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Water content and density distribution in buffer and backfill of the inner section of the Prototype Repository

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Abstract

The Prototype Repository experiment was designed as a full-scale replica of the KBS-3V repository and included studies of the Engineered Barriers System (EBS) and their interaction with groundwater and surrounding rock. The experiment was divided into two sections, Section 1 which included four deposition holes and Section 2 which included two deposition holes. The installation of buffer blocks, canisters with heaters, backfill and a concrete plug was done during autumn 2001 for Section 1 and during the spring and autumn 2003 for Section 2.

Section 2 of the experiment was dismantled between November 2010 and December 2011. The scientific experiences and conclusions are described in various reports and summarized in a final report (Svemar et al. 2016).

This report presents the results from initial analysis on water content and density distribution of the buffer in the four deposition holes and the backfill in the deposition tunnel in Section 1. In total, the water content and density were determined in approximately 4600 positions of the buffer in each of the four deposition holes. Since the backfill installed in the Prototype Repository was very different compared to the present reference design, the sampling of the backfill in the inner section was kept at a minimum. Above each deposition hole, 34 samples were taken in a cross-section of the tunnel.

Some comments on the results are 1) that the uppermost solid blocks in all four deposition holes had clearly swelled axially and had thereby reduced dry density, 2) the blocks just above the canister were saturated or almost saturated in all four deposition holes and 3) large differences between the degree of saturation in the lower part of the deposition holes were observed in that deposition holes 1 and 3 were judged to be saturated while lower degrees of saturation were measured in deposition holes 2 and 4.

Sammanfattning

Prototypförvaret designades för att efterlikna det så kallade KBS-3V-konceptet för slutförvaring av utbränt kärnbränsle och inkluderade studier av olika ingenjörsbarriärer och hur de interagerar med grundvatten och det omgivande berget. Experimentet var uppdelat i två sektioner, Sektion 1 som innehöll fyra deponeringshål och Sektion 2 som innehöll två deponeringshål. Installationen av buffert, kapslar med elektriska värmare, återfyllning och en betongplugg gjordes under hösten 2001 för Sektion 1 och under våren och hösten 2003 för Sektion 2.

Sektion 2 av experimentet avslutades och provtagning gjordes mellan november 2010 och december 2011. De vetenskapliga erfarenheterna och slutsatserna är beskrivna i ett antal rapporter och sammanfattas i en slutrapport (Svemar et al. 2016).

Denna rapport presenterar resultaten från de initiala analyserna av vatteninnehåll och densitetsfördelning i bufferten i de fyra deponeringshålen och i återfyllningen av deponeringstunneln i Sektion 1. Vatteninnehåll och densitet bestämdes i cirka 4600 positioner i bufferten i vart och ett av de fyra deponeringshålen. Eftersom återfyllningen som installerades i Prototypförvaret är helt annorlunda jämfört med den nuvarande referensdesignen, har provtagningen av denna hållits nere till ett minimum. Över varje deponeringshål har 34 prover tagits i ett tvärsnitt av tunneln.

Några kommentarer till resultaten är 1) att de översta blocken i alla fyra deponeringshålen hade svällt axiellt och hade därmed minskad torrdensitet, 2) blocken strax ovanför kapseln var vattenmättade eller nästan mättade i alla fyra deponeringshålen och 3) stora skillnader mellan mättnadsgraden i den nedre delen av deponeringshålen observerades i och med att deponeringshålen 1 och 3 bedömdes vara mättade medan lägre mättnadsgrader uppmättes i deponeringshålen 2 och 4.

Contents

1 Introduction

1.1 The KBS-3V concept

The KBS-3V concept for a repository for spent nuclear fuel consists of an underground facility with more than 200 tunnels, each measuring several hundred meters (see e.g. Svensson et al. 2019). In the tunnel floors, eight-meter-deep deposition-holes will be bored vertically. The spent fuel is encapsulated in copper canisters which are placed in the deposition holes. The canisters are surrounded by highly compacted buffer blocks, and the deposition tunnels backfilled with bentonite materials.

1.2 The Prototype repository

1.2.1 General

The Prototype Repository is located at the end of the Äspö HRL ramp, at 450 m depth below the ground surface. The experiment was designed as a replica of the KBS-3V repository and included studies of Engineered Barriers System (EBS) and their interaction with groundwater and surrounding rock. The Prototype Repository experiment is described in detail in (Persson and Broman 2000) and in (Svemar and Pusch 2000).

The tunnel section where the experiment is situated was excavated with a Tunnel Boring Machine (TBM). The experiment was divided into two sections, one inner section with four deposition holes and one outer with two deposition holes. The two sections were separated from each other by a stiff and water-tight concrete plug and the whole experiment was separated from the rest of the Äspö HRL by a cast concrete plug of the same design as the inner one. A schematic drawing of the experiment is provided in Figure 1-1. The installation of buffer blocks, canisters with heaters, backfill and concrete plugs was done during autumn 2001 for Section 1 and during spring and autumn 2003 for Section 2. The outer plug in Section 2 was completed during October 2003.

Section 2 of the experiment was dismantled between November 2010 and December 2011. The scientific experiences and conclusions are described in various reports and summarized in a final report (Svemar et al. 2016).

1.2.2 Buffer and backfill

The buffer blocks were compacted to an average dry density of 1798 kg/m^3 for the ring-shaped blocks and 1726 kg/m^3 for the cylindrical blocks, Figure 1-1. The calculated average dry density of the buffer after homogenization was 1570 kg/m^3. The gap between the blocks and the deposition hole wall was filled with bentonite pellets. The deposition tunnel above the deposition hole was filled with a mixture of bentonite and crushed rock (30 % bentonite and 70 % crushed rock). The backfill was compacted in inclined layers by using a vibrating slope compactor. This was the reference design for the backfill at the time for the installation, described by e.g. Börgesson et al. (2002).

The manufacturing of buffer blocks is described in (Johannesson 2002) and the manufacturing of the backfill material is described in (Gunnarsson 2002).

1.2.3 Canisters/Heaters

The canisters were equipped with electrical heaters to simulate the heat produced from the decay of the radioactive waste. The heating of the canisters in the two sections was started successively after the backfilling of the tunnel had reached the deposition hole. The heating of the canister in deposition hole 1 started on the third of October 2001 and the corresponding date for the heating of the canister in deposition hole 6 was the twenty-third of May 2003.

The canisters were heated with a power of 1800 W from the start. The power was lowered by approximately 30 W per year. Due to problems with the electrical heaters, the heating of Deposition hole 2 was stopped in 2004, the heating of Deposition hole 3 was stopped in 2015 and the heating of Deposition hole 1 was stopped in 2019. The heating of Deposition hole 4 continued (with low power, 570 W) until it was decided to dismantle the experiment.

The applied power and registered temperature to the different heaters are presented in periodic reports (e.g. Goudarzi 2023).

1.2.4 Instrumentation

More than 300 sensors were installed in the rock, backfill and buffer to monitor the pressure build-up from the swelling bentonite, the water pressure, the wetting process of bentonite, and the temperature distribution.

Registered data is presented in periodic reports (e.g. Goudarzi 2023).

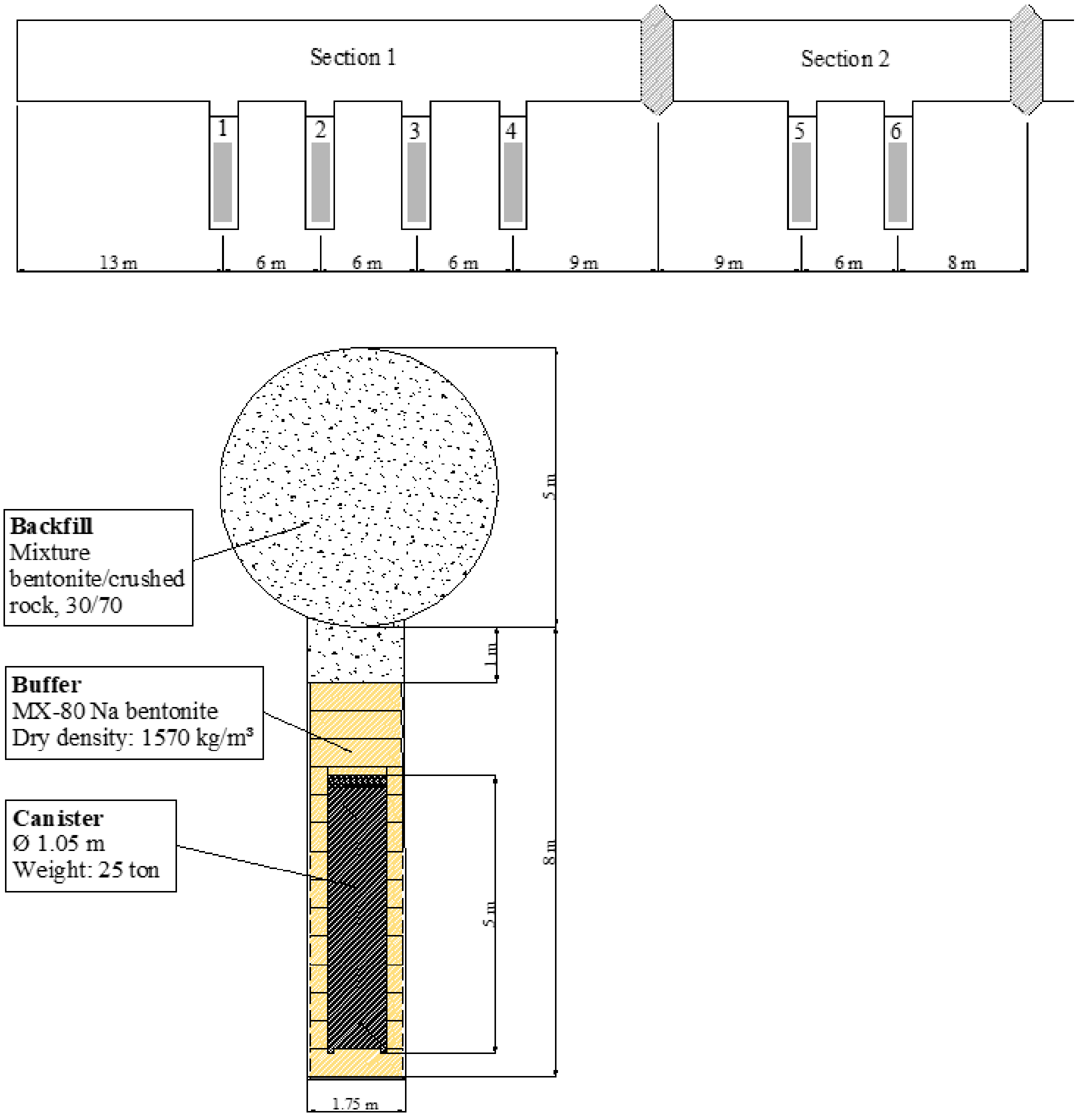


__Figure 1-1.__ Upper: Schematic drawing of the deposition tunnel and the deposition holes of the Prototype Repository. Lower: Cross-section showing a schematic drawing of a deposition hole and the tunnel above. The buffer dry density of 1570 kg/m³ is the calculated average of the blocks and rings after homogenization.

1.3 Objective

The objective with this report is to present results from the initial analysis of the buffer and backfill in Section 1 of the Prototype Repository after dismantling.

1.4 This report

In conjunction with the dismantling of Section 1 of the Prototype repository, many samples were taken from the buffer and backfill for further analyses in the laboratory. Two types of analysis were planned:

1. **Initial analysis**. Many samples, approximately 18400 samples from the buffer (4 x 4600) and 150 samples from the backfill, were taken to determine the water content and dry density distribution. These analyses were performed in conjunction with the sampling to minimize the risk of drying and redistribution of water within the samples.
2. **Hydro-mechanical and chemical analyses**. Analyses e.g., to determine the hydraulic conductivity and the swelling pressure, mineralogical changes etc. will also be made. These tests do not require immediate processing and can be performed later.

This report describes the results from the *initial analysis* of buffer and backfill in Section 1 of the Prototype Repository. Corresponding results from the initial analyses from Section 2 are reported in (Johannesson et al. 2014). The data will be used for THM-modelling of the experiment but also as an input for the following laboratory investigations.

Background data such as measured water inflow, data regarding the buffer components and the backfill installation are described in Chapter 2. The sample positions and the sampling technique are described in Chapter 3. Data from the sampling of the four deposition holes are presented in Chapter 4 to 7 (note that the result from the sampling is provided in the same order as the dismantling progressed i.e., the results from deposition hole 4 are presented in Chapter 4). Results from each block are presented in separate sections and a summary of the results from each deposition hole is given at the end of each chapter. The results from the sampling of the backfill are presented in Chapter 8. Comments and conclusions to the sampling of Section 1 of the Prototype Repository are provided in Chapter 9.

In the appendices data from each block are presented in four separate appendices presenting different types of diagrams. The denomination of the appendices begins with a sequential number 1, 2, 3 and 4 indicating which Deposition hole 4, 3, 2 and 1 the presented results come from. The order, in which the Deposition holes are presented, has been chosen to be consistent with the presentations in Chapter 4-7.

2 Experimental data

2.1 Location of the experiment

The Prototype Repository is situated in the last part of the "A-tunnel", see schematic drawing of Äspö HRL in Figure 2-1. The tunnel strikes close to the E-W direction with an exact strike of 278° from the magnetic north.

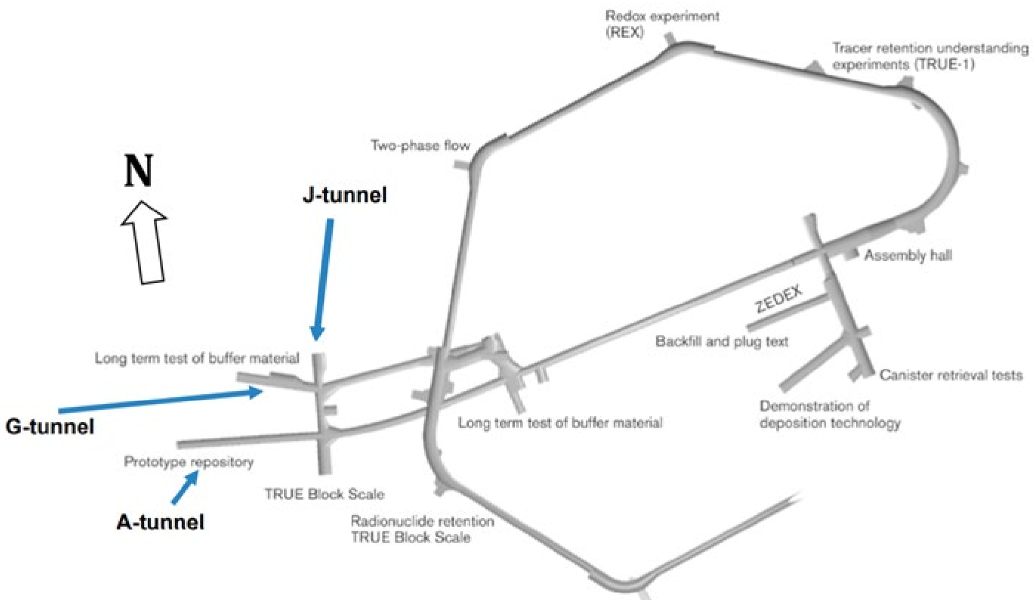


Figure 2-1. *Location of different experiments in the Äspö HRL. The Prototype Repository tunnel strikes close to the E-W direction with an exact strike of 278° from the magnetic north. The Prototype Repository is situated in the last part of the "A-tunnel". The adjacent tunnels are termed "G-tunnel" and "J-tunnel". (Svemar et al. 2016).*

2.2 Water inflow into deposition holes

The water inflow into the deposition holes was measured before installation using different methods:

1. Leakage from single fractures. These measurements were made by applying plastic bags on the rock surface to collect water from a mapped wet fracture. Once a day during a period of one month the collected volume was measured.
2. Absorbent Pad Method (or diaper measurements). Ordinary diapers were applied to the rock surface for a certain time. The diapers were weighed before and afterwards.

The results from the measurements of leakages from single fractures, method 1 above, showed that the inflow was below 0.1 l/min in all holes. The highest inflow was in deposition hole No 1, 0.08 l/min. The inflow to deposition holes No 2 and No 3 was 0.002 and 0.003 l/min respectively. The lowest inflow, 0.0007 l/min, was measured in deposition hole No 4. The measured inflow rates are compiled in Table 2-1 (Svemar et al. 2016).

The deposition holes were carefully mapped after drilling, see visualized fracture pattern of the four deposition holes provided in Figure 2-2 and Figure 2-3 (Rhén and Forsmark 2001). A schematic of the deposition hole, diameter and depth is given in Figure 3-4.

Table 2-1. Measured inflows to deposition holes (Svemar et al. 2016). While No 1-4 refer to the inner section, No 5-6 refer to the outer section and are shown here for completeness

Deposition hole, No.	Designation	Measured water inflow, l/min
1	DA3587G01	0.08
2	DA3581G01	0.002
3	DA3575G01	0.003
4	DA3569G01	0.0007
5	DA3551G01	0.002
6	DA3545G01	0.003

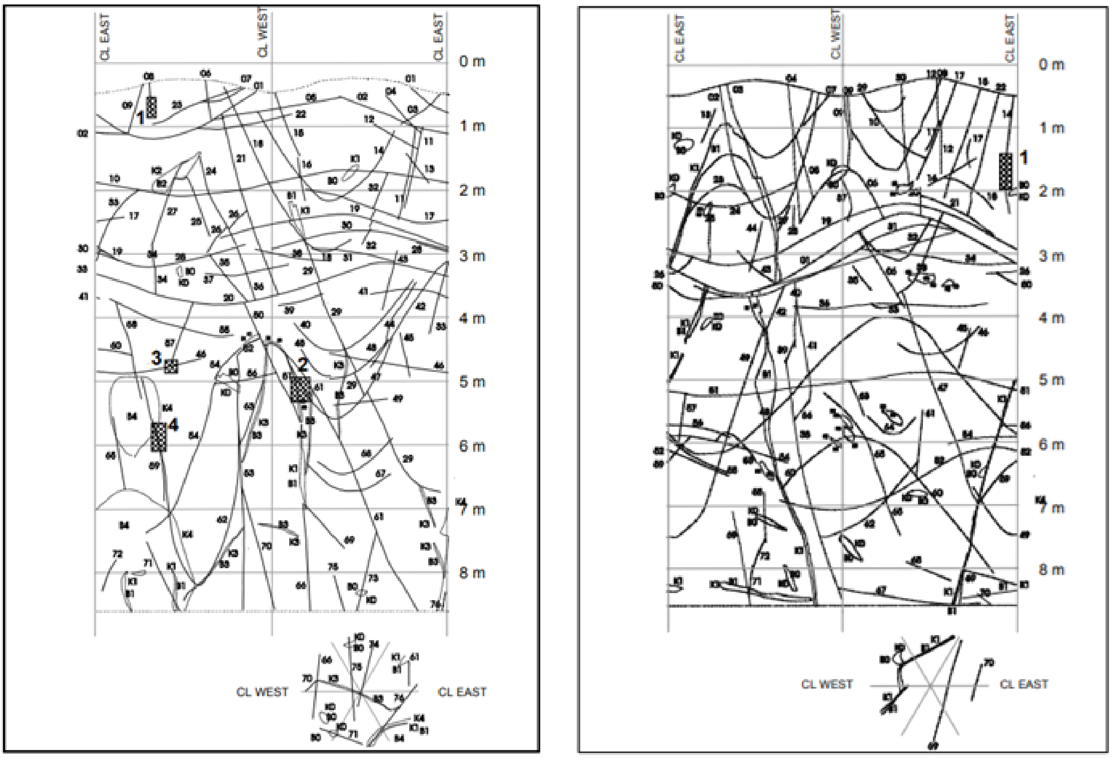


Figure 2-2. Fracture mapping in deposition hole No 1 (left) and No 2 (right). Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001).

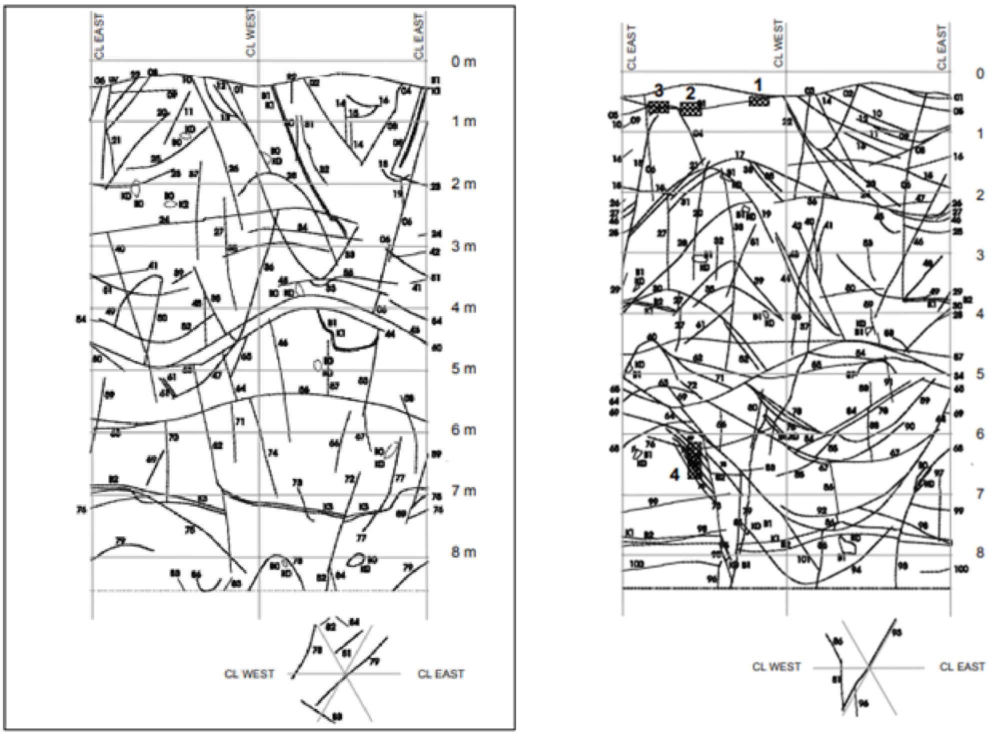


Figure 2-3. Fracture mapping in deposition hole No 3 (left) and No 4 (right). Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001).

2.3 Water inflow into deposition tunnel

The total water inflow into the deposition tunnel in Section 1 was in the range of 5 l/min. Most of the water inflow came in the innermost sections 3581-3600 m (Rhén and Forsmark 2001), i.e. the innermost 19 m to the left in Figure 1-1. To be able to install the buffer and backfill it was necessary to handle the inflowing water. This was done by placing plastic mats on the rock walls that collected the water and led it from the mats through tubes to a sump that had been excavated in the tunnel floor. The sump was equipped with two pumps that pumped the water out of the tunnel, through a borehole, to an adjacent tunnel (the G-tunnel). The mats collected most of the water but there was still a small amount coming from the bottom of the tunnel. Since it was judged important to also collect this water, the inner wet part of the tunnel was filled with drainage material from the sump to the end of the tunnel (see Figure 5-1 and 5-2 in Börgesson et al. 2002).

2.4 Buffer blocks and pellets

The manufacturing of buffer blocks for the Prototype Repository experiment is described in (Johannesson 2002). The blocks were manufactured of MX-80 bentonite (sodium bentonite from Wyoming, USA). Two types of blocks were manufactured, ring-shaped blocks that were placed around the canister (R1-R10) and solid blocks that were placed below the canister (C1) and above the canister (C2-C4), see Figure 3-4 for the block denominations. The blocks were slightly conical and had an outer diameter of 1630-1650 mm. The ring-shaped blocks had an inner diameter of 1070 mm. At manufacturing of the blocks, a lubricant for lubricating at high pressure was used, see Johannesson (2002).

After compaction, the blocks were weighed and measured. The water contents were determined on samples taken in conjunction with the compaction. With this data, it was possible to calculate the bulk density, the dry density, the degree of saturation and the void ratio for every individual block. The data achieved is provided in Table 2-2 to Table 2-5. The average dry density and water content for all ring-shaped blocks were 1798 kg/m^3 and 17.1 % respectively (Johannesson 2002). Corresponding values for the solid blocks were 1726 kg/m^3 and 17.8 % (Johannesson 2002).

The outer gap between the buffer blocks and the deposition hole was filled with bentonite pellets. The pellet filling had an average dry density of 1060 kg/m^3 and a water content of 13 %.

The estimated buffer density after saturation in the four deposition holes varied between 2028 and 2037 kg/m^3, corresponding to a dry density between 1605 and 1620 kg/m^3 (Börgesson et al. 2002).

Table 2-2. Determined data for the blocks used in deposition hole 1 (see block denominations in Chapter 3). The presented data is taken from (Johannesson 2002)

Block No.	Weight	Water content	Bulk density	Dry density	Degree of saturation	Void ratio
	kg	%	kg/m^3	kg/m^3	%	-
DH1:C1	2146	18.2	2032	1719	81.9	0.617
DH1:R1	1266	17.5	2107	1793	88.5	0.550
DH1:R2	1290	17.4	2095	1785	86.7	0.557
DH1:R3	1270	17.2	2109	1800	87.7	0.544
DH1:R4	1284	16.8	2106	1803	86.3	0.542
DH1:R5	1266	17.4	2109	1797	88.3	0.547
DH1:R6	1288	17.5	2087	1777	86.2	0.565
DH1:R7	1276	17.3	2109	1798	88.1	0.547
DH1:R8	1268	17.3	2107	1796	87.9	0.549
DH1:R9	1276	17.3	2097	1788	86.6	0.554
DH1:R10	1266	17.2	2105	1796	87.3	0.548
DH1:C2	2164	17.8	2037	1729	81.5	0.608
DH1:C3	2166	17.9	2033	1725	81.3	0.612
DH1:C4	2128	17.3	2025	1726	78.8	0.611

Table 2-3. Determined data for the blocks used in deposition hole 2 (see block denominations in Chapter 3). The presented data is taken from (Johannesson 2002)

Block No.	Weight	Water content	Bulk density	Dry density	Degree of saturation	Void ratio
	kg	%	kg/m^3	kg/m^3	%	-
DH2:C1	2154	17.9	2040	1730	82.0	0.606
DH2:R1	1276	16.9	2086	1784	84.2	0.558
DH2:R2	1278	17.2	2103	1794	87.0	0.549
DH2:R3	1298	17.1	2094	1788	85.8	0.555
DH2:R4	1274	17.2	2092	1785	85.6	0.557
DH2:R5	1296	17.4	2096	1785	86.8	0.557
DH2:R6	1290	17.2	2106	1797	87.4	0.548
DH2:R7	1304	17.2	2109	1800	87.9	0.545
DH2:R8	1284	16.7	2104	1803	85.7	0.542
DH2:R9	1294	17.2	2096	1788	86.3	0.555
DH2:R10	1264	17.4	2095	1785	86.7	0.557
DH2:C2	2116	17.3	2005	1709	76.7	0.626
DH2:C3	2096	17.7	2008	1706	78.0	0.629
DH2:C4	2122	17.0	1996	1706	75.1	0.630

Table 2-4. Determined data for the blocks used in deposition hole 3 (see block denominations in Chapter 3). The presented data is taken from (Johannesson 2002)

Block No.	Weight	Water content	Bulk density	Dry density	Degree of saturation	Void ratio
	kg	%	kg/m³	kg/m³	%	-
DH3:C1	2116	17.4	2031	1730	79.5	0.607
DH3:R1	1280	17.5	2109	1795	88.5	0.549
DH3:R2	1266	17.2	2108	1799	87.7	0.546
DH3:R3	1278	16.8	2110	1806	86.6	0.539
DH3:R4	1286	17.4	2110	1797	88.4	0.547
DH3:R5	1266	17.0	2096	1792	85.7	0.552
DH3:R6	1284	17.2	2101	1792	86.8	0.551
DH3:R7	1282	16.7	2105	1803	85.8	0.542
DH3:R8	1270	17.4	2093	1783	86.6	0.560
DH3:R9	1278	17.0	2107	1801	86.8	0.544
DH3:R10	1274	17.6	2100	1785	87.7	0.557
DH3:C2	2158	18.0	2035	1725	81.7	0.612
DH3:C3	2146	17.4	2030	1729	79.6	0.608
DH3:C4	2130	17.5	2025	1723	79.3	0.613

Table 2-5. Determined data for the blocks used in deposition hole 4 (see block denominations in Chapter 3). The presented data is taken from (Johannesson 2002)

Block No.	Weight	Water content	Bulk density	Dry density	Degree of saturation	Void ratio
	kg	%	kg/m³	kg/m³	%	-
DH4:C1	2144	17.9	2038	1729	81.9	0.609
DH4:R1	1276	16.8	2089	1788	84.3	0.555
DH4:R2	1284	16.8	2105	1802	85.9	0.542
DH4:R3	1292	16.8	2103	1800	85.9	0.544
DH4:R4	1284	16.8	2115	1811	87.2	0.535
DH4:R5	1290	17.0	2108	1802	87.1	0.543
DH4:R6	1266	16.3	2116	1820	86.0	0.528
DH4:R7	1292	16.9	2108	1803	86.7	0.542
DH4:R8	1284	17.1	2106	1798	87.0	0.545
DH4:R9	1284	16.6	2117	1816	86.7	0.530
DH4:R10	1264	16.9	2110	1805	87.0	0.540
DH4:C2	2110	17.1	1999	1707	75.6	0.628
DH4:C3	2140	18.1	2031	1719	81.7	0.618
DH4:C4	2174	17.8	2039	1731	81.5	0.606

2.5 Backfill

The backfill material consisted of a mixture of a sodium activated bentonite from Milos, Greece (30 %) and ballast consisting of excavated TBM-muck of granodioritic bedrock (70 %), crushed to grain sizes ranging from 0-20 mm, (Gunnarsson 2002).

The backfill material was compacted in inclined layers by using a vibrating slope compactor attached on a backhoe loader at the installation. The installed dry density of the backfill material varied in the deposition tunnel: approximately 1700 kg/m^3 in the central parts, 1600 kg at the roof and close to the walls, and 1500 kg close to the floor. The average installed density in the tunnel was estimated to between 1580 and 1650 kg/m^3, see detailed description of the backfill installation in (Börgesson et al. 2002).

The backfill in the uppermost meter of the deposition holes was compacted with a handheld compactor. The average installed dry density varied between 1570 and 1830 kg/m^3. The lowest dry density, 1570 kg/m^3 was achieved in deposition hole 2 (DA3581G01). In the other three deposition holes the dry density was between 1770-1830 kg/m^3, (Börgesson et al. 2002).

3 Sampling of the buffer and the backfill

3.1 Buffer

3.1.1 Background

At time for dismantling, the buffer was expected to be close to saturation which means that there will be a swelling pressure acting against both the canisters and the rock surface of the deposition holes. It was also assumed that the saturation was not axis-symmetric which means that samples must be taken in many directions. To be able to take the samples and to remove the buffer from the deposition holes, a combination of core drilling and stitch drilling was used, Figure 3-1. The technique is described in detail in a separate report (Johannesson and Hagman 2013).

An example of the sampling strategy for the cylindrical-shaped blocks is shown in Figure 3-2. The sampling included both cores that were taken at different radius in eight different directions but also large sections that were used for more advanced investigations in laboratory. One type of larger samples were the so-called end sectors (marked blue), which were taken close to the periphery against the rock wall at all eight directions. These samples were used to determine the water content and density in detail in this region (the former pellet filled gap). In addition, a large sample (marked green) with an extent over the complete radius was taken from every block, to be used for further investigations which were not a part of the current study.

The sampling strategy for the ring-shaped blocks is shown in Figure 3-3. The sampling was made in the same way in these blocks as in the cylindrical, but in addition, larger samples (end sectors) were also taken close to the canister. These samples were used to determine the water content and density in detail in this region (the former empty gap between block and canister).

The eight sampled main directions were chosen to avoid, as much as possible, the different sensors positioned in deposition hole 1 and 3.

Figure 3-1. *Left: The core drilling machines standing on the tunnel floor. Right: Holes from cores taken from a buffer block. (Johannesson 2014).*

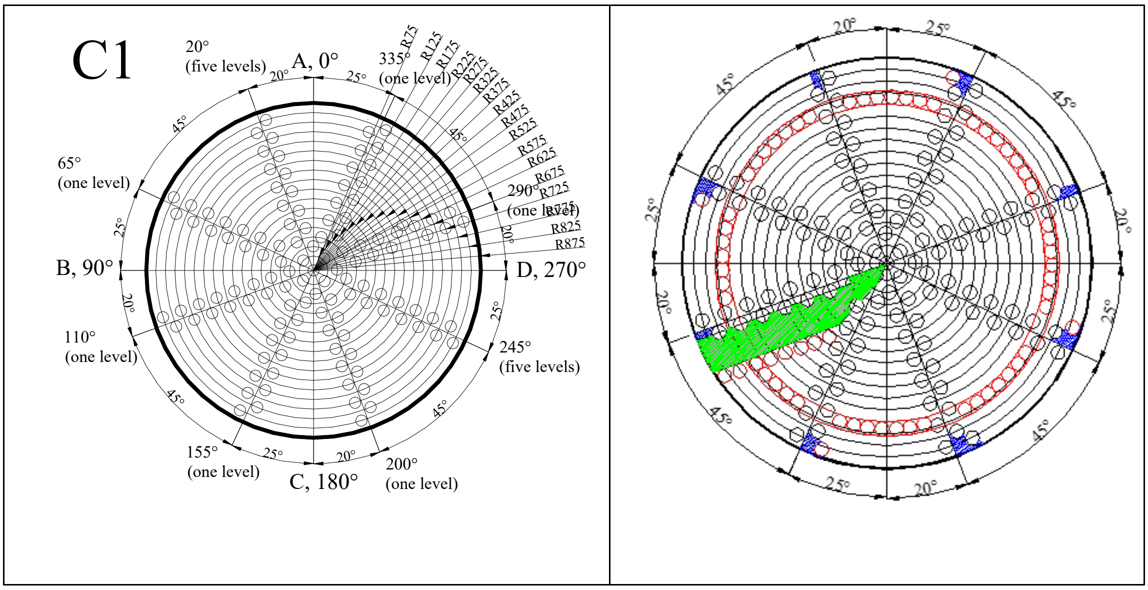


Figure 3-2. Sampling of cylindrical-shaped block. Left: Cores were taken in eight directions at different radius. Right: Extra cores (red) were drilled to loosen the buffer from the deposition hole. A large sample (green) was taken for further investigations in the laboratory and extra samples (blue) were taken close to the rock wall to determine the water content and density distribution here.

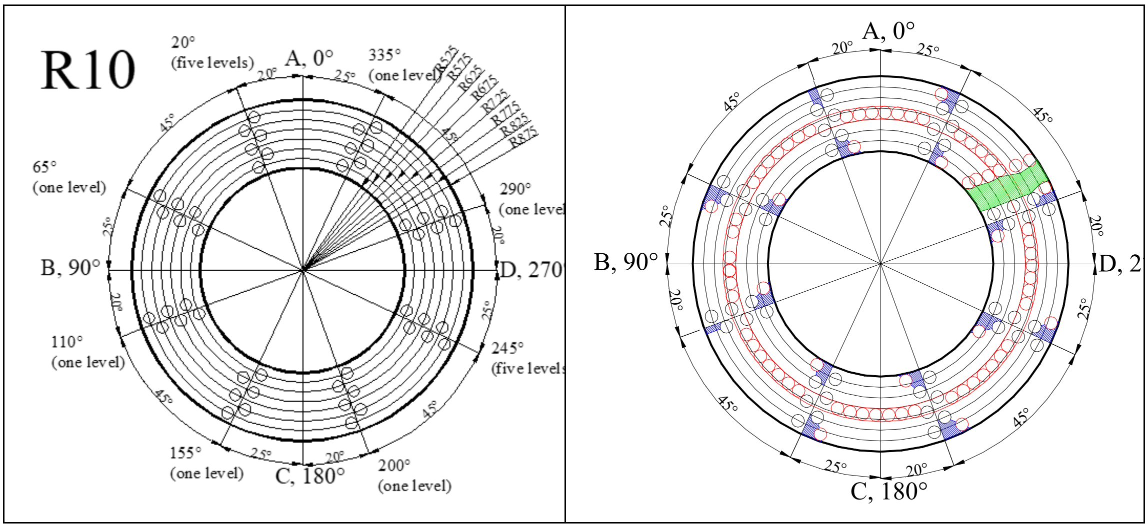


Figure 3-3. Sampling of ring-shaped block. Left: Cores were taken in eight directions at different radius. Right: Extra cores (red) were drilled to loosen the buffer from the deposition hole. A large sample (green) was taken for further investigations in the laboratory and extra samples (blue) were taken close to the canister and close to the rock wall to determine the water content and density distribution here.

3.1.2 Sample positions

The designation of the buffer blocks and some important dimensions in a deposition hole are provided in Figure 3-4 (left). Note, however, that the average deposition hole diameter was determined to 1760 mm by (Andersson and Johansson 2002) and this number have been used in this report to determine the sample positions. The bottom block below the canister is denominated “C1”. The ring-shaped blocks along with the canister are denominated “R1” to “R10”, and the three blocks above the canister are denominated “C2”, “C3” and “C4”. The material in the uppermost meter of the deposition hole is a part of the backfill.

The position of the taken samples was described according to the same coordinate system as was used at the installation, see the right schematic in Figure 3-4. The *z*-axis started from the cement casting in the bottom of the deposition hole and the angle α counted counter clockwise from direction A. Directions A and C were placed along the tunnel's axial direction, with A oriented towards the end of the tunnel i.e., almost towards west. The position of each sample was thus 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 3-4 (right).

The angle α was marked in advance on the wall at the upper part of the deposition hole and furthermore, graduated rulers were placed on the top of the blocks before the sampling started, Figure 3-5. The accuracy of the determination was approximately ±1 degree. The z-coordinate was determined with a laser levelling instrument. The accuracy of this measurement was approximately ±0.5 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 was approximately ±2.5 mm.

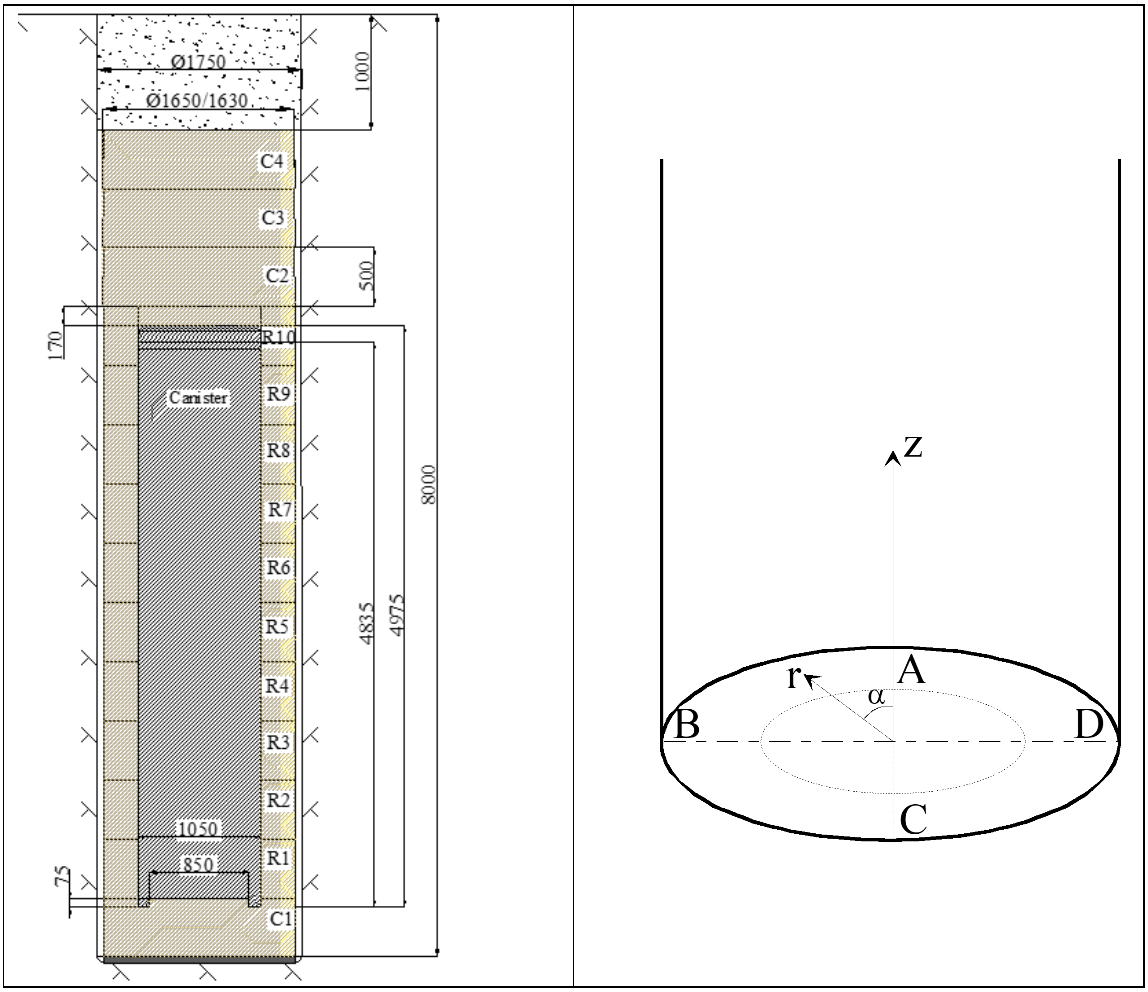


Figure 3-4. *Left: Schematic showing the designation of the buffer blocks and some important dimensions in a deposition hole. Right: The coordinate system used to describe the positions of the samples. 0° is the direction towards the end of the drift and 270° is the direction almost to the north. (Johannesson 2014).*

__Figure 3-5.__ Graduated rulers were placed towards the canister and the rock surface to facilitate the determination of the sample positions. (Johannesson 2014).

Samples were taken from every block according to the following:

- **Drill cores.** Cores were drilled out in eight main directions every 50 mm. The cores had a diameter of 50 mm and a length of 500 mm.
    - Cores from direction 65°, 110°, 155°, 200°, 290° and 335°. One sample was cut out from every core at a depth of 50 mm below the block surface.
    - Cores from direction 20° and 245°. Samples were cut out from these cores at depths of 50, 150, 250, 350 and 450 mm from the block surface.
- **End sectors**. End sectors were taken close to the wall of the deposition hole and from the ring-shaped blocks also close to the canister, see schematic drawings in Figure 3-3. The end sectors were cut in pieces with a thickness of ten mm in a radial direction.
- **Large sectors**. One “large sector” was taken from every block. These sectors had an extent over the complete radius and a thickness of approximately 100 mm. These sectors were stored for later investigations.

The measurements for determining the water content and the density of the buffer tests were made a short time after the sampling to minimize the risk of air drying of the bentonite. The samples were after removal placed in plastic bags and transported to the surface laboratory at Äspö. Each sample was divided into two pieces, one was used to determine the water content and one to determine the density. The subsamples taken were recorded in a sampling log. The rest of the drill cores were restored in the plastic wrapping. This material was then used as a backup and could also be used for other analyses and tests.

In total, approximately 4600 samples were planned to be taken from the buffer in each of the deposition holes.

3.2 Backfill

3.2.1 Background

The backfill material consisted of a mixture of a sodium activated bentonite from Milos, Greece (30 %) and ballast consisting of excavated TBM-muck of granodioritic bedrock (70 %), crushed to grain sizes ranging from 0-20 mm, (Gunnarsson 2002).

Based on findings from the outer section and data from the sensors, the backfill in the inner section was believed to be fully saturated.

3.2.2 Sample positions

Since the backfill-material installed in the Prototype Repository, see section 1.2.2, was quite different compared to the present reference design (Arvidsson et al. 2015), the sampling of the backfill in the inner section was kept at a minimum. Above each deposition hole, samples were taken in a cross-section of the tunnel, see schematic drawing provided in Figure 3-6 (black dots indicate sample positions for determining water content and density and the red dots indicate positions for samples that were taken to determine the sulphur content). In total 28 samples, water content and density, were taken from each cross section. In addition, six samples were taken from the backfill in the uppermost meter of the deposition hole. Three samples were taken at 500 mm from the tunnel floor and three samples just above the first buffer block (1000 mm from the tunnel floor at installation), Figure 3-7.

In total, approximately 136 samples were planned to be taken from the backfill.

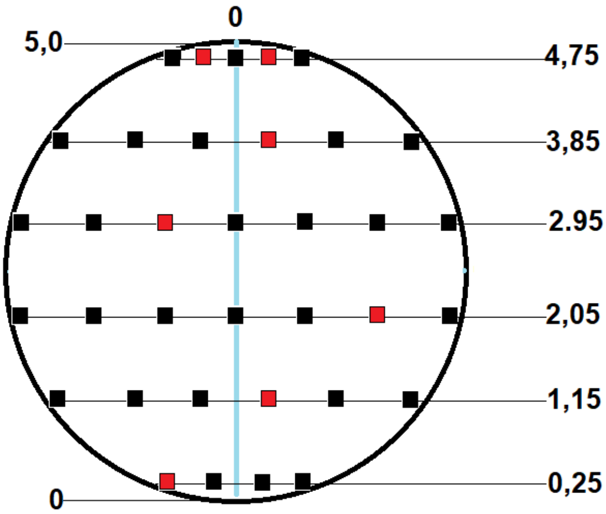


__Figure 3-6.__ Sample positions of backfill material in a cross-section above the deposition holes.

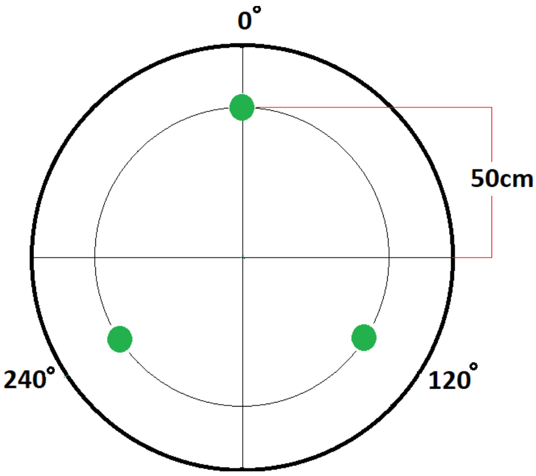


__Figure 3-7.__ Sample positions of backfill material in the deposition holes. Three samples were taken at two depths, 500 mm from the tunnel floor and 1000 mm from the tunnel floor (just above the first buffer block).

3.3 Water content, density, and degree of saturation

Water content

The water content is defined as the ratio of the mass of water to the mass of dry material. The dry mass is obtained by drying the wet specimen at 105°C for 24 hours.

The sample was placed in an aluminium tin and the bulk mass (m_b) of the sample was determined by use of a laboratory balance. The sample was placed in an oven for 24 h at a temperature of 105 °C. The dry mass of the sample (m_s) was determined immediately after removal from the oven. From these measurements the water mass (m_w) was calculated:

$$m_w = m_b - m_s \qquad 3\text{-}1$$

and the water content (w) of the sample determined:

$$w = \frac{m_w}{m_s} \qquad 3\text{-}2$$

Bulk density, dry density, and degree of saturation

The bulk density (ρ_b) was determined by hanging the sample in a thin thread under a balance. The sample was then weighed, first in air (m_b) and then submerged into paraffin oil (m_{bp}). The volume of the sample was then calculated:

$$V = \frac{(m_b - m_{bp})}{\rho_p} \qquad 3\text{-}3$$

where ρ_p is the paraffin oil density. The bulk density of the sample was then calculated:

$$\rho_b = \frac{m_b}{V} \qquad 3\text{-}4$$

After determining the water content and the bulk density of each sample it was possible to calculate the dry density (ρ_d):

$$\rho_d = \frac{\rho_b}{1+w} \qquad 3\text{-}5$$

Since the grain density (ρ_s) and the density of the water (ρ_w) are known the degree of saturation (Sr) can be calculated:

$$Sr = \frac{w \cdot \rho_b \cdot \rho_s}{[\rho_s \cdot [1+w] - \rho_b]} \frac{}{\rho_w} \qquad 3\text{-}6$$

In the calculations, a particle density (ρ_s) of 2780 kg/m^3 (e.g. Börgesson et al. 1995) has been used for the buffer material and 2688 kg/m^3 has been used for the backfill. The density of the solid particles in the backfill which consists of 30 % bentonite and 70 % crushed rock was stated to be 2688 kg/m^3. This density was calculated with the assumption that the solid bentonite particles have a density of 2780 kg/m^3 and the crushed rock particles have a particle density of 2650 kg/m^3 (commonly used particle density of sand, e.g. Johannesson 2014). For the calculation of degree of saturation (S_r) a water density (ρ_w) of 1000 kg/m^3 has been used.

4 Results from measurements in Deposition hole 4

4.1 Background

4.1.1 Heating history

The heating of the canister started 2001-10-11. The applied power was set to 1800 W from start, Figure 4-1. The registered temperature on the canister surface was approximately 90°C (Goudarzi 2023) during the first 1300 days. After that time, the sensor (optical fiber cable) stopped working. The power was then lowered in steps during the following years, approximately 30 W per year. Due to heater failure, the applied power was after approximately 5497 days test duration 300 W. The power was again increased from day 6239 to 570 W. Detailed information regarding the applied canister power is available in the report by Goudarzi (2023).

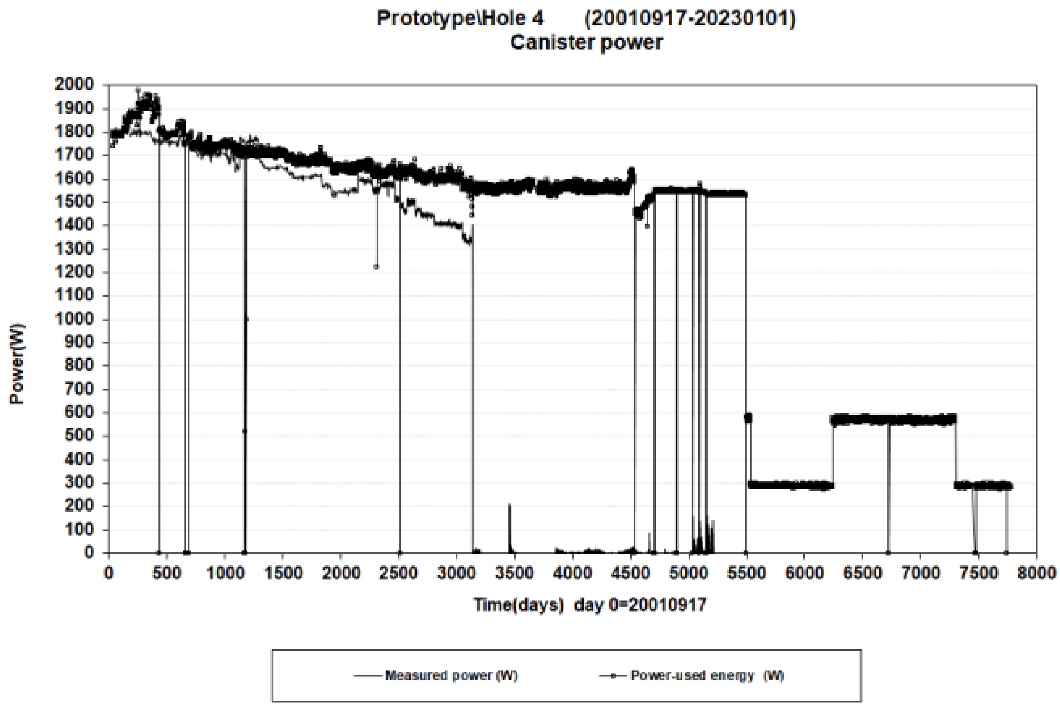


Figure 4-1. The applied power in the canister in deposition hole 4 (Goudarzi 2023).

4.1.2 Water inflow

The measured water inflow to this deposition hole was small, 0.0007 l/min, Table 2-1. Mapping of water-bearing fractures was made in January 2000 (Rhén and Forsmark 2001). The inflow from four water bearing fractures was measured, see shaded areas in Figure 2-3 (right). The inflow from these fractures varied between 0 and 5.1 x 10^{-5} l/min (Rhén and Forsmark 2001).

4.1.3 Dismantling of Deposition hole 4 (Dh4)

This was the first deposition hole that was dismantled in Section 1. The sampling of the buffer in Deposition hole 4 was performed during the period April-August 2023.

The density and water content were determined in all fourteen buffer blocks including the pellet filled gap between block and rock surface. The sampling was made in eight directions, see detailed description in Chapter 3. In total, the density and water content were planned to be determined in approximately 4600 positions in Deposition hole 4.

4.2 Results from sampling of all buffer blocks in Dh4

The results from the sampling are presented in the same order as the dismantling of the deposition hole proceeded i.e., the first block that was sampled was the block closest to the backfill, block C4.

Several graphs were produced for every single block to present the data determined. In addition, contour plots were generated by DPLot (ARA, Applied Research Associates). The denomination of the appendices begins with a sequential number and in the appendices beginning with 1 the following graphs and plots (a-d) are produced for all blocks n (1-14) in Dh4:

- Appendix 1-n (1-14) a. Results from sampling in eight directions on the level 50 mm below the block surface. The graphs show the water content, the dry density, and the degree of saturation distribution. In the graphs, a red line indicates the initial water content, dry density, and the degree of saturation respectively.
- Appendix 1-n (1-14) b. Results from sampling in direction 20°. The sampling was done at five levels below the block surface (50, 150, 250, 350, and 450 mm). The graphs show the water content, the dry density, and the degree of saturation distribution.
- Appendix 1-n (1-14) c. Results from sampling in direction 245°. The sampling was done at five levels below the block surface (50, 150, 250, 350, and 450 mm). The graphs show the water content, the dry density, and the degree of saturation distribution.
- Appendix 1-n (1-14) d. Contour plots showing the water content, the dry density, and the degree of saturation distribution on the level 50 mm down from the block surface.

A contour plot showing the water content distribution is provided for every single block in this chapter together with a picture showing the fracture mapping of the deposition hole.

The sample coordinates used in the graphs (radius and directions in degrees) are described in Section 3.1.

4.2.1 Block C4 (uppermost block)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 1-1 (a-d). The determined water content distribution for block C4 is provided in Figure 4-2 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C4:

- **Dry density**. The dry density was low, mainly between 1300-1420 kg/m^3 (50 mm from block surface) and up to 1480 kg/m^3 at the lowest level (450 mm from block surface). This indicates that the block has swelled upwards, compacting the backfill above, and by that the density has decreased. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that there was an obvious difference in density between the different levels (higher density at higher depth) which also indicated that the block had swelled upwards.
- **Degree of saturation**. The degree of saturation was in general high, between 99 and 100 %.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a certain difference in density between the central parts of the block and the parts close to the periphery.
- **Deviations**. At some spots, in the contact zone to the rock, the bentonite samples were not saturated. These spots had a low water content and a rather high dry density, compared to the initial density of the pellets in the former gap. It is believed that these samples, to some extent, have been mixed with the backfill material above, which means that there might be pieces of rock material mixed with the clay (the same phenomenon have been seen in all deposition holes for the uppermost blocks).

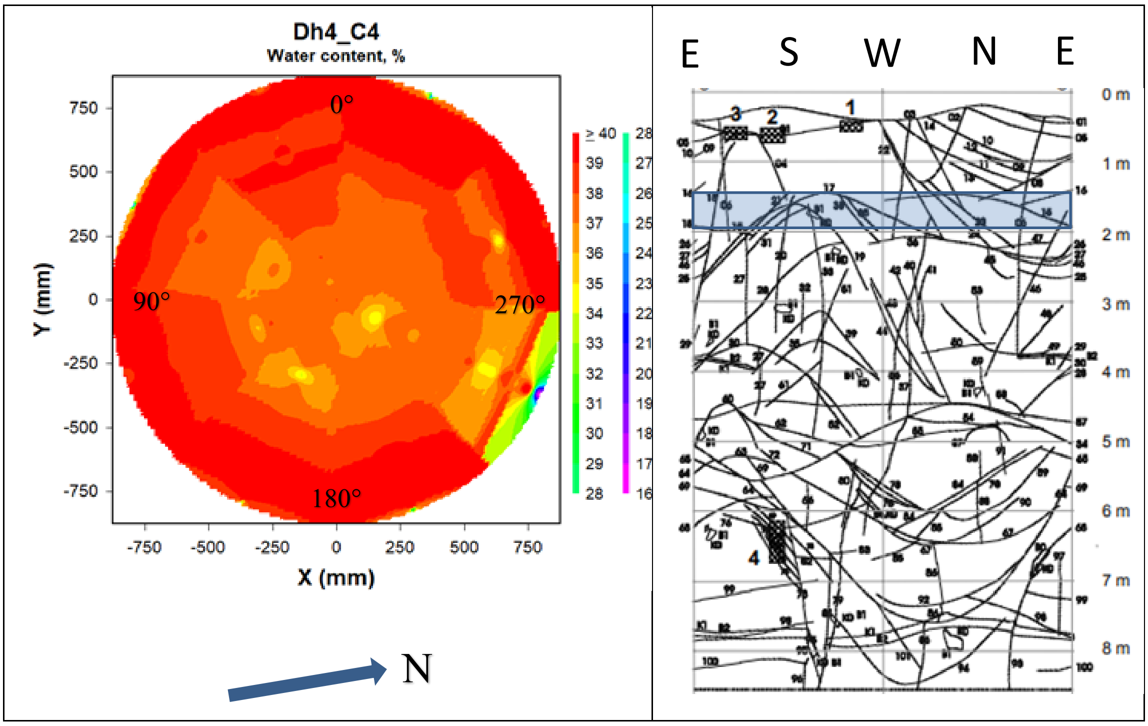


__Figure 4-2.__ Left: Contour plot showing the water content distribution in block C4 in deposition hole 4. The degrees given are those used for sampling. Right: Fracture mapping in deposition hole No 4. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C4 relative to the fractures.

4.2.2 Block C3 (above the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 1-2 (a-d). The sampling from the former gap at five depths was made in the directions 20° and 200° (instead of 20° and 245°), see Appendix 1-2c. The determined water content distribution for block C3 is provided in Figure 4-3 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C3:

- **Dry density**. The dry density was clearly higher compared to block C4. The dry density was mainly between 1400-1500 kg/m^3 on the upper level (50 mm from block surface) and up to 1550 kg/m^3 at the lowest level (450 mm from block surface). The determined density is rather low compared to what is expected around the canister. This indicates that also this block has been affected by the upward swelling. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that there was an obvious difference in density between the different levels (higher density at higher depth) which also was an indication that this block had swelled upwards.

- **Degree of saturation**. The degree of saturation was in general high, between 98 and 100 %. However, in the central parts of the block, the degree of saturation was somewhat lower, between 96-98 %.

- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a certain difference in density between the central parts of the block and the parts close to the periphery. It was also clear that the dry density was somewhat lower at the periphery in directions between 155 to 245°.

- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap.

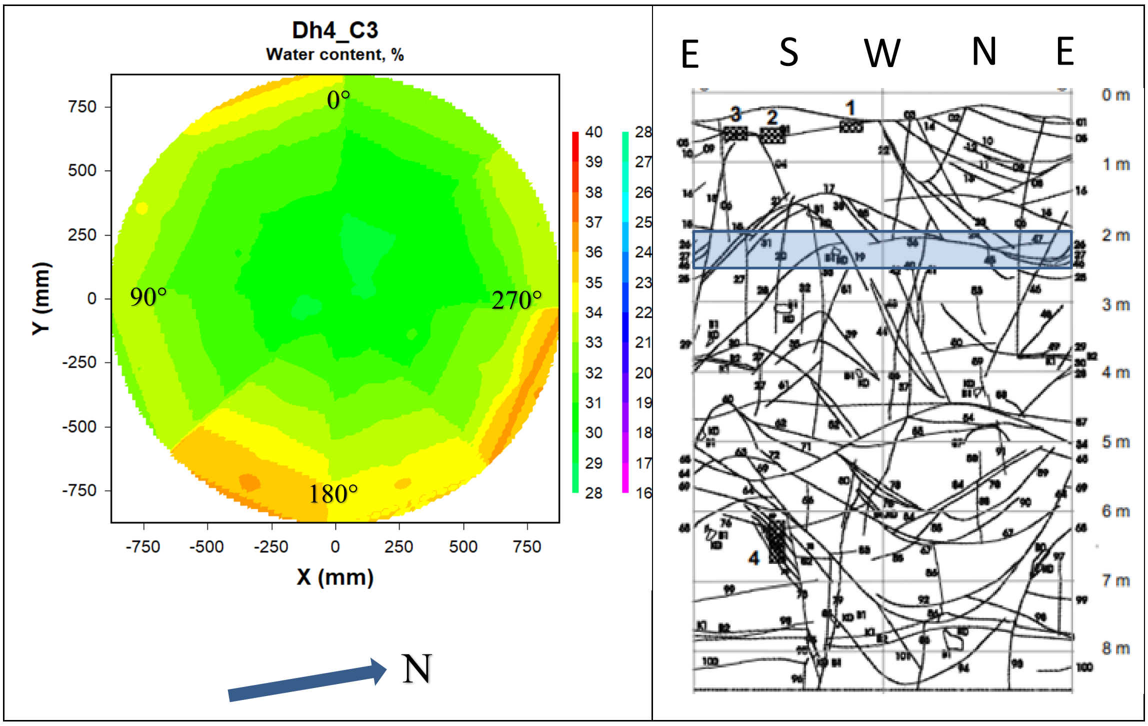


__Figure 4-3.__ Left: Contour plot showing the water content distribution in block C3 in deposition hole 4. The degrees given are those used for sampling. Right: Fracture mapping in deposition hole No 4. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C3 relative to the fractures.

4.2.3 Block C2 (above the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 1-3 (a-d). The determined water content distribution for block C2 is provided in Figure 4-4 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C2:

- **Dry density**. The dry density was somewhat higher compared to block C3. The dry density was mainly between 1420-1575 kg/m^3. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was smaller compared to block C3 and C4.
- **Degree of saturation**. The degree of saturation varied in this block. The peripheral parts in direction 155-270° had a rather high degree of saturation, between 98 to 100 %, while the peripheral parts in the other directions had a somewhat lower degree of saturation, between 95 to 98 %. The degree of saturation in the central parts of the block was between 92-95 %.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a certain difference in density between the central parts of the block and the parts close to the periphery. The dry density was somewhat lower at the periphery in the directions of 155 to 245°.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap.

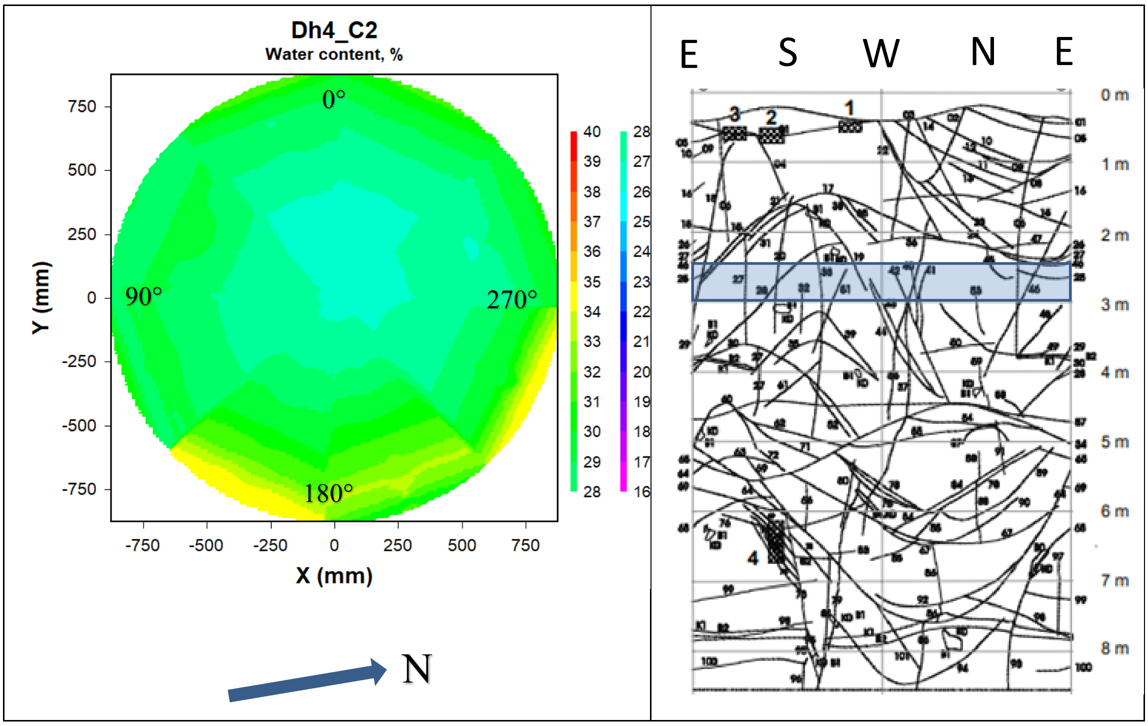


Figure 4-4. Left: Contour plot showing the water content distribution in block C2 in deposition hole 4. The degrees given are those used for sampling. Right: Fracture mapping in deposition hole No 4. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C2 relative to the fractures.

4.2.4 Block R10 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 1-4 (a-d). The determined water content distribution for block R10 is provided in Figure 4-5 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R10:

- **Dry density**. The dry density was somewhat higher compared to the cylindrical blocks above. The dry density varied mainly between 1500-1680 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied between 94 to 100 %. The lowest degree of saturation was found close to the canister in the directions of 20° and 65°.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest dry density values were found in the directions of 155-245°.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

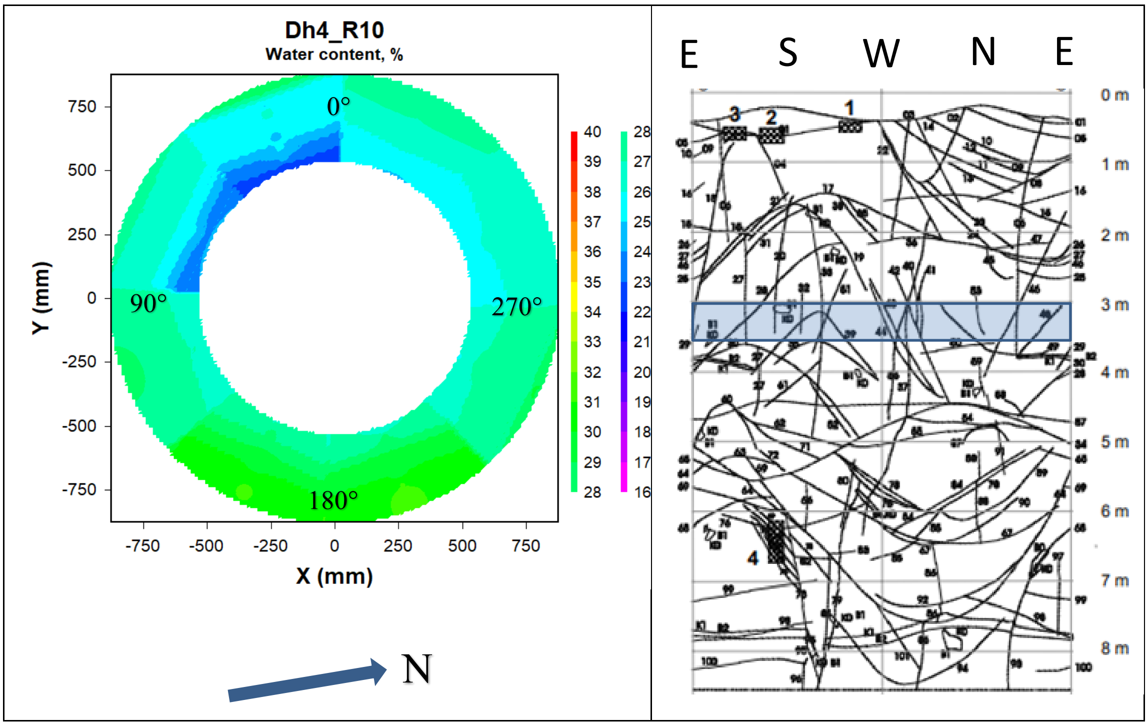


Figure 4-5. Left: Contour plot showing the water content distribution in block R10 in deposition hole 4. The degrees given are those used for sampling. Right: Fracture mapping in deposition hole No 4. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R10 relative to the fractures.

4.2.5 Block R9 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 1-5 (a-d). The determined water content distribution for block R9 is provided in Figure 4-6 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R9:

- **Dry density**. The dry density varied mainly between 1500-1650 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied mainly between 96 to 100 %. The lowest degree of saturation was found in the directions of 20 and 65° and at some spots close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest dry density values were found in the directions of 155 and 200°.
- **Deviations**. The results from the water content and density determinations were in general consistent. No sampling of the end-pieces was made in the direction of 20°, neither against the rock wall nor against the canister. Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

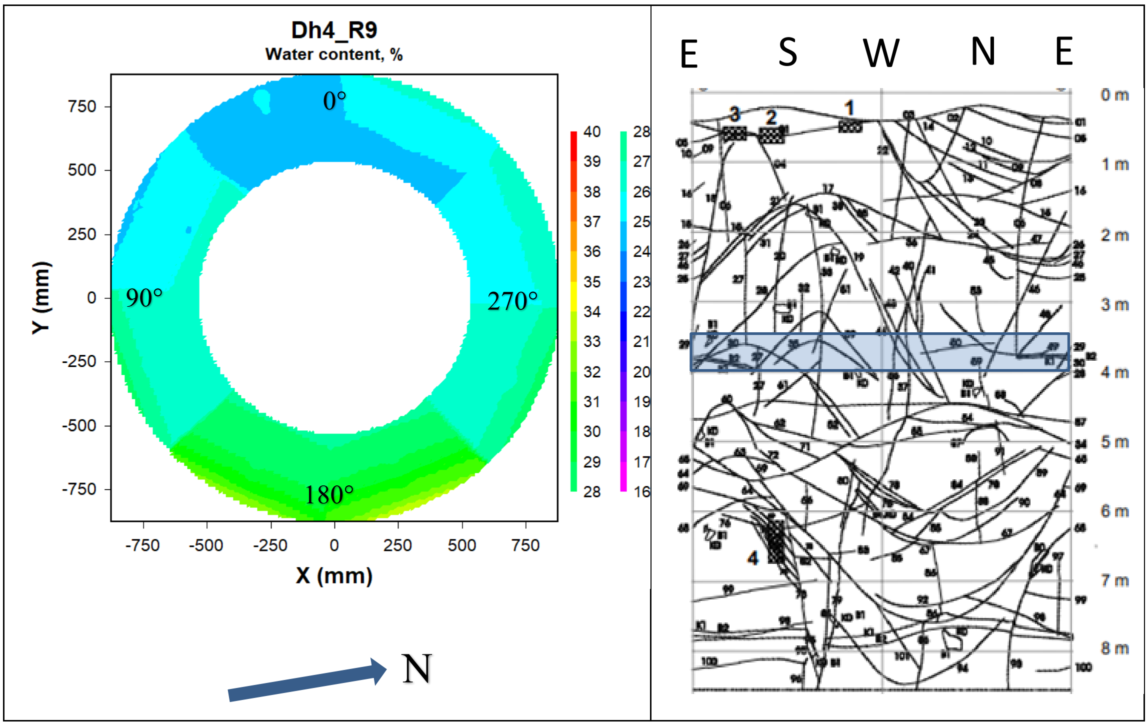


Figure 4-6. *Left: Contour plot showing the water content distribution in block R9 in deposition hole 4. The degrees given are those used for sampling. Right: Fracture mapping in deposition hole No 4. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R9 relative to the fractures.*

4.2.6 Block R8 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 1-6 (a-d). The determined water content distribution for block R8 is provided in Figure 4-7 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R8:

- **Dry density**. The dry density varied mainly between 1550-1660 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied between 95 to 100 %. The lowest degree of saturation was found in the direction of 20° and at some spots close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest dry density values were found in the directions of 155 and 200°.
- **Deviations**. The results from the water content and density determinations were in general consistent. No sampling of the end-pieces in direction 110° against the rock wall were made (same positions as where the large test sample that should be used for different laboratory tests was taken). Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

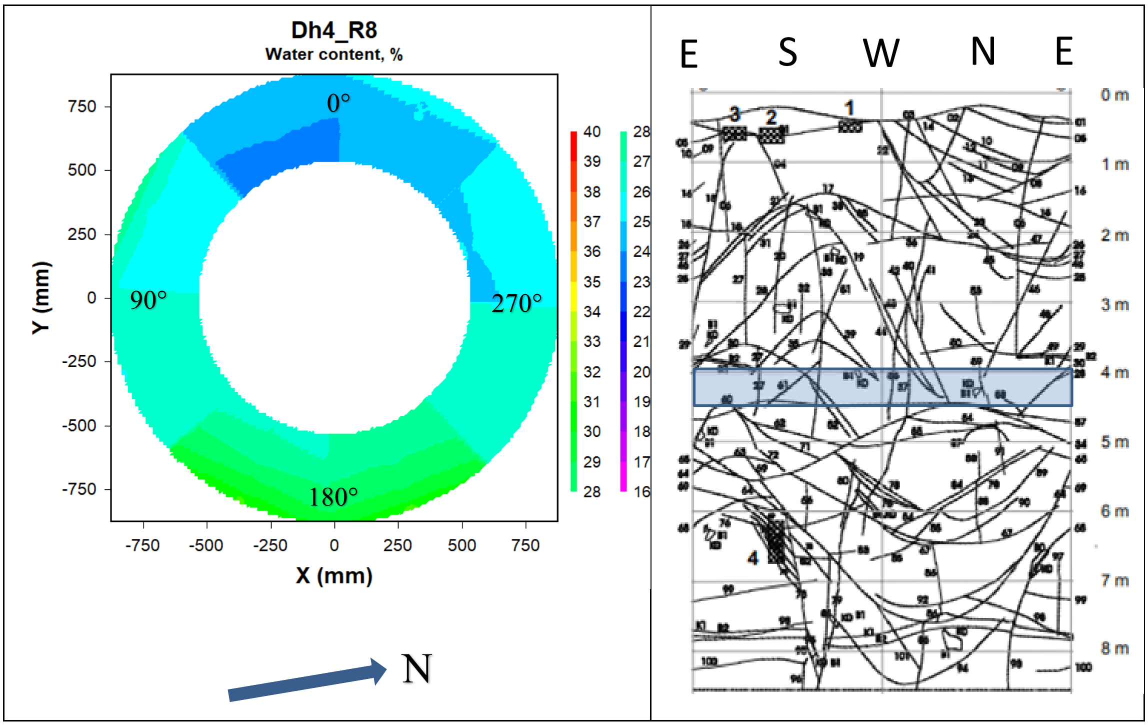


Figure 4-7. Left: Contour plot showing the water content distribution in block R8 in deposition hole 4. The degrees given are those used for sampling. Right: Fracture mapping in deposition hole No 4. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R8 relative to the fractures.

4.2.7 Block R7 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 1-7 (a-d). The determined water content distribution for block R7 is provided in Figure 4-8 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R7:

- **Dry density**. The dry density was somewhat higher than in the block above, R8. The dry density varied mainly between 1550-1690 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied between 96 to 100 %. The lowest degree of saturation was found in the directions of 20 and 65° and at some spots close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest dry density values were found in the directions of 155 and 200°.
- **Deviations**. The results from the water content and density determinations were in general consistent. No sampling of the end-pieces in direction 200° was made, neither against the rock wall or against the canister (same positions as where the large test sample that should be used for different laboratory tests was taken).

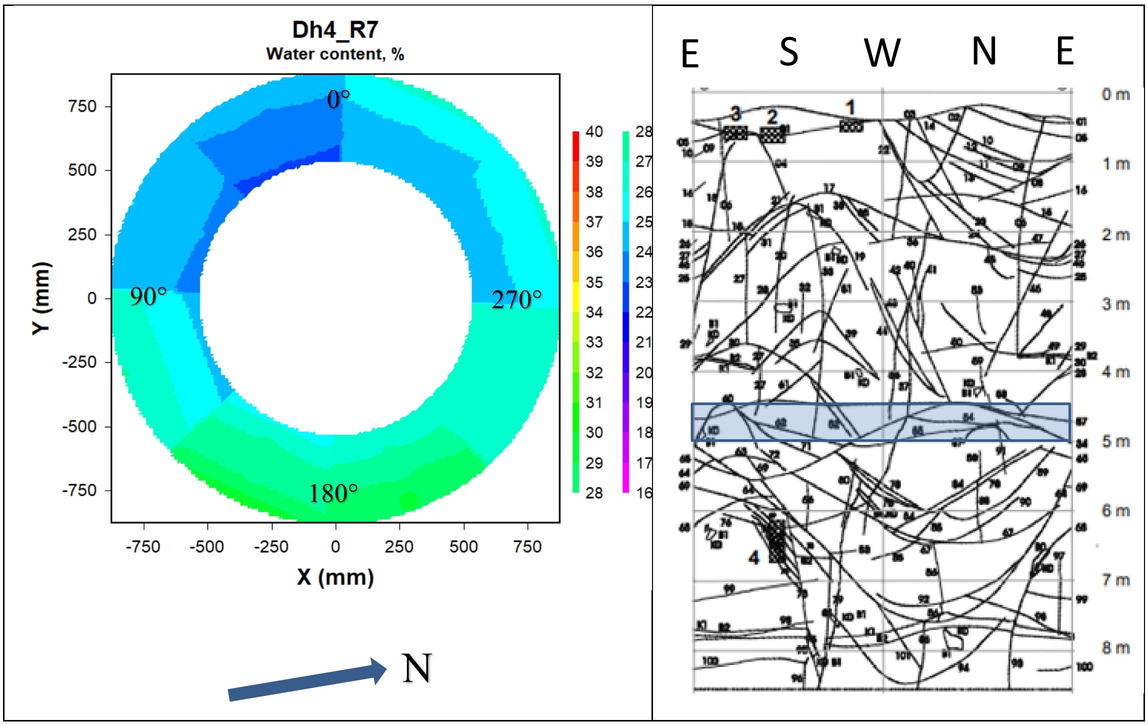


Figure 4-8. Left: Contour plot showing the water content distribution in block R7 in deposition hole 4. The degrees given are those used for sampling. Right: Fracture mapping in deposition hole No 4. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R7 relative to the fractures.

4.2.8 Block R6 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 1-8 (a-d). The determined water content distribution for block R6 is provided in Figure 4-9 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R6:

- **Dry density**. The dry density was in the same range as the block above, R7, mainly between 1570-1680 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied between 95 to 100 %. The lowest degree of saturation was found in some spots close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest dry density values were found in the directions of 155 and 200°.
- **Deviations**. The results from the water content and density determinations were in general consistent. No sampling of the end-pieces in direction 290° was made, neither against the rock wall nor against the canister. Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

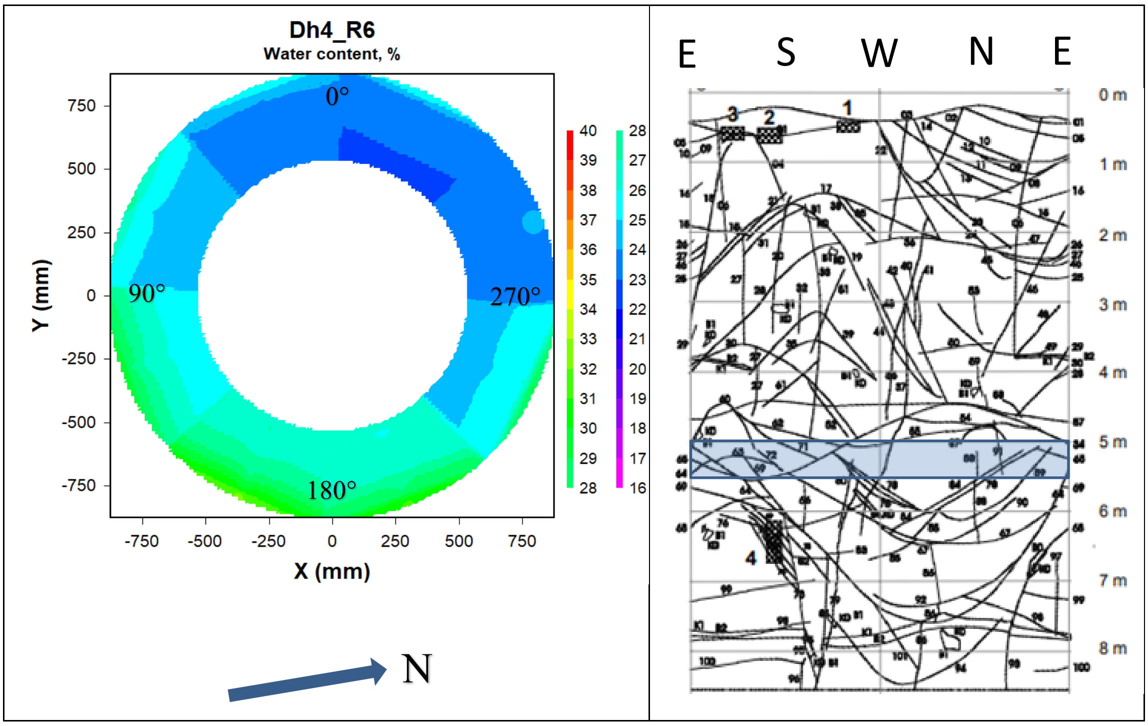


Figure 4-9. *Left: Contour plot showing the water content distribution in block R6 in deposition hole 4. The degrees given are those used for sampling. Right: Fracture mapping in deposition hole No 4. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R6 relative to the fractures.*

4.2.9 Block R5 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 1-9 (a-d). The determined water content distribution for block R5 is provided in Figure 4-10 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R5:

- **Dry density**. The dry density was in the same range as the block above, R6, mainly between 1530-1700 kg/m³. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied between 95 to 100 %. The lowest degree of saturation was found in the directions of 290° and 335° and at some spots close to the canister. The highest water contents, and lowest density values, were found in a south-easterly direction (approximately between 90-180°), i.e. in the same directions as where the water bearing fractures at this depth are situated.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

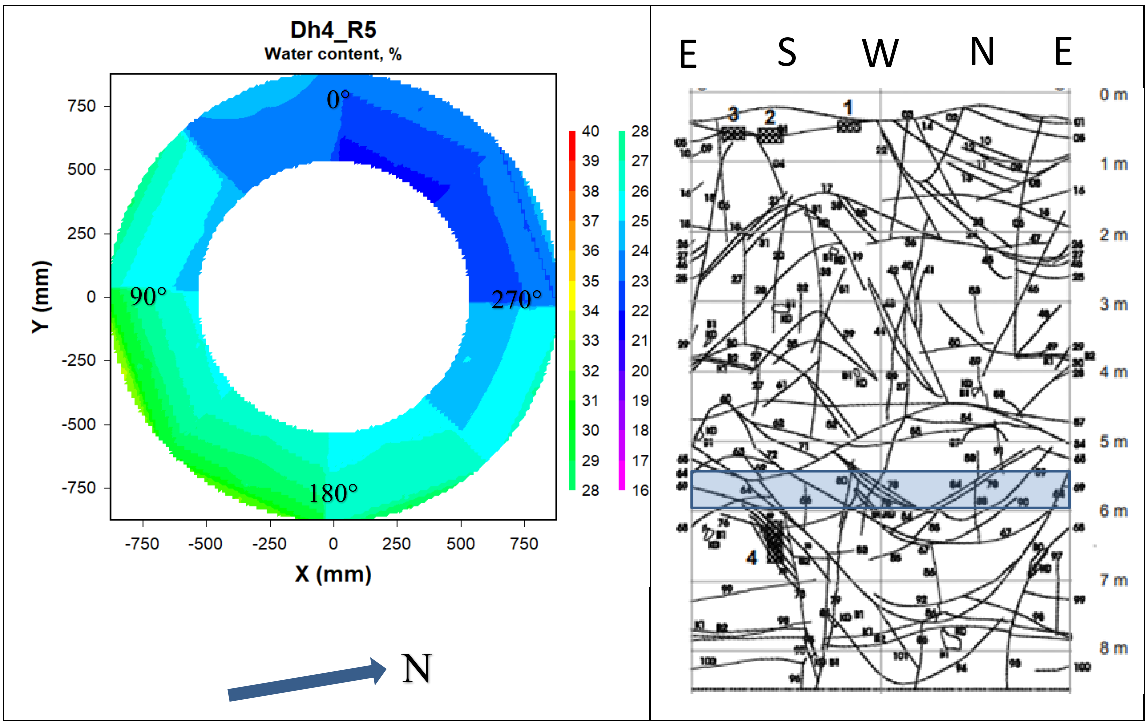


__Figure 4-10.__ Left: Contour plot showing the water content distribution in block R5 in deposition hole 4. The degrees given are those used for sampling. Right: Fracture mapping in deposition hole No 4. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R5 relative to the fractures.

4.2.10 Block R4 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 1-10 (a-d). The determined water content distribution for block R4 is provided in Figure 4-11 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R4:

- **Dry density**. The dry density varied mainly between 1550-1720 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. Some minor differences in density between the different levels were found.
- **Degree of saturation**. The degree of saturation varied quite a lot in this block, between 80 to 100 %. The lowest degree of saturation was found in the directions of 290 and 335°. The graphs also indicate that the degree of saturation was lower at the depths of 350 and 450 mm (direction 20° and 245°) from the block surface.
- **Homogenization**. In this block there were rather large differences in density between the different directions. The highest water contents, and lowest density values, were found in a south-easterly direction (approximately between 110-200°), i.e. in the same directions as where the water bearing fractures at this depth are situated.
- **Deviations**. The results from the water content and density determinations were in general consistent. The sampling of the end-pieces in direction 200° and 245° was limited, both against the rock wall and against the canister.

