the buffer. The samples were marked with unique names showing their position in the buffer. They were also noted in separate protocols for each sample. The samples were placed in plastic boxes, which were piled on a pallet. Each box contained samples from only one bentonite block.

2.7 Detemination of density and water ratio of the samples

Some tests were made immediately after the samples were taken in order to minimize the risk of air drying of the bentonite. The samples were transported to a surface laboratory at Äspö where small pieces were detached to determine the water ratio and density. The subsamples taken were recorded in a sampling log. The rest of the samples were restored in the plastic wrapping. This material will be used for other analyses and tests.

The following equipment was used in the laboratory

1. **A bandsaw** for sawing out pieces form the samples
2. **A precision balance** with 0-2000 g range of measurement.
3. **Two ovens** for drying samples at 105 °C.

Determination of water ratio.

The water ratio of the cut subsamples was determined by drying a sample at a temperature of 105 °C for 24 h. The mass of water dried from the sample was determined according to Eqn. 2-1:

$$m_{water} = m_{bulk} - m_{solid} \tag{2-1}$$

and the water ratio (w) was calculated according to Eqn. 2-2.

$$w = \frac{m_{water}}{m_{solid}} \tag{2-2}$$

Determination of density.

The bulk density of the samples was determined by weighing the samples both in the air and immerged in paraffin oil with known density. The determination was made as follows:

1. A piece of thread was weighed.
2. The sample was weighed hanging in the thread underneath the balance (m_{bulk}).
3. The sample was then lowered in the paraffin oil with the density $\rho_{paraffin}$ and the weight ($m_{parraffin}$) was noted

The volume of the sample (V_{buk}) and the density (ρ_{bulk}) were calculated according to Eqns. 2-3 and 2-3.

$$V_{bulk} = (m_{bulk} - m_{paraffine}) / \rho_{parffine} \tag{2-3}$$

$$\rho_{bulk} = \frac{m_{bulk}}{V_{bulk}} \tag{2-4}$$

Calculation of other parameters

The dry density (ρ_{dry}) and the degree of saturation (S_r) can be calculated according to Eqns 2-5 and 2-6.

$$\rho_{dry} = \frac{\rho_{bulk}}{(1+w)} \tag{2-5}$$

$$S_r = \frac{w \times \rho_{bulk} \times \rho_s / \rho_w}{\rho_s \times (1+w) - \rho_{bulk}} \tag{2-6}$$

For calculating the degree of saturation the values of the density of the solid particles ρ_s = 2780 kg/m^3 and the density of water to ρ_w = 1000 kg/m^3 are used. The void ratio (e) can be calculated according to Eqn. 2-7.

$$e = \frac{\rho_s - \rho_{bulk}}{\rho_{bulk} - \rho_w \times S_r} \tag{2-7}$$

3 Estimation of the density of different parts of the buffer during installation

Two types of large bentonite blocks, ring shaped blocks and solid blocks, were used for the installation in the deposition hole. The outer diameter of the bentonite blocks was initially slightly tapered conical and varied between 1630 -1650 mm, with an approximate inner diameter of the ring shaped blocks of 1070 mm. The canister had a diameter of 1050 mm while the average diameter of the deposition hole was measured to 1762 mm. The outer gap (average width 61 mm) between the bentonite blocks and the deposition hole wall was filled with bentonite pellets. The void between the pellets was filled with water before casting of the concrete plug above the upper bentonite block. Brick shaped blocks were also placed on top of the canister to fill the volume between the canister lid and the upper surface of the ring shaped block R10. The average density and the water ratio of the buffer at different axial positions in the deposition hole can thus be calculated with the known dimensions of the deposition hole and the blocks together with the weight of the blocks (ring shaped blocks, solid blocks and brick sized blocks) and pellets (see Table 3-1). Two different densities are determined for the slot filled with pellets, first the density before filling the voids between the pellets with water (Pellets I) and secondly the density after the filling of water (Pellets II).

Table 3-1. Estimated densities, water ratios, void ratios and degree of saturation for different parts of the buffer before the saturation phase.

Section	Density (kg/m^3)	Water ratio	Dry density (kg/m^3)	Void ratio	Degr. of saturation
Solid block	1991	0,172	1699	0,636	0,751
Ring shaped block	2087	0,171	1782	0,560	0,849
Bricks	1883	0,165	1616	0,720	0,637
Pellets I	1101	0,100	1001	1,778	0,156
Pellets II	1574	0,572	1001	1,778	0,895

4 Results of measured densities and water ratios in the buffer

Measurements of density and water ratio in the 8 investigated blocks were made in 4 radial lines (see section 2.4). Samples were also taken in other directions, referred to as "extra samples" in this report. In the following sections the results from the measurements of the density are described along three sections;

1. Above the canister (block C4),
2. At the level of the canister lid (block R10)
3. At a section along the canister (block R7).

The results are for all of the investigated blocks are provided in Appendix 6-14.

4.1 Measurements above the canister (Block C4)

The measured water ratio, degree of saturation and dry density for block C4 are shown in Figure 4-1 and Appendix 6:2. The results are plotted as function of the radial distance from the centre of the deposition hole. The initial conditions of the buffer are plotted in the same figures. The following observations can be made:

- Very small differences in the measured/calculated results can be seen between the four directions
- The water ratio in the block part has increased at all measuring points compared to the initial values while it has decreased in the outer slot that was originally filled with pellets.
- The degree of saturation in the outer slot is close to 100%, while the degree of saturation in the block-filled part is lower than 90 % within a radial distance of 500 mm from the deposition hole axis.
- A significant increase of the dry density compared to the initial conditions was observed for the pellet-filled slot.
- The dry density of the blocks has decreased due to swelling. This is most pronounced close to the outer slot.
- The scatter of the measured water ratio and density is higher for the outer slot then for the rest of the buffer.
- The results of the measurements made in the direction 135° at different depths from the upper surface of the block show small variation with the depth (Appendix 6:2).

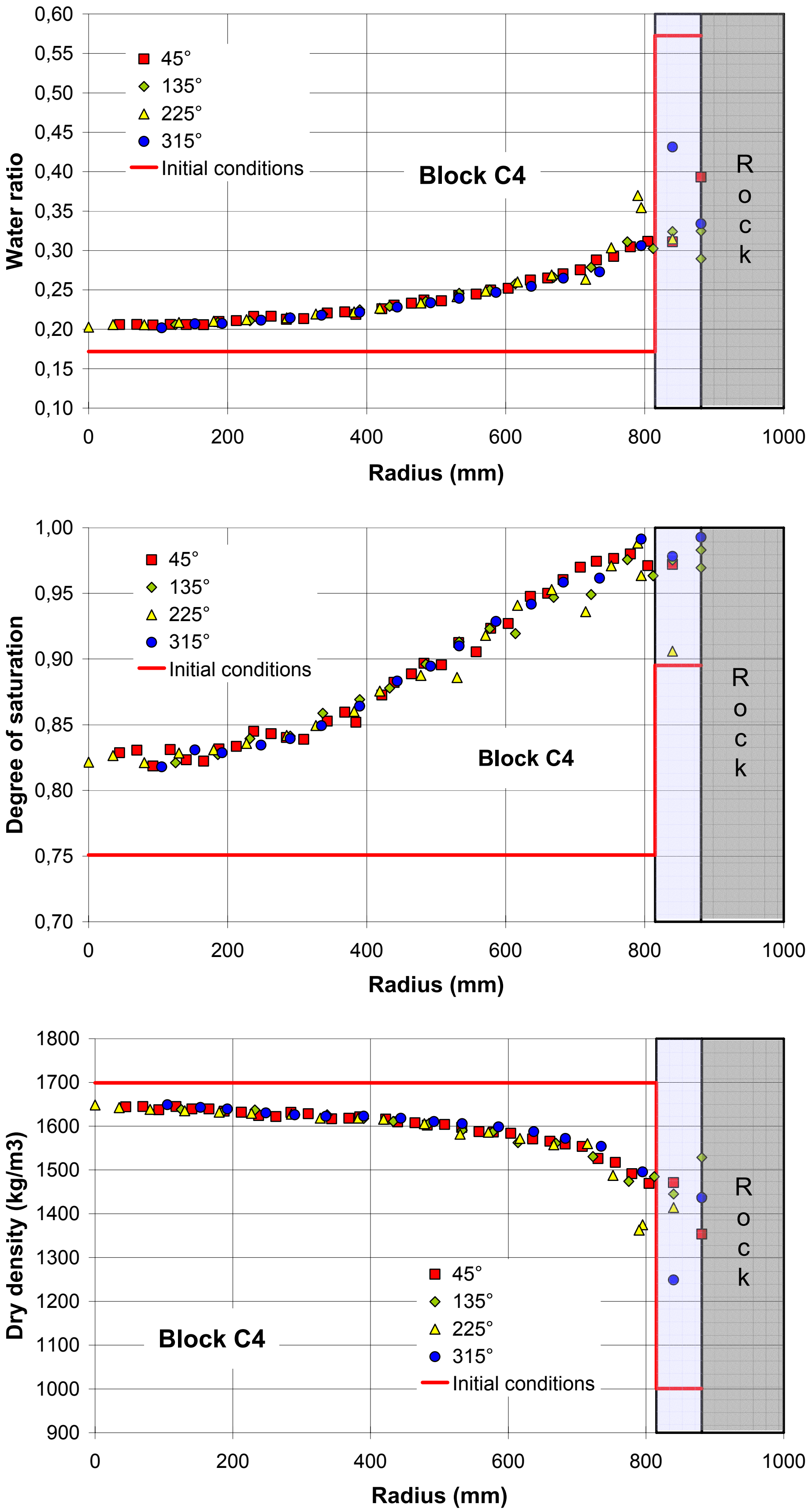


Figure 4-1. *Water ratio, degree of saturation and dry density on samples taken from block C4.*

4.2 Measurements at the level of the canister lid (Block R10)

The measured water ratio, degree of saturation and dry density for block R10 are shown in Figure 4-2 and Appendix 9:2. These values are plotted as a function of the radial distance from the centre of the deposition hole. The initial conditions of the buffer are also plotted in the same figures. The buffer in this section consists of three parts, bricks of compacted bentonite, ring shaped block and pellets in the outer slot. The following observations and conclusions can be made:

- Very small differences can be seen between the four directions.
- The water ratio of both the bricks and the ring shaped block has increased at all measuring points compared to the initial values, while the water ratio of the pellets filling in the outer slot has decreased.
- The degree of saturation in the outer slot is close to 100% while the degree of saturation of the block is lower than 90 % within a radius of 500 mm.
- The relatively large difference in the dry density of the bricks and the ring shaped block has disappeared during the saturation phase.
- The measured density and water ratio in the outer pellets-filled slot show a larger scatter compared to the measurements in the block (both the bricks and the ring shaped block). An explanation might be that the filling of the slot was initially not homogeneous due to the cables and tubes being led from the installed sensors out from the deposition hole through the outer slot. The small scatter in the calculated degree of saturation indicates this. Another reason could be a difference in initial slot width caused by eccentrically location of the block.
- A significant increase of the dry density compared to the initial conditions was observed for the pellets filled slot.
- The measurements made in the direction 135° and at different depth from the upper surface of the block show small variations with the depth (Appendix 10:2).

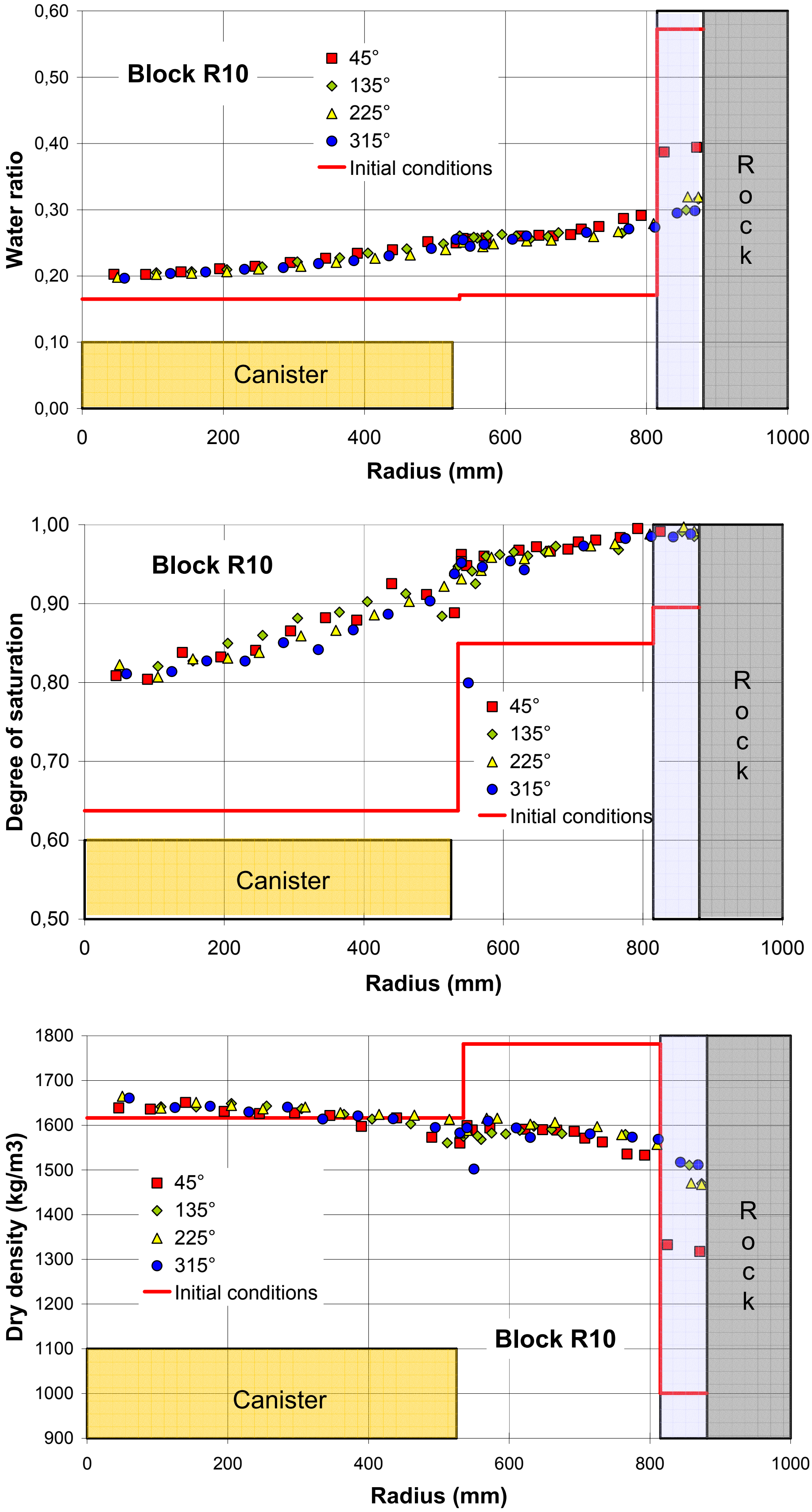


Figure 4-2. Water ratio, degree of saturation and dry density on samples taken from block R10.

4.3 Measurements at the canister level (Block R7)

The measured water ratio, degree of saturation, void ratio and dry density for block R7 are shown in Figure 4-3 and Appendix 12:2. The results are plotted as function of the radial distance from the centre of the deposition hole. The initial conditions of the buffer are also plotted in the same figures. The following observations and conclusions can be made from the plots:

- Very small differences can be seen between the four directions
- The water ratios measured in the ring shaped block have increased at all measuring points compared to the initial values. The water ratio is almost constant from the surface of the canister to a radius of 700 mm. At larger radii there is a tendency of increasing water ratio with increasing radial distance in the pellet-filled slot.
- The water ratio of the pellets has decreased compared to the initial state.
- The degree of saturation of both the block and the pellets is close to 100%. Some of the samples taken close to the canister show a degree of saturation of about 95%. This low degree of saturation might be caused by drying of the samples during excavation since the time needed to recover the samples was much longer compared with the upper-most blocks in the deposition hole (see Table 2-1).
- The measured density and water ratio in the outer slot filled with pellets show larger scatter compared to the measurements in the block. An explanation might be that the filling of the slot was initially not homogeneous due to the cables and tubes being led from the installed sensors out from the deposition hole through the outer slot. The small scatter in the calculated degree of saturation indicates this. Another reason could be a difference in initial slot width caused by eccentrically location of the ring.
- The measurements show a small but significant decrease in density close to the canister.
- A significant increase of the dry density compared to the initial conditions was observed for the pellets filled slot.
- The measurements made in the direction 135° and at different depth from the upper surface of the block show small variation with the depth.

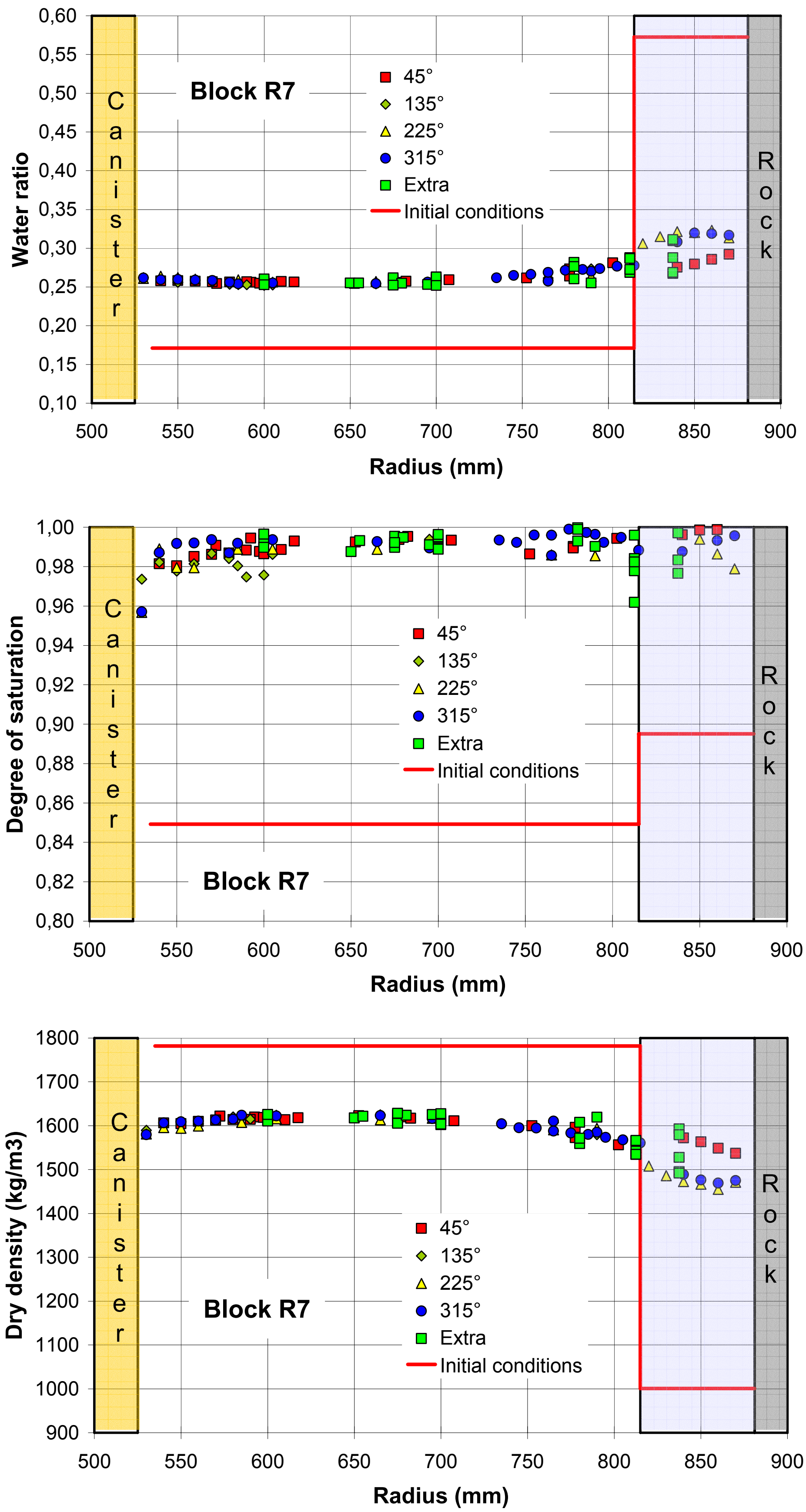


Figure 4-3*. Water ratio, degree of saturation and dry density on samples taken from block R7.*

4.4 Detailed measurements of water ratio and density in the outer pellets-filled slot

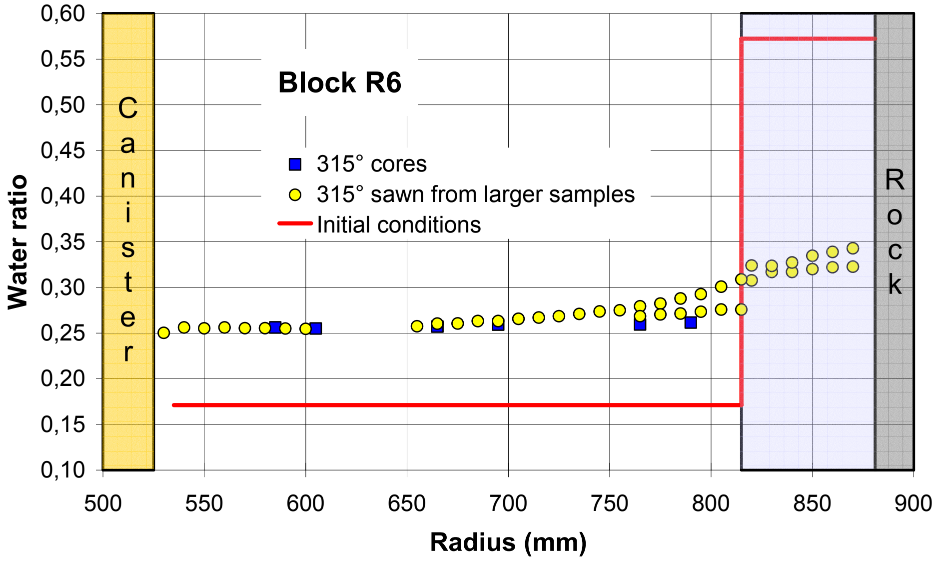
As noted earlier the scatter of density and water ratio values are generally larger in the outer pellet-filled slot compared with the rest of the buffer. An explanation for this might be that the filters placed on the wall of the deposition hole used for saturating the buffer did not cover the entire wall. This means that after the voids between the pellets were filled with water, those pellets which were in direct contact with the filters could more easily take up water and swell, causing a lower dry density of this part of the filling. Although there is a scatter in water ratio and density the variation in the calculated degree of saturation is small. The calculated degree of saturation in the pellets filling is with very few exceptions larger than 97%.