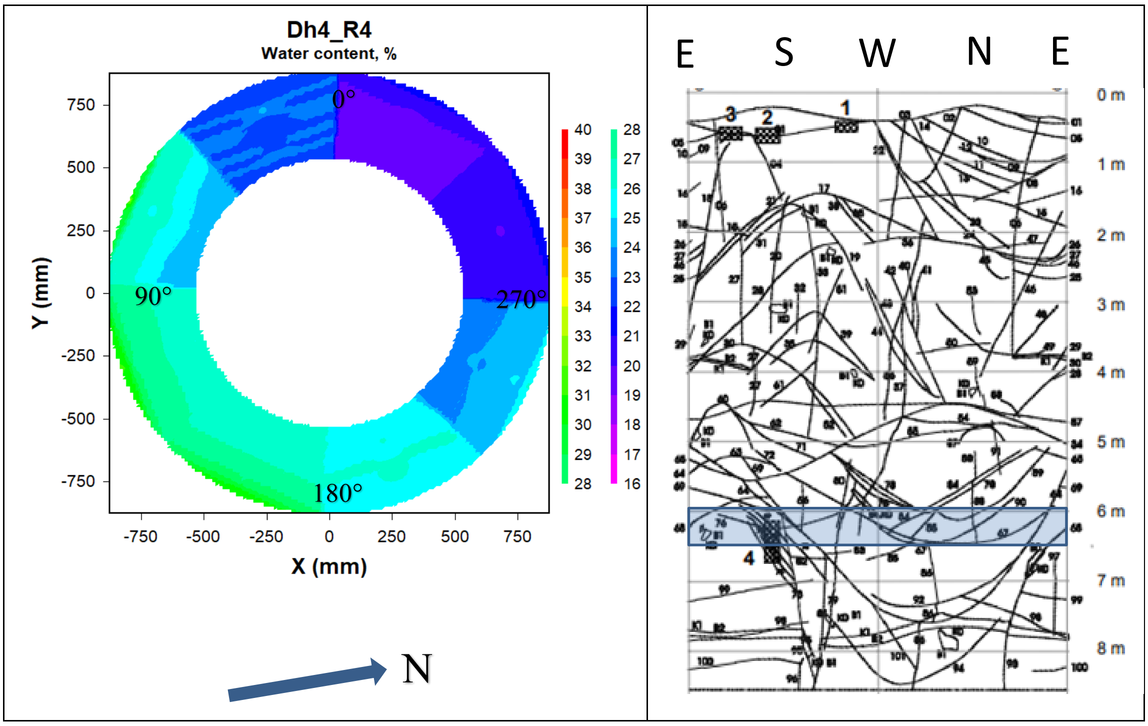


Figure 4-11. *Left: Contour plot showing the water content distribution in block R4 in deposition hole 4. The degrees given are those used for sampling. Right: Fracture mapping in deposition hole No 4. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R4 relative to the fractures.*

4.2.11 Block R3 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 1-11 (a-d). The determined water content distribution for block R3 is provided in Figure 4-12 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R3:

- **Dry density**. The dry density varied largely for the different directions, between 1580-1800 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. Only some minor differences in density between the different levels were found.
- **Degree of saturation**. The degree of saturation varied quite a lot in this block, between 80 to 100 %. The lowest degree of saturation was found in directions 290 and 335°. The graphs also indicate that the degree of saturation was lower at the depths of 350 and 450 mm (direction 20° and 245°) from the block surface.
- **Homogenization**. In this block there were rather large differences in density between the different directions. The highest water contents, and lowest density values, were found in a south-easterly direction (approximately between 110-200°), i.e. in the same directions as where the water bearing fractures at this depth are situated.
- **Deviations**. The results from the water content and density determinations were in general consistent. The sampling of the end-pieces in direction 200° and 335° was limited, both against the rock wall and against the canister.

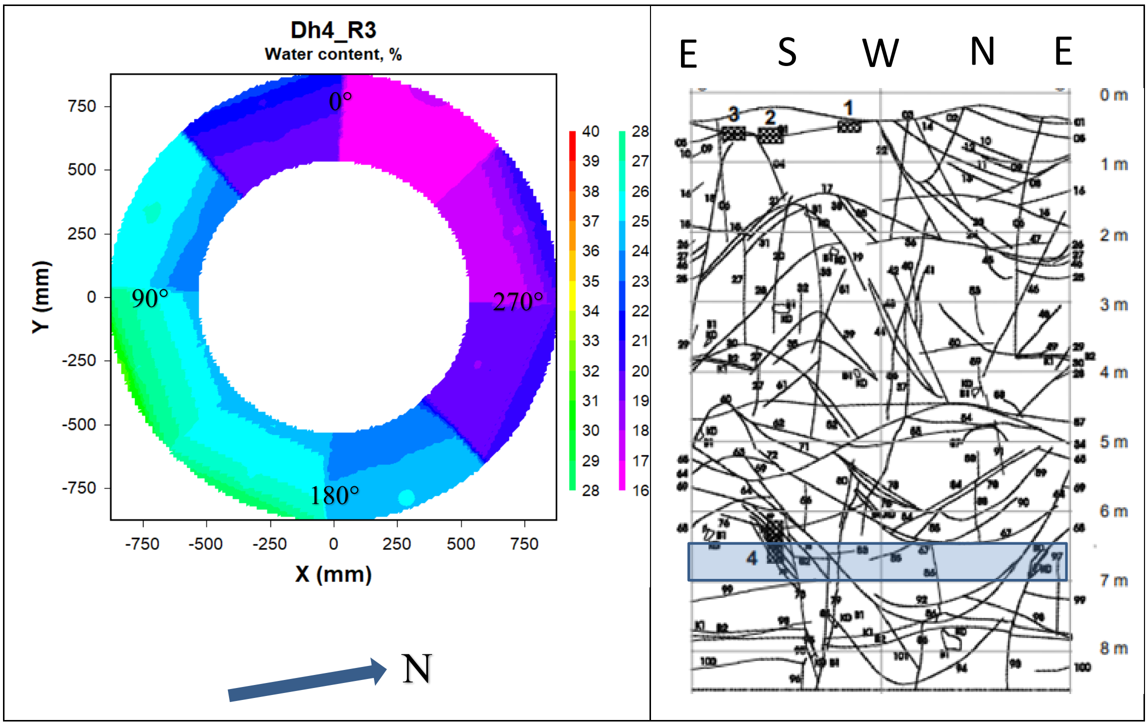


Figure 4-12. Left: Contour plot showing the water content distribution in block R3 in deposition hole 4. The degrees given are those used for sampling. Right: Fracture mapping in deposition hole No 4. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R3 relative to the fractures.

4.2.12 Block R2 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 1-12 (a-d). The determined water content distribution for block R2 is provided in Figure 4-13 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R2:

- **Dry density**. The dry density varied largely for the different directions, between 1580-1820 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied quite a lot in this block, between 67 to 100 %. The lowest degree of saturation was found in directions 20, 200, 245, 290 and 335°.
- **Homogenization**. In this block there were rather large differences in density between the different directions. The highest water contents, and lowest density values, were found in the directions of approximately between 65-155°, i.e. in the same directions as where the water bearing fractures at this depth are situated.
- **Deviations**. The results from the water content and density determinations were in general consistent. The sampling of the end-pieces in direction 20, 245 and 290° was limited, both against the rock wall and against the canister (dry pellets).

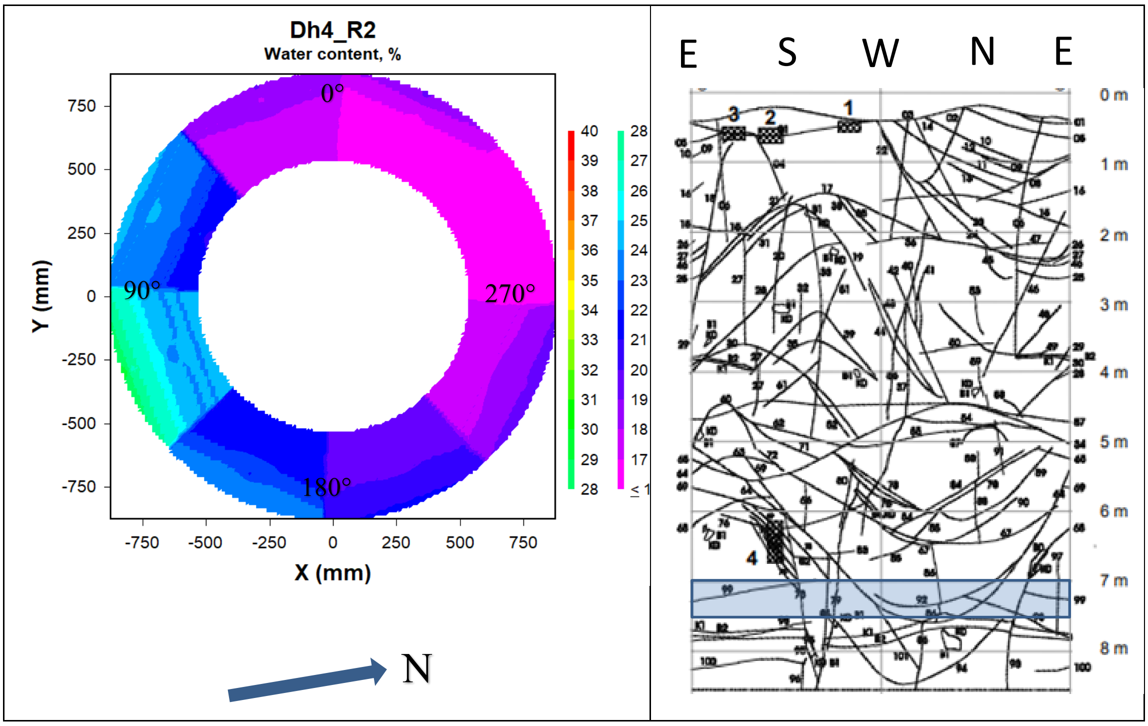


Figure 4-13. Left: Contour plot showing the water content distribution in block R2 in deposition hole 4. The degrees given are those used for sampling. Right: Fracture mapping in deposition hole No 4. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R2 relative to the fractures.

4.2.13 Block R1 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 1-13 (a-d). The determined water content distribution for block R1 is provided in Figure 4-14 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R1:

- **Dry density**. The dry density varied largely for the different directions, between 1650-1800 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied quite a lot in this block, between 67 to 100 %. The lowest degree of saturation was found in the directions of 245, 290 and 335°. The highest water contents, and lowest density values, were found in a southeasterly direction (between 90-180°) i.e., in the same directions as where the water bearing fractures at this depth are situated, but just below.
- **Homogenization**. In this block there were rather large differences in density between the different directions. The highest water contents, and lowest density values, were found in the directions of approximately between 65-200°.
- **Deviations**. The results from the water content and density determinations were in general consistent. The sampling of the end-pieces in direction 20 and 245° was limited, both against the rock wall and against the canister.

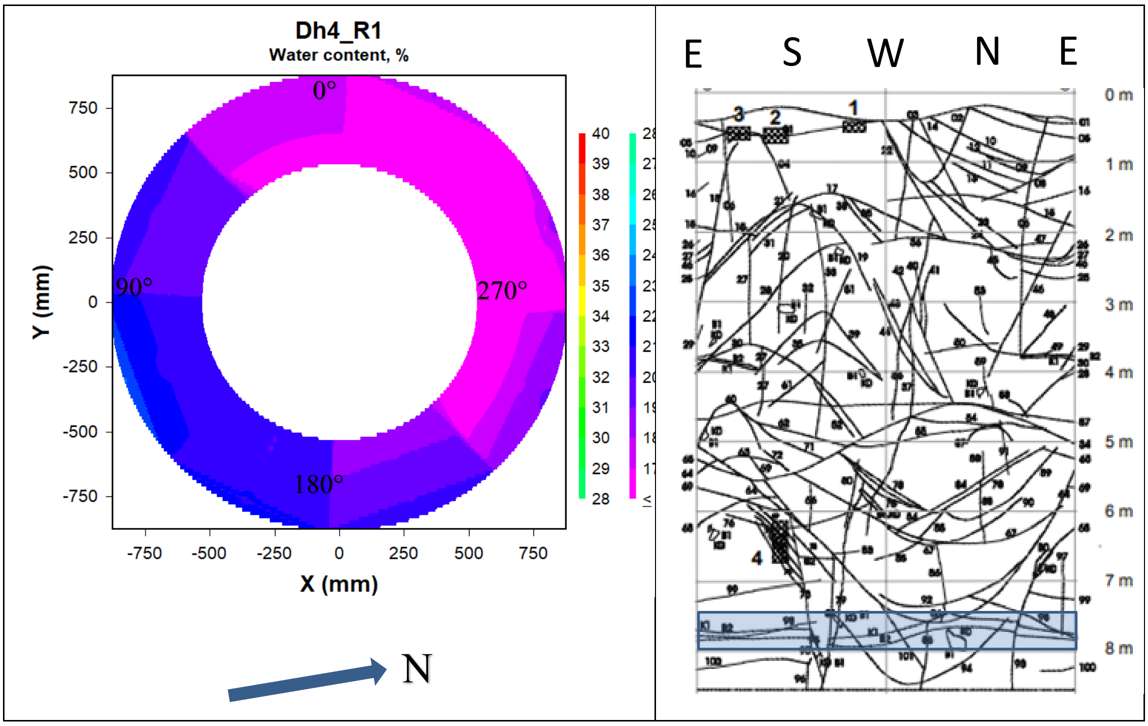


Figure 4-14. Left: Contour plot showing the water content distribution in block R1 in deposition hole 4. The degrees given are those used for sampling. Right: Fracture mapping in deposition hole No 4. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R1 relative to the fractures.

4.2.14 Block C1 (below the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 1-14 (a-d). The determined water content distribution for block C1 is provided in Figure 4-15 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C1:

- **Dry density**. The dry density varied largely for the different directions, between 1630-1720 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was very small.
- **Degree of saturation**. The degree of saturation was rather low in this block, mainly between 77 to 87 %. The lowest degree of saturation was found in the outer pellet filled gap.
- **Homogenization**. The density was rather similar in all directions. The large differences were between the block and the pellet filled gap. The highest water contents, and lowest density values, were found in the directions of 155 and 200°.
- **Deviations**. The results from the water content and density determinations were in general consistent. The sampling of the end-pieces in direction 110 and 155° was limited.

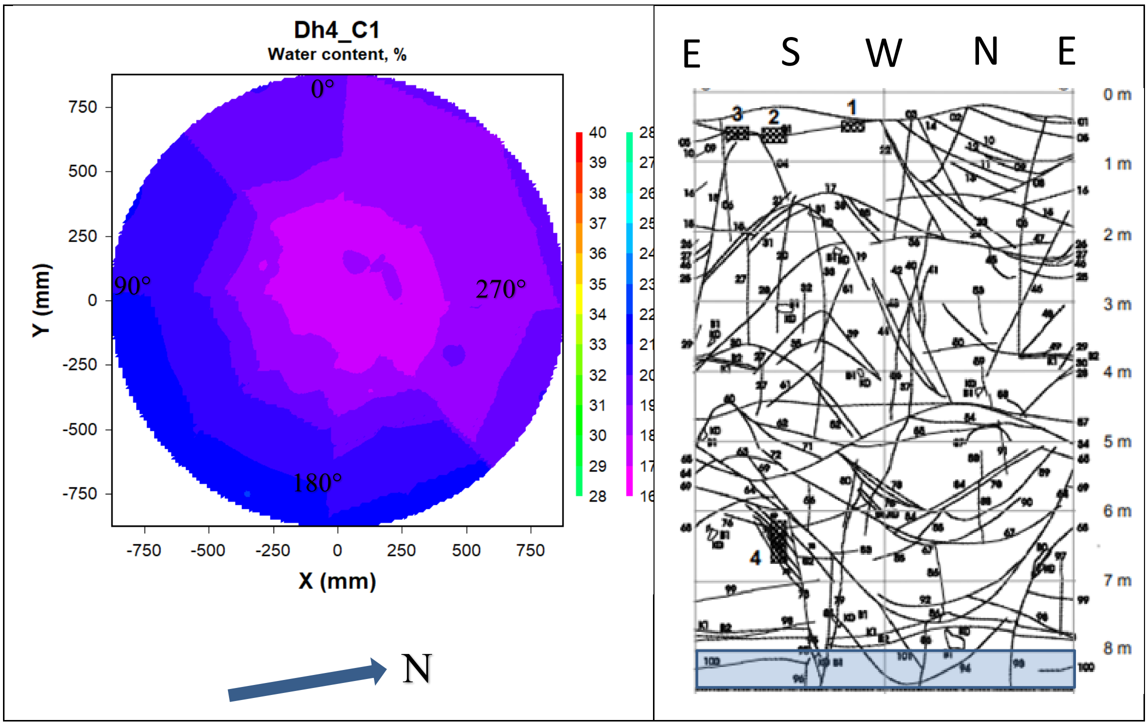


__Figure 4-15.__ Left: Contour plot showing the water content distribution in block C1 in deposition hole 4. The degrees given are those used for sampling. Right: Fracture mapping in deposition hole No 4. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C1 relative to the fractures.

4.3 Summary of results from Dh4

4.3.1 Access to water

The buffer blocks in the deposition holes have had access to water both from fractures in the rock and via the backfill above the deposition hole.

The fracture mappings for all deposition holes are provided in Figure 2-2 and Figure 2-3, and the measured inflows are listed in Table 2-1. The inflow rate to deposition hole 4 was determined to 0.0007 l/min. This was the deposition hole with the lowest inflow. The identified water bearing fractures are positioned in southeast direction (approximately in directions between 100-150°, see description of the α angle used for the sampling in Figure 3-4), at depths of 0.5 meter and 6 to 7 meters.

The water bearing fractures positioned at a depth of between 6 to 7 meters may have contributed to the buffer saturation locally. The water content at this depth and in the directions between 90-180° was somewhat higher than the other parts of the blocks (see Section 4.2.9 to 4.2.11 for description of block R5, R4 and R3).

The registered pore pressure in the backfill was for almost seven years between 0.4 to 1.4 MPa and after that for a period of more than five years between 1.9 to 2.4 MPa (Goudarzi 2023). Since the hydraulic conductivity of the backfill is considerably higher than for the buffer material (k for the backfill is between 10^{-10} to 10^{-9} m/s for the central parts of the tunnel and considerably higher close to the rock, see Johannesson et al. 1999), it is believed that water flowing from the backfill down to the buffer has greatly contributed to the saturation of the buffer.

4.3.2 Compilation of data

To give a picture of the status of the complete deposition hole (see Appendix 1-nm for all blocks n and diagrams m) regarding water content, dry density, and degree of saturation distribution, two different methods have been used:

1. The individual contour plots of every single block (sampling level 50 mm below upper surface) have been compressed and stacked on each other, Figure 4-16. These figures give a rather good picture of the water content, the dry density, and the degree of saturation distribution for the complete deposition hole.
2. Contour plots were generated by DPlot. The plots are showing the water content, the dry density and the degree of saturation distribution in eight vertical cross-sections of deposition hole 4, Figure 4-17, Figure 4-18 and Figure 4-19. The first plot in each figure shows the distribution in direction 20° and 245°. In these two directions the water content and density were determined at five levels in each block. The amount of data used for these plots gives thus a very good picture of the water content, dry density and degree of saturation distribution. The second plot shows the distribution in direction 65° and 200°, the third plot shows the distribution in direction 110° and 290°, and the fourth plot shows the distribution in direction 155° and 335°. In these other six directions, the water content and density were determined at one level in each block. It should be noted that in the plots, nominal values of the vertical sampling position in each block have been used (i.e., no compensation has been made for the vertical swelling).

The following conclusions can be made from the figures:

- Block C4 and C3 (top blocks). Both these blocks had swelled axially and by that decreased the density. The dry density for block C4 was mainly between 1300 and 1400 kg/m^3 and for block C3 between 1400 and 1500 kg/m^3. Both blocks were largely water saturated. The degree of saturation was, however, somewhat lower in the central parts of block C3, approximately between 96 to 98 %.
- Block C2 (block above canister). This block had also swelled axially and by that decreased in density. The dry density for this block was mainly between 1420 and 1560 kg/m^3. The degree of saturation was mainly between 94 to 98 %, and only the peripheral parts were completely saturated. This was probably an effect of the temperature from the canister.

- Block R10-R5 (ring-shaped blocks along the upper half of the canister). These blocks did not seem to be especially affected by any axial swelling. The dry density varied mainly between 1500 and 1700 kg/m^3 depending on direction. The blocks were largely water saturated, between 98 and 100 %, but there were some parts where the degree of saturation was lower, between 94 and 98 %. The parts with the lowest degree of saturation were mainly in the directions between 270 and 90° (some variations), i.e., the upper part of the contour-plots (Appendix 1-4d to 1-9d).
- Block R4-R1 (ring-shaped blocks along the lower half of the canister). The degree of saturation varied a lot between the different directions for these blocks. The degree of saturation varied between 80 and 100 % for block R4 and R3 while the degree of saturation was as low as 67 % for parts of block R2 and R1. The dry density of the blocks varied mainly between 1600 and 1800 kg/m^3. It was obvious that the homogenization had not proceeded far since it was still possible to identify individual pellets in the gap between block and rock at several positions.
- Block C1 (block below canister). The degree of saturation varied between 77 and 87 % for the complete block and was even lower in the pellet filled gap. The block was rather homogeneous, and the dry density varied mainly between 1650 and 1720 kg/m^3. The density of the central parts of the block was close to the original density of the block.
- Differences in density and degree of saturation can be seen in different directions, see e.g., ring shaped blocks R1 to R4, but the large differences can be seen at different depths of the deposition hole.

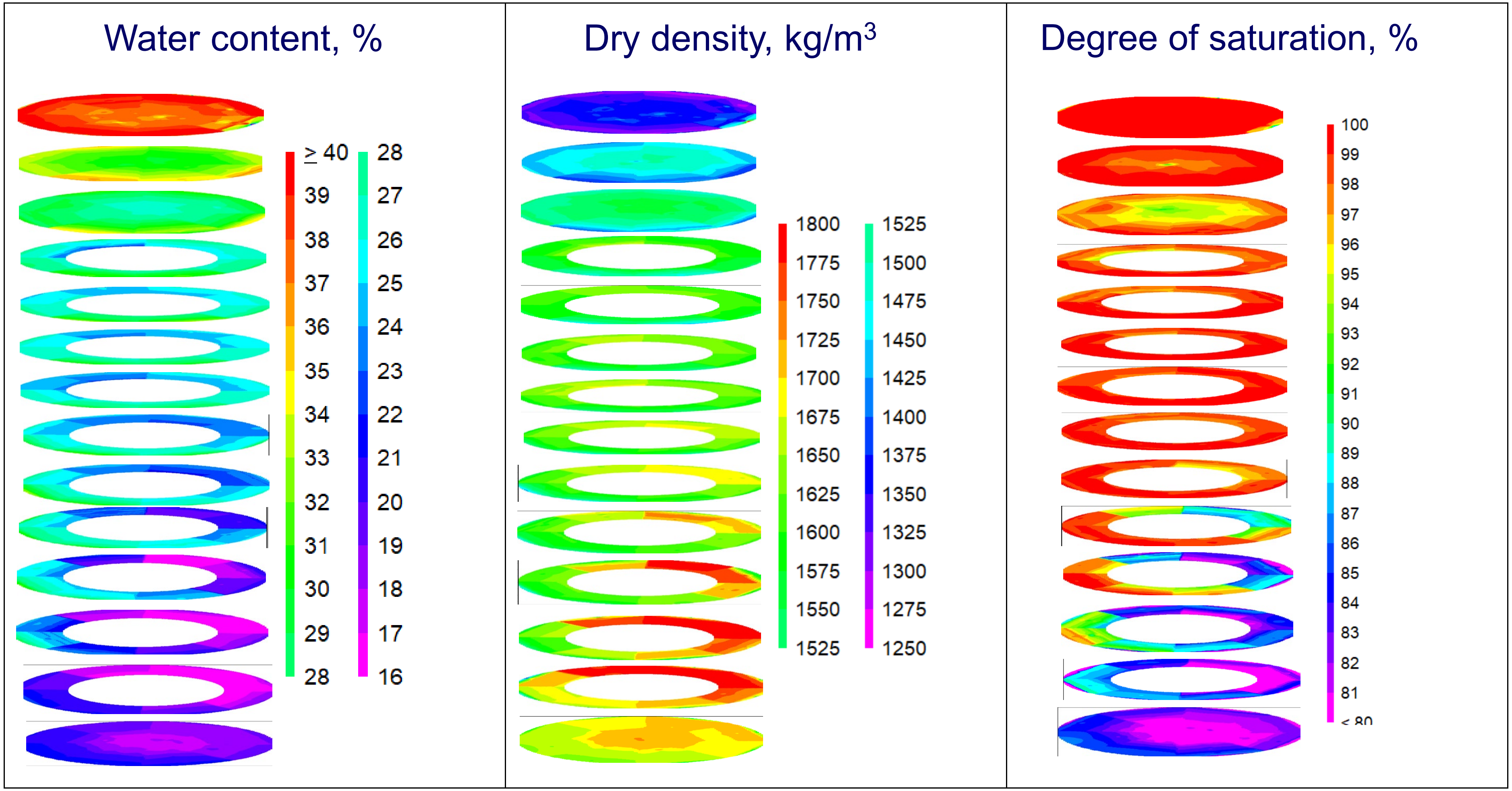


Figure 4-16. *Compressed contour plots of every single block in Dh 4 stacked on each other. Left: the water content distribution (%) Middle: the dry density distribution (kg/m³) Right: the degree of saturation distribution (%).*

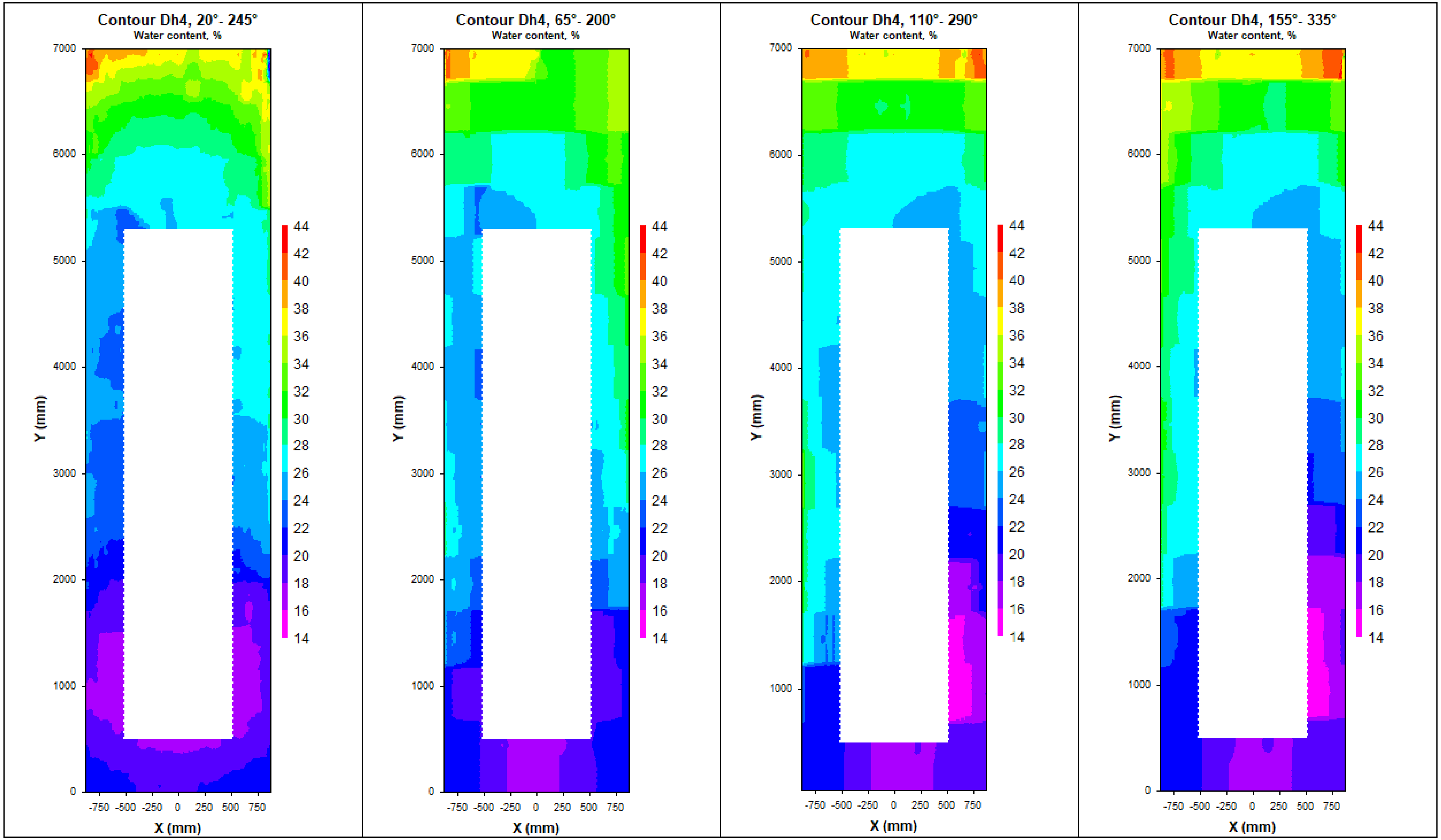


Figure 4-17. *Four contour plots showing the water content distribution in eight vertical cross-sections of deposition hole 4.*

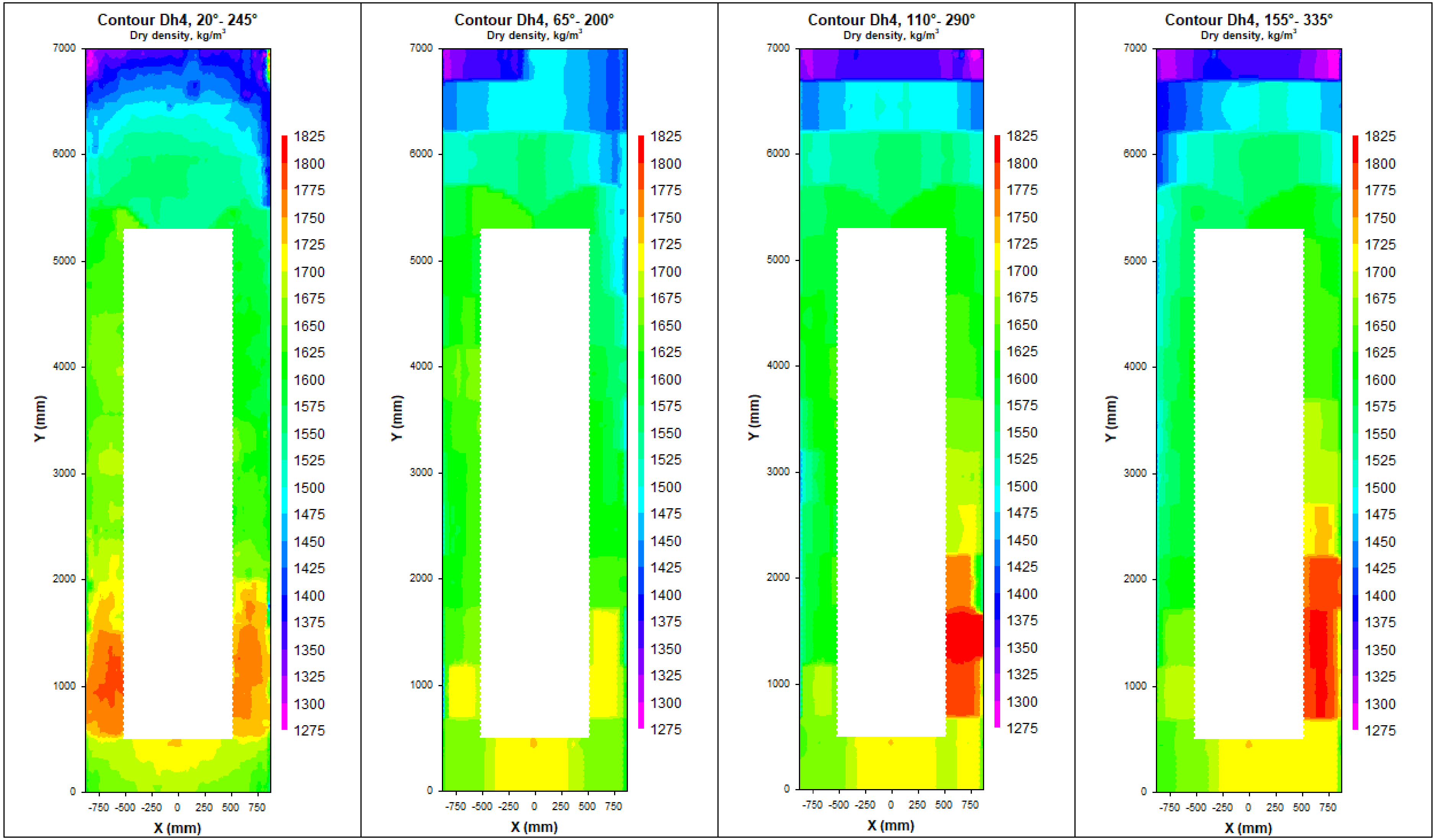


Figure 4-18. *Four contour plots showing the dry density distribution in eight vertical cross-sections of deposition hole 4.*

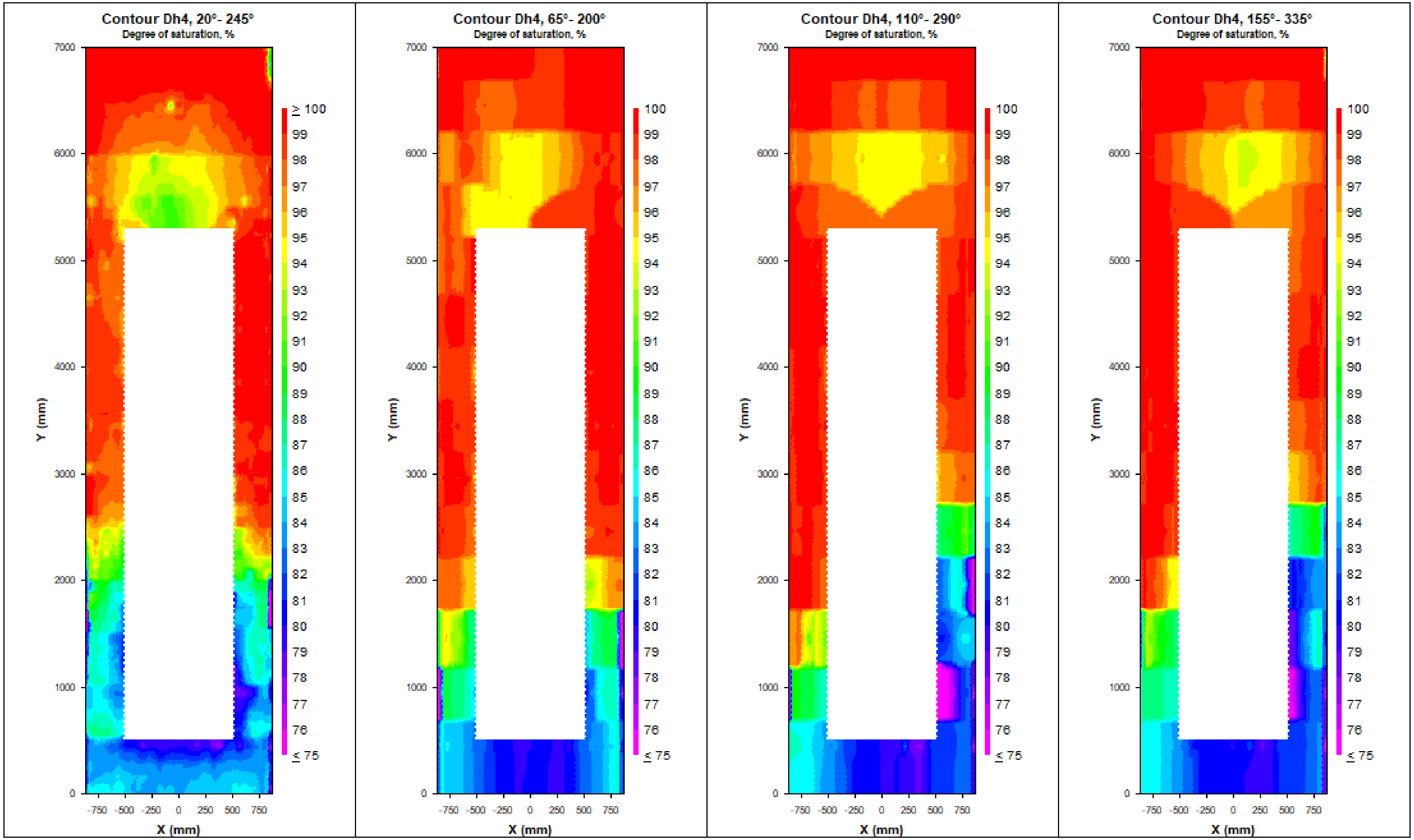


Figure 4-19. Four contour plots showing the degree of saturation distribution in eight vertical cross-sections of deposition hole 4.

5 Results from measurements in Deposition hole 3

5.1 Background

5.1.1 Heating history

The heating of the canister started 2001-10-11. The applied power was set to 1800 W from the start. The applied power was then lowered in steps during the following years, approximately 30 W per year. After these reductions the power was 1560 W until day 4264. Due to heater failure, the power was lowered to 490 W. The power was again lowered on day 4615 due to failure of the electrical heaters. The heaters continued to fail and the power was finally switched off 2015-10-07 after 5133 days test duration. Detailed information regarding the applied canister power is available in the report by Goudarzi (2023).

The registered temperature on the canister surface was during the first 1300 days approximately between 90°C to 95°C (Goudarzi 2023). After that time, the sensor (optical fiber cable) stopped working.

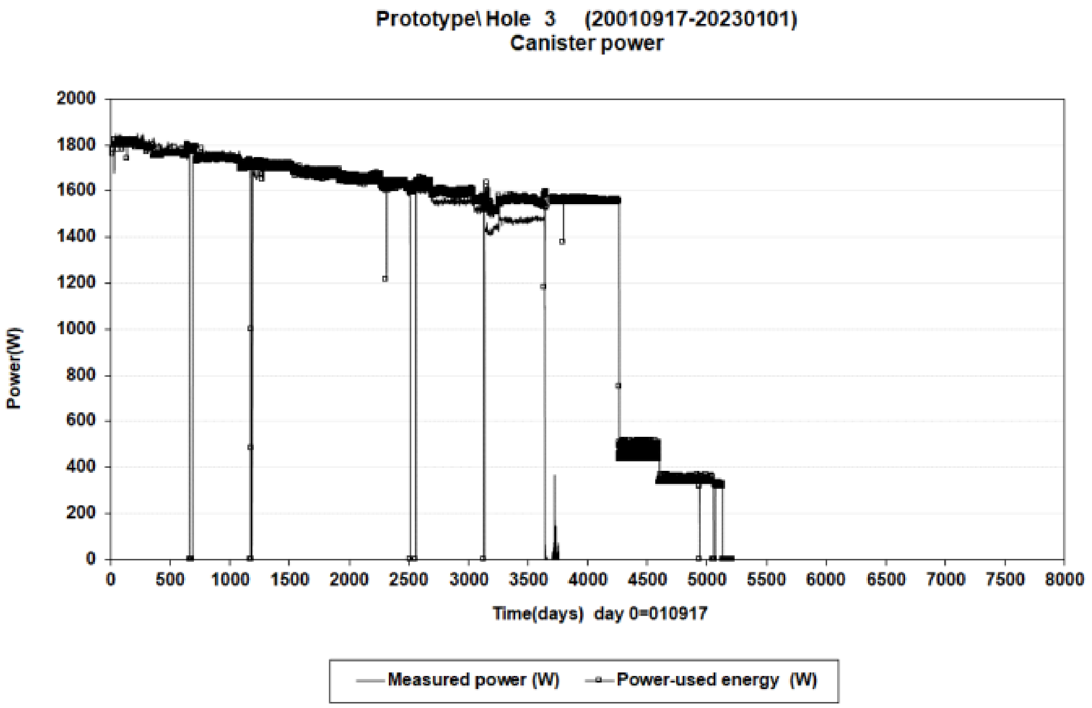


Figure 5-1. *The applied power in the canister in deposition hole 3 (Goudarzi 2023).*

5.1.2 Water inflow

The measured water inflow to this deposition hole was 0.003 l/min, Table 2-1.Mapping of fractures was made in January 2000 (Rhén and Forsmark 2001). No water bearing fractures were observed, Figure 2-3 (left).

5.1.3 Dismantling of Deposition hole 3 (Dh3)

The sampling of the buffer in Deposition hole 3 was performed during the period September 2023-February 2024.

The density and water content were determined in all fourteen buffer blocks including the pellet filled gap between block and rock surface. The sampling was made in eight directions, see detailed description in Chapter 3. In total, the density and water content were planned to be determined in approximately 4600 positions in Deposition hole 3.

5.2 Results from sampling of all buffer blocks in Dh3

The results from the sampling are presented in the same order as the dismantling of the deposition hole proceeded i.e., the first block that was sampled was the block closest to the backfill, block C4.

Several graphs were produced for every single block to show the determined data. In addition, contour plots were generated by DPlot. The denomination of the appendices begins with a sequential number and in the appendices beginning with 2 the following graphs and plots are provided for all blocks n (1-14) in Dh3:

- Appendix 2-n (1-14) a. Results from sampling in eight directions on the level 50 mm below the block surface. The graphs show the water content, the dry density, and the degree of saturation distribution.
- Appendix 2-n (1-14) b. Results from sampling in direction 20°. The sampling was done at five levels below the block surface (50, 150, 250, 350, and 450 mm). The graphs show the water content, the dry density, and the degree of saturation distribution.
- Appendix 2-n (1-14) c. Results from sampling in direction 245°. The sampling was done at five levels below the block surface (50, 150, 250, 350, and 450 mm). The graphs show the water content, the dry density, and the degree of saturation distribution.
- Appendix 2-n (1-14) d. Contour plots showing the water content, the dry density, and the degree of saturation distribution on the level 50 mm down from the block surface.

A contour plot showing the water content distribution is provided for every single block in this chapter together with a picture showing the fracture mapping of the deposition hole.

The sample coordinates used in the graphs (radius and directions in degrees) are described in Section 3.1.

5.2.1 Block C4 (uppermost block)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 2-1 (a-d). The determined water content distribution for block C4 is provided in Figure 5-2 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C4:

- **Dry density**. The dry density was low, mainly between 1300-1420 kg/m^3 (50 mm from block surface). Samples with lower density were found in the former pellet filled gap. This indicates that the block has swelled upwards, compacting the backfill above, and by that the density has decreased. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that there was an obvious difference in density between the different levels (higher density at higher depth) which also indicated that the block had swelled upwards.
- **Degree of saturation**. The degree of saturation was in general high, between 99 and 100 %.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a certain difference in density between the central parts of the block and the parts close to the periphery.
- **Deviations**. At some spots, in the contact zone to the rock, the bentonite samples had a low water content and a rather high dry density. It is believed that these samples, to some extent, have been mixed with the backfill material above, which means that there might be pieces of rock material mixed with the clay (the same phenomenon have been seen in all deposition holes for the uppermost blocks). No sampling was made in the former pellet filled gap between block and rock in direction 20°.

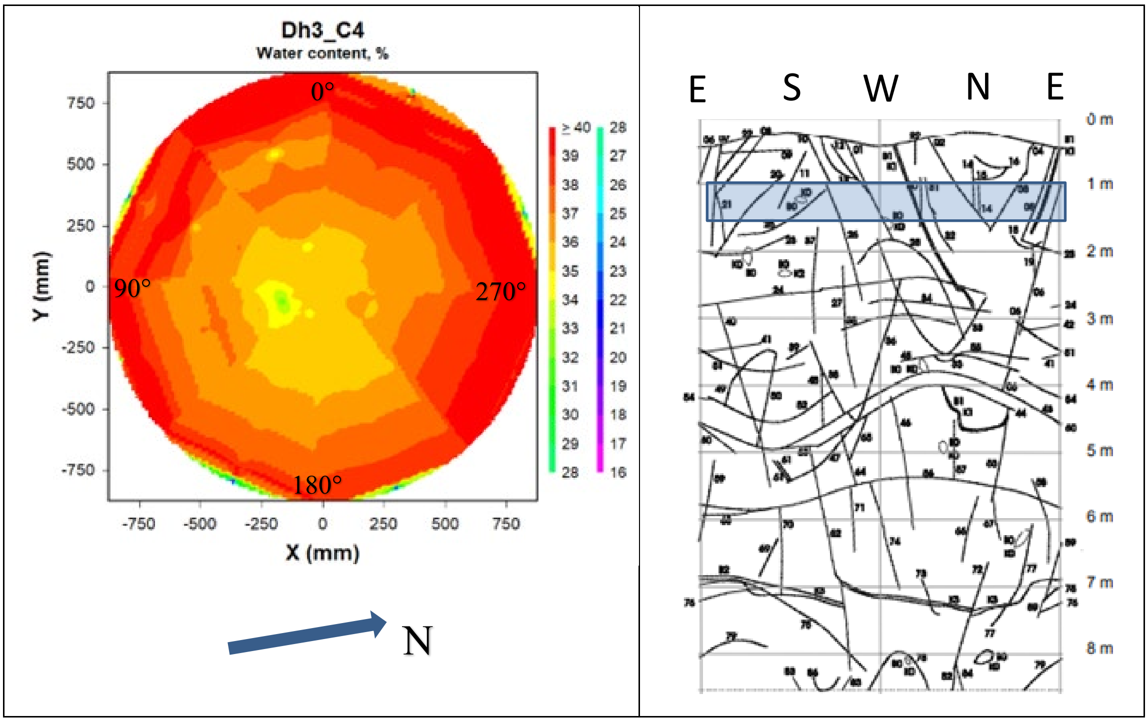


__Figure 5-2.__ Left: Contour plot showing the water content distribution in block C4 in deposition hole 3. Right: Fracture mapping in deposition hole No 3. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C4 relative to the fractures.

5.2.2 Block C3 (above the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 2-2 (a-d). The determined water content distribution for block C3 is provided in Figure 5-3 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C4:

- **Dry density**. The dry density was clearly higher compared to block C4, mainly between 1400-1500 kg/m^3 (50 mm from block surface). This indicates that also this block has been affected by the upward swelling. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that there was a small difference in density between the different levels (higher density at higher depth) which also was an indication that the block had swelled upwards. The difference was, however, smaller compared to block C4.
- **Degree of saturation**. The degree of saturation was in general high, between 98 and 100 %.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a certain difference in density between the central parts of the block and the parts close to the periphery.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap.

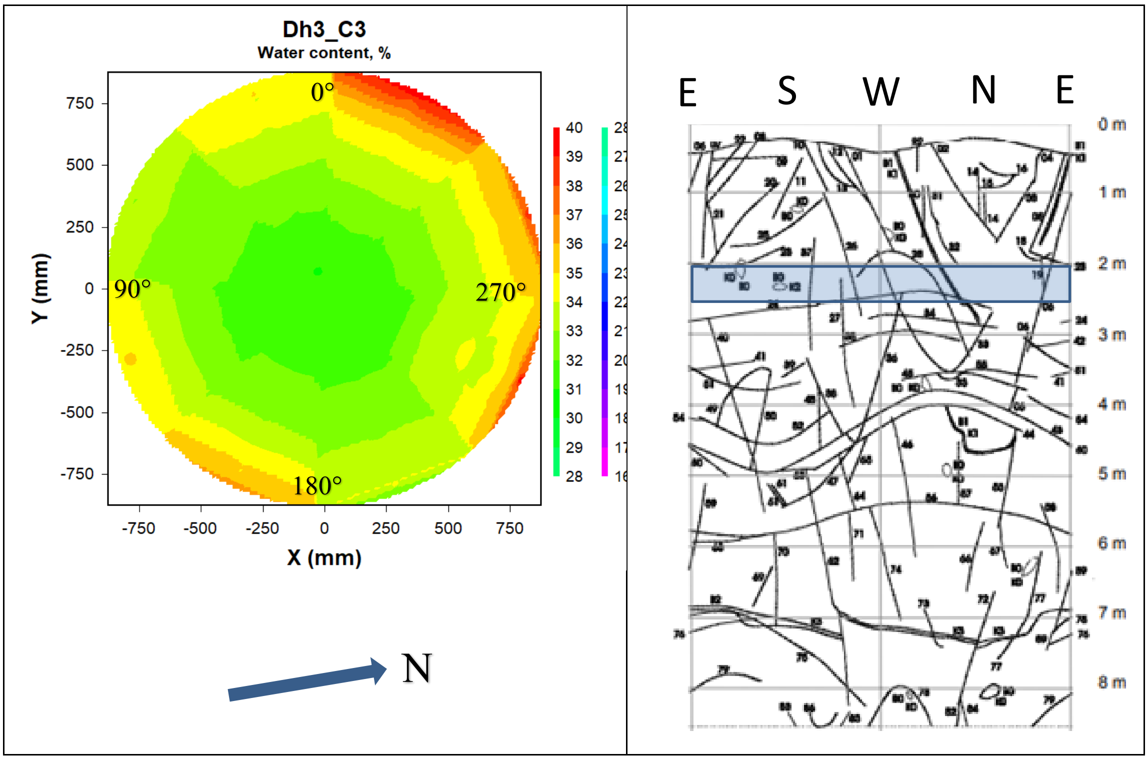


__Figure 5-3.__ Left: Contour plot showing the water content distribution in block C3 in deposition hole 3. Right: Fracture mapping in deposition hole No 3. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C3 relative to the fractures.

5.2.3 Block C2 (above the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 2-3 (a-d). The determined water content distribution for block C2 is provided in Figure 5-4 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C2:

- **Dry density**. The dry density was somewhat higher compared to block C3. The dry density was mainly between 1400 and 1520 kg/m^3. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small.
- **Degree of saturation**. The degree of saturation was high in this block, mainly between 98 and 100 %. In block C2 in Dh4, the degree of saturation in the central parts of the block was somewhat lower, between 92-95 %, but the difference in this block between the central parts of the block and the outer parts was small.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a certain difference in density between the central parts of the block and parts of the former pellet gap close to the periphery. The dry density was somewhat lower at the periphery in the directions of 335° and 20°.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap.

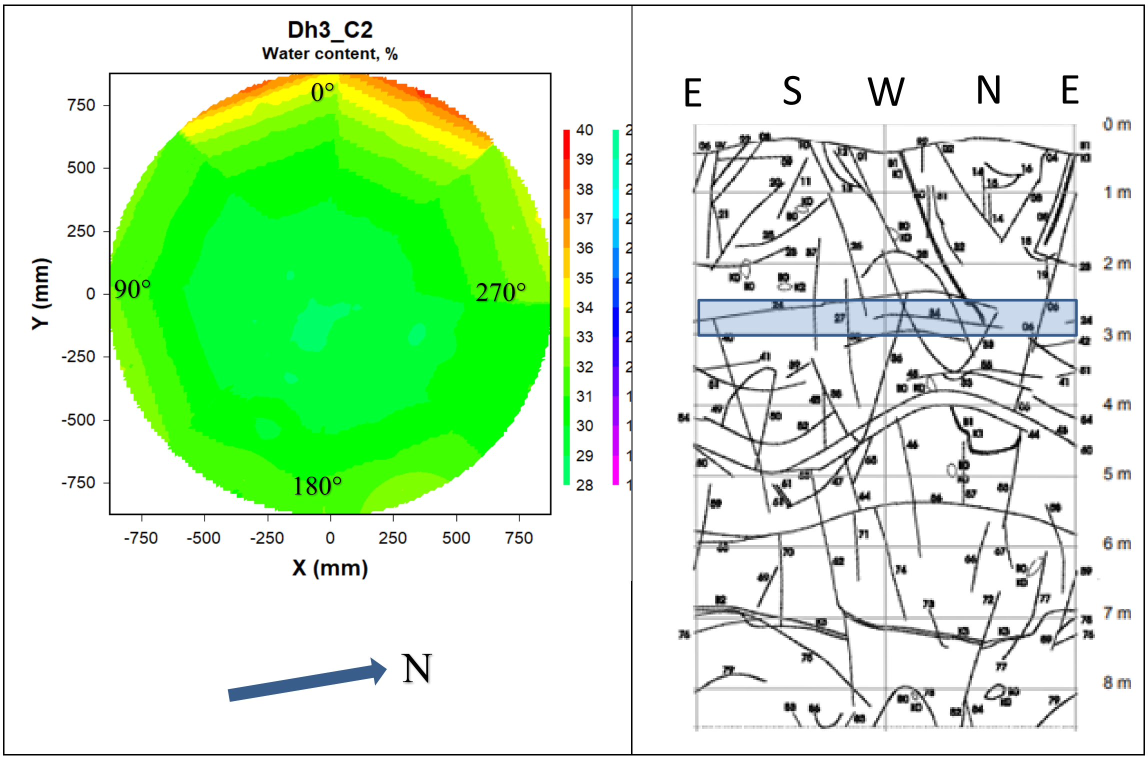


__Figure 5-4.__ Left: Contour plot showing the water content distribution in block C2 in deposition hole 3. Right: Fracture mapping in deposition hole No 3. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C2 relative to the fractures.

5.2.4 Block R10 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 2-4 (a-d). The determined water content distribution for block R10 is provided in Figure 5-5 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R10:

- **Dry density**. The dry density varied mainly between 1450-1600 kg/m^3, which was somewhat higher compared to the cylindrical blocks above. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small.

- **Degree of saturation**. The degree of saturation was high at all positions, mainly between 96 and 100 %, with the lowest values close to the canister and close to the rock.

- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest density values were found close to the rock in the directions of 20 and 335°.

- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

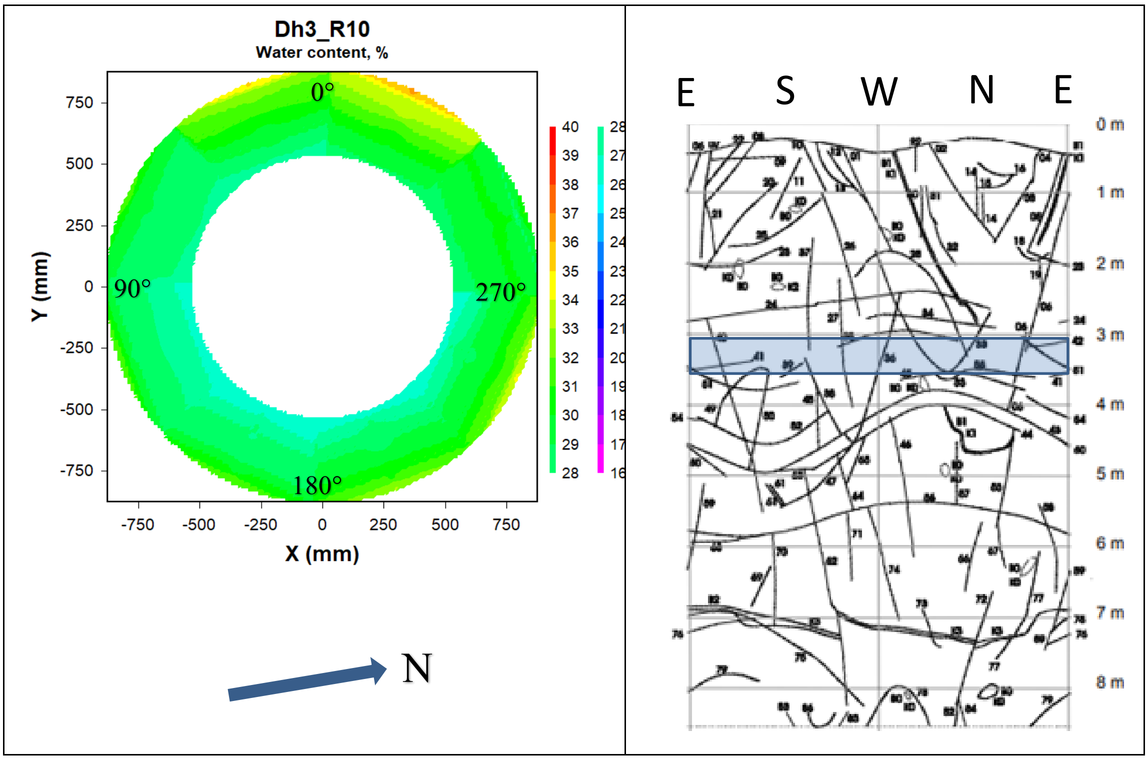


__Figure 5-5.__ Left: Contour plot showing the water content distribution in block R10 in deposition hole 3. Right: Fracture mapping in deposition hole No 3. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R10 relative to the fractures.

5.2.5 Block R9 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 2-5 (a-d). The determined water content distribution for block R9 is provided in Figure 5-6 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R9:

- **Dry density**. The dry density varied mainly between 1500-1600 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied between 96 to 100 %. The lowest degree of saturation was found at some spots close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap. The lowest density values were found close to the rock in the directions of 290 and 335°.
- **Deviations**. The results from the water content and density determinations were in general consistent. No sampling was made of the end-pieces in direction 20°, neither against the rock wall or against the canister (same positions as where the large test sample that should be used for different laboratory tests was taken). Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

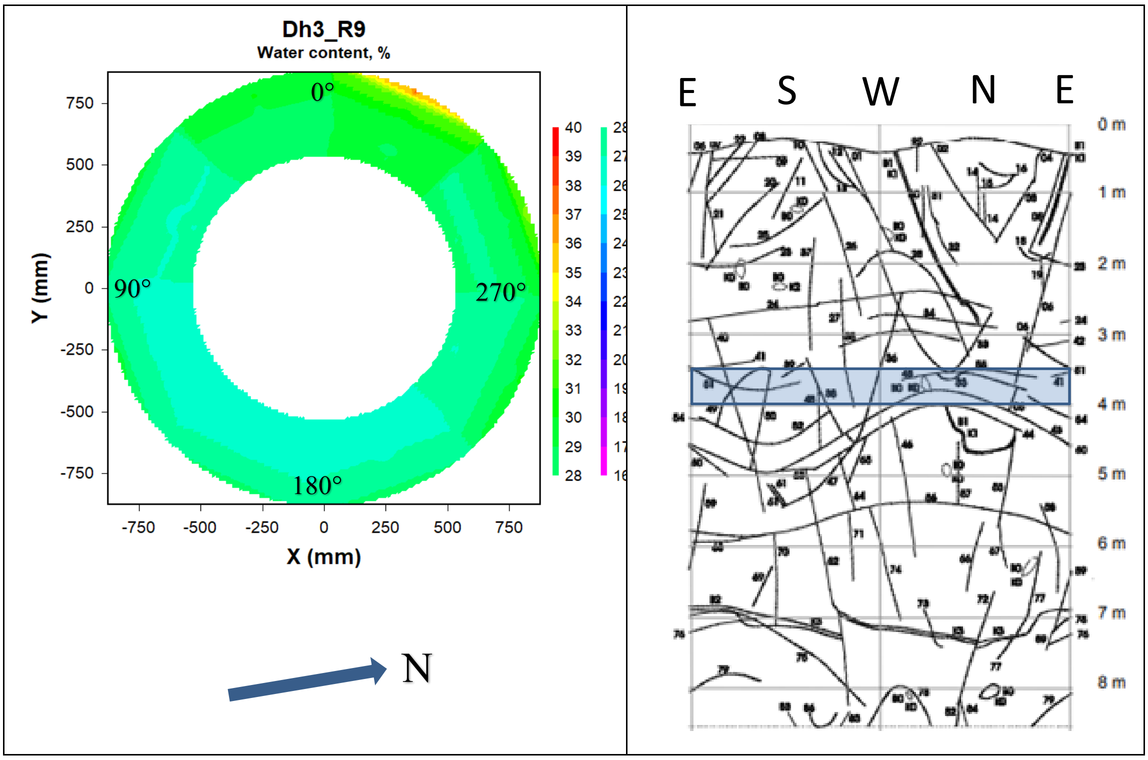


__Figure 5-6.__ Left: Contour plot showing the water content distribution in block R9 in deposition hole 3. Right: Fracture mapping in deposition hole No 3. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R9 relative to the fractures.

5.2.6 Block R8 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 2-6 (a-d). The determined water content distribution for block R8 is provided in Figure 5-7 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R8:

- **Dry density**. The dry density varied mainly between 1540-1620 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied between 96 to 100 %. The lowest degree of saturation was found at some spots close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap. The lowest density values were found close to the rock in the directions of 20 and 335°.
- **Deviations**. The results from the water content and density determinations were in general consistent. No sampling was made of the end-pieces in direction 110°, neither against the rock wall or against the canister (same positions as where the large test sample that should be used for different laboratory tests was taken).

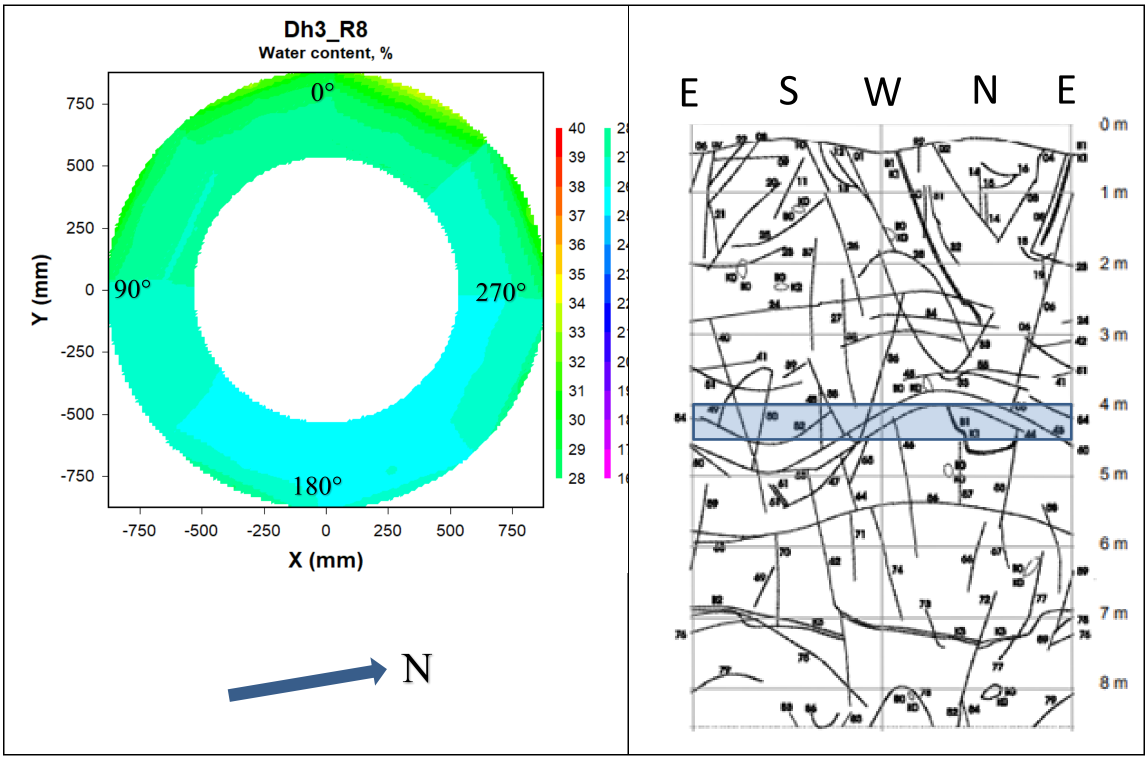


Figure 5-7. Left: Contour plot showing the water content distribution in block R8 in deposition hole 3. Right: Fracture mapping in deposition hole No 3. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R8 relative to the fractures.

5.2.7 Block R7 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 2-7 (a-d). The determined water content distribution for block R7 is provided in Figure 5-8 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R7:

- **Dry density**. The dry density was mainly between 1520-1650 kg/m^3, but somewhat lower at some positions in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied mainly between 98 to 100 %, but somewhat lower (94-97 %) at some positions close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap. The dry density was somewhat lower at the periphery in the directions of 290°, 335° and 20°.
- **Deviations**. The results from the water content and density determinations were in general consistent. No sampling was made of the end-pieces in direction 200°, neither against the rock wall or against the canister (same positions as where the large test sample that should be used for different laboratory tests was taken).

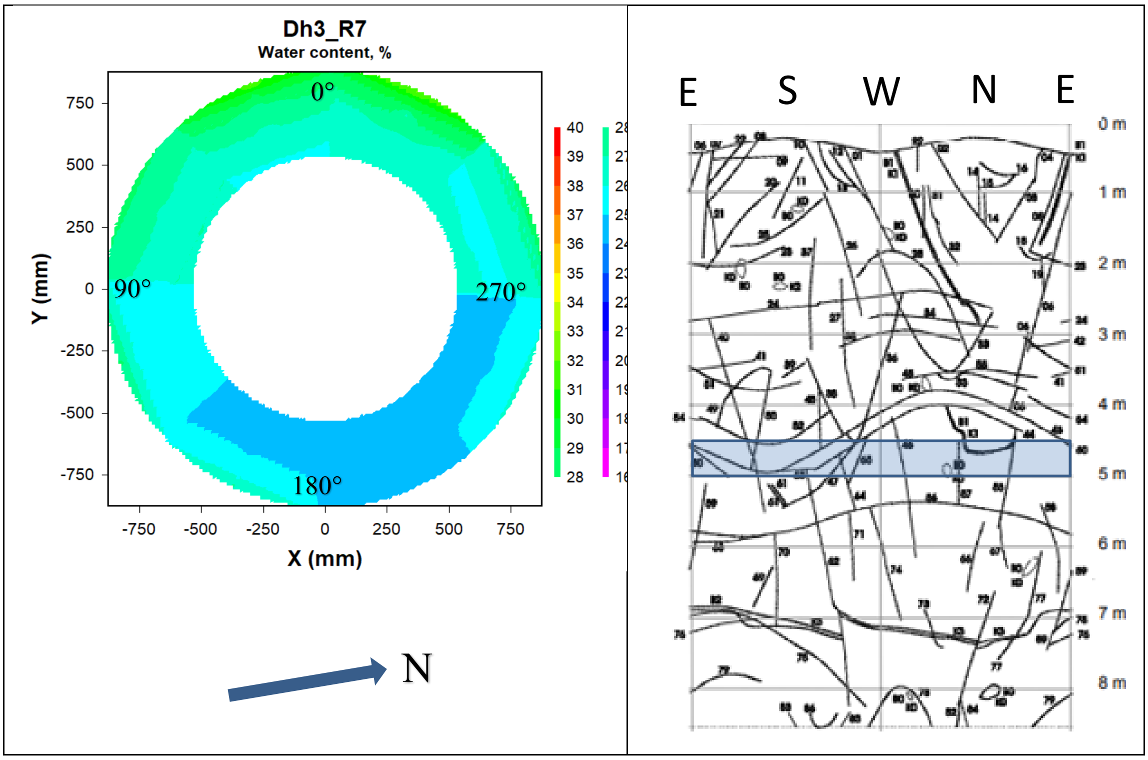


__Figure 5-8.__ Left: Contour plot showing the water content distribution in block R7 in deposition hole 3. Right: Fracture mapping in deposition hole No 3. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R7 relative to the fractures.

5.2.8 Block R6 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 2-8 (a-d). The determined water content distribution for block R6 is provided in Figure 5-9 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R6:

- **Dry density**. The dry density varied mainly between 1540-1670 kg/m³. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied mainly between 98 to 100 %, but somewhat lower (94-97 %) at some positions close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap. The dry density was somewhat lower at the periphery in the directions of 335° and 20°.
- **Deviations**. The results from the water content and density determinations were in general consistent. No sampling was made in direction 290°.

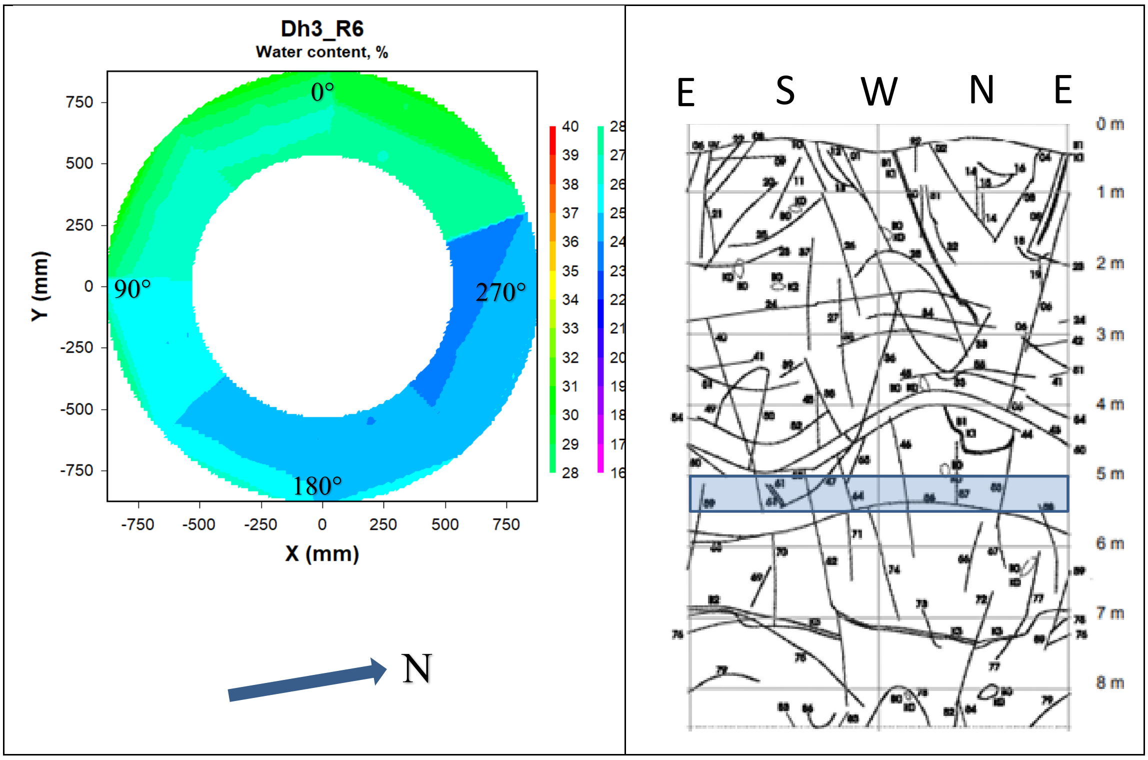


Figure 5-9. Left: Contour plot showing the water content distribution in block R6 in deposition hole 3. Right: Fracture mapping in deposition hole No 3. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R6 relative to the fractures.

5.2.9 Block R5 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 2-9 (a-d). The determined water content distribution for block R5 is provided in Figure 5-10 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R5:

- **Dry density**. The dry density was mainly between 1550-1700 kg/m^3, but somewhat lower at some positions in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied mainly between 95 to 100 %. The lowest degree of saturation was found at some spots close to the canister. The degree of saturation was also in the lower range in directions 200° and 245°.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The dry density was somewhat lower at the periphery in the directions of 65°, 110° and 335°.
- **Deviations**. The results from the water content and density determinations were in general consistent. No sampling was made of the end-pieces in direction 20°, neither against the rock wall nor against the canister.

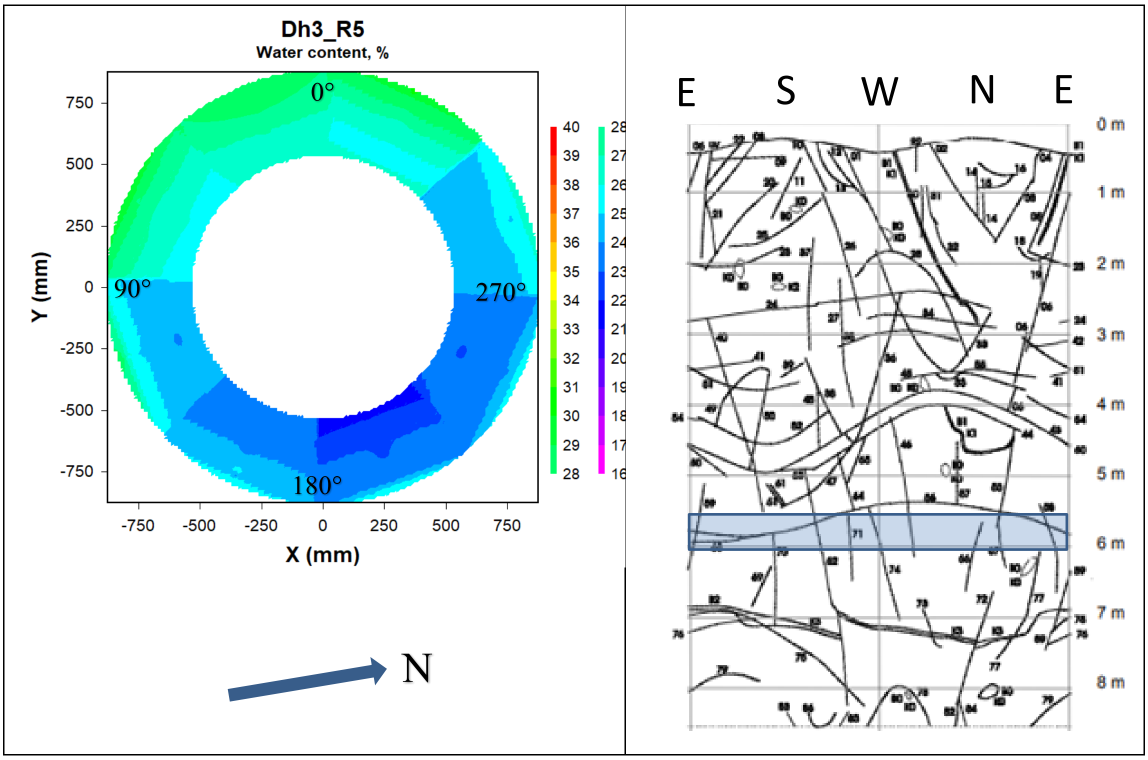


Figure 5-10. Left: Contour plot showing the water content distribution in block R5 in deposition hole 3. Right: Fracture mapping in deposition hole No 3. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R5 relative to the fractures.

5.2.10 Block R4 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 2-10 (a-d). The determined water content distribution for block R4 is provided in Figure 5-11 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R4:

- **Dry density**. The dry density was mainly between 1600-1700 kg/m^3, but somewhat lower at some positions in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied mainly between 93 to 100 %. The lowest degree of saturation was found at some spots close to the canister. The degree of saturation was also in the lower range in directions 200° and 245°.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister.
- **Deviations**. The results from the water content and density determinations were in general consistent. No sampling was made of the end-pieces in direction 110°, neither against the rock wall or against the canister.

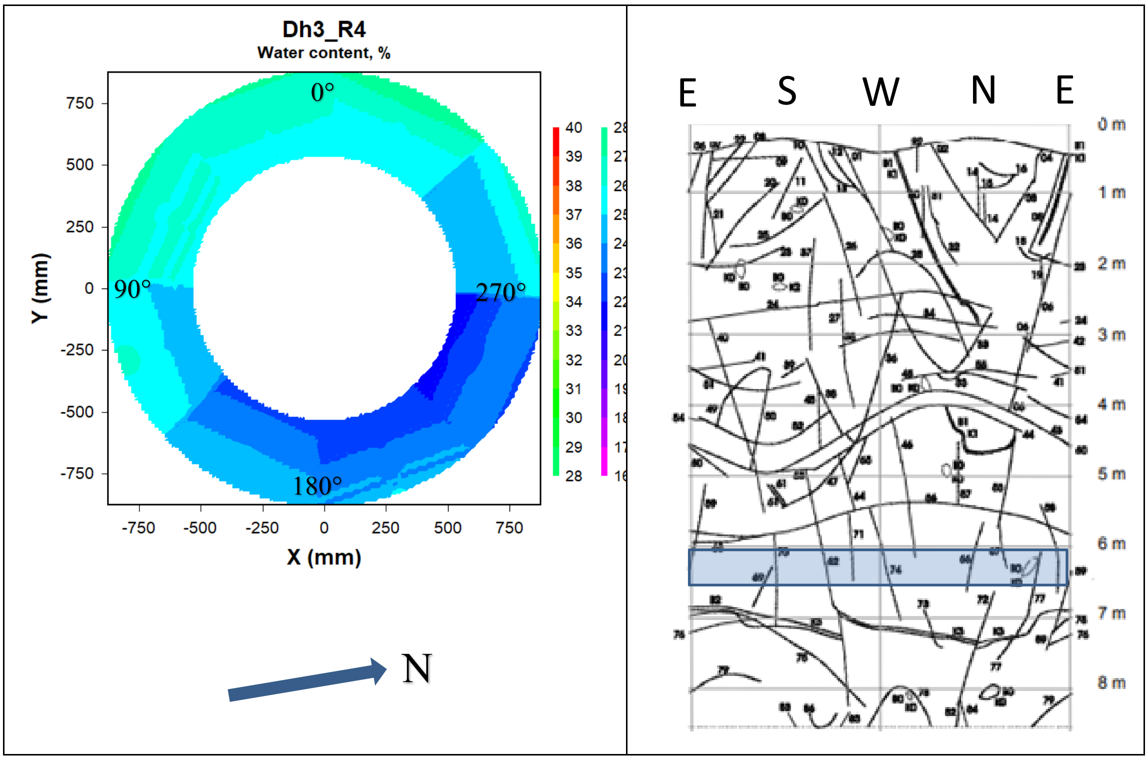


Figure 5-11. Left: Contour plot showing the water content distribution in block R4 in deposition hole 3. Right: Fracture mapping in deposition hole No 3. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R4 relative to the fractures.

5.2.11 Block R3 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 2-11 (a-d). The determined water content distribution for block R3 is provided in Figure 5-12 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R3:

- **Dry density**. The dry density was mainly between 1580-1700 kg/m^3, but somewhat lower at some positions in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied mainly between 93 to 100 %. The lowest degree of saturation was found at some spots close to the canister. The degree of saturation was also in the lower range in directions 200° and 245°.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The dry density was somewhat lower at the periphery in the directions of 20° and 335°.
- **Deviations**. The results from the water content and density determinations were in general consistent. No sampling was made of the end-pieces in the direction 200°, neither against the rock wall nor against the canister.

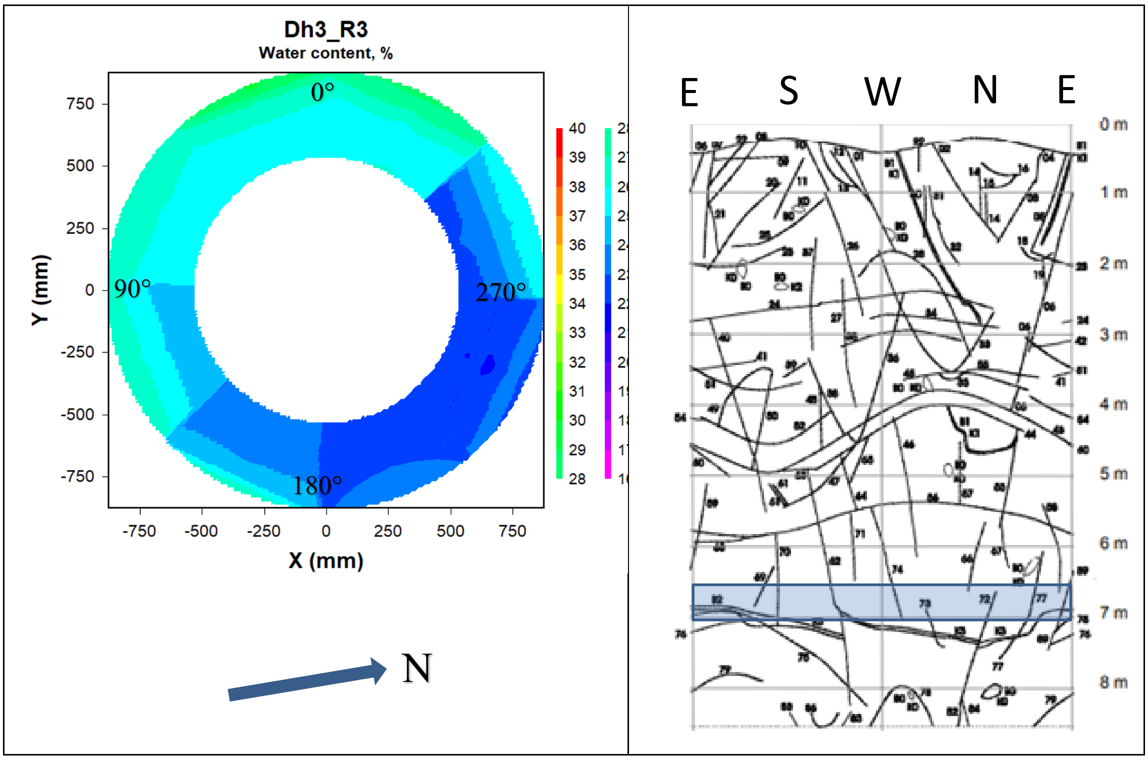


Figure 5-12. Left: Contour plot showing the water content distribution in block R3 in deposition hole 3. Right: Fracture mapping in deposition hole No 3. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R3 relative to the fractures.

5.2.12 Block R2 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 2-12 (a-d). The determined water content distribution for block R2 is provided in Figure 5-13 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R2:

- **Dry density**. The dry density was mainly between 1580-1700 kg/m^3, but somewhat lower at some positions in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied mainly between 95 to 100 %. The lowest degree of saturation was found at some spots close to the canister. The degree of saturation was also in the lower range in directions 200° and 245°.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The dry density was somewhat lower at the periphery in the directions of 65°, 110° and 335°.
- **Deviations**. The results from the water content and density determinations were in general consistent. No sampling was made of the end-pieces in direction 290° neither against the rock wall or against the canister.

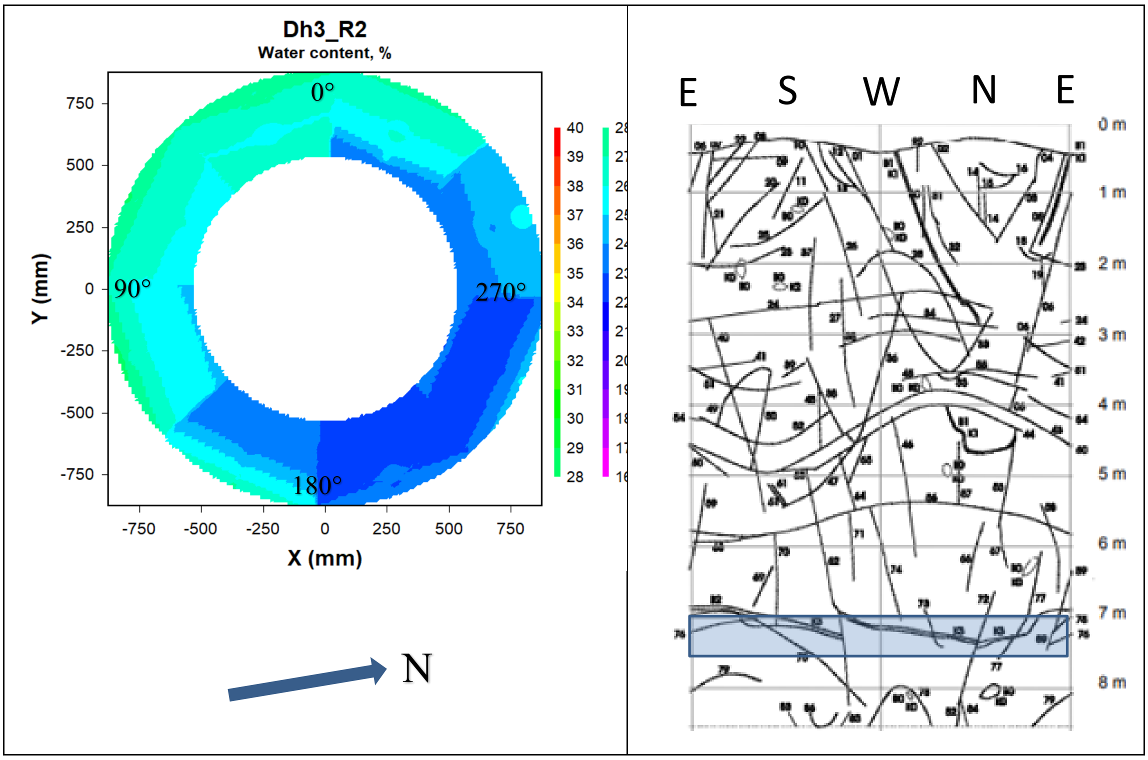


Figure 5-13. Left: Contour plot showing the water content distribution in block R2 in deposition hole 3. Right: Fracture mapping in deposition hole No 3. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R2 relative to the fractures.

5.2.13 Block R1 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 2-13 (a-d). The determined water content distribution for block R1 is provided in Figure 5-14 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R1:

- **Dry density**. The dry density was mainly between 1580-1680 kg/m^3, but somewhat lower at some positions in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied mainly between 95 to 100 %. The lowest degree of saturation was found at some spots close to the canister. The degree of saturation was also in the lower range in directions 200° and 245°.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The dry density was somewhat lower at the periphery in the directions of 65°, 110° and 335°.
- **Deviations**. The results from the water content and density determinations were in general consistent. No sampling was made of the end-pieces in direction 20°, neither against the rock wall nor against the canister.

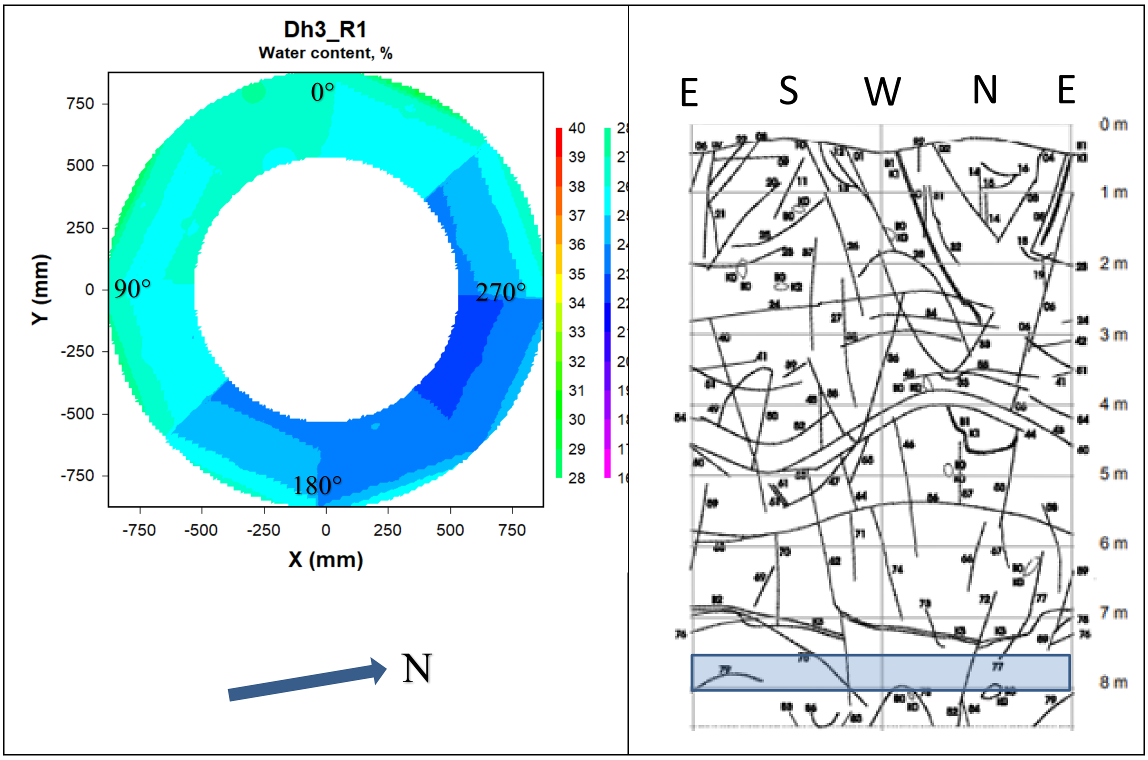


Figure 5-14. Left: Contour plot showing the water content distribution in block R1 in deposition hole 3. Right: Fracture mapping in deposition hole No 3. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R1 relative to the fractures.

5.2.14 Block C1 (below the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 2-14 (a-d). The determined water content distribution for block C1 is provided in Figure 5-15 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C1:

- **Dry density**. The dry density was mainly between 1550-1670 kg/m^3. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation varied mainly between 95 to 100 %. The lowest degree of saturation was found in the central parts of the block.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap between block and rock.
- **Deviations**. The results from the water content and density determinations were in general consistent. Due to sensors positioned in direction 20° and 155° (Aitemin displacement sensors), the sampling in direction 20°was moved to 30°, and the sampling in direction 155° was moved to 165°. However, the original directions 20° and 155° have been kept in the plots.

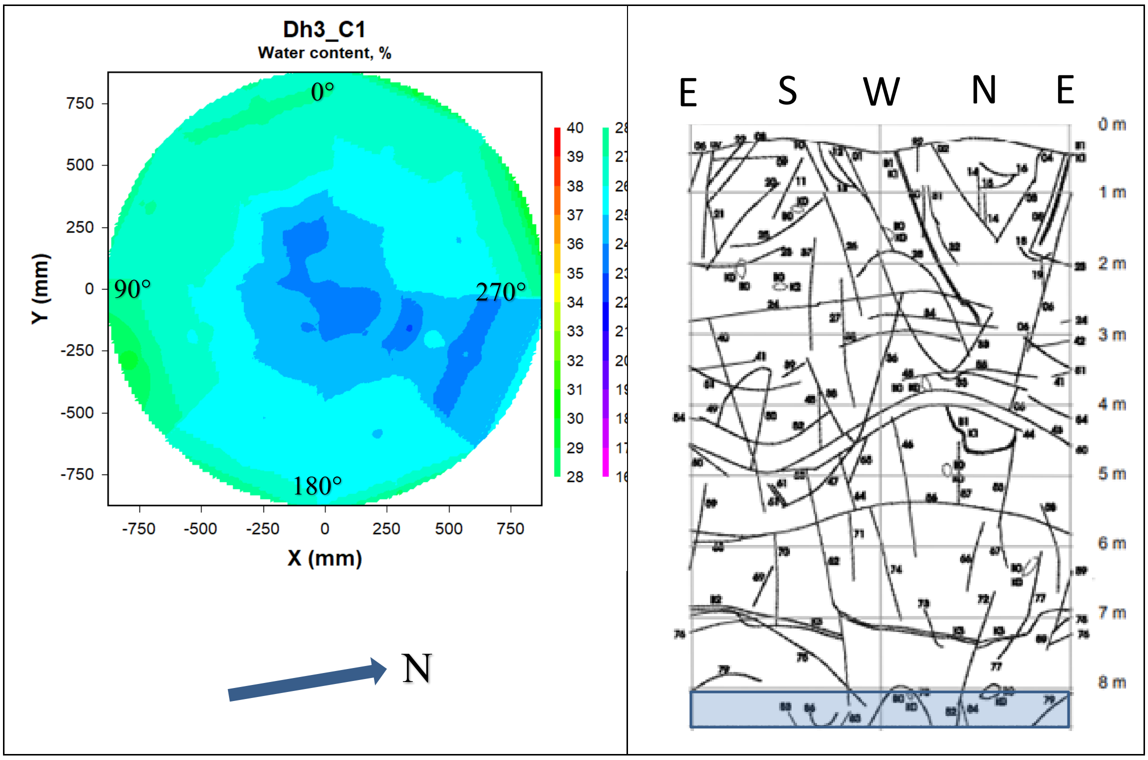


Figure 5-15. Left: Contour plot showing the water content distribution in block C1 in deposition hole 3. Right: Fracture mapping in deposition hole No 3. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C1 relative to the fractures.

5.3 Summary of results from Dh3

5.3.1 Access to water

The buffer blocks in the deposition holes have had access to water both from fractures in the rock and via the backfill above the deposition hole.

The fracture mappings for all deposition holes are provided in Figure 2-2 and Figure 2-3, and the measured inflows are listed in Table 2-1. The inflow rate to deposition hole 3 was determined to 0.003 l/min. This inflow rate was of the same order of magnitude as for deposition holes 2, 5 and 6 but in this deposition hole, no. 3, no water bearing fractures were identified.

As described in Section 4.3.1, it is believed that water flowing from the backfill down to the buffer has greatly contributed to the saturation of the buffer.

5.3.2 Compilation of data

As described in Section 4.3.2, two different methods have been used to give a picture of the status of the complete deposition hole (see Appendix 2-nm for all blocks n and diagrams m) regarding water content, dry density, and degree of saturation distribution:

1. The individual contour plots of every single block have been compressed and stacked on each other, Figure 5-16. These figures give a rather good picture of the water content, the dry density, and the degree of saturation distribution for the complete deposition hole.
2. Contour plots were generated by DPlot. The plots are showing the water content, the dry density and the degree of saturation distribution in eight vertical cross-sections of deposition hole 3, Figure 5-17, Figure 5-18 and Figure 5-19.

The following conclusions can be made from the figures:

- Block C4 and C3 (top blocks). Both these blocks had swelled axially and by that decreased the density. The dry density for block C4 was mainly between 1300 and 1400 kg/m^3 and for block C3 between 1400 and 1500 kg/m^3. Both blocks were largely water saturated.
- Block C2 (block above canister). This block had also swelled axially and by that decreased in density. The dry density for this block was mainly between 1400 and 1540 kg/m^3. The degree of saturation was mainly between 97 to 100 %. In the corresponding block in Dh4, the central parts had a lower degree of saturation, which probably was an effect of the temperature from the canister. In this deposition hole, Dh3, no heating has been applied since 2015, and this block, C2, was almost completely saturated.
- Block R10-R7 (ring-shaped blocks along the upper half of the canister). These blocks did not seem to be especially affected by any axial swelling. The dry density varied mainly between 1450 and 1650 kg/m^3 depending on direction. The blocks are largely water saturated, between 98 and 100 %.
- Block R6-R1 (ring-shaped blocks along the lower half of the canister). The dry density of the blocks varied mainly between 1550 and 1700 kg/m^3. The degree of saturation varied somewhat between the different directions for these blocks. The degree of saturation varied between 95 and 100 % with the lowest degree of saturation in the directions between 180°-270°.
- Block C1 (block below canister). The degree of saturation varied mainly between 95 and 100 % for the complete block. The parts with the lowest degree of saturation were found in the central parts of the block.

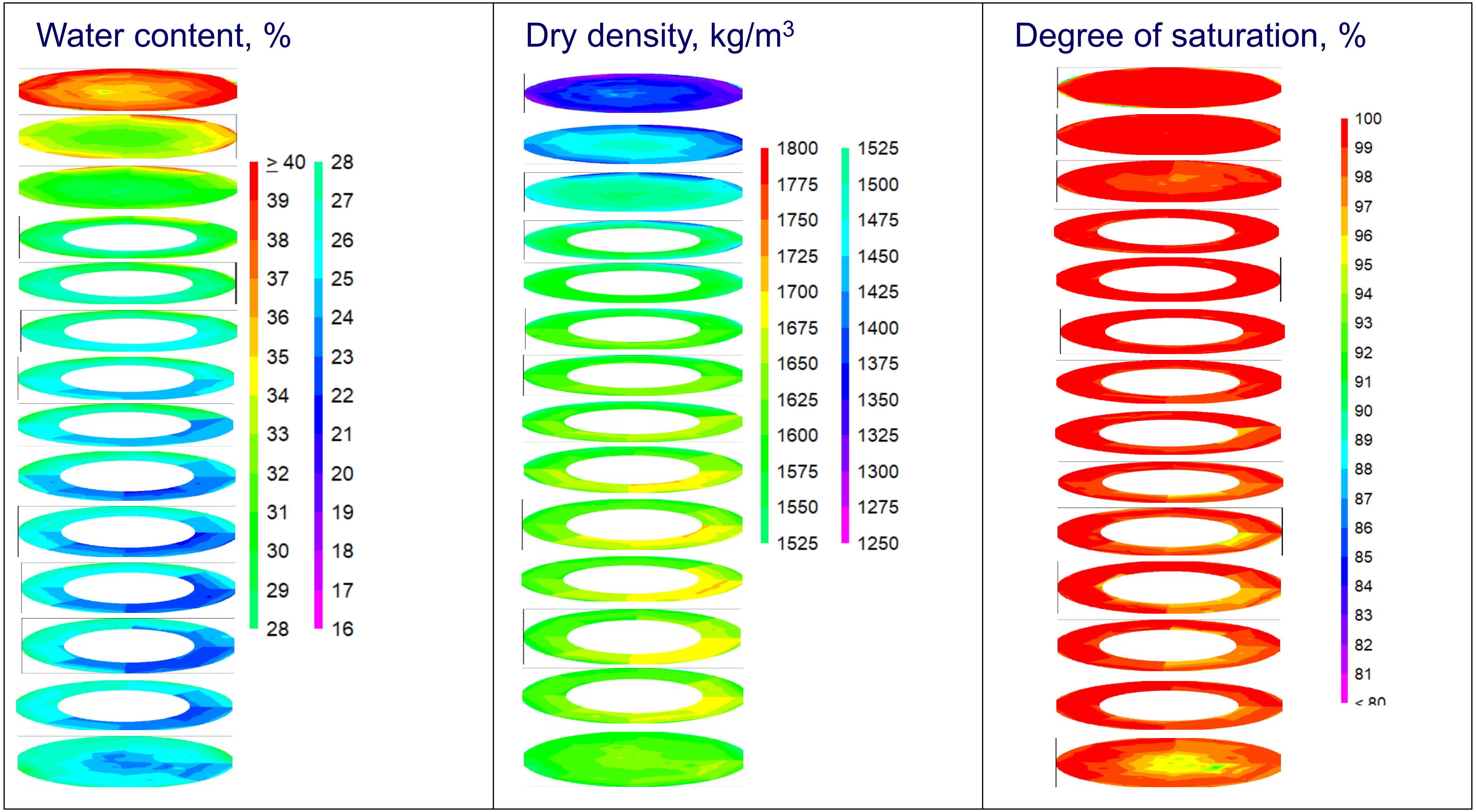


Figure 5-16. *Compressed contour plots of every single block in Dh 3 stacked on each other. Left: the water content distribution (%) Middle: the dry density distribution (kg/m³) Right: the degree of saturation distribution (%).*

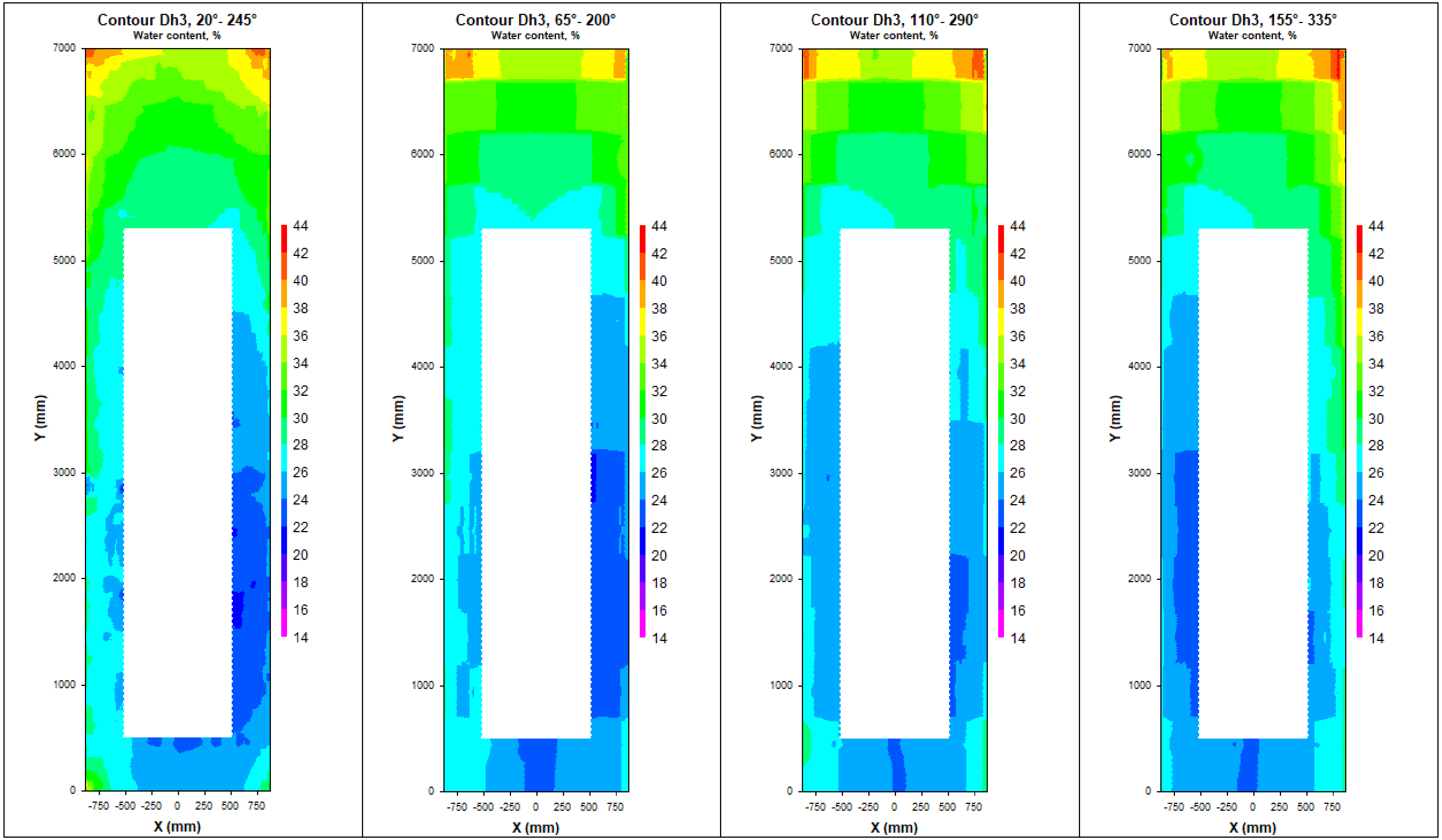


Figure 5-17. *Four contour plots showing the water content distribution in eight vertical cross-sections of deposition hole 3*

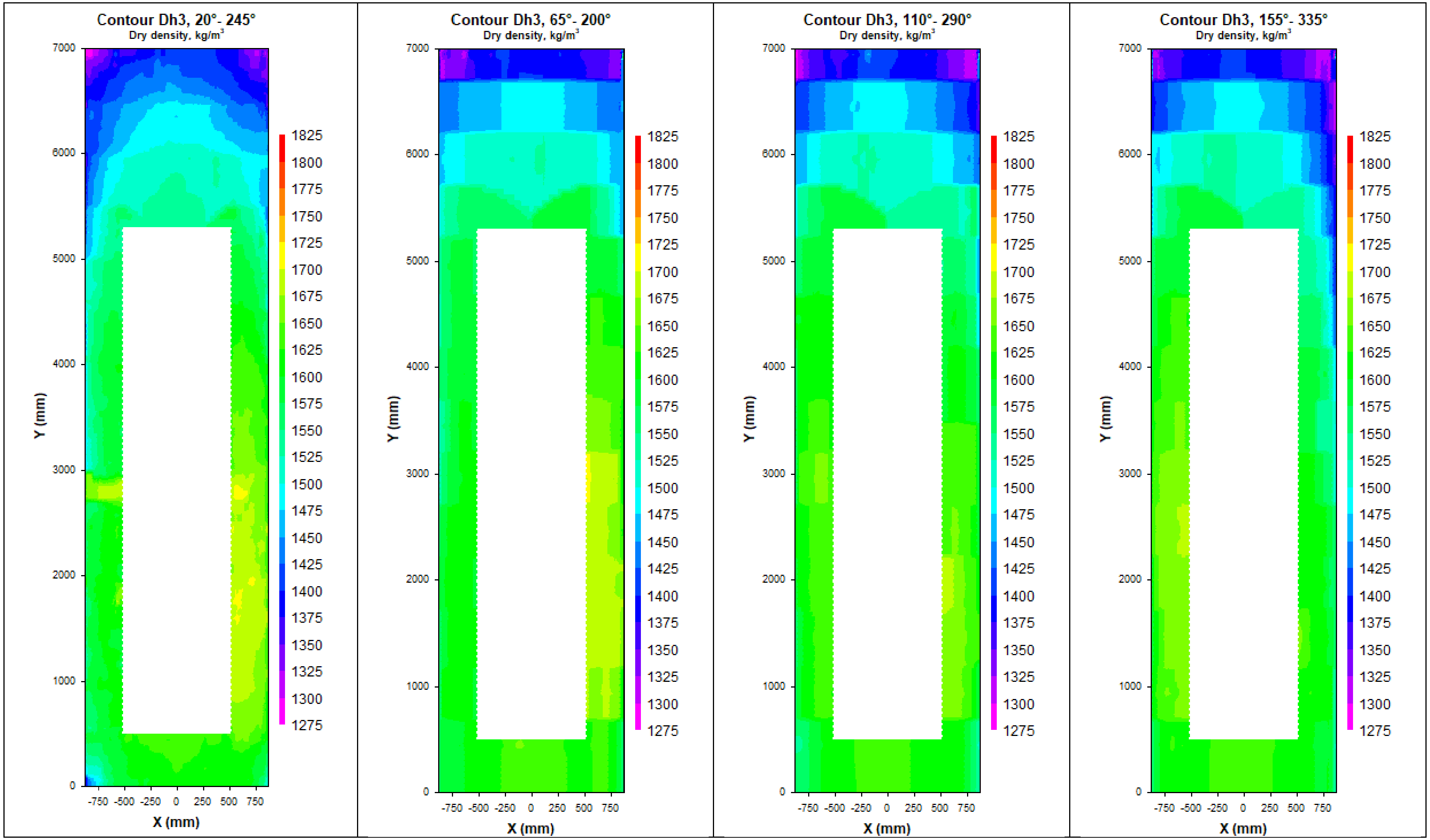


Figure 5-18. *Four contour plots showing the dry density distribution in eight vertical cross-sections of deposition hole 3.*

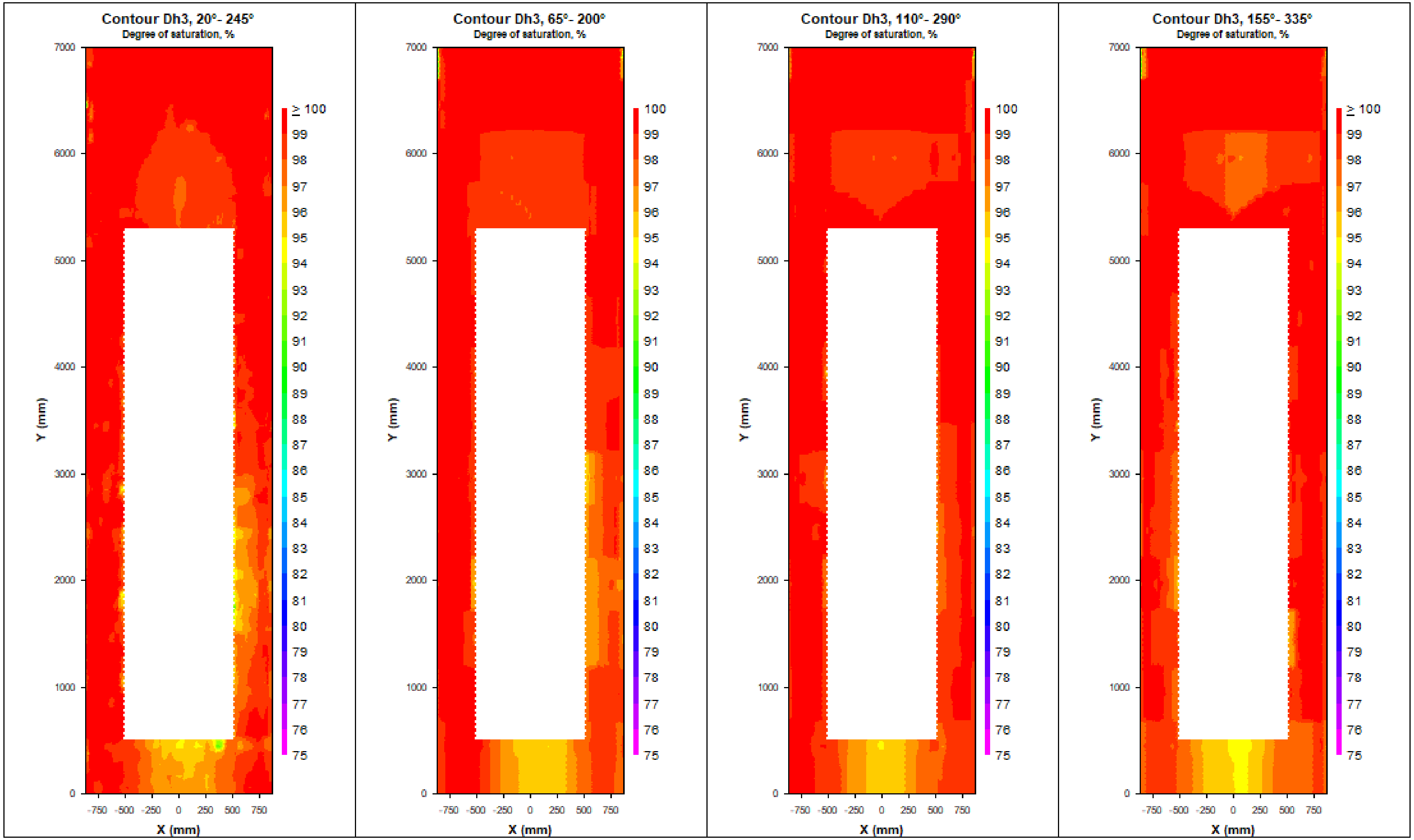


Figure 5-19. Four contour plots showing the degree of saturation distribution in eight vertical cross-sections of deposition hole 3.

6 Results from measurements in Deposition hole 2

6.1 Background

6.1.1 Heating history

The heating of the canister started 2001-09-24. The applied power was set to 1800 W from the start. After some minor adjustments during the following three years, the power was switched off 2004-12-01 due to the failure of the electrical heaters. Detailed information regarding the applied canister power is available in the report by Goudarzi (2023).

The registered temperature on the canister surface was during the first 1300 days approximately between 95°C to 110°C (Goudarzi 2023). After that time, the sensor (optical fiber cable) stopped working.

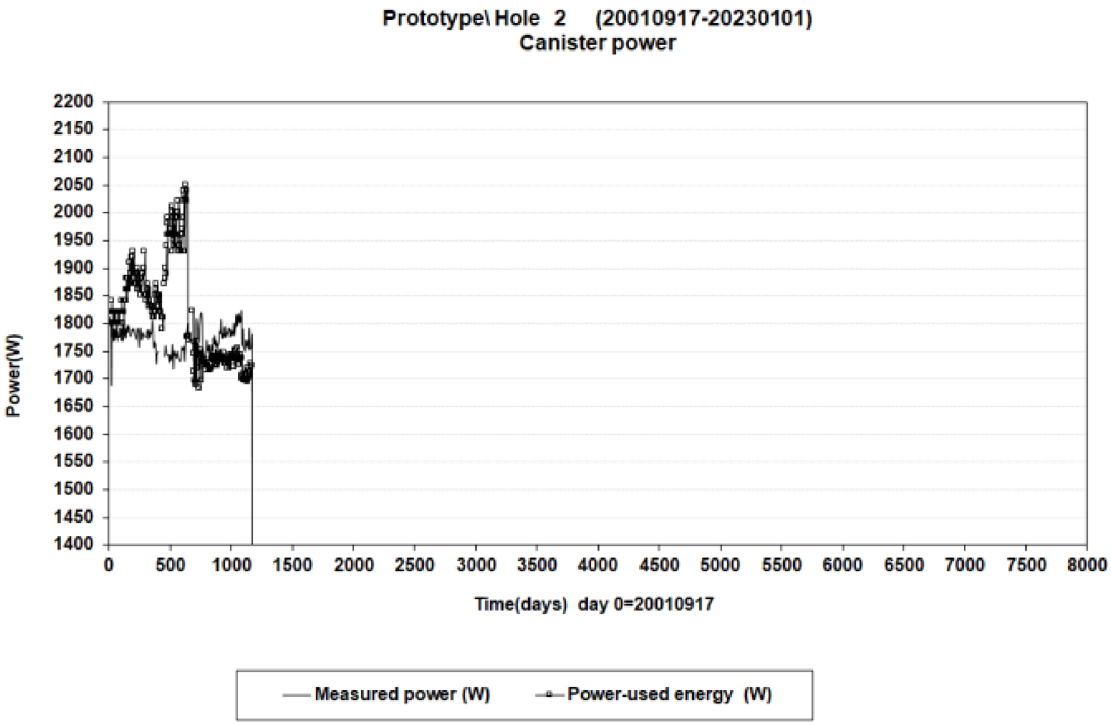


Figure 6-1. The applied power in the canister in deposition hole 2 (Goudarzi 2023).

6.1.2 Water inflow

The measured water inflow to this deposition hole was small, 0.002 l/min, Table 2-1. Mapping of water-bearing fractures was made in January 2000 (Rhén and Forsmark 2001). The inflow from one water bearing fracture was measured, see shaded area in Figure 2-2 (right). The inflow was determined to 1.67 x 10^{-4} l/min (Rhén and Forsmark 2001).

6.1.3 Dismantling of Deposition hole 2 (Dh2)

The sampling of the buffer in Deposition hole 2 was performed during the period February-July 2024.

The density and water content were determined in all fourteen buffer blocks including the pellet filled gap between block and rock surface. The sampling was made in eight directions, see detailed description in Chapter 3. In total, the density and water content were planned to be determined in approximately 4600 positions in Deposition hole 2.

6.2 Results from sampling of all buffer blocks in Dh2

The results from the sampling are presented in the same order as the dismantling of the deposition hole proceeded i.e., the first block that was sampled was the block closest to the backfill, block C4.

Several graphs were produced for every single block to show the determined data. In addition, contour plots were generated by DPlot. The denomination of the appendices begins with a sequential number and in the appendices beginning with 3 the following graphs and plots are provided for all blocks n (1-14) in Dh2:

- Appendix 3-n (1-14) a. Results from sampling in eight directions on the level 50 mm below the block surface. The graphs show the water content, the dry density, and the degree of saturation distribution.
- Appendix 3-n (1-14) b. Results from sampling in direction 20°. The sampling was done at five levels below the block surface (50, 150, 250, 350, and 450 mm). The graphs show the water content, the dry density, and the degree of saturation distribution.
- Appendix 3-n (1-14) c. Results from sampling in direction 245°. The sampling was done at five levels below the block surface (50, 150, 250, 350, and 450 mm). The graphs show the water content, the dry density, and the degree of saturation distribution.
- Appendix 3-n (1-14) d. Contour plots showing the water content, the dry density, and the degree of saturation distribution on the level 50 mm down from the block surface.

A contour plot showing the water content distribution is provided for every single block in this chapter together with a picture showing the fracture mapping of the deposition hole.

The sample coordinates used in the graphs (radius and directions in degrees) are described in Section 3.1.

6.2.1 Block C4 (uppermost block)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 3-1 (a-d). The determined water content distribution for block C4 is provided in Figure 6-2 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C4:

- **Dry density**. The dry density was low, mainly between 1300-1420 kg/m^3 (50 mm from block surface). This indicates that the block has swelled upwards, compacting the backfill above, and by that the density has decreased. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that there was a difference in density between the different levels (higher density at higher depth) which also indicated that the block had swelled upwards.
- **Degree of saturation**. The degree of saturation was in general high, between 99 and 100 % (except for some samples taken from the contact zone against the rock, see last bullet).
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far.
- **Deviations**. At some spots, in the contact zone to the rock, the bentonite samples were not saturated. These spots had a low water content and a rather high dry density, compared to the initial density of the pellets in the former gap. It is believed that these samples, to some extent, have been mixed with the backfill material above, which means that there might be pieces of rock material mixed with the clay (the same phenomenon have been seen in all deposition holes for the uppermost blocks). No sampling was made in the former pellet filled gap between block and rock in direction 20°.

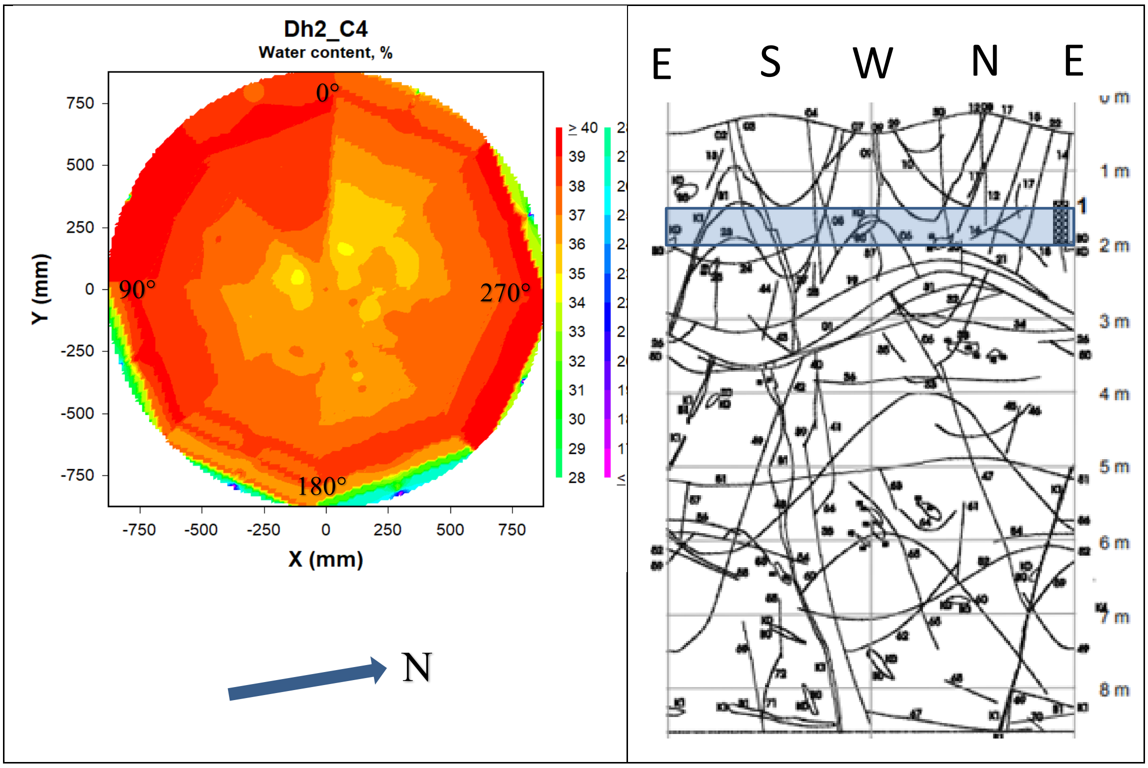


Figure 6-2. Left: Contour plot showing the water content distribution in block C4 in deposition hole 2. Right: Fracture mapping in deposition hole No 2. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C4 relative to the fractures.

6.2.2 Block C3 (above canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 3-2 (a-d). The determined water content distribution for block C3 is provided in Figure 6-3 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C3:

- **Dry density**. The dry density was clearly higher compared to block C4. The dry density was mainly between 1400-1500 kg/m^3 (50 mm from block surface). Samples with lower density were found in the former pellet filled gap. The rather low density indicates that also this block has been affected by the upward swelling. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that there was a certain difference in density between the different levels (higher density at higher depth) which also was an indication that the block had swelled upwards. The difference was, however, smaller compared to block C4.
- **Degree of saturation**. The degree of saturation was in general high, between 97 and 100 %.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a certain difference in density between the central parts of the block and the parts close to the periphery.
- **Deviations**. At some spots, in the contact zone to the rock, the bentonite samples were not saturated. These spots had a low water content and a rather high dry density, compared to the initial density of the pellets in the former gap. It is believed that these samples, to some extent, have been mixed with the backfill material above, which means that there might be pieces of rock material mixed with the clay.

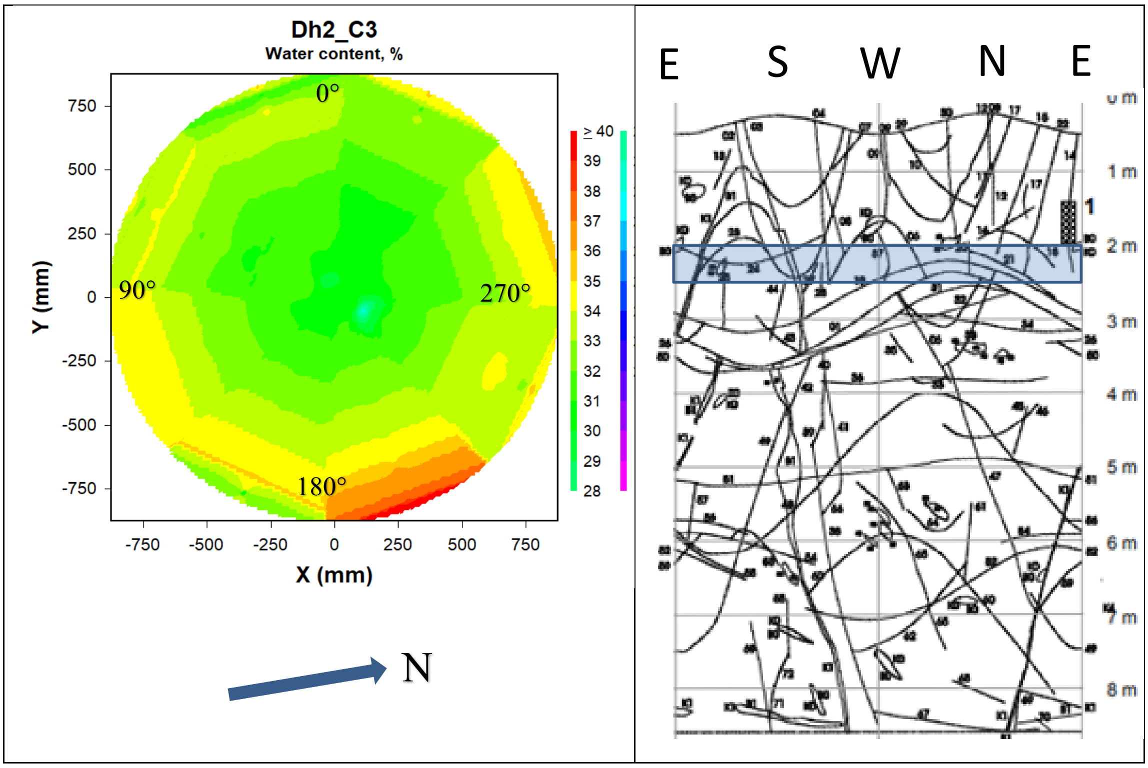


Figure 6-3. Left: Contour plot showing the water content distribution in block C3 in deposition hole 2. Right: Fracture mapping in deposition hole No 2. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C3 relative to the fractures.

6.2.3 Block C2 (above canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 3-3 (a-d). The determined water content distribution for block C2 is provided in Figure 6-4 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C2:

- **Dry density**. The dry density was somewhat higher compared to block C3. The dry density was mainly between 1420-1540 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small.

- **Degree of saturation**. The degree of saturation was high in this block, mainly between 96 and 100 %. The central parts of the block had the lowest degree of saturation.

- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a certain difference in density between the central parts of the block and parts of the former pellet gap close to the periphery. The dry density was somewhat lower at the periphery in directions between 65° and 200°.

- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap.

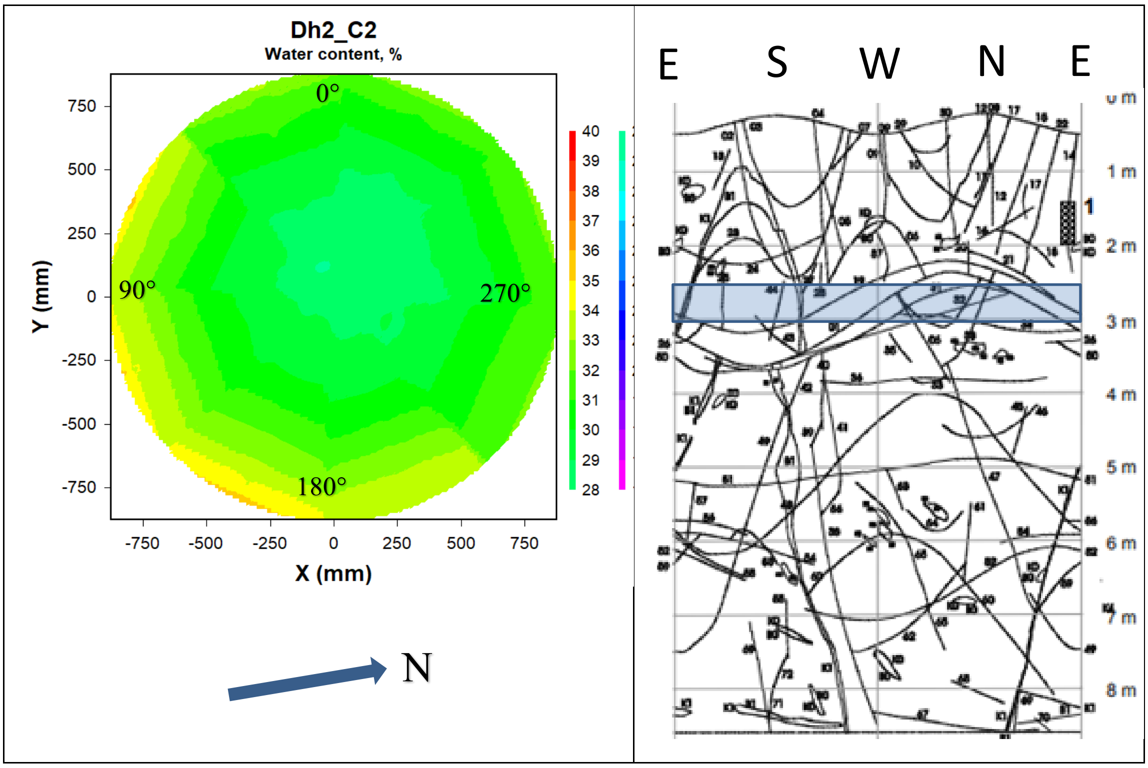


Figure 6-4. Left: Contour plot showing the water content distribution in block C2 in deposition hole 2. Right: Fracture mapping in deposition hole No 2. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C2 relative to the fractures.

6.2.4 Block R10 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 3-4 (a-d). The determined water content distribution for block R10 is provided in Figure 6-5 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R10:

- **Dry density**. The dry density was mainly between 1450-1600 kg/m^3 which was somewhat higher compared to the cylindrical block above. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the levels was rather small.
- **Degree of saturation**. The degree of saturation was high at all positions, mainly between 96 and 100 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest density values were found close to the rock in direction 155°.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap. The samples close to the canister were taken from level 350 mm, instead of 50 mm, in directions 65°, 110°, 155°, 200° and 335°.

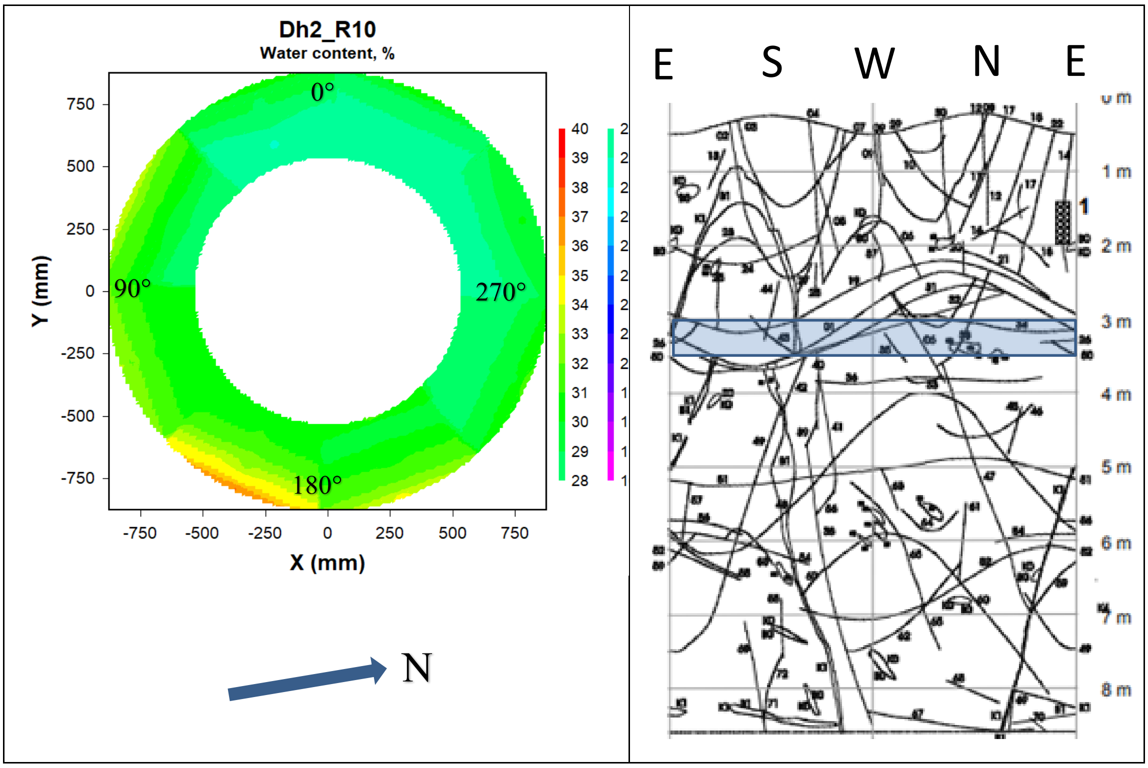


Figure 6-5. Left: Contour plot showing the water content distribution in block R10 in deposition hole 2. Right: Fracture mapping in deposition hole No 2. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R10 relative to the fractures.

6.2.5 Block R9 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 3-5 (a-d). The determined water content distribution for block R9 is provided in Figure 6-6 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R9:

- **Dry density**. The dry density was mainly between 1500-1600 kg/m^3, which was somewhat higher compared to the block above. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block (only one level was sampled in direction 20°). These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation was high at all positions, mainly between 95 and 100 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest density values were found close to the rock in the directions 155° and 200°.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

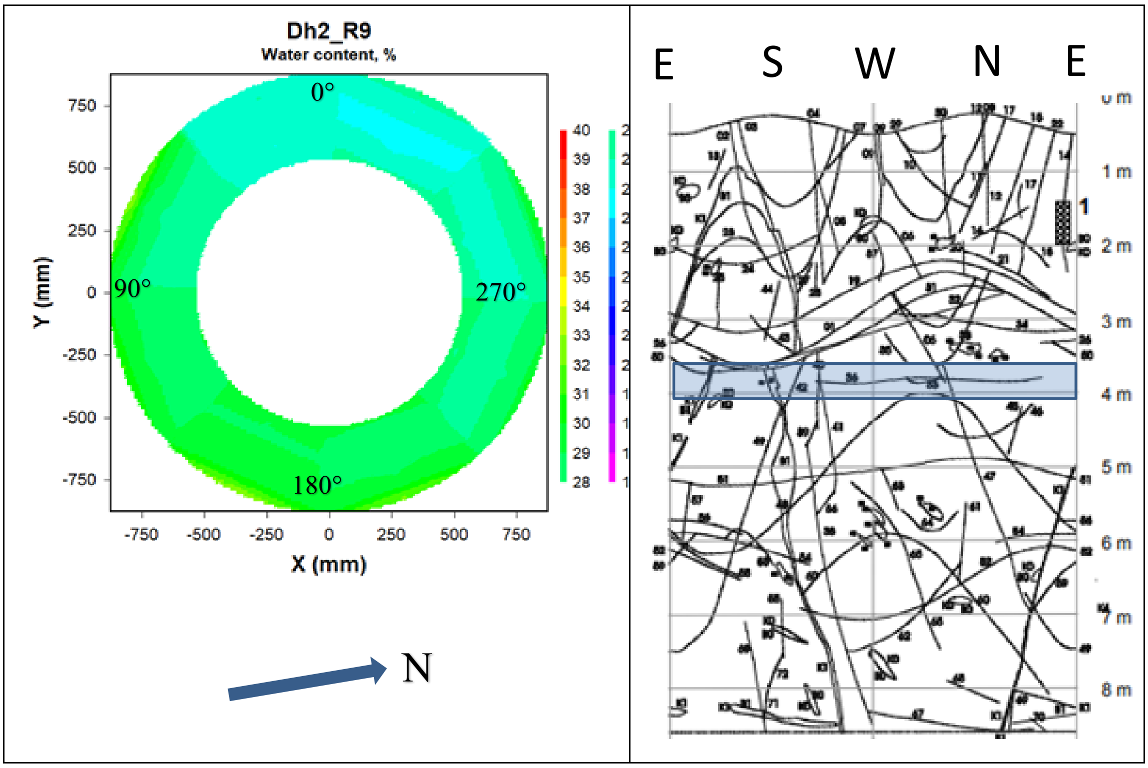


Figure 6-6. Left: Contour plot showing the water content distribution in block R9 in deposition hole 2. Right: Fracture mapping in deposition hole No 2. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R9 relative to the fractures.

6.2.6 Block R8 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 3-6 (a-d). The determined water content distribution for block R8 is provided in Figure 6-7 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R8:

- **Dry density**. The dry density was mainly between 1550-1670 kg/m^3, which was somewhat higher compared to the block above. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small (somewhat higher in the direction of 20°).
- **Degree of saturation**. The degree of saturation varied between 88 and 100 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite in this block varied between the different sampling directions. The sections between 270° and 90° (upper half) were drier and had a higher density.
- **Deviations**. The results from the water content and density determinations were in general consistent. Large variations of the water content were found in the former pellet filled gap and close to the former gap between block and canister for the different sampling directions.

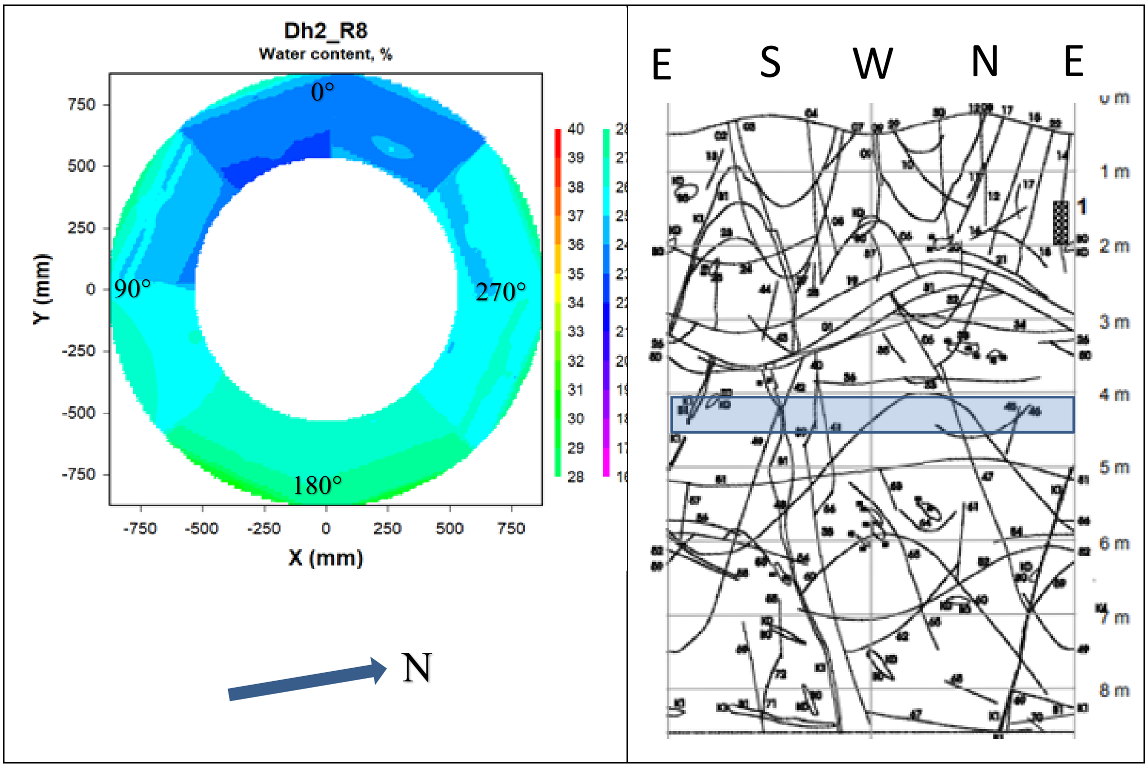


Figure 6-7. Left: Contour plot showing the water content distribution in block R8 in deposition hole 2. Right: Fracture mapping in deposition hole No 2. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R8 relative to the fractures.

6.2.7 Block R7 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 3-7 (a-d). The determined water content distribution for block R7 is provided in Figure 6-8 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R7:

- **Dry density**. The dry density was mainly between 1600-1770 kg/m^3, which was somewhat higher compared to the block above. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small.
- **Degree of saturation**. The degree of saturation varied mainly between 82 and 98 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite in this block varied strongly between the different sampling directions. The sections between 315° and 135° were drier and had a higher density.
- **Deviations**. The results from the water content and density determinations were in general consistent. Large variations of the water content were found in the former pellet filled gap and close to the former gap between block and canister for the different sampling directions.

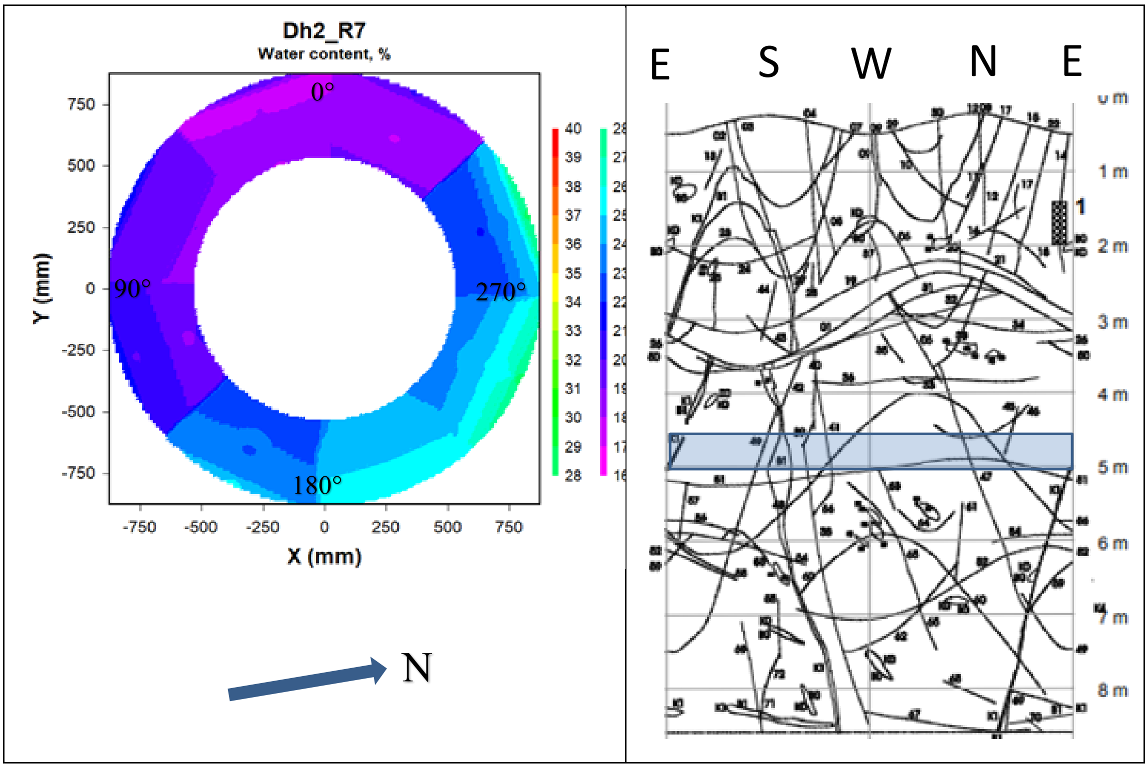


Figure 6-8. Left: Contour plot showing the water content distribution in block R7 in deposition hole 2. Right: Fracture mapping in deposition hole No 2. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R7 relative to the fractures.

6.2.8 Block R6 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 3-8 (a-d). The determined water content distribution for block R6 is provided in Figure 6-9 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R6:

- **Dry density**. The dry density was mainly between 1680-1800 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. No difference in density between the different heights were found in direction 20°. In direction 245°, the density varied between 1630 kg/m^3 (50 mm level) and 1770 kg/m^3 (250-450 mm level).
- **Degree of saturation**. The degree of saturation varied mainly between 77 and 88 %, with the lowest values close to the canister.
- **Homogenization**. The results from the sampling showed that this block was partly dry i.e. the water content and the density were in the same range as when the block was installed. The sections between 245° and 270° had the highest water content.
- **Deviations**. The results from the water content and density determinations were in general consistent. Large variations of the water content were found in the former pellet filled gap and close to the former gap between block and canister for the different sampling directions.

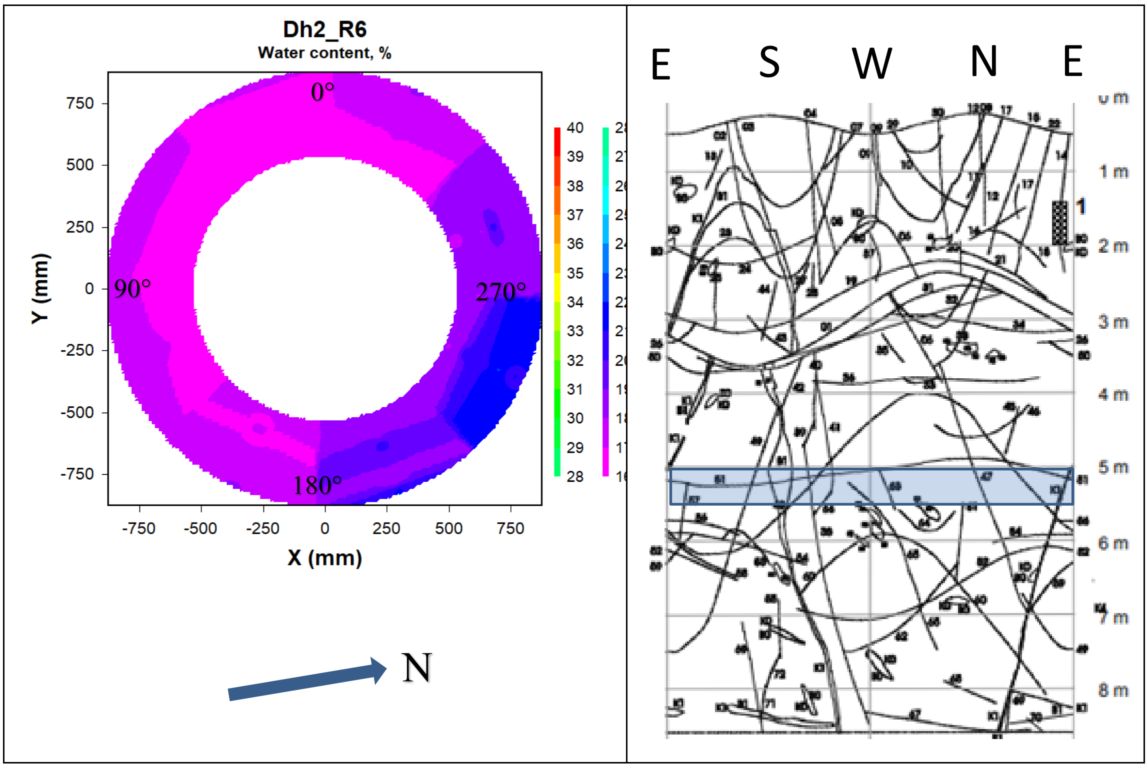


Figure 6-9. Left: Contour plot showing the water content distribution in block R6 in deposition hole 2. Right: Fracture mapping in deposition hole No 2. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R6 relative to the fractures.

6.2.9 Block R5 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 3-9 (a-d). The determined water content distribution for block R5 is provided in Figure 6-10 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R5:

- **Dry density**. The dry density was mainly between 1750-1800 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. No difference in density between the different heights were found.
- **Degree of saturation**. The degree of saturation varied mainly between 75 and 87 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that this block had only taken up small amounts of water from the rock or from the bentonite above. The water content and the density were in the same range as when the block was installed.
- **Deviations**. The results from the water content and density determinations were in general consistent.

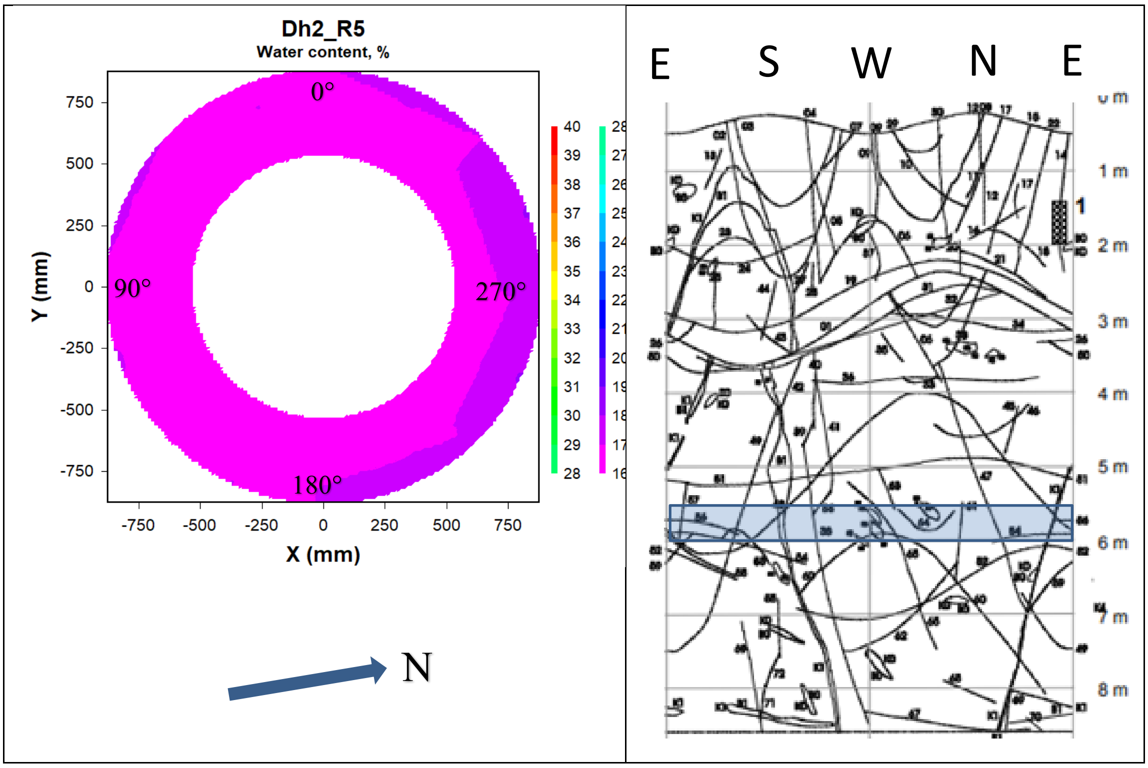


Figure 6-10. Left: Contour plot showing the water content distribution in block R5 in deposition hole 2. Right: Fracture mapping in deposition hole No 2. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R5 relative to the fractures.

6.2.10 Block R4 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 3-10 (a-d). The determined water content distribution for block R4 is provided in Figure 6-11 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R4:

- **Dry density**. The dry density was mainly between 1750-1800 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. No difference in density between the different heights were found.
- **Degree of saturation**. The degree of saturation varied mainly between 75 and 87 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that this block had only taken up small amounts of water from the rock or from the bentonite above. The water content and the density were in the same range as when the block was installed.
- **Deviations**. The results from the water content and density determinations were in general consistent.

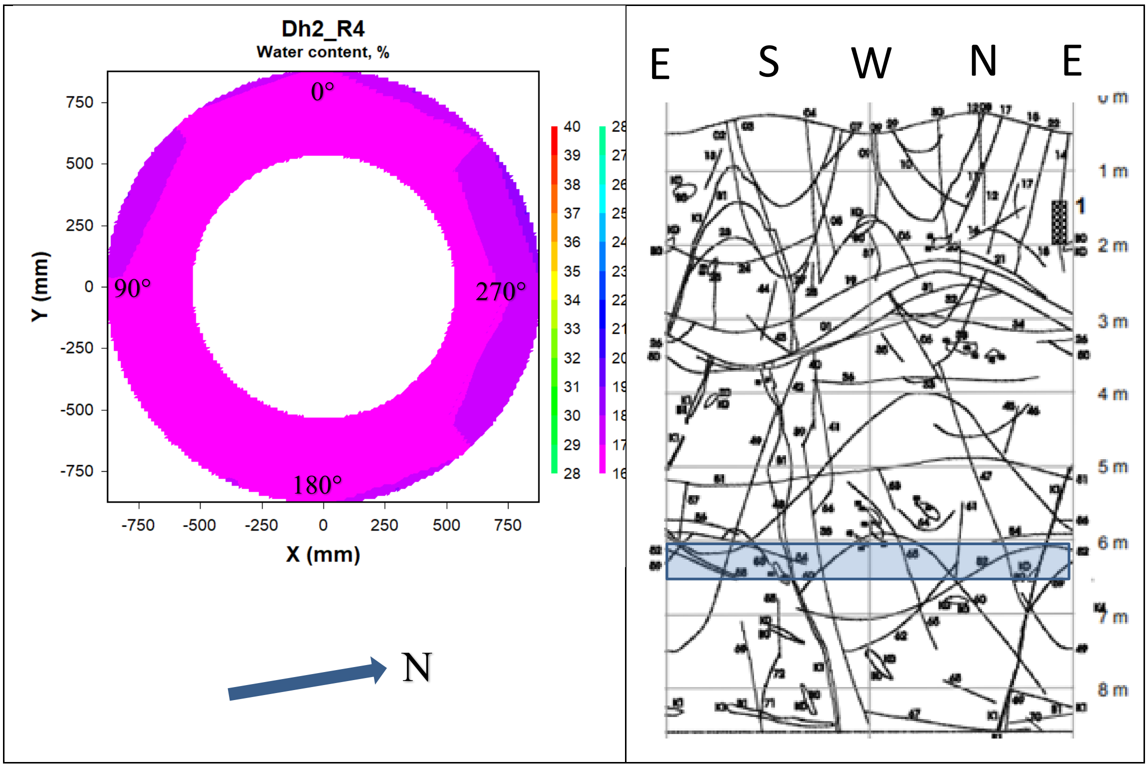


Figure 6-11. Left: Contour plot showing the water content distribution in block R4 in deposition hole 2. Right: Fracture mapping in deposition hole No 2. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R4 relative to the fractures.

6.2.11 Block R3 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 3-11 (a-d). The determined water content distribution for block R3 is provided in Figure 6-12 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R3:

- **Dry density**. The dry density was mainly between 1750-1800 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. No difference in density between the different heights were found.
- **Degree of saturation**. The degree of saturation varied mainly between 75 and 87 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that this block had only taken up small amounts of water from the rock or from the bentonite above. The water content and the density were in the same range as when the block was installed.
- **Deviations**. The results from the water content and density determinations were in general consistent.

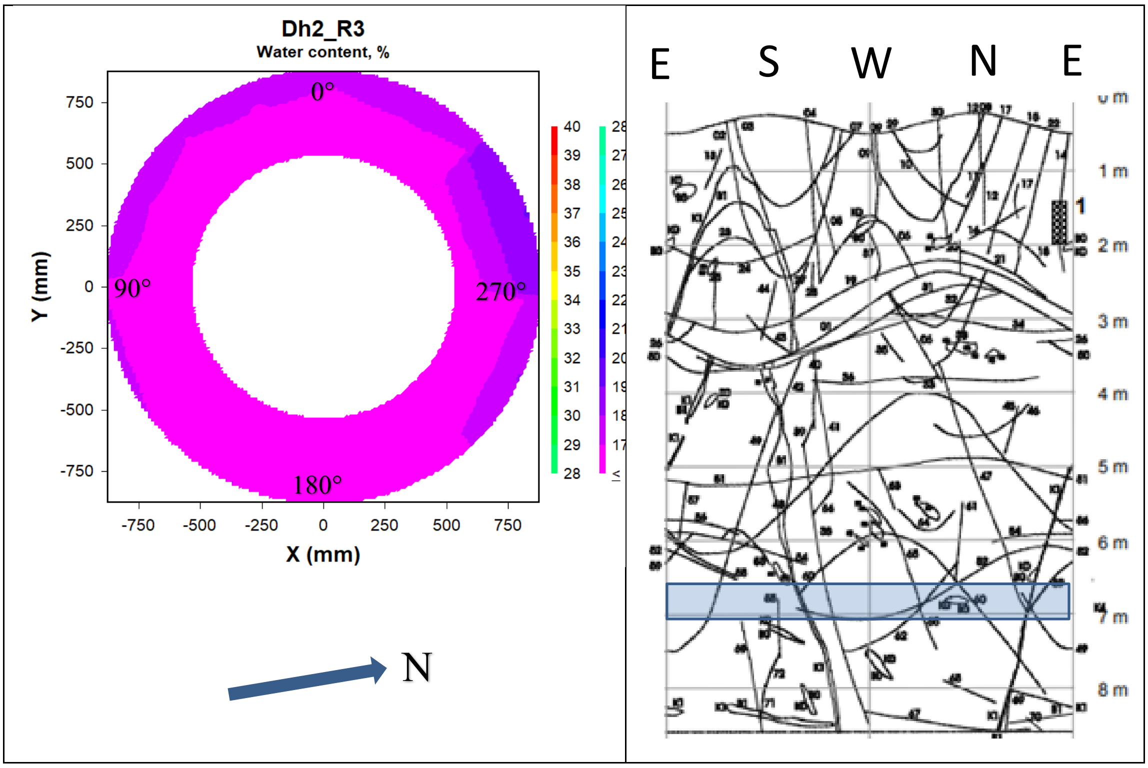


Figure 6-12. Left: Contour plot showing the water content distribution in block R3 in deposition hole 2. Right: Fracture mapping in deposition hole No 2. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R3 relative to the fractures.

6.2.12 Block R2 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 3-12 (a-d). The determined water content distribution for block R2 is provided in Figure 6-13 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R2:

- **Dry density**. The dry density was mainly between 1770-1810 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. No difference in density between the different heights were found.
- **Degree of saturation**. The degree of saturation varied mainly between 75 and 87 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that this block had only taken up small amounts of water from the rock or from the bentonite above. The water content and the density were in the same range as when the block was installed.
- **Deviations**. The results from the water content and density determinations were in general consistent.

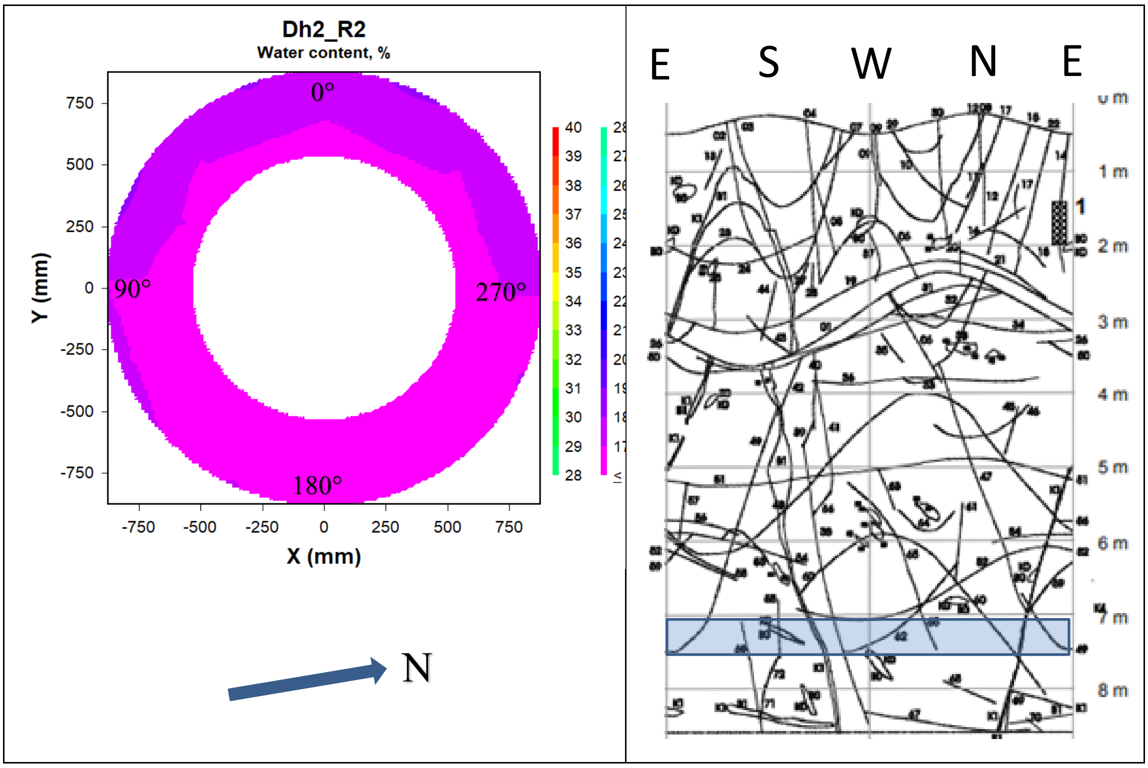


Figure 6-13. Left: Contour plot showing the water content distribution in block R2 in deposition hole 2. Right: Fracture mapping in deposition hole No 2. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R2 relative to the fractures.

6.2.13 Block R1 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 3-13 (a-d). The determined water content distribution for block R1 is provided in Figure 6-14 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R1:

- **Dry density**. The dry density was mainly between 1750-1800 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. Only small differences in density between the different heights were found.
- **Degree of saturation**. The degree of saturation varied mainly between 75 and 85 %.
- **Homogenization**. The sampling showed that this block had only taken up small amounts of water from the rock or from the bentonite above. The water content and the density were in the same range as when the block was installed.
- **Deviations**. The results from the water content and density determinations were in general consistent. No sampling close to the canister and close to the rock was made in direction 20°.

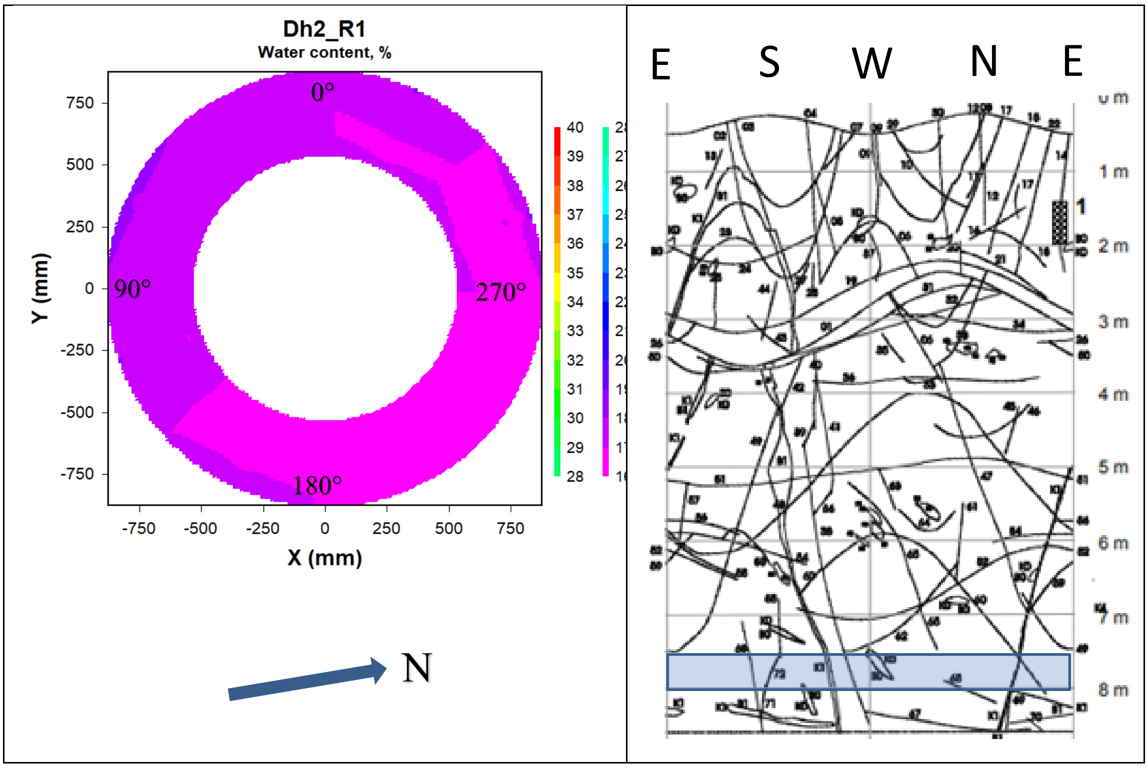


Figure 6-14. Left: Contour plot showing the water content distribution in block R1 in deposition hole 2. Right: Fracture mapping in deposition hole No 2. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R1 relative to the fractures.

6.2.14 Block C1 (below the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 3-14 (a-d). The determined water content distribution for block C1 is provided in Figure 6-15 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C1:

- **Dry density**. The dry density was mainly between 1670-1720 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. The difference in density between the different heights was small.
- **Degree of saturation**. The degree of saturation varied mainly between 76 and 83 %.
- **Homogenization**. The sampling showed that this block had only taken up small amounts of water from the rock or from the bentonite above. The water content and the density were in the same range as when the block was installed.
- **Deviations**. The results from the water content and density determinations were in general consistent.

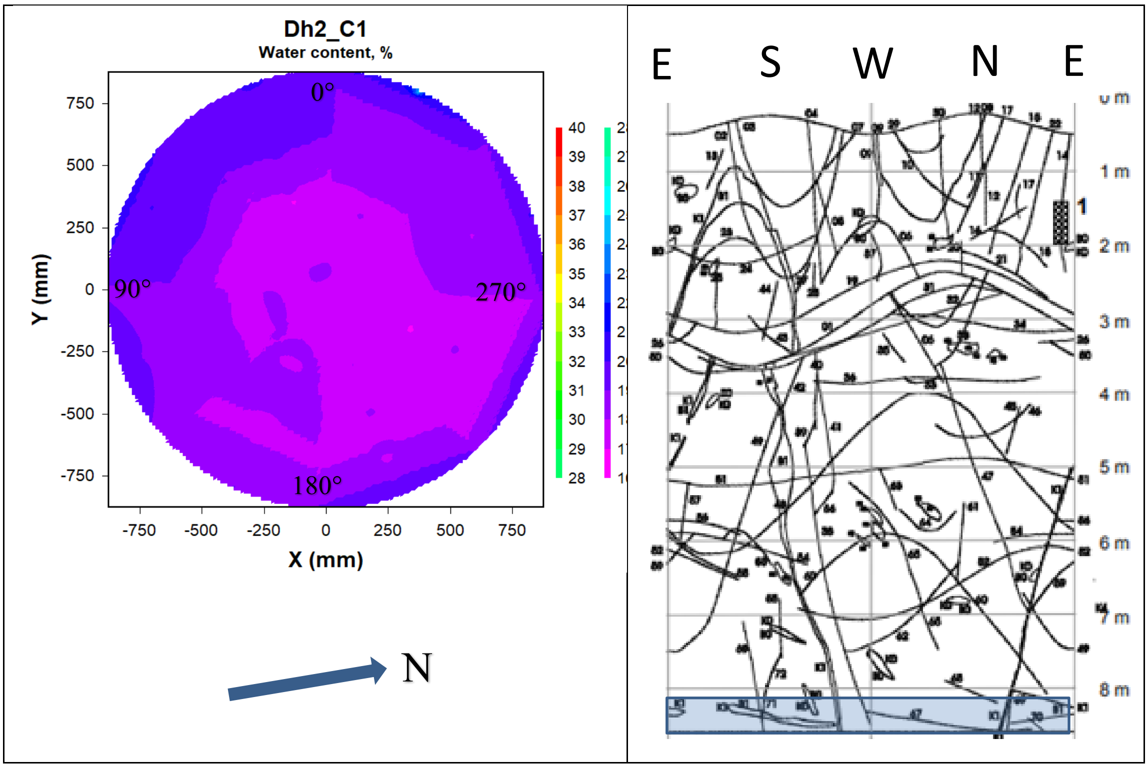


__Figure 6-15.__ Left: Contour plot showing the water content distribution in block C1 in deposition hole 2. Right: Fracture mapping in deposition hole No 2. Water bearing fractures are marked with shaded areas (no such areas in this deposition hole), (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C1 relative to the fractures.

6.3 Summary of results from Dh2

6.3.1 Access to water

The buffer blocks in the deposition holes have had access to water both from fractures in the rock and via the backfill above the deposition hole.

The fracture mappings for all deposition holes are provided in Figure 2-2 and Figure 2-3, and the measured inflows are listed in Table 2-1. The inflow rate to deposition hole 2 was determined to 0.002 l/min. This inflow rate was of the same order of magnitude as for deposition holes 5 and 6.

As described in Section 4.3.1, it is believed that water flowing from the backfill down to the buffer has greatly contributed to the saturation of the buffer.

6.3.2 Compilation of data

As described in Section 4.3.2, two different methods have been used to give a picture of the status of the complete deposition hole (see Appendix 3-nm for all blocks n and diagrams m) regarding water content, dry density, and degree of saturation distribution:

1. The individual contour plots of every single block have been compressed and stacked on each other, Figure 6-16. These figures give a rather good picture of the water content, the dry density, and the degree of saturation distribution for the complete deposition hole.
2. Contour plots were generated by DPlot. The plots are showing the water content, the dry density and the degree of saturation distribution in eight vertical cross-sections of deposition hole 2, Figure 6-17, Figure 6-18 and Figure 6-19.

The following conclusions can be made from the figures:

- Block C4 and C3 (top blocks). Both these blocks had swelled axially and by that decreased the density. The dry density for block C4 was mainly between 1300 and 1400 kg/m3 and for block C3 between 1400 and 1500 kg/m3. Both blocks were largely water saturated.
- Block C2 (block above canister). This block had also swelled axially and by that decreased in density. The dry density for this block was mainly between 1400 and 1540 kg/m3. The degree of saturation was mainly between 95 to 100 %. In the corresponding block in Dh4, the central parts had a lower degree of saturation, which probably was an effect of the temperature from the canister. In this deposition hole, Dh2, no heating has been applied since December 2004, and this block, C2, had a high degree of saturation.
- Block R10-R8 (ring-shaped blocks along the upper half of the canister). These blocks did not seem to be especially affected by any axial swelling. The dry density varied mainly between 1450 and 1700 kg/m3 depending on direction. The blocks are largely water saturated, between 93 and 100 %.
- Block R7 (ring-shaped block along the upper half of the canister). This block was only partially affected by water uptake. The variations in density and degree of saturation were large between different directions.
- Block R6-R1 (ring-shaped blocks along the lower half of the canister). These blocks were only partially affected by water uptake. The dry density and degree of saturation of the blocks were close to the original values. It was obvious that the homogenization had not proceeded far since it was still possible to identify individual pellets in the gap between block and rock at several positions.
- Block C1 (block below canister). This block was only affected by water uptake to a very small degree (outermost parts). The dry density and degree of saturation was close to the original values.

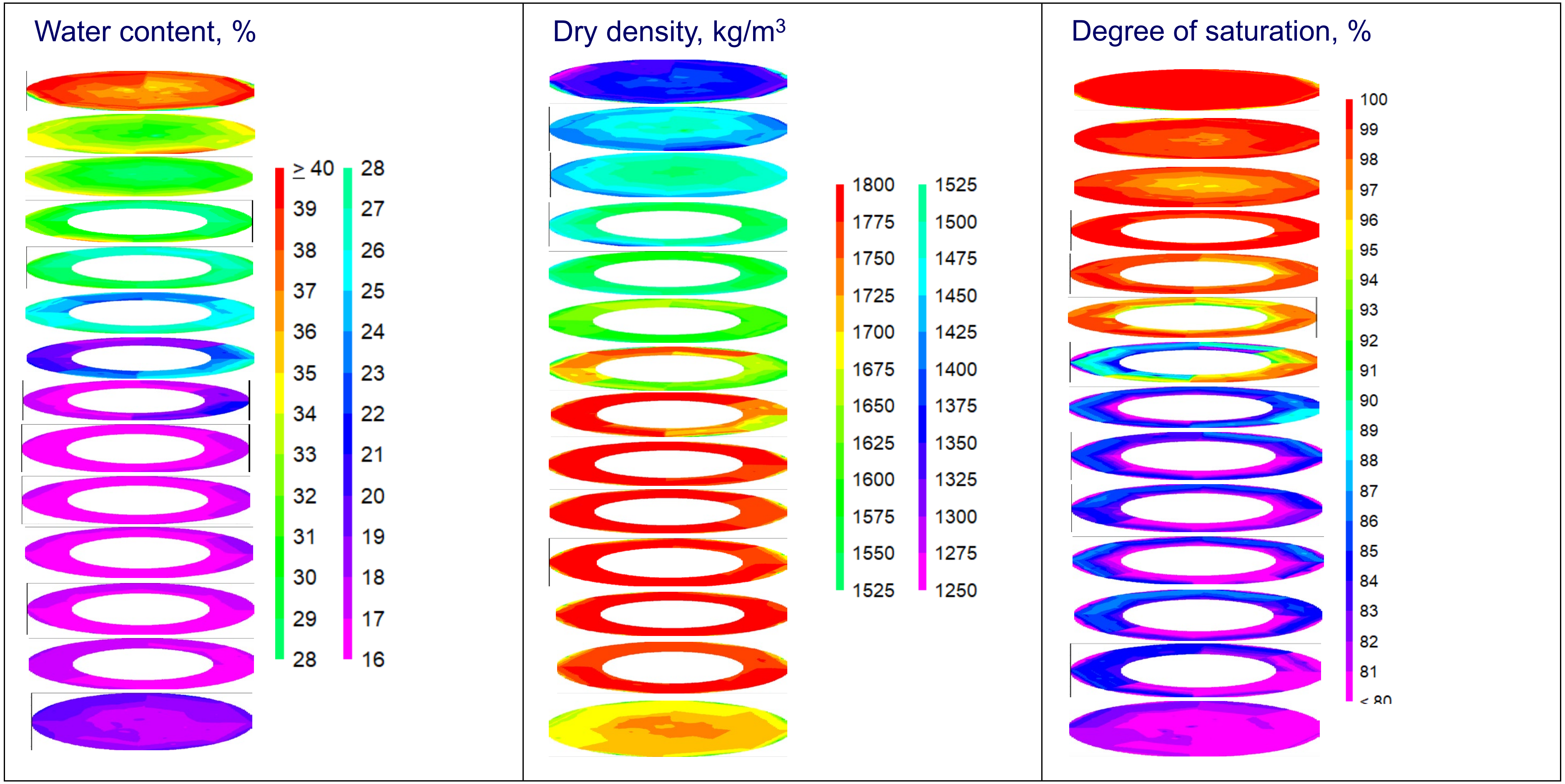


Figure 6-16. *Compressed contour plots of every single block in Dh 2 stacked on each other. Left: the water content distribution (%) Middle: the dry density distribution (kg/m^3) Right: the degree of saturation distribution (%).*

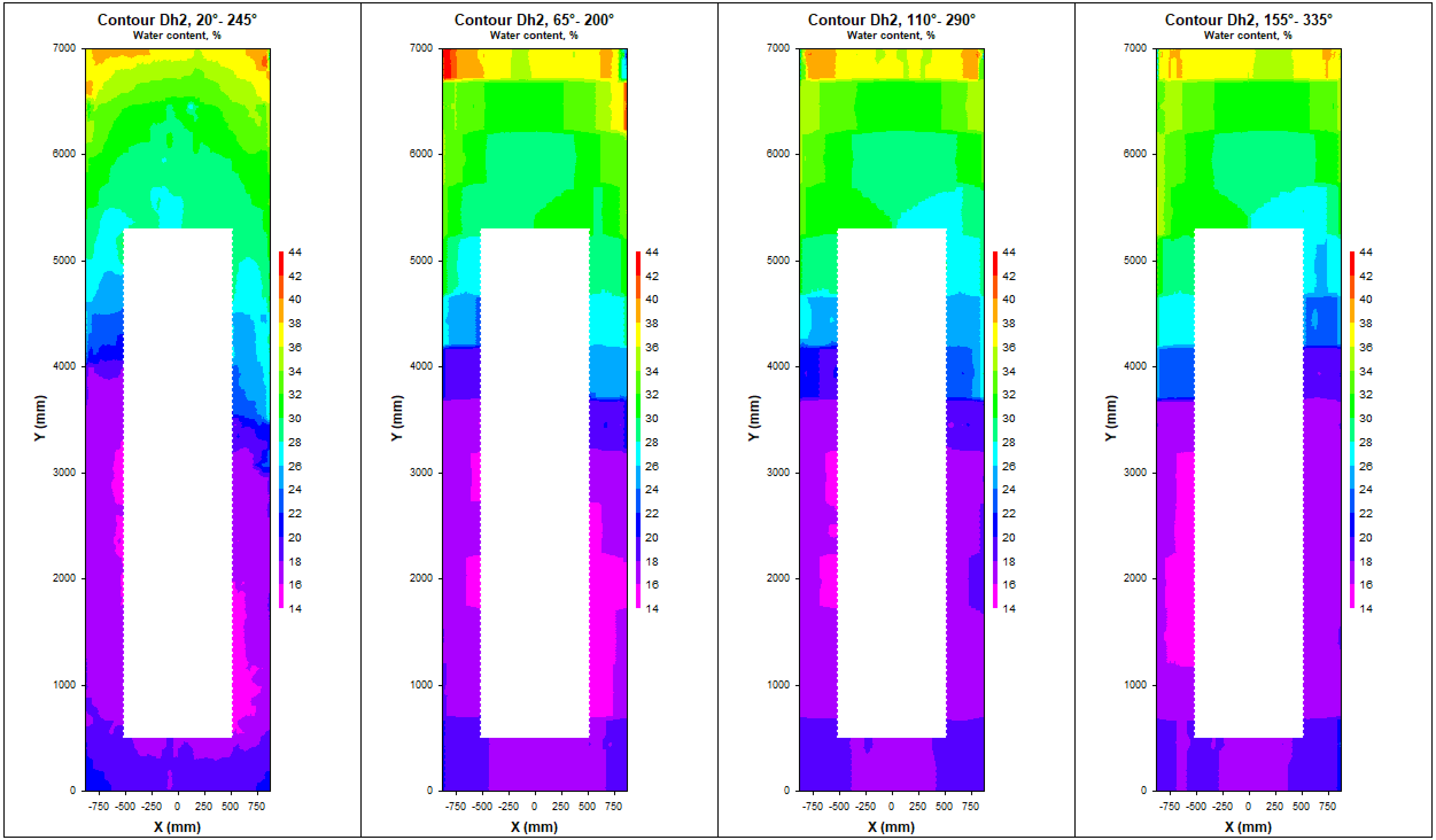


Figure 6-17. Four contour plots showing the water content distribution in eight vertical cross-sections of deposition hole 2.