Another explanation to the scatter in the water ratio and the density might be that the initial filling of the pellets was not homogeneous. This could be caused by the tubes coming from the installed sensors in the buffer and led out from the deposition hole through the outer slot.

A third explanation to the large scatter might be that it is caused by the sampling technique, which might induce a drying of the sample.

A fourth reason could be a difference in initial slot width caused by eccentrically location of the blocks.

When the buffer was removed from the deposition hole, samples were taken with core drilling but also as larger pieces taken out of the buffer. Smaller samples used to determine water ratio and density were cut from these pieces. As an example, results from the samples taken in block R6 in direction 315° are shown in Figure 4-4. The figure shows that there are some differences in the measured water ratio between the samples taken with the two methods but the difference is small.



***Figur 4-4**. Water ratio on samples taken from block R6. The water ratios are determined on different type of samples.*

4.5 Detailed measurements of the water ratio close to three total pressure sensors in block R5

Many of the installed total pressure sensors measured lower pressures than expected during the saturation phase. One explanation for this might be that the density of the buffer close to the sensor was lower than the surrounding buffer. This was examined by core drilling over sensors during dismantling of the CRT. The sensors had a diameter of about 25 mm and a length of 120 mm. The core consisted of both buffer and a sensor. Three cores with sensors were taken from block R5. No more samples were taken from this block. The water ratio and the density were then determined on the core and plotted as function of the distance from the tip of the sensor. The results from the determinations are shown in Figure 4-5. The figure shows that the highest water ratio is measured close to the tip of the sensors. The water ratio close to the sensor tip varies between 25.5-27 % and decreases to about 24.5% at 100 mm from the tip. This compares to the water ratio measured in block R6 of about 26%. The lower water ratio far from the tip compared to the water ratio in block R6 might be caused by drying of the samples taken close to the sensors since these samples were examined about ½ year after they were taken from the block R6. A water ratio of 26,5 % corresponds to a density at saturation of 2025 kg/m^3 which corresponds to a swelling pressure of about 8,2 MPa. The maximum measured total pressure (water pressure + swelling pressure) with the three sensors are 6.1 MPa (P113), 7 MPa (P115) and 4.7 MPa (P116). An explanation for the low swelling pressures measured with the sensors might be that although the water ratios of the samples close to the sensor tips are in the same range as the surrounding blocks, this material is not completely saturated or homogenised and so has a lower dry density than the rest of the block. This cannot be excluded since no measurement of dry density was done on these samples. However, a more plausible explanation is that the samples have dried ~ 1.5 %, which means that the dry density close to the tip is 1560 kg/m^3. The dry density corresponds to a swelling pressure of about 6,2 MPa.

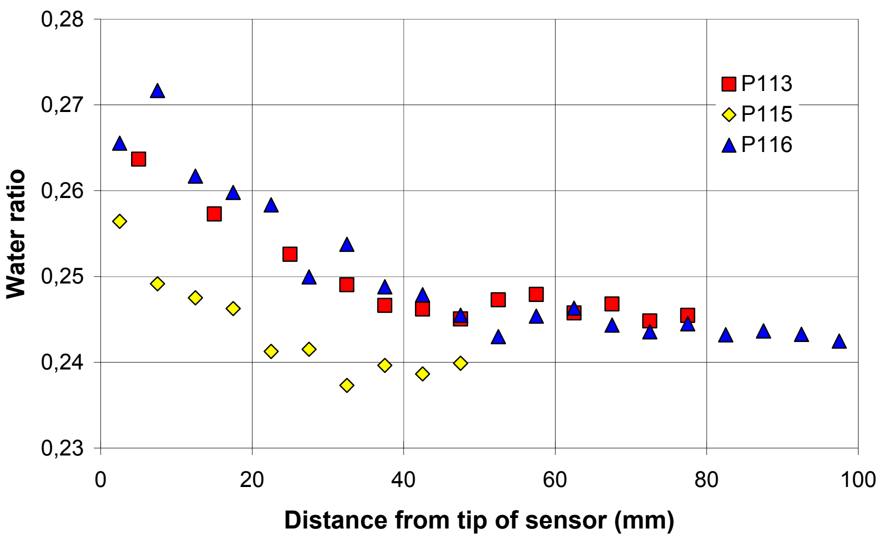


Figure 4-5*. The water ratio determined on samples close to three total pressure sensors in block R5.*

4.6 Contour plots of measured results

Contour plots of the measured and calculated variables density, water ratio and degree of saturation were made using an interpolation program. The plots are shown in Appendix 14. The calculations are made for two sections through the buffer in the upper part of the deposition hole, directions 45-225° and 135-315°. The plots with the interpolated water ratios and dry density indicate that the water uptake was, as expected, axi-symmetric since water was applied to the buffer from filters placed on the wall of the deposition hole. The water ratios in direction 45-225°are shown in Figure 4-6 as example. The plots show also that the buffer is fully saturated between the canister and the rock surface. The figures also show a large variation in dry density. The highest dry density was measured in centre of the deposition hole just above the top of the canister due to the low water uptake and low swelling of the buffer in this region. The lowest density was measured in the pellets at the level of the canister lid. Since the water uptake seems to be axisymmetric, it is possible to use all the data determined from the samples and plot them only as function of the radius and the depth and neglecting the direction angle. These types of plots are also shown in Appendix 14.

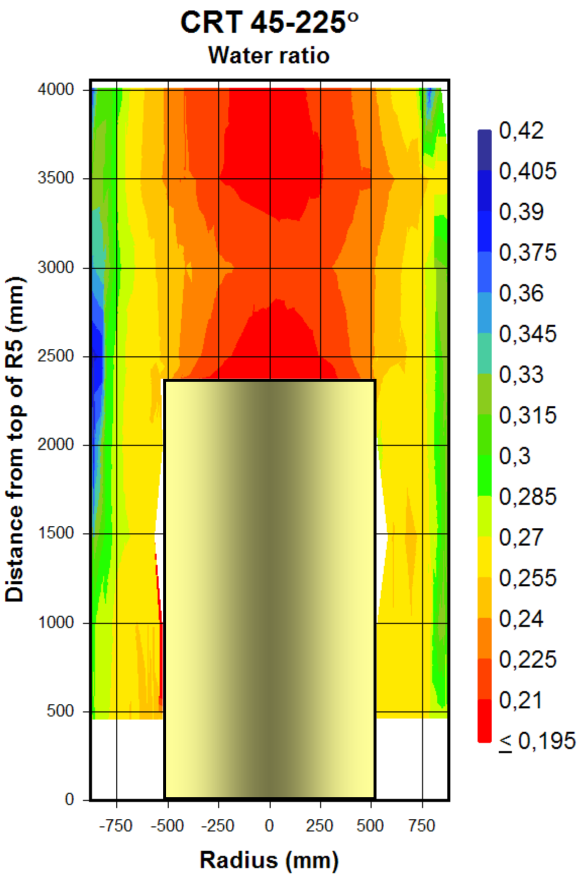


Figure 4-6*. The contour plot of the water ratio in direction 45-225° for the buffer.*

5 Analyses of upwards swelling and water balance

The axial displacement of the buffer can be estimated with the following technique: From the known initial densities and water ratios of the buffer the initial average dry density from different block sections can be determined. These values are presented in Table 5-1. The average dry density at the time of dismantling can be calculated from the evaluated measured results (e.g. by fitting a curve to the values as shown in Figure 5-1). The vertical deformation of the buffer can then be evaluated from the density changes at the different sections (see Table 5-1). The data in Table 5-1 indicate that the deformation (swelling) of the three upper blocks (C4, C3 and C3) were about 10 mm while block R10 swelled about 6 mm and block R9 about 3 mm. The rest of the blocks yield an increase in dry density and are estimated to have negative displacement. The total deformation of the upper most part of the buffer (block C4 – R9) according to this calculation is about 40 mm. This upwards swelling can be compared with the continuous measurements of the deformation of the plug which was measured to be about 20 mm prior to the dismantling of the test. The difference is judged to be caused by the swelling that occurred before the anchors were mounted and the casting of the plug.

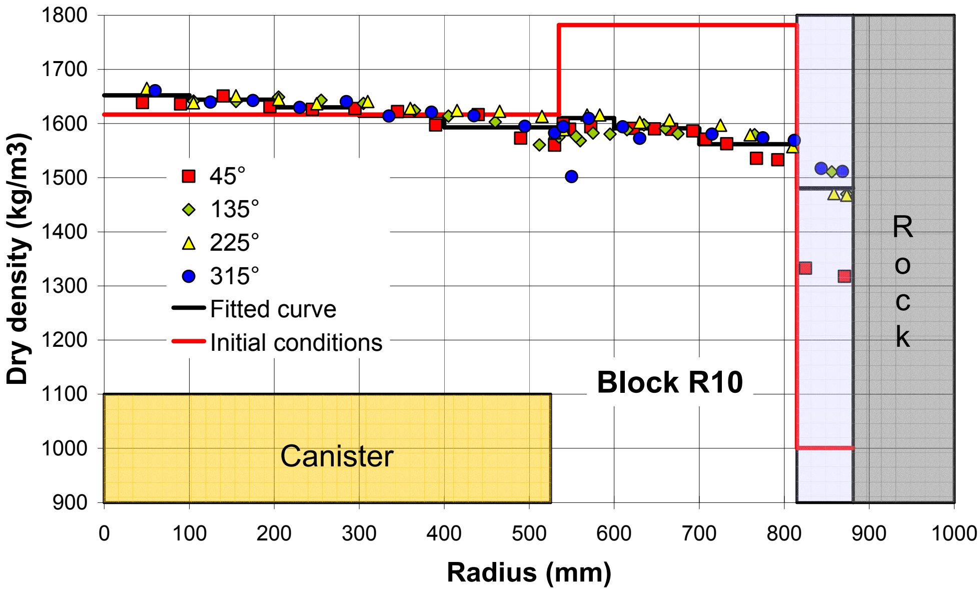


Figure 5-1 Dry density as function of distance from the centre of the deposition hole for a section just above the canister top. A line fitting the data and the initial dry density are also shown.

Similar calculations can also be made for the water balances revealing the amount of water that has entered the different sections of the buffer. The results from the calculations are shown in Table 5-1. Assuming that the blocks below block R6 have similar water ratios to the investigated blocks, the total amount of water added to the buffer can be roughly estimated. The increasing water ratio corresponds to a total water uptake of about 918 litres. The buffer had access to some of this water from the start since the inner slot between the buffer and the canister is judged to have been filled with water during the water filling of the voids between the pellets in the outer slot. The inner slot had a volume of about 160 litres. With these assumptions a rough estimation of the amount of water added to the buffer through the filters is 918-160= 758 litres. This volume can be compared with the accumulated measured inflow into the filter which was about 670 litres just before the dismantling.

The results from Table 5-1 are also plotted in Figure 5-2. For the accumulated deformation of the buffer it is assumed that the deformation is zero from the upper surface of block R8.

Table 5-1. The average dry density at installation and at dismantling at different sections of the buffer together with the calculated vertical displacement and absorbed amount of water. The absorbed water for block R5-R1 is assumed to be the average absorbed water for block R9-R6. The absorbed water for block C1 is assumed to be the same as for block C2.

Block No	Average dry density at installation. (kg/m^3)	Average dry density at dismantling (kg/m^3)	Calculated vertical displacement (mm)	Absorbed water (kg)
C4	1598	1558	12.9	79.7
C3	1598	1578	6.5	89.6
C2	1598	1563	10.9	83.6
R10*)	1608	1578	4.2	47.7
R10**)	1569	1559	1.8	35.7
R9	1569	1560	2.9	61.,0
R8	1569	1580	-3.3	53.7
R7	1569	1574	-1.4	50.4
R6	1569	1575	-2.0	56.6
R5***)	1569		0	55.4
R4***)	1569		0	55.4
R3***)	1569		0	55.4
R2***)	1569		0	55.4
R1***)	1569		0	55.4
C1***)	1598		0	83.6
Σ			39.1	918.2

*) Above the canister top **) Underneath the canister top ***) Estimated

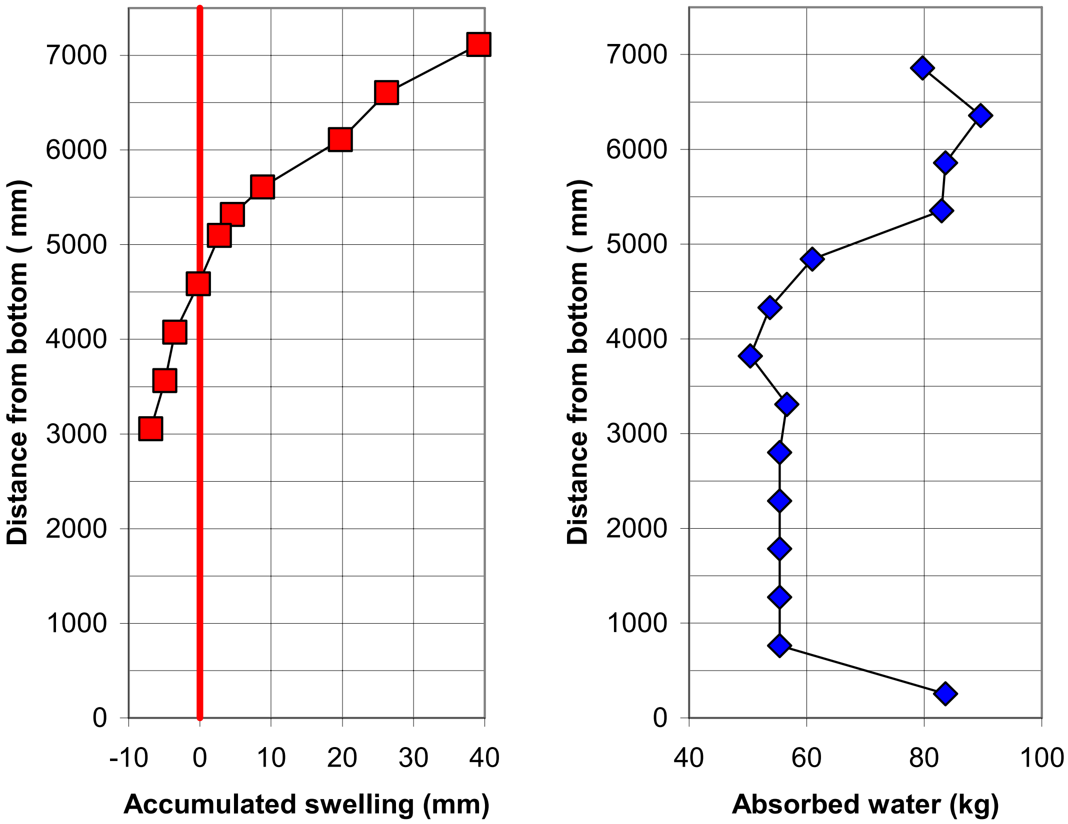


***Figure 5-2**. The calculated accumulated swelling of the buffer and absorbed water at different locations in the deposition hole.*

6 Dismantling of the power cables

When the samples in block R10 had been taken and the rest of the block had been removed (see Figure 6-1) the upper lid of the canister was unbolted and lifted up from the deposition hole. The mixture of 30% bentonite and 70% sand which was placed around the power cables and between the intermediate portions of copper was then removed (see Figure 6-2). The analyses of the samples taken from the 30/70 mixture showed that the material was not homogeneous. The examination by eye of the material and the measurement of the water ratio indicate that a bentonite rich material was located to the top of the filling (w = 41-43%) while the material close to the canister lid consisted of mostly sand (w = 4-6%). Figure 6-3 shows the power cables to the heaters and the connectors on top of the canister. When the 30/70 mixture was removed comprehensive damages were observed on the power cables close to the connectors. Damages were also observed on other parts of the cables. These damages consisted of cracks on the coating. The coating was also very brittle. The damages were so severe that the conductors in the cables were exposed. These damages were located to the part of the cables which were lying close to the top of the canister. The cables were also affected by the swelling pressure from the buffer. These damages were considered not to have affected the function of the cable on its protection against high water pressure. The cables were lifted up from the deposition hole and more comprehensive analyses and tests were initialized. The results from these analyses will be presented in a separate report. When the cables were removed from the lid of the canister the isolation of the heaters installed in the canister were measured. The measurements show that the isolation of the heaters was good. The preliminary conclusion concerning the previous observed heater problems was that they were caused by the observed damages on the cables.