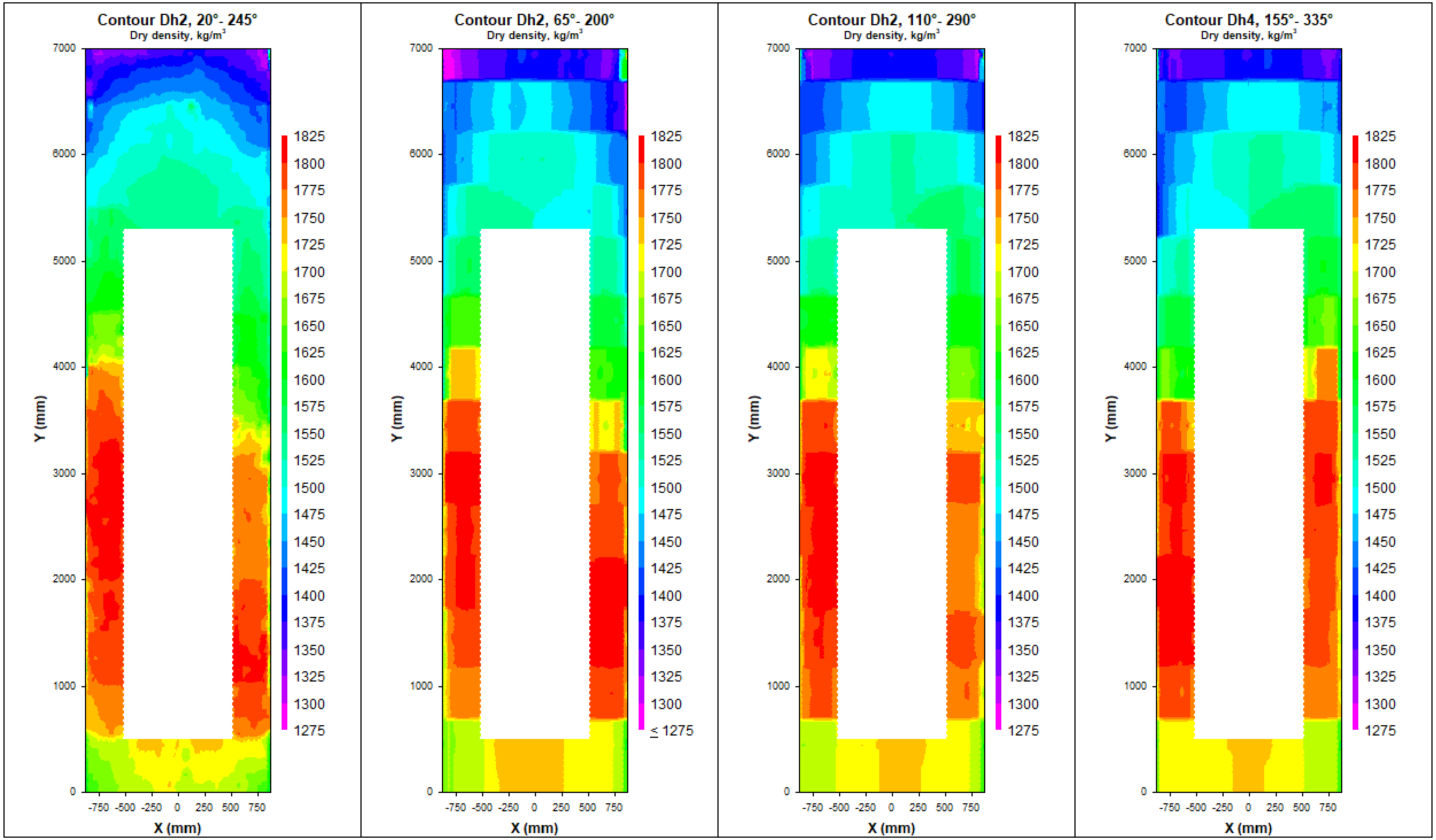


Figure 6-18. *Four contour plots showing the dry density distribution in eight vertical cross-sections of deposition hole 2.*

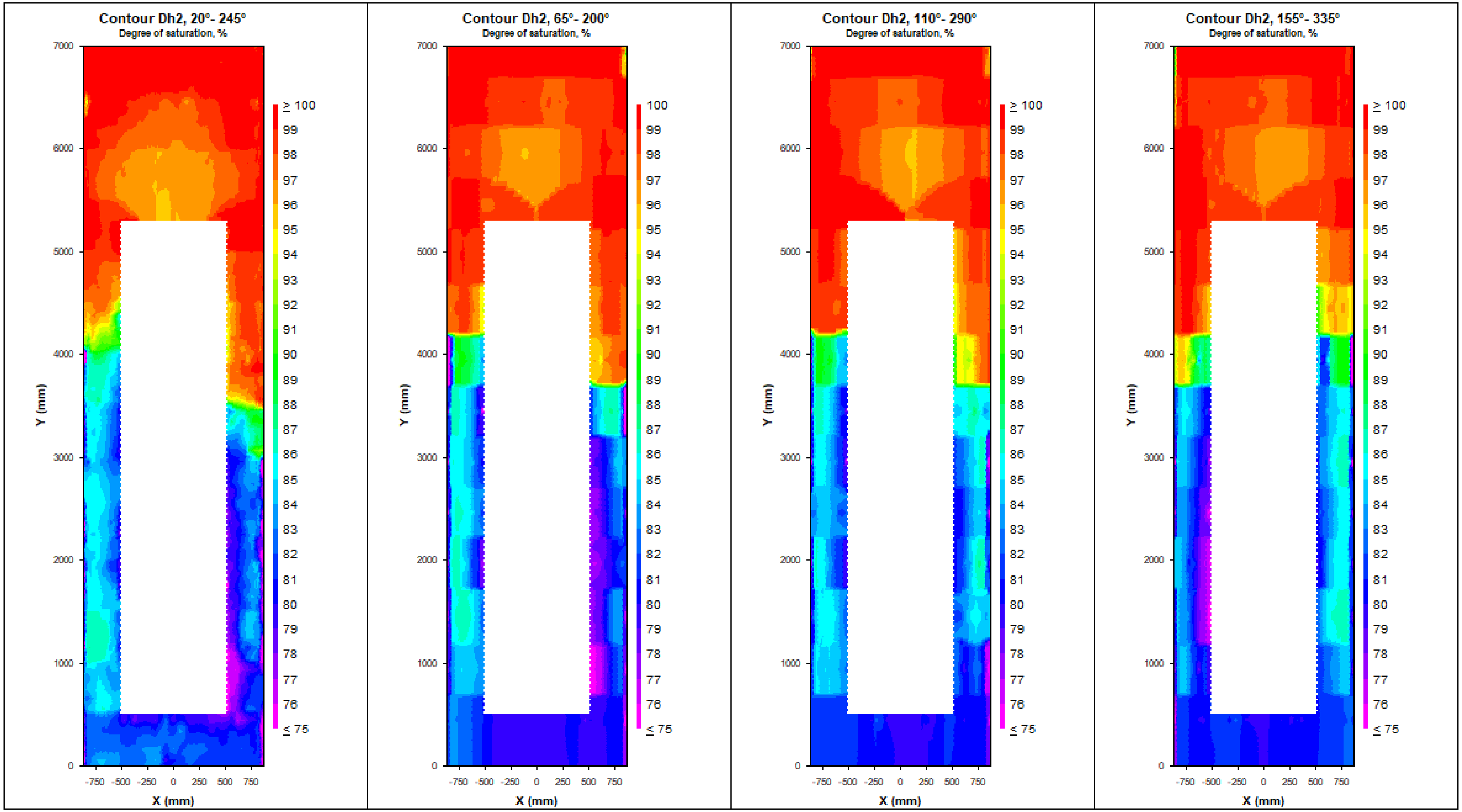


Figure 6-19. *Four contour plots showing the degree of saturation distribution in eight vertical cross-sections of deposition hole 2.*

7 Results from measurements in Deposition hole 1

7.1 Background

7.1.1 Heating history

The heating of the canister started 2001-09-17. The applied power was set to 1800 W from the start. The applied power was then lowered in steps during the following years, approximately 30 W per year. Due to heater failure, the lowering in 2013 was larger, from 1560 to 1440 W. The heaters continued to failure and the applied power was after approximately 6250 days test duration 300 W. The heaters were switched off 2019-12-17 after 6665 days test duration, due to failure. Detailed information regarding the applied canister power is available in the report by Goudarzi (2023).

The registered temperature on the canister surface was during the first 1300 days approximately between 70 °C to 80 °C (Goudarzi 2023). After that time, the sensor (optical fiber cable) stopped working.

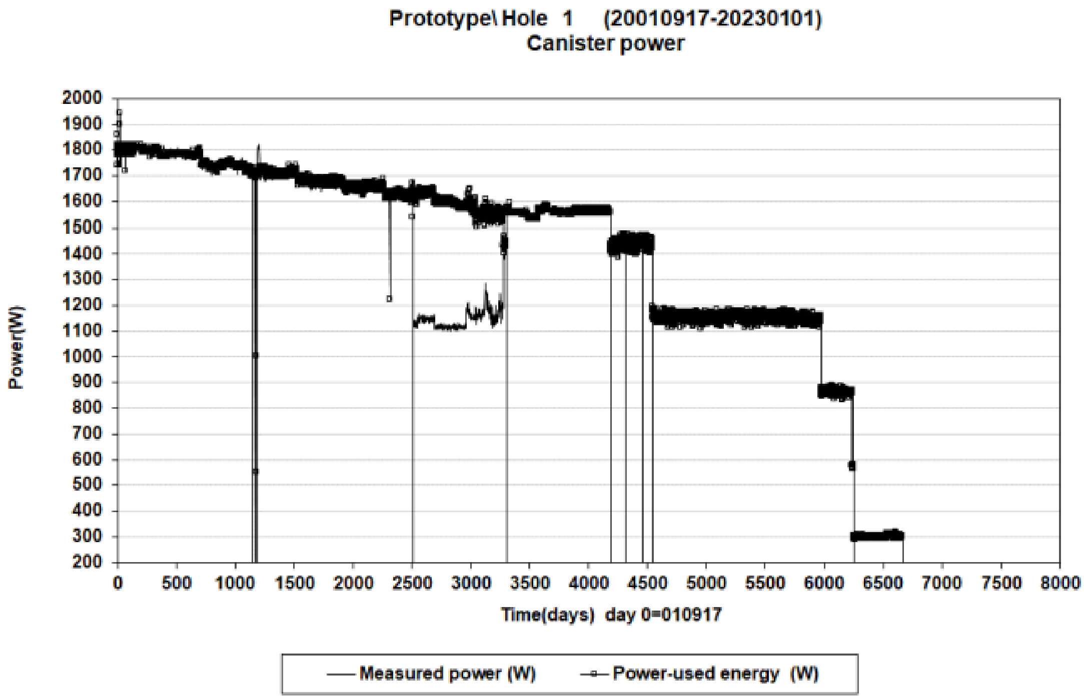


Figure 7-1. The applied power in the canister in deposition hole 1 (Goudarzi 2023).

7.1.2 Water inflow

The measured water inflow to deposition hole was rather large, 0.08 l/min, Table 2-1. Mapping of water-bearing fractures was made in January 2000 (Rhén and Forsmark 2001). The inflow from four water bearing fractures was measured, see shaded areas in Figure 2-2 (left). The inflow varied between 0 and 1.11 x 10^{-4} l/min (Rhén and Forsmark 2001).

7.1.3 Dismantling of Deposition hole 1 (Dh1)

The sampling of the buffer in Deposition hole 1 was performed during the period September 2024-February 2025.

The density and water content were determined in all fourteen buffer blocks including the pellet filled gap between block and rock surface. The sampling was made in eight directions, see detailed description in Chapter 3. In total, the density and water content were planned to be determined in approximately 4600 positions in Deposition hole 1.

7.2 Results from sampling of all buffer blocks in Dh1

The results from the sampling are presented in the same order as the dismantling of the deposition hole proceeded i.e., the first block that was sampled was the block closest to the backfill, block C4.

Several graphs were produced for every single block to show the determined data. In addition, contour plots were generated by DPlot. The denomination of the appendices begins with a sequential number and in the appendices beginning with 4 the following graphs and plots are provided for all blocks n (1-14) in Dh1:

- Appendix 4-n (1-14) a. Results from sampling in eight directions on the level 50 mm below the block surface. The graphs show the water content, the dry density, and the degree of saturation distribution.
- Appendix 4-n (1-14) b. Results from sampling in direction 20°. The sampling was done at five levels below the block surface (50, 150, 250, 350, and 450 mm). The graphs show the water content, the dry density, and the degree of saturation distribution.
- Appendix 4-n (1-14) c. Results from sampling in direction 245°. The sampling was done at five levels below the block surface (50, 150, 250, 350, and 450 mm). The graphs show the water content, the dry density, and the degree of saturation distribution.
- Appendix 4-n (1-14) d. Contour plots showing the water content, the dry density, and the degree of saturation distribution on the level 50 mm down from the block surface.

A contour plot showing the water content distribution is provided for every single block in this chapter together with a picture showing the fracture mapping of the deposition hole.

The sample coordinates used in the graphs (radius and directions in degrees) are described in Section 3.1.

7.2.1 Block C4 (uppermost block)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 4-1 (a-d). The determined water content distribution for block C4 is provided in Figure 7-2 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C4:

- **Dry density**. The dry density was low, mainly between 1200-1400 kg/m^3 (50 mm from block surface). This indicates that the block has swelled upwards, compacting the backfill above, and by that the density of the block has decreased. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that there was an obvious difference in density between the different levels (higher density at higher depth) which also indicated that the block had swelled upwards.
- **Degree of saturation**. The degree of saturation was in general high, mainly between 98 and 100 % (with exception of some spots in the former pellet filled gap).
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a certain difference in density between the central parts of the block and the parts close to the periphery.
- **Deviations**. At some spots, in the contact zone to the rock, the bentonite samples were not saturated. These spots had a low water content and a rather high dry density, compared to the initial density of the pellets in the former gap. It is believed that these samples, to some extent, have been mixed with the backfill material above, which means that there might be pieces of rock material mixed with the clay (the same phenomenon have been seen in all deposition holes for the uppermost blocks). The sampling in direction 245° was limited.

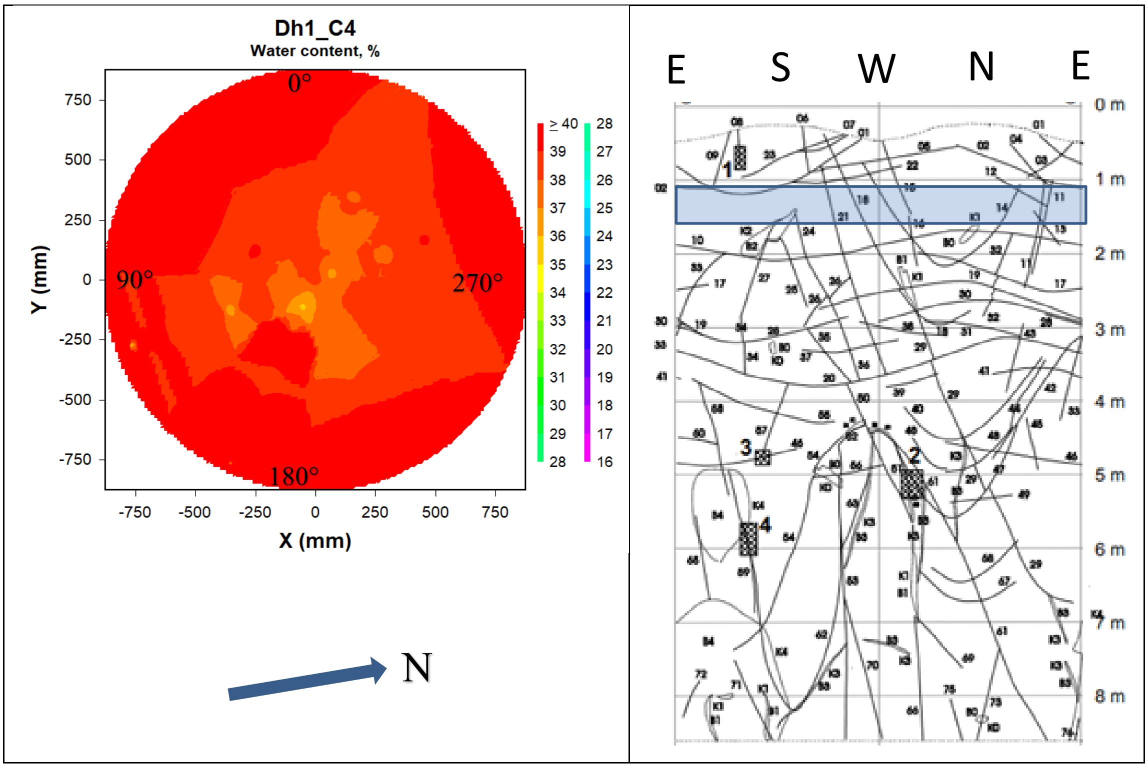


__Figure 7-2.__ Left: Contour plot showing the water content distribution in block C4 in deposition hole 1. Right: Fracture mapping in deposition hole No 1. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C4 relative to the fractures.

7.2.2 Block C3 (above canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 4-2 (a-d). The determined water content distribution for block C3 is provided in Figure 7-3 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C3:

- **Dry density**. The dry density was higher compared to block C4, mainly between 1350-1480 kg/m^3 (50 mm from block surface). Samples with lower density were found in the former pellet filled gap. The rather low density indicates that also this block has been affected by the upward swelling. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that there was a certain difference in density between the different levels (higher density at higher depth) which also was an indication that the block had swelled upwards. The difference in density was, however, smaller compared to block C4.
- **Degree of saturation**. The degree of saturation was in general high, between 97 and 100 %.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a certain difference in density between the central parts of the block and the parts close to the periphery.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap.

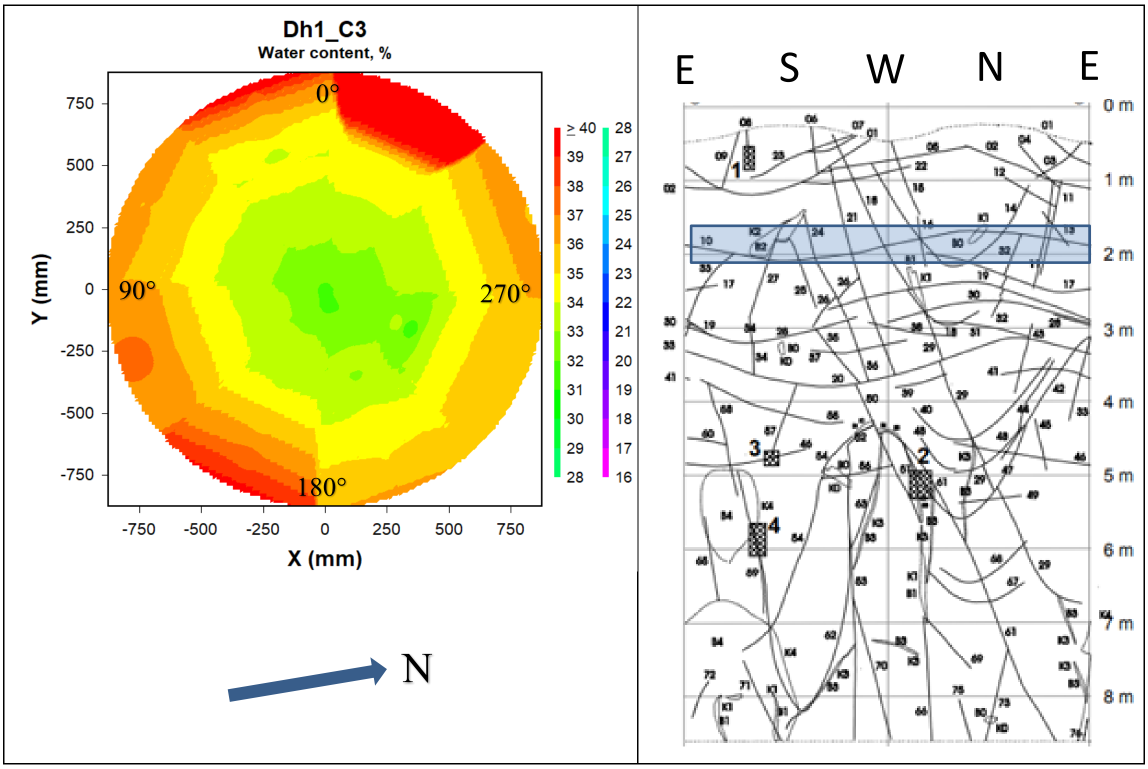


Figure 7-3. Left: Contour plot showing the water content distribution in block C3 in deposition hole 1. Right: Fracture mapping in deposition hole No 1. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C3 relative to the fractures.

7.2.3 Block C2 (above canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 4-3 (a-d). The determined water content distribution for block C2 is provided in Figure 7-4 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C2:

- **Dry density**. The dry density was somewhat higher compared to block C3, mainly between 1350-1500 kg/m^3. Samples with lower density were found in the former pellet filled gap. The rather low density indicates that also this block has been affected by the upward swelling. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small.
- **Degree of saturation**. The degree of saturation was in general high, between 97 and 100 %.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a certain difference in density between the central parts of the block and the parts close to the periphery.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap.

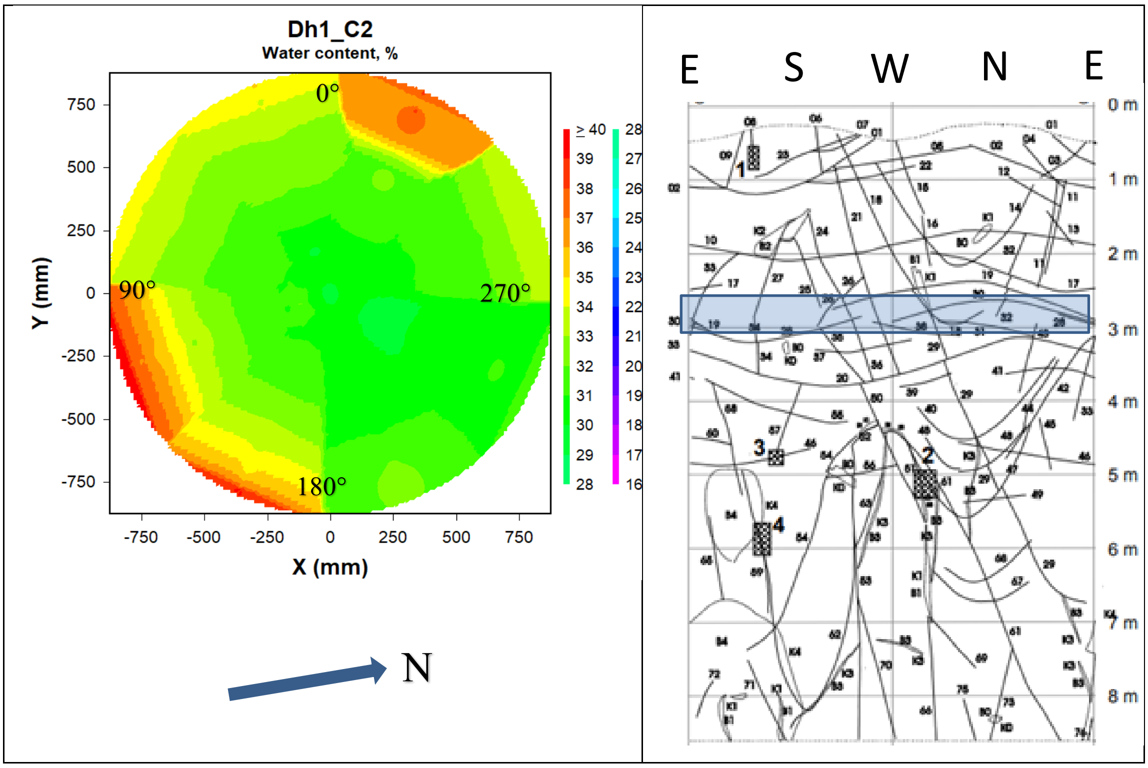


__Figure 7-4.__ Left: Contour plot showing the water content distribution in block C2 in deposition hole 1. Right: Fracture mapping in deposition hole No 1. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C2 relative to the fractures.

7.2.4 Block R10 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 4-4 (a-d). The determined water content distribution for block R10 is provided in Figure 7-5 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R10:

- **Dry density**. The dry density was mainly between 1400-1570 kg/m^3 which was somewhat higher compared to the cylindrical block above. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small.
- **Degree of saturation**. The degree of saturation was high at all positions, mainly between 96 and 100 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest density values were found close to the rock in the direction of 155°.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap.

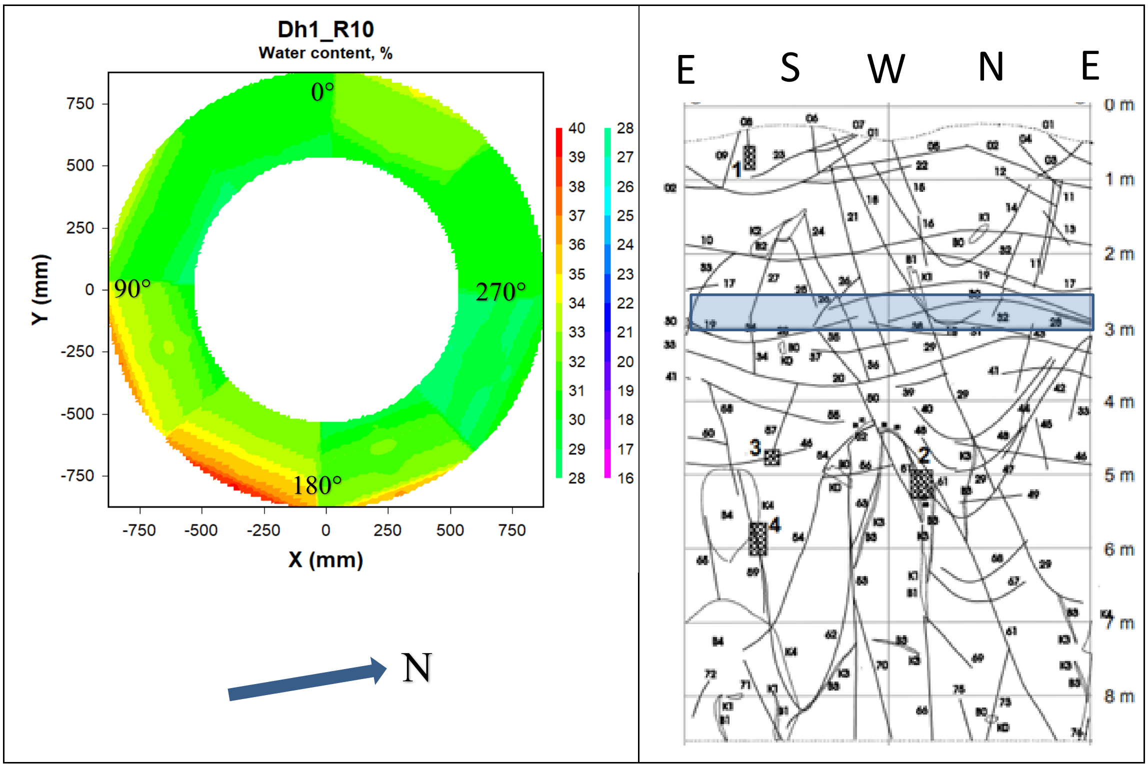


Figure 7-5. *Left: Contour plot showing the water content distribution in block R10 in deposition hole 1. Right: Fracture mapping in deposition hole No 1. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R10 relative to the fractures.*

7.2.5 Block R9 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 4-5 (a-d). The determined water content distribution for block R9 is provided in Figure 7-6 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R9:

- **Dry density**. The spread in density was rather high in this block. The dry density was mainly between 1450-1620 kg/m^3. Samples with lower density, below 1300 kg/m^3, were found in the former pellet filled gap in the direction of 110°. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block (only one level was sampled in direction 20°). These measures showed that the difference in density between the different levels was small.

- **Degree of saturation**. The degree of saturation was high at all positions, mainly between 95 and 100 %, with the lowest values close to the canister.

- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest density values were found close to the rock in the direction 110°.

- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister. The sampling in direction 20° was limited.

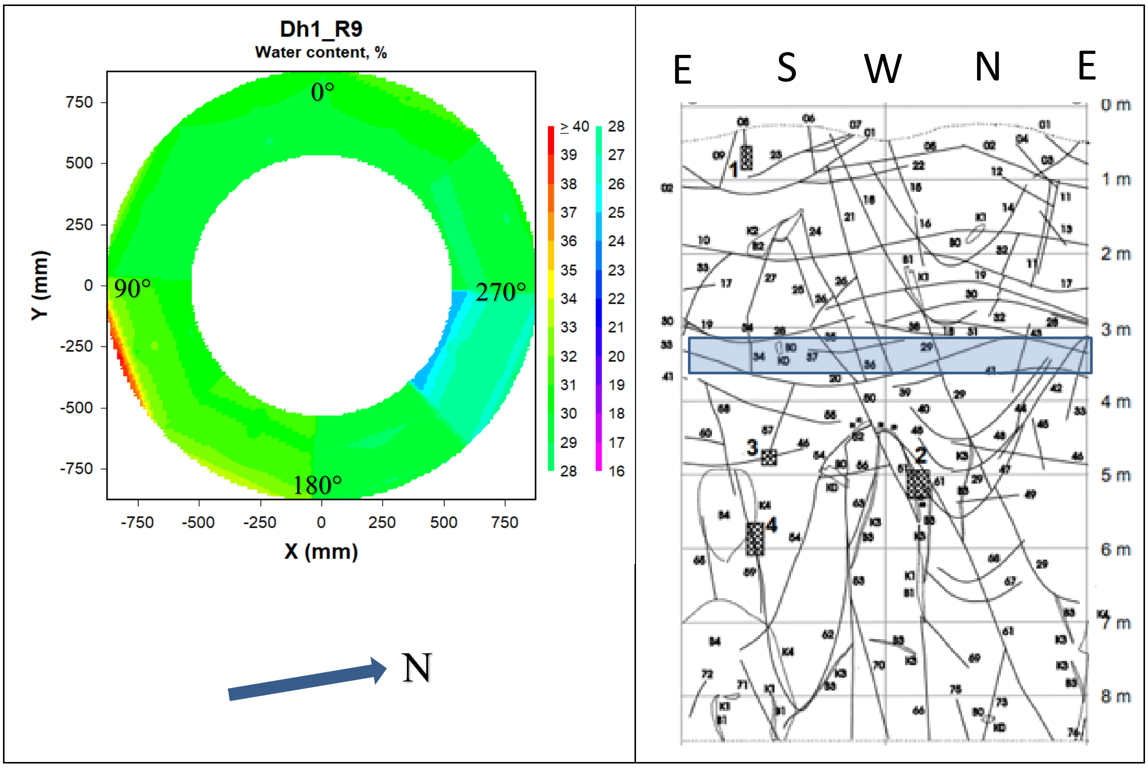


Figure 7-6. *Left: Contour plot showing the water content distribution in block R9 in deposition hole 1. Right: Fracture mapping in deposition hole No 1. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R9 relative to the fractures.*

7.2.6 Block R8 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 4-6 (a-d). The determined water content distribution for block R8 is provided in Figure 7-7 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R8:

- **Dry density**. The dry density was mainly between 1450-1600 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small.
- **Degree of saturation**. The degree of saturation was high at all positions, mainly between 95 and 100 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest density values were found close to the rock in the direction of 110°.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

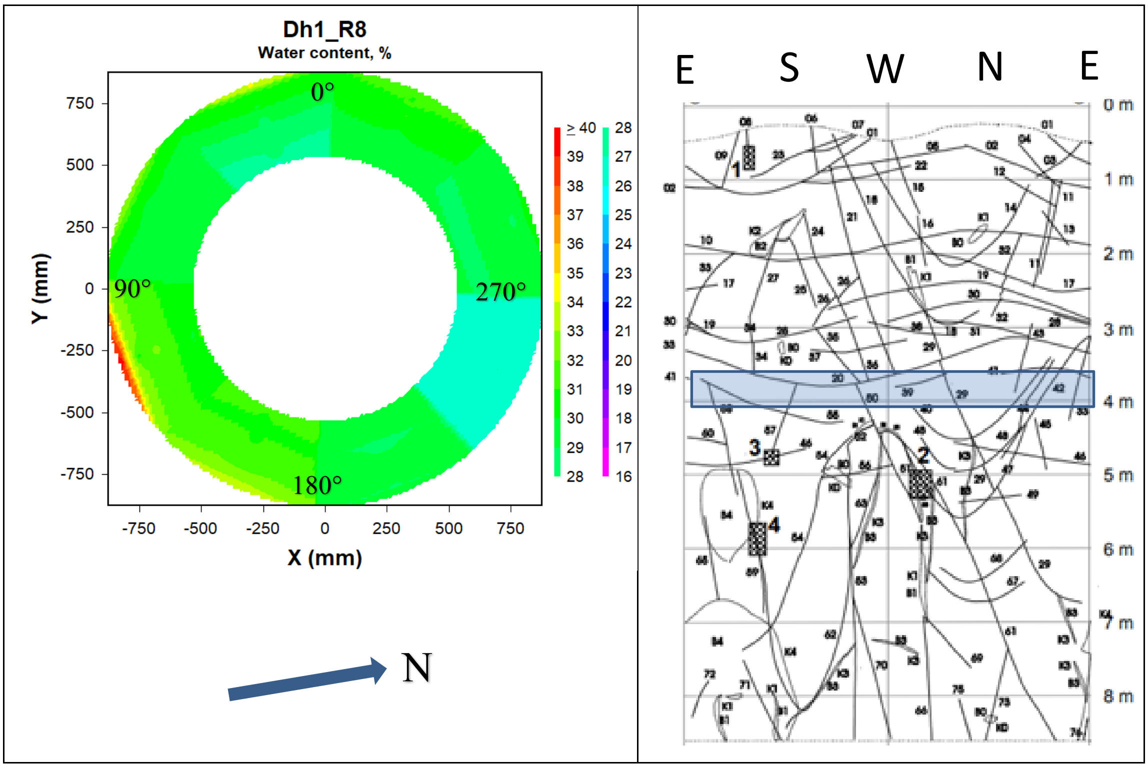


Figure 7-7. Left: Contour plot showing the water content distribution in block R8 in deposition hole 1. Right: Fracture mapping in deposition hole No 1. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R8 relative to the fractures.

7.2.7 Block R7 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 4-7 (a-d). The determined water content distribution for block R7 is provided in Figure 7-8 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R7:

- **Dry density**. The dry density was mainly between 1500-1670 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small.
- **Degree of saturation**. The degree of saturation was high at all positions, mainly between 95 and 100 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest density values were found close to the rock in the direction of 20°.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

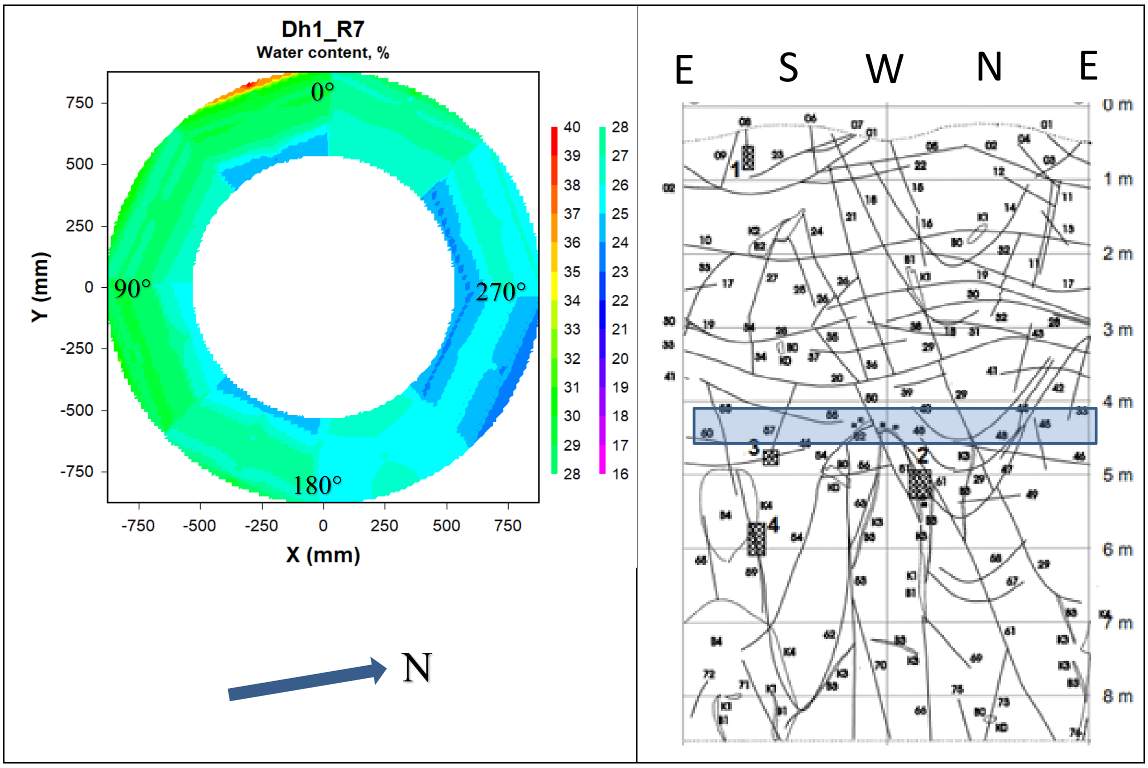


__Figure 7-8.__ Left: Contour plot showing the water content distribution in block R7 in deposition hole 1. Right: Fracture mapping in deposition hole No 1. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R7 relative to the fractures.

7.2.8 Block R6 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 4-8 (a-d). The determined water content distribution for block R6 is provided in Figure 7-9 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R6:

- **Dry density**. The dry density was mainly between 1520-1670 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small.
- **Degree of saturation**. The degree of saturation was high at all positions, mainly between 95 and 100 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest density values were found close to the rock in the directions of 20° and 110°.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

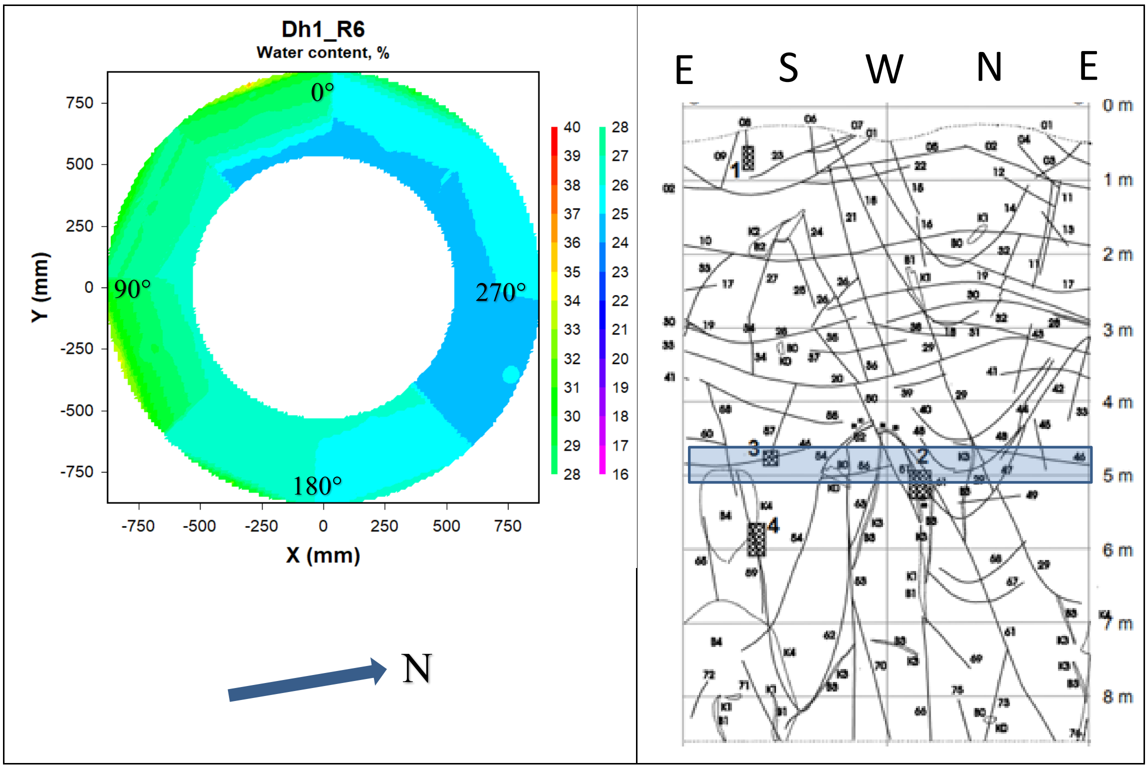


Figure 7-9. *Left: Contour plot showing the water content distribution in block R6 in deposition hole 1. Right: Fracture mapping in deposition hole No 1. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R6 relative to the fractures.*

7.2.9 Block R5 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 4-9 (a-d). The determined water content distribution for block R5 is provided in Figure 7-10 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R5:

- **Dry density**. The dry density was mainly between 1550-1670 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small.
- **Degree of saturation**. The degree of saturation was high at all positions, mainly between 95 and 100 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest density values were found close to the rock in the direction of 110°.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

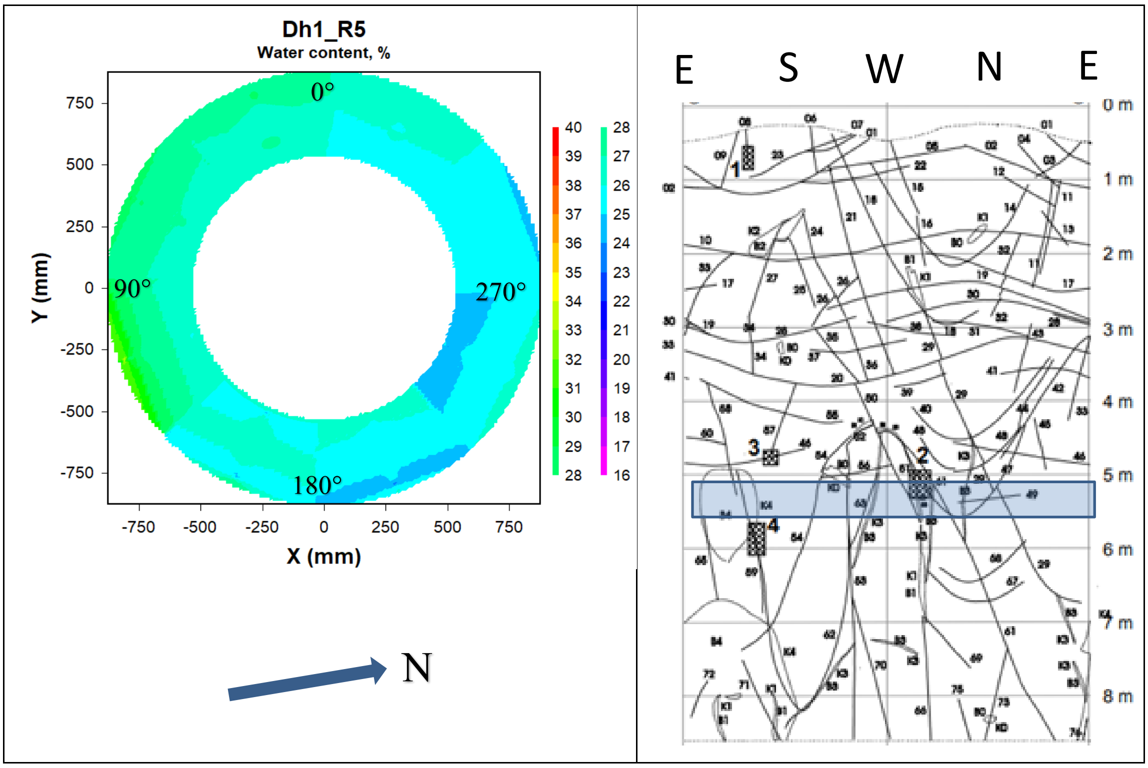


__Figure 7-10.__ Left: Contour plot showing the water content distribution in block R5 in deposition hole 1. Right: Fracture mapping in deposition hole No 1. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R5 relative to the fractures.

7.2.10 Block R4 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 4-10 (a-d). The determined water content distribution for block R4 is provided in Figure 7-11 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R4:

- **Dry density**. The dry density was mainly between 1550-1690 kg/m^3 except for in one direction (110°) where the density profile varied between 1420 and 1500 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small.
- **Degree of saturation**. The degree of saturation was high at all positions, mainly between 95 and 100 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest density values were found in the direction of 110°, all the way from the canister and out to the rock surface.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

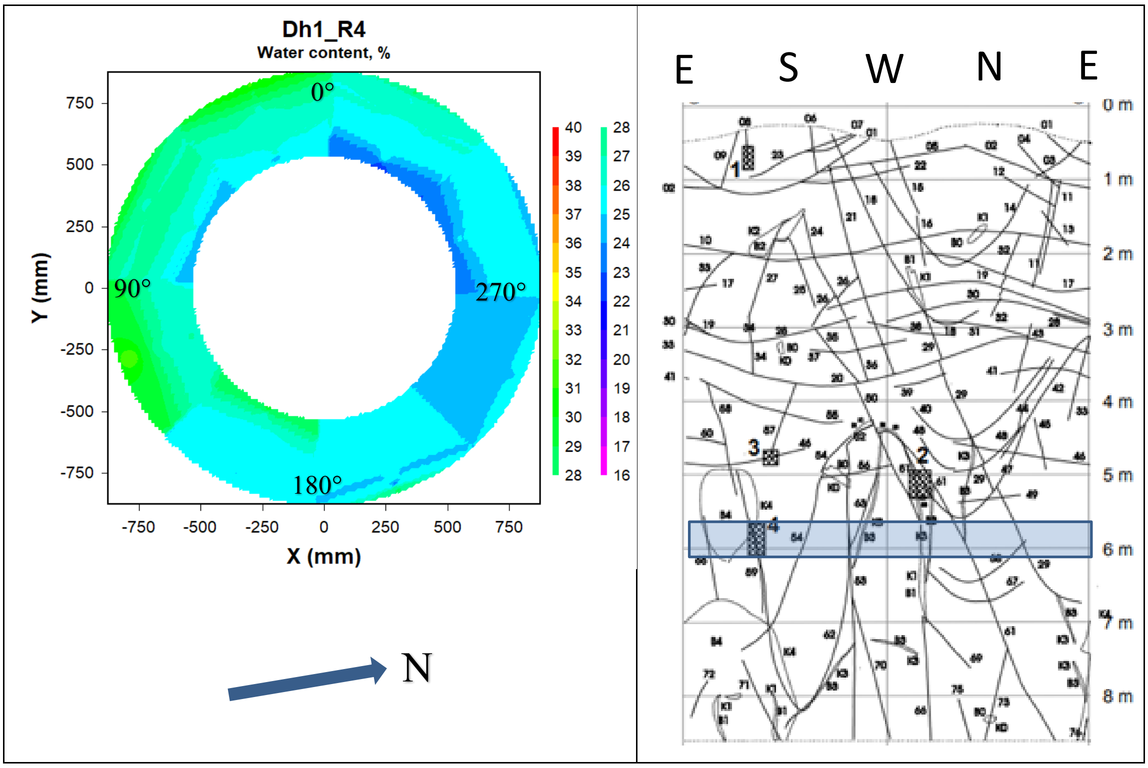


__Figure 7-11.__ Left: Contour plot showing the water content distribution in block R4 in deposition hole 1. Right: Fracture mapping in deposition hole No 1. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R4 relative to the fractures.

7.2.11 Block R3 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 4-11 (a-d). The determined water content distribution for block R3 is provided in Figure 7-12 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R3:

- **Dry density**. The dry density was mainly between 1500-1670 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small.
- **Degree of saturation**. The degree of saturation was high at all positions, mainly between 95 and 100 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest density values were found in the directions 20° and 110°, all the way from the canister and out to the rock surface.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

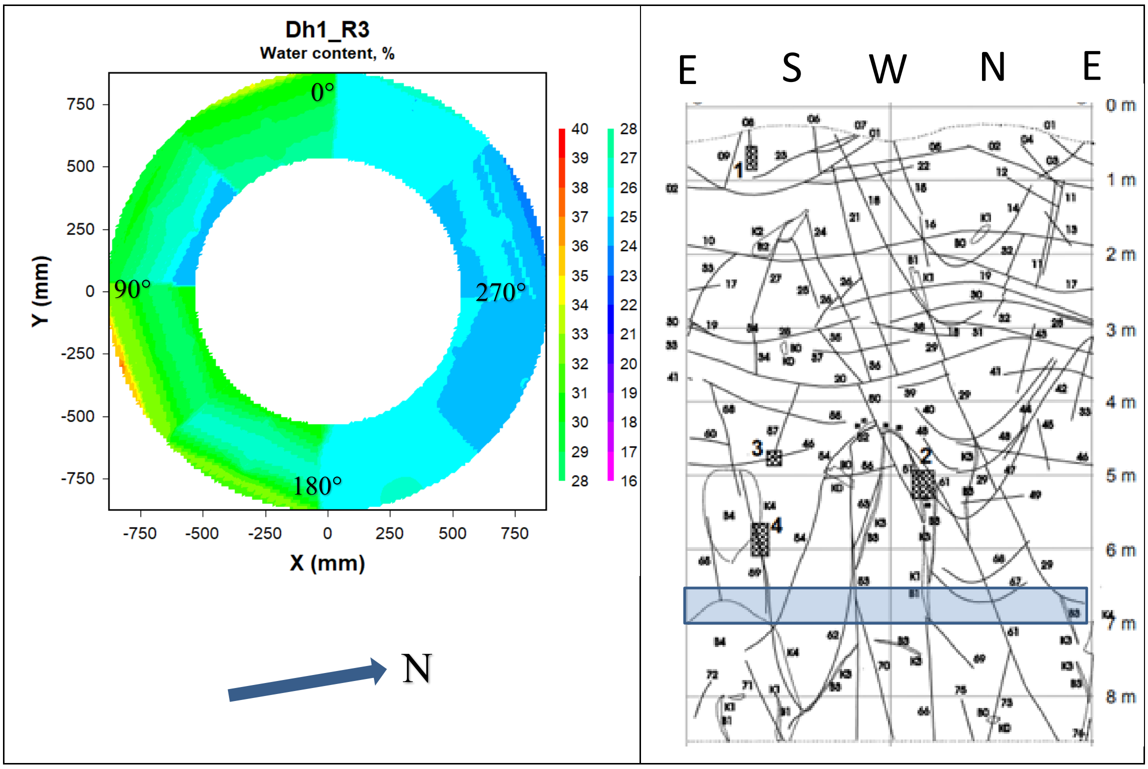


Figure 7-12. Left: Contour plot showing the water content distribution in block R3 in deposition hole 1. Right: Fracture mapping in deposition hole No 1. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R3 relative to the fractures.

7.2.12 Block R2 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 4-12 (a-d). The determined water content distribution for block R2 is provided in Figure 7-13 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R2:

- **Dry density**. The dry density was mainly between 1520-1680 kg/m^3 except for in one direction (110°) where the density profile varied between 1420 and 1560 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small.
- **Degree of saturation**. The degree of saturation was high in all positions, mainly between 95 and 100 %. Some positions close to the canister had a degree of saturation between 90 and 95 %.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest density values were found in the direction of 110°, all the way from the canister and out to the rock surface.
- **Deviations**. The results from the water content and density determinations were in general consistent. Some minor variations were found in the former pellet filled gap and close to the former gap between block and canister.

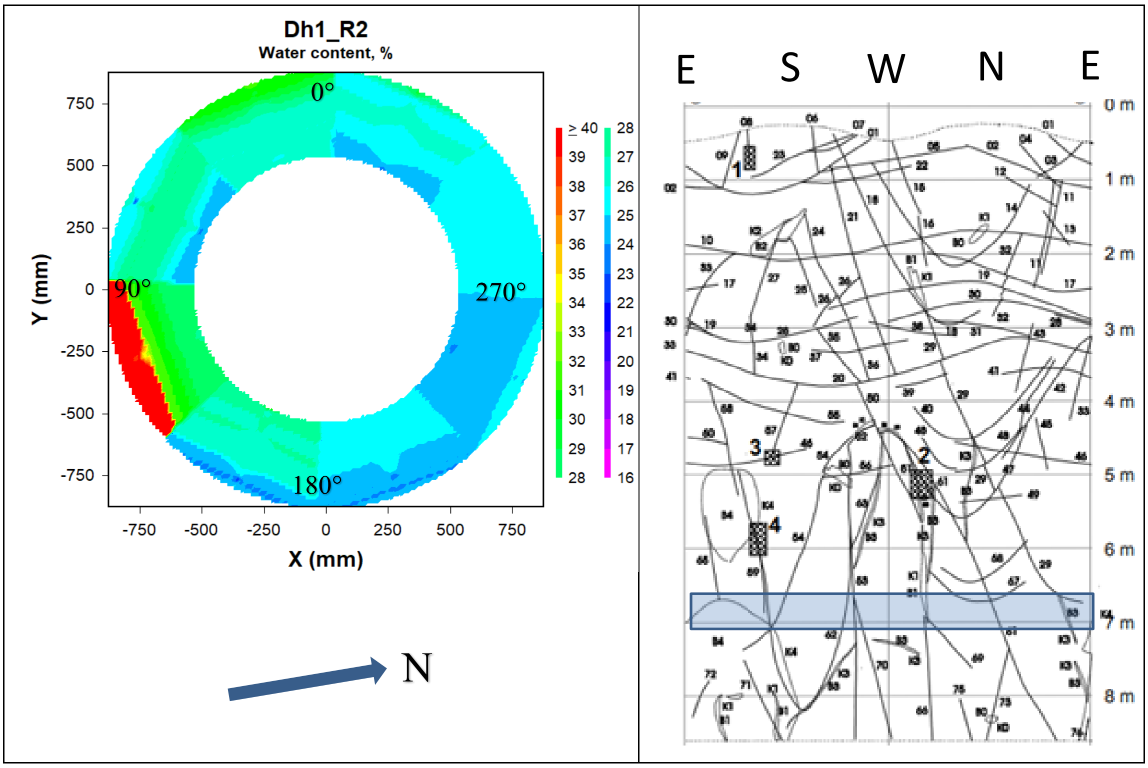


Figure 7-13. Left: Contour plot showing the water content distribution in block R2 in deposition hole 1. Right: Fracture mapping in deposition hole No 1. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R2 relative to the fractures.

7.2.13 Block R1 (along with the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 4-13 (a-d). The determined water content distribution for block R1 is provided in Figure 7-14 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block R1:

- **Dry density**. The dry density was mainly between 1480-1640 kg/m^3. Samples with lower density were found in the former pellet filled gap. In two of the sampled directions, 20° and 245°, samples were taken at five different levels in the block. These measures showed that the difference in density between the different levels was rather small.
- **Degree of saturation**. The degree of saturation was high at all positions, mainly between 96 and 100 %, with the lowest values close to the canister.
- **Homogenization**. The sampling showed that the homogenization of the bentonite had gone far. There was, however, still a difference in density between the central parts of the block and the parts close to the former pellet filled gap and close to the former gap between block and canister. The lowest density values were found in the direction of 110°, all the way from the canister and out to the rock surface.
- **Deviations**. The results from the water content and density determinations were in general consistent.

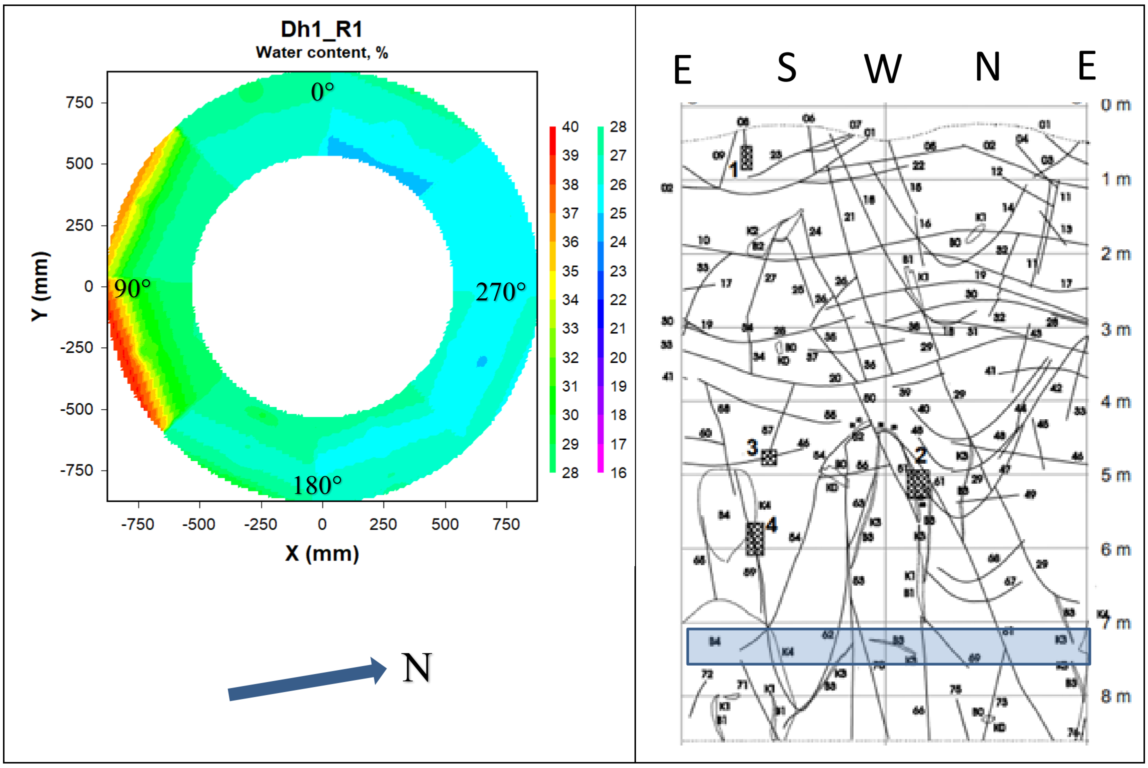


Figure 7-14. *Left: Contour plot showing the water content distribution in block R1 in deposition hole 1. Right: Fracture mapping in deposition hole No 1. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block R1 relative to the fractures.*

7.2.14 Block C1 (below the canister)

All measured and calculated data regarding water content, dry density and degree of saturation is compiled in graphs provided in Appendix 4-14 (a-d). The determined water content distribution for block C1 is provided in Figure 7-15 (left) together with the fracture mapping for the deposition hole (right). The approximate position of the block in the deposition hole is marked as a blue rectangle. Some comments on the data determined for block C1:

- **Dry density**. (Limited sampling, see last bullet below). The dry density was mainly between 1400-1570 kg/m^3 in the former pellet filled gap. In one of the sampled directions, 20°, samples were taken at four different levels in the block. These measures showed that the difference in density between the different levels was small.
- **Degree of saturation**. The degree of saturation was high at all positions, mainly between 96 and 100 %.
- **Homogenization**. The sampling (limited) showed that the homogenization of the bentonite had gone far. The lowest density values were found close to the rock in the direction of 65°.
- **Deviations**. Due to problems with inflowing water, the sampling of this block was limited. No cores were drilled but end sectors were taken in all directions but 110° and 245°. The results from the water content and density determinations were in general consistent.

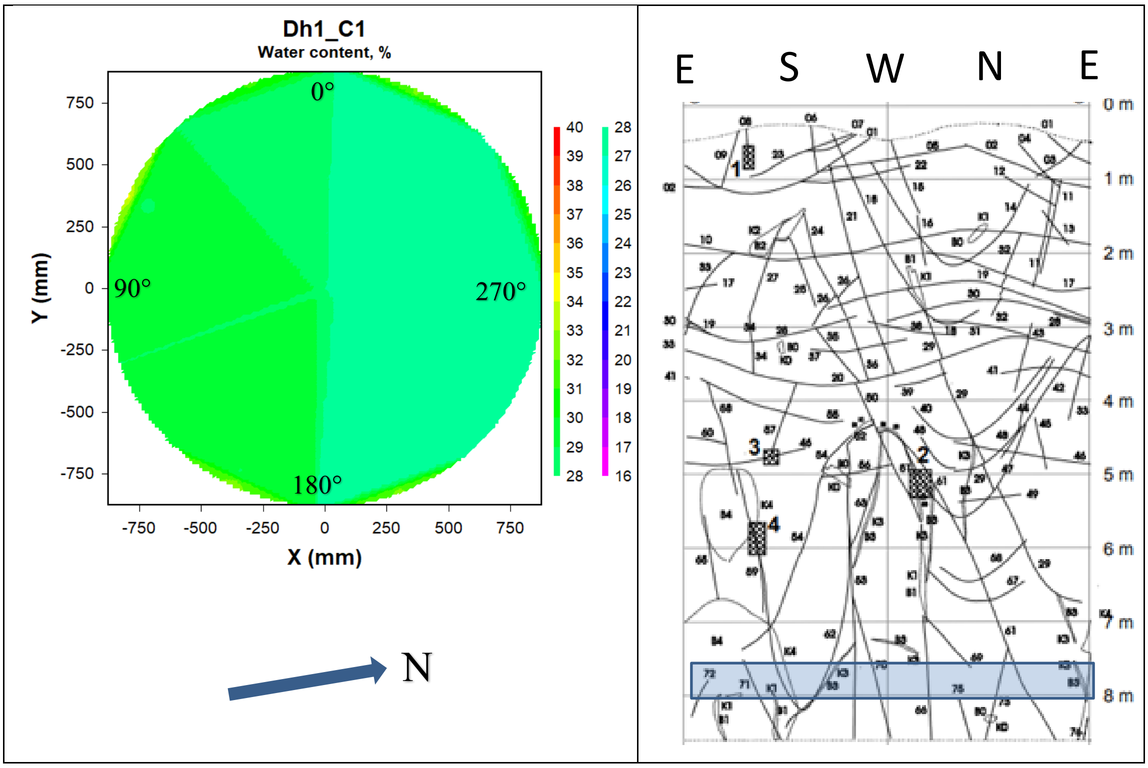


Figure 7-15. *Left: Contour plot showing the water content distribution in block C1 in deposition hole 1. Right: Fracture mapping in deposition hole No 1. Water bearing fractures are marked with shaded areas, (Rhén and Forsmark 2001). The blue rectangle indicates the approximate position of block C1 relative to the fractures.*

7.3 Summary of results from Dh1

7.3.1 Access to water

The buffer blocks in the deposition holes have had access to water both from fractures in the rock and via the backfill above the deposition hole.

The fracture mappings for all deposition holes are provided in Figure 2-2 and Figure 2-3, and the measured inflows are listed in Table 2-1. The inflow rate to deposition hole 1 was determined to 0.08 l/min. This inflow rate was the highest of the six deposition holes in the Prototype repository.

As described in Section 4.3.1, it is believed that water flowing from the backfill down to the buffer has greatly contributed to the saturation of the buffer.

7.3.2 Compilation of data

As described in Section 4.3.2, two different methods have been used to give a picture of the status of the complete deposition hole (see Appendix 4-nm for all blocks n and diagrams m) regarding water content, dry density, and degree of saturation distribution:

1. The individual contour plots of every single block have been compressed and stacked on each other, Figure 7-16. These figures give a rather good picture of the water content, the dry density, and the degree of saturation distribution for the complete deposition hole.
2. Contour plots were generated by DPlot. The plots are showing the water content, the dry density and the degree of saturation distribution in eight vertical cross-sections of deposition hole 1, Figure 7-17, Figure 7-18 and Figure 7-19.

The following conclusions can be made from the figures:

- Block C4 and C3 (top blocks). Both these blocks had swelled axially and by that decreased the density. The dry density for block C4 was mainly between 1250 and 1390 kg/m^3 and for block C3 between 1350 and 1480 kg/m^3. Both blocks were largely water saturated.
- Block C2 (block above canister). This block had also swelled axially and by that decreased in density. The dry density for this block was mainly between 1400 and 1500 kg/m^3. The degree of saturation was mainly between 97 to 100 %. In the corresponding block in Dh4, the central parts had a lower degree of saturation, which probably was an effect of the temperature from the canister. In this deposition hole, Dh1, no heating has been applied since the end of 2019, and this block, C2, was largely saturated.
- Block R10-R8 (ring-shaped blocks along the upper half of the canister). Some minor effect of the axial swelling could be seen on these blocks, especially on block R10 where the dry density varied mainly between 1400 and 1560 kg/m^3 depending on direction. These blocks were largely water saturated, between 95 and 100 %.
- Block R7-R1 (ring-shaped blocks along the lower half of the canister). The dry density of the blocks varied mainly between 1520 and 1700 kg/m^3. However, in block R4-R1, the density profiles in the direction of 110°, showed clearly lower values of the determined density. The degree of saturation varied mainly between 95 and 100 %.
- Block C1 (block below canister). Due to problems with inflowing water, the sampling of this block was limited (no cores were drilled but the end sections against the rock were sampled in all directions but 110° and 245°). The degree of saturation varied mainly between 96 and 100 % for the complete block.

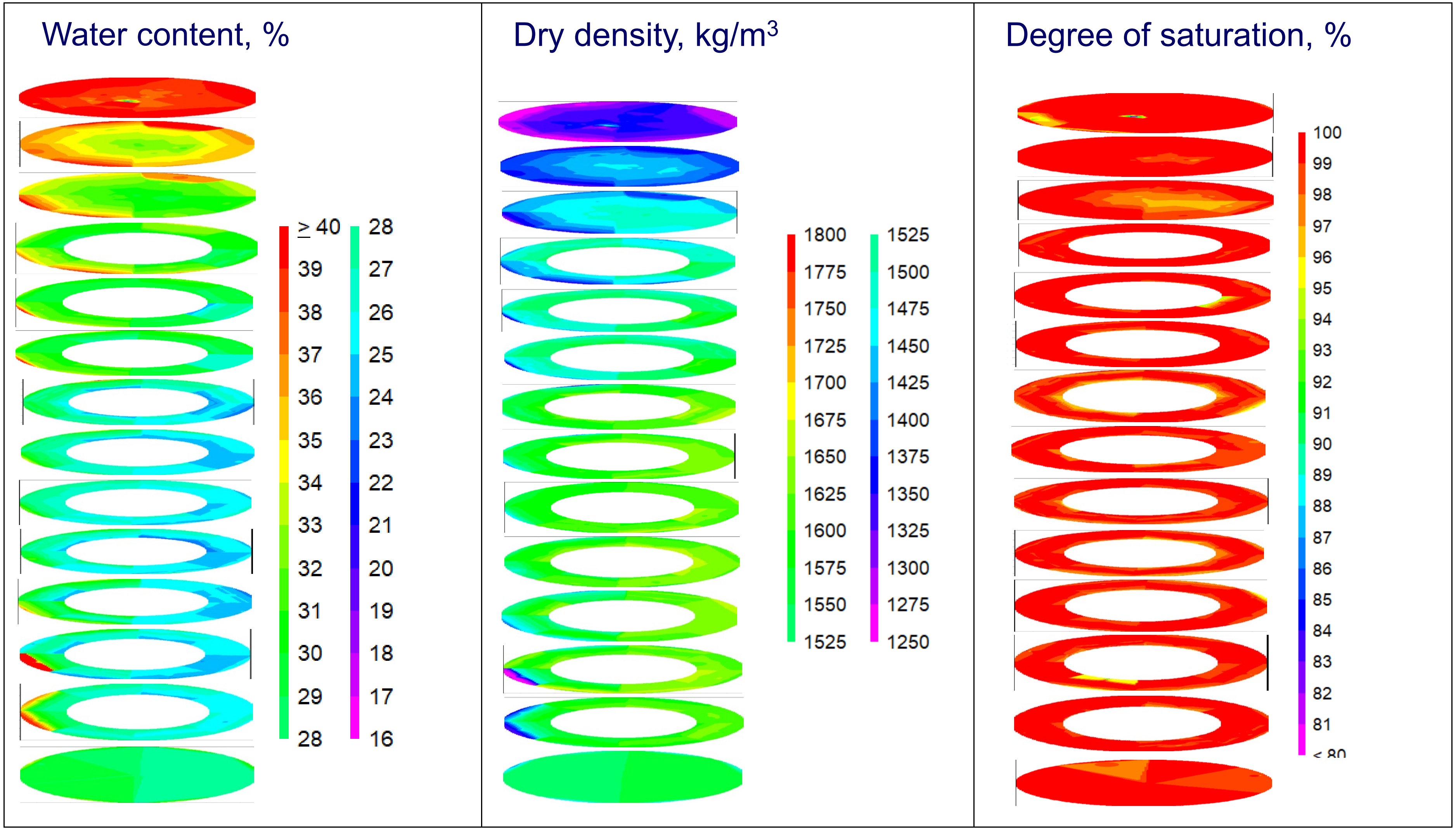


Figure 7-16. *Compressed contour plots of every single block in Dh 1 stacked on each other. Left: the water content distribution (%) Middle: the dry density distribution (kg/m*^{3}*) Right: the degree of saturation distribution (%).*

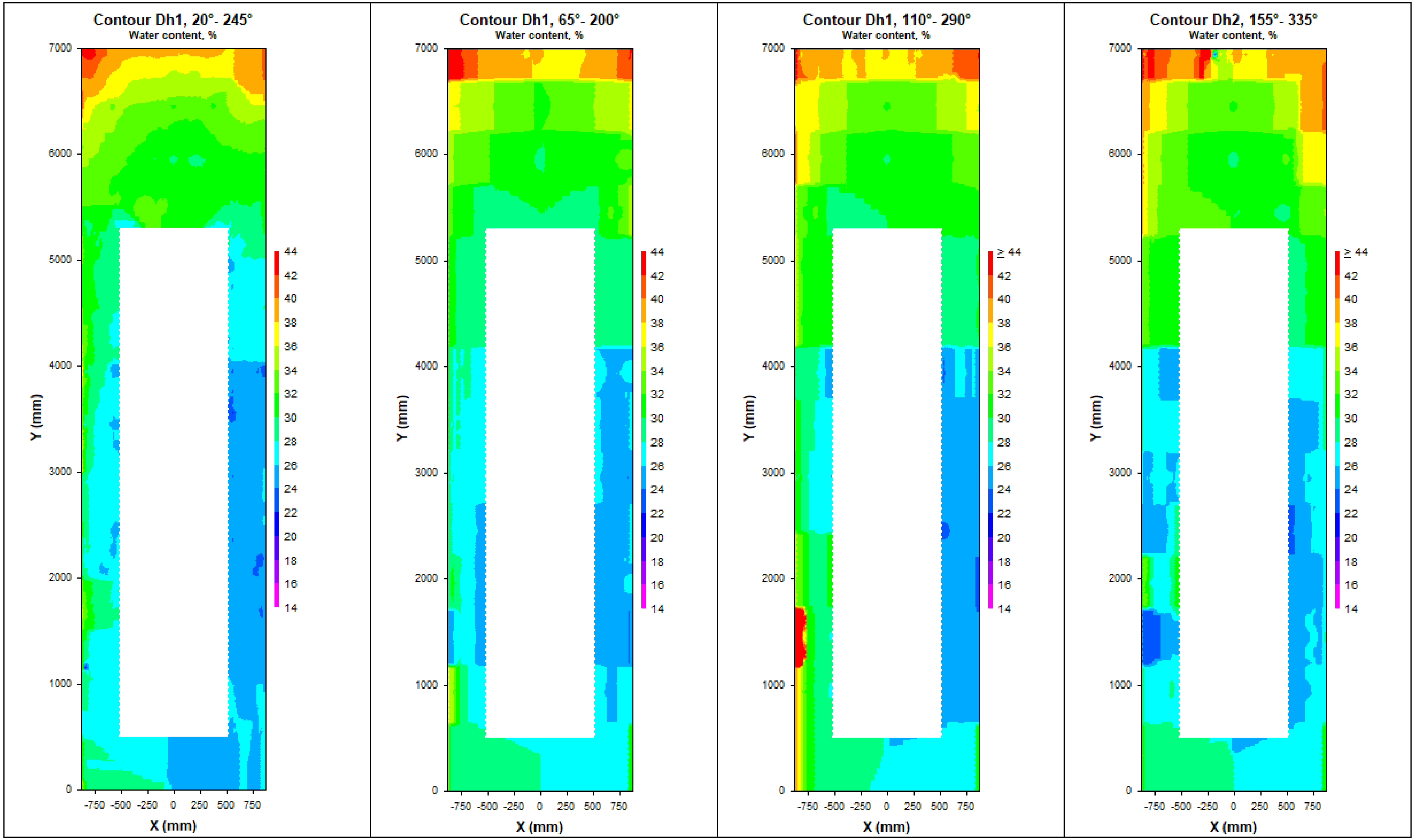


Figure 7-17. *Four contour plots showing the water content distribution in eight vertical cross-sections of deposition hole 1.*

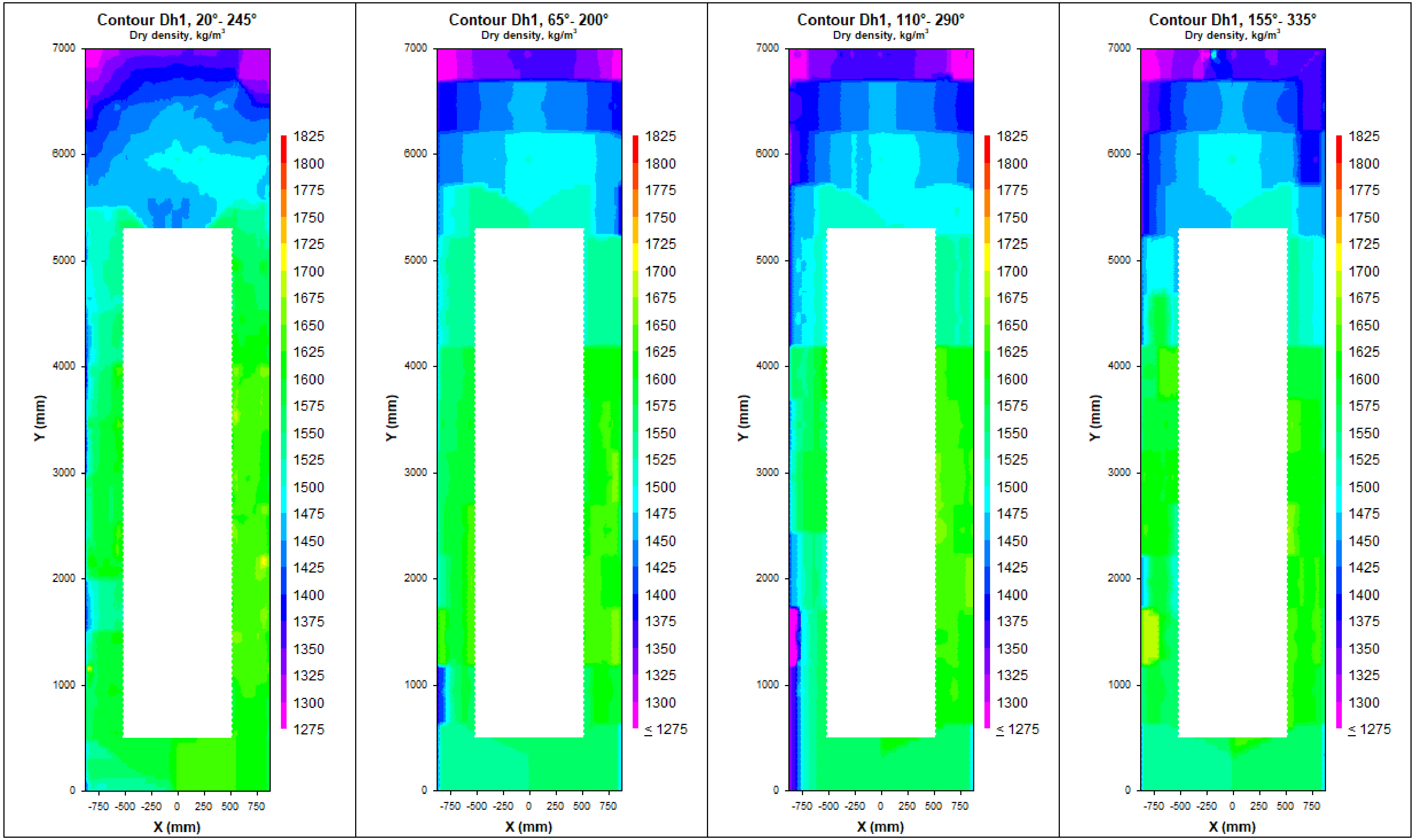


Figure 7-18. *Four contour plots showing the dry density distribution in eight vertical cross-sections of deposition hole 1.*

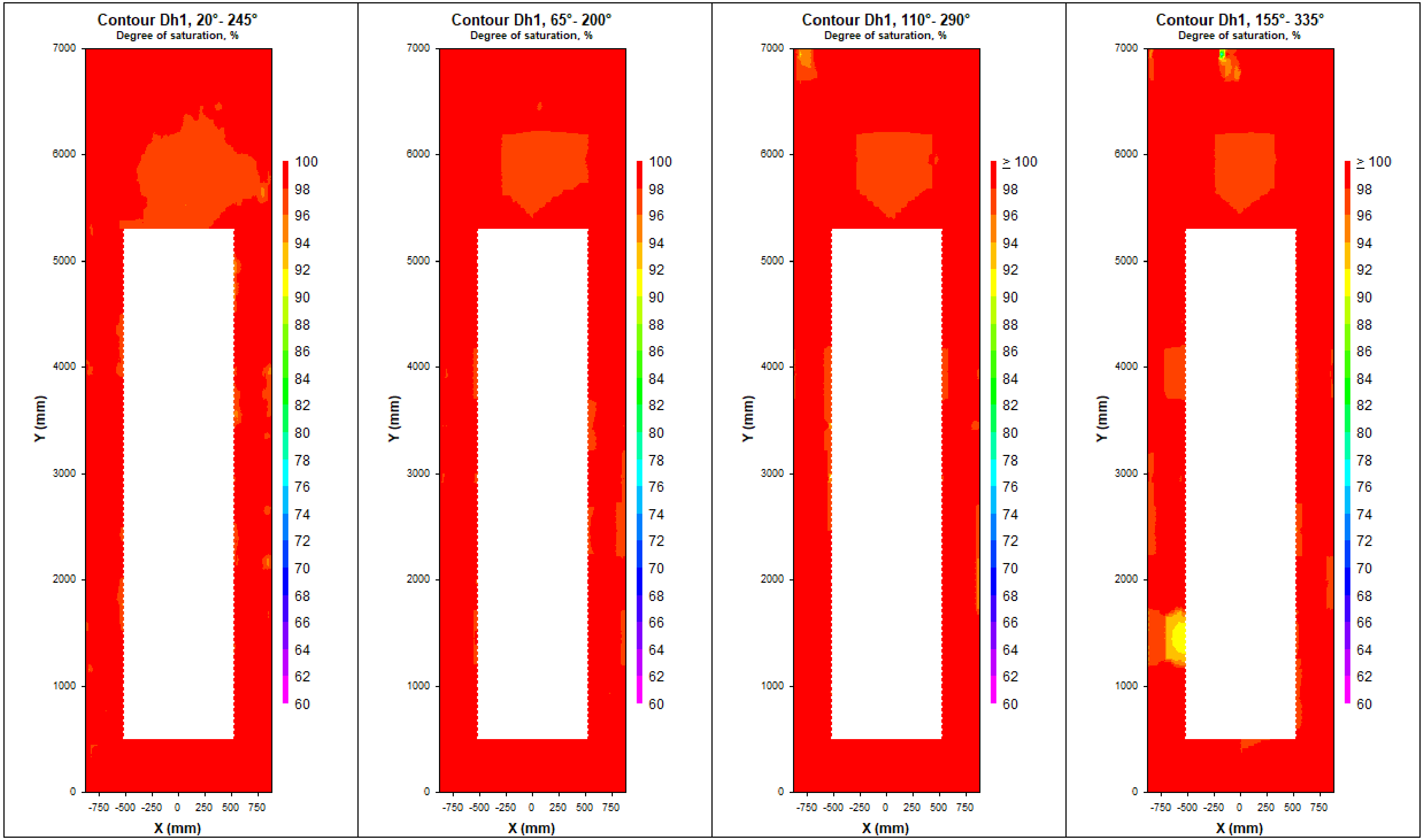


Figure 7-19. *Four contour plots showing the degree of saturation distribution in eight vertical cross-sections of deposition hole 1.*

8 Results from measurements in the backfill

8.1 Background

As described in Section 3.2, the backfill material installed in the Prototype Repository was very different compared to the present reference design, and therefore the sampling of the backfill in the inner section was kept at a minimum. Above each deposition hole, samples were taken in a cross-section of the tunnel, see description in Section 3.2. In total 28 samples were taken from each cross section. In addition, six samples were taken from the backfill in the uppermost meter of the deposition hole.

8.2 Cross-section above Dh4

The determined water content, dry density and degree of saturation are presented in three graphs, Figure 8-1. The values measured at different heights from the tunnel floor, see description in Figure 3-6, are plotted versus the distance from the tunnel center. The black line in the upper graph indicates the initial water content of the backfill material.

The graphs show that the backfill had a low density and a high water content close to the rock walls, especially close to the tunnel ceiling. The density in the central and lower parts of the tunnel was considerably higher. The variation in data was, however, large and thereby also the calculated degree of saturation. There are three main reasons for the large spread in data regarding the backfill:

1. **The backfill material is very heterogenic**. The backfill material consisted of a mixture of bentonite (30 %) and ballast (70 %). The ballast consisted of crushed rock with grain sizes ranging from 0-20 mm, see description in Section 2.5.
2. **Sample size.** Since the heterogeneity of the backfill material was large, it was assessed important to have rather large samples. Considering the current results from the measurements, the samples should perhaps have been even larger.
3. **Calculating the degree of saturation.** The degree of saturation was calculated from the measurements of water content and density which were determined on two different samples although they were taken from almost the same spot in the backfill. This may be an additional reason for the large spread in the calculated degree of saturation.

The results from the sampling of the backfill in the *uppermost part of the deposition hole* is compiled in Table 8-1. The average dry density of the backfill in the deposition hole was 1746 kg/m^3.

Table 8-1. Compilation of data from the sampling of backfill in the uppermost part of Deposition hole 4

Sample	Water content	Dry density	Void ratio	Degree of saturation
	%	kg/m^3	-	%
Depth 500 mm, 0°, radius 500 mm	16.7	1769	0.519	86.4
Depth 500 mm, 120°, radius 500 mm	23.3	1710	0.572	109.6
Depth 500 mm, 240°, radius 500 mm	20.3	1699	0.582	93.7
Depth 800 mm, 0°, radius 500 mm	24.0	1625	0.655	98.5
Depth 800 mm, 120°, radius 500 mm	18.9	1807	0.487	104.3
Depth 800 mm, 240°, radius 500 mm	17.9	1865	0.441	108.8

Contour plots were generated by DPlot. Contour plots showing the water content, the dry density, and the degree of saturation distribution of the backfill above the deposition hole, including the uppermost part of the deposition hole (average values for each level), are provided in Figure 8-2. The number of samples taken from the backfill was rather limited, and the spread in data was large, but the plots provide anyway a general picture of the backfill regarding water content, dry density, and degree of saturation distribution.

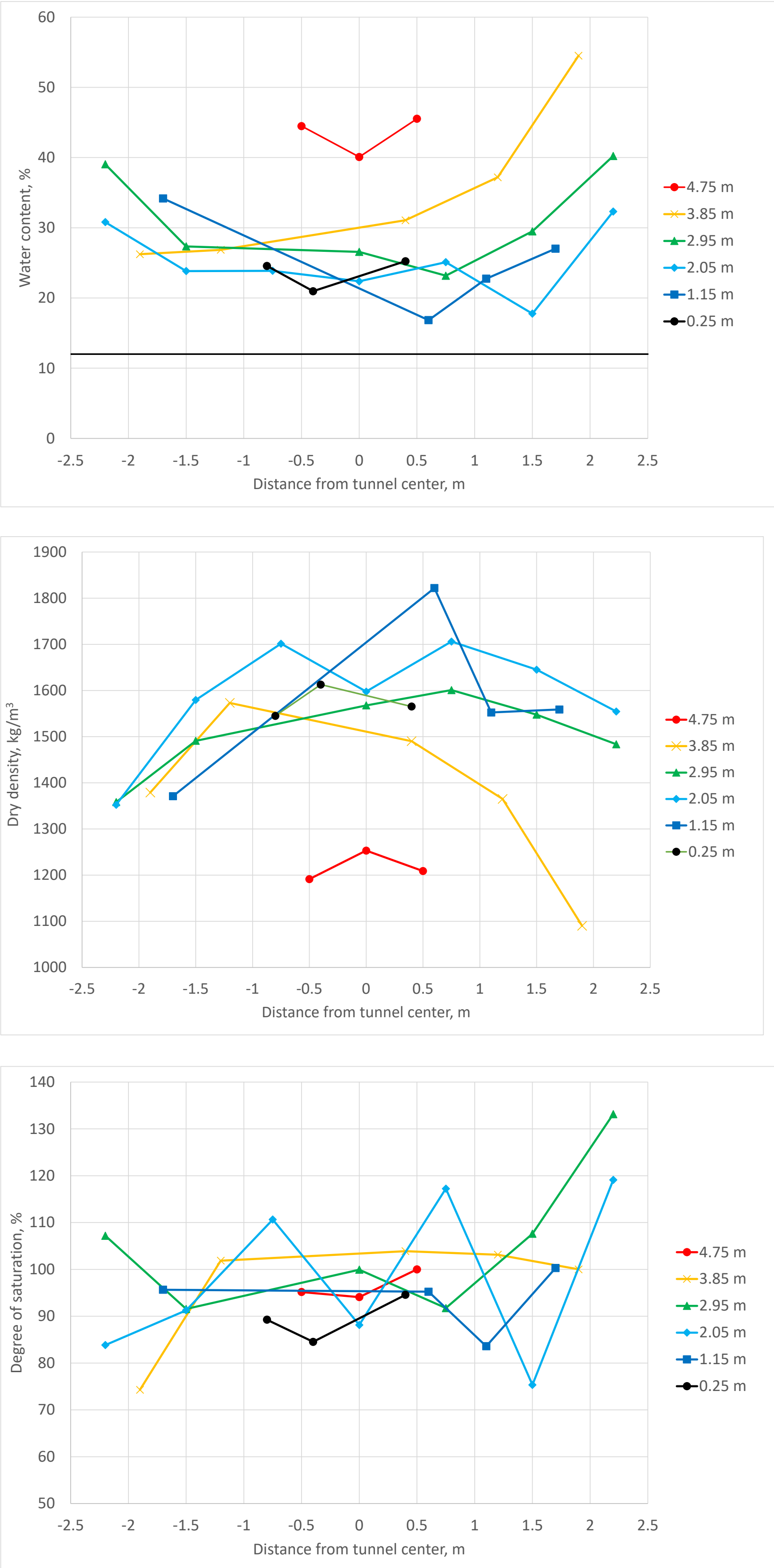


Figure 8-1. *The measured water content (upper), dry density, (middle) and degree of saturation (lower) in the backfill above deposition hole 4. The values measured at different heights from the tunnel floor are plotted versus the distance from the tunnel center.*

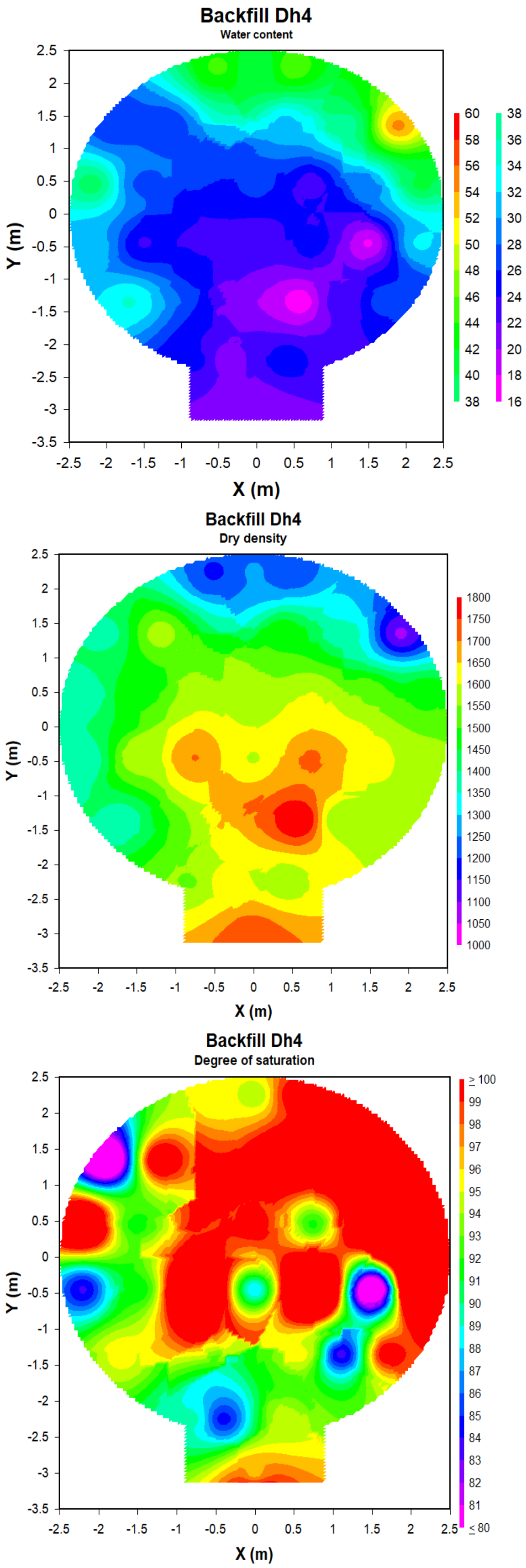


Figure 8-2. *Three contour plots showing the measured water content (upper), the dry density (middle) and the degree of saturation (lower) distribution in the backfill above deposition hole 4.*

8.3 Cross-section above Dh3

The determined water content, dry density and degree of saturation are presented in three graphs, Figure 8-3. The values measured at different heights from the tunnel floor, see Figure 3-6, are plotted versus the distance from the tunnel center. The black line in the upper graph indicates the initial water content of the backfill material.

The graphs show that the dry density above deposition hole 3 is like the backfill above deposition hole 4. The backfill has a low density and a high water content close to the rock walls. However, in this cross-section, the density close to the ceiling was rather high. The density in the central parts of the tunnel was, however, considerably higher. The calculated degree of saturation varied a lot (see explanation in Section 8.2), but the spread was not as large as for the backfill above Deposition hole 4.

A compilation of data from the sampling of the backfill in the *uppermost part of the deposition hole* is provided in Table 8-2. The average dry density of the backfill in the deposition hole was 1767 kg/m^3.

Table 8-2. Compilation of data from the sampling of backfill in the uppermost part of Deposition hole 3

Sample	Water content	Dry density	Void ratio	Degree of saturation
	%	kg/m^3	-	%
Depth 500 mm, 0°, radius 500 mm	14.4	1758	0.529	73.3
Depth 500 mm, 120°, radius 500 mm	16.4	1771	0.517	85.3
Depth 500 mm, 240°, radius 500 mm	20.1	1740	0.545	99.4
Depth 800 mm, 0°, radius 500 mm	18.9	1742	0.543	93.5
Depth 800 mm, 120°, radius 500 mm	18.3	1772	0.517	95.1
Depth 800 mm, 240°, radius 500 mm	17.7	1818	0.479	99.2

Contour plots were generated by DPlot. Contour plots showing the water content, the dry density, and the degree of saturation distribution of the backfill above the deposition hole, including the uppermost part of the deposition hole (average values for each level), are provided in Figure 8-4. The number of samples taken from the backfill was rather limited, and the spread in data was large, but the plots provide anyway a general picture of the backfill regarding water content, dry density, and degree of saturation distribution.

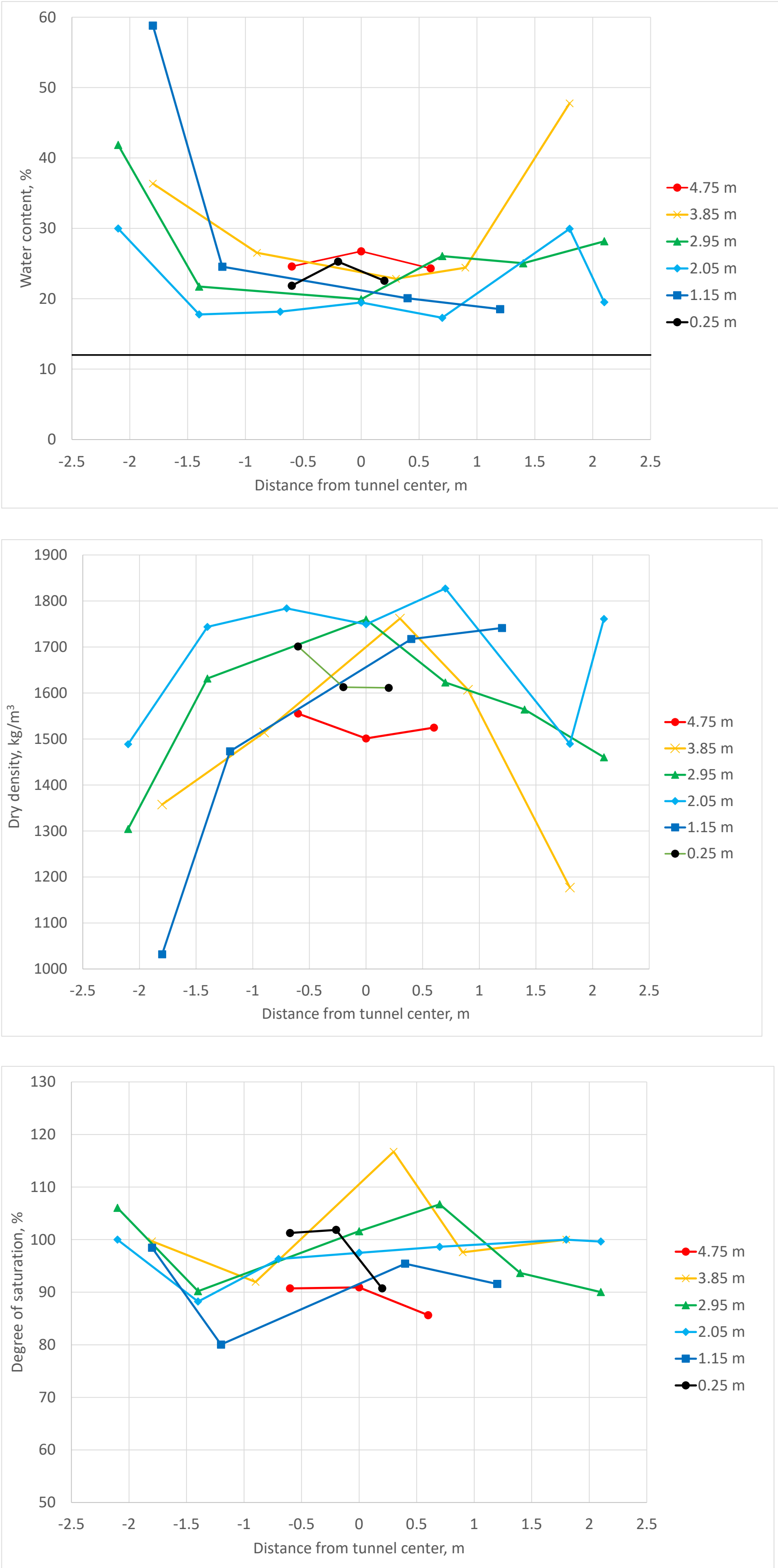
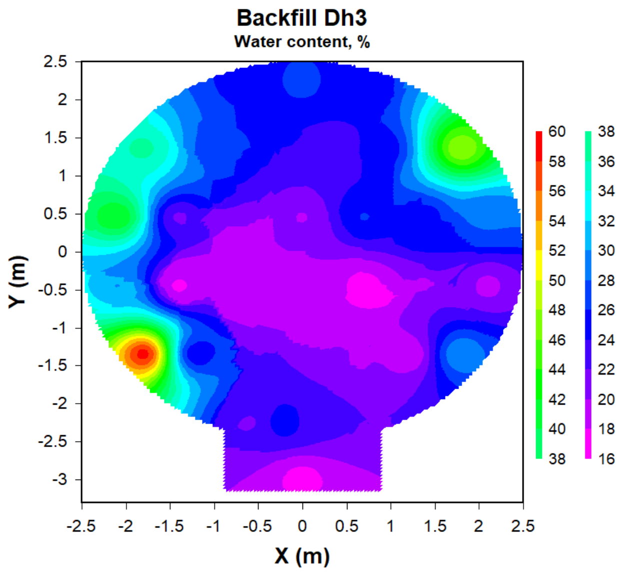
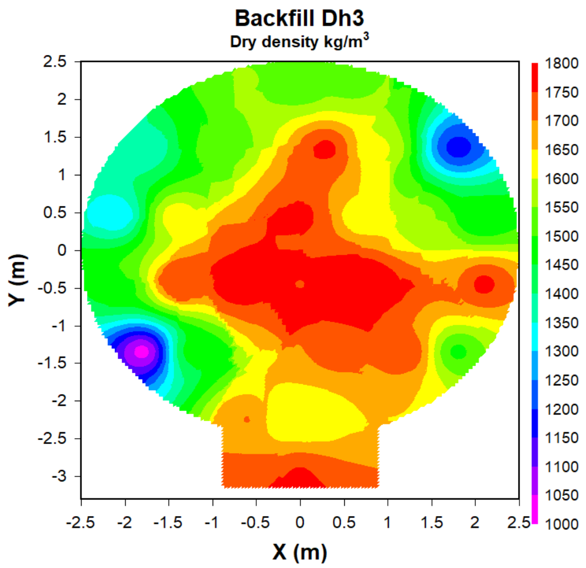


Figure 8-3. *The measured water content (upper), dry density, (middle) and degree of saturation (lower) in the backfill above deposition hole 3. The values measured at different heights from the tunnel floor are plotted versus the distance from the tunnel center.*





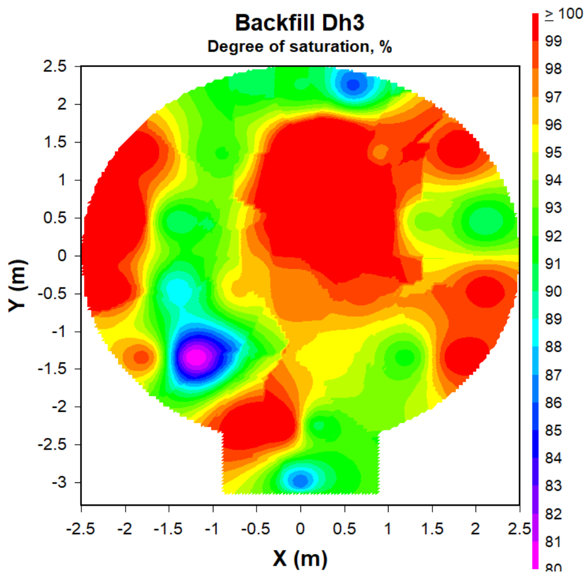


Figure 8-4. *Three contour plots showing the measured water content (upper), the dry density (middle) and the degree of saturation (lower) distribution in the backfill above deposition hole 3.*

8.4 Cross-section above Dh2

The determined water content, dry density and degree of saturation are presented in three graphs, Figure 8-5. The values measured at different heights from the tunnel floor, see Figure 3-6, are plotted versus the distance from the tunnel center. The black line in the upper graph indicates the initial water content of the backfill material.

Similar to the backfill above Deposition hole 3 and 4, the graphs show that the backfill has a low density and a high water content close to the rock walls. In this cross-section, the density close to the ceiling was rather high. The density in the central parts of the tunnel was, however, considerably higher. The calculated degree of saturation varied a lot (see explanation in Section 8.2), but the spread was not as large as for the backfill above Deposition hole 4.

A compilation of data from the sampling of the backfill in the *uppermost part of the deposition hole* is provided in Table 8-3. The average dry density of the backfill in the deposition hole was 1806 kg/m^3 (note that this value does not match the dry density determined at installation, see Section 2.5).

Table 8-3. Compilation of data from the sampling of backfill in the uppermost part of Deposition hole 2

Sample	Water content	Dry density	Void ratio	Degree of saturation
	%	kg/m^3	-	%
Depth 500 mm, 0°, radius 500 mm	16.4	1863	0.443	99.3
Depth 500 mm, 120°, radius 500 mm	16.0	1823	0.474	90.9
Depth 500 mm, 240°, radius 500 mm	18.4	1752	0.535	92.5
Depth 800 mm, 0°, radius 500 mm	19.2	1745	0.540	95.5
Depth 800 mm, 120°, radius 500 mm	15.1	1820	0.477	85.1
Depth 800 mm, 240°, radius 500 mm	17.7	1833	0.466	102.0

Contour plots were generated by DPlot. Contour plots showing the water content, the dry density, and the degree of saturation distribution of the backfill above the deposition hole, including the uppermost part of the deposition hole (average values for each level), are provided in Figure 8-6. The number of samples taken from the backfill was rather limited, and the spread in data was large, but the plots provide anyway a general picture of the backfill regarding water content, dry density, and degree of saturation distribution.

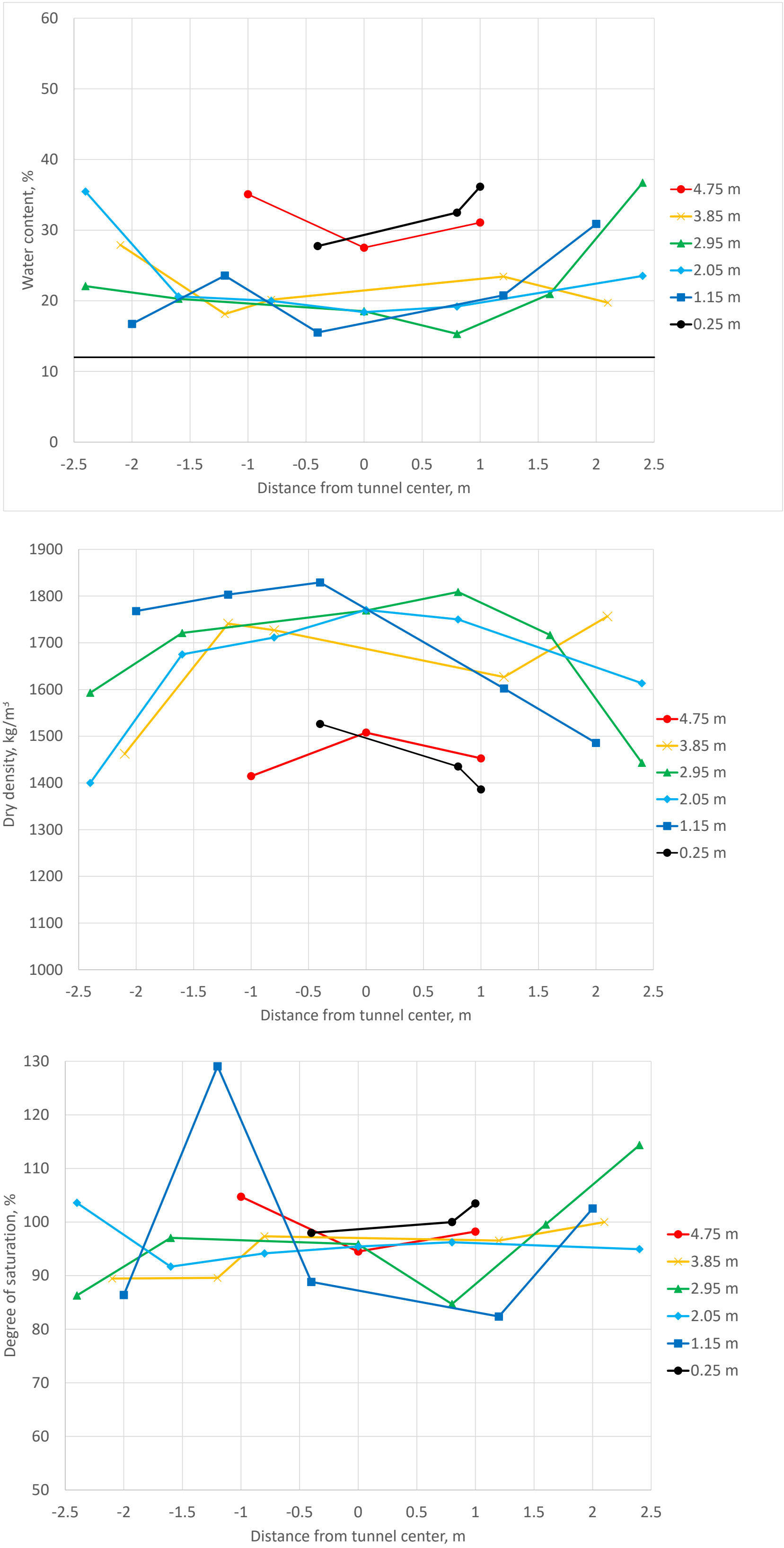


Figure 8-5. *The measured water content (upper), dry density, (middle) and degree of saturation (lower) in the backfill above deposition hole 2. The values measured at different heights from the tunnel floor are plotted versus the distance from the tunnel center.*

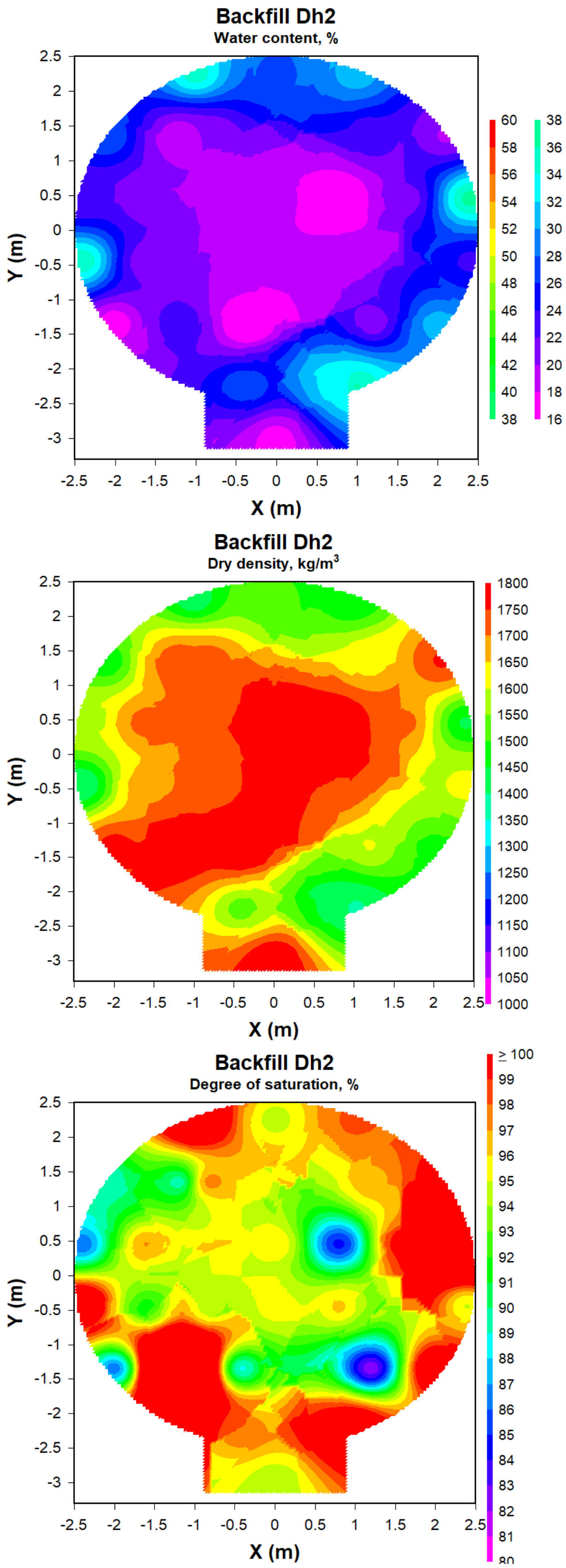


Figure 8-6. *Three contour plots showing the measured water content (upper), the dry density (middle) and the degree of saturation (lower) distribution in the backfill above deposition hole 2.*

8.5 Cross-section above Dh1

The determined water content, dry density and degree of saturation are presented in three graphs, Figure 8-7. The values measured at different heights from the tunnel floor, see Figure 3-6, are plotted versus the distance from the tunnel center. The black line in the upper graph indicates the initial water content of the backfill material.

Like the backfill above Deposition hole 2, 3, and 4, the graphs show that the backfill has a low density and a high water content close to the rock walls. The density in the central parts of the tunnel was, however, considerably higher. The calculated degree of saturation varied a lot (see explanation in Section 8.2), but the spread was not as large as for the backfill above Deposition hole 4.

A compilation of data from the sampling of the backfill in the *uppermost part of the deposition hole* is provided in Table 8-4 (one of the planned samples was not taken). The average dry density of the backfill in the deposition hole was 1677 kg/m^3.

Table 8-4. Compilation of data from the sampling of backfill in the uppermost part of Deposition hole 1

Sample	Water content	Dry density	Void ratio	Degree of saturation
	%	kg/m^3	-	%
Depth 500 mm, 0°, radius 500 mm	21.1	1635	0.645	88.0
Depth 500 mm, 120°, radius 500 mm	22.2	1680	0.600	99.3
Depth 500 mm, 240°, radius 500 mm	17.8	1776	0.513	93.3
Depth 800 mm, 0°, radius 500 mm	-	-	-	-
Depth 800 mm, 120°, radius 500 mm	20.6	1674	0.606	91.1
Depth 800 mm, 240°, radius 500 mm	23.1	1619	0.660	94.1

Contour plots were generated by DPlot. Contour plots showing the water content, the dry density, and the degree of saturation distribution of the backfill above the deposition hole, including the uppermost part of the deposition hole (average values for each level), are provided in Figure 8-8. The number of samples taken from the backfill was rather limited, and the spread in data was large, but the plots provide anyway a general picture of the backfill regarding water content, dry density, and degree of saturation distribution.

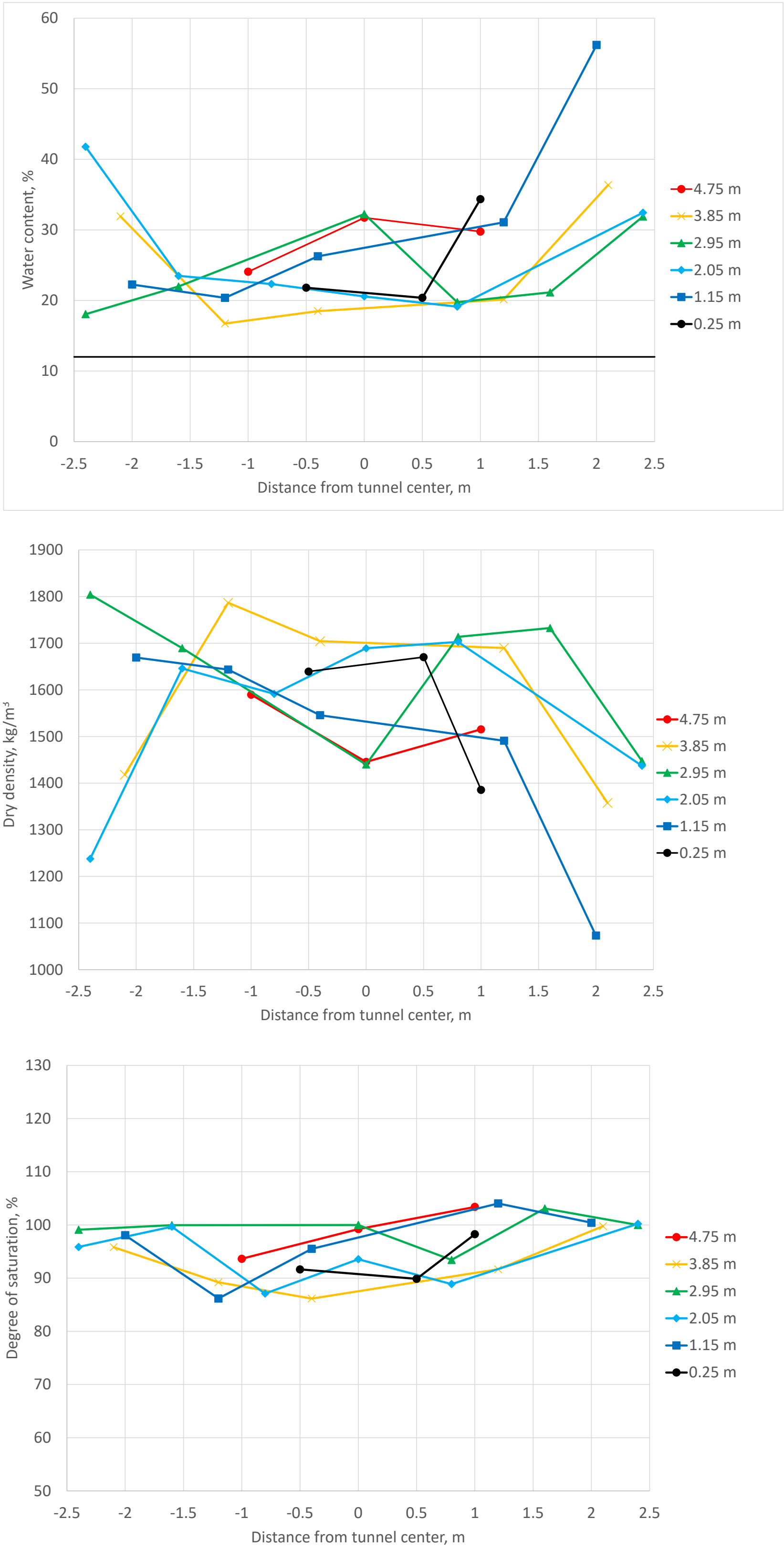


Figure 8-7. *The measured water content (upper), dry density, (middle) and degree of saturation (lower) in the backfill above deposition hole 1. The values measured at different heights from the tunnel floor are plotted versus the distance from the tunnel center.*

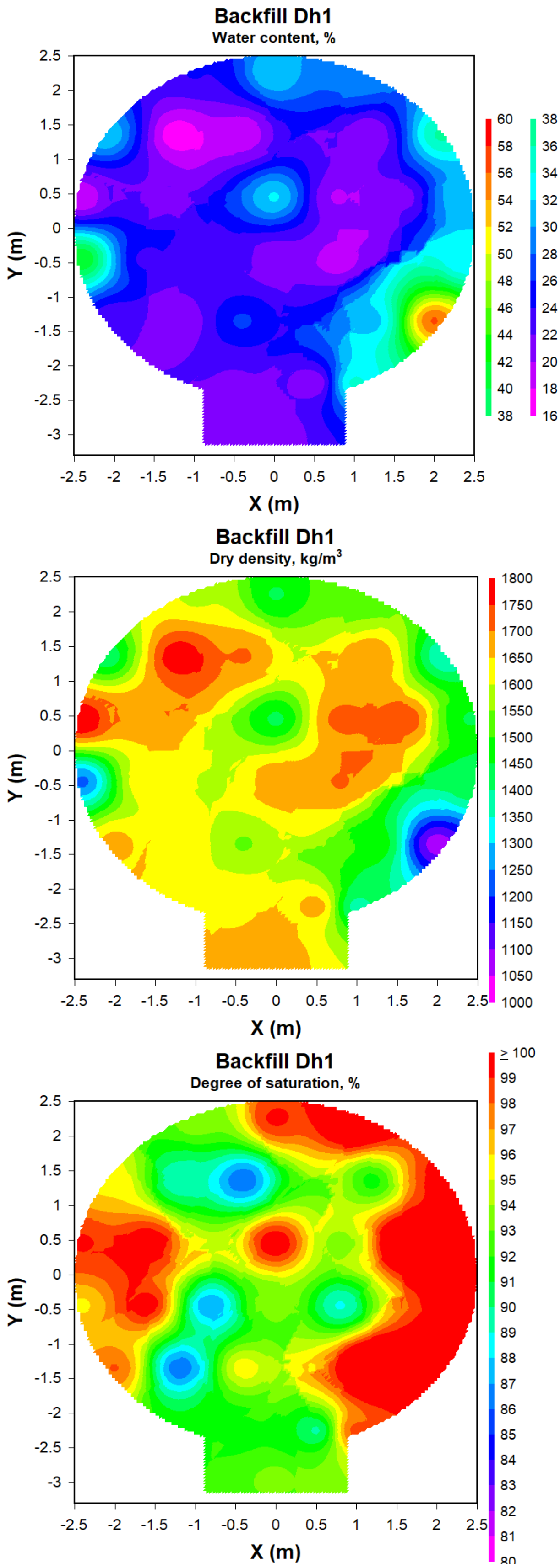


Figure 8-8. *Three contour plots showing the measured water content (upper), the dry density (middle) and the degree of saturation (lower) distribution in the backfill above deposition hole 1.*

9 Comments and conclusions

9.1 Buffer

9.1.1 Water content, dry density and degree of saturation

The figures including contour plots of every single block that have been compressed and stacked on each other, are judged to give a good picture of the water content, the dry density, and the degree of saturation distribution for the complete deposition holes. These figures have been used to show a comparison of results from the measured water content and dry density from all four deposition holes, see Figure 9-1 and Figure 9-2. The corresponding comparison showing the calculated degree of saturation is presented in Figure 9-3. The figures show that there are differences in water content and density between the different sampling directions (see the detailed contour plots for every single block), but the large differences are clearly in vertical direction. The figures provided are thus judged to give a rather good picture of the overall status of the buffer in each of the deposition holes.

Some comments on the results:

- The two uppermost solid blocks, have in all four deposition holes clearly swelled axially and by that decreased the density. The dry density for block C4 was mainly between 1300 and 1400 kg/m^3 and for block C3 between 1400 and 1500 kg/m^3. Both these upper blocks were in all four deposition holes largely water saturated.
- The blocks just above the canister, C2, and the uppermost ring-blocks around the canister, R10, R9, and to some extent also R8, did also have a high degree of saturation in all four deposition holes. The central parts of block C2, in deposition holes 2 and 4, had however a somewhat lower degree of saturation, between 94 and 96 %.
- Regarding the ring-blocks below R8, i.e. R7-R1, and the bottom block C1, there were large differences between the deposition holes. In Dh1 and Dh3, all these blocks were judged to be largely saturated. However, in Dh4, the bottom block and the four ring-shaped blocks above (R7-R10), had in whole or in part, a lower degree of saturation. In Dh2, the bottom block and the seven ring-shaped blocks above, R4-R10, had in whole or in part a lower degree of saturation.

Two of the deposition holes, Dh1 and Dh3, were thus largely saturated. In the two other deposition holes, Dh2 and Dh4, several blocks in the lower part of the buffer had a low degree of saturation.

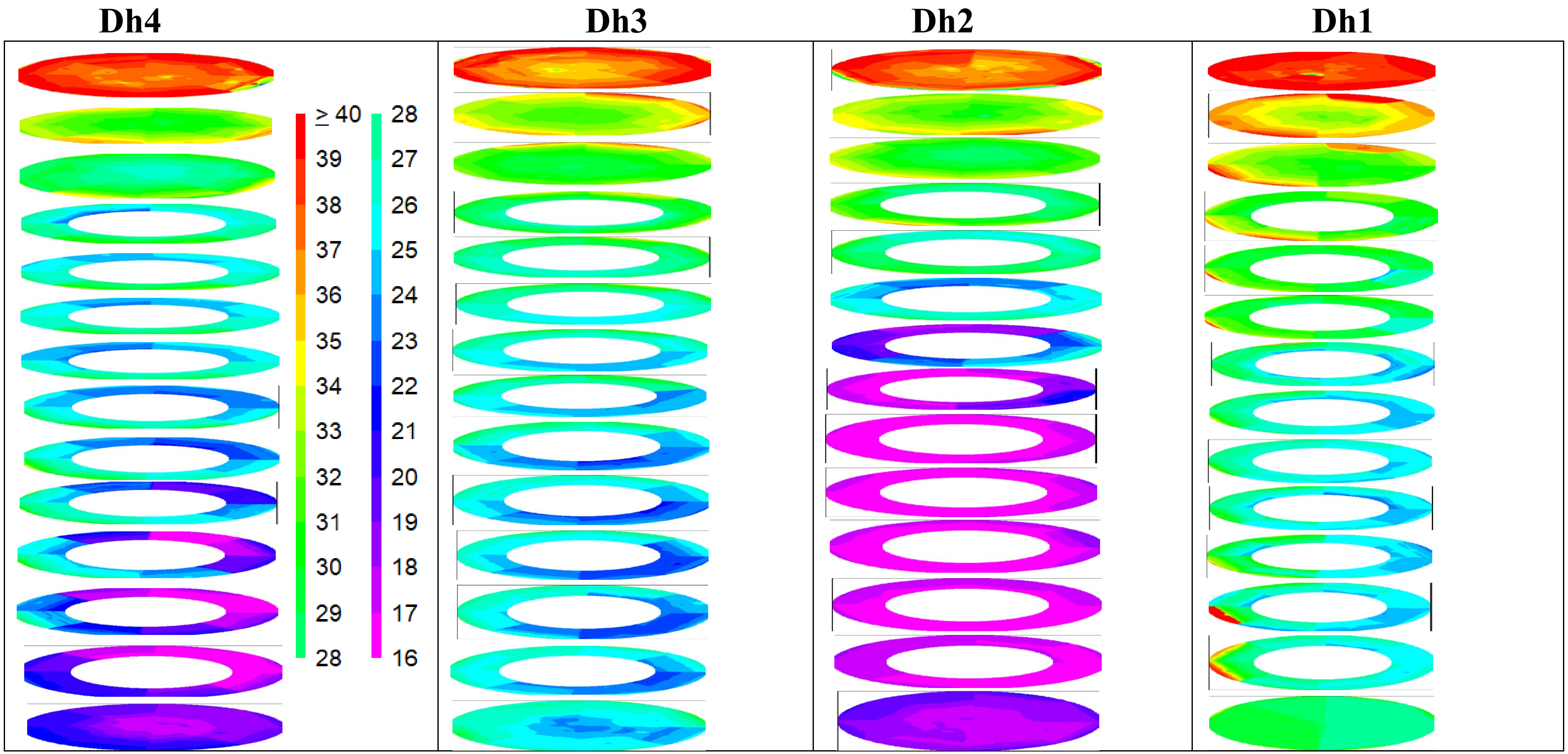


Figure 9-1. *Measured water content (%) distribution in the four deposition holes in the inner section of the Prototype Repository.*

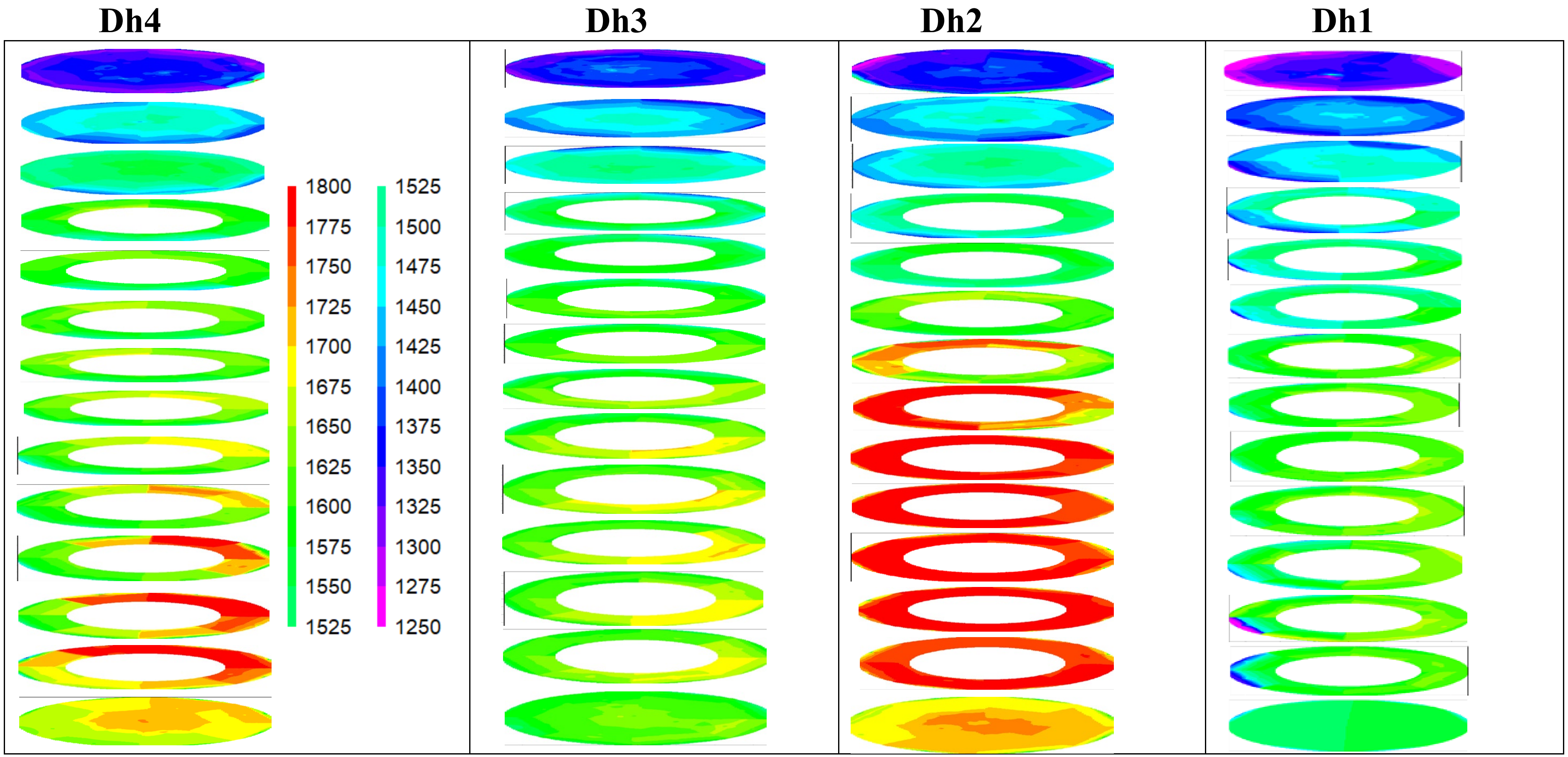


Figure 9-2. *Measured dry density (kg/m³) distribution in the four deposition holes in the inner section of the Prototype Repository.*

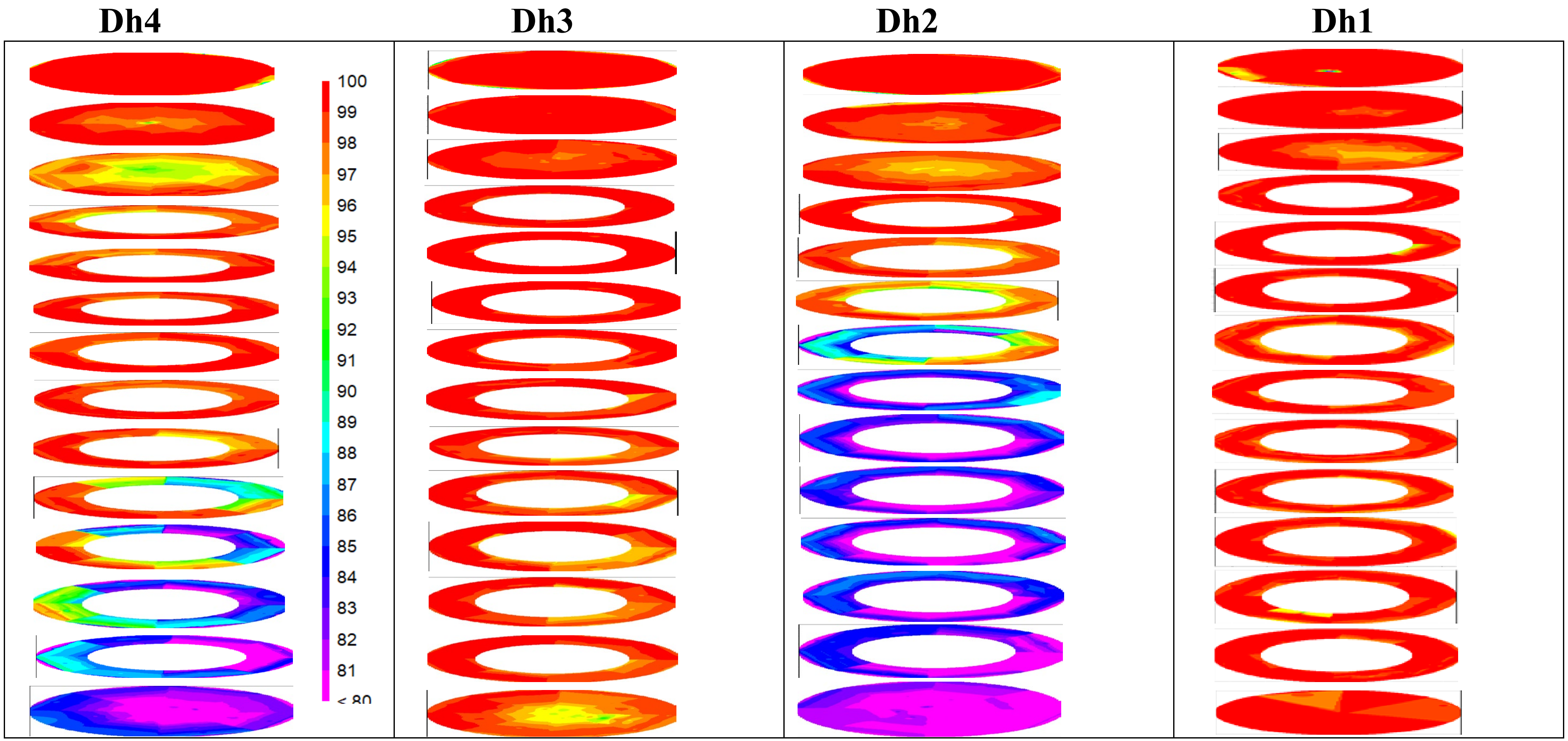


Figure 9-3. *Calculated degree of saturation (%) distribution in the four deposition holes in the inner section of the Prototype Repository.*

9.2 Backfill

9.2.1 Measured dry density of the backfill

The average dry density determined in conjunction with the dismantling of the cross sections above each of the deposition holes is provided in Table 9-1. An attempt to weight the samples regarding the representative volume (Börgesson et al. 2002, Figure 5-22) was also done, see middle column, but the difference was rather small. The last column shows the average dry density of the backfill in the uppermost part of the deposition hole. The density of the backfill was notable higher in this upper part of the deposition holes compared to the backfill in the tunnel. It should, however, be mentioned that the spread in determined density and water content of the backfill was large, see explanations in Section 8.2.

Table 9-1. Measured average dry density of the backfill in the different cross-sections and in the different deposition holes

Backfill section	Average dry density of backfill in cross-section	*Weighted dry density of backfill in cross-section	Average dry density of backfill in deposition hole
	kg/m^3	kg/m^3	kg/m^3
Deposition hole 1	1563	1580	1677
Deposition hole 2	1624	1632	1806
Deposition hole 3	1574	1580	1767
Deposition hole 4	1491	1490	1746

*The figures have been weighted regarding the representative volume of each sample.

9.2.2 Backfill in cross-sections above the deposition holes

The average dry density of the backfill was *after installation* calculated to between 1580 and 1650 kg/m^3 (Börgesson et al. 2002). The measured dry density *at dismantling* for the backfill above deposition holes 1,2 and 3, was between 1580 and 1632 kg/m^3, which was consistent with the installation data. However, the measured dry density of the backfill above deposition hole 4 was lower, 1490 kg/m^3.

9.2.3 Backfill in the top of the deposition holes

The average dry density of the backfill in the uppermost meter of the deposition holes was *after installation* determined to between 1570 and 1830 kg/m^3 (Börgesson et al. 2002). The lowest dry density, 1570 kg/m^3 was measured in deposition hole 2 and in the other three deposition holes the dry density was measured to between 1770-1830 kg/m^3. Corresponding figures determined in conjunction with the *dismantling*, varied between 1677 and 1806 kg/m^3, see last column in Table 9-1. The determined dry density at dismantling were thus close to the density determined at installation except for deposition hole 2. The density determined at installation for this deposition hole (1570 kg/m^3) must thus be wrong.

The average dry density of the backfill in the uppermost part of the deposition holes was higher than the average density determined in the cross sections above the deposition holes, Table 9-1.

9.2.4 Degree of saturation

It is judged that the backfill in general was saturated even if there were rather large variations in the calculated degree of saturation (see explanations in Section 8.2).

10 References

SKB's (Svensk Kärnbränslehantering AB) publications can be found at www.skb.com/publications. SKBdoc documents will be submitted upon request to document@skb.se.

Andersson C, Johansson Å, 2002. Boring of full scale deposition holes at the Äspö Hard Rock Laboratory. Operational experiences including boring performance and work time analysis. SKB TR-02-26, Svensk Kärnbränslehantering AB.

Arvidsson A, Josefsson P, Eriksson P, Sandén T, Ojala M, 2015. System design of backfill. Project results. SKB TR-14-20, Svensk Kärnbränslehantering AB.

Börgesson L, Johannesson L-E, Sandén T, Hernelind J, 1995. Modelling of the physical behaviour of water saturated clay barriers. Laboratory tests, material models and finite element application. SKB TR 95-20, Svensk Kärnbränslehantering AB.

Börgesson L, Gunnarsson D, Johannesson L-E, Sandén T, 2002. Äspö Hard Rock Laboratory. Prototype Repository. Installation of buffer, canisters, backfill and instruments in Section 1. SKB IPR-02-23, Svensk Kärnbränslehantering AB.

Goudarzi R, 2023. Prototype Repository-Sensor data report. Period 2001-09-17 to 2023-01-01. Report No 34. SKB P-23-12, Svensk Kärnbränslehantering AB.

Gunnarsson D, 2002. Äspö Hard Rock Laboratory. Backfill production for Prototype Repository. SKB IPR-02-20, Svensk Kärnbränslehantering AB.

Johannesson L-E, 2002. Äspö Hard Rock Laboratory. Manufacturing of bentonite buffer for the Prototype Repository. IPR-02-19, Svensk Kärnbränslehantering AB.

Johannesson L-E, 2014. Prototype Repository. Measurements of water content and density of the retrieved buffer material from deposition holes 5 and 6 and the backfill in the outer section of the Prototype Repository. SKB P-13-14, Svensk Kärnbränslehantering AB.

Johannesson L-E, Hagman P, 2013. Prototype Repository. Method for opening and retrieval of the outer section. SKB P-13-15, Svensk Kärnbränslehantering AB.

Johannesson L-E, Börgesson L, Sandén T, 1999. Äspö Hard Rock Laboratory. Backfill materials based on crushed rock (part 2). Geotechnical properties determined in laboratory. SKB IPR-99-23, Svensk Kärnbränslehantering AB.

Persson G, Broman O, 2000. Äspö Hard Rock Laboratory. Prototype Repository. Project plan. FIKW-CT-2000-000555. SKB IPR-00-31, Svensk Kärnbränslehantering AB.

Rhén I, Forsmark T, 2001. Äspö Hard Rock Laboratory. Prototype Repository. Hydrogeology. Summary report of investigations before the operation phase. SKB IPR-01-65, Svensk Kärnbränslehantering AB.

Svemar C, Pusch R, 2000. Äspö Hard Rock Laboratory. Prototype Repository. Project description. FIKW-CT-2000-00055. SKB IPR-00-30, Svensk Kärnbränslehantering AB.

Svemar C, Johannesson L-E, Grahm P, Svensson D, Kristensson O, Lönnqvist M, Nilsson U, 2016. Prototype Repository. Opening and retrieval of outer section of Prototype Repository at Äspö Hard Rock Laboratory. Summary report. SKB TR-13-22, Svensk Kärnbränslehantering AB.

Svensson D, Eriksson P, Johannesson L-E, Lundgren C, Bladström T, 2019. Development and testing of methods suitable for quality control of bentonite as KBS-3 buffer and backfill. SKB TR-19-25, Svensk Kärnbränslehantering AB.

11 Appendices

The denomination of the appendices begins with a sequential number 1, 2, 3 and 4 indicating which Deposition hole 4, 3, 2 and 1 the presented results come from. The order, in which the Deposition holes are presented, has been chosen to be consistent with the presentations in Chapter 4-7. The full denomination of the appendices also includes information about the Block number (1-14) and the types of diagrams (a-d) used. For example, Appendix 1-1b presents results from deposition hole 4, block 1 in diagrams of the type b.

The following types of diagrams are used for the presentation of results from each Block and Deposition hole:

a. Water content, dry density, and degree of saturation in eight directions on the level 50 mm.

b. Water content, dry density, and degree of saturation at five depths in direction 20°.

c. Water content, dry density, and degree of saturation at five depths in direction 245°.

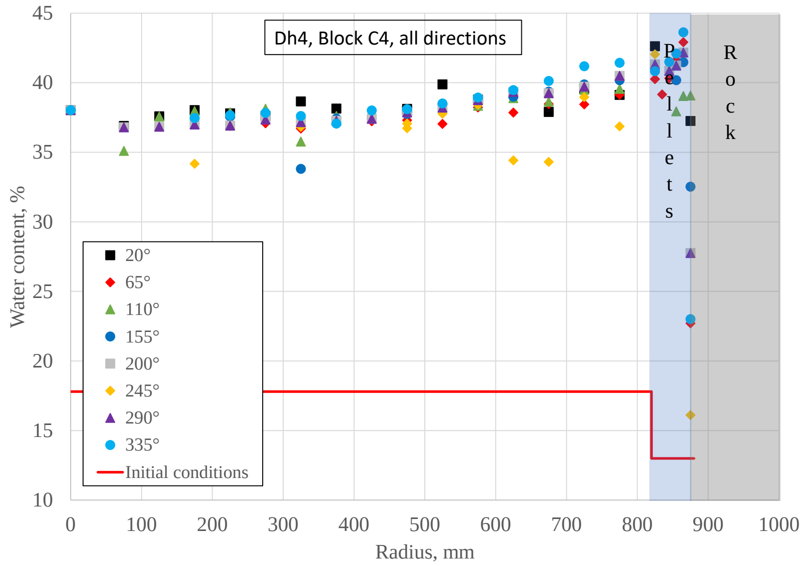
d. Water content, dry density, and degree of saturation distribution on the level 50 mm.

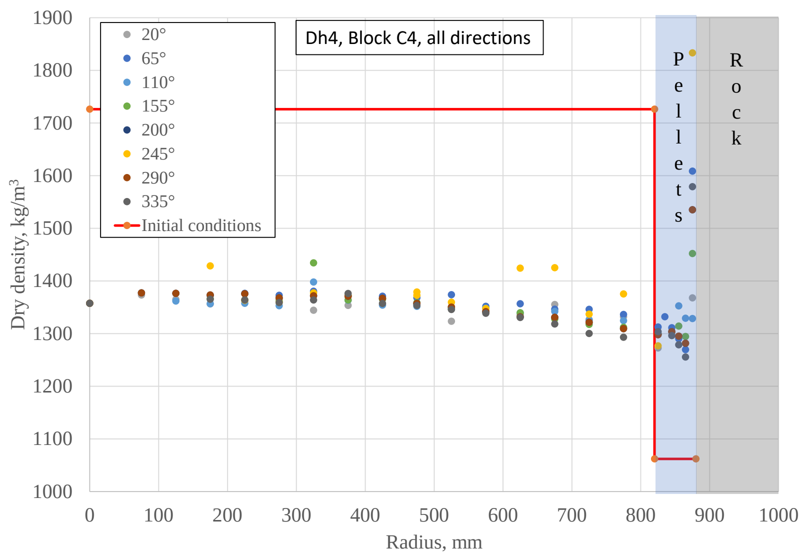
The following appendices are presented:

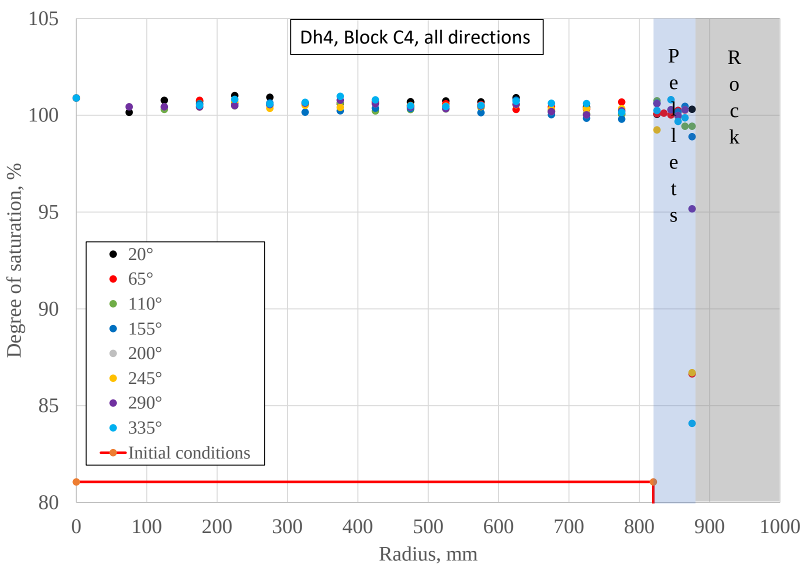
Appendices	Dh and Block	Deposition hole
Appendix 1-1(a-d)	Dh4, Block C4	**Deposition hole 4**
Appendix 1-2(a-d)	Dh4, Block C3	
Appendix 1-3(a-d)	Dh4, Block C2	
Appendix 1-4(a-d)	Dh4, Block R1	
Appendix 1-5(a-d)	Dh4, Block R2	
Appendix 1-6(a-d)	Dh4, Block R3	
Appendix 1-7(a-d)	Dh4, Block R4	
Appendix 1-8(a-d)	Dh4, Block R5	
Appendix 1-9(a-d)	Dh4, Block R6	
Appendix 1-10(a-d)	Dh4, Block R7	
Appendix 1-11(a-d)	Dh4, Block R8	
Appendix 1-12(a-d)	Dh4, Block R9	
Appendix 1-13(a-d)	Dh4, Block R10	
Appendix 1-14(a-d)	Dh4, Block C1	
Appendix 2-1(a-d)	Dh3, Block C4	**Deposition hole 3**
Appendix 2-2(a-d)	Dh3, Block C3	
Appendix 2-3(a-d)	Dh3, Block C2	
Appendix 2-4(a-d)	Dh3, Block R1	
Appendix 2-5(a-d)	Dh3, Block R2	
Appendix 2-6(a-d)	Dh3, Block R3	
Appendix 2-7(a-d)	Dh3, Block R4	
Appendix 2-8(a-d)	Dh3, Block R5	
Appendix 2-9(a-d)	Dh3, Block R6	
Appendix 2-10(a-d)	Dh3, Block R7	
Appendix 2-11(a-d)	Dh3, Block R8	
Appendix 2-12(a-d)	Dh3, Block R9	
Appendix 2-13(a-d)	Dh3, Block R10	
Appendix 2-14(a-d)	Dh3, Block C1	

Appendices	Dh and Block	Deposition hole
Appendix 3-1(a-d)	Dh2, Block C4	**Deposition hole 2**
Appendix 3-2(a-d)	Dh2, Block C3	
Appendix 3-3(a-d)	Dh2, Block C2	
Appendix 3-4(a-d)	Dh2, Block R1	
Appendix 3-5(a-d)	Dh2, Block R2	
Appendix 3-6(a-d)	Dh2, Block R3	
Appendix 3-7(a-d)	Dh2, Block R4	
Appendix 3-8(a-d)	Dh2, Block R5	
Appendix 3-9(a-d)	Dh2, Block R6	
Appendix 3-10(a-d)	Dh2, Block R7	
Appendix 3-11(a-d)	Dh2, Block R8	
Appendix 3-12(a-d)	Dh2, Block R9	
Appendix 3-13(a-d)	Dh2, Block R10	
Appendix 3-14(a-d)	Dh2, Block C1	
Appendix 4-1(a-d)	Dh1, Block C4	**Deposition hole 1**
Appendix 4-2(a-d)	Dh1, Block C3	
Appendix 4-3(a-d)	Dh1, Block C2	
Appendix 4-4(a-d)	Dh1, Block R1	
Appendix 4-5(a-d)	Dh1, Block R2	
Appendix 4-6(a-d)	Dh1, Block R3	
Appendix 4-7(a-d)	Dh1, Block R4	
Appendix 4-8(a-d)	Dh1, Block R5	
Appendix 4-9(a-d)	Dh1, Block R6	
Appendix 4-10(a-d)	Dh1, Block R7	
Appendix 4-11(a-d)	Dh1, Block R8	
Appendix 4-12(a-d)	Dh1, Block R9	
Appendix 4-13(a-d)	Dh1, Block R10	
Appendix 4-14(a-d)	Dh1, Block C1	

Appendix 1-1a Dh4, Block C4.
Water content, dry density, and degree of saturation in eight directions.

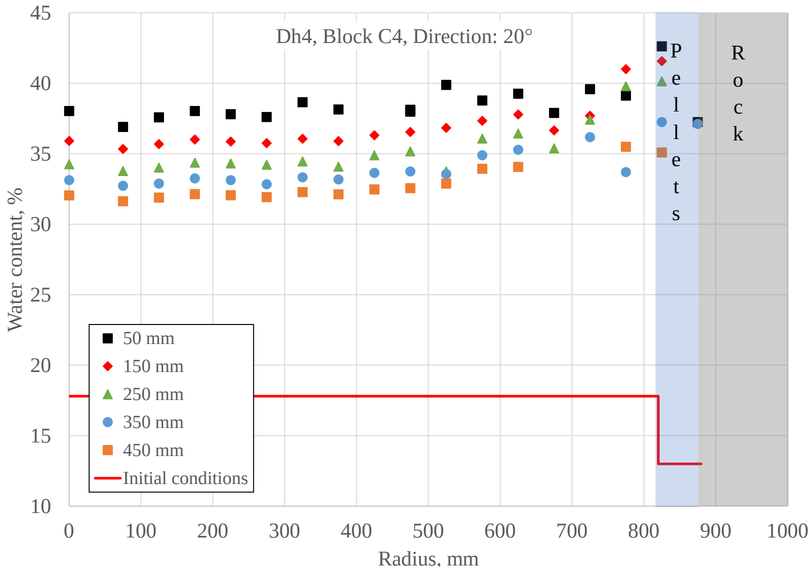


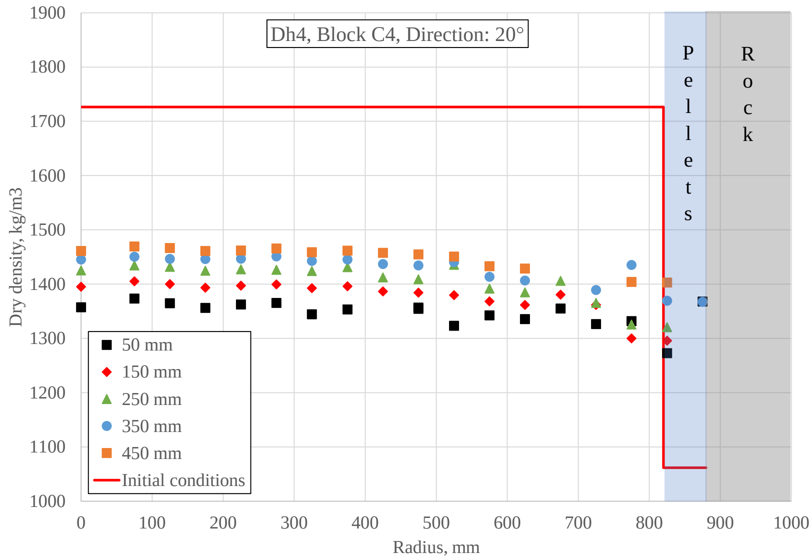


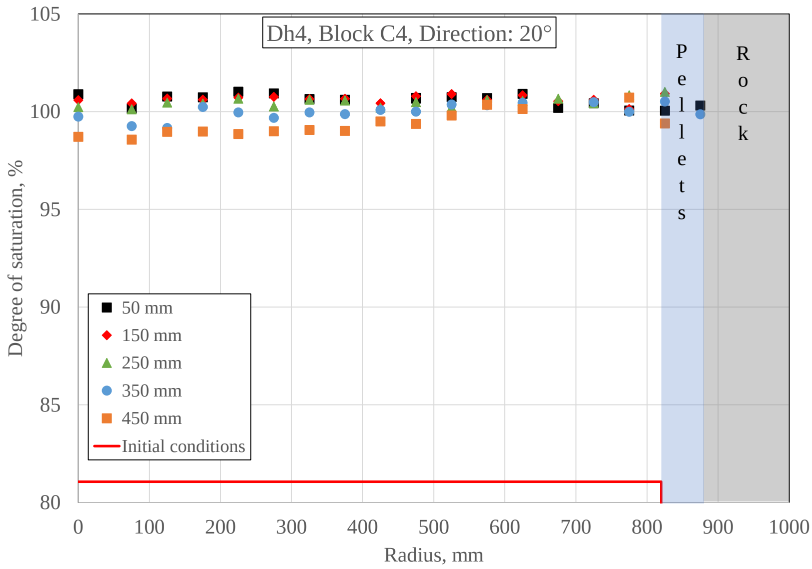


Appendix 1-1b Dh4, Block C4.

Water content, dry density, and degree of saturation at five depths in direction 20°.

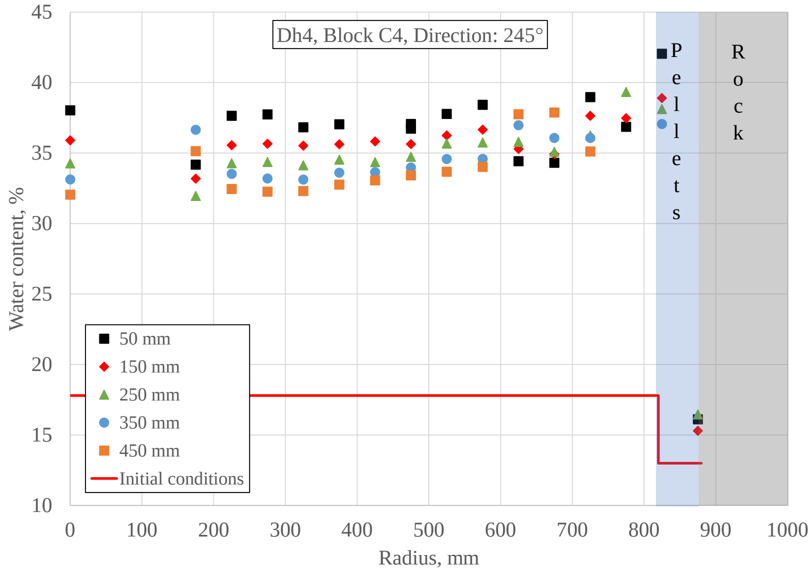


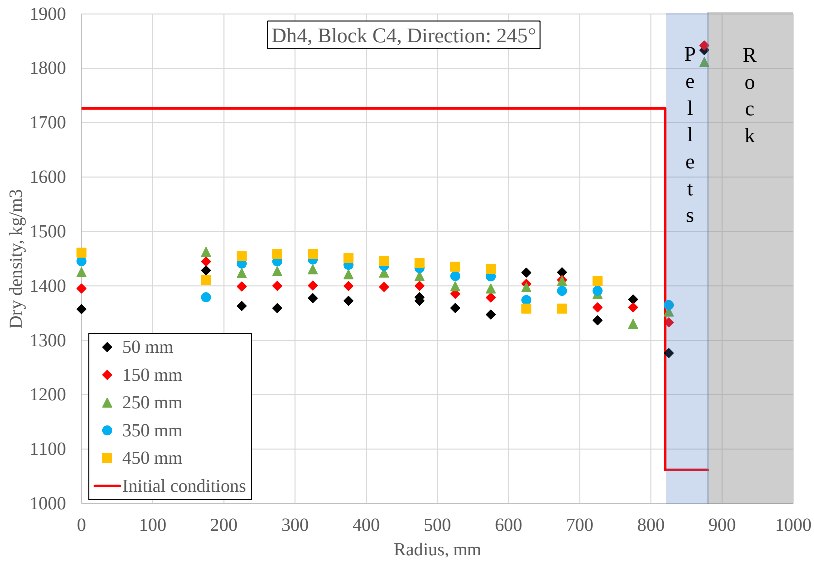


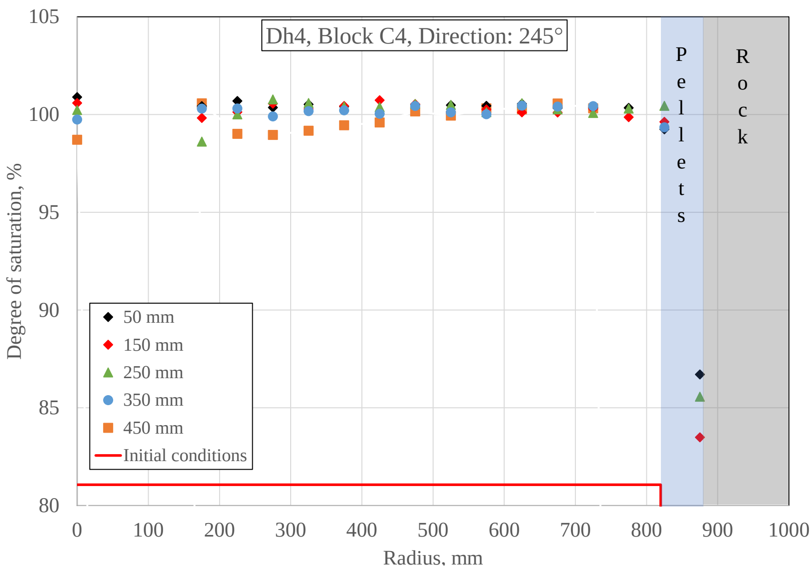


Appendix 1-1c Dh 4, Block C4.

Water content, dry density, and degree of saturation at five depths in direction 245°.

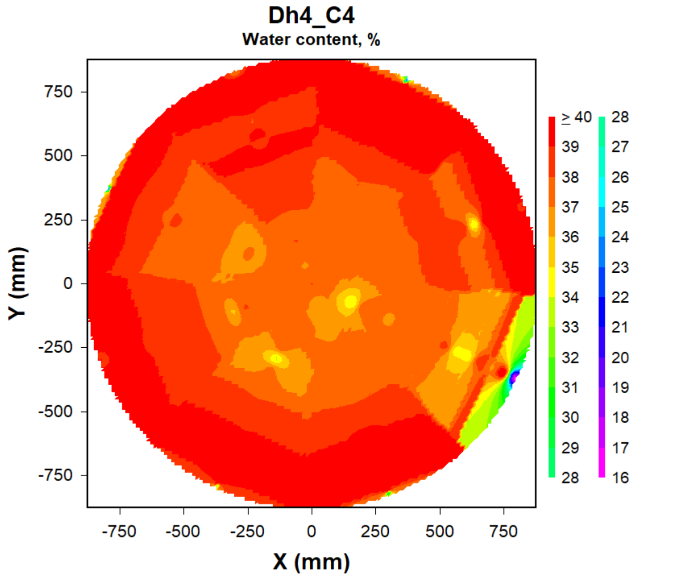


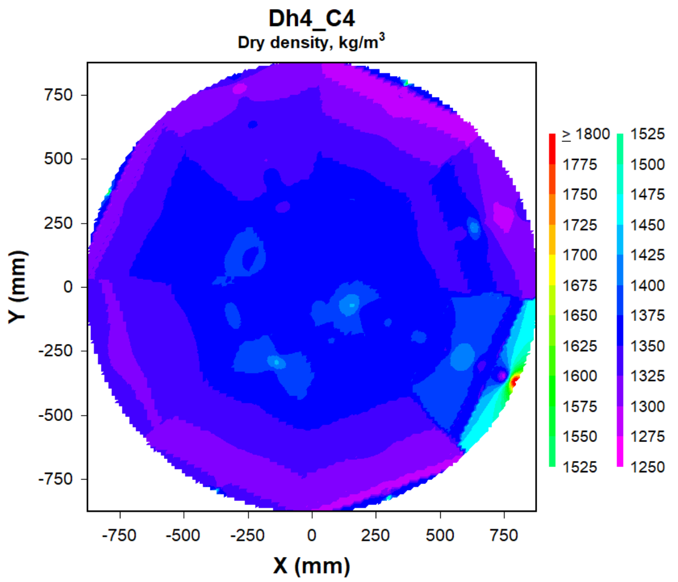


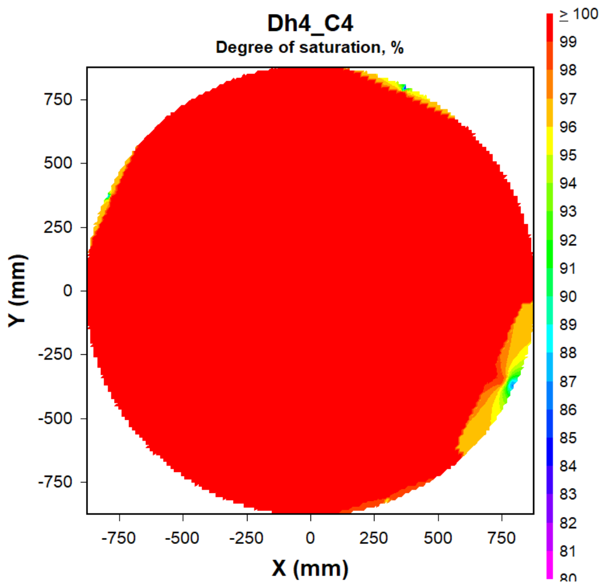


Appendix 1-1d   Dh 4, Block C4.

Water content, dry density, and degree of saturation distribution.

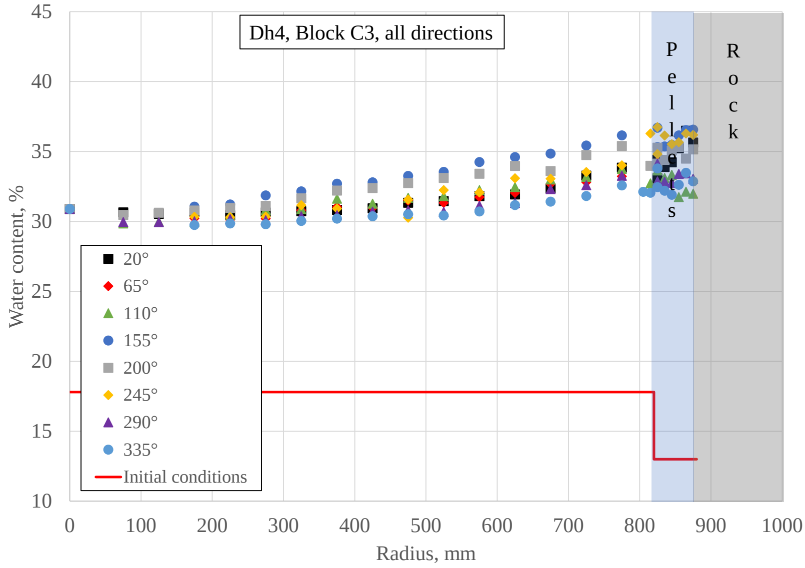


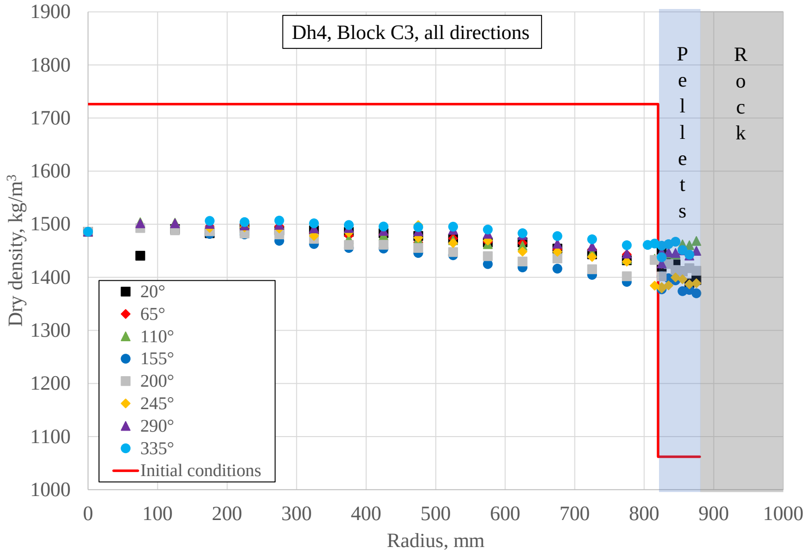


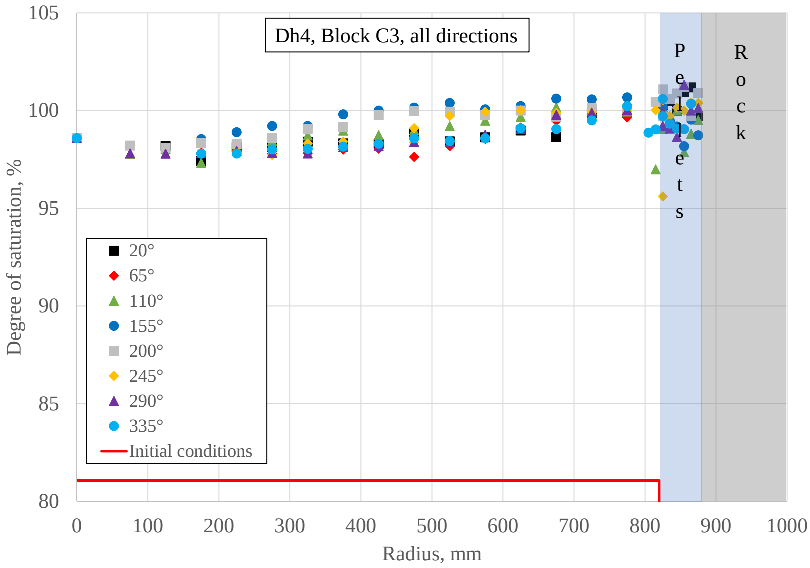


Appendix 1-2a Dh4, Block C3.

Water content, dry density, and degree of saturation in eight directions.

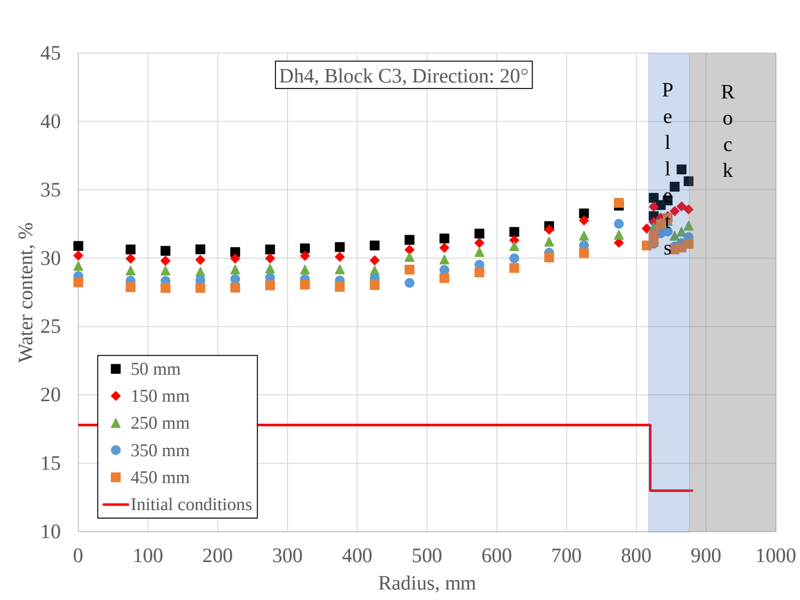


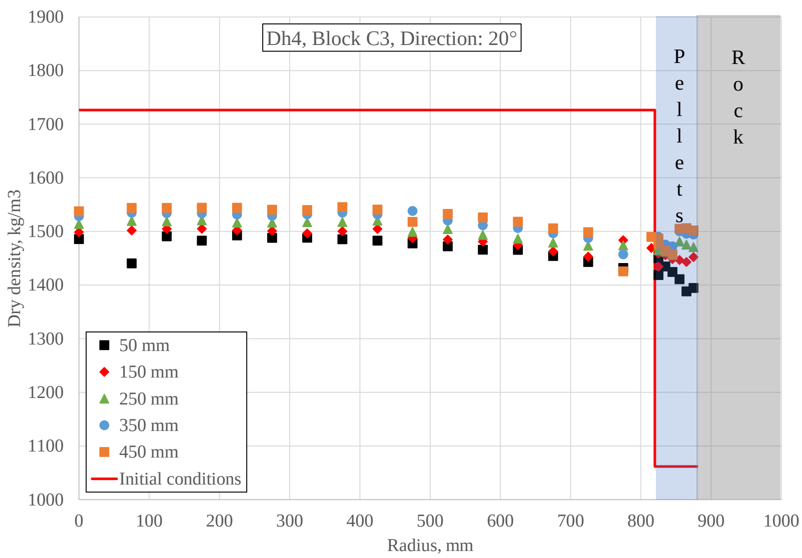


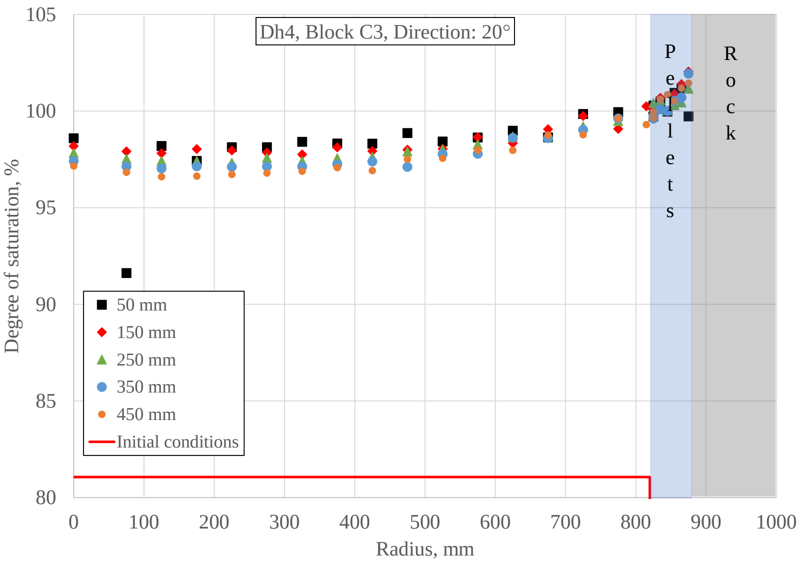


Appendix 1-2b Dh4, Block C3.

Water content, dry density, and degree of saturation at five depths in direction 20°.

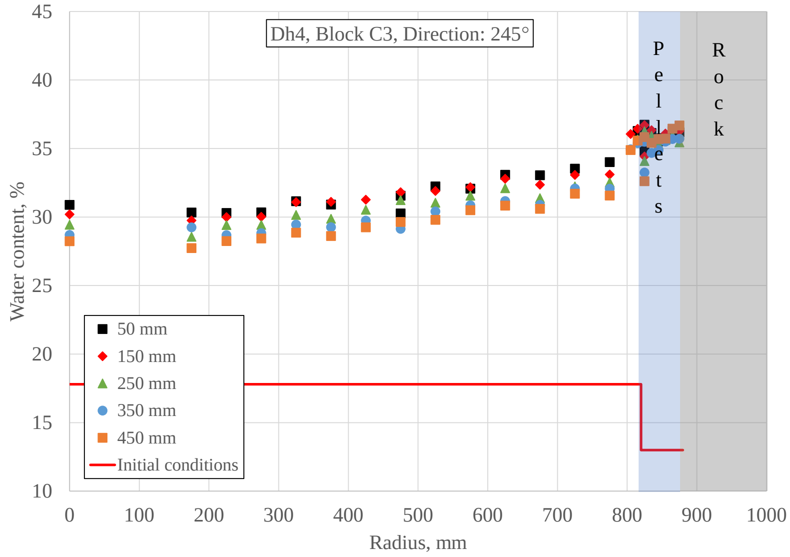


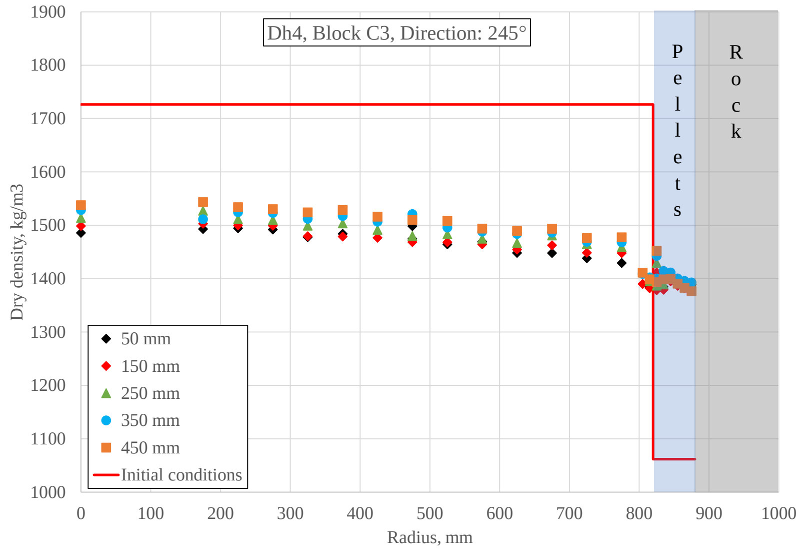


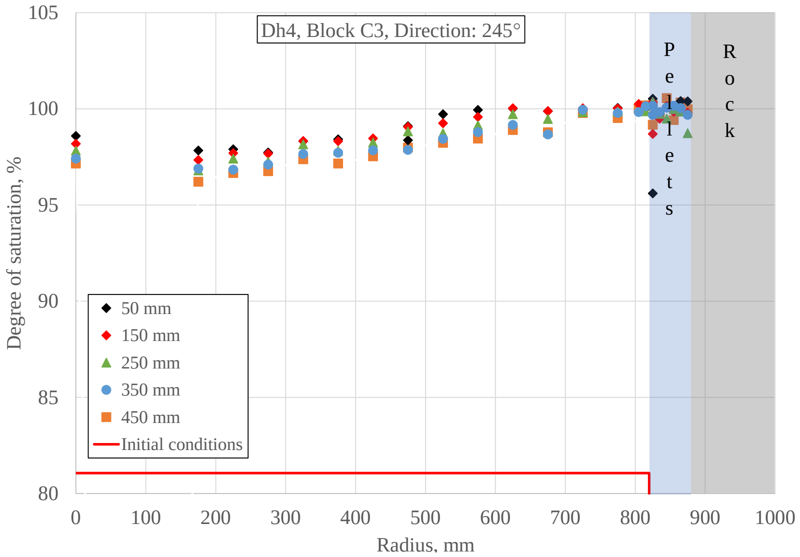


Appendix 1-2c Dh4, Block C3.