***Figure 6-1**. The upper lid is lifted up from the deposition hole.*

***Figure 6-2**. The upper lid is removed: The 30/70 mixture and the* intermediate portions of copper *are exposed.*

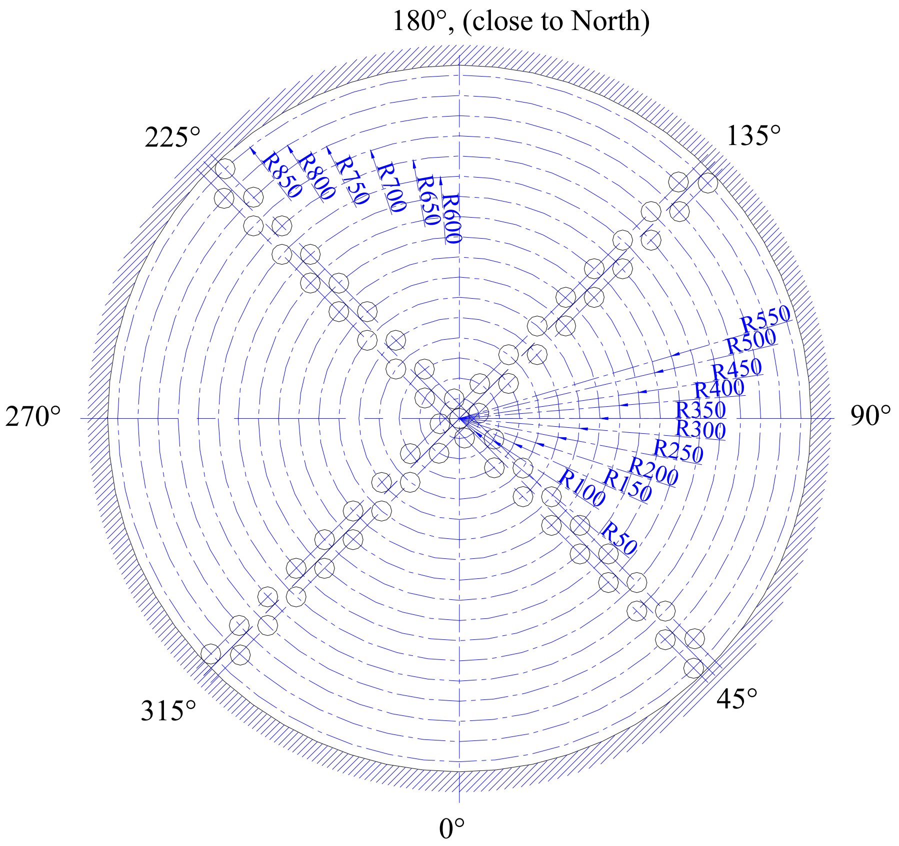
***Figure 6-3**. The cables and connectors on the top of the canister.*

Appendices

Appendix 1

RevNo	Revision note	Date	Signnature	Checked

Planned sampling in cylindrical blocks.
68 cores, d=50 mm, L=500 mm



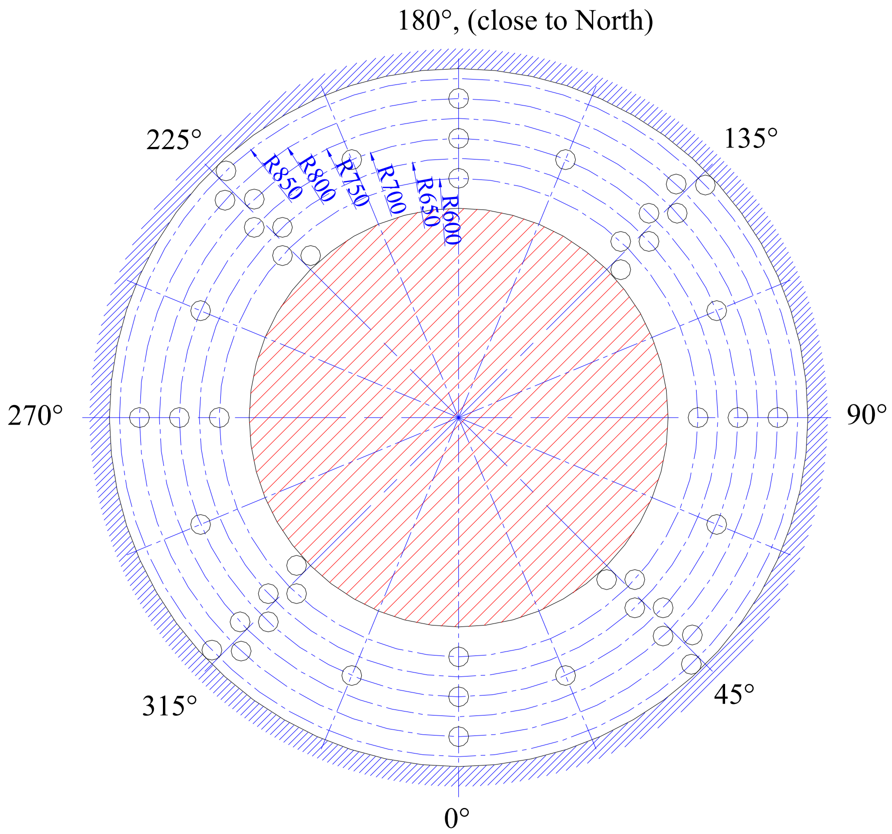
		Block C2, C3 och C4			
Itemref	Quantity	Title/Name, designation, material, dimension etc		Article No. / Reference	
Designed by TS		Checked by TS	Approved by-date	File name	Date 051205	Scale

Clay Technology AB Ideon 223 70, Lund Tel: 046-286 2570, Fax: 046-134230	Sampling		
	CRT	Edetion	Sheet

Appendix 2

RevNo	Revision note	Date	Signnature	Checked

Planned sampling in ring shaped blocks.
48 (28 i R10) cores, d=50 mm, L=500 mm

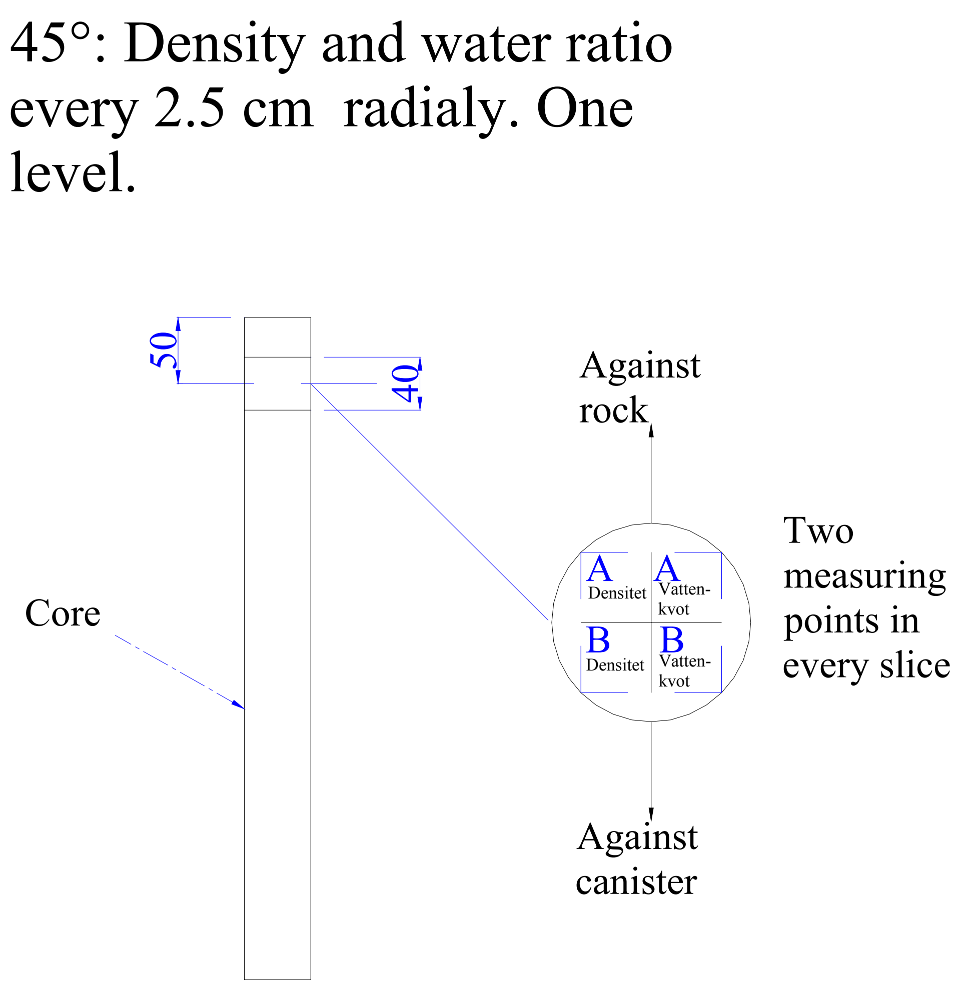


OBS! In R10 cores are only taken in the main directions
45°, 135°, 225° and 315°

		Block R6, R7, R8, R9, R10			
Itemref	Quantity	Title/Name, designation, material, dimension etc		Article No. / Reference	
Designed by TS		Checked by TS	Approved by-date	File name	Date 051205	Scale

Clay Technology AB Ideon 223 70, Lund Tel: 046-286 2570, Fax: 046-134230	Sampling		
	CRT	Edetion	Sheet

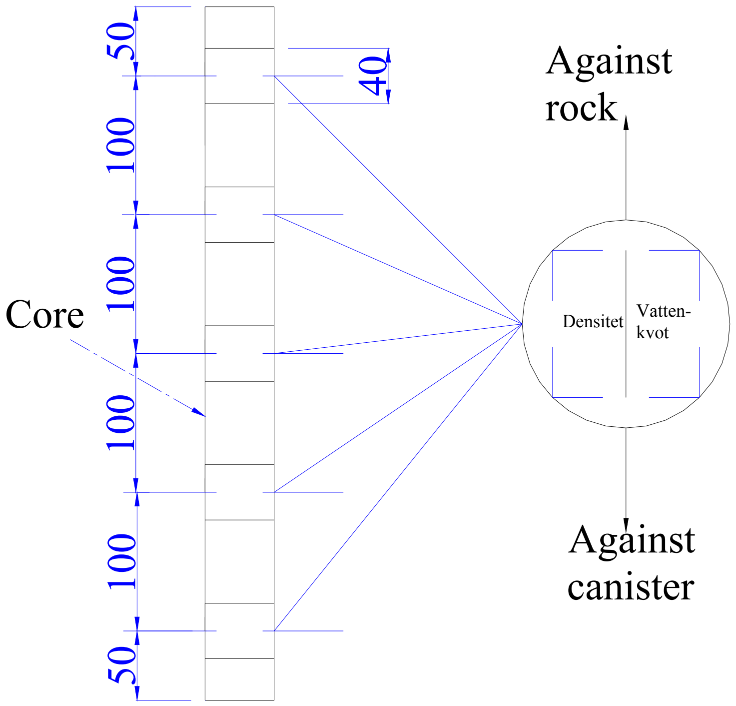
RevNo	Revision note	Date	Signnature	Checked



		Standard sampling cores 45°				
Itemref	Quantity	Title/Name, designation, material, dimension etc			Article No. / Reference	
Designed by TS		Checked by TS	Approved by-date	File name	Date 051205	Scale
Clay Technology AB Ideon 223 70, Lund Tel: 046-286 2570, Fax: 046-134230			Sampling			
			CRT		Edetion	Sheet

RevNo	Revision note	Date	Signnature	Checked

135°: Density and water ratio every 5 cm. Five levels.

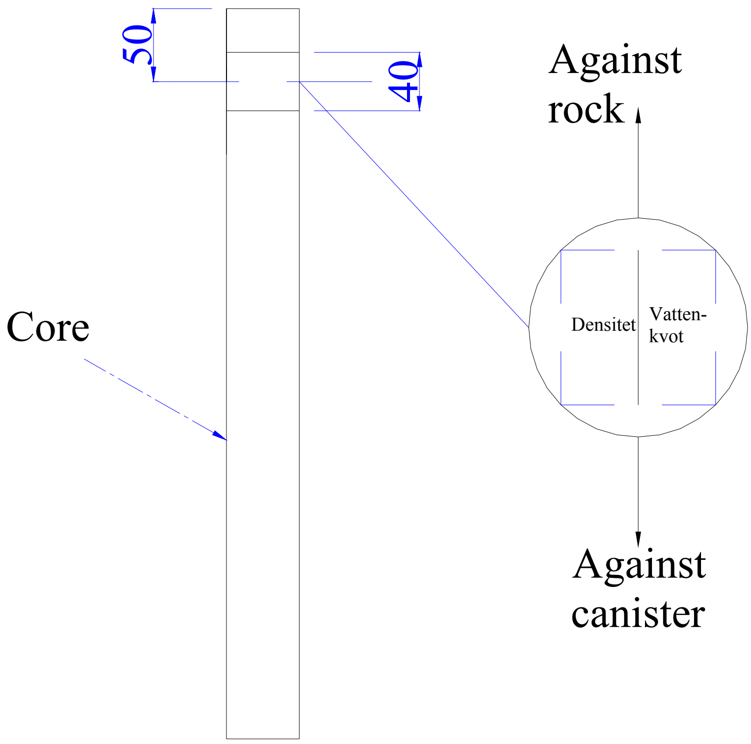


		Standard sampling 135°			
Itemref	Quantity	Title/Name, designation, material, dimension etc		Article No. / Reference	
Designed by TS	Checked by TS	Approved by-date	File name	Date 051205	Scale

Clay Technology AB Ideon 223 70, Lund Tel: 046-286 2570, Fax: 046-134230	Sampling		
	CRT	Edetion	Sheet

RevNo	Revision note	Date	Signnature	Checked

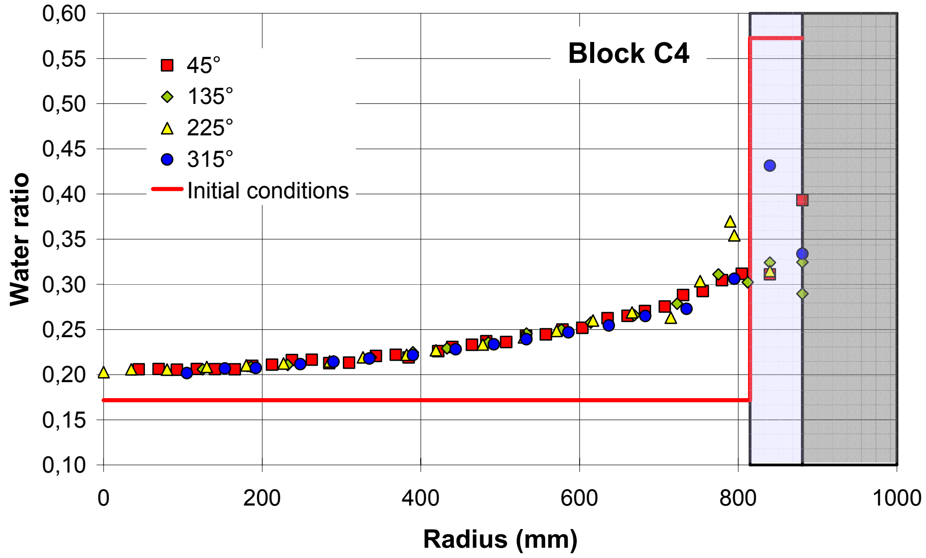
225°, 315° and cores from between the main directions: Density and water ratio every 5 cm radialy. One level.



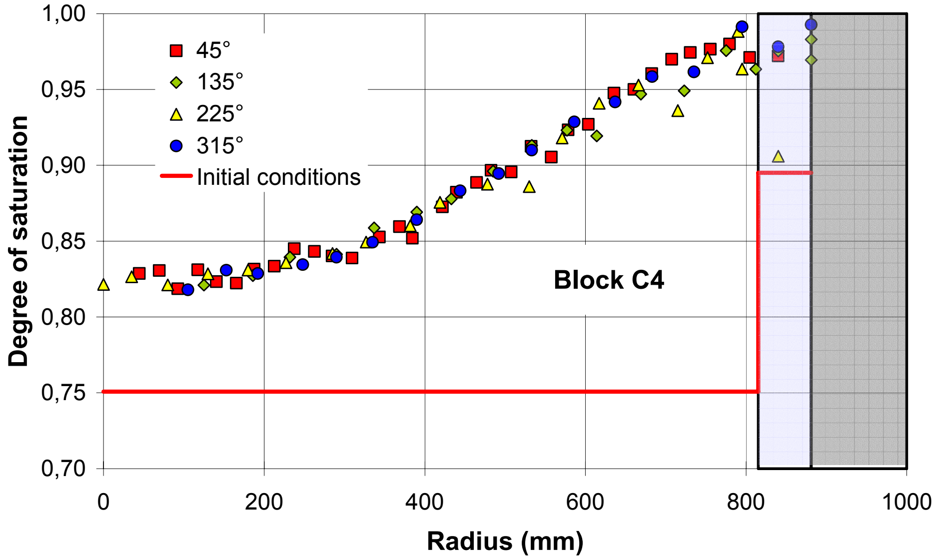
		Standard sampling 225°, 315°	
Itemref	Quantity	Title/Name, designation, material, dimension etc	Article No. / Reference

Designed by	Checked by	Approved by-date	File name	Date	Scale
TS	TS			051205	

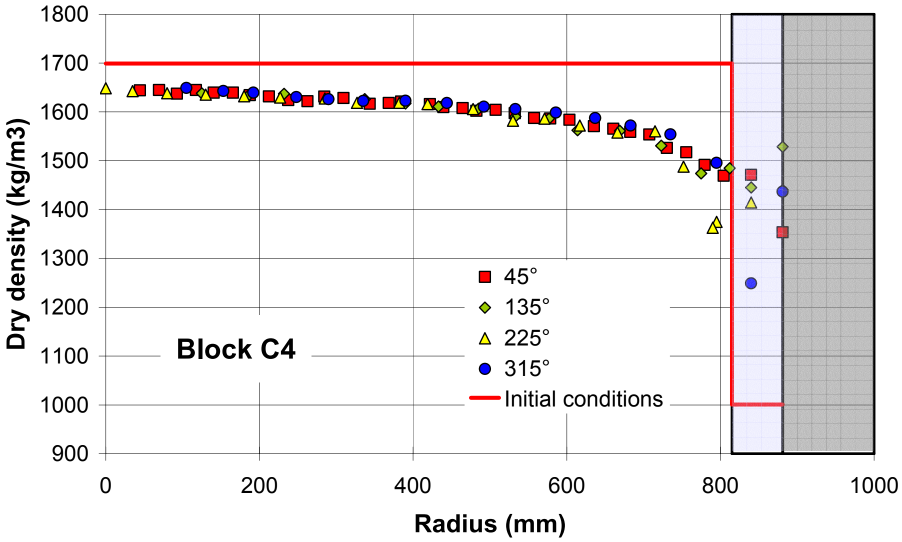
Clay Technology AB Ideon 223 70, Lund Tel: 046-286 2570, Fax: 046-134230	Sampling		
	CRT	Edetion	Sheet



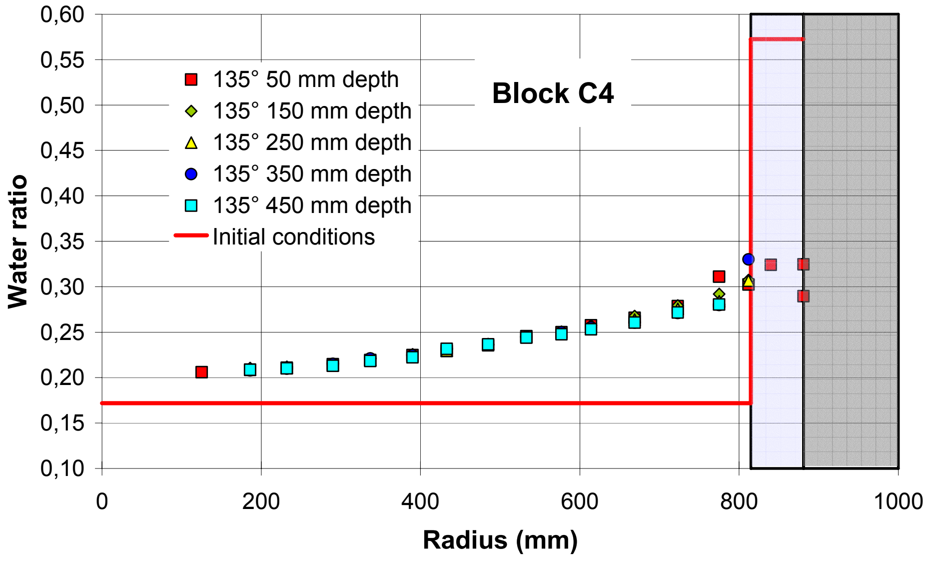
Block C4
45°
135°
225°
315°
Initial conditions
Water ratio
0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0
200
400
600
800
1000
Radius (mm)