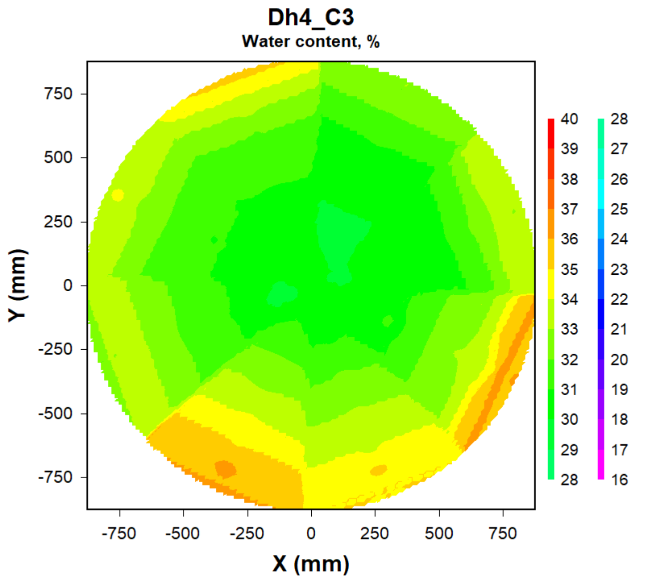
Water content, dry density, and degree of saturation at five depths in direction 245°.
Note that the samples from the former pellet gap are all from direction 200°.

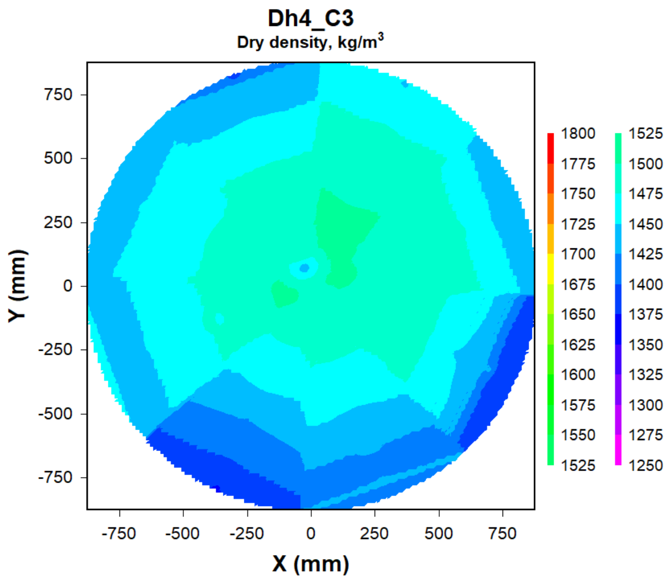


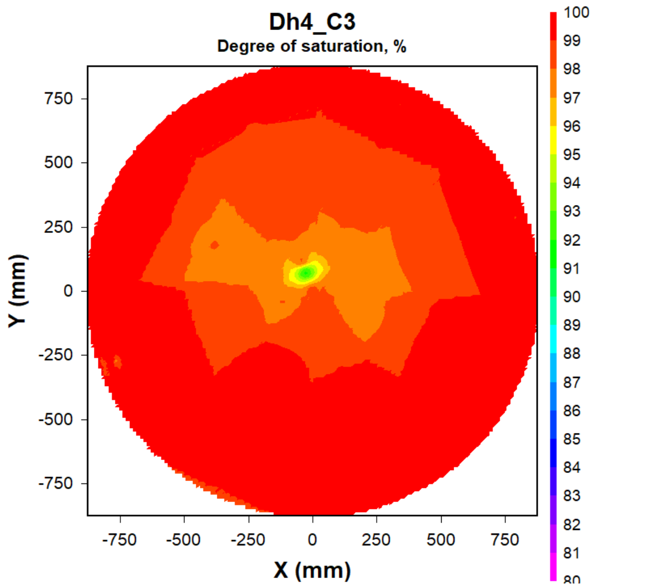




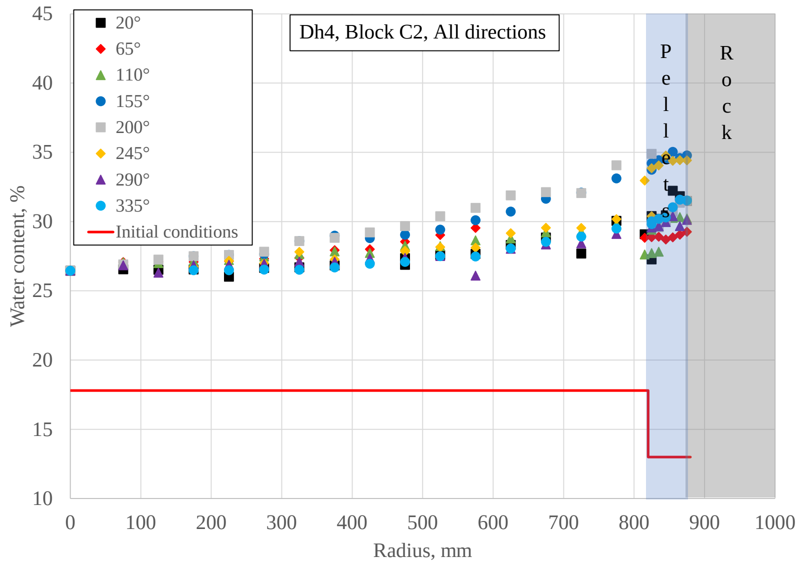
Appendix 1-2d Dh4, Block C3.
Water content, dry density, and degree of saturation distribution.

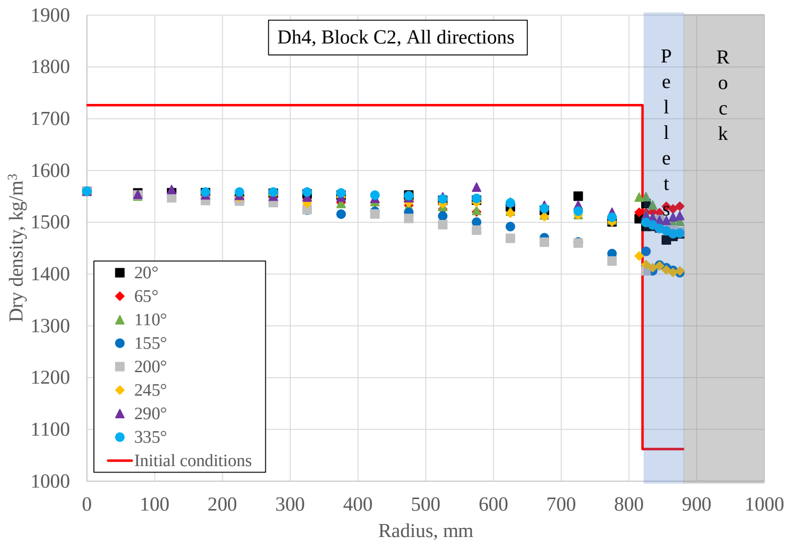


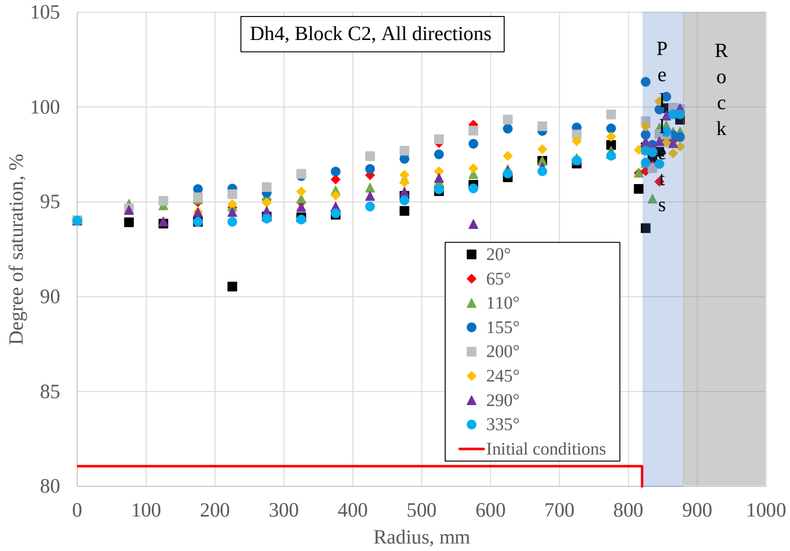




Appendix 1-3a Dh4, Block C2.
Water content, dry density, and degree of saturation in eight directions.

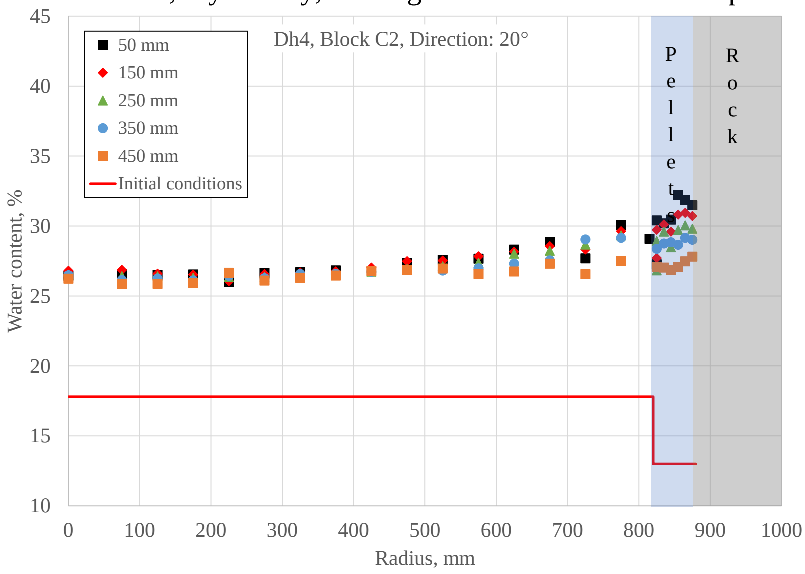


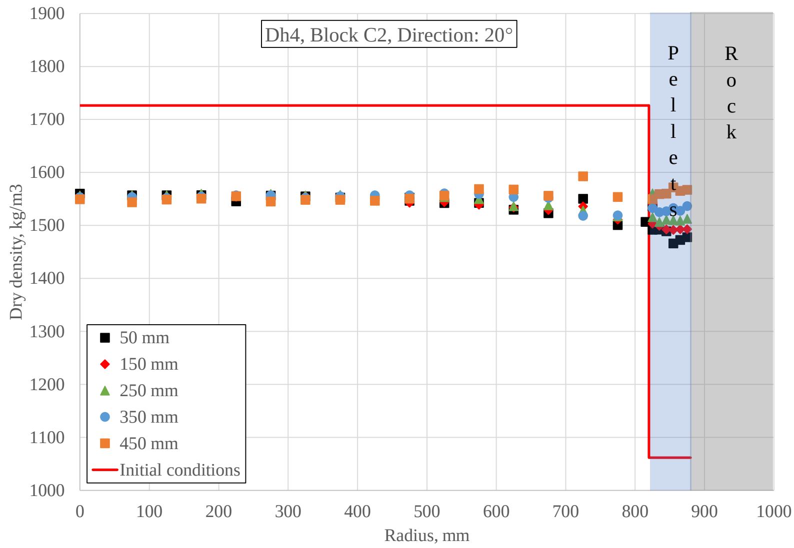


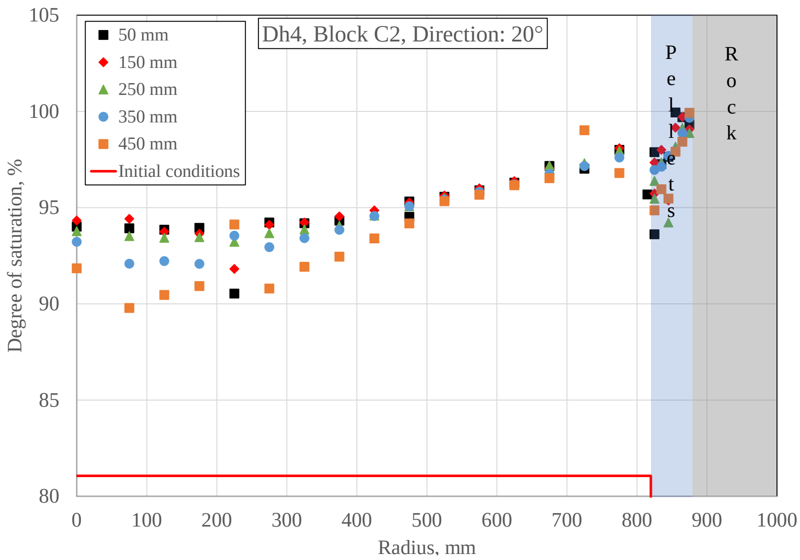


Appendix 1-3b Dh4, Block C2.

Water content, dry density, and degree of saturation at five depths in direction 20°.

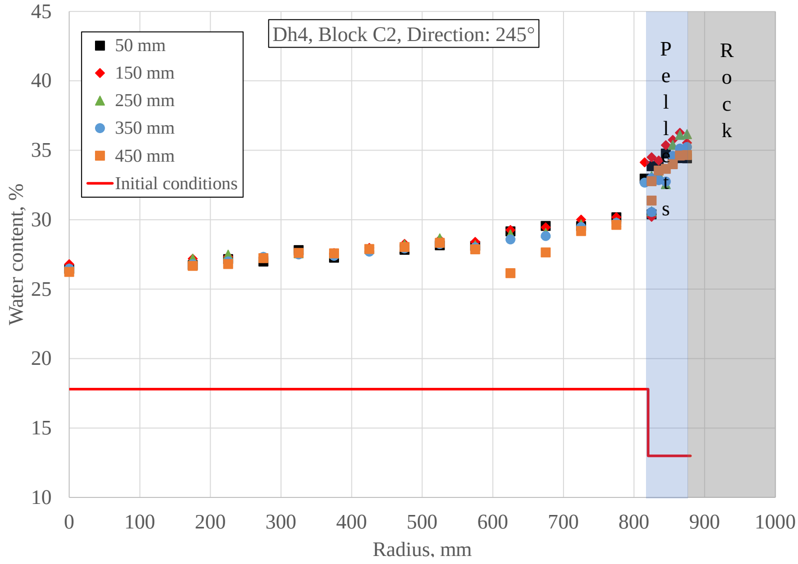


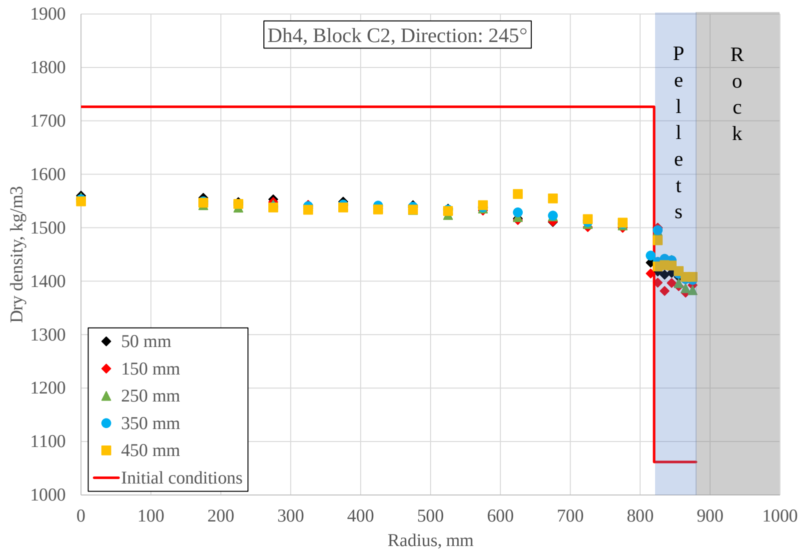


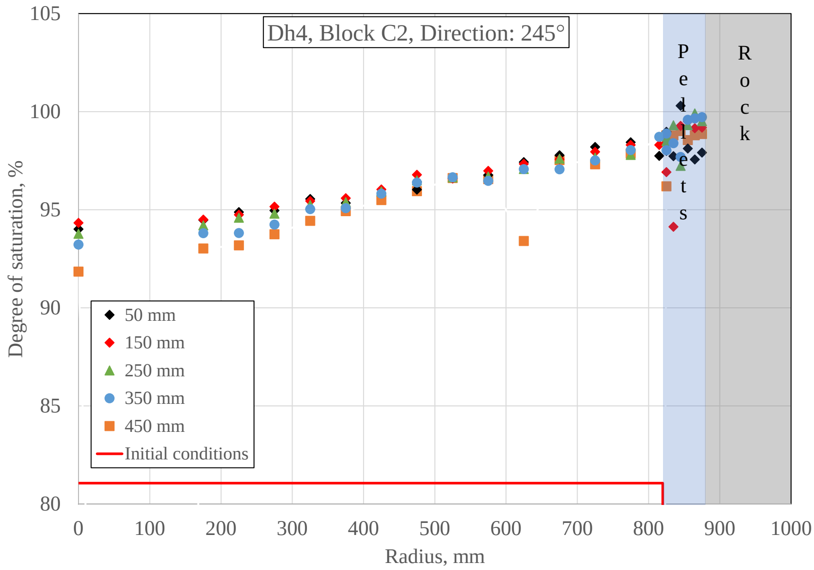


Appendix 1-3c Dh4, Block C2.

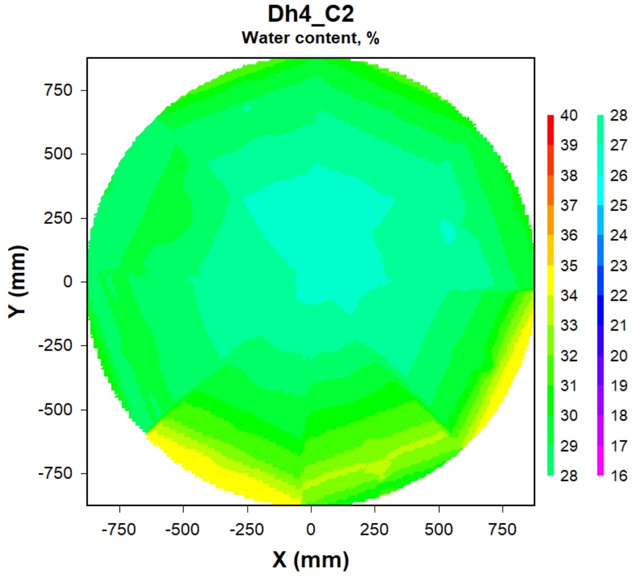
Water content, dry density, and degree of saturation at five depths in direction 245°.

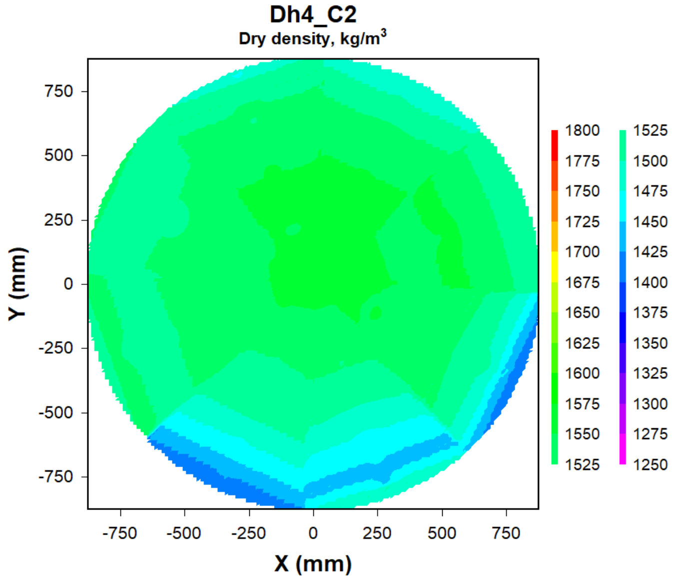


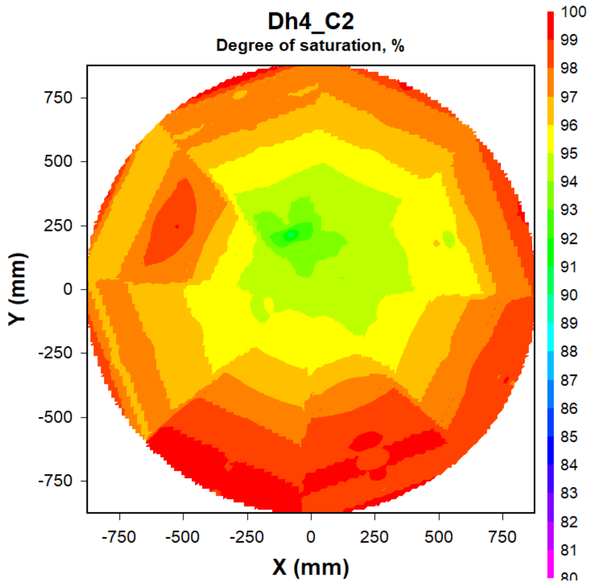




Appendix 1-3d Dh4, Block C2.
Water content, dry density, and degree of saturation distribution.

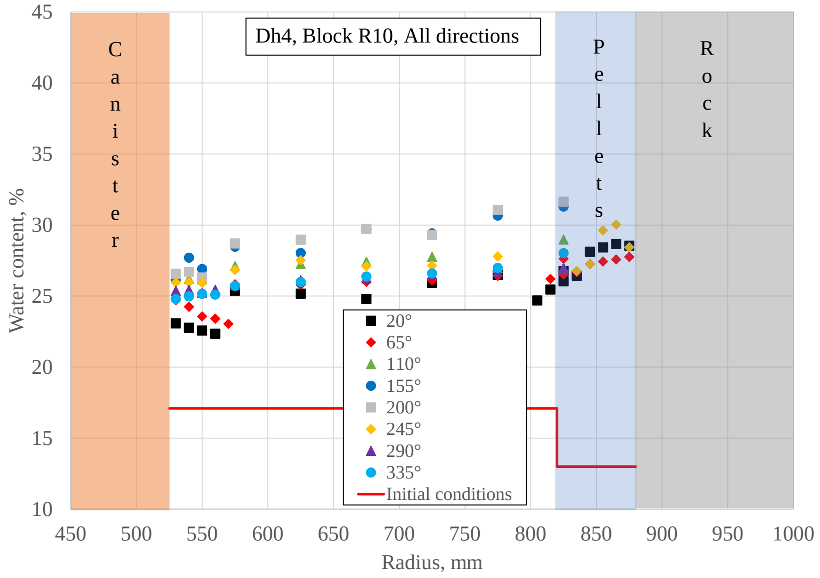


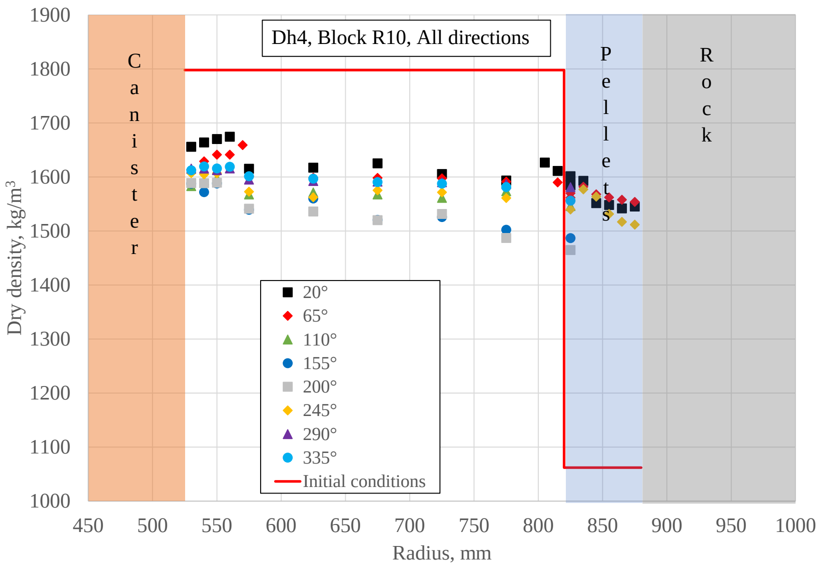


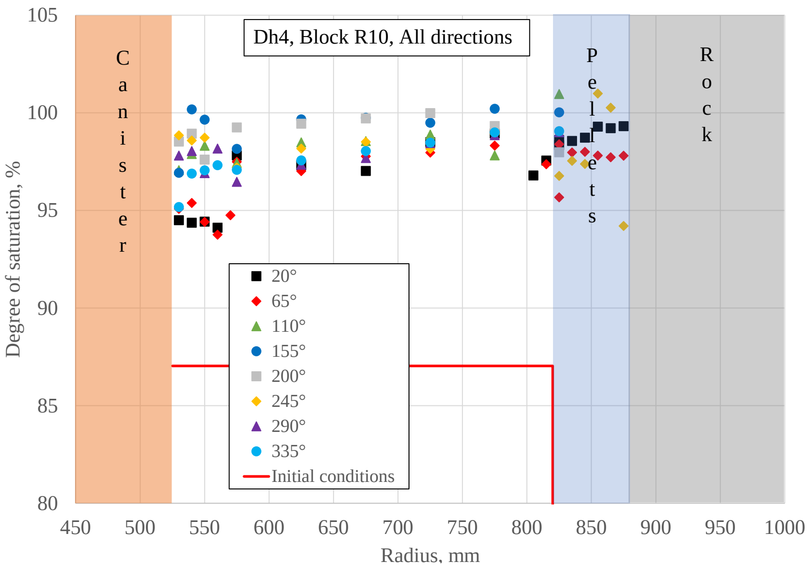


Appendix 1-4a Dh4, Block R10.

Water content, dry density, and degree of saturation in eight directions.

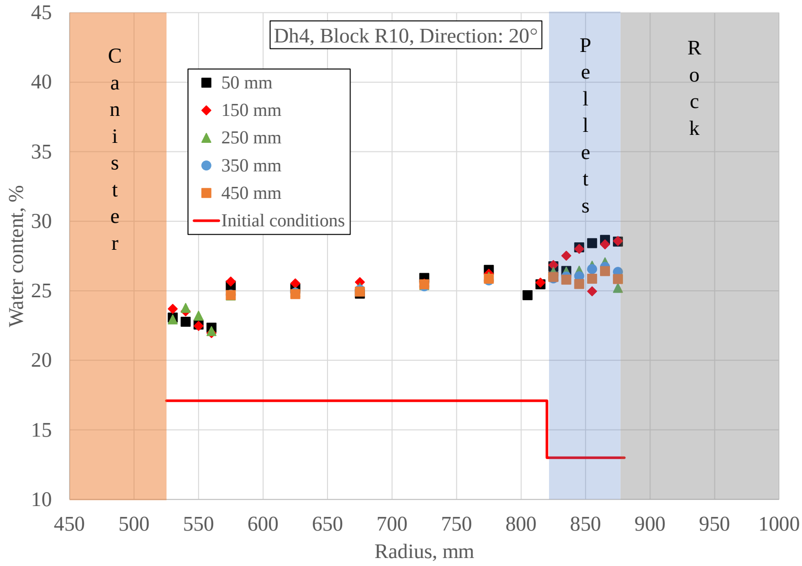


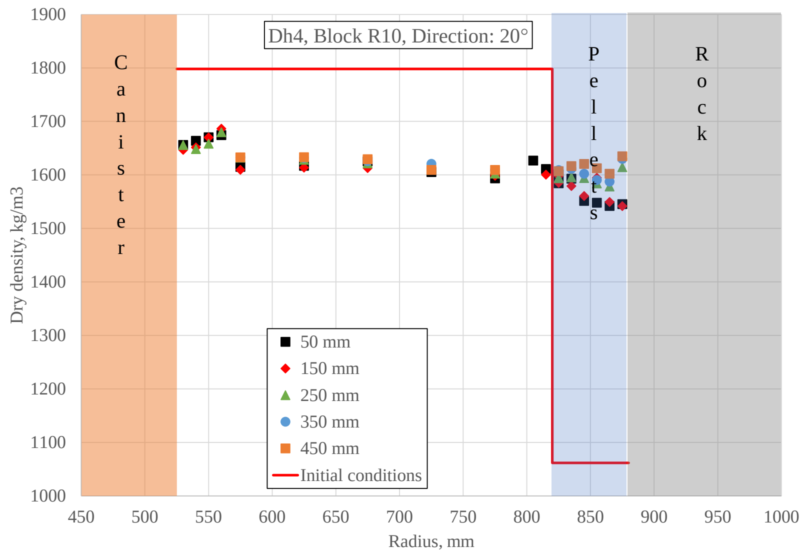


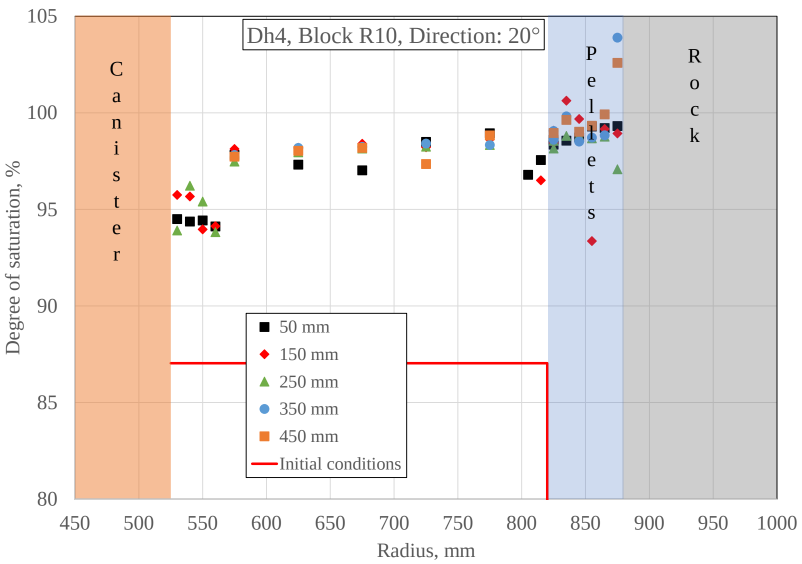


Appendix 1-4b Dh4, Block R10.

Water content, dry density, and degree of saturation at five depths in direction 20°.

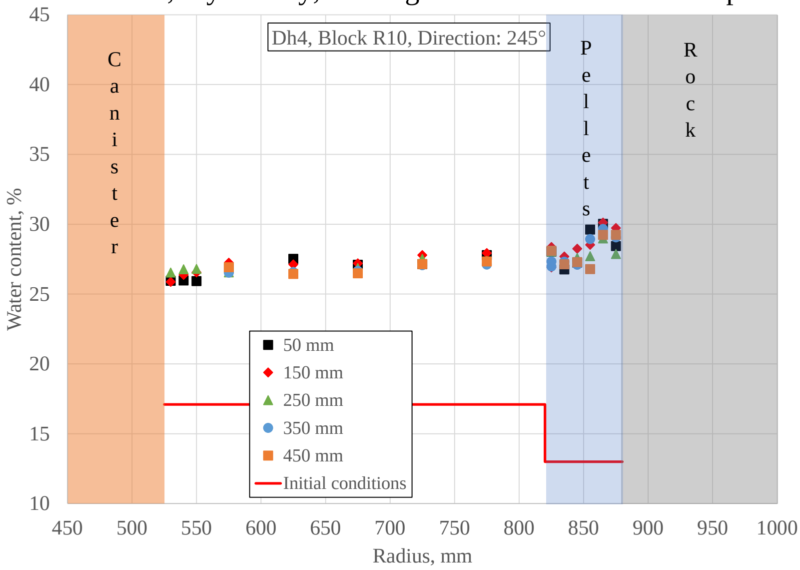


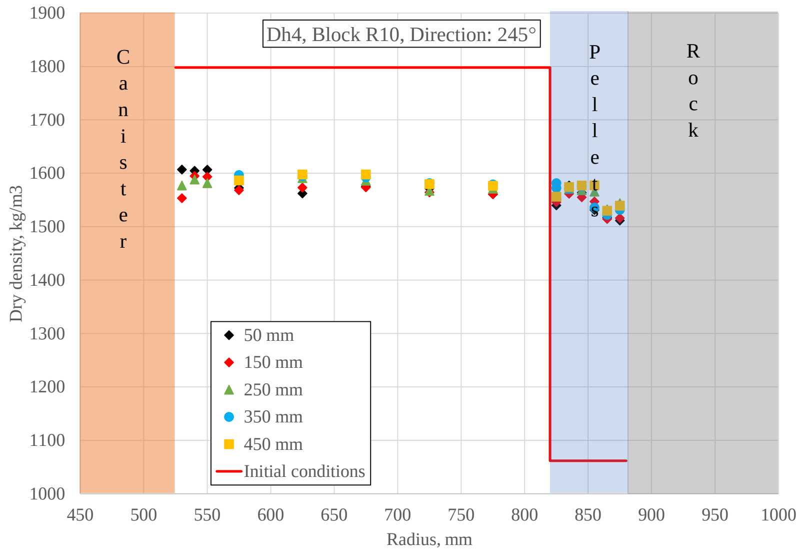


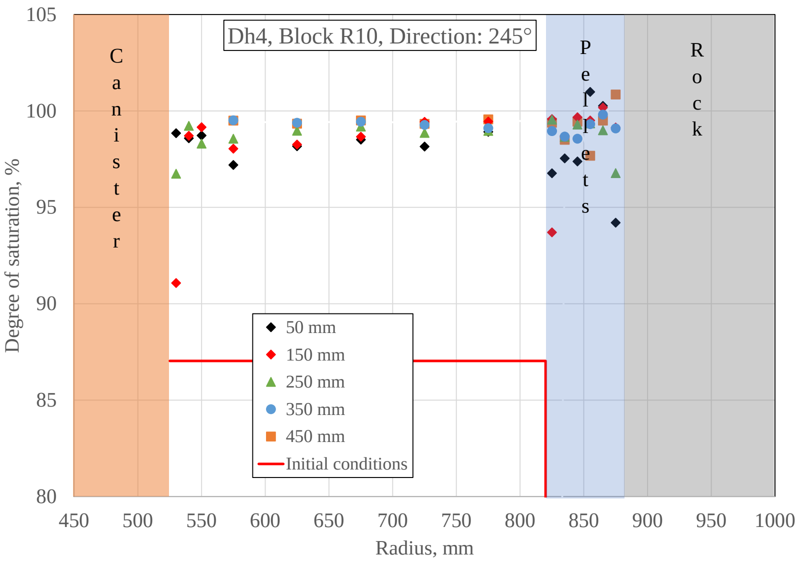


Appendix 1-4c Dh4, Block R10.

Water content, dry density, and degree of saturation at five depths in direction 245°.

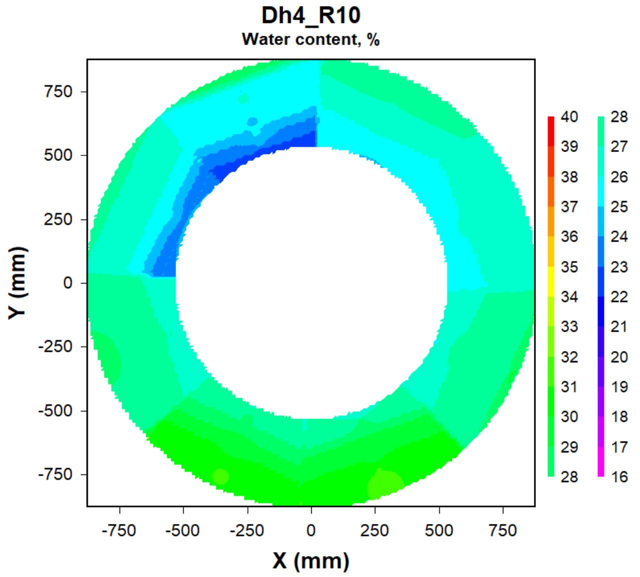


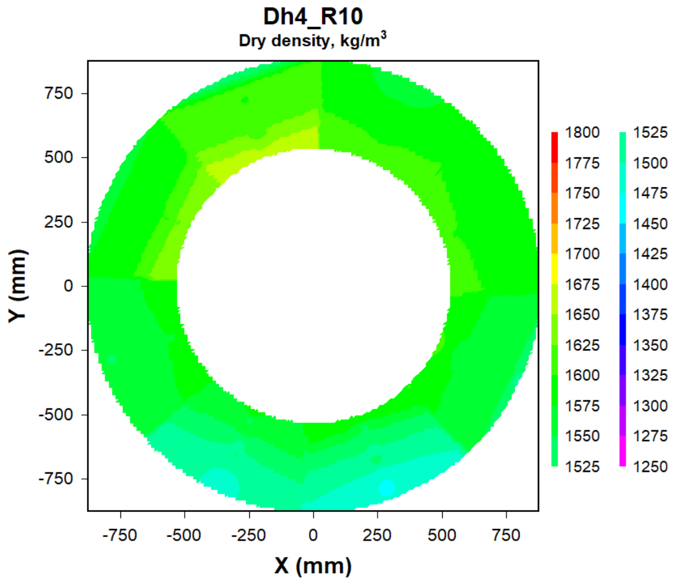


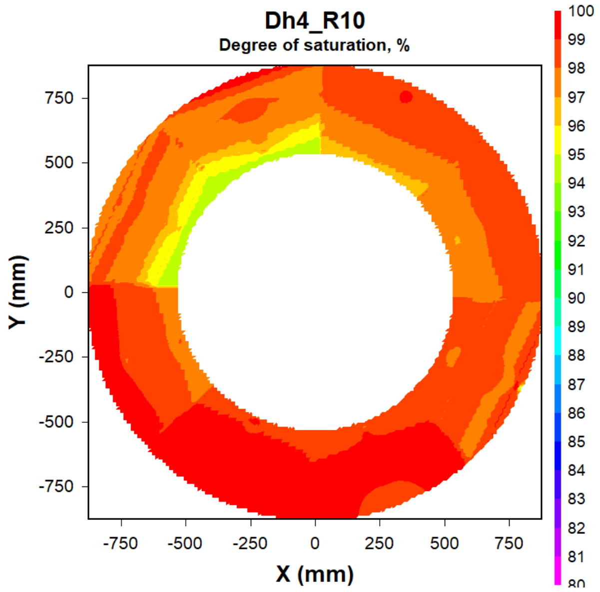


Appendix 1-4d Dh4, Block R10.

Water content, dry density, and degree of saturation distribution.

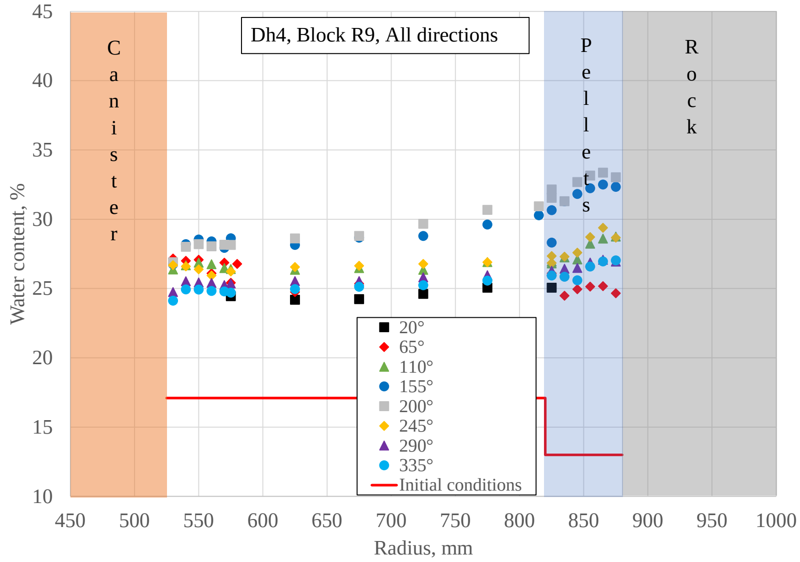


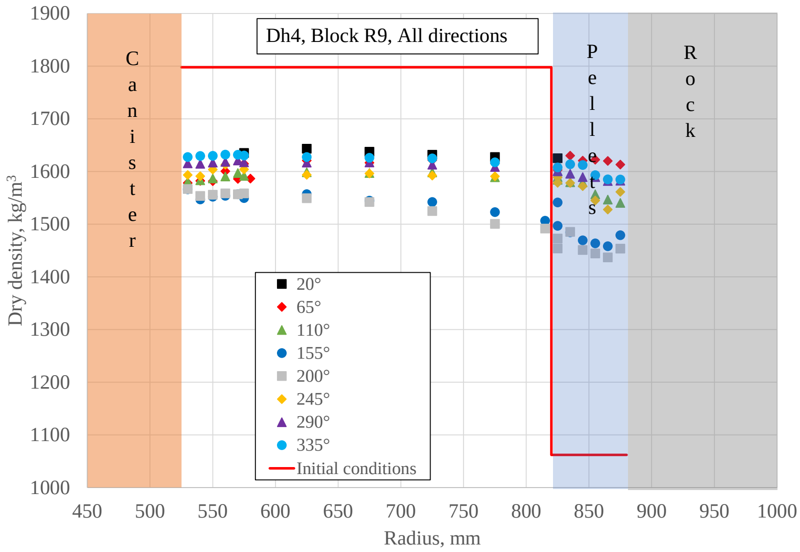


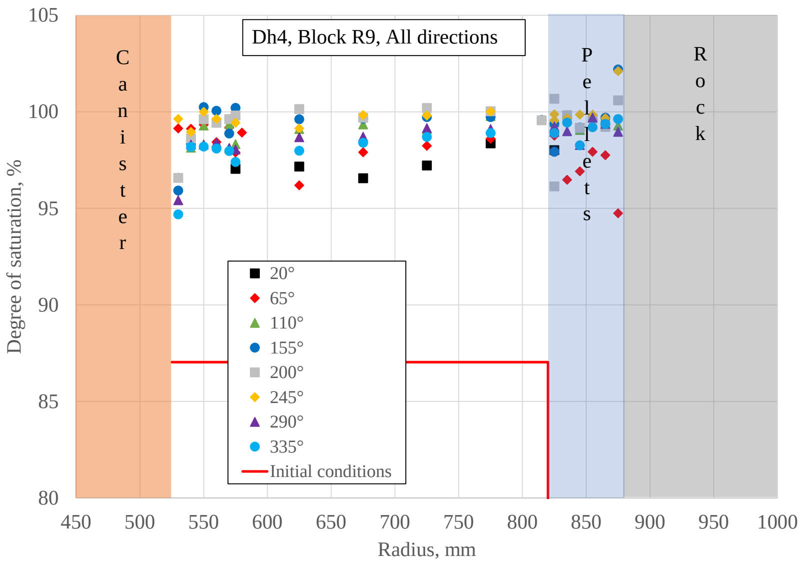


Appendix 1-5a Dh4, Block R9.

Water content, dry density, and degree of saturation in eight directions.

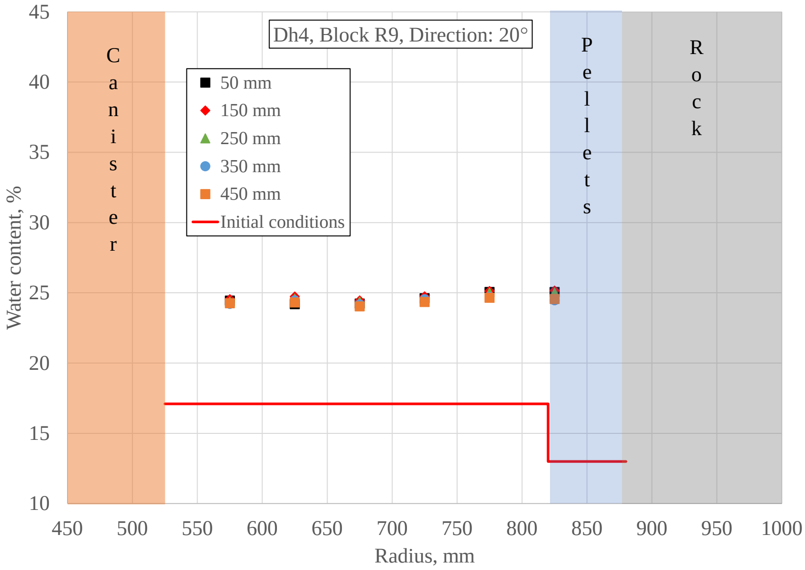


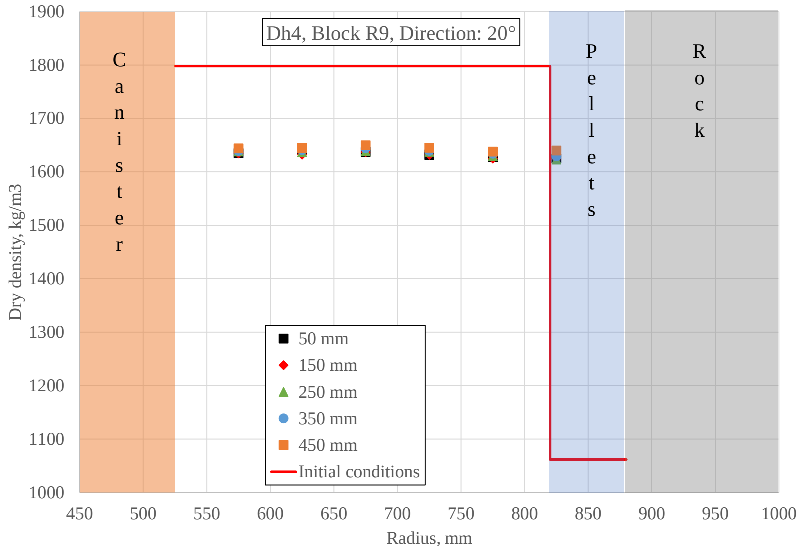


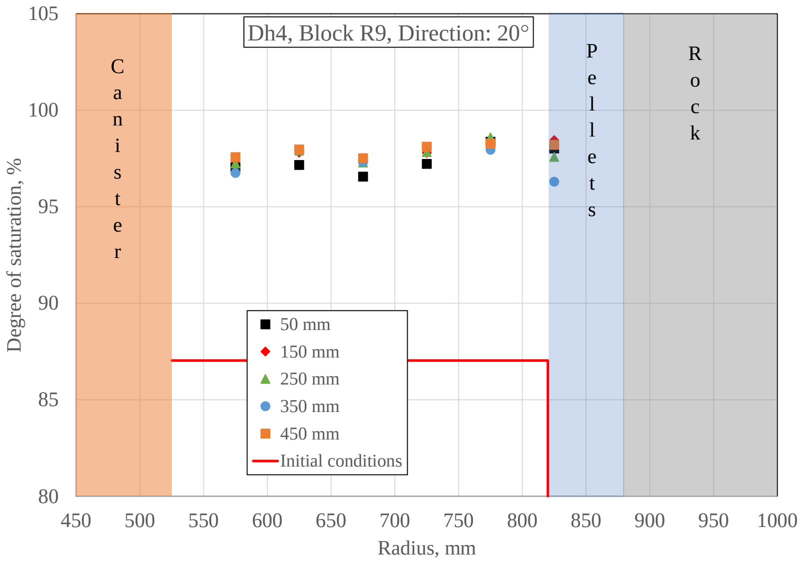


Appendix 1-5b Dh4, Block R9.

Water content, dry density, and degree of saturation at five depths in direction 20°.

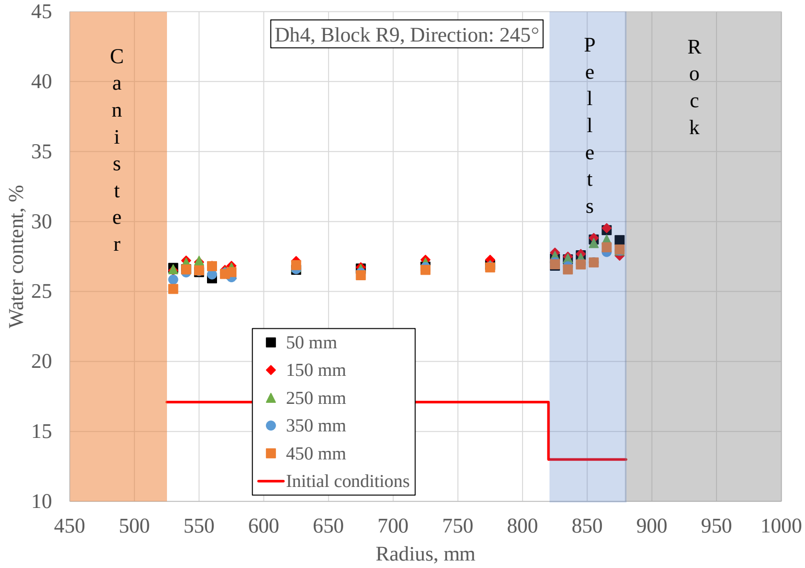


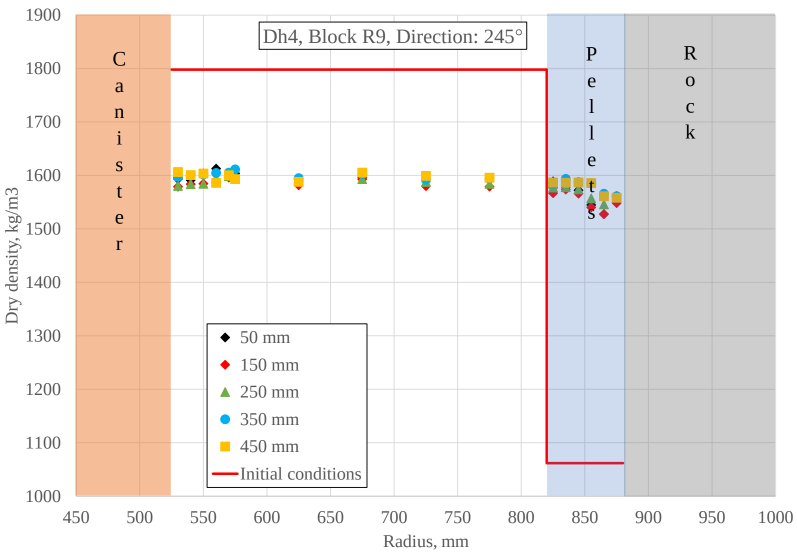


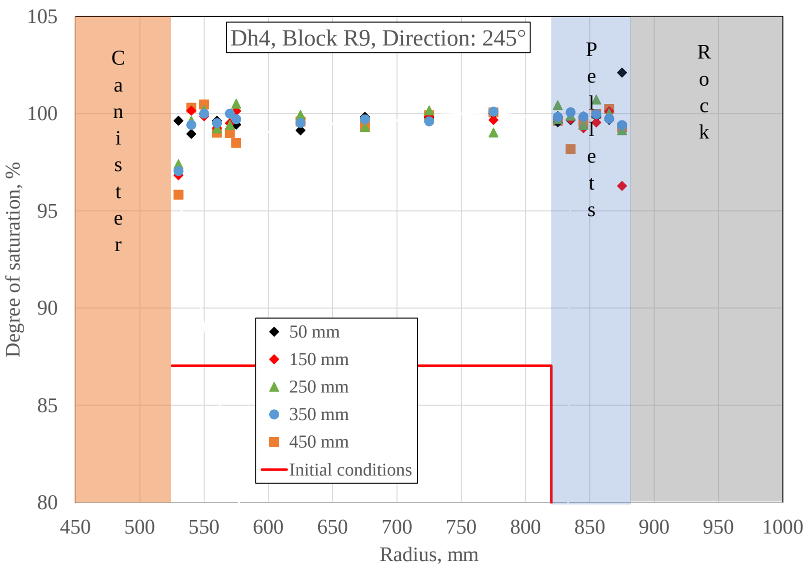


Appendix 1-5c Dh4, Block R9.

Water content, dry density, and degree of saturation at five depths in direction 245°.

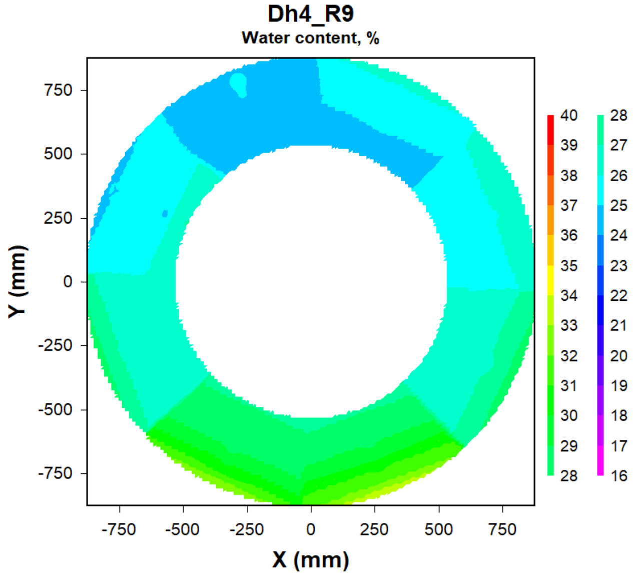


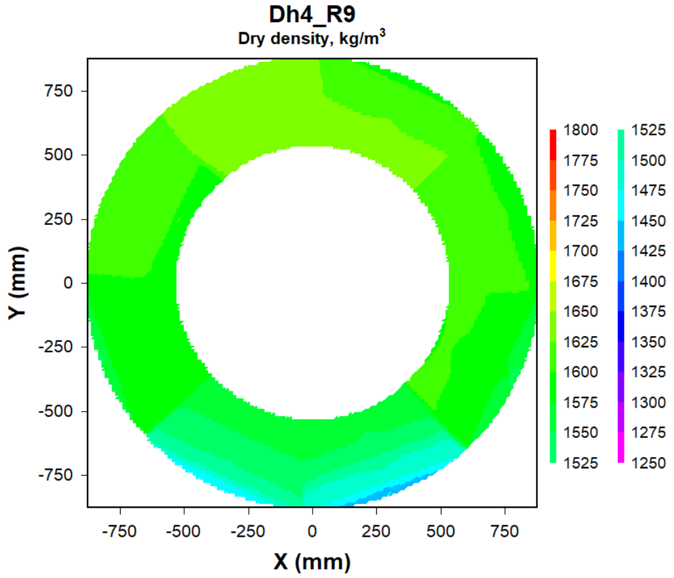


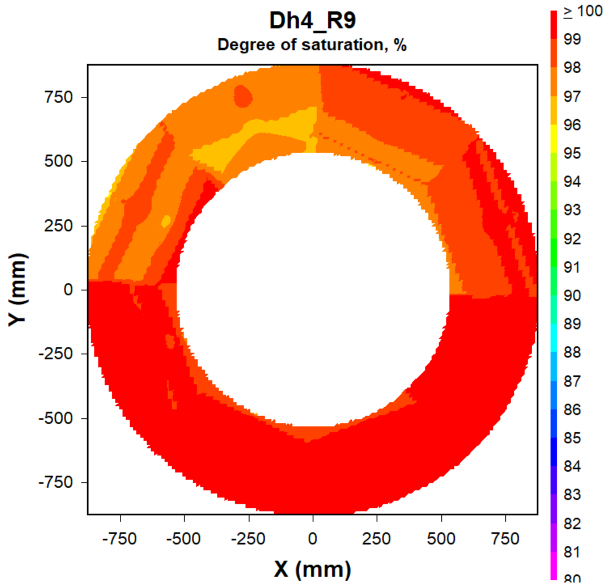


Appendix 1-5d Dh4, Block R9.

Water content, dry density, and degree of saturation distribution.

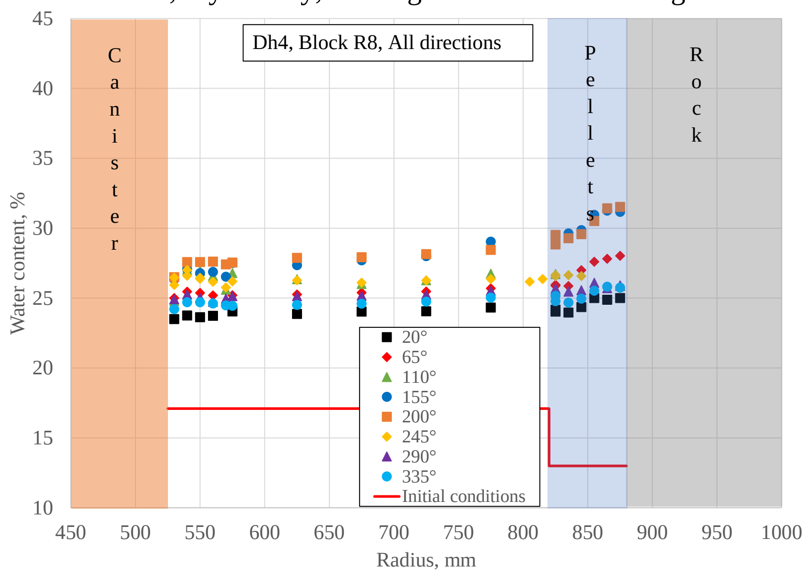


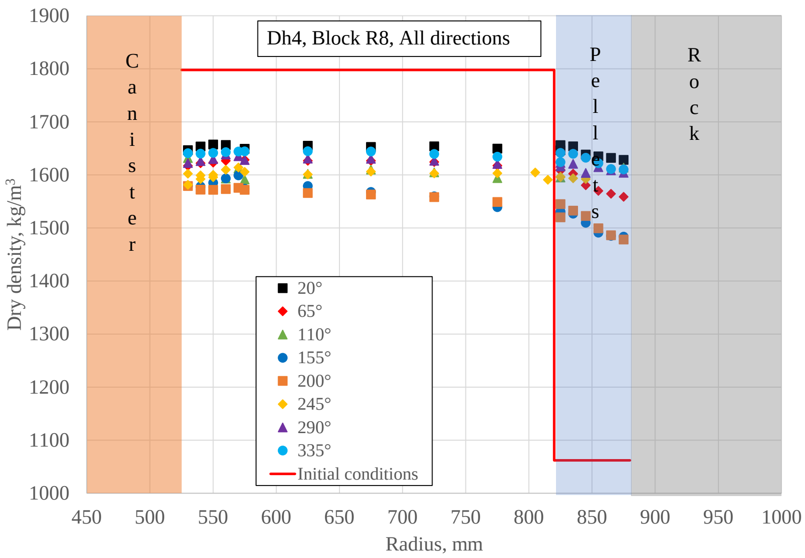


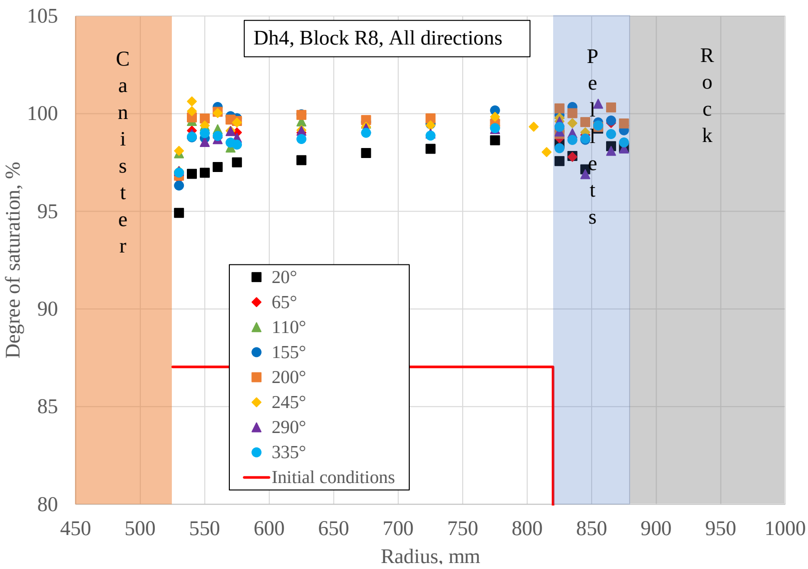


Appendix 1-6a Dh4, Block R8.

Water content, dry density, and degree of saturation in eight directions.

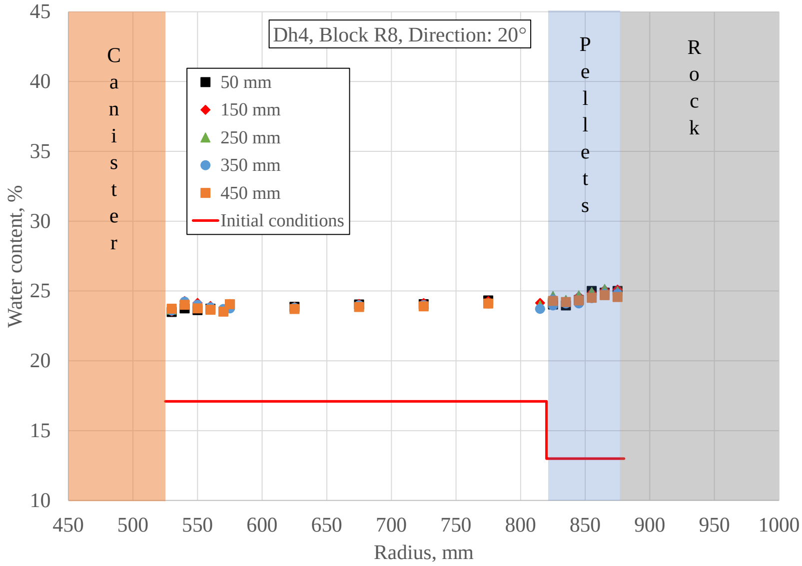


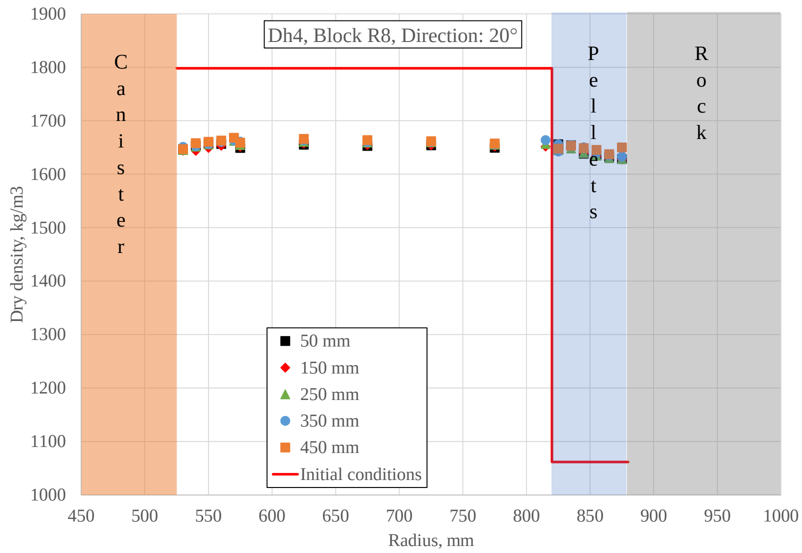


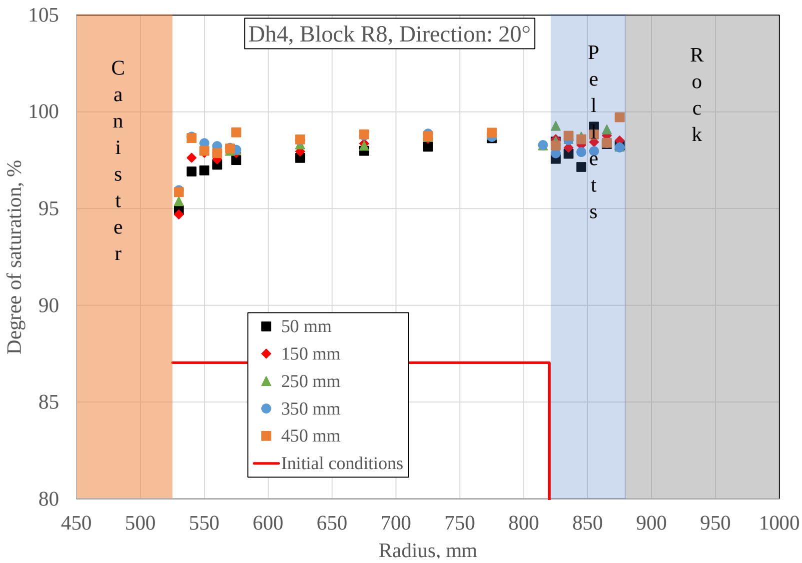


Appendix 1-6b Dh4, Block R8.

Water content, dry density, and degree of saturation at five depths in direction 20°.

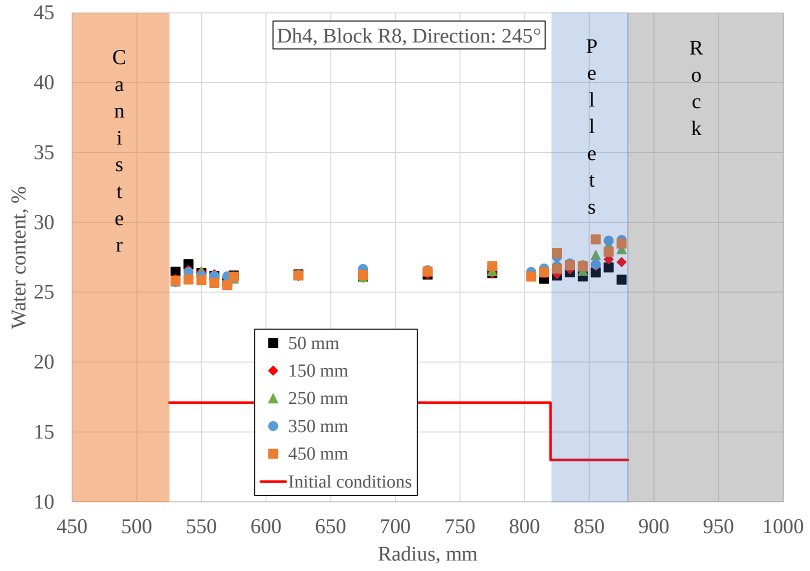


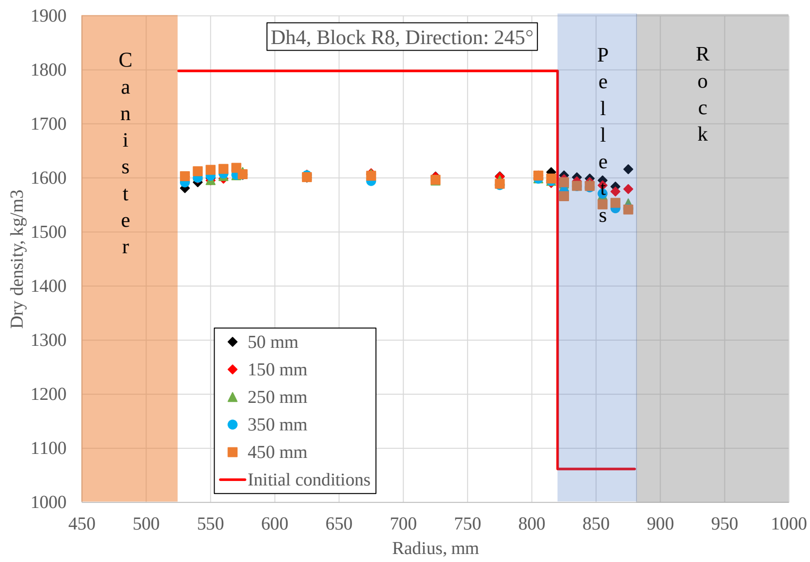


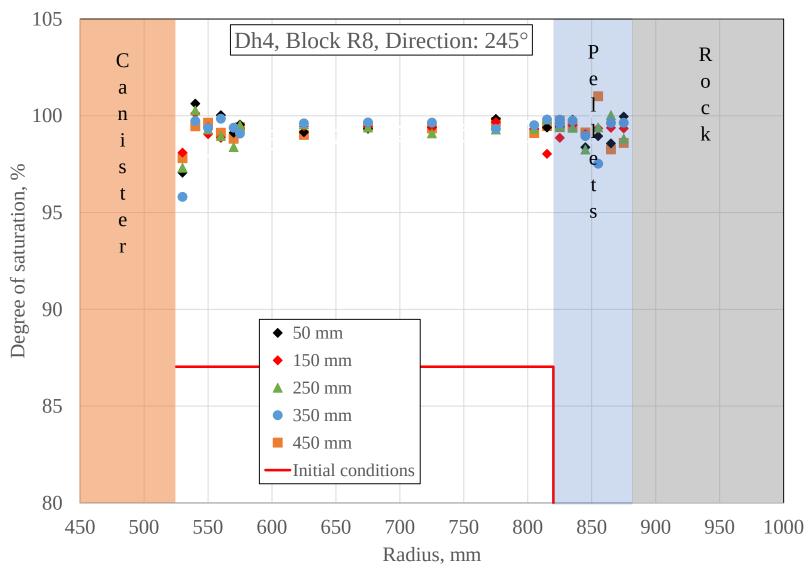


Appendix 1-6c Dh4, Block R8.

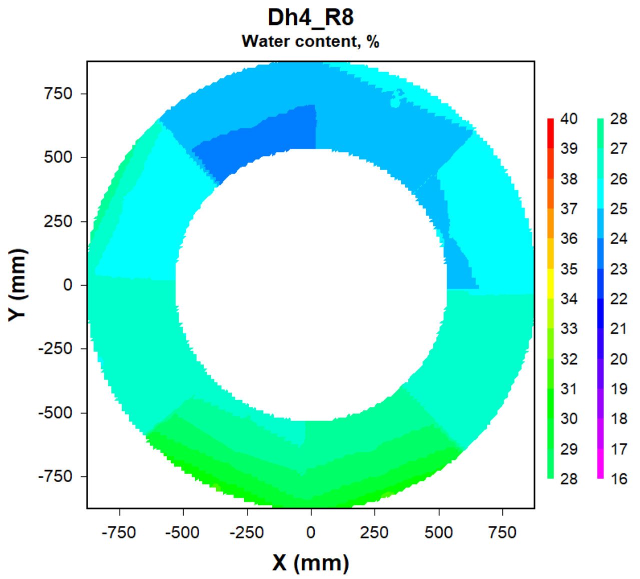
Water content, dry density, and degree of saturation at five depths in direction 245°.

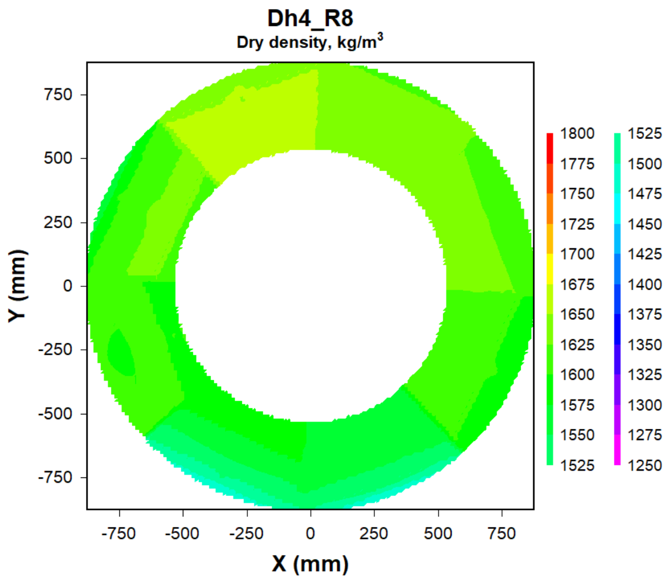


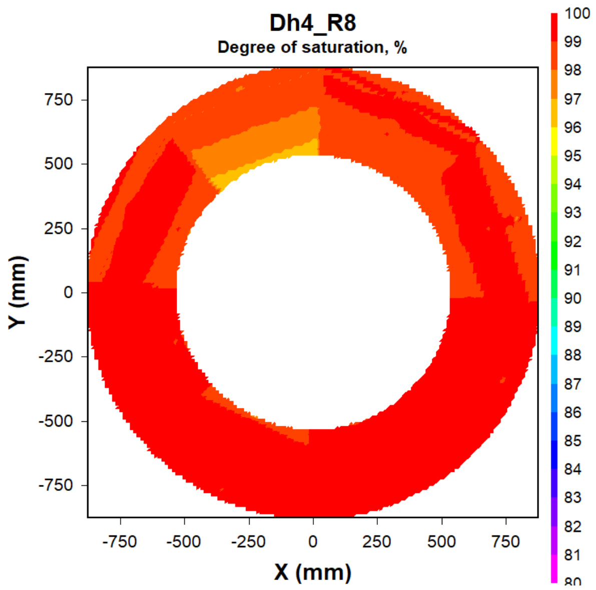




Appendix 1-6d Dh4, Block R8.
Water content, dry density, and degree of saturation distribution.

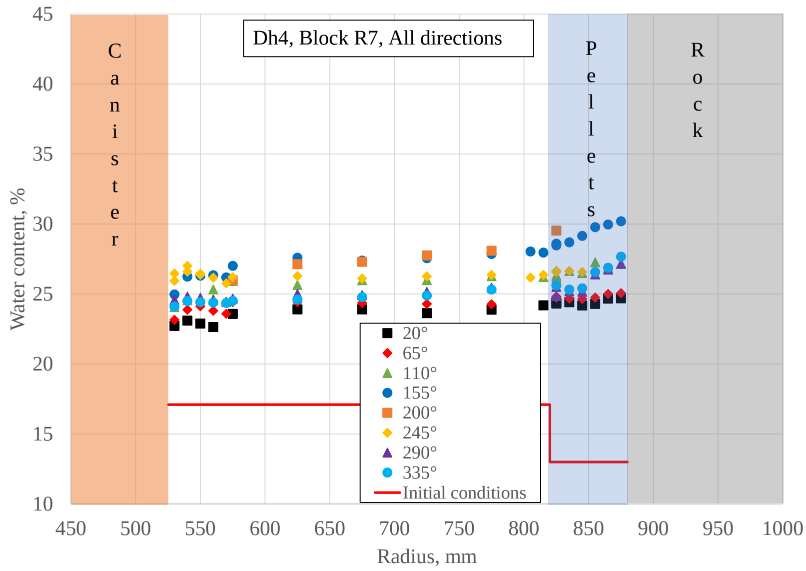


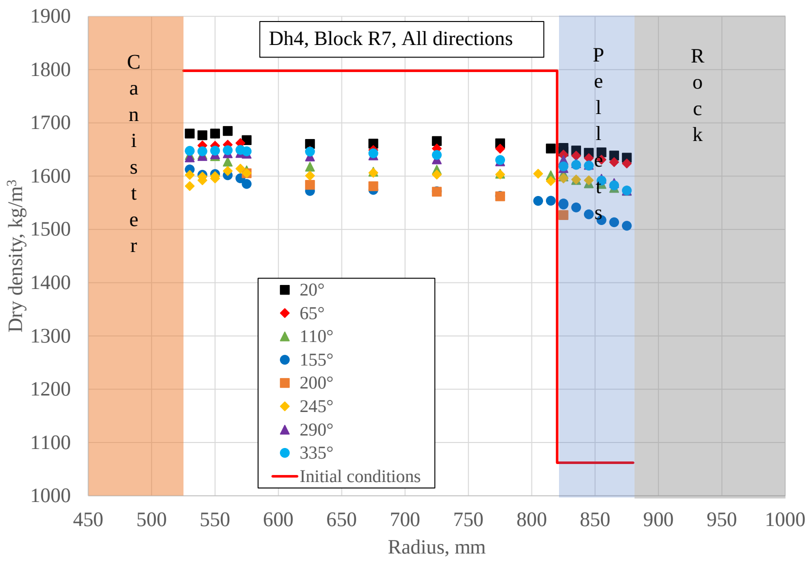


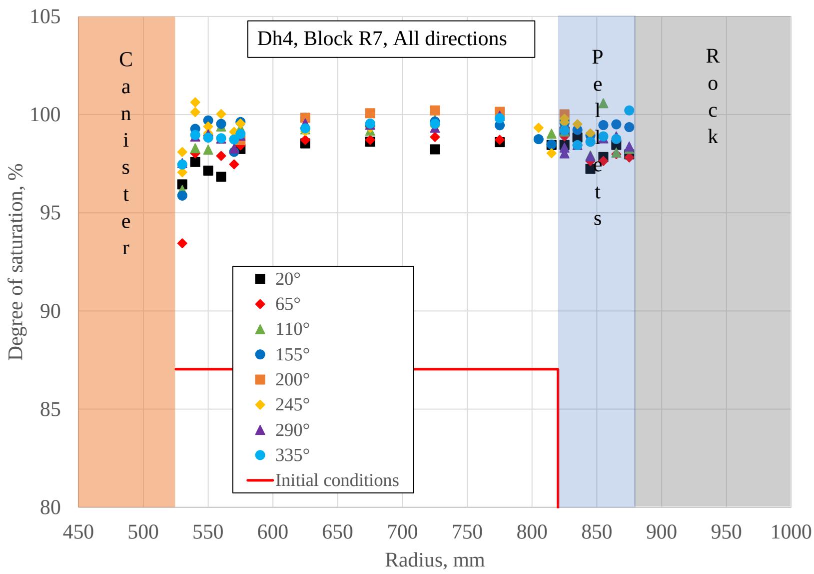


Appendix 1-7a Dh4, Block R7.

Water content, dry density, and degree of saturation in eight directions.

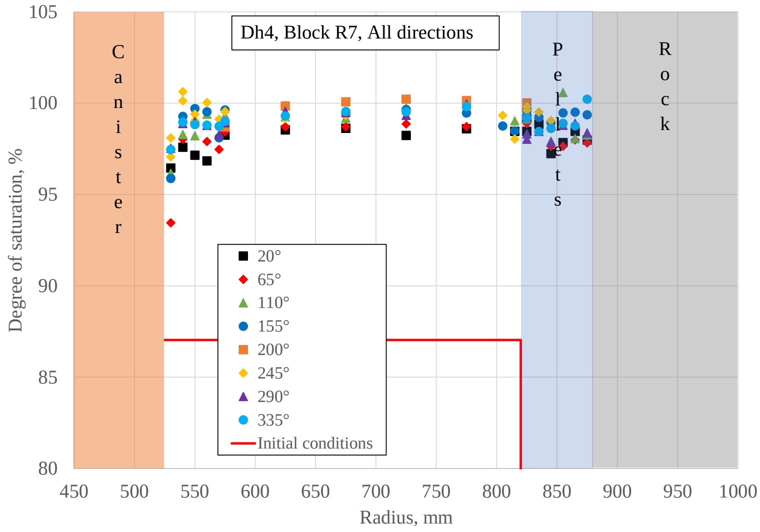


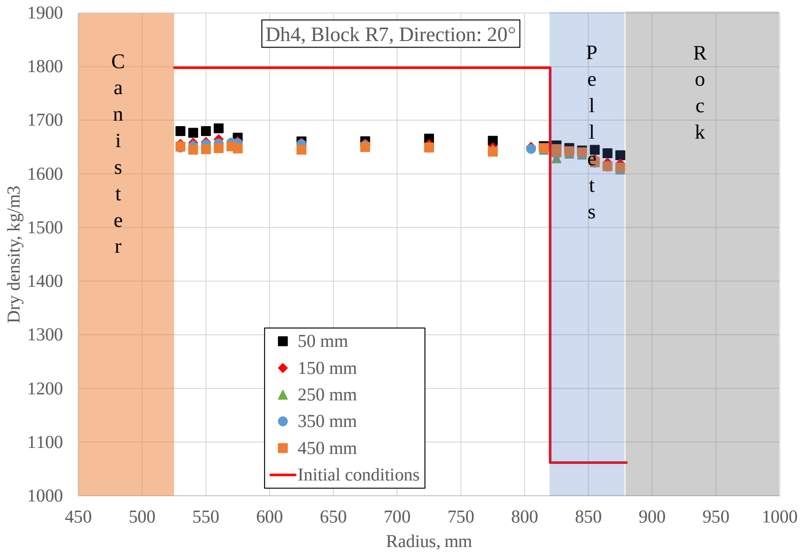


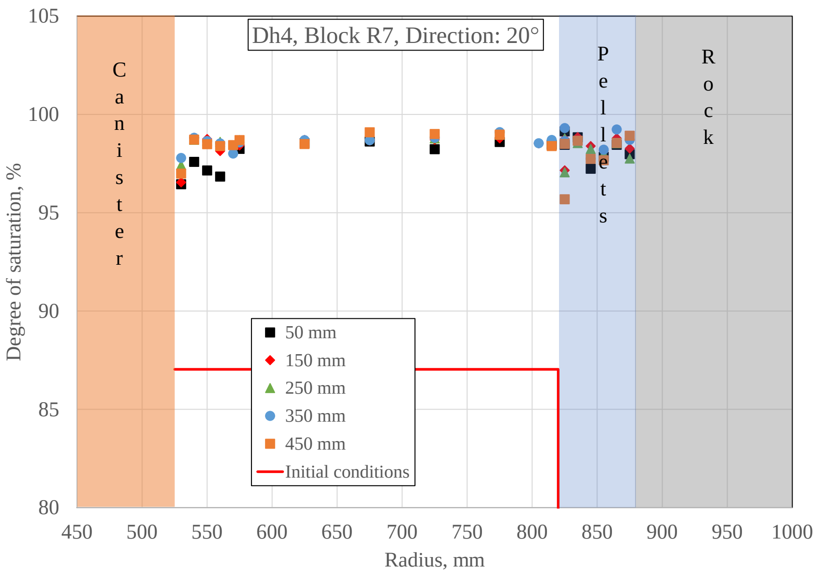


Appendix 1-7b Dh4, Block R7.

Water content, dry density, and degree of saturation at five depths in direction 20°.

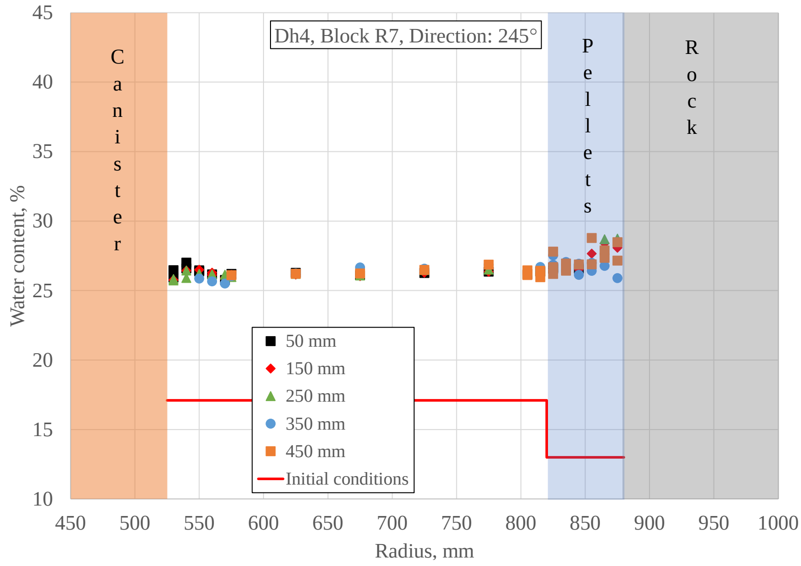


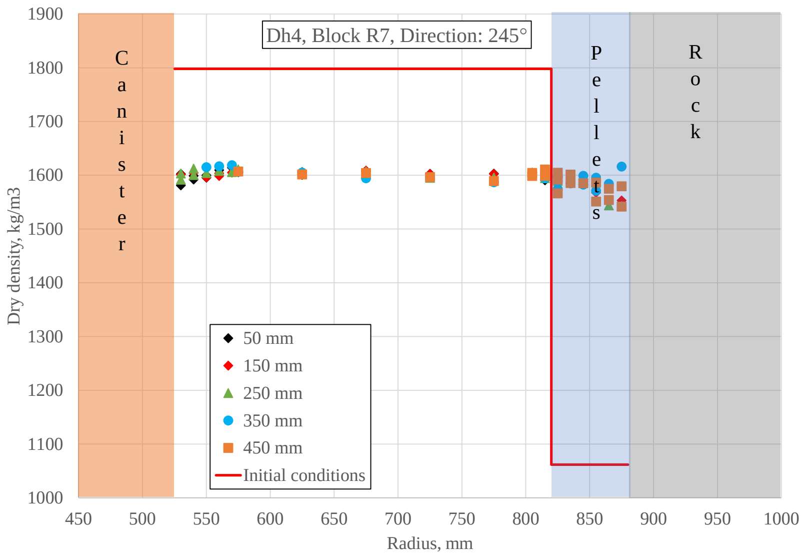


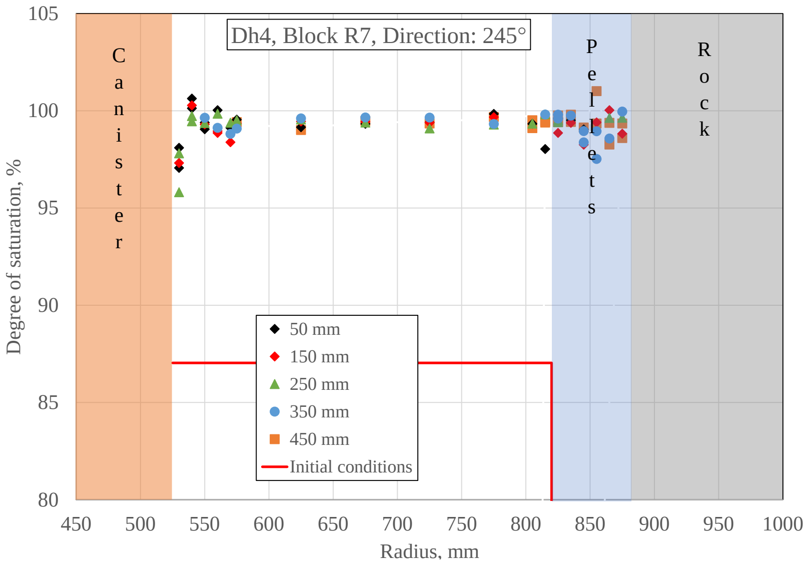


Appendix 1-7c Dh4, Block R7.

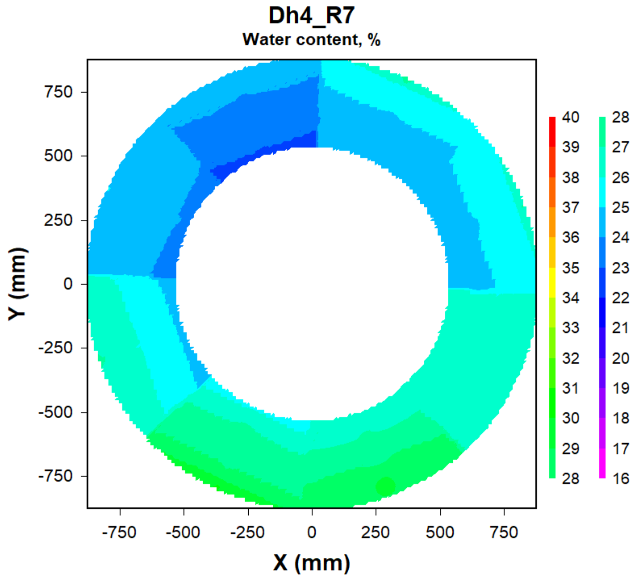
Water content, dry density, and degree of saturation at five depths in direction 245°.

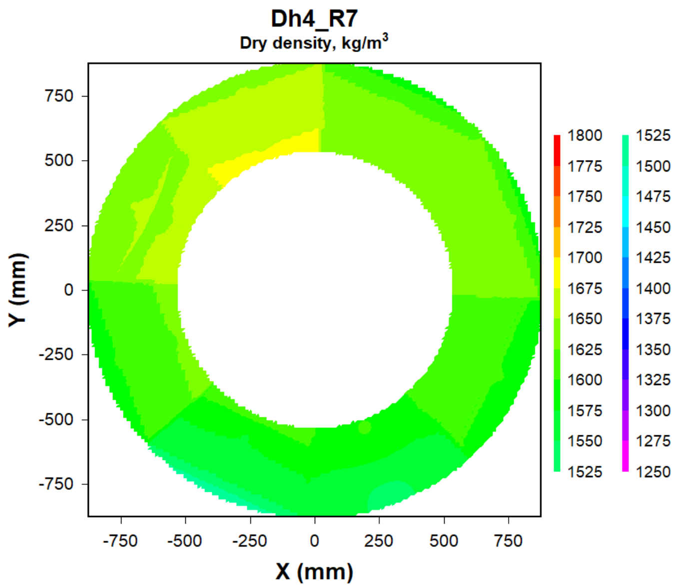


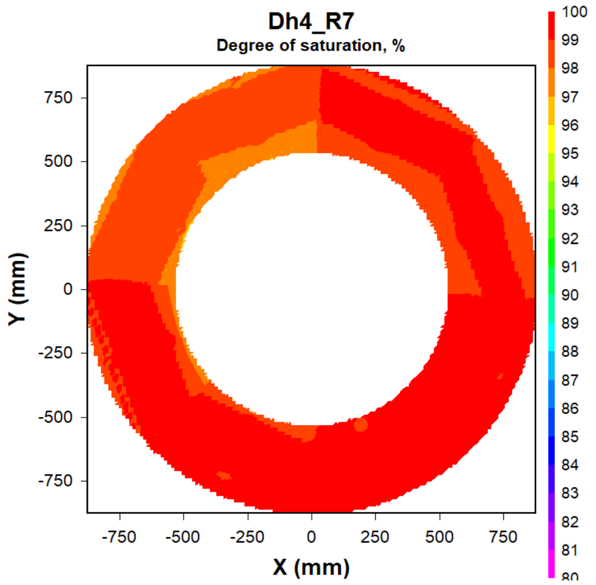




Appendix 1-7d Dh4, Block R7.
Water content, dry density, and degree of saturation distribution.

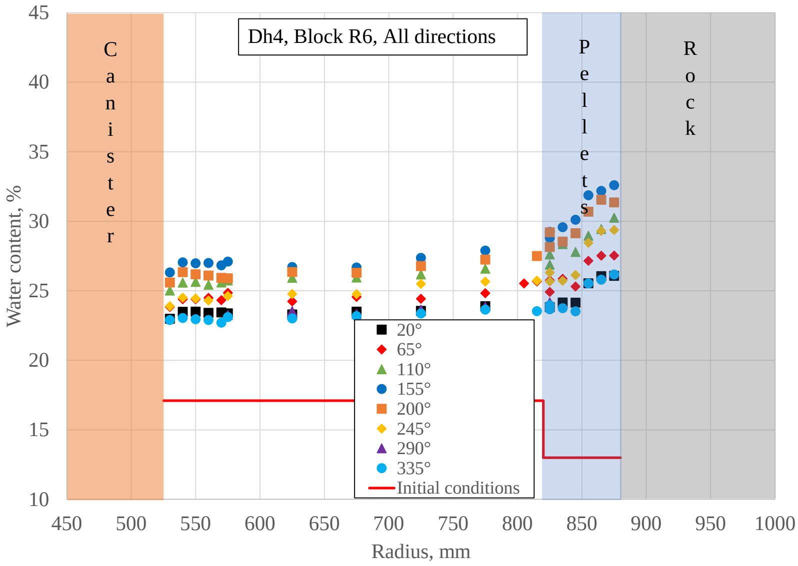


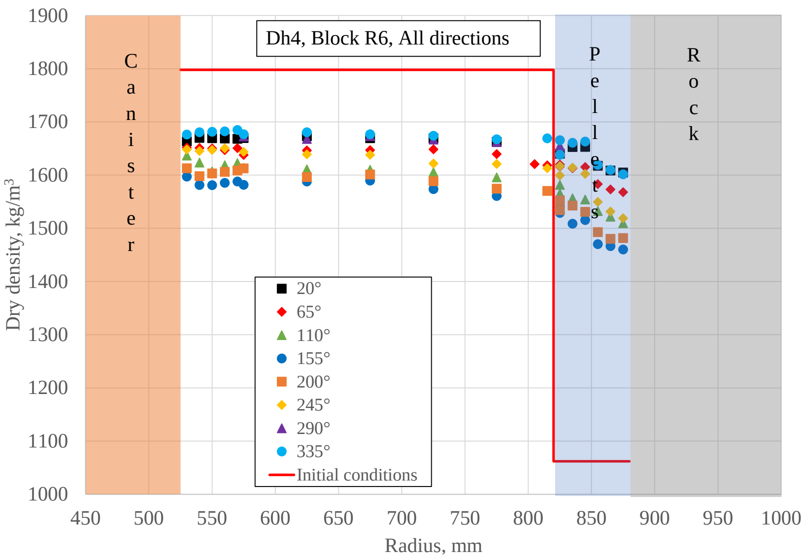


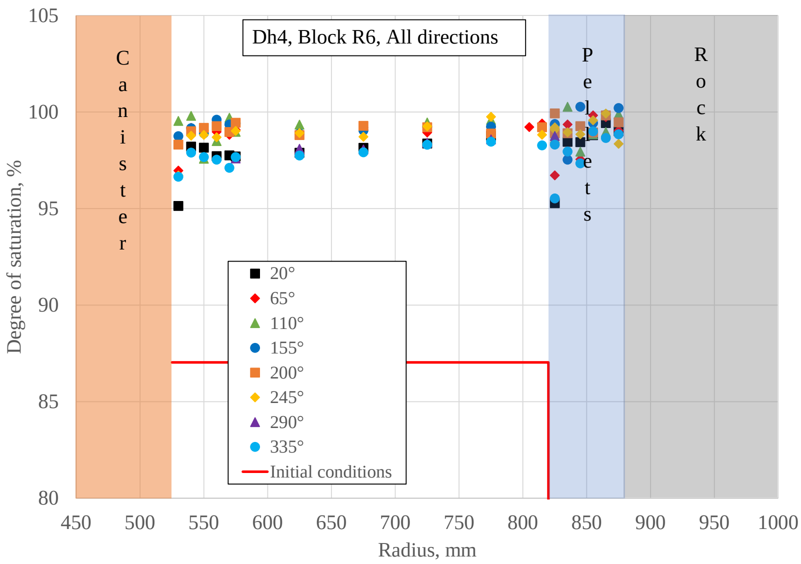


Appendix 1-8a Dh4, Block R6.

Water content, dry density, and degree of saturation in eight directions.

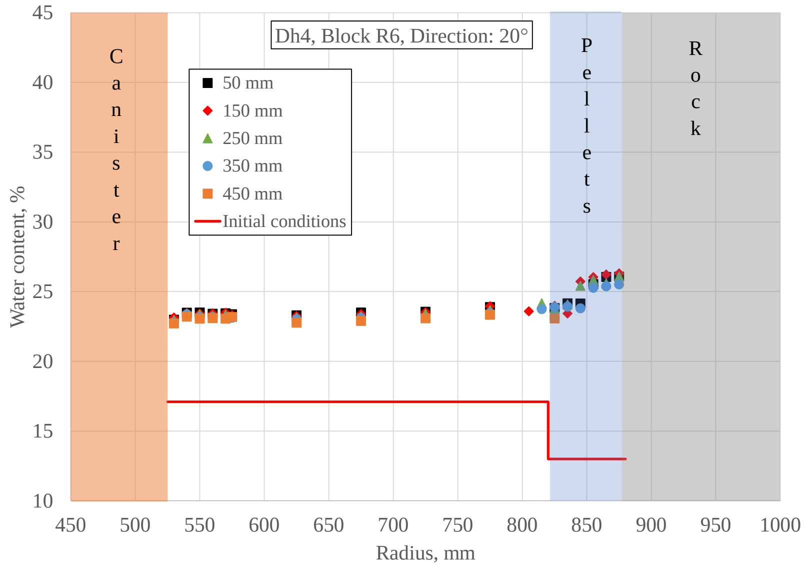


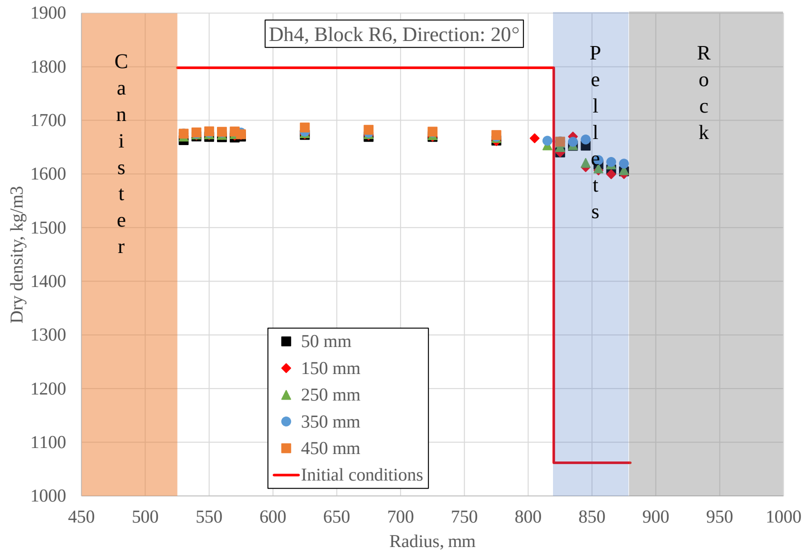


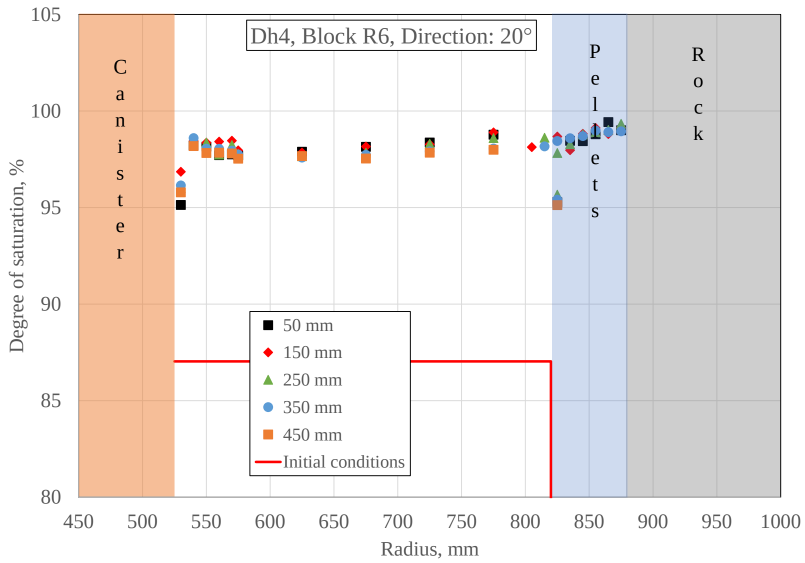


Appendix 1-8b Dh4, Block R6.

Water content, dry density, and degree of saturation at five depths in direction 20°.

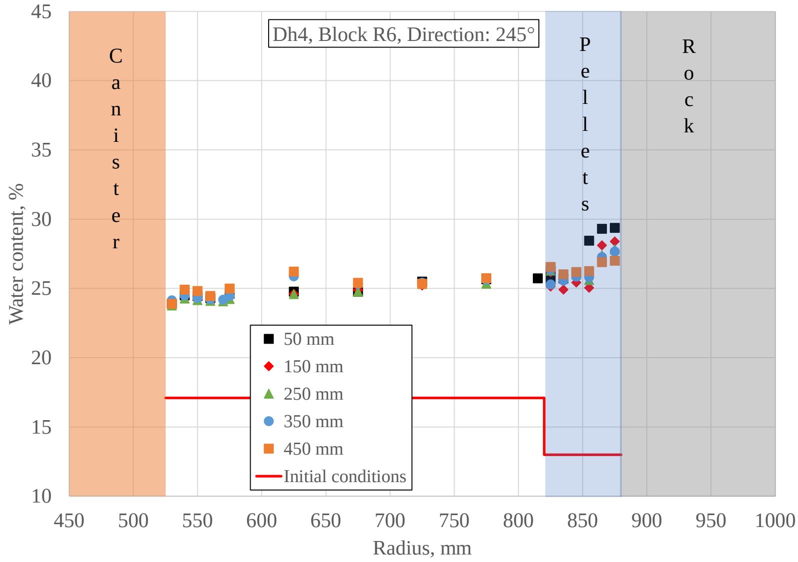


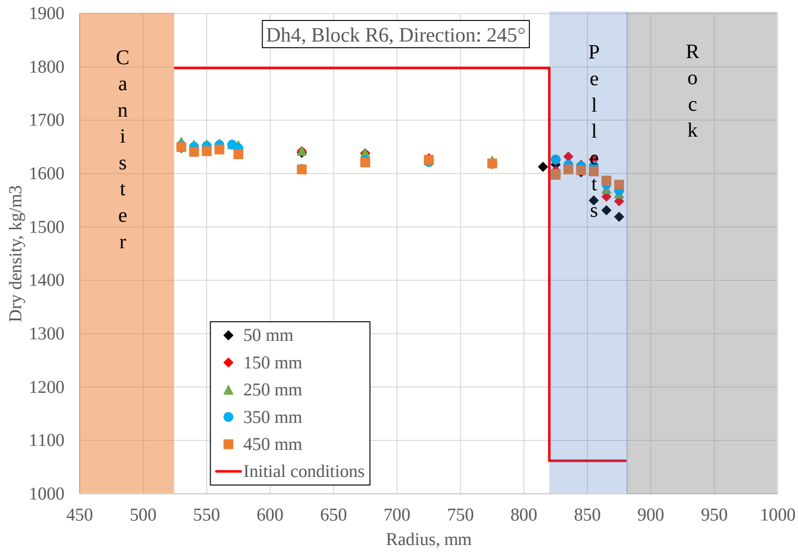


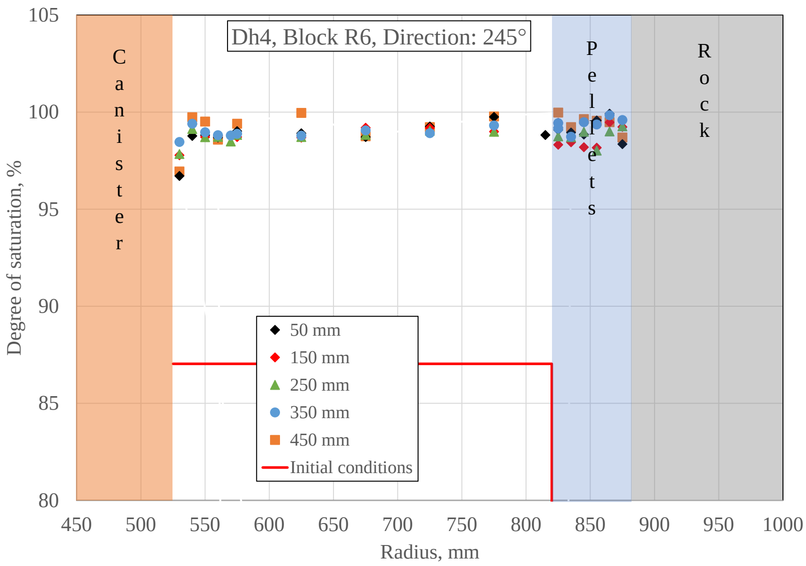


Appendix 1-8c Dh4, Block R6.

Water content, dry density, and degree of saturation at five depths in direction 245°.

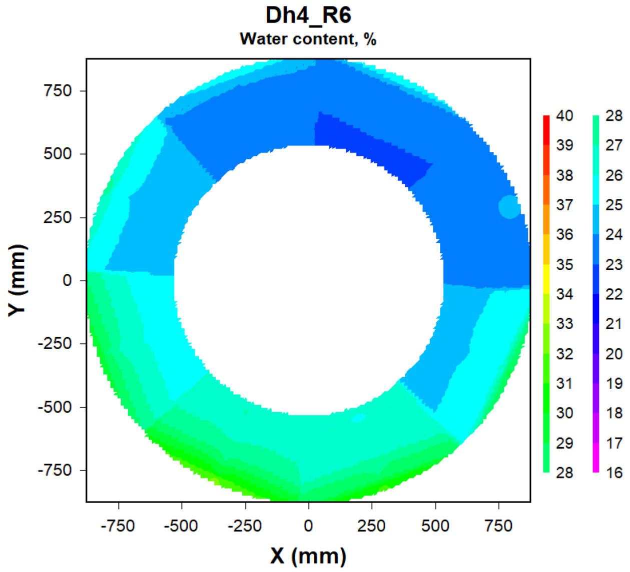


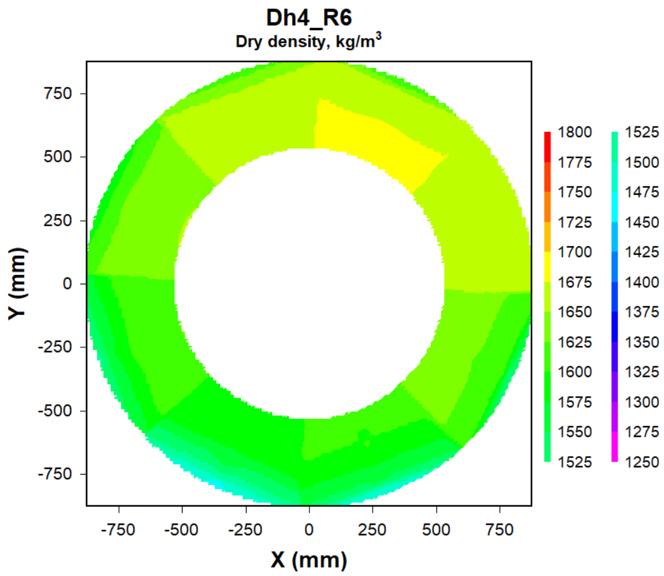


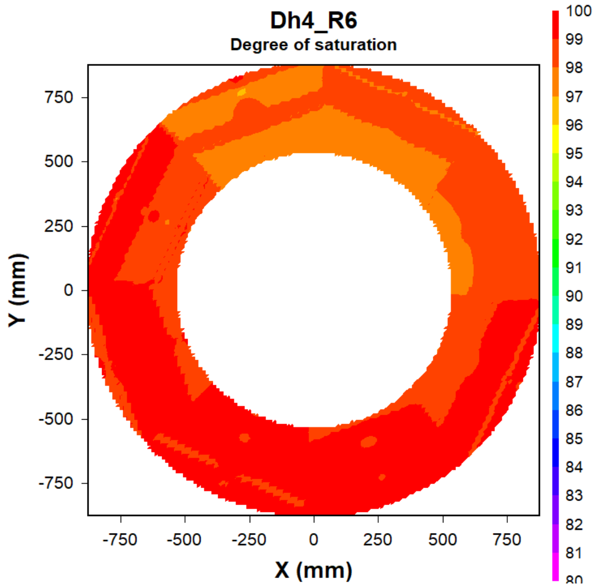


Appendix 1-8d Dh4, Block R6.

Water content, dry density, and degree of saturation distribution.

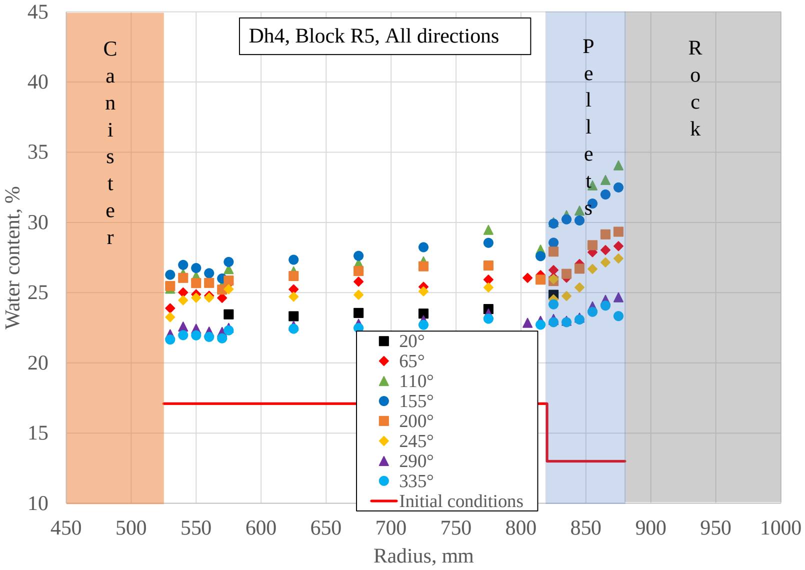


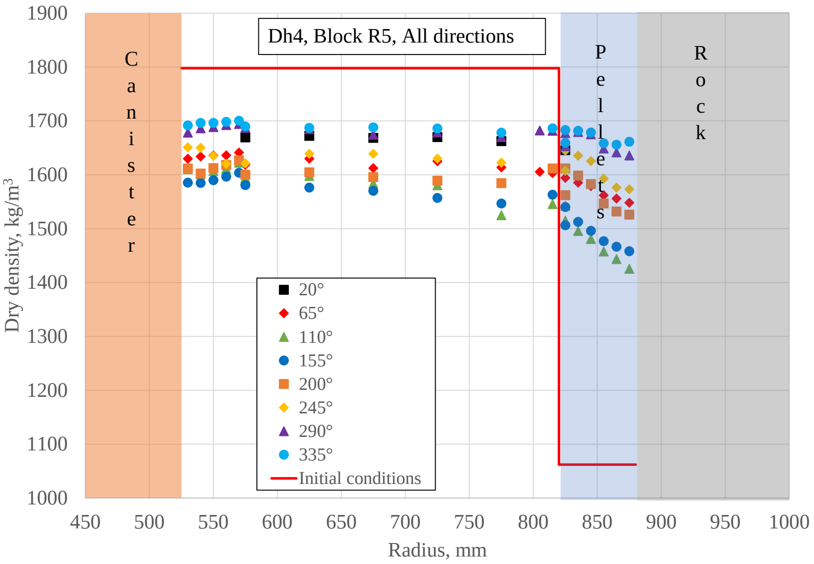


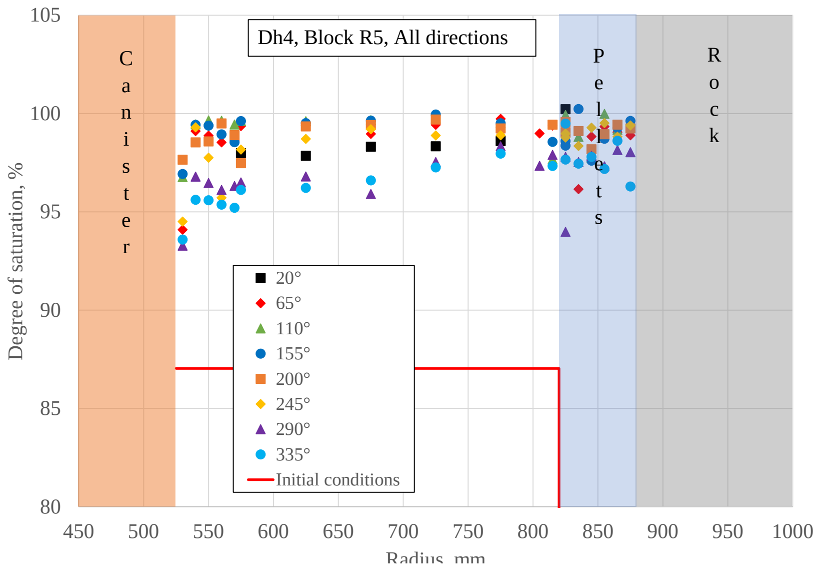


Appendix 1-9a Dh4, Block R5.

Water content, dry density, and degree of saturation in eight directions.

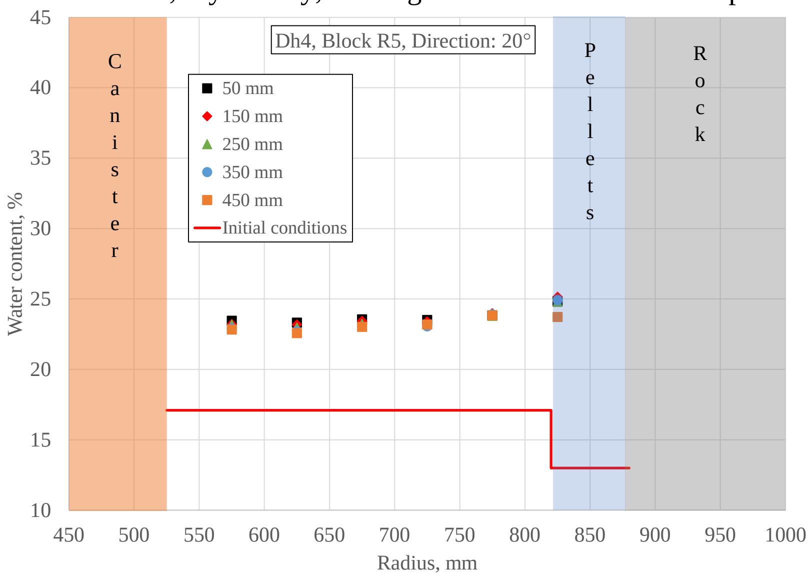


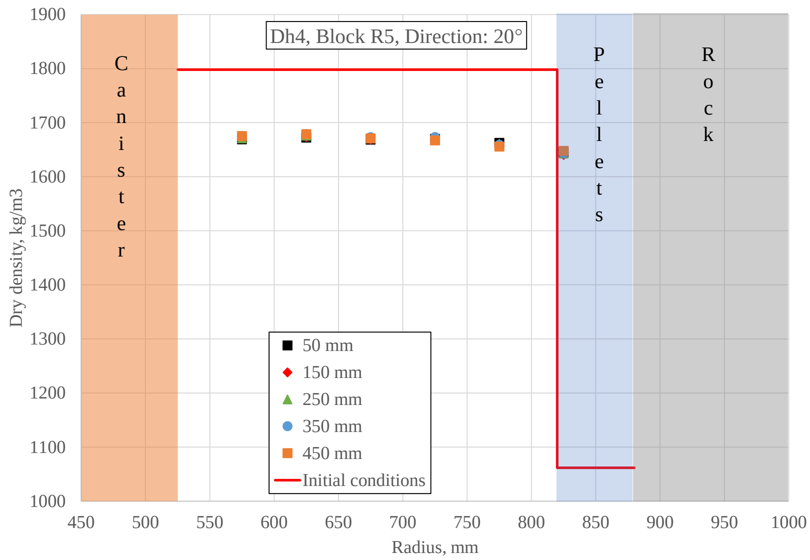


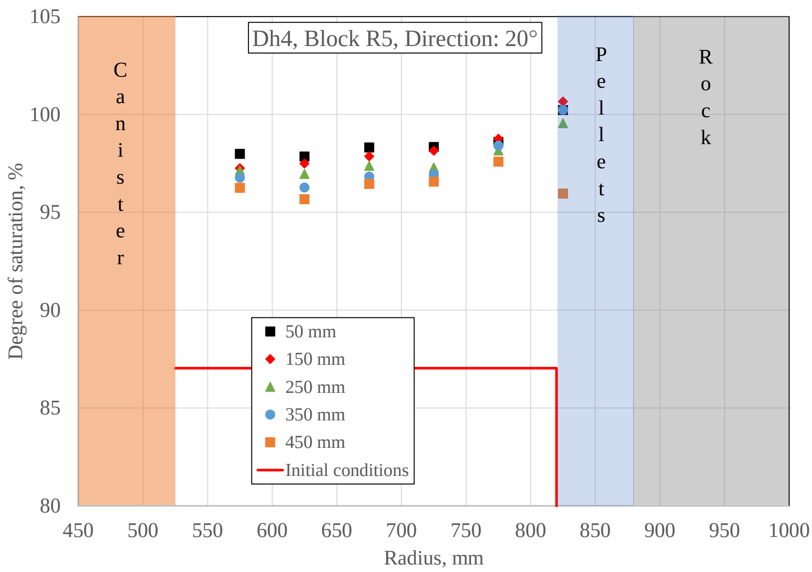


Appendix 1-9b Dh4, Block R5.

Water content, dry density, and degree of saturation at five depths in direction 20°.

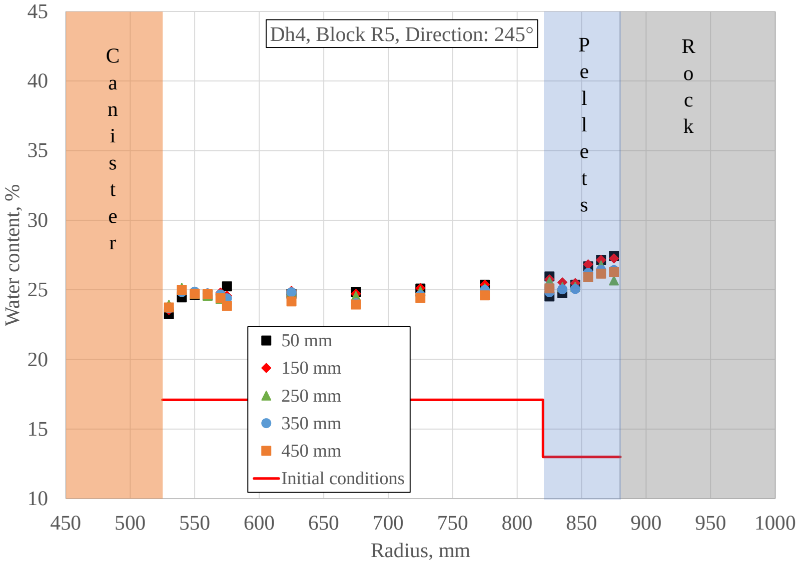


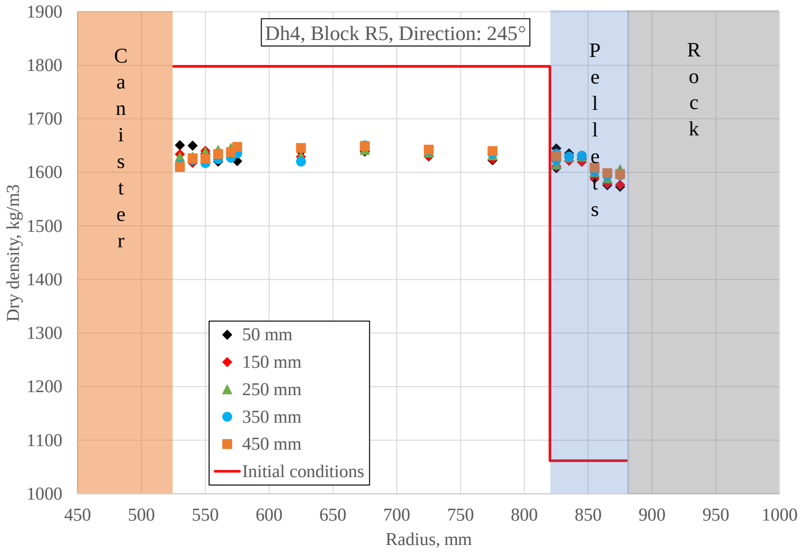


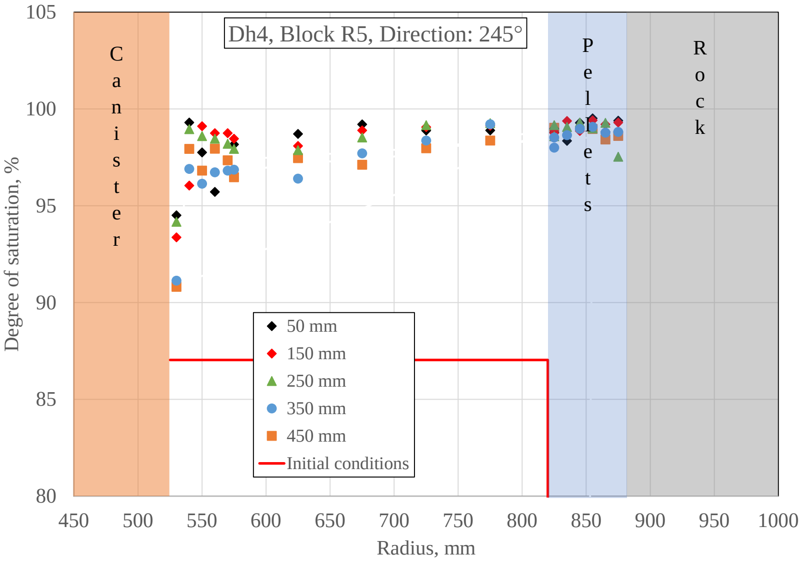


Appendix 1-9c Dh4, Block R5.

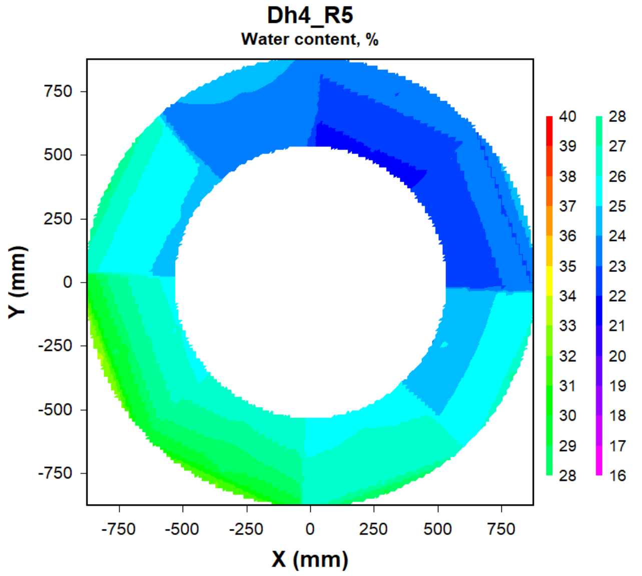
Water content, dry density, and degree of saturation at five depths in direction 245°.

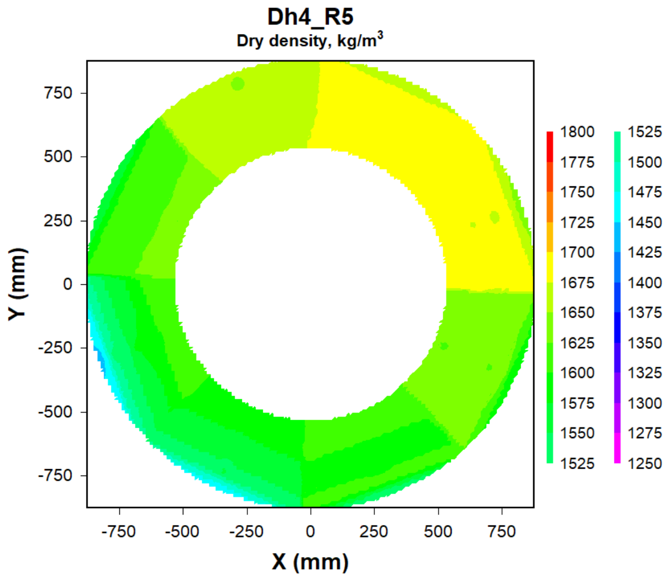


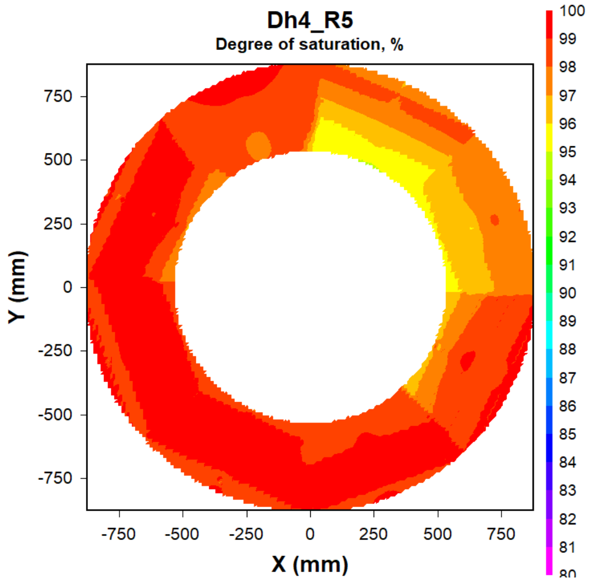




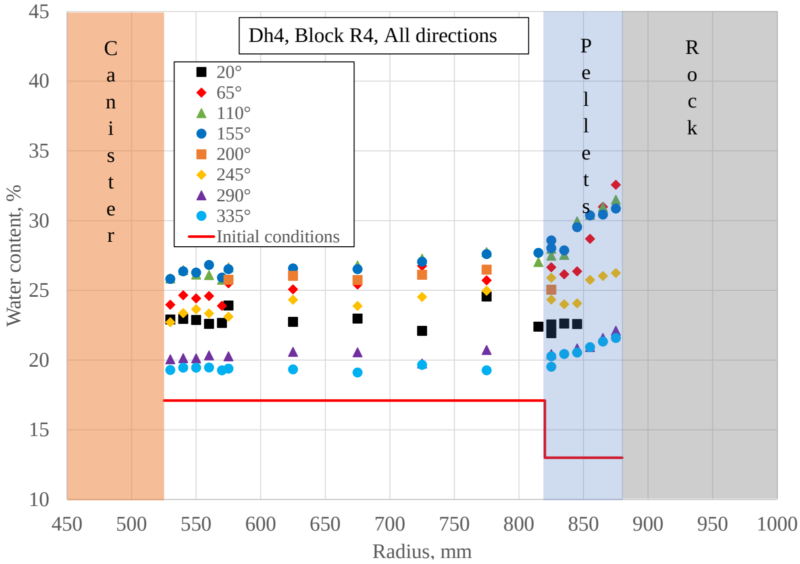
Appendix 1-9d Dh4, Block R5.
Water content, dry density, and degree of saturation distribution.

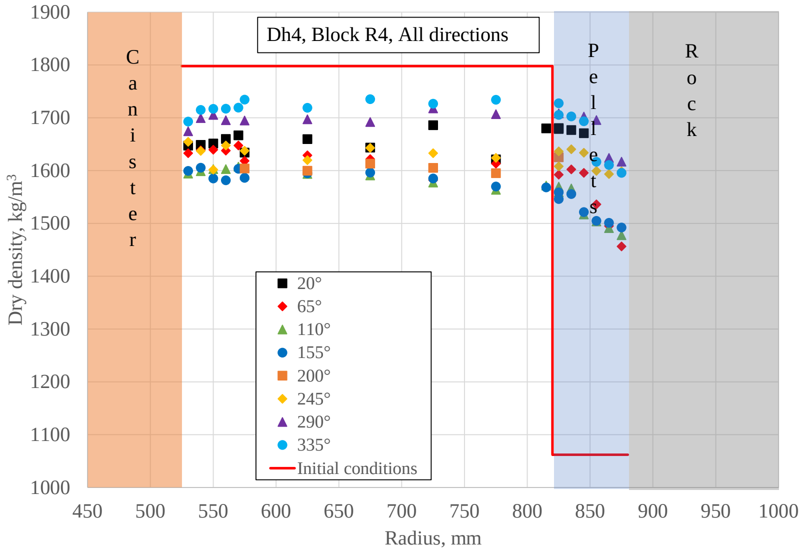


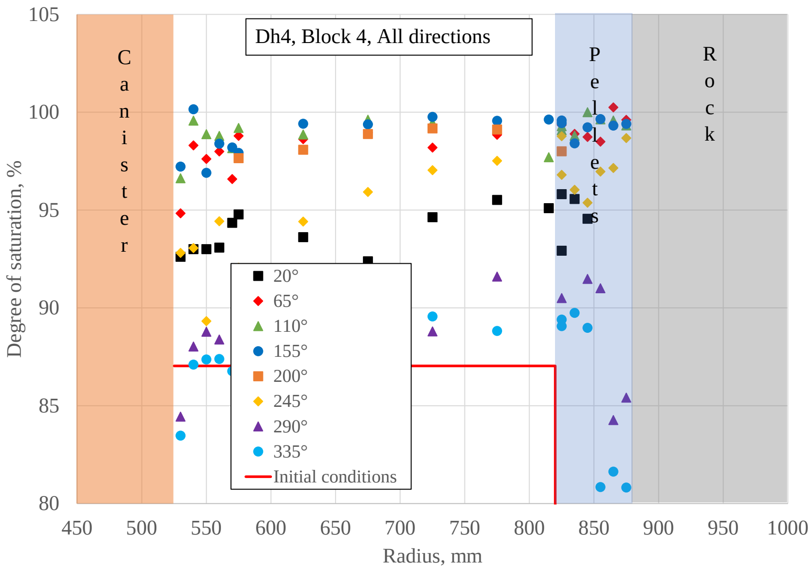




Appendix 1-10a Dh4, Block R4.
Water content, dry density, and degree of saturation in eight directions.

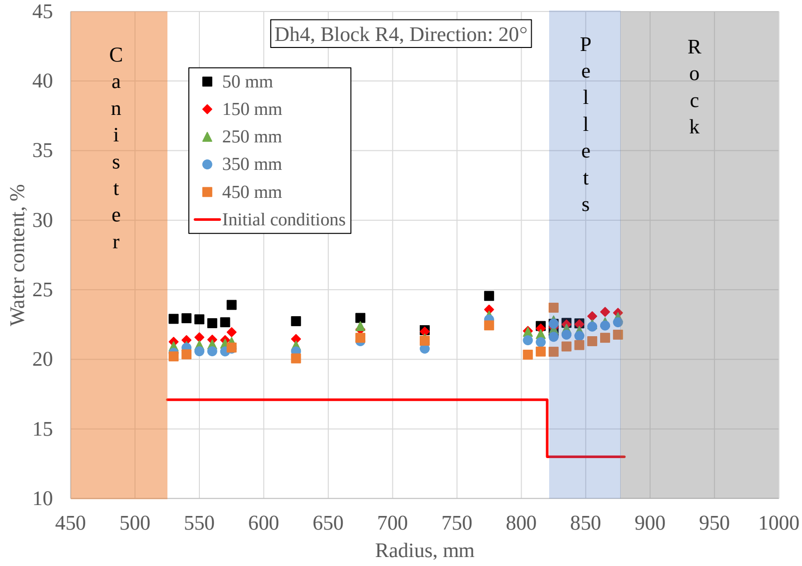


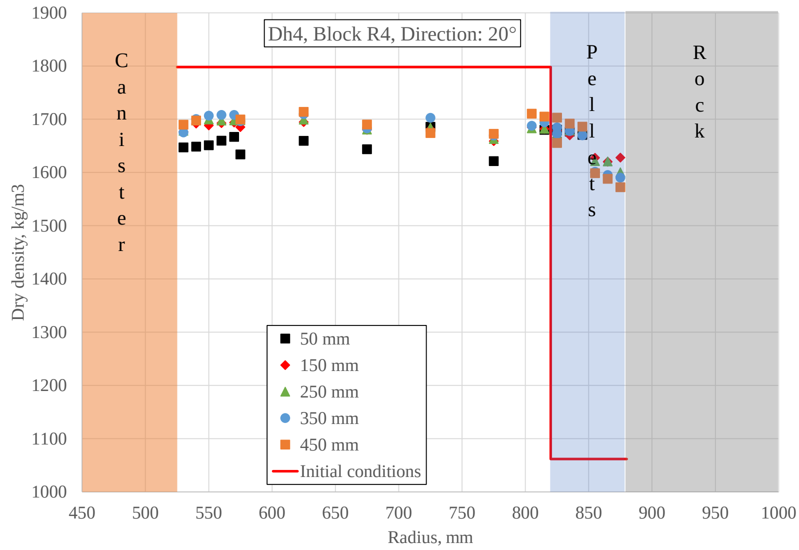


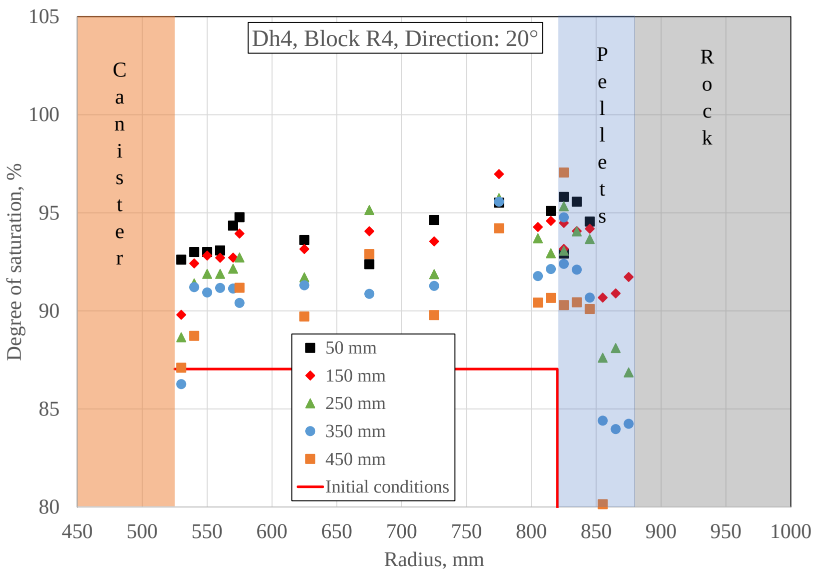


Appendix 1-10b Dh4, Block R4.

Water content, dry density, and degree of saturation at five depths in direction 20°.

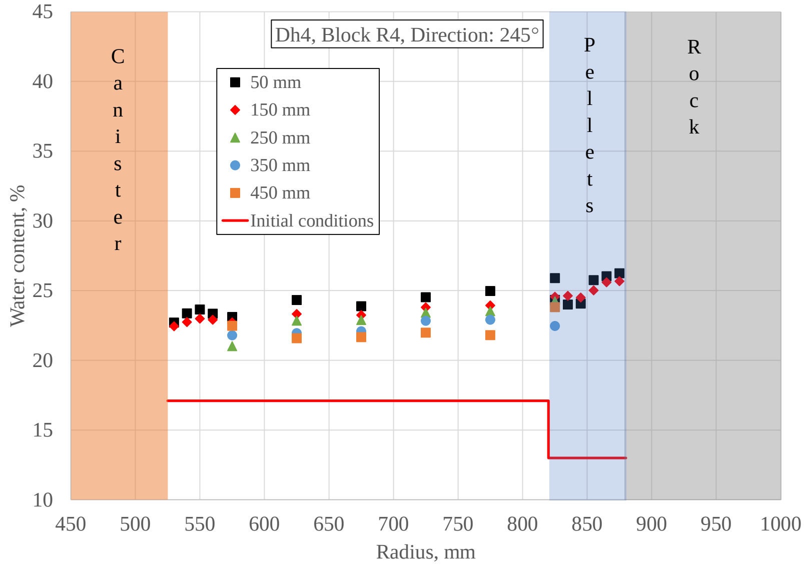


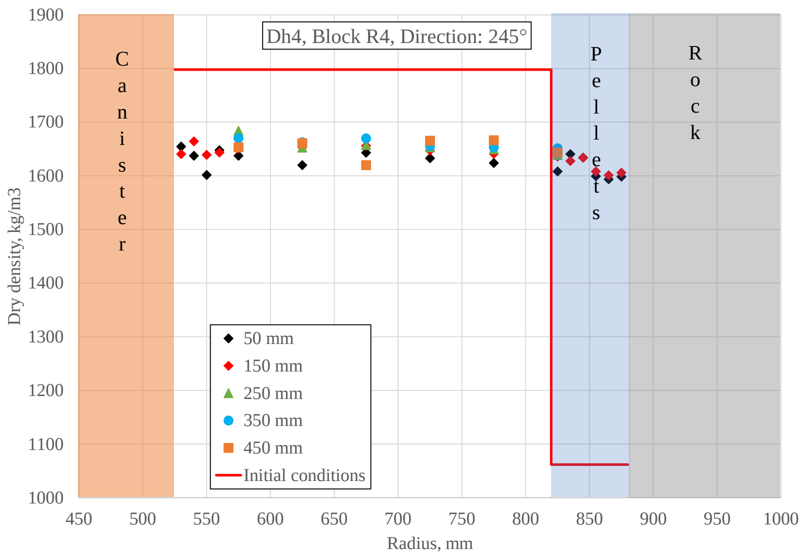


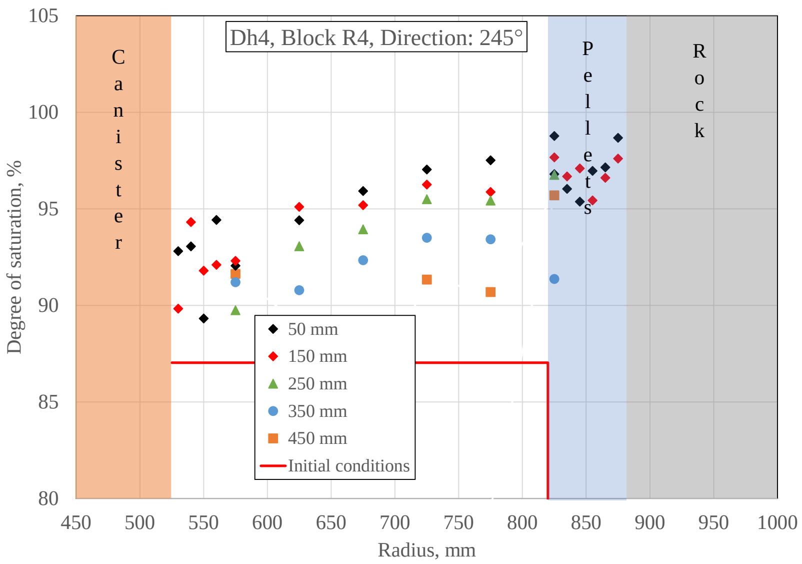


Appendix 1-10c Dh4, Block R4.

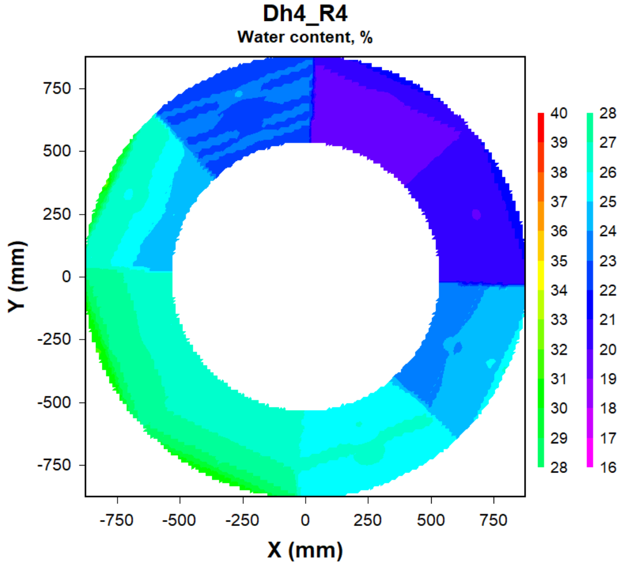
Water content, dry density, and degree of saturation at five depths in direction 245°.

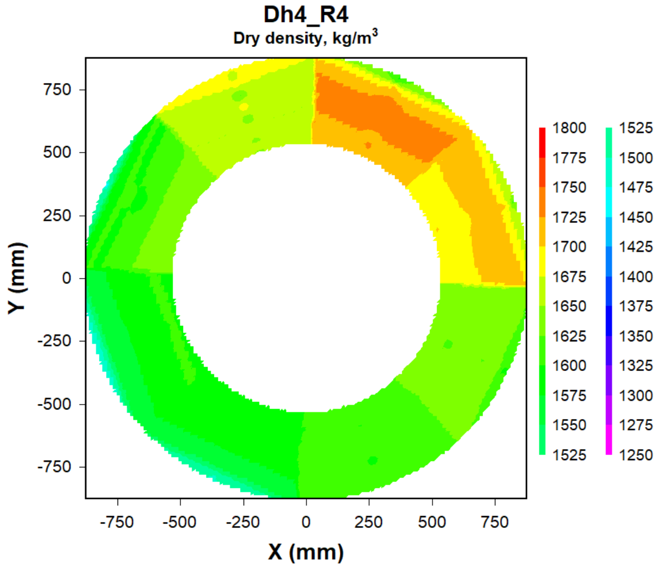


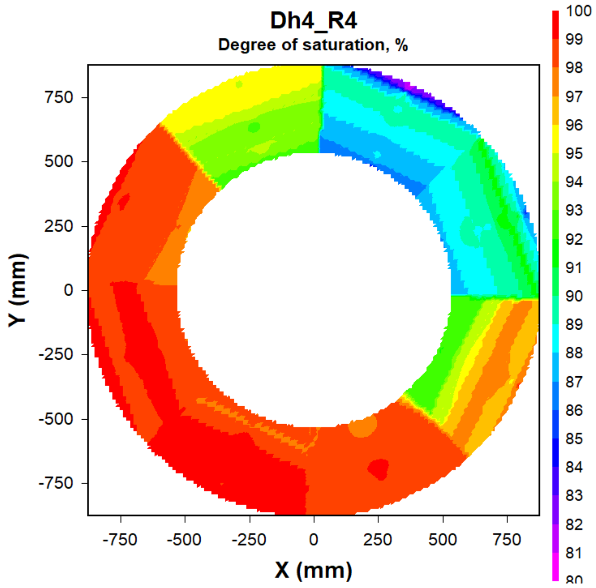




Appendix 1-10d Dh4, Block R4.
Water content, dry density, and degree of saturation distribution.

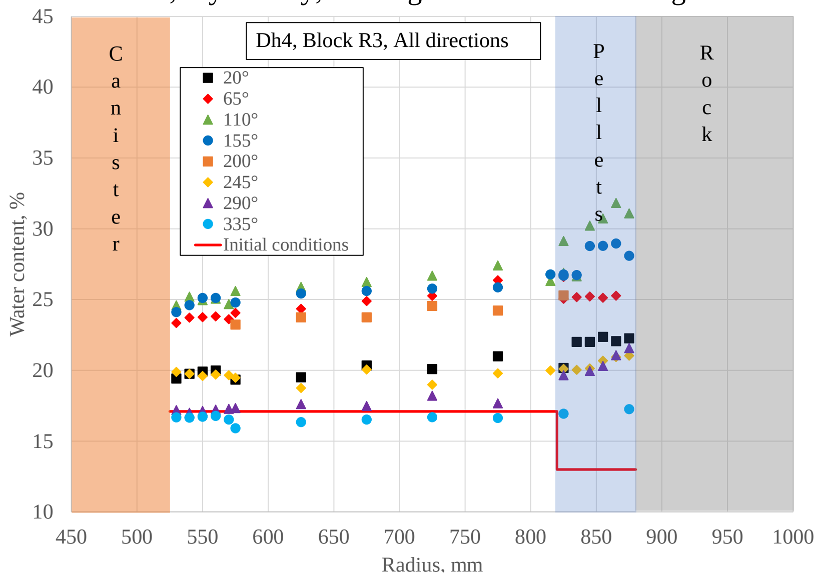


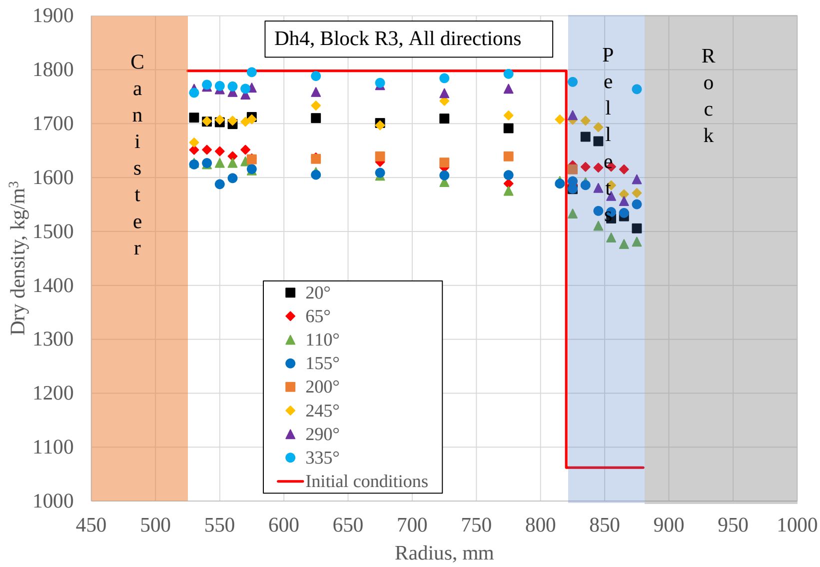


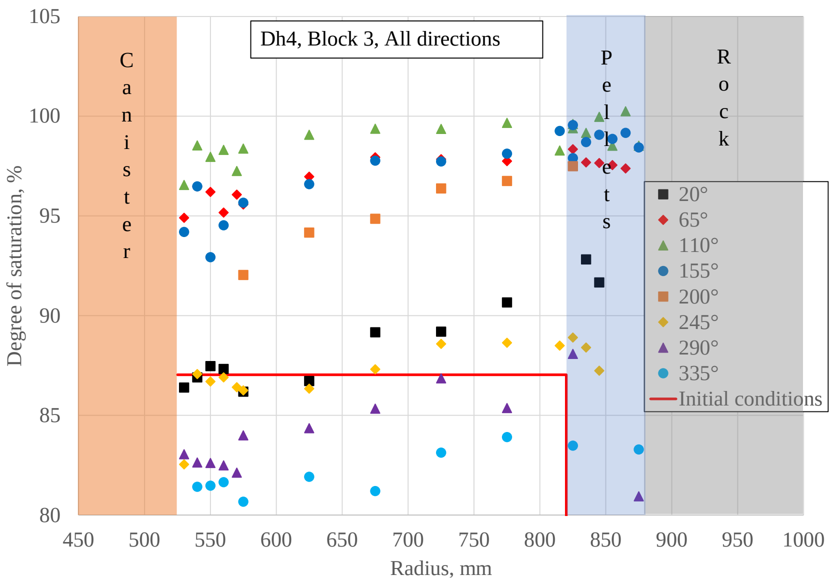


Appendix 1-11a Dh4, Block R3.

Water content, dry density, and degree of saturation in eight directions.

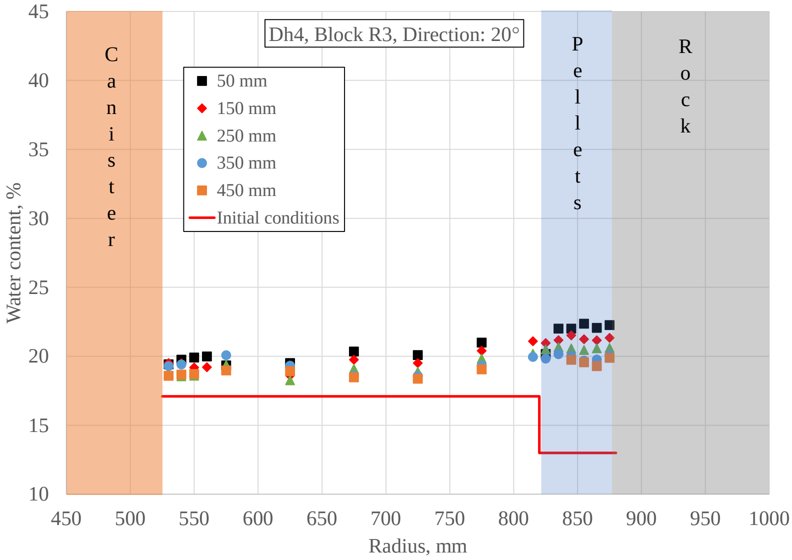


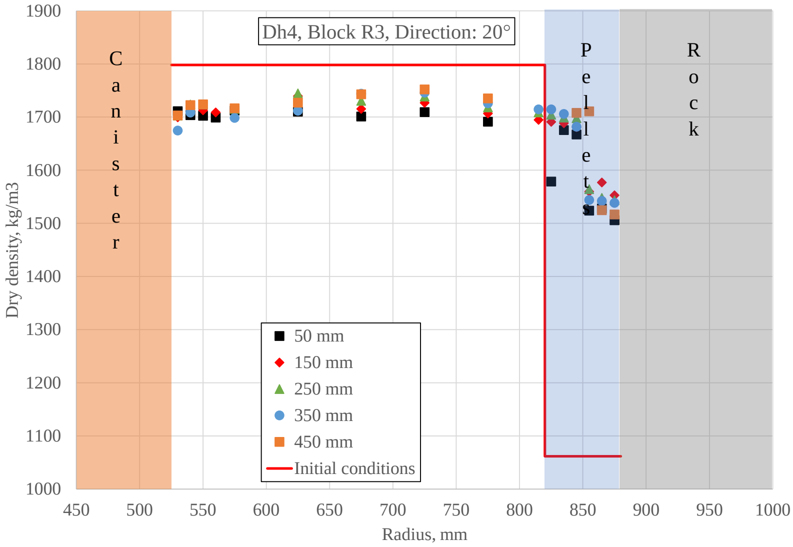


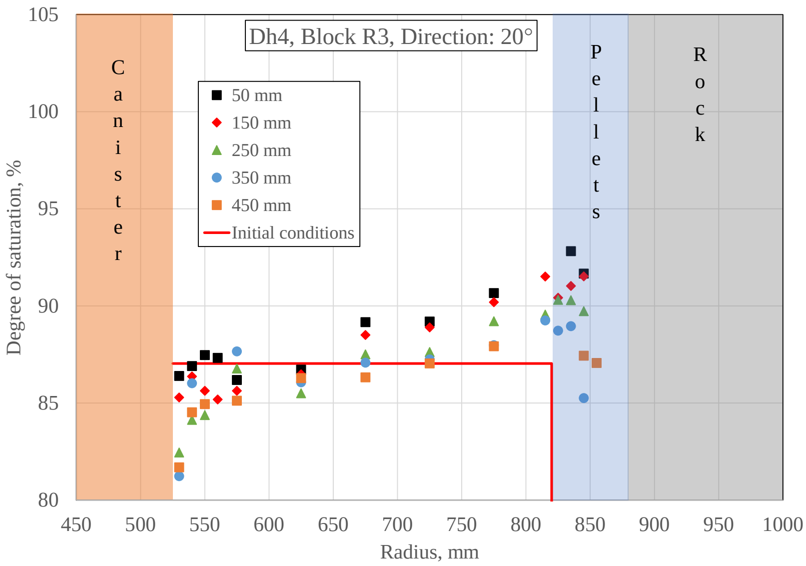


Appendix 1-11b Dh4, Block R3.

Water content, dry density, and degree of saturation at five depths in direction 20°.

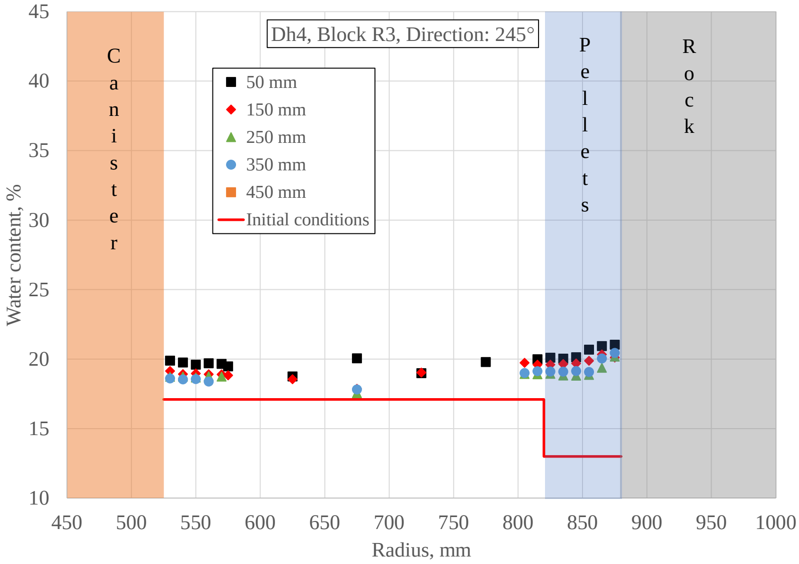


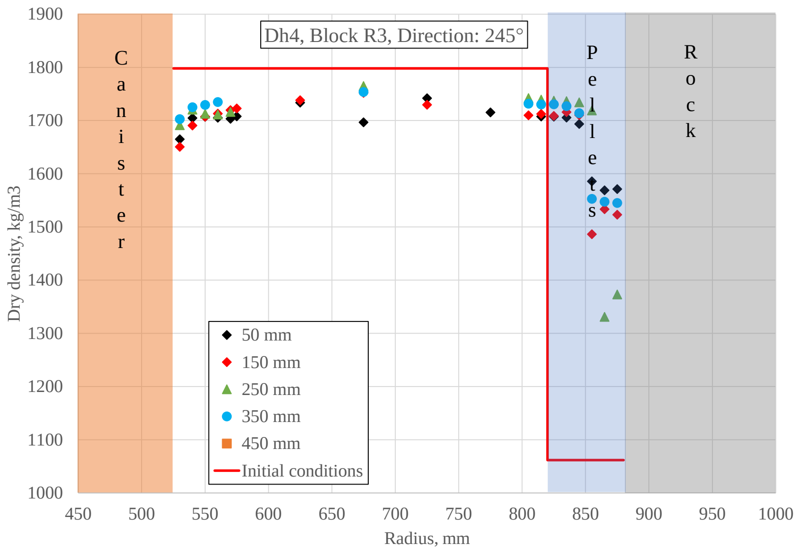


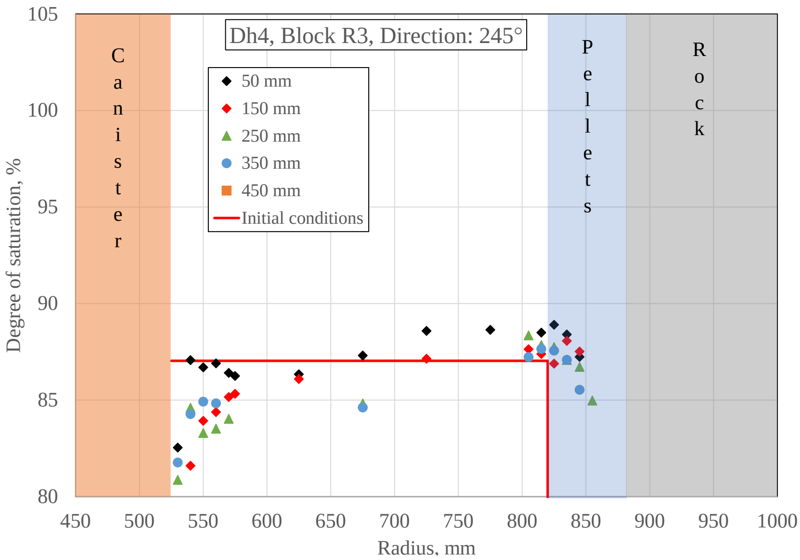


Appendix 1-11c Dh4, Block R3.

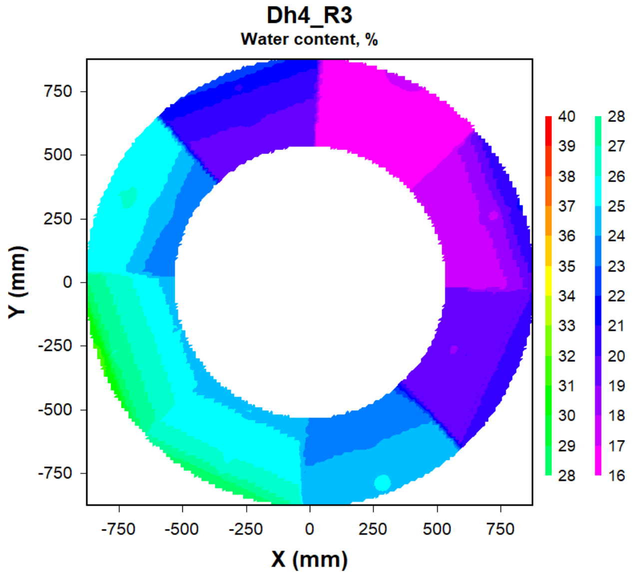
Water content, dry density, and degree of saturation at five depths in direction 245°.

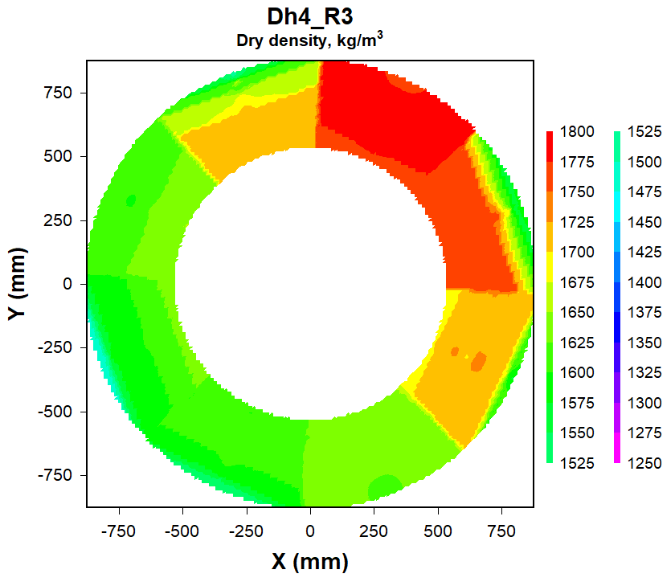


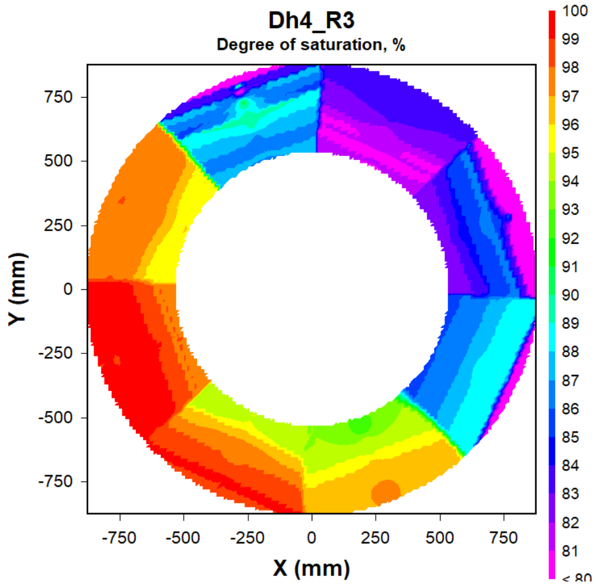




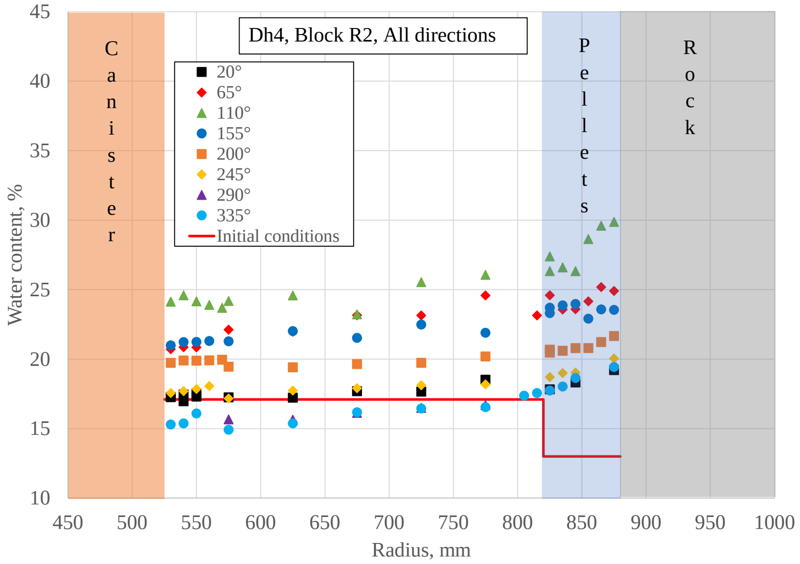
Appendix 1-11d Dh4, Block R3.
Water content, dry density, and degree of saturation distribution.

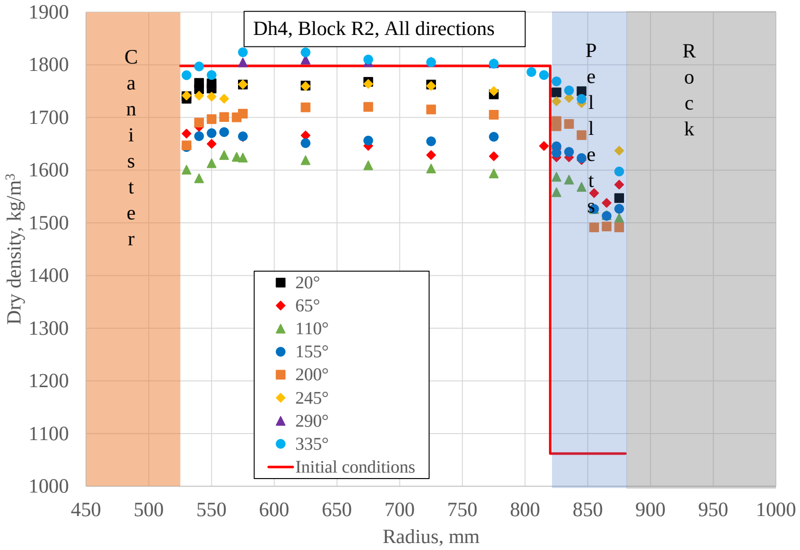


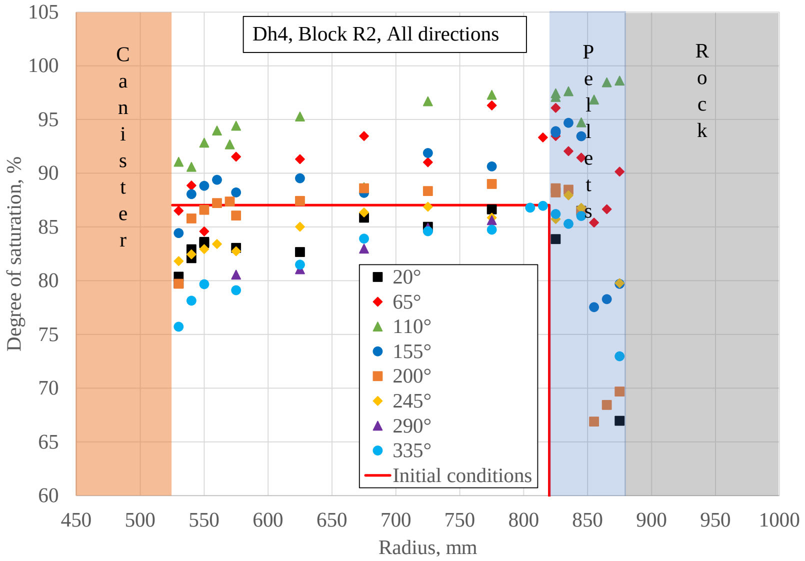




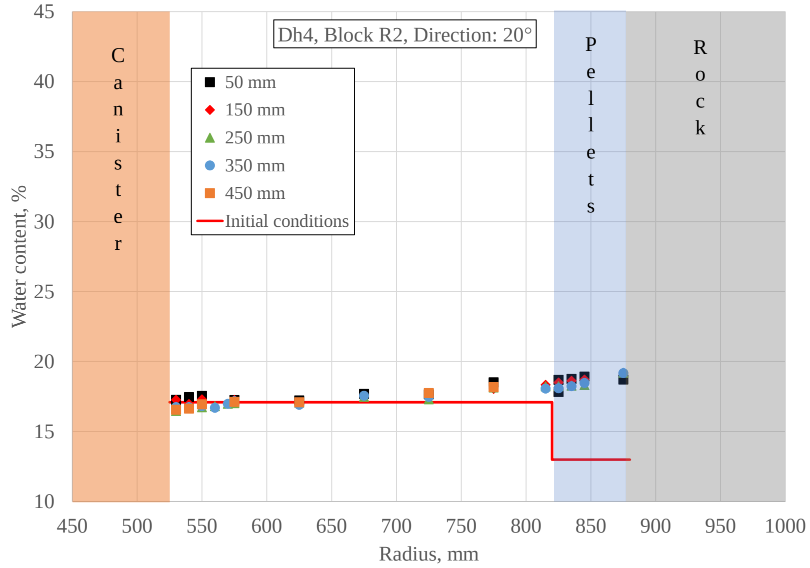
Appendix 1-12a Dh4, Block R2.
Water content, dry density, and degree of saturation in eight directions.

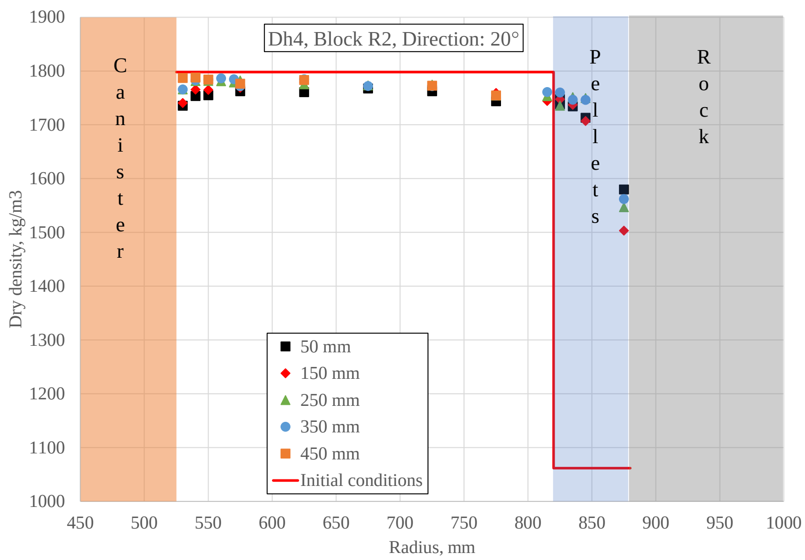


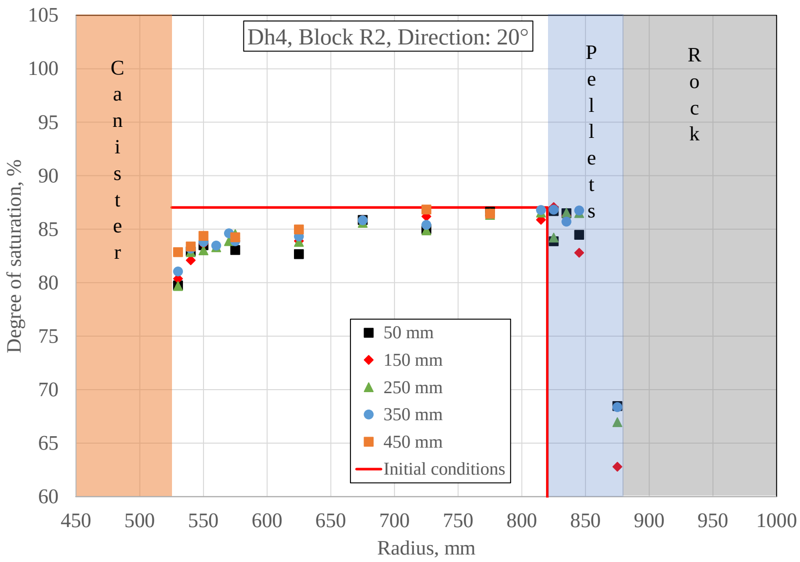




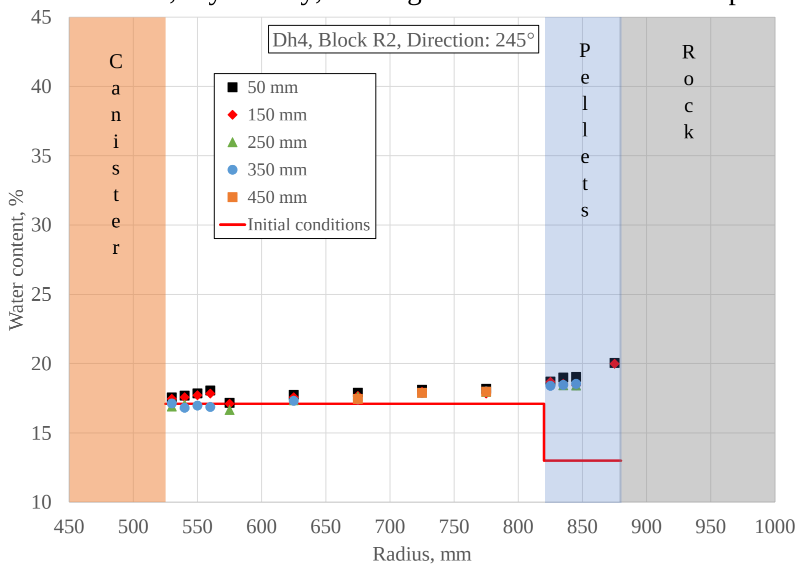
Appendix 1-12b Dh4, Block R2.
Water content, dry density, and degree of saturation at five depths in direction 20°.

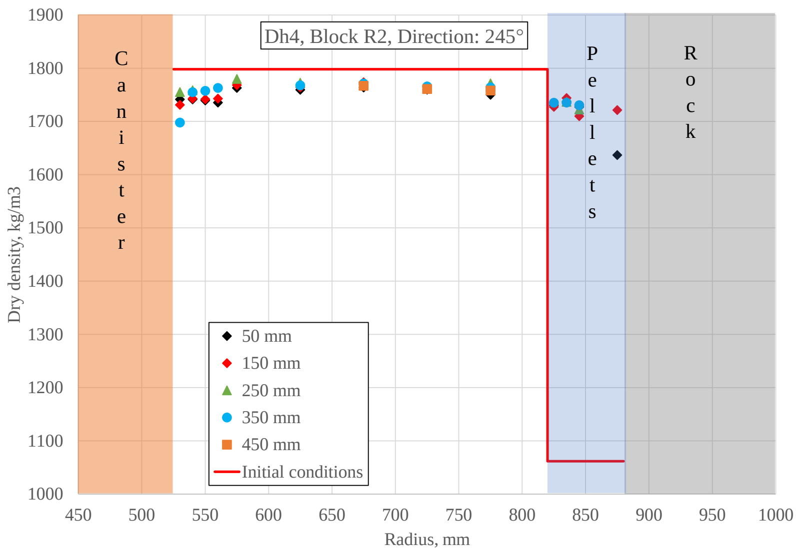


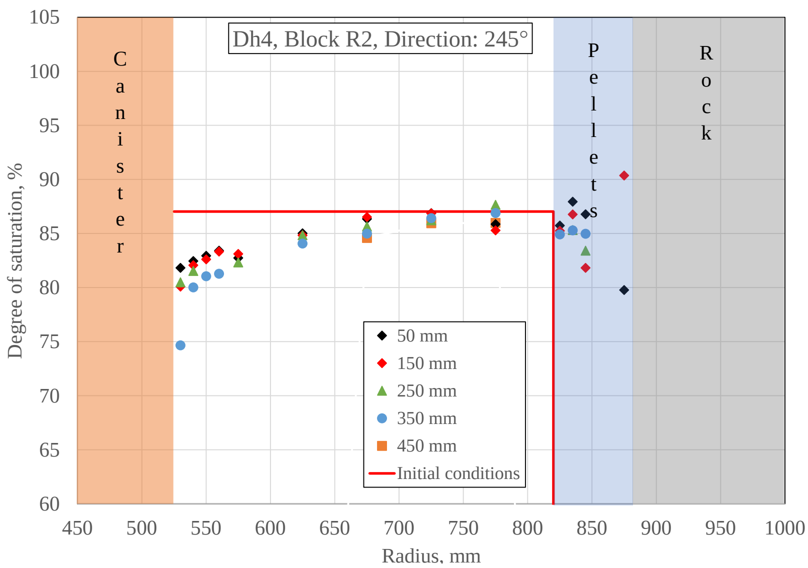




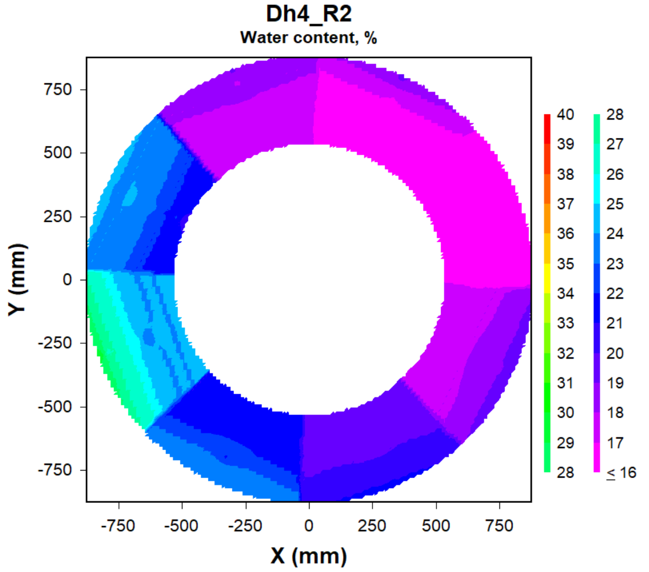
Appendix 1-12c Dh4, Block R2.
Water content, dry density, and degree of saturation at five depths in direction 245°.