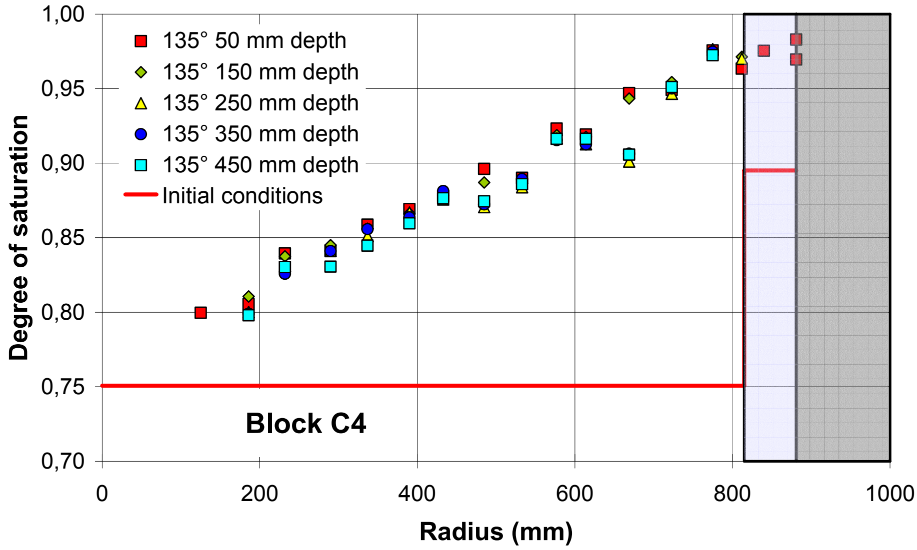


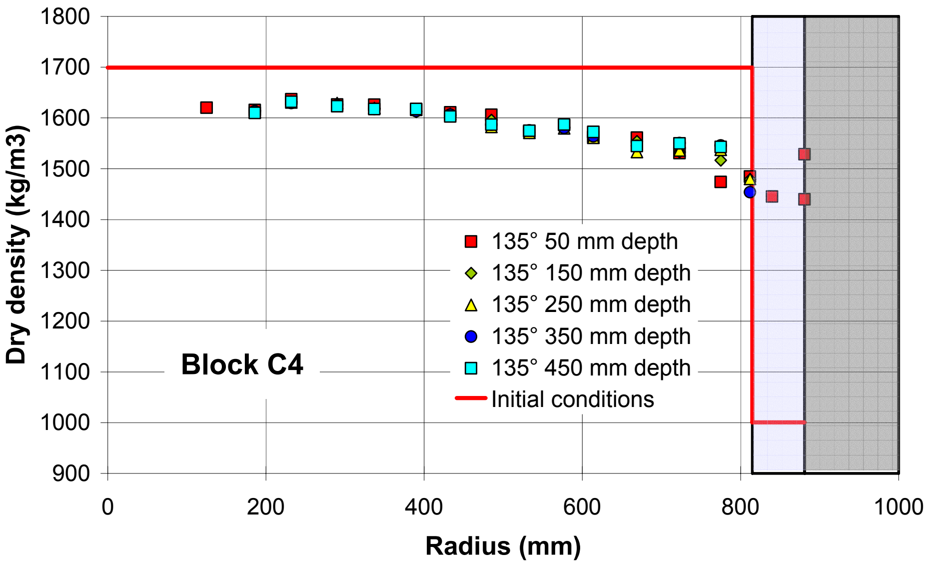
45°
135°
225°
315°
Initial conditions
Block C4
Degree of saturation
1,00
0,95
0,90
0,85
0,80
0,75
0,70
0
200
400
600
800
1000
Radius (mm)

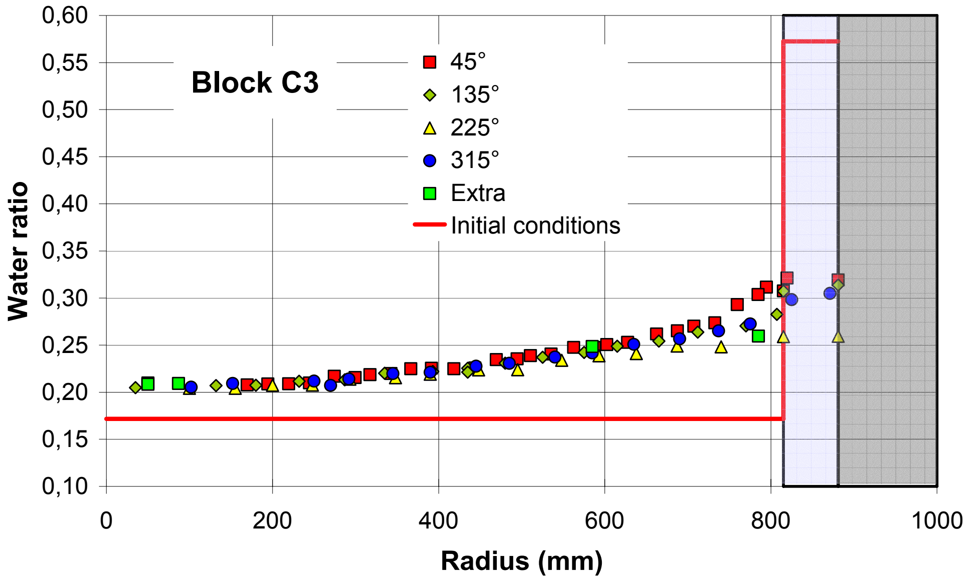


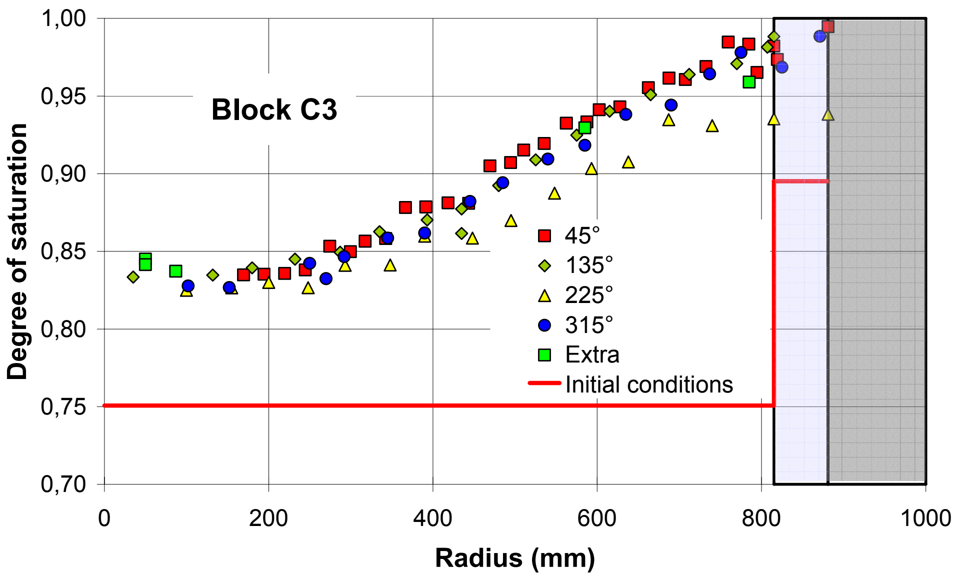
Dry density (kg/m3)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
Block C4
45°
135°
225°
315°
Initial conditions
0
200
400
600
800
1000
Radius (mm)

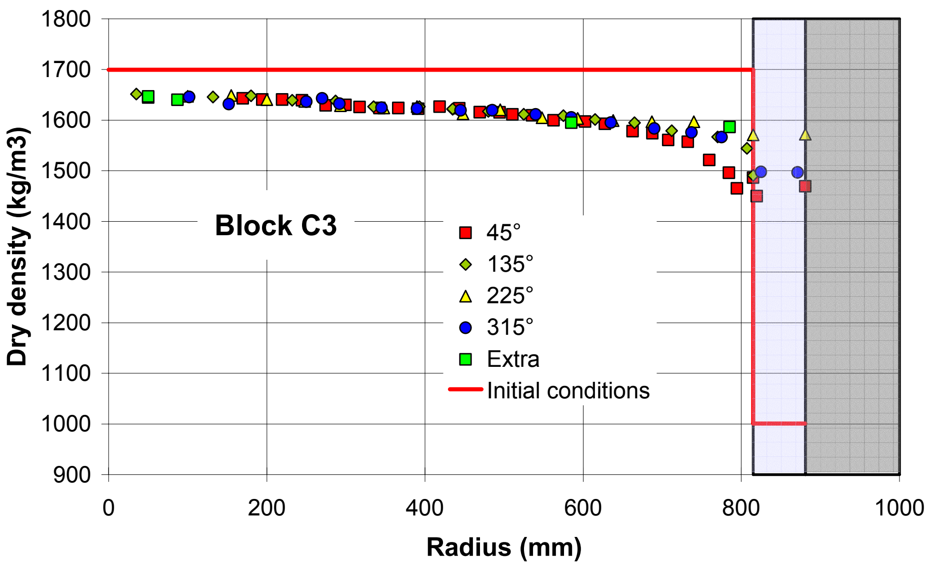

0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
Water ratio
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
Block C4
0
200
400
600
800
1000
Radius (mm)

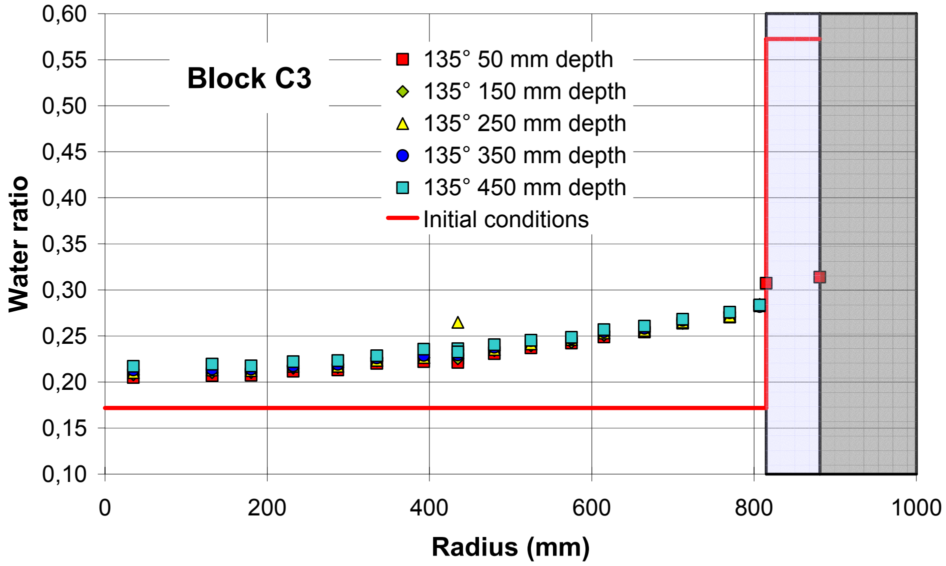

1,00
0,95
0,90
0,85
0,80
0,75
0,70
Degree of saturation
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
Block C4
0
200
400
600
800
1000
Radius (mm)

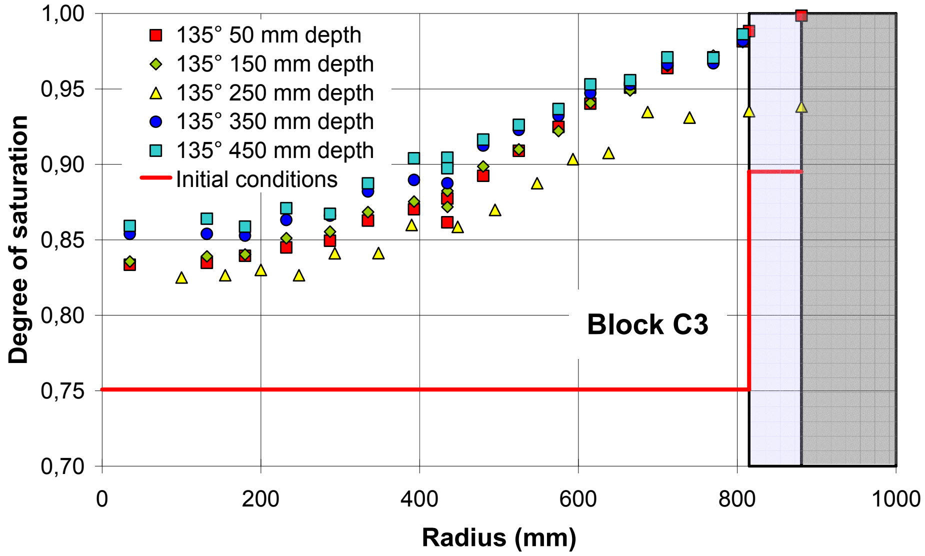

1800
1700
1600
1500
1400
1300
1200
1100
1000
900
Dry density (kg/m3)
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
Block C4
0
200
400
600
800
1000
Radius (mm)

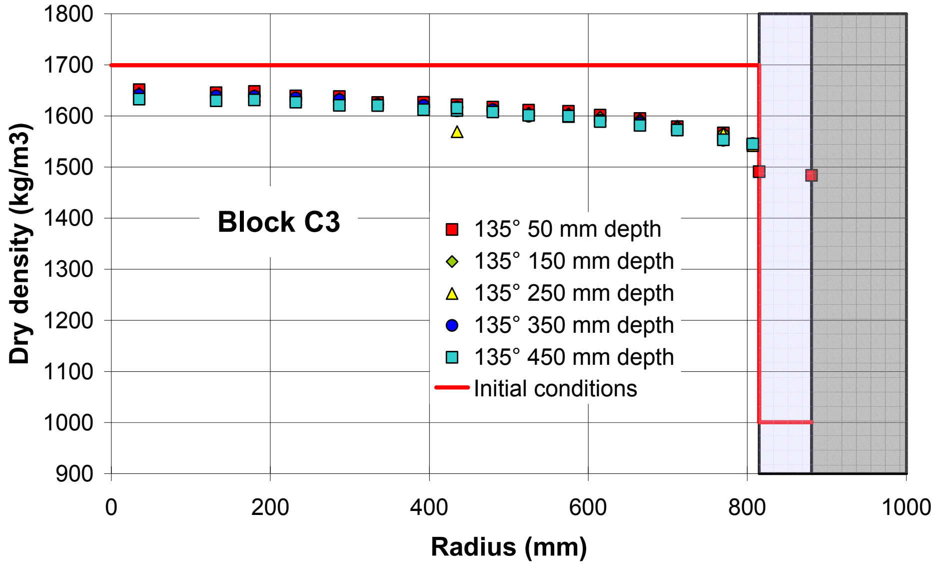

Block C3
45°
135°
225°
315°
Extra
Initial conditions
Water ratio
Radius (mm)
0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0
200
400
600
800
1000

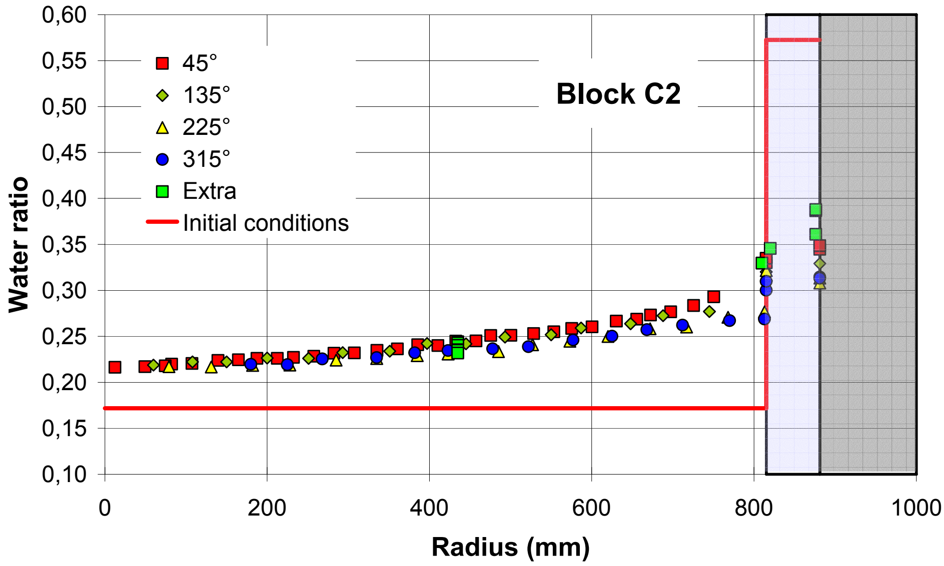

Block C3
45°
135°
225°
315°
Extra
Initial conditions
Degree of saturation
Radius (mm)
1,00
0,95
0,90
0,85
0,80
0,75
0,70
0
200
400
600
800
1000

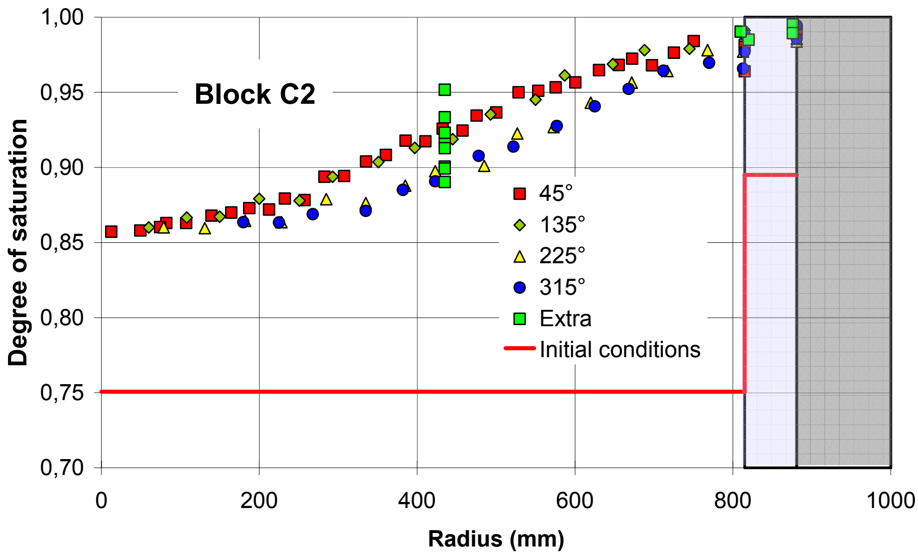

Block C3
45°
135°
225°
315°
Extra
Initial conditions
Dry density (kg/m3)
Radius (mm)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
0
200
400
600
800
1000

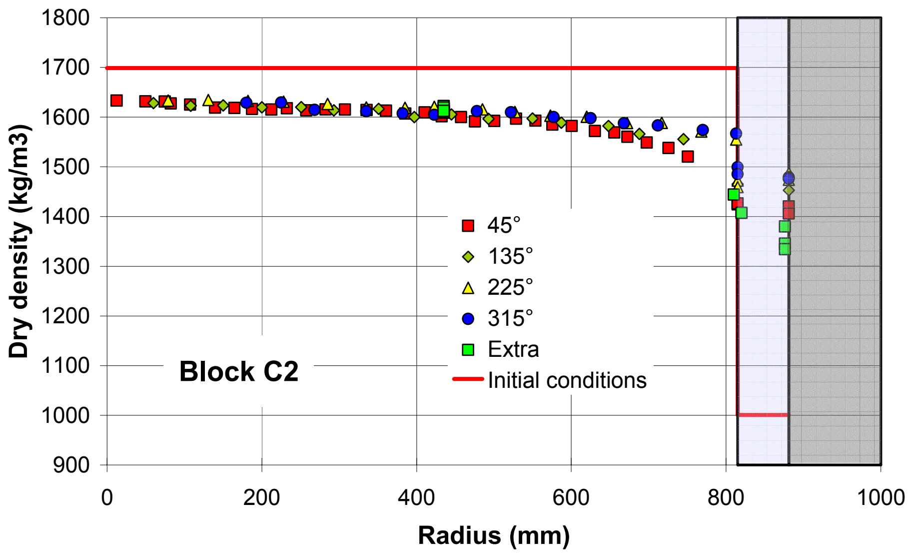

Block C3
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
Water ratio
Radius (mm)
0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0
200
400
600
800
1000

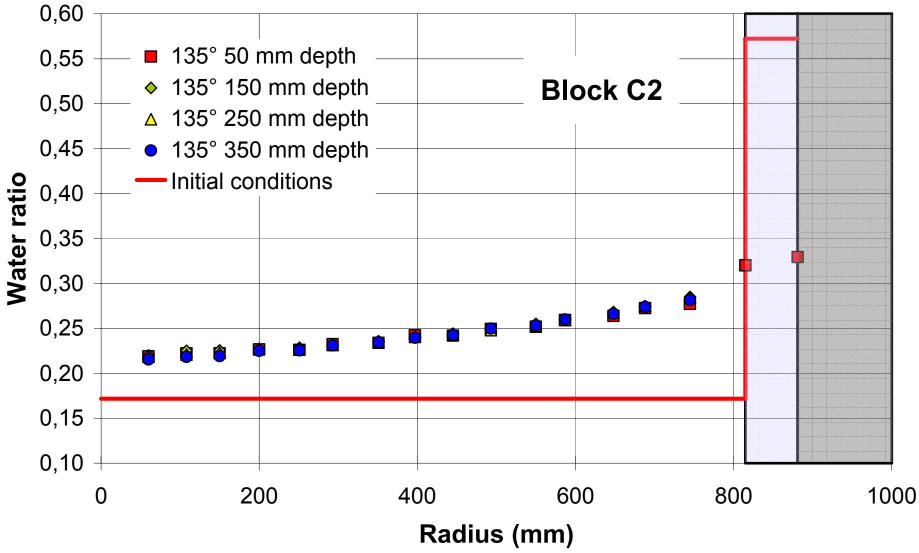

135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
Block C3
Degree of saturation
Radius (mm)
1,00
0,95
0,90
0,85
0,80
0,75
0,70
0
200
400
600
800
1000

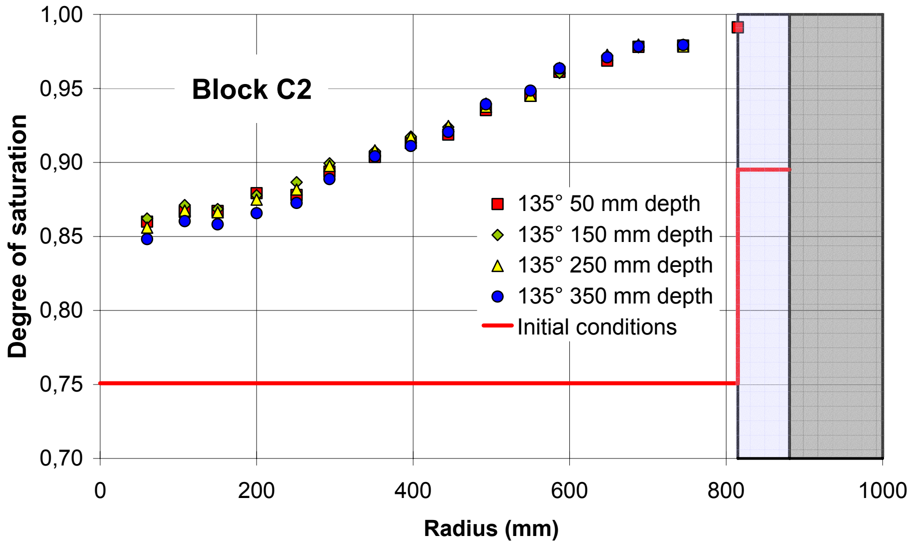

Block C3
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
Dry density (kg/m3)
Radius (mm)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
0
200
400
600
800
1000

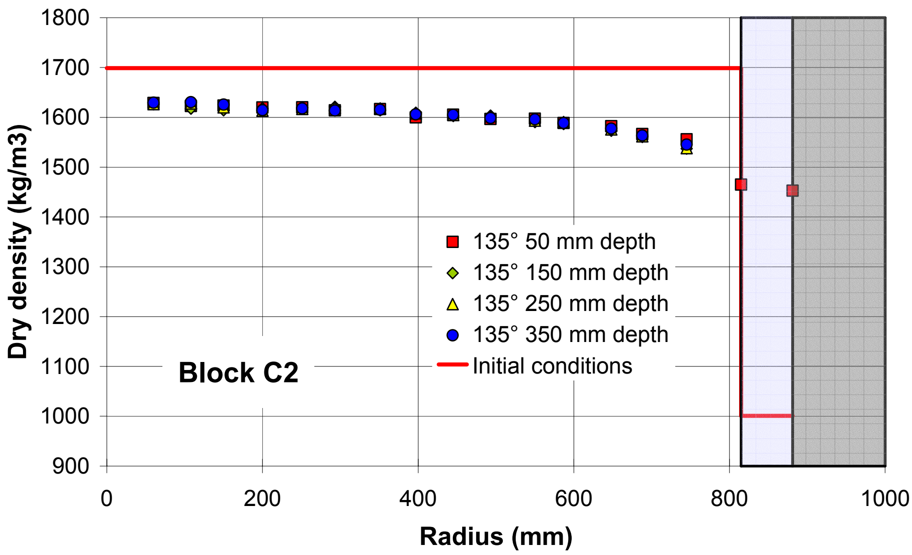

Block C2
Water ratio
Radius (mm)
45°
135°
225°
315°
Extra
Initial conditions
0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
0
200
400
600
800
1000

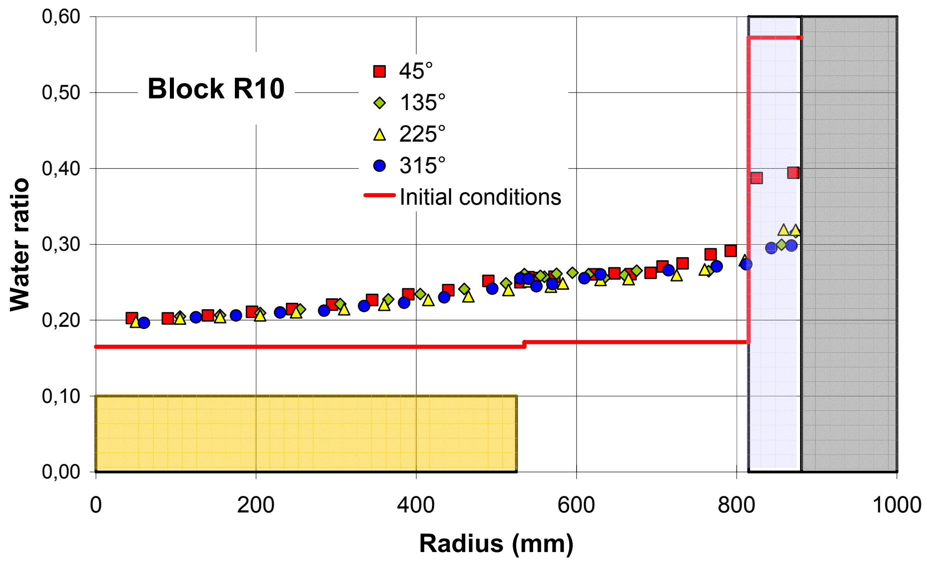

Block C2
Degree of saturation
Radius (mm)
45°
135°
225°
315°
Extra
Initial conditions
1,00
0,95
0,90
0,85
0,80
0,75
0,70
0
200
400
600
800
1000

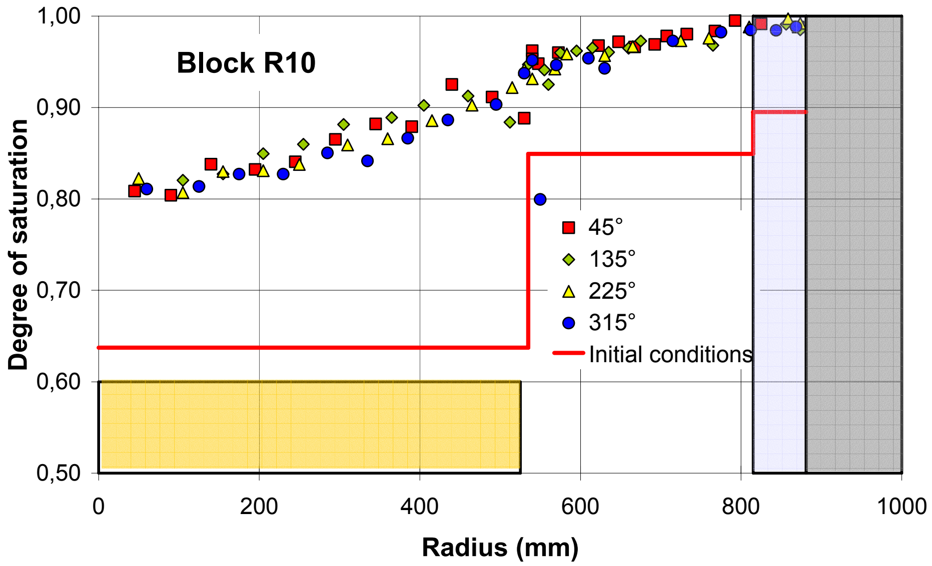

Block C2
Dry density (kg/m3)
Radius (mm)
45°
135°
225°
315°
Extra
Initial conditions
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
0
200
400
600
800
1000

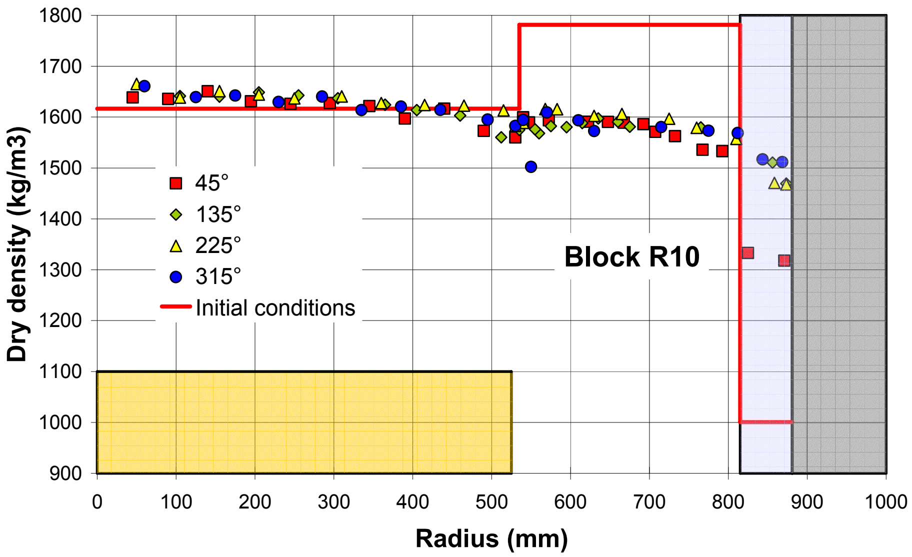

0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
Water ratio
0
200
400
600
800
1000
Radius (mm)
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
Initial conditions
Block C2

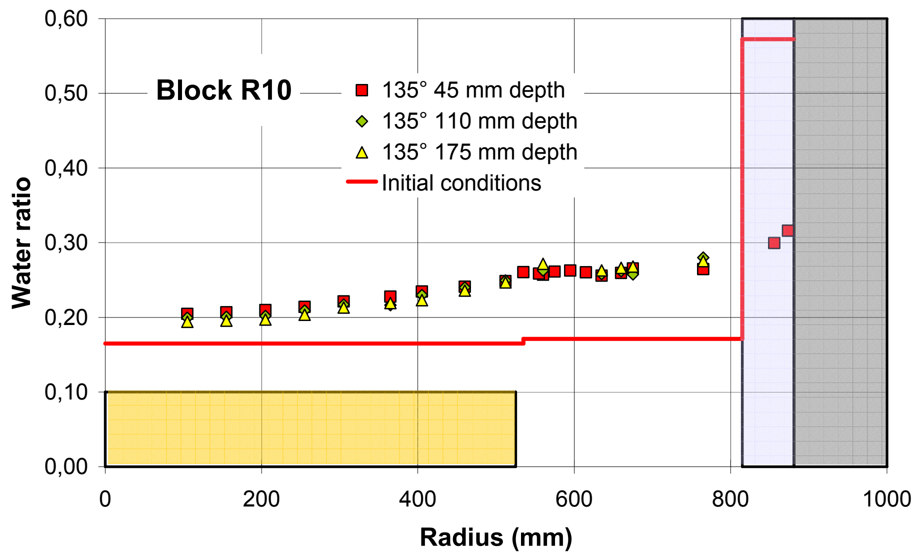

1,00
0,95
0,90
0,85
0,80
0,75
0,70
Degree of saturation
0
200
400
600
800
1000
Radius (mm)
Block C2
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
Initial conditions

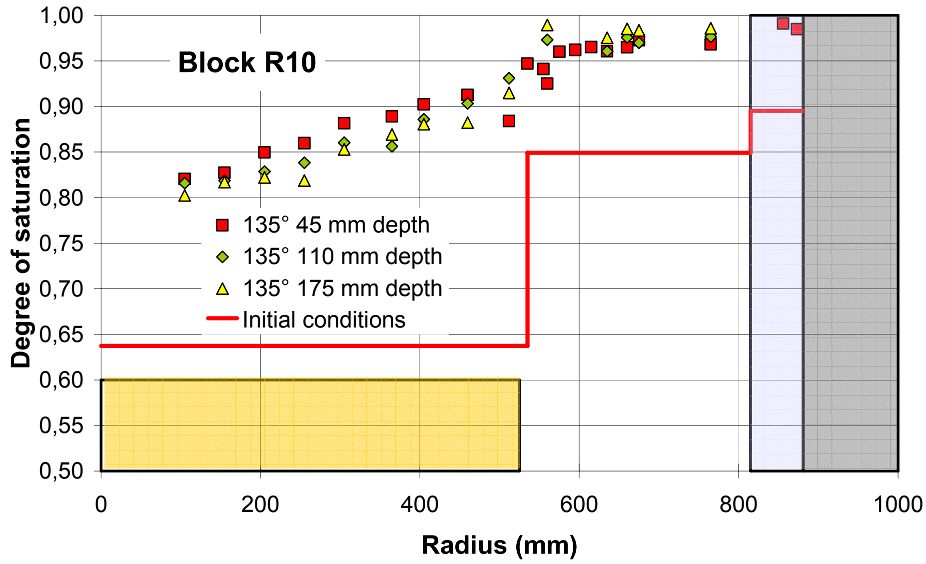

1800
1700
1600
1500
1400
1300
1200
1100
1000
900
Dry density (kg/m3)
0
200
400
600
800
1000
Radius (mm)
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
Initial conditions
Block C2

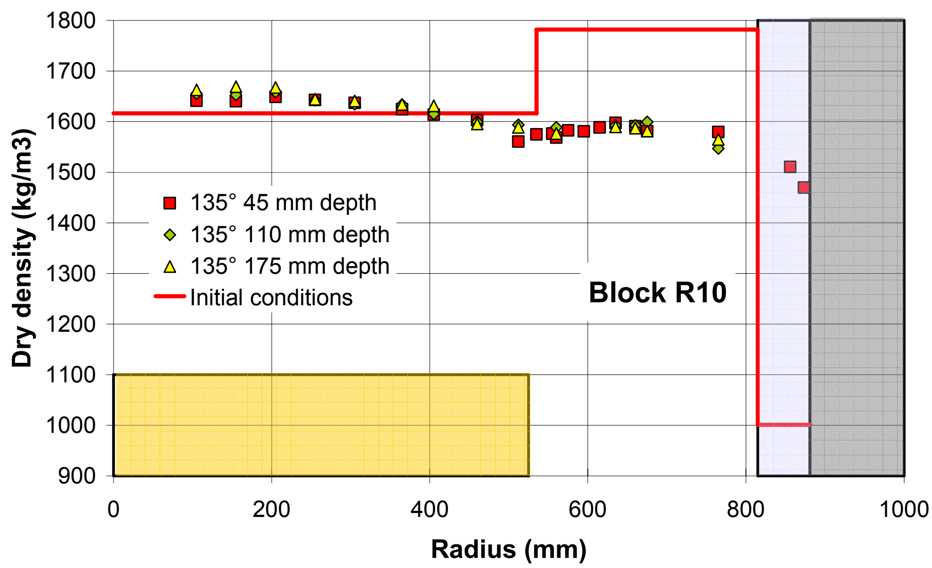

Block R10
45°
135°
225°
315°
Initial conditions
Water ratio
0,60
0,50
0,40
0,30
0,20
0,10
0,00
0
200
400
600
800
1000
Radius (mm)

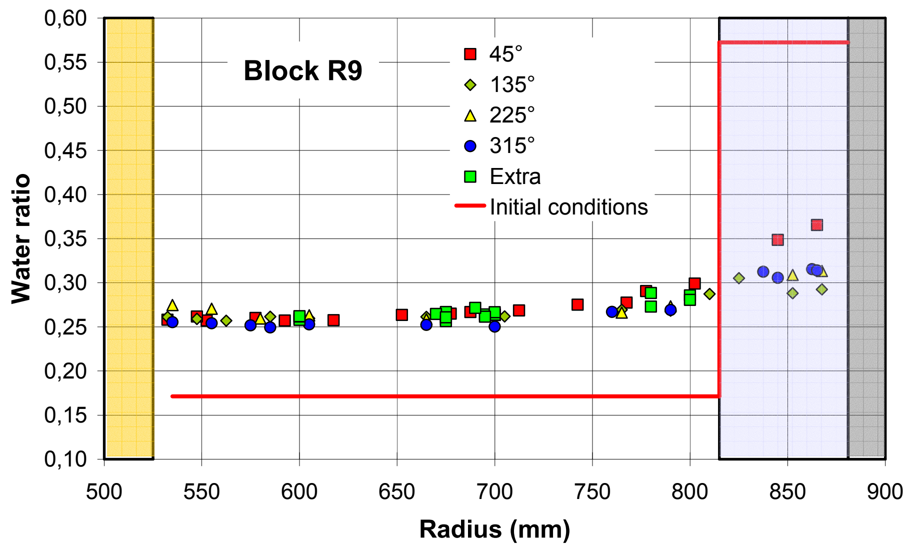

Block R10
45°
135°
225°
315°
Initial conditions
Degree of saturation
1,00
0,90
0,80
0,70
0,60
0,50
0
200
400
600
800
1000
Radius (mm)

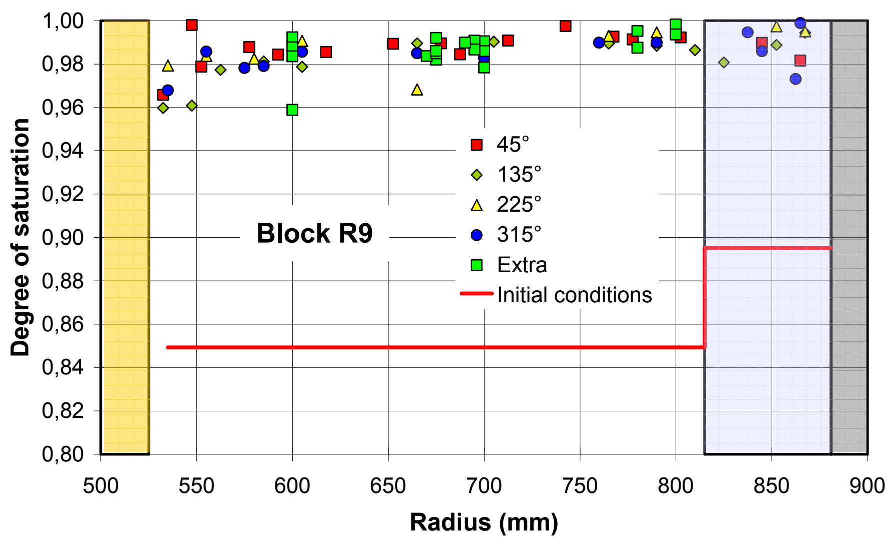

Block R10
45°
135°
225°
315°
Initial conditions
Dry density (kg/m3)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
0
100
200
300
400
500
600
700
800
900
1000
Radius (mm)