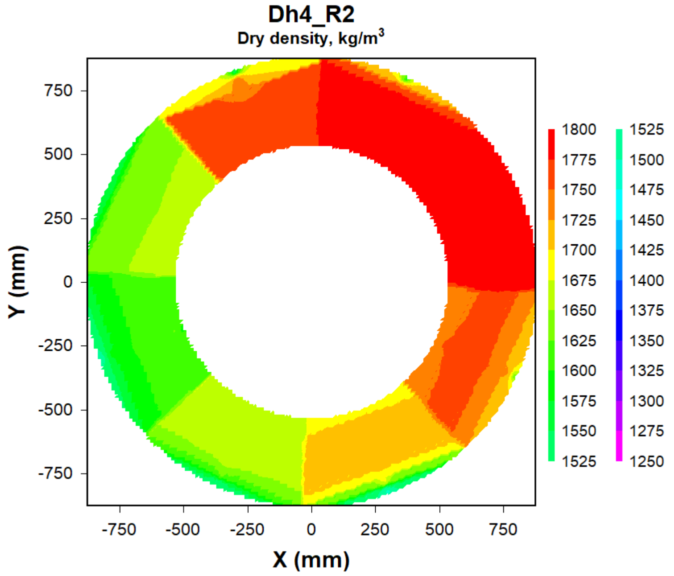


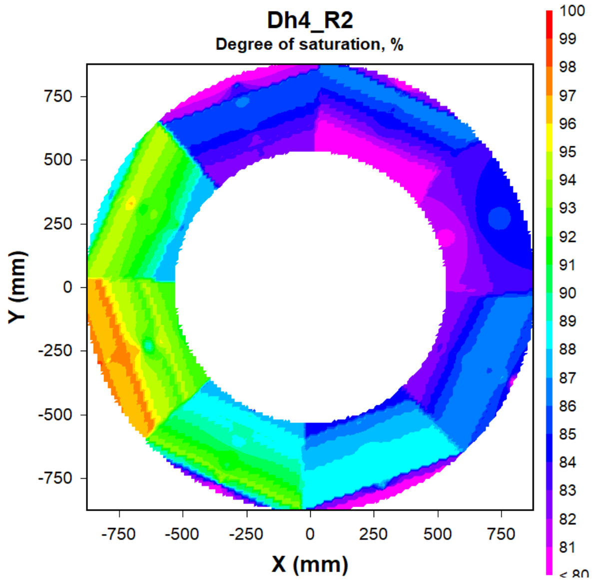




Appendix 1-12d Dh4, Block R2.
Water content, dry density, and degree of saturation distribution.

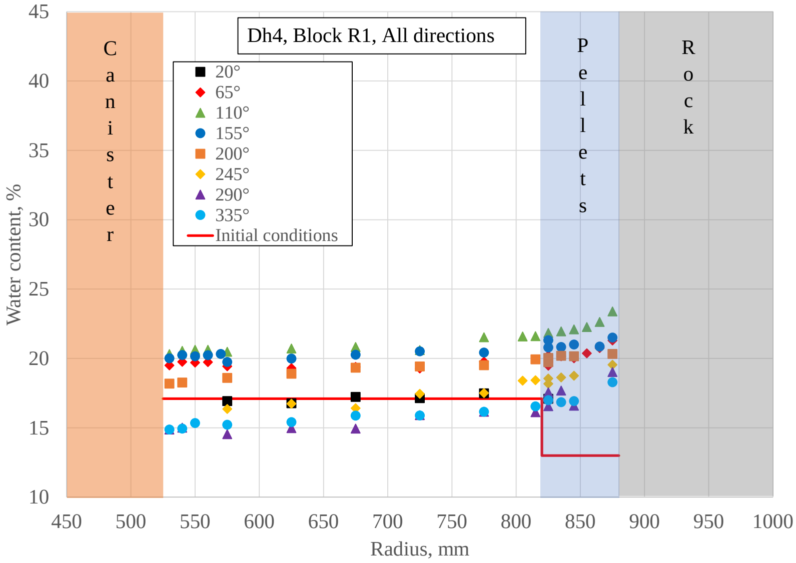


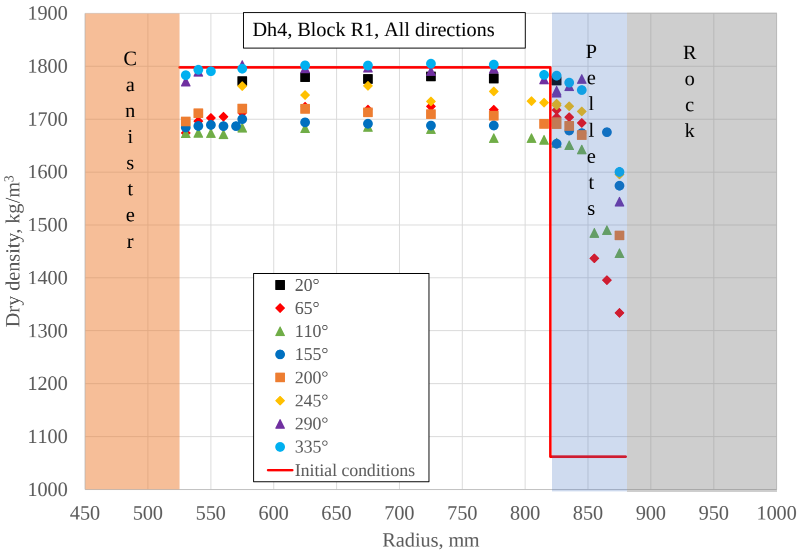


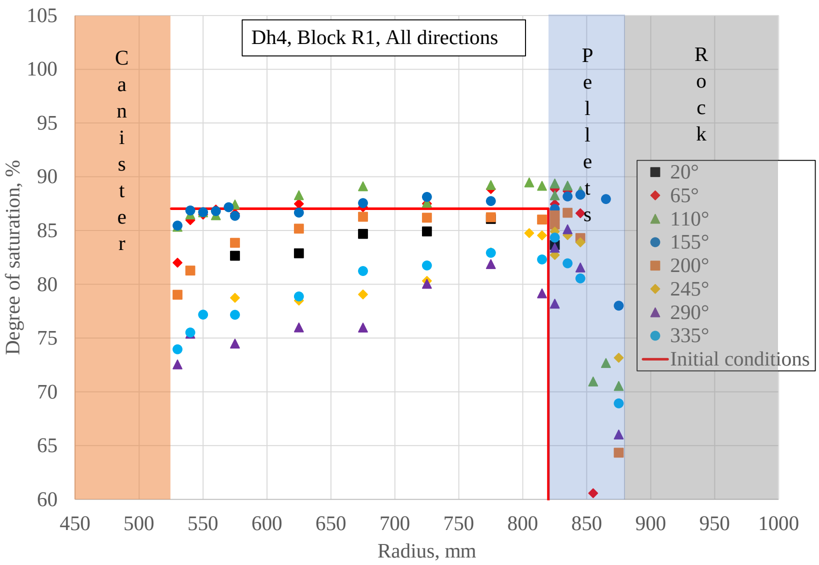


Appendix 1-13a Dh4, Block R1.

Water content, dry density, and degree of saturation in eight directions.

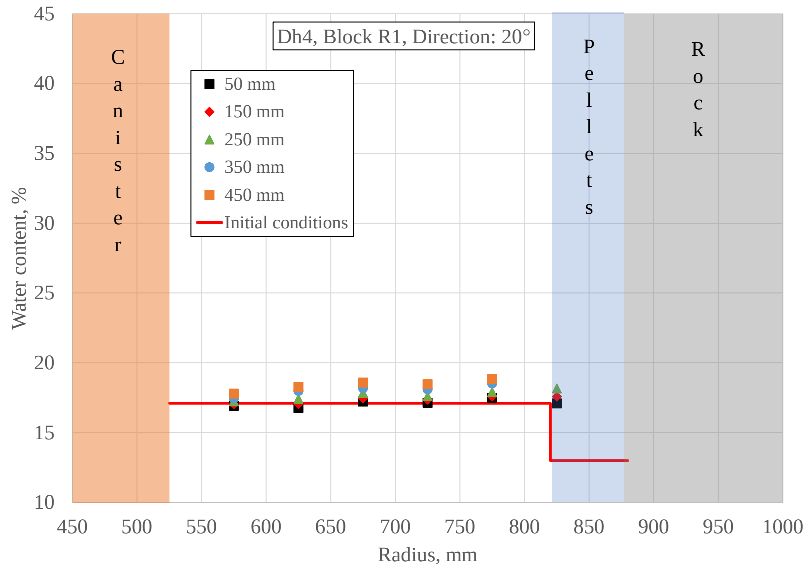


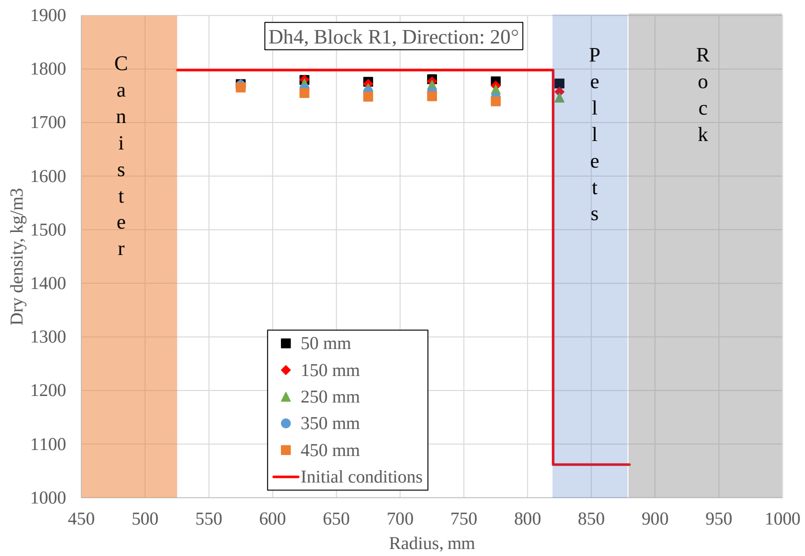


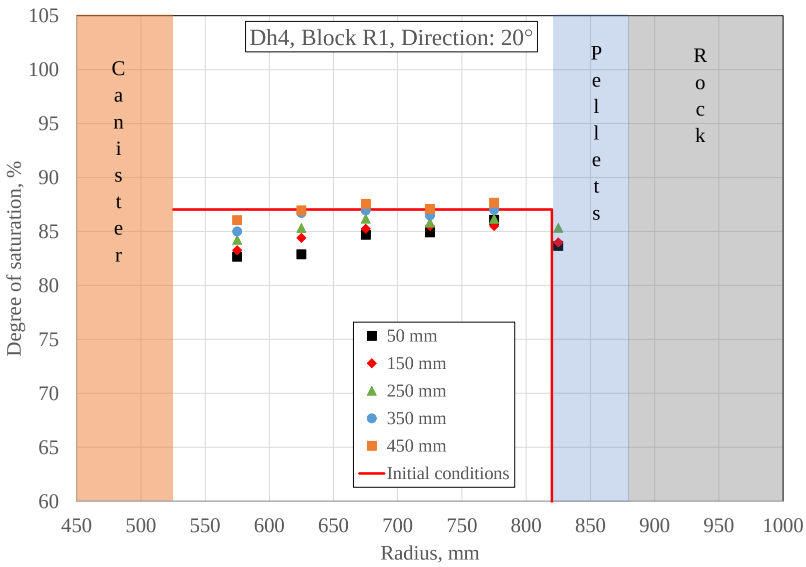


Appendix 1-13b Dh4, Block R1.

Water content, dry density, and degree of saturation at five depths in direction 20°.

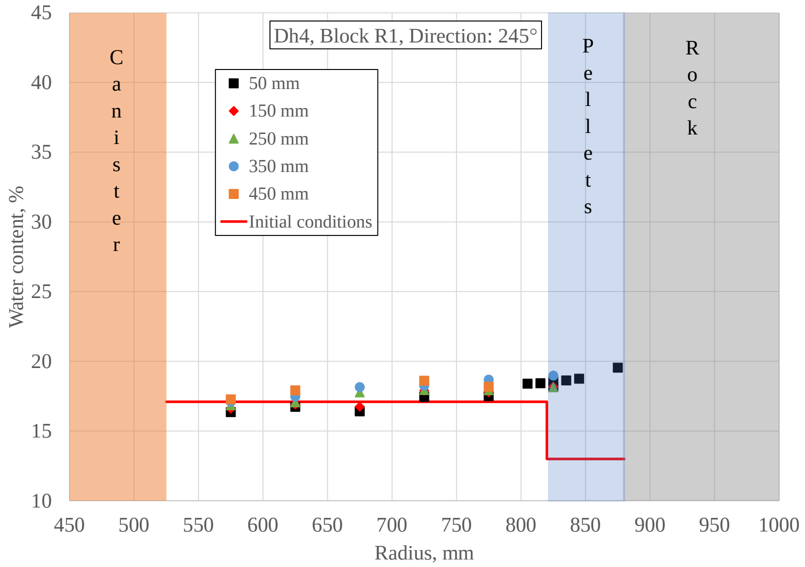


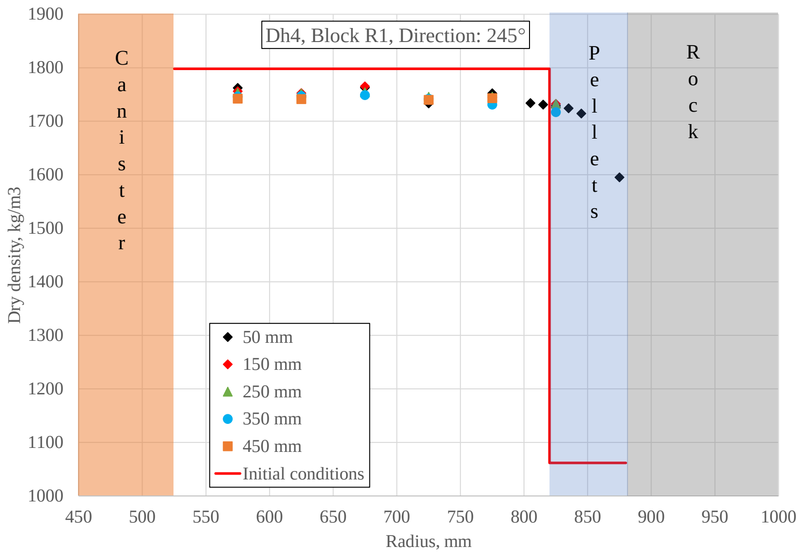


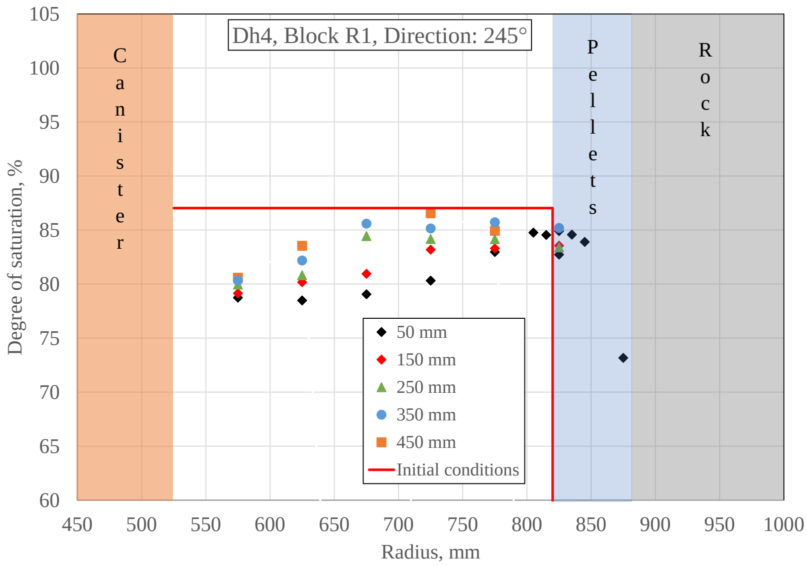


Appendix 1-13c Dh4, Block R1.

Water content, dry density, and degree of saturation at five depths in direction 245°.

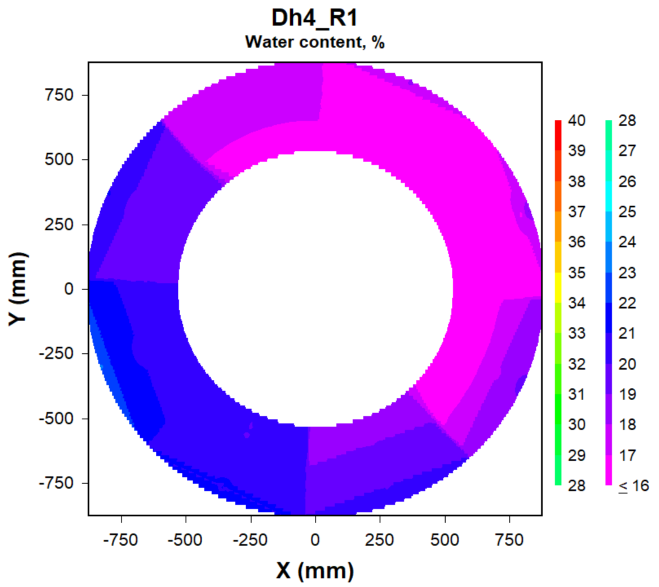


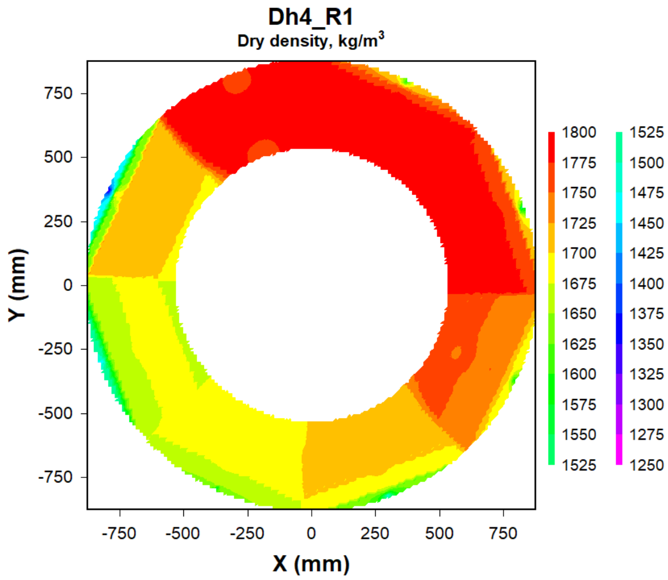


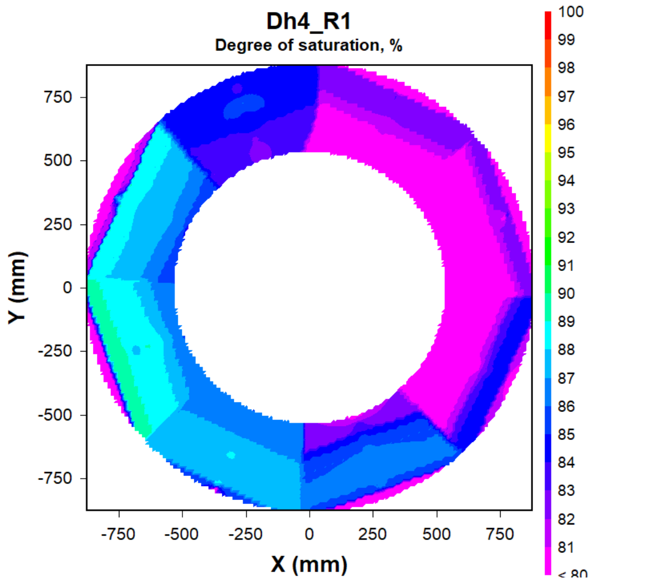


Appendix 1-13d Dh4, Block R1.

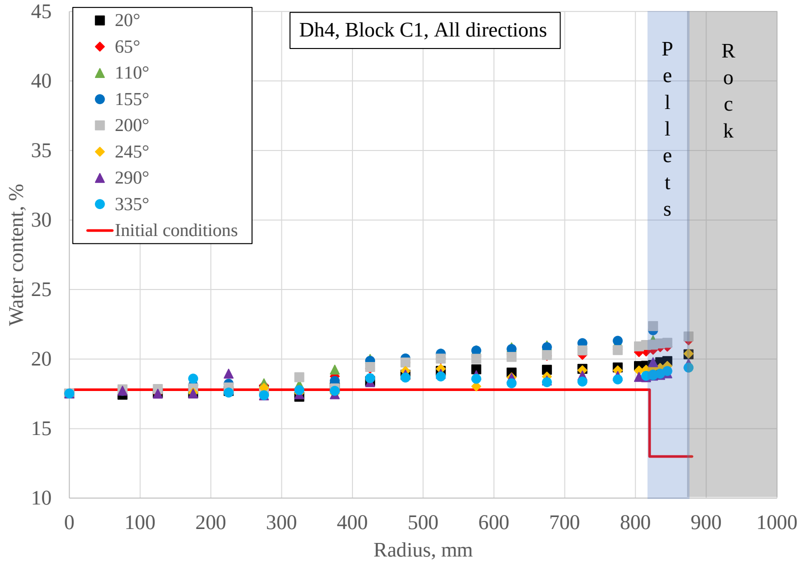
Water content, dry density, and degree of saturation distribution.

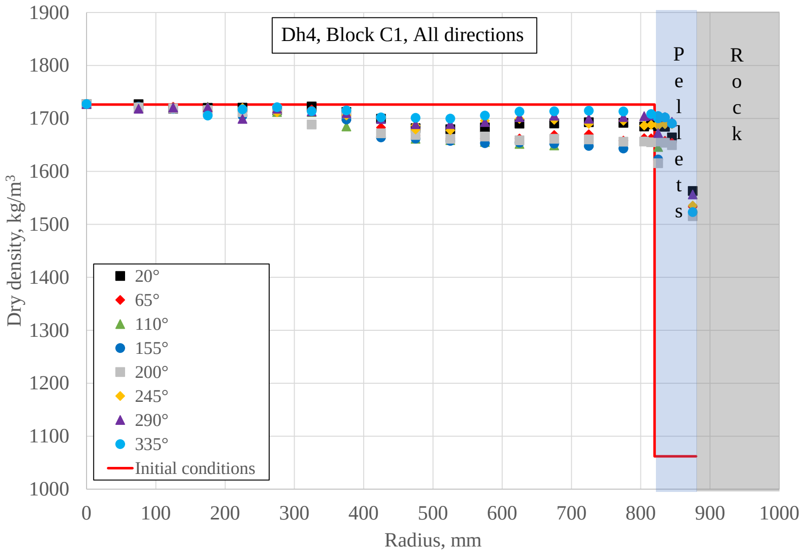


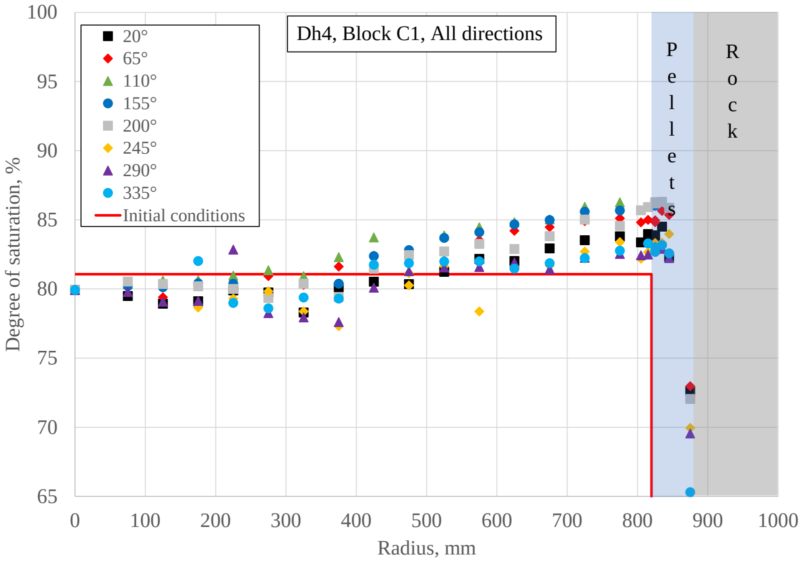




Appendix 1-14a Dh4, Block C1.
Water content, dry density, and degree of saturation in eight directions.

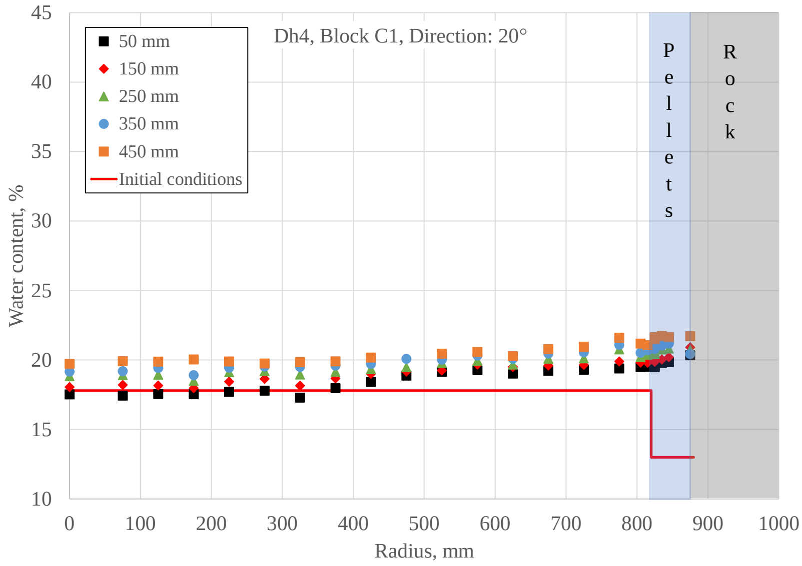


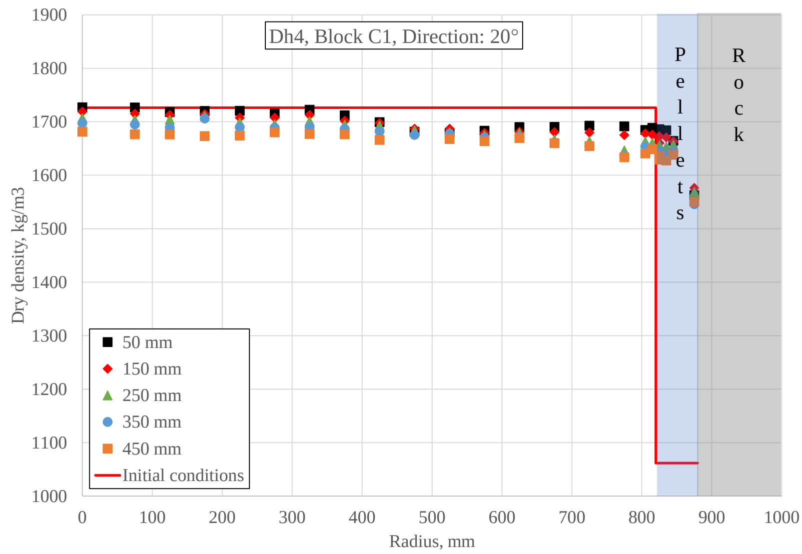


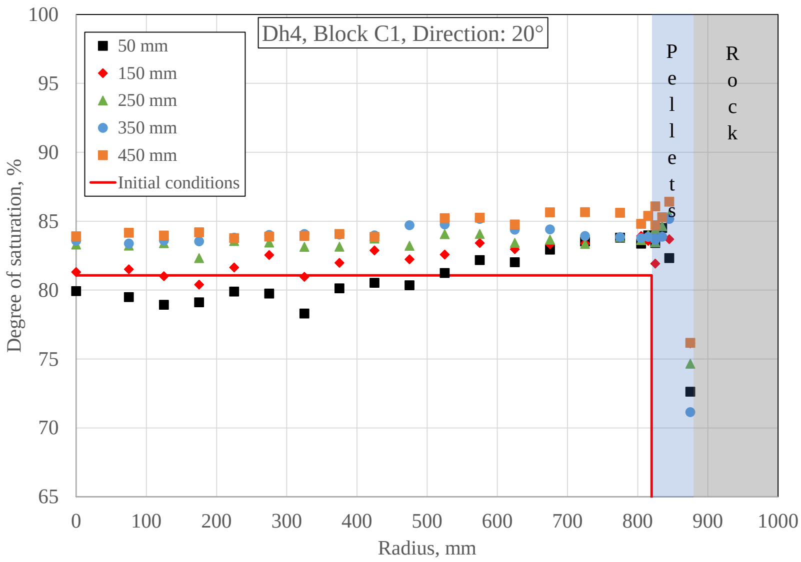


Appendix 1-14b Dh4, Block C1.

Water content, dry density, and degree of saturation at five depths in direction 20°.

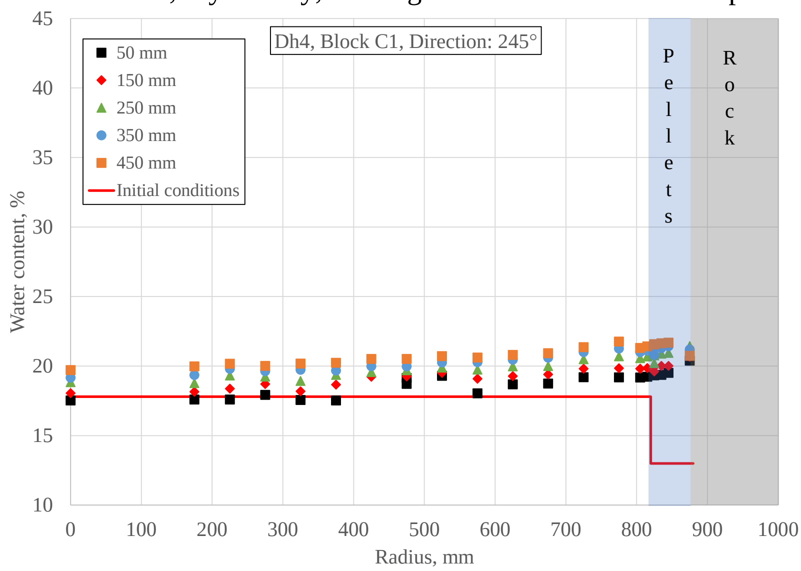


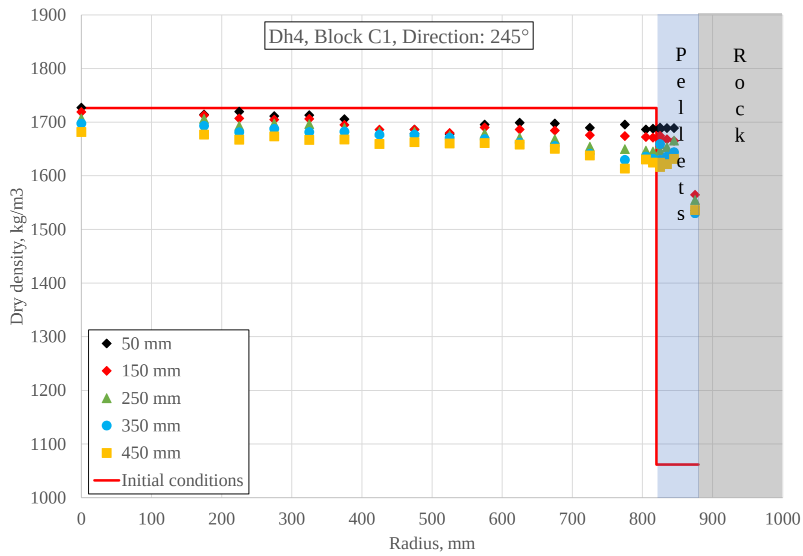


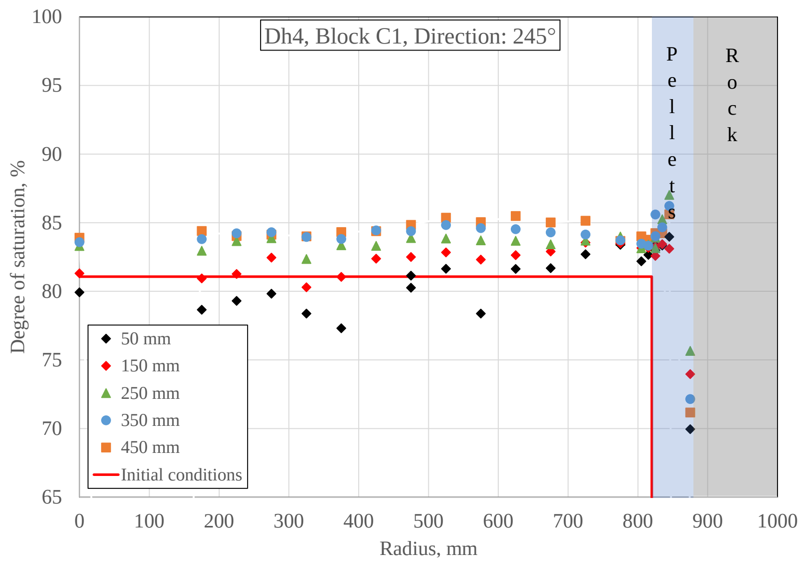


Appendix 1-14c Dh4, Block C1.

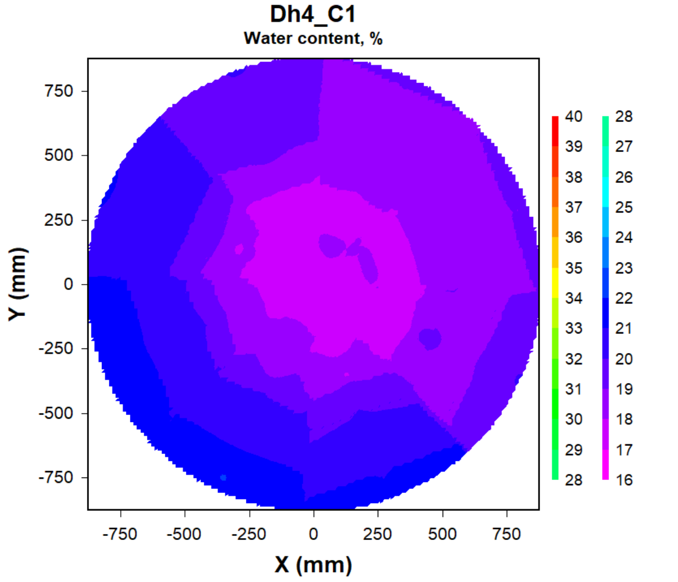
Water content, dry density, and degree of saturation at five depths in direction 245°.

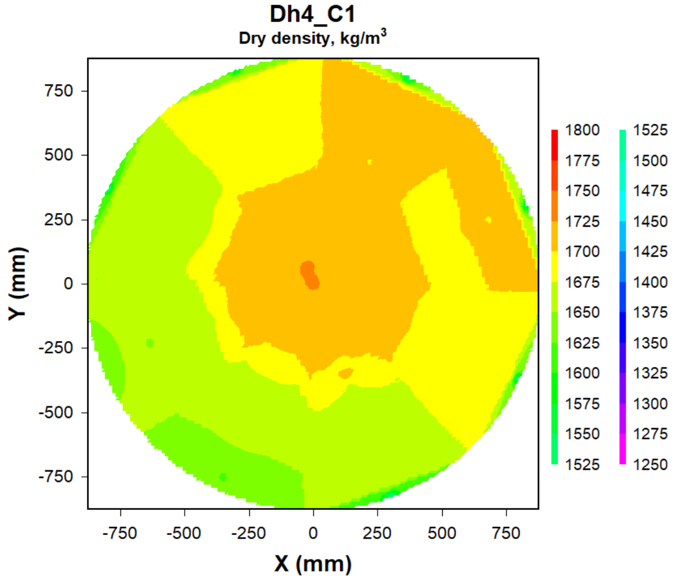


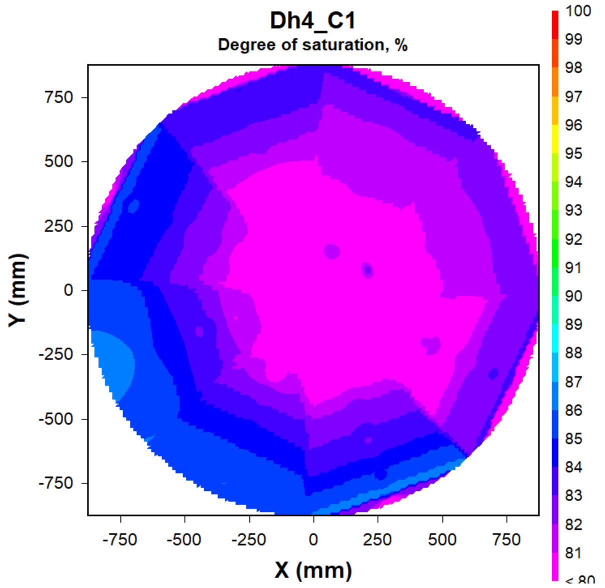




Appendix 1-14d Dh4, Block C1.
Water content, dry density, and degree of saturation distribution.

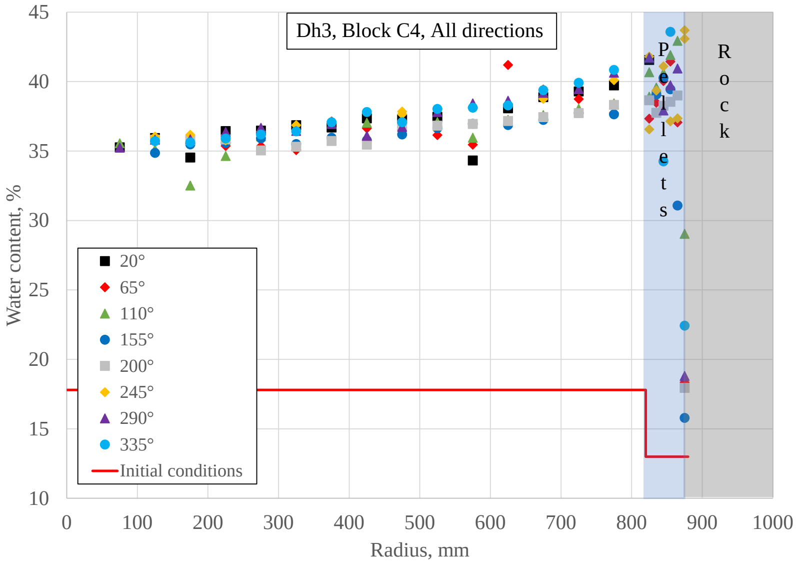


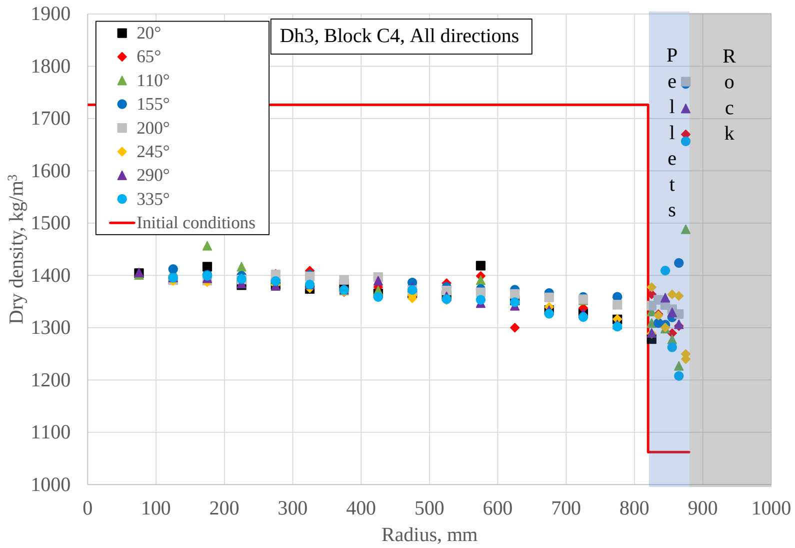


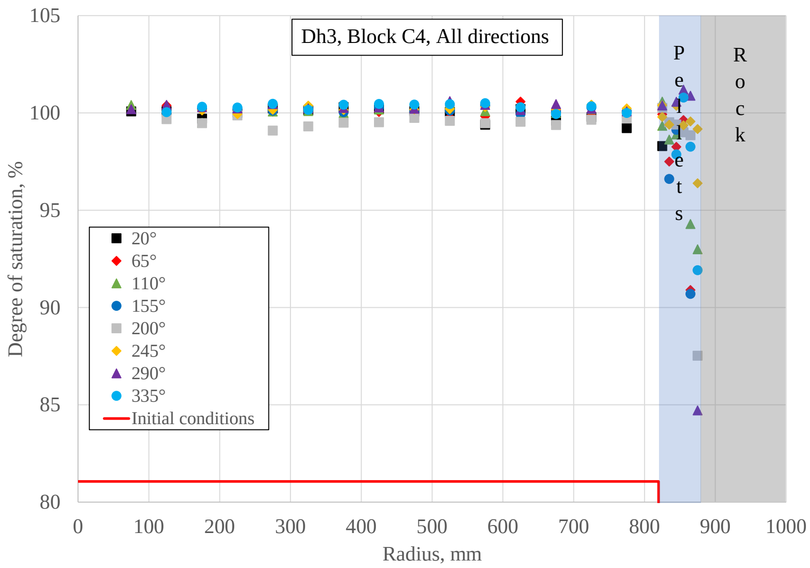


Appendix 2-1a Dh3, Block C4.

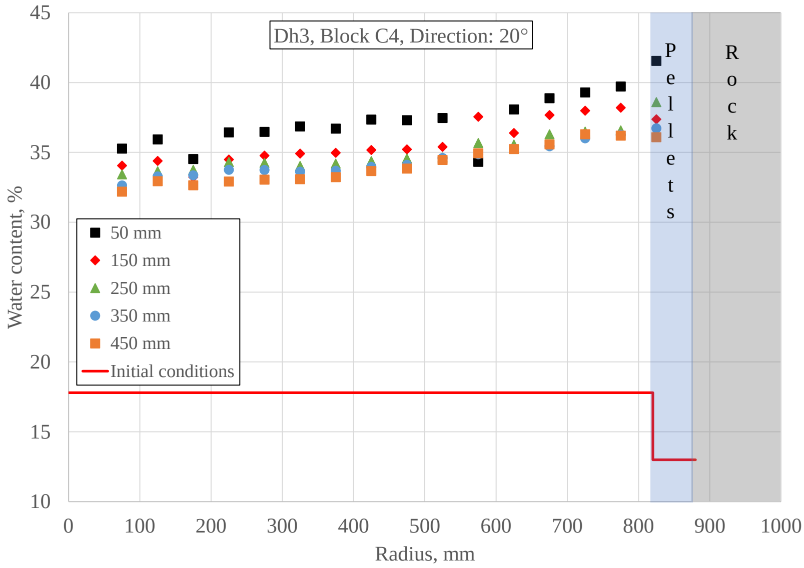
Water content, dry density, and degree of saturation in eight directions.

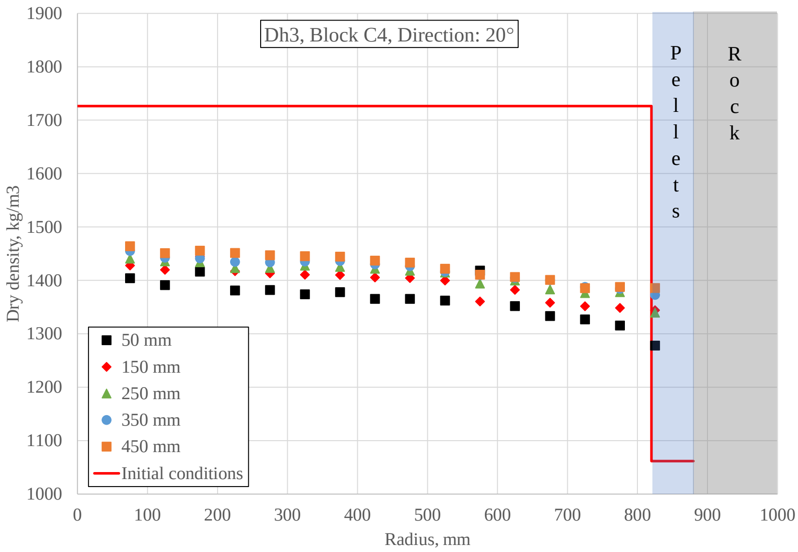


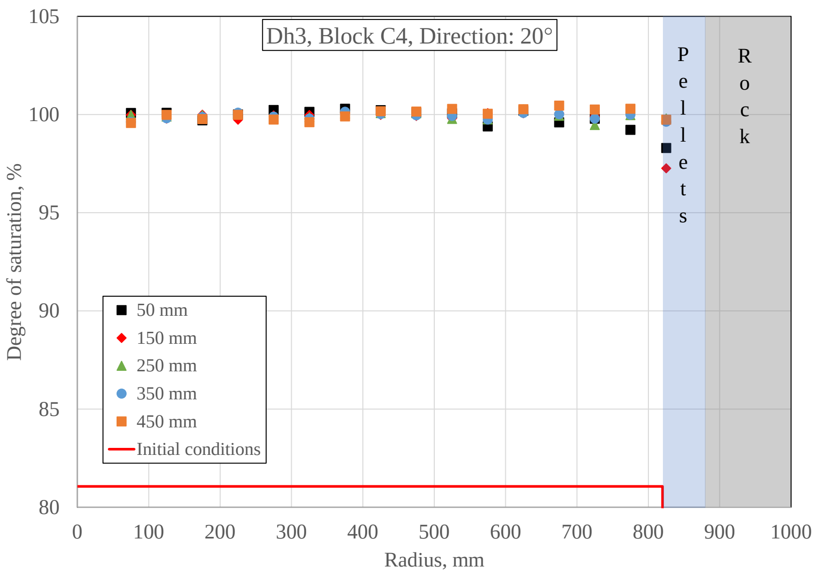




Appendix 2-1b Dh3, Block C4.
Water content, dry density, and degree of saturation at five depths in direction 20°.

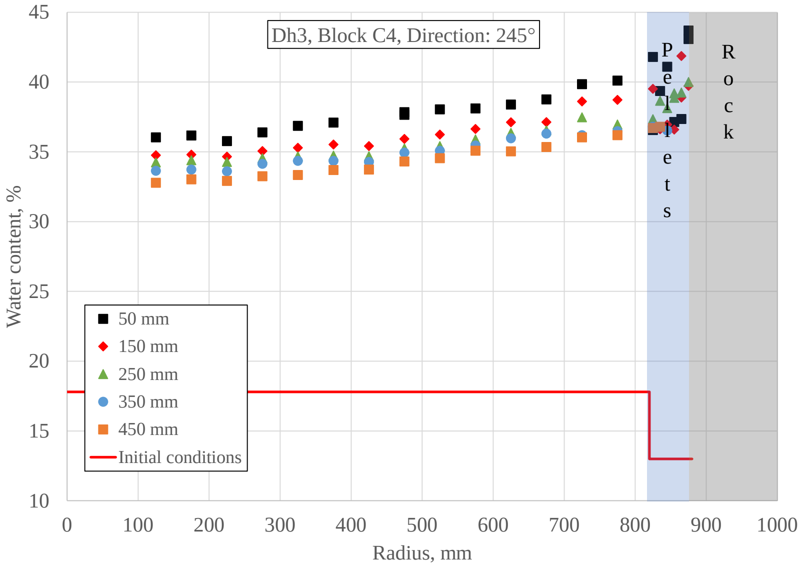


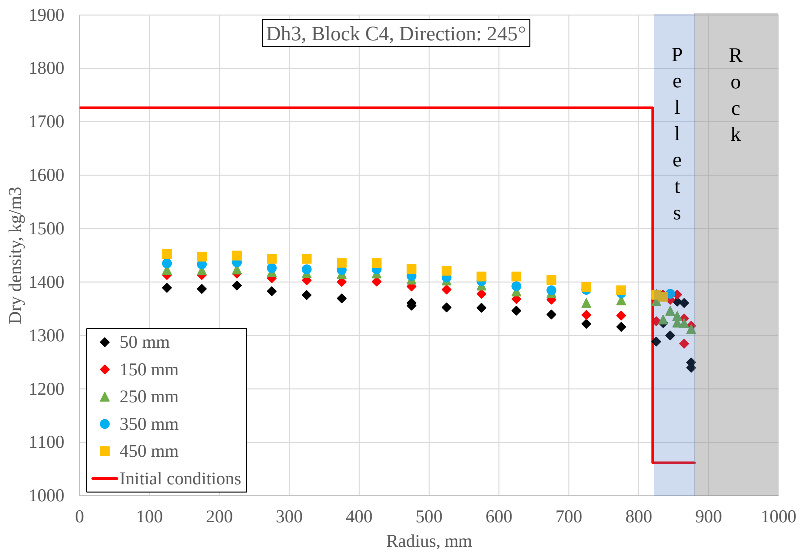


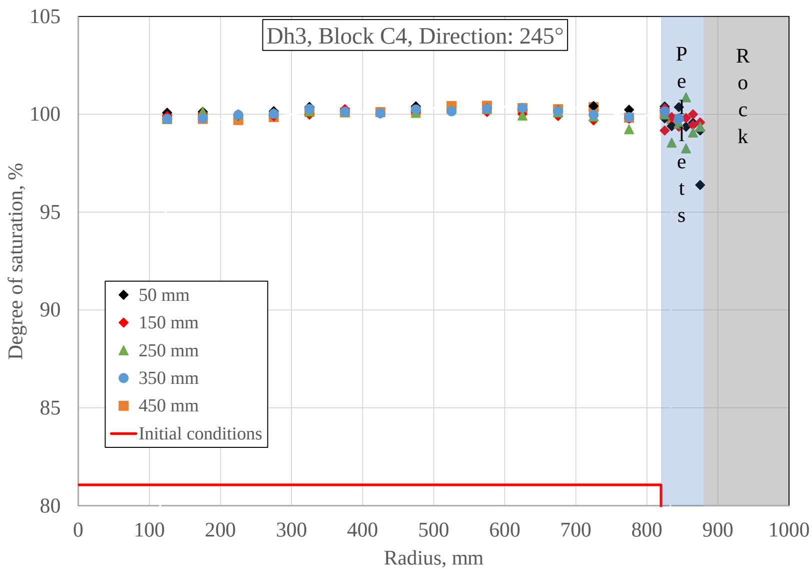


Appendix 2-1c Dh3, Block C4.

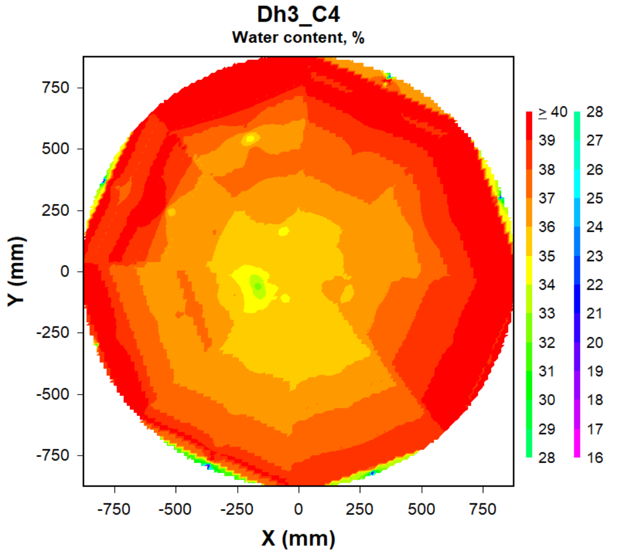
Water content, dry density, and degree of saturation at five depths in direction 245°.

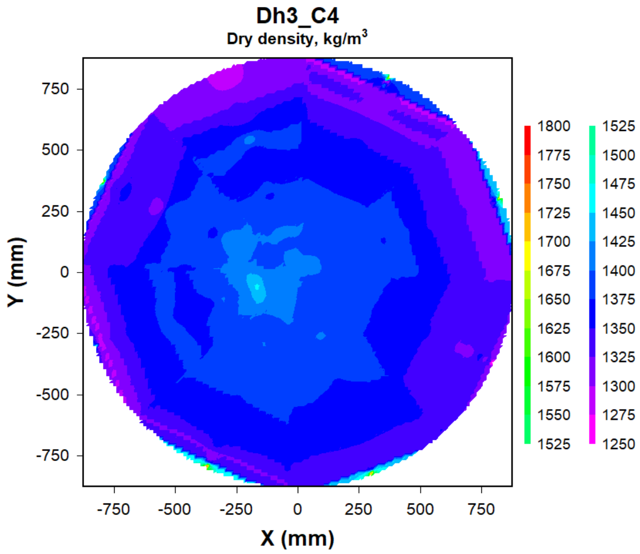


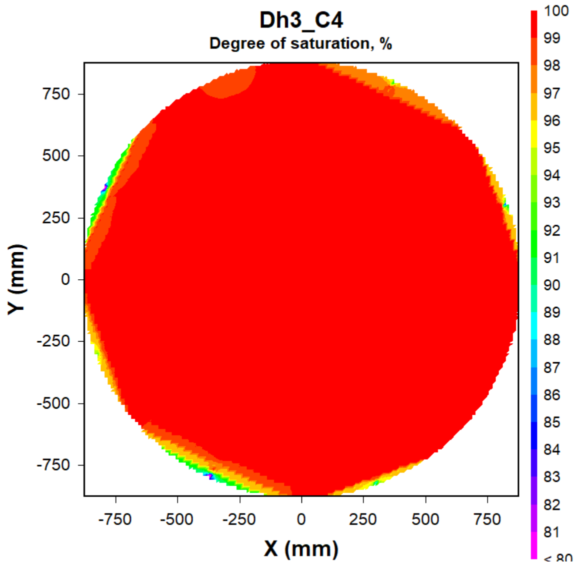




Appendix 2-1d Dh3, Block C4.
Water content, dry density, and degree of saturation distribution.

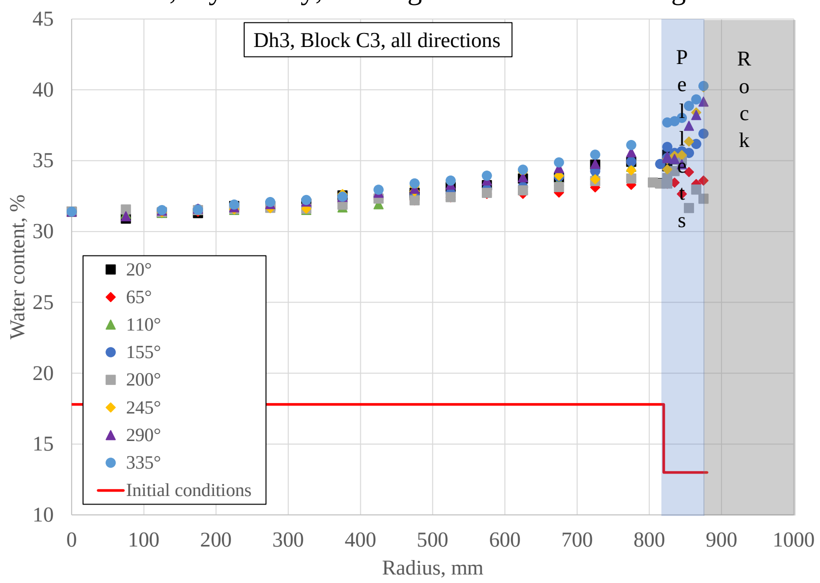


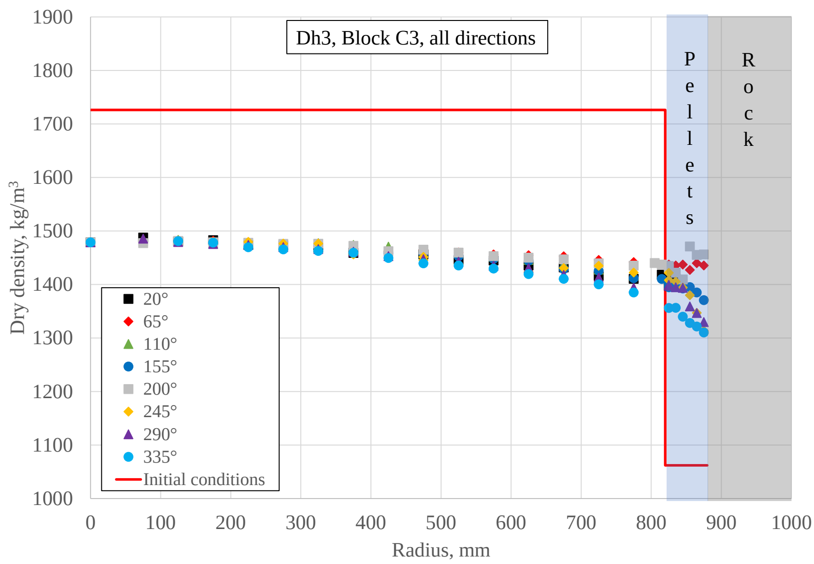


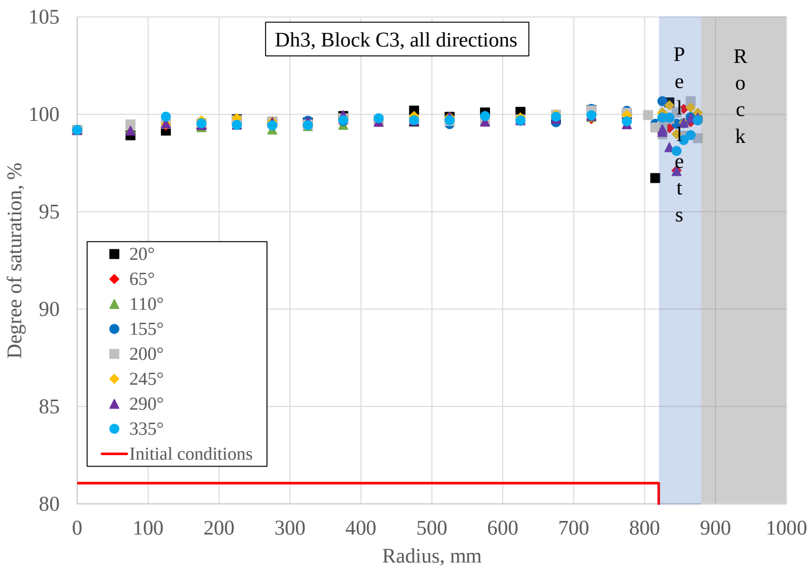


Appendix 2-2a Dh3, Block C3.

Water content, dry density, and degree of saturation in eight directions.

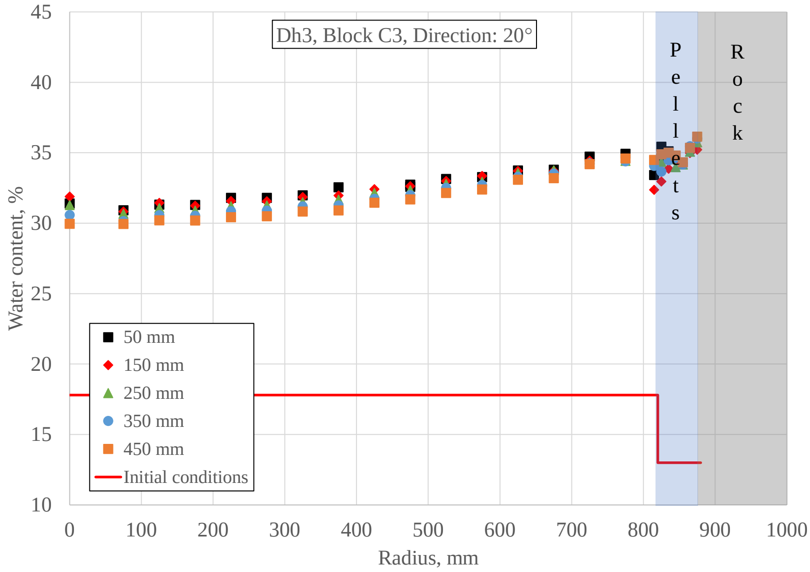


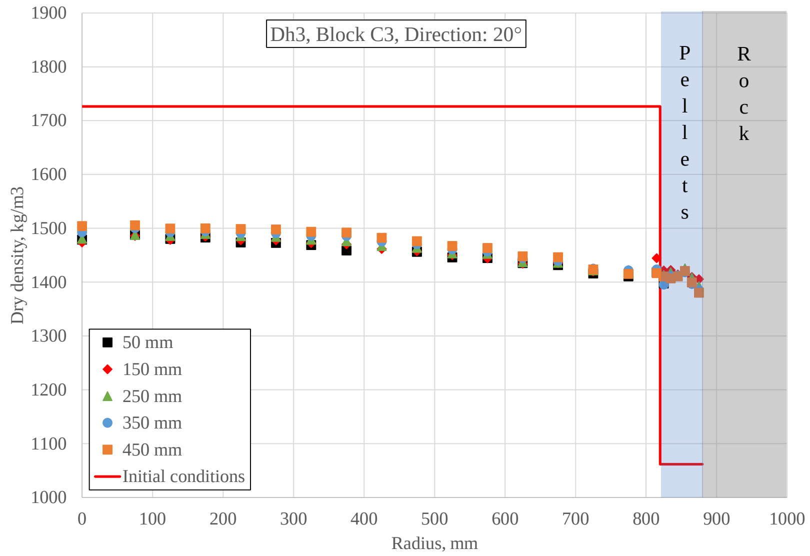


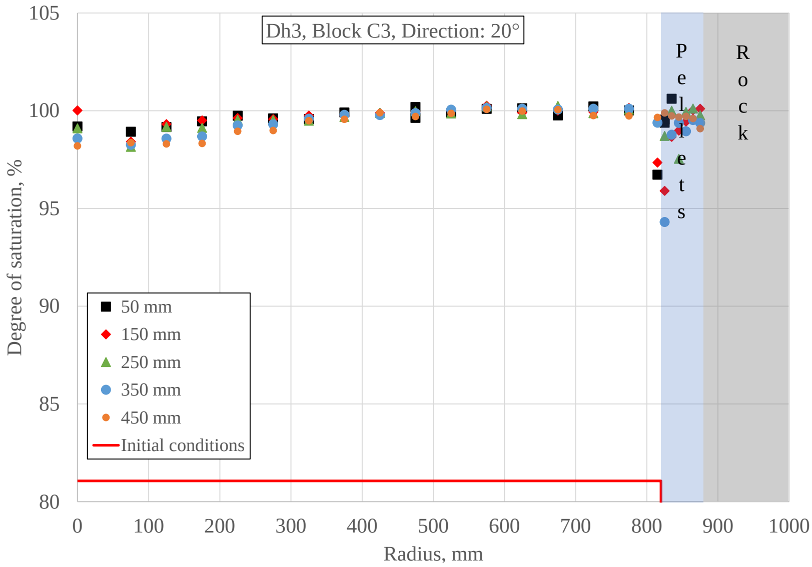


Appendix 2-2b Dh3, Block C3.

Water content, dry density, and degree of saturation at five depths in direction 20°.

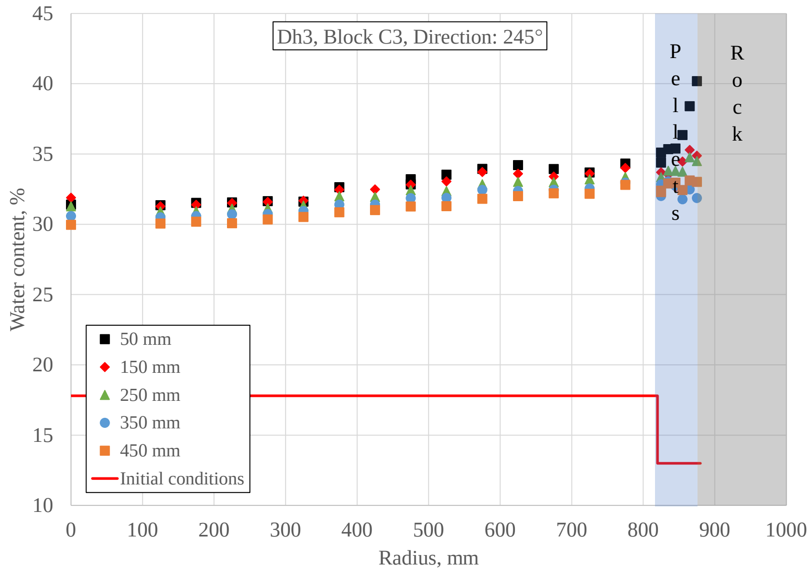


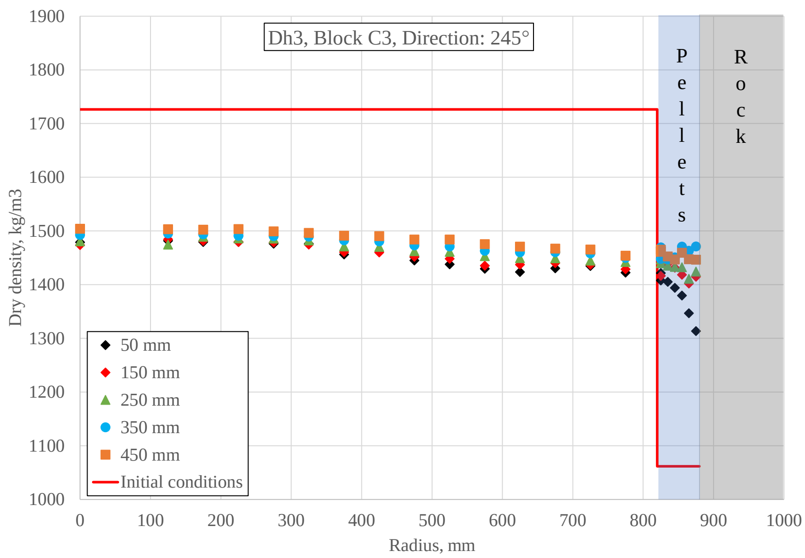


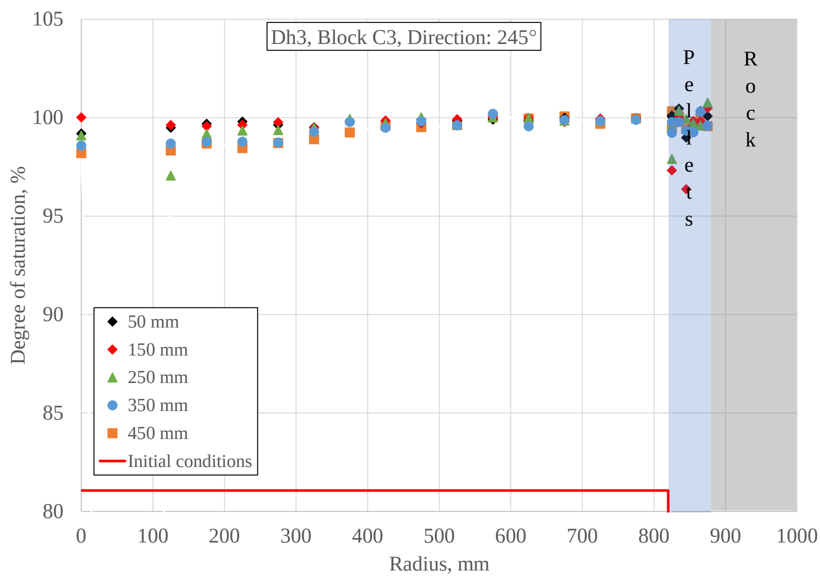


Appendix 2-2c Dh3, Block C3.

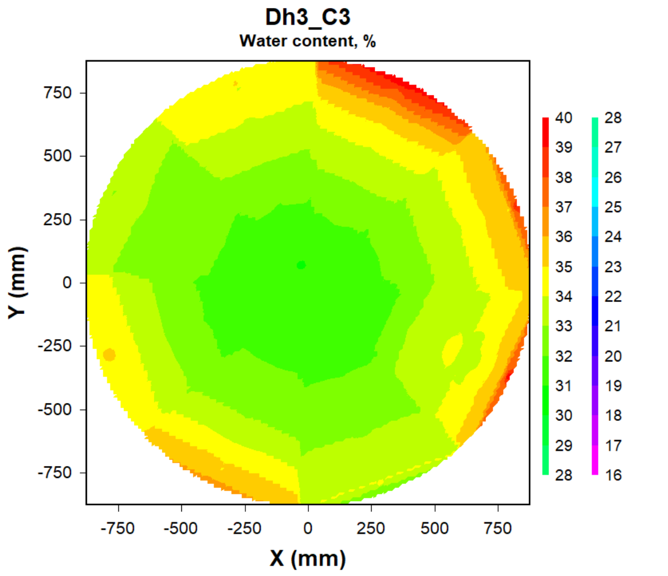
Water content, dry density, and degree of saturation at five depths in direction 245°.

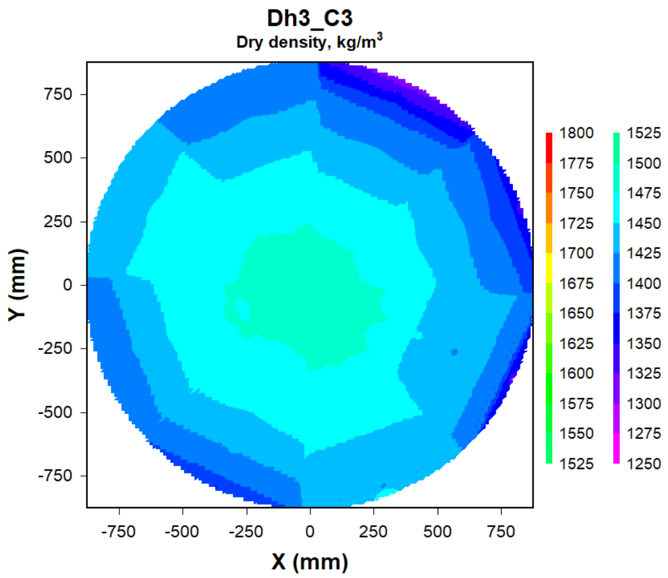


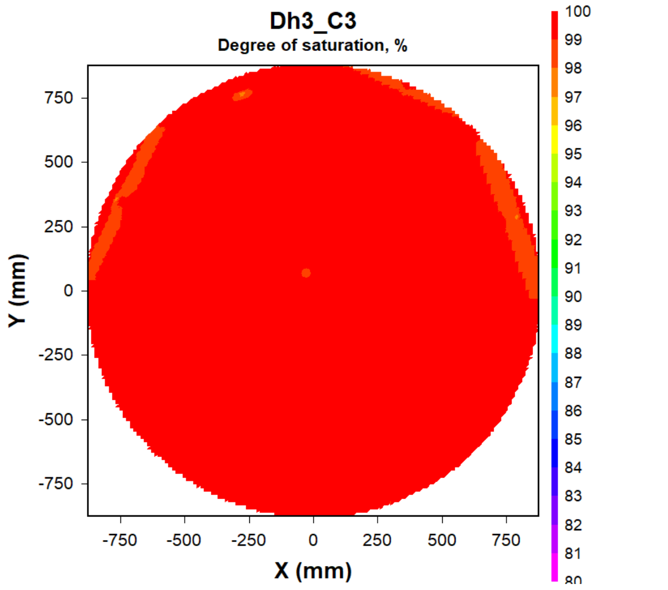




Appendix 2-2d Dh3, Block C3.
Water content, dry density, and degree of saturation distribution.

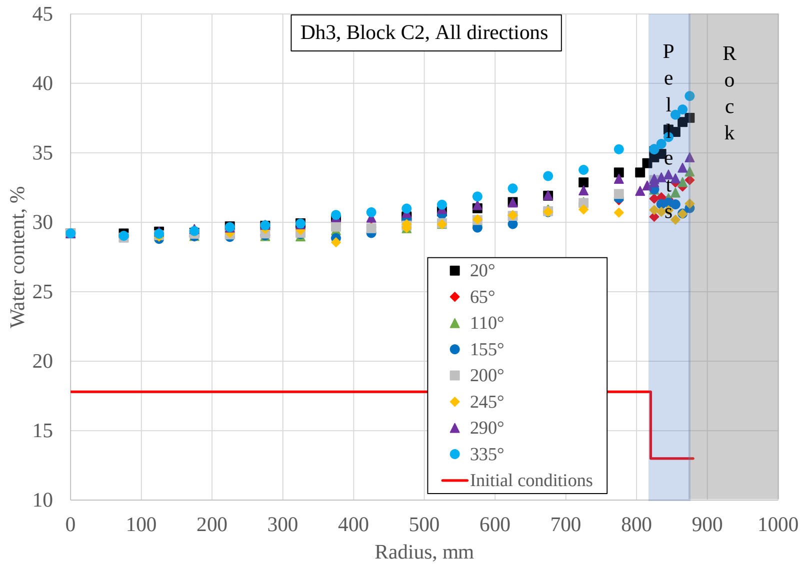


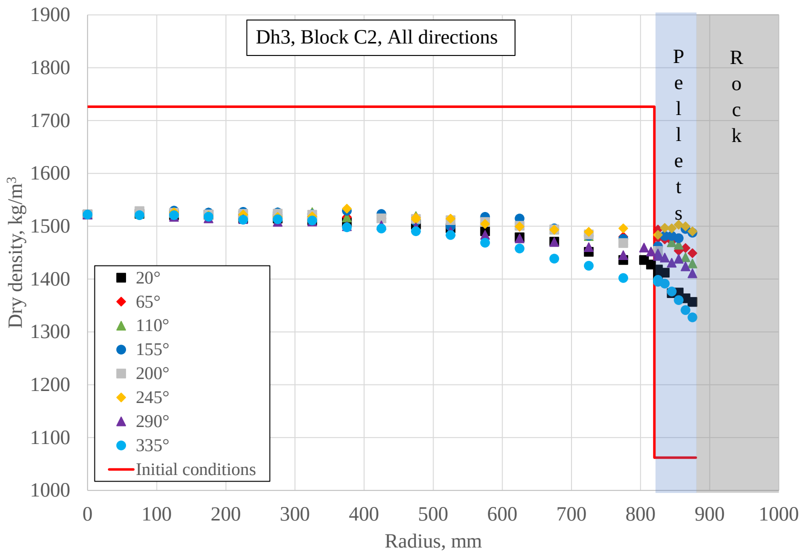


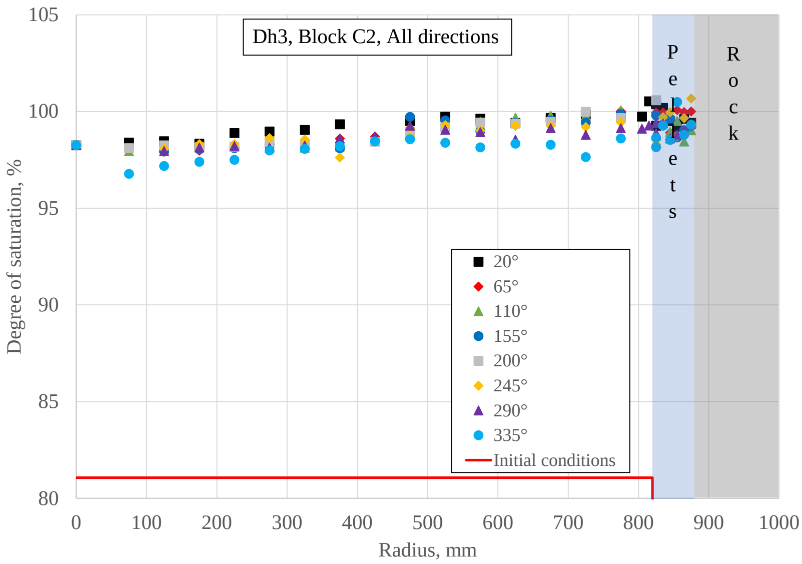


Appendix 2-3a Dh3, Block C2.

Water content, dry density, and degree of saturation in eight directions.

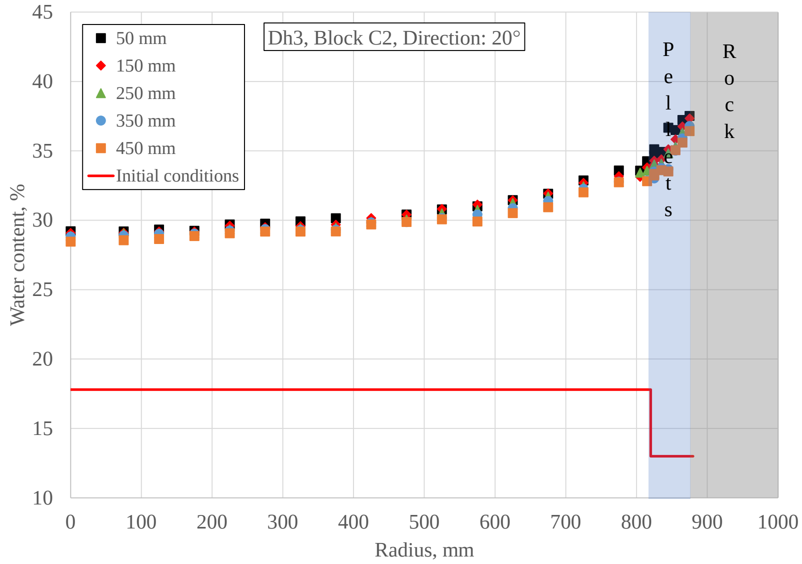


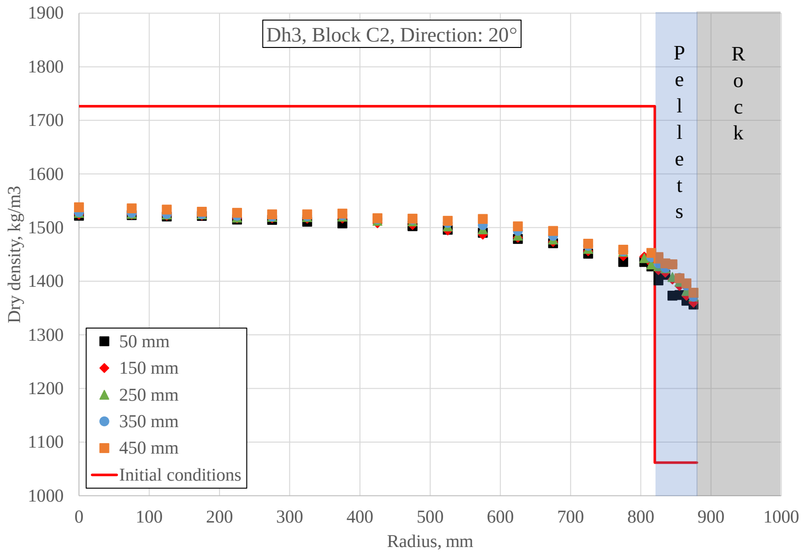


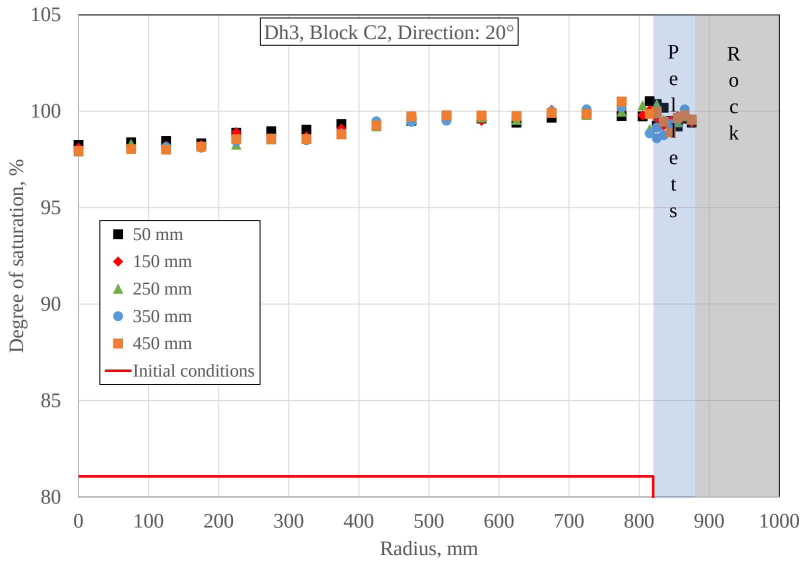


Appendix 2-3b Dh3, Block C2.

Water content, dry density, and degree of saturation at five depths in direction 20°.

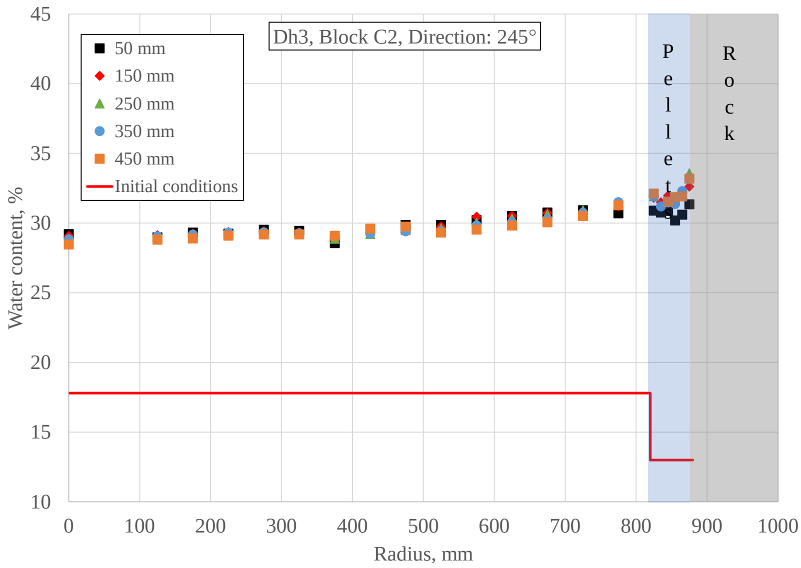


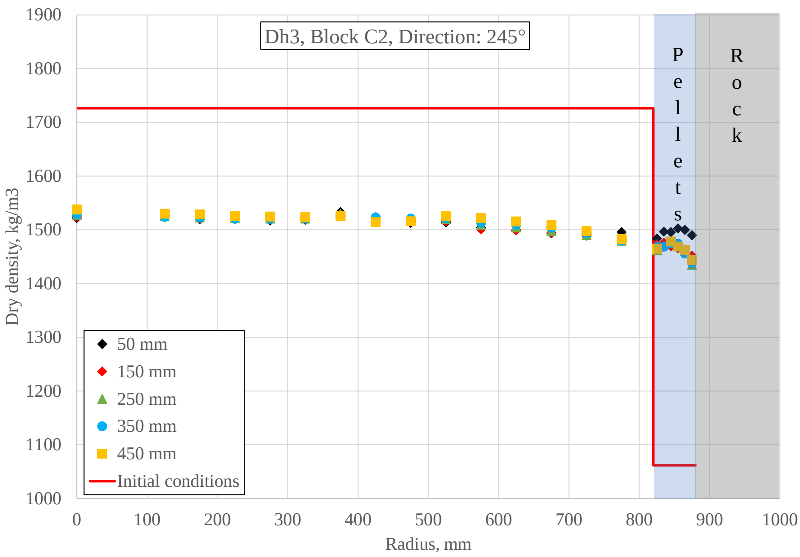


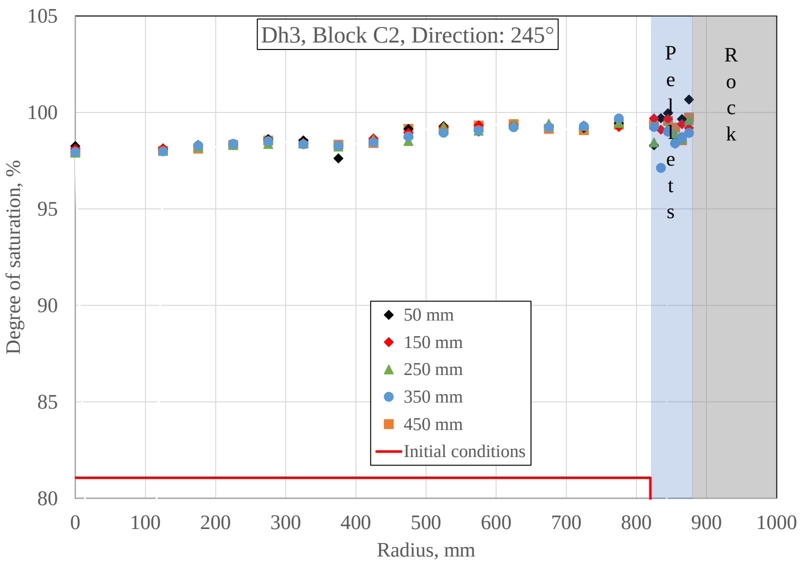


Appendix 2-3c Dh3, Block C2.

Water content, dry