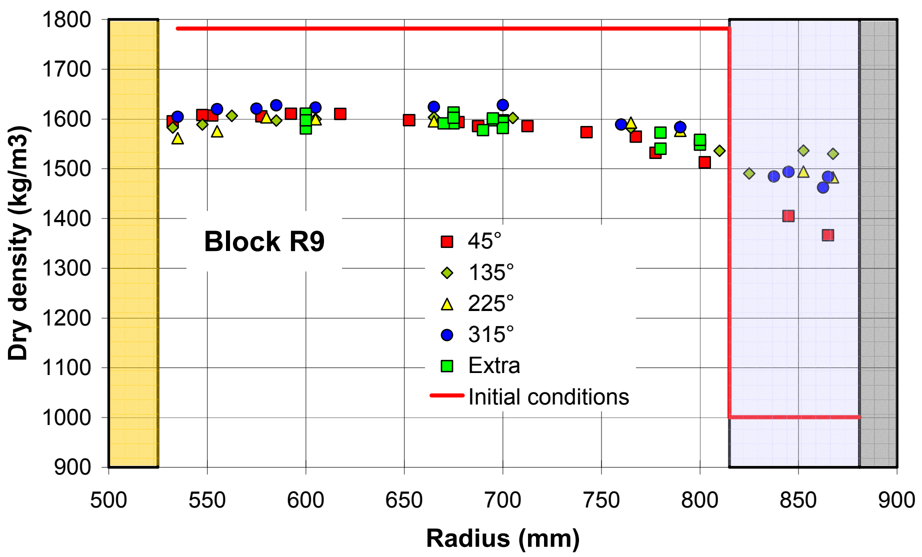

0,60
0,50
0,40
0,30
0,20
0,10
0,00
Water ratio
Block R10
135° 45 mm depth
135° 110 mm depth
135° 175 mm depth
Initial conditions
0
200
400
600
800
1000
Radius (mm)

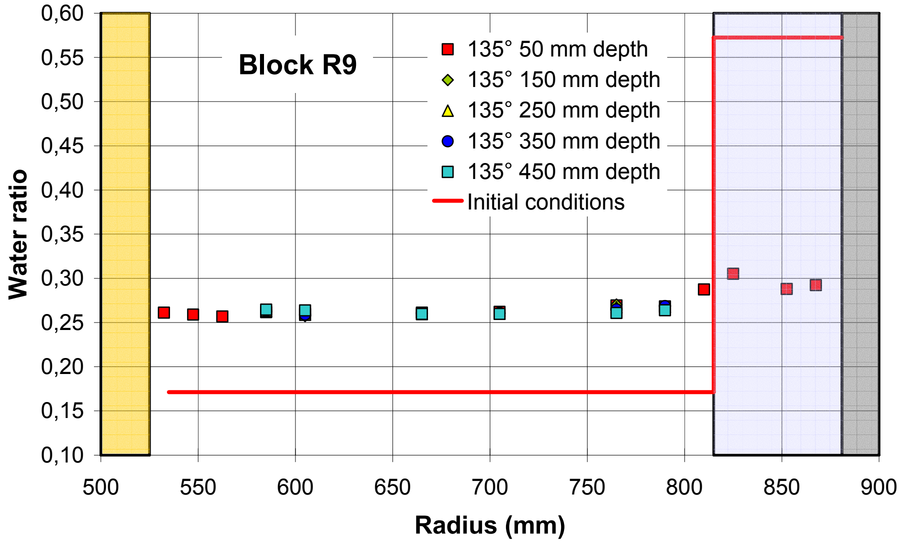

1,00
0,95
0,90
0,85
0,80
0,75
0,70
0,65
0,60
0,55
0,50
Degree of saturation
Block R10
135° 45 mm depth
135° 110 mm depth
135° 175 mm depth
Initial conditions
0
200
400
600
800
1000
Radius (mm)


1800
1700
1600
1500
1400
1300
1200
1100
1000
900
Dry density (kg/m3)
135° 45 mm depth
135° 110 mm depth
135° 175 mm depth
Initial conditions
Block R10
0
200
400
600
800
1000
Radius (mm)

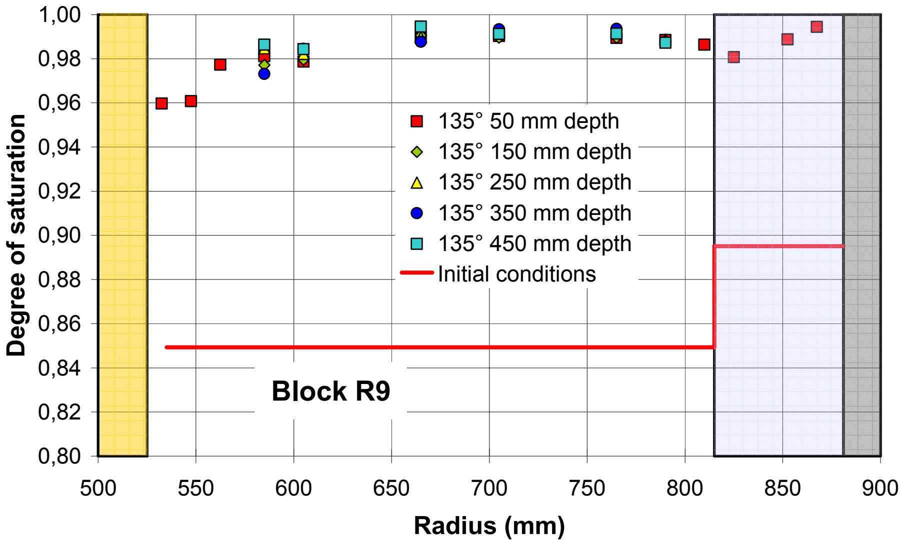

Block R9
45°
135°
225°
315°
Extra
Initial conditions
Water ratio
Radius (mm)


Block R9
45°
135°
225°
315°
Extra
Initial conditions
Degree of saturation
Radius (mm)

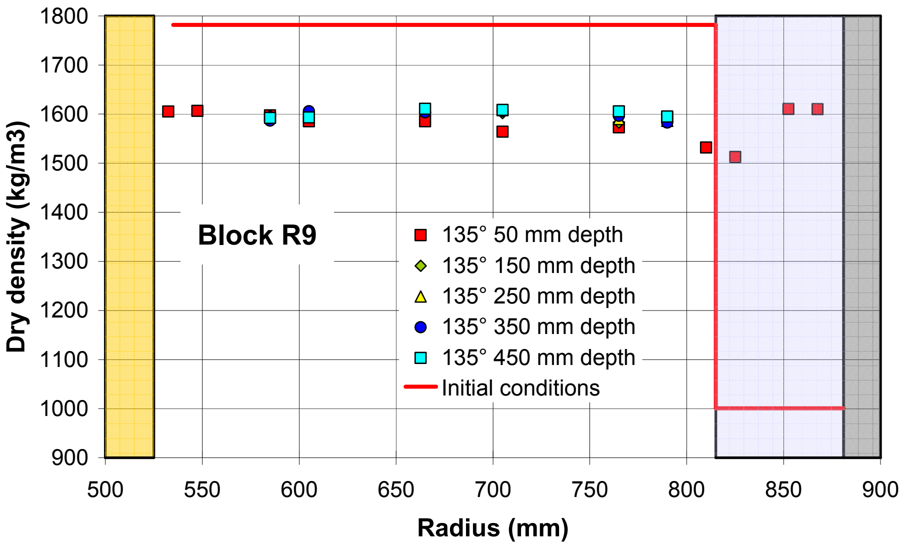

Block R9
45°
135°
225°
315°
Extra
Initial conditions
Dry density (kg/m3)
Radius (mm)



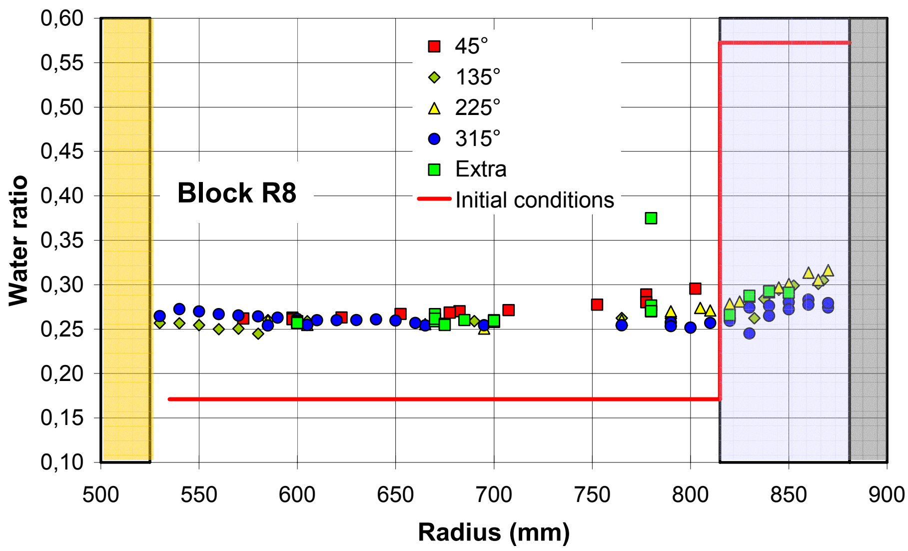
Block R9
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
Water ratio
0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
500
550
600
650
700
750
800
850
900
Radius (mm)



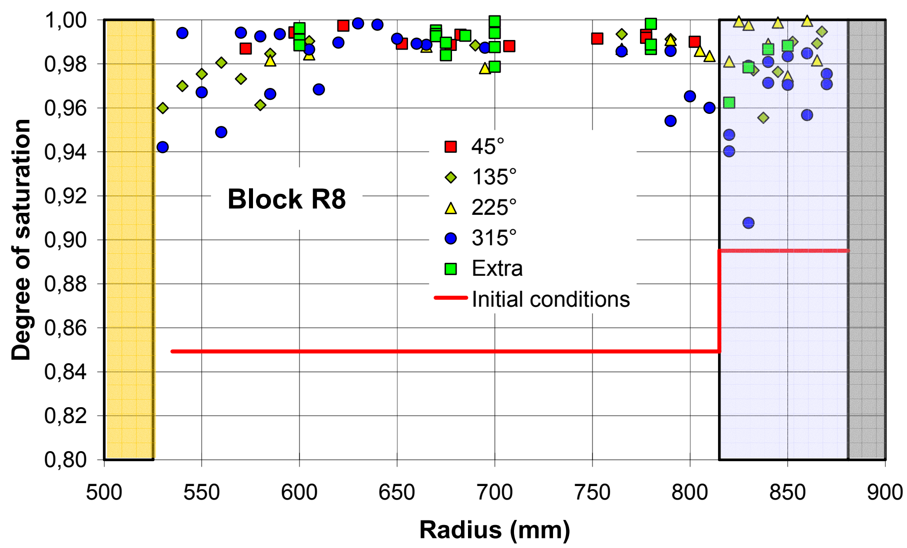
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
Block R9
Degree of saturation
1,00
0,98
0,96
0,94
0,92
0,90
0,88
0,86
0,84
0,82
0,80
500
550
600
650
700
750
800
850
900
Radius (mm)



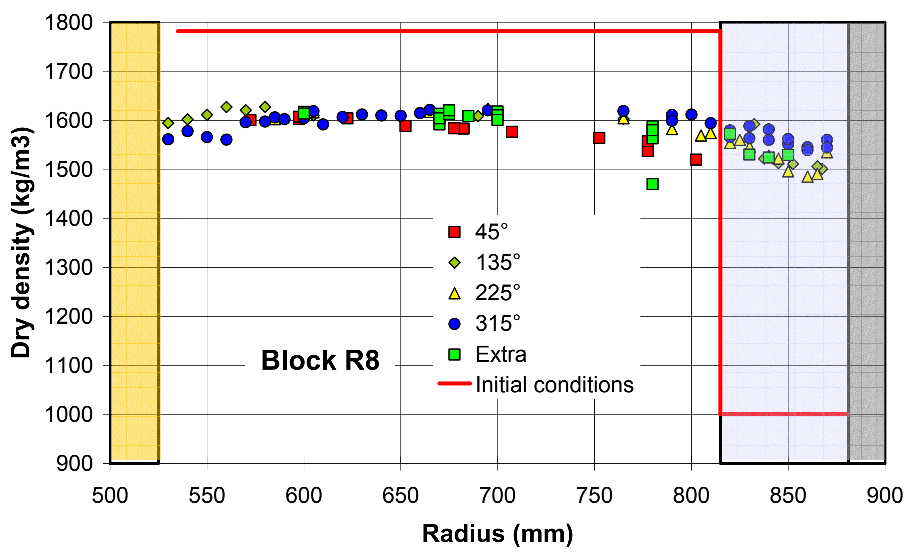
Block R9
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
Dry density (kg/m3)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
500
550
600
650
700
750
800
850
900
Radius (mm)



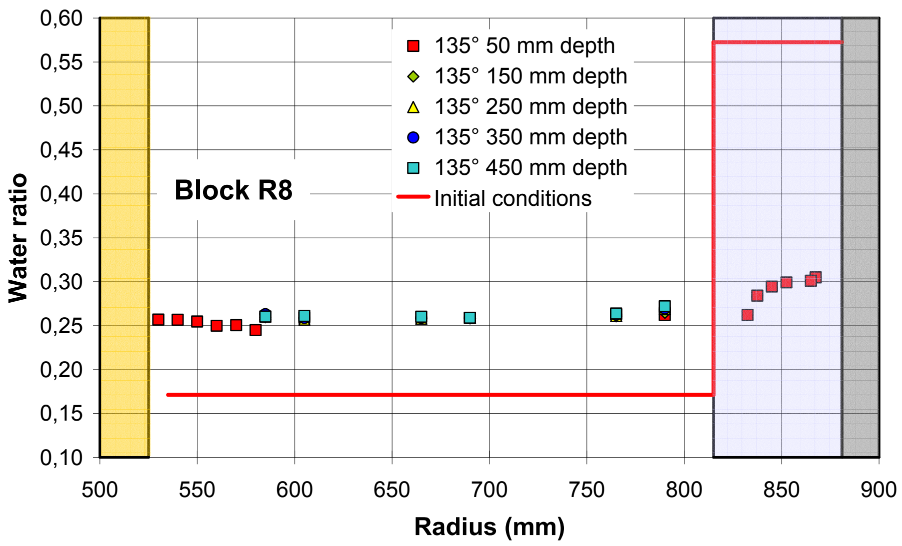
Water ratio
Radius (mm)
Block R8
45°
135°
225°
315°
Extra
Initial conditions



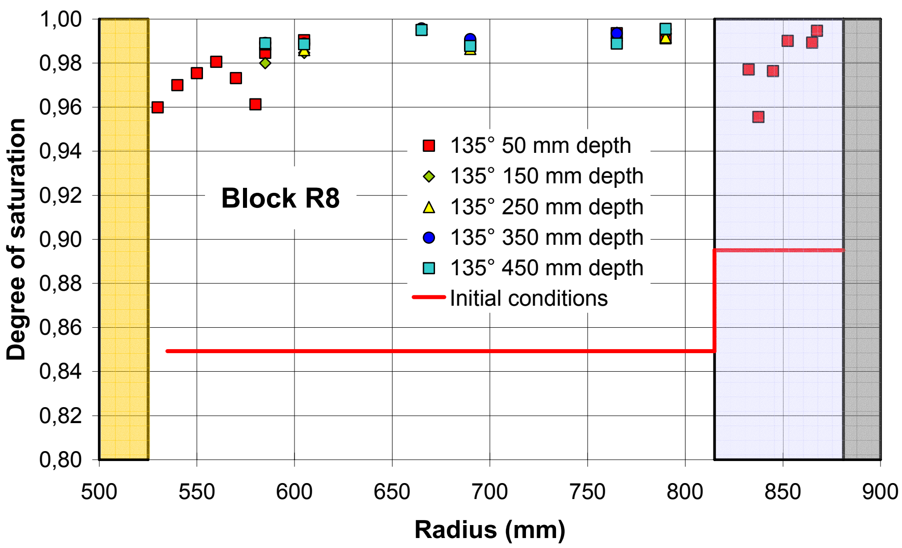
Degree of saturation
Radius (mm)
Block R8
45°
135°
225°
315°
Extra
Initial conditions



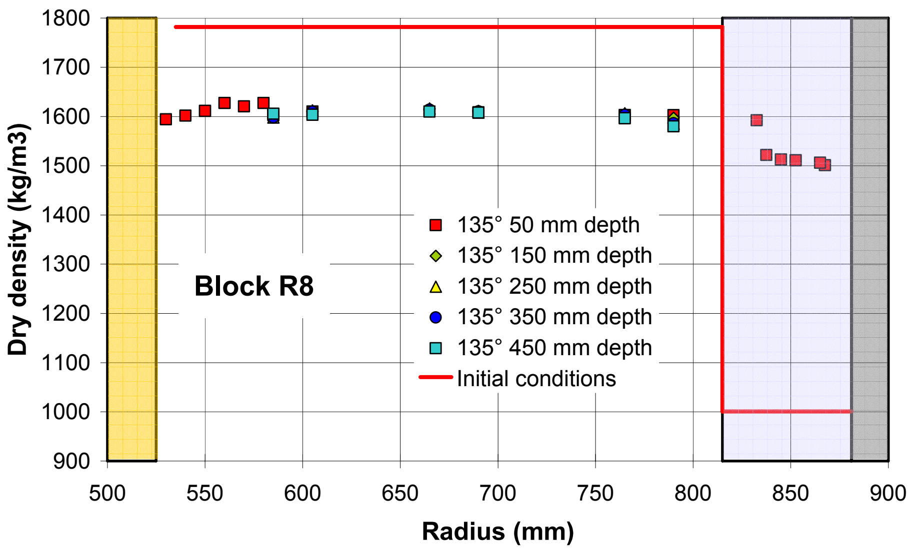
Dry density (kg/m3)
Radius (mm)
Block R8
45°
135°
225°
315°
Extra
Initial conditions



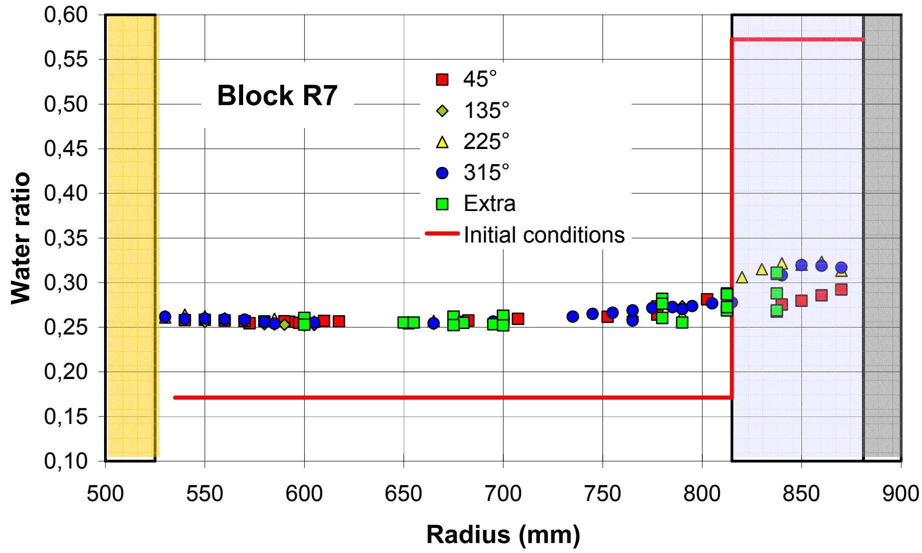
Water ratio
0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
500
550
600
650
700
750
800
850
900
Radius (mm)
Block R8
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions



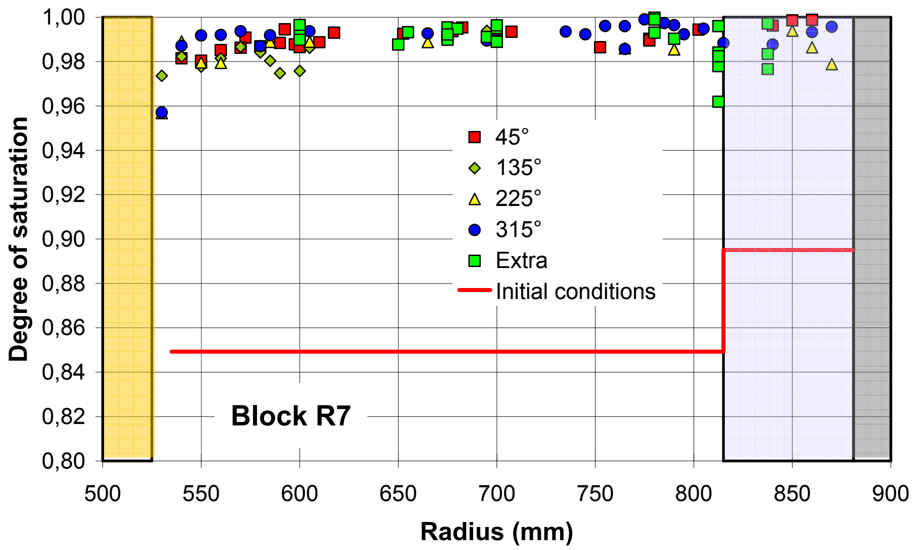
Degree of saturation
1,00
0,98
0,96
0,94
0,92
0,90
0,88
0,86
0,84
0,82
0,80
500
550
600
650
700
750
800
850
900
Radius (mm)
Block R8
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions



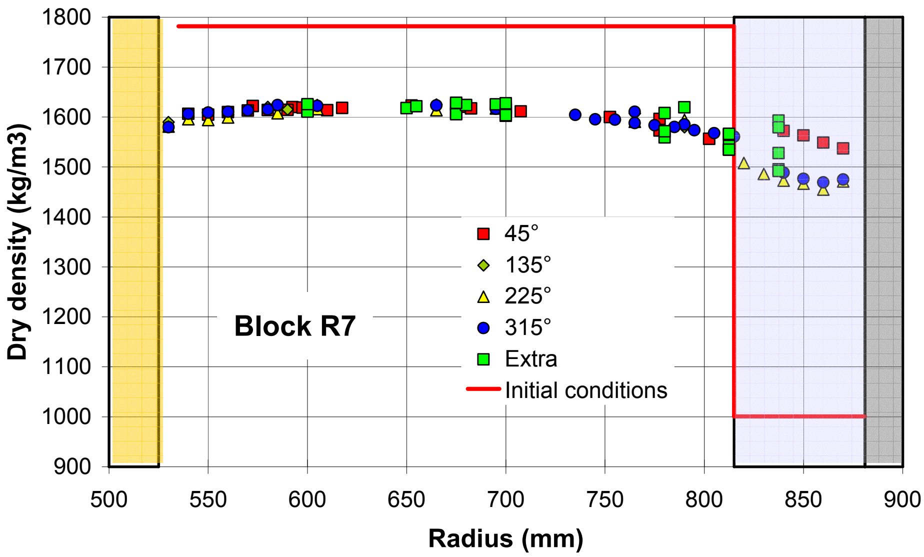
Dry density (kg/m3)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
500
550
600
650
700
750
800
850
900
Radius (mm)
Block R8
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions



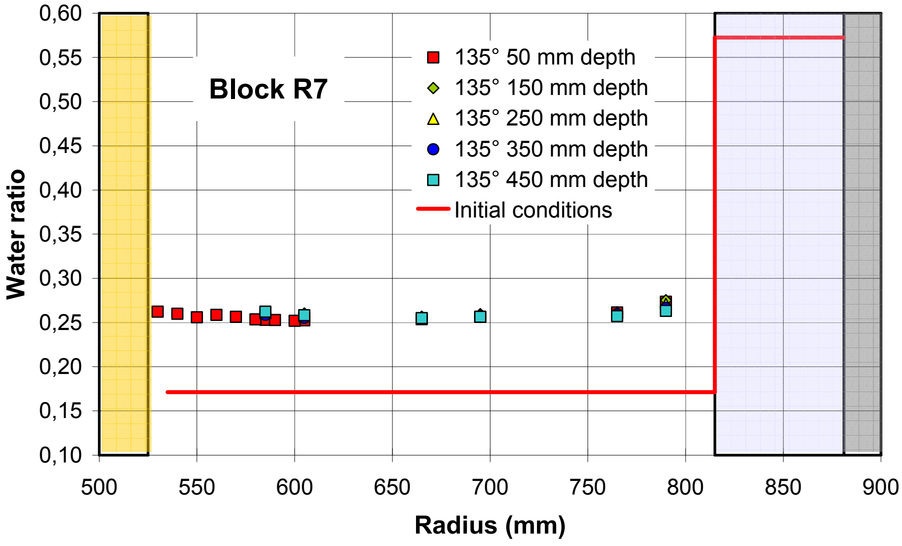
Water ratio
0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
Block R7
45°
135°
225°
315°
Extra
Initial conditions
500
550
600
650
700
750
800
850
900
Radius (mm)

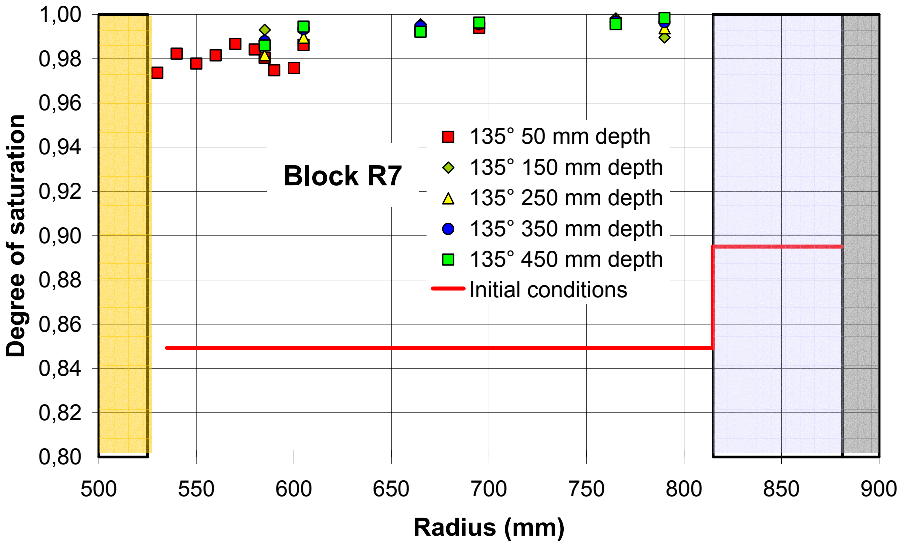


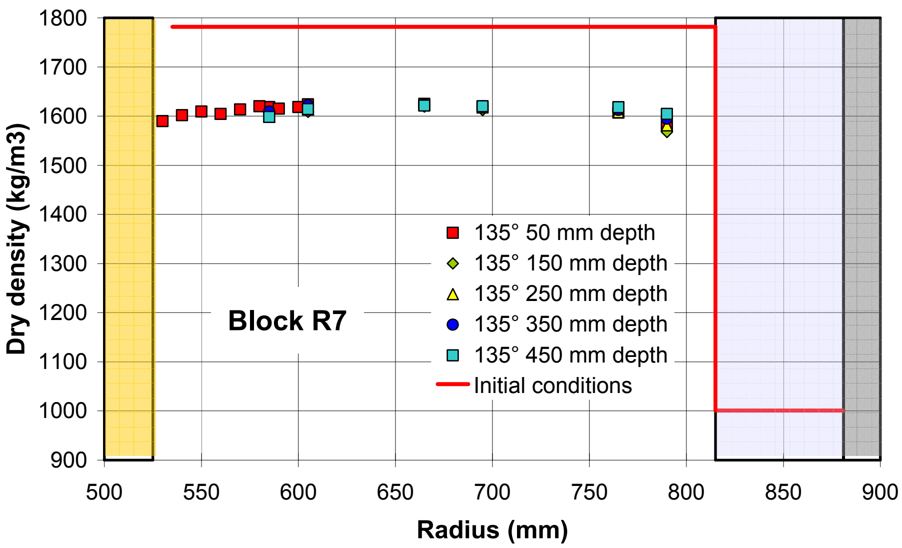
Degree of saturation
1,00
0,98
0,96
0,94
0,92
0,90
0,88
0,86
0,84
0,82
0,80
45°
135°
225°
315°
Extra
Initial conditions
Block R7
500
550
600
650
700
750
800
850
900
Radius (mm)

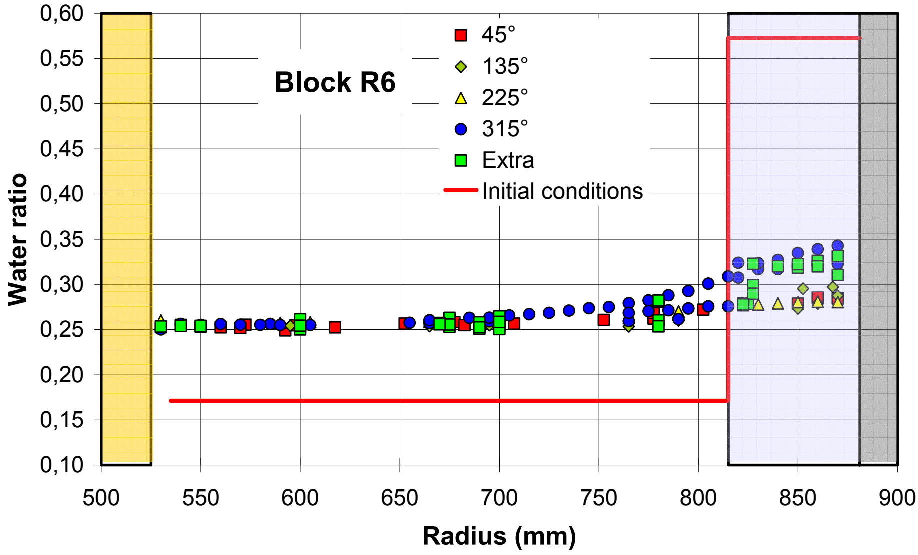


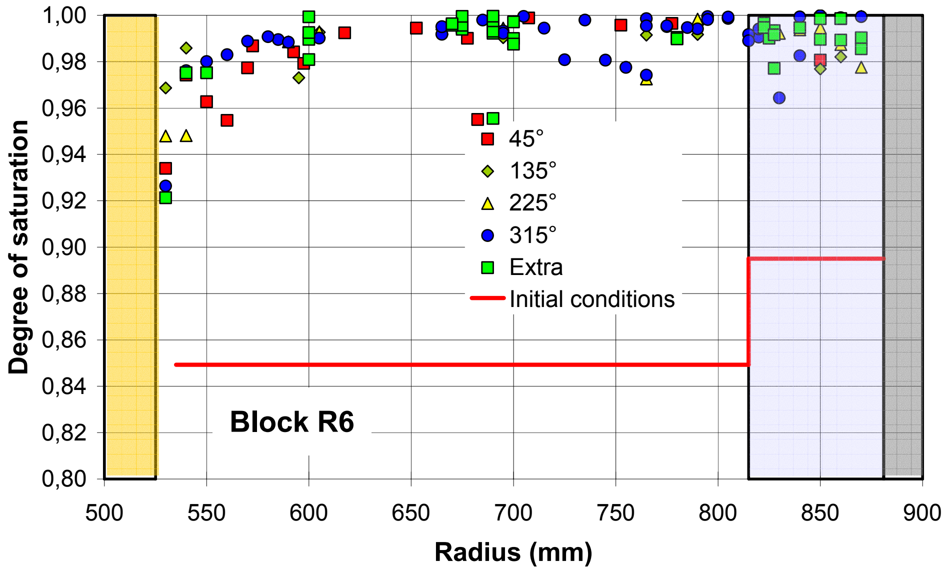
Dry density (kg/m3)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
45°
135°
225°
315°
Extra
Initial conditions
Block R7
500
550
600
650
700
750
800
850
900
Radius (mm)

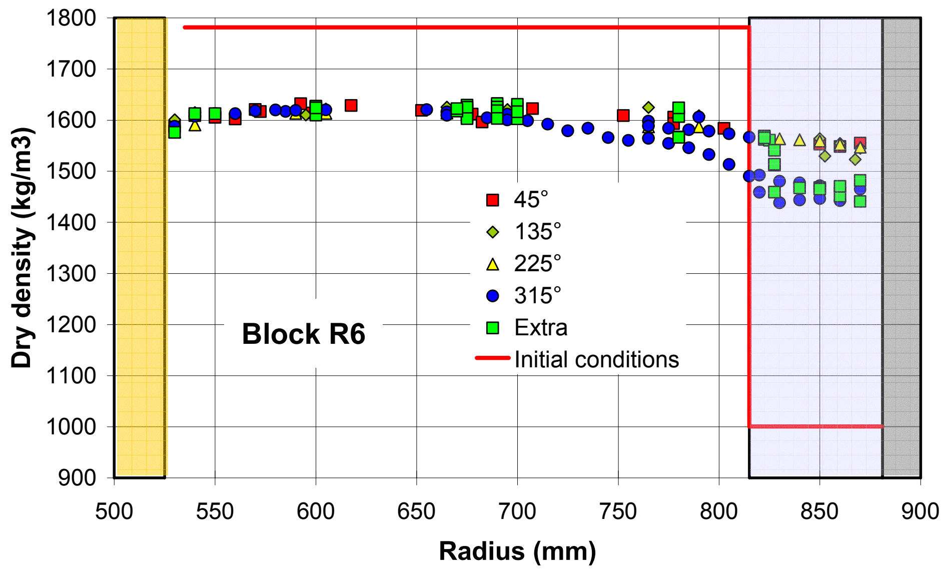

Block R7
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
Water ratio
0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
500
550
600
650
700
750
800
850
900
Radius (mm)

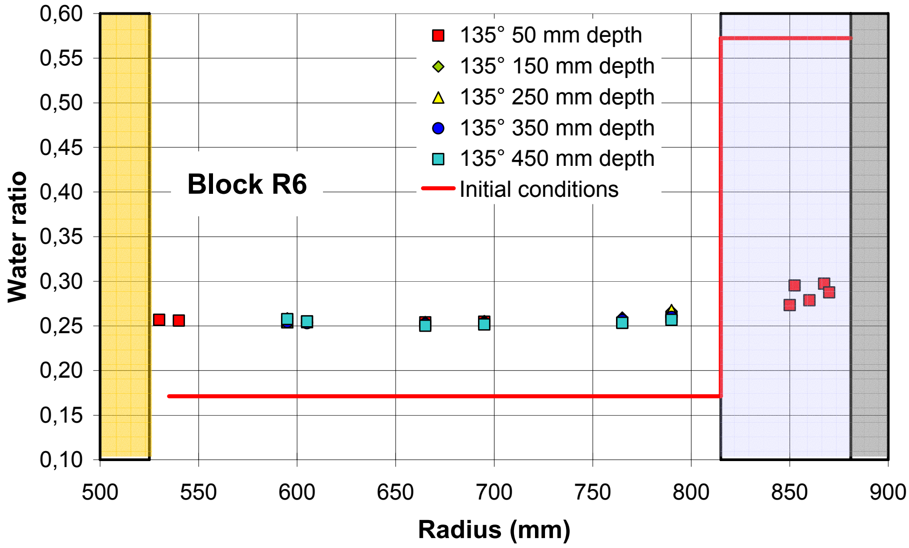

Block R7
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
Degree of saturation
1,00
0,98
0,96
0,94
0,92
0,90
0,88
0,86
0,84
0,82
0,80
500
550
600
650
700
750
800
850
900
Radius (mm)

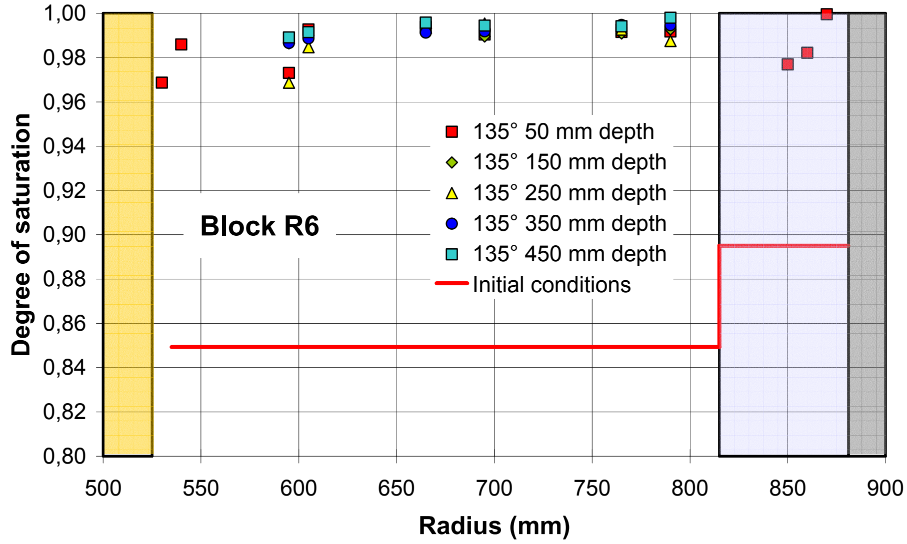

Block R7
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
Dry density (kg/m3)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
500
550
600
650
700
750
800
850
900
Radius (mm)

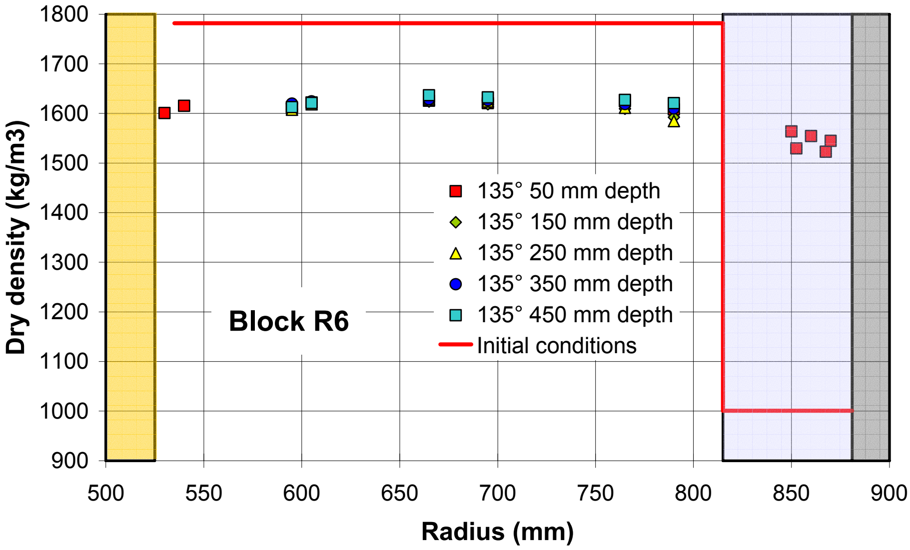

Block R6
45°
135°
225°
315°
Extra
Initial conditions
Water ratio
0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
500
550
600
650
700
750
800
850
900
Radius (mm)

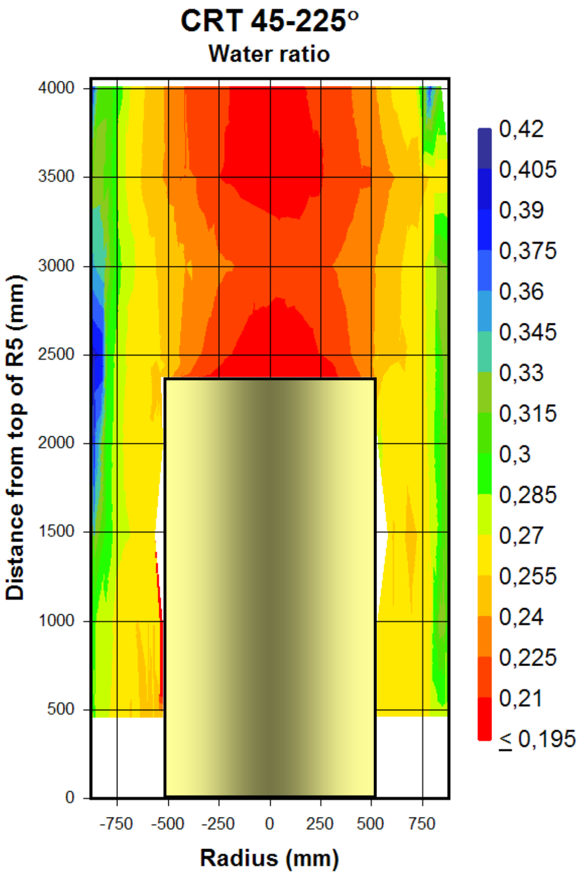

45°
135°
225°
315°
Extra
Initial conditions
Block R6
Degree of saturation
1,00
0,98
0,96
0,94
0,92
0,90
0,88
0,86
0,84
0,82
0,80
500
550
600
650
700
750
800
850
900
Radius (mm)

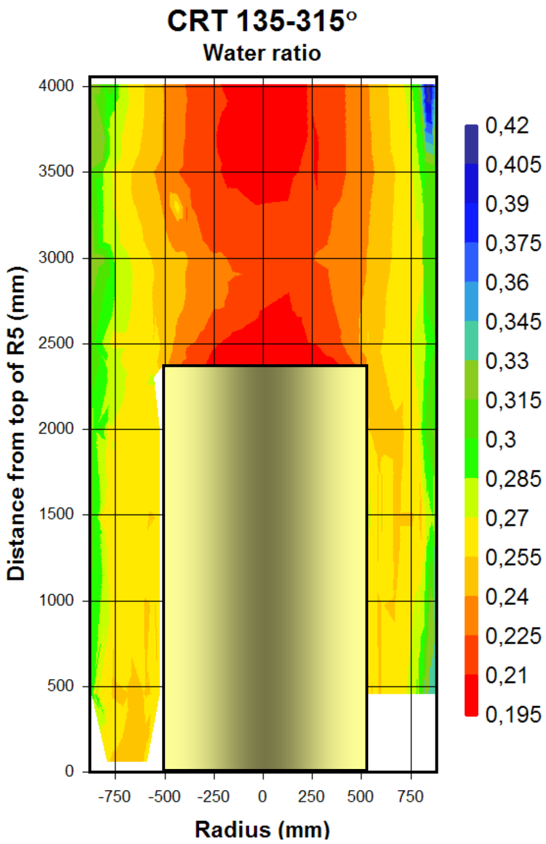

45°
135°
225°
315°
Extra
Initial conditions
Block R6
Dry density (kg/m3)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
500
550
600
650
700
750
800
850
900
Radius (mm)

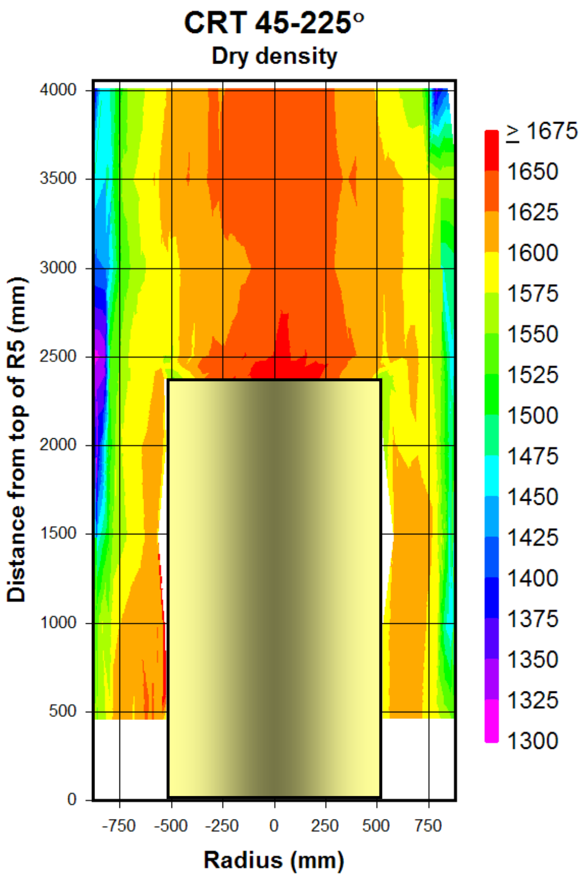

Water ratio
0,60
0,55
0,50
0,45
0,40
0,35
0,30
0,25
0,20
0,15
0,10
Block R6
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
500
550
600
650
700
750
800
850
900
Radius (mm)

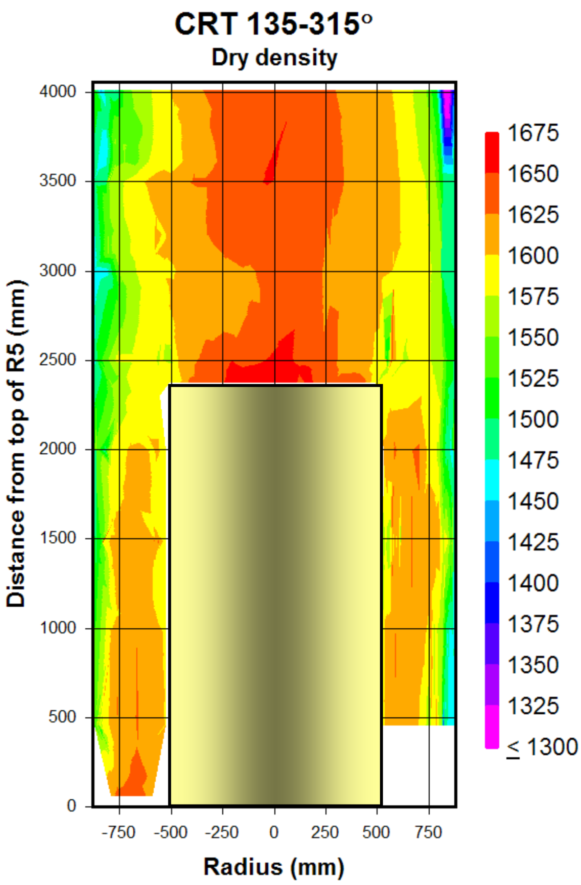

Degree of saturation
1,00
0,98
0,96
0,94
0,92
0,90
0,88
0,86
0,84
0,82
0,80
Block R6
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
500
550
600
650
700
750
800
850
900
Radius (mm)

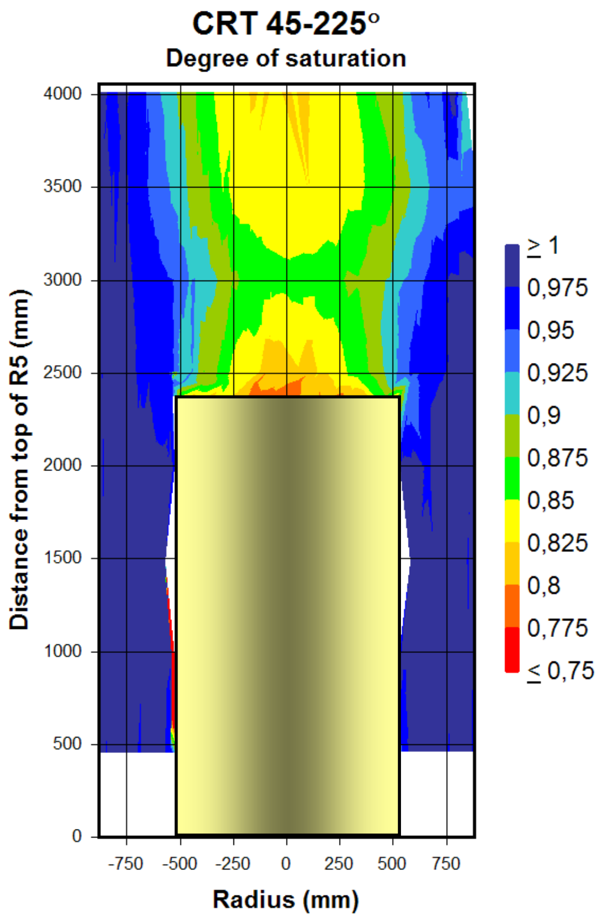

Dry density (kg/m3)
1800
1700
1600
1500
1400
1300
1200
1100
1000
900
Block R6
135° 50 mm depth
135° 150 mm depth
135° 250 mm depth
135° 350 mm depth
135° 450 mm depth
Initial conditions
500
550
600
650
700
750
800
850
900
Radius (mm)

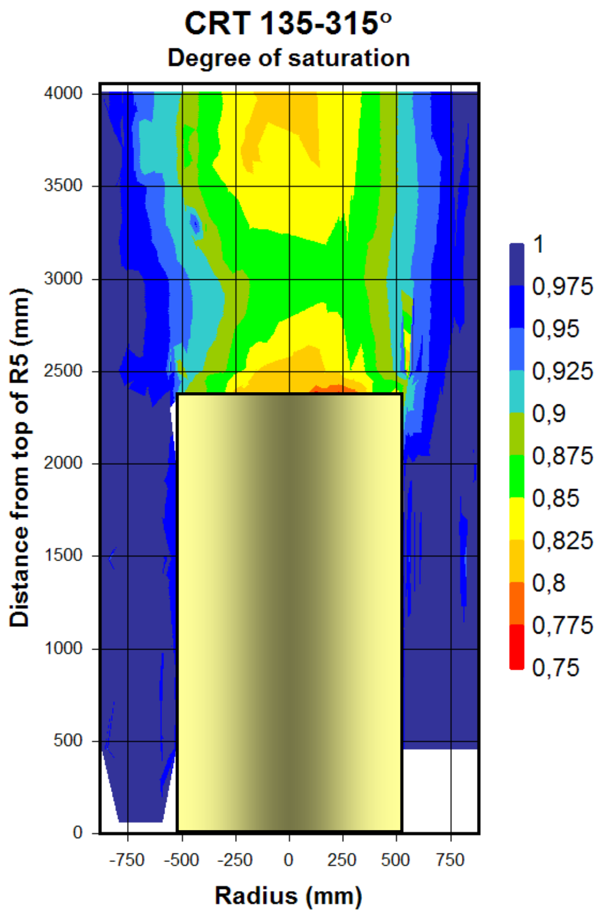

CRT 45-225°
Water ratio
Distance from top of R5 (mm)
Radius (mm)
4000
3500
3000
2500
2000
1500
1000
500
0
-750
-500
-250
0
250
500
750
0,42
0,405
0,39
0,375
0,36
0,345
0,33
0,315
0,3
0,285
0,27
0,255
0,24
0,225
0,21
≤ 0,195

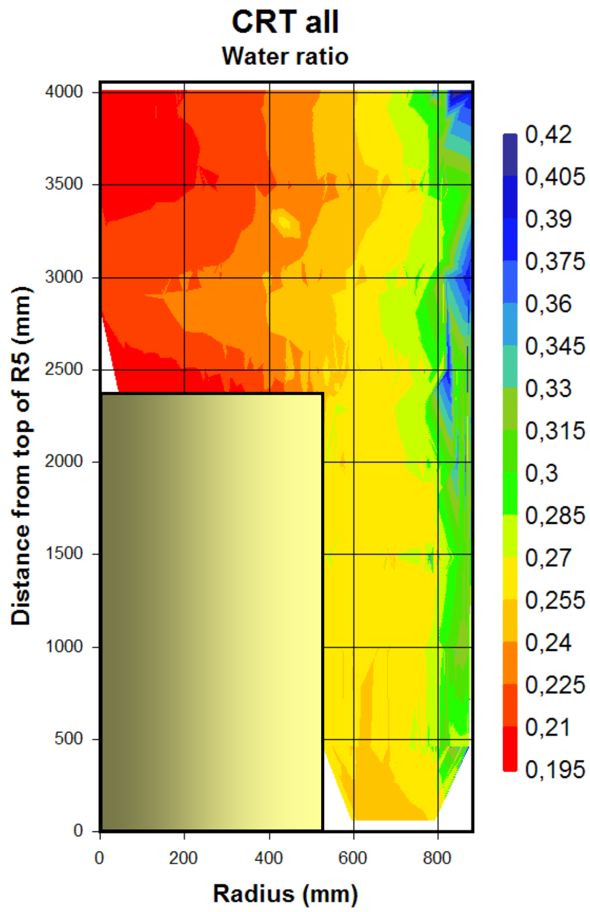

CRT 135-315°
Water ratio
Distance from top of R5 (mm)
Radius (mm)
4000
3500
3000
2500
2000
1500
1000
500
0
-750
-500
-250
0
250
500
750
0,42
0,405
0,39
0,375
0,36
0,345
0,33
0,315
0,3
0,285
0,27
0,255
0,24
0,225
0,21
0,195

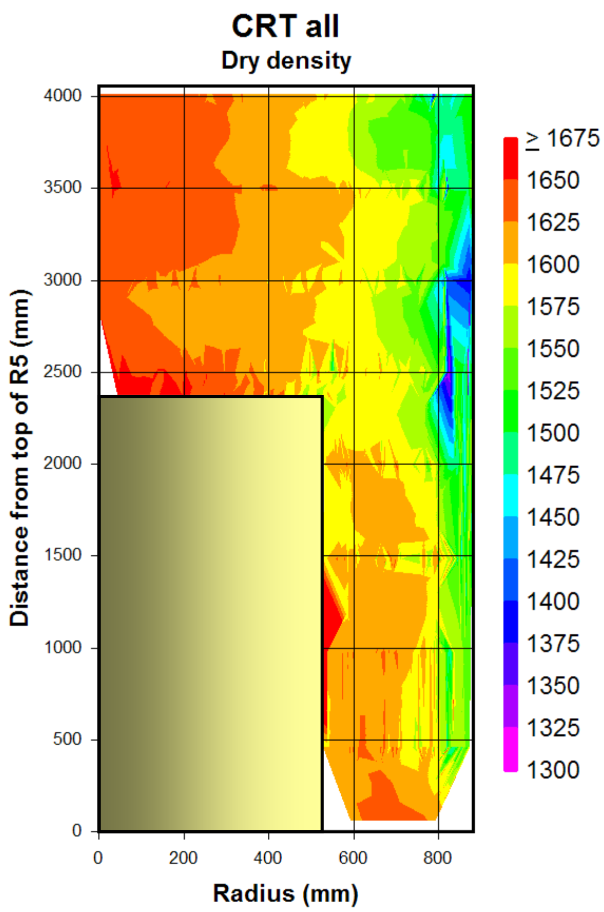

CRT 45-225°
Dry density
Distance from top of R5 (mm)
4000
3500
3000
2500
2000
1500
1000
500
0
-750
-500
-250
0
250
500
750
Radius (mm)
≥ 1675
1650
1625
1600
1575
1550
1525
1500
1475
1450
1425
1400
1375
1350
1325
1300

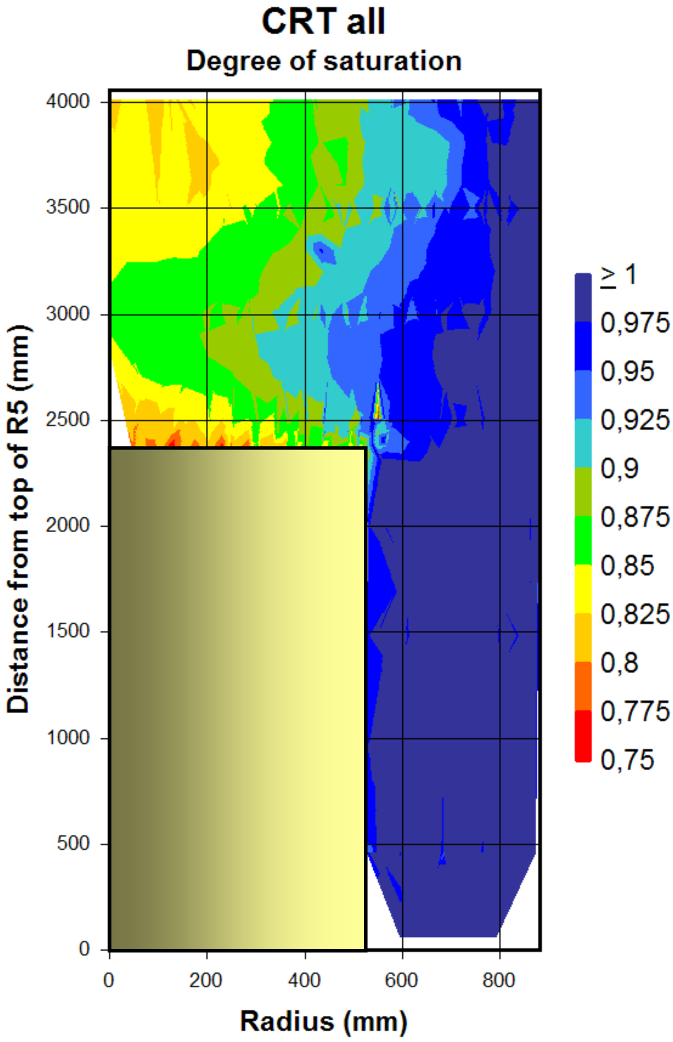

CRT 135-315°
Dry density
Distance from top of R5 (mm)
4000
3500
3000
2500
2000
1500
1000
500
0
-750
-500
-250
0
250
500
750
Radius (mm)
1675
1650
1625
1600
1575
1550
1525
1500
1475
1450
1425
1400
1375
1350
1325
≤ 1300


CRT 45-225°
Degree of saturation
4000
3500
3000
2500
2000
1500
1000
500
0
Distance from top of R5 (mm)
-750
-500
-250
0
250
500
750
Radius (mm)
≥ 1
0,975
0,95
0,925
0,9
0,875
0,85
0,825
0,8
0,775
≤ 0,75


CRT 135-315°
Degree of saturation
4000
3500
3000
2500
2000
1500
1000
500
0
Distance from top of R5 (mm)
-750
-500
-250
0
250
500
750
Radius (mm)
1
0,975
0,95
0,925
0,9
0,875
0,85
0,825
0,8
0,775
0,75


CRT all
Water ratio
4000
3500
3000
2500
2000
1500
1000
500
0
Distance from top of R5 (mm)
0
200
400
600
800
Radius (mm)
0,42
0,405
0,39
0,375
0,36
0,345
0,33
0,315
0,3
0,285
0,27
0,255
0,24
0,225
0,21
0,195


CRT all
Dry density
4000
3500
3000
2500
2000
1500
1000
500
0
Distance from top of R5 (mm)
0
200
400
600
800
Radius (mm)
≥ 1675
1650
1625
1600
1575
1550
1525
1500
1475
1450
1425
1400
1375
1350
1325
1300


CRT all
Degree of saturation
Distance from top of R5 (mm)
4000
3500
3000
2500
2000
1500
1000
500
0
0
200
400
600
800
Radius (mm)
≥ 1
0,975
0,95
0,925
0,9
0,875
0,85
0,825
0,8
0,775
0,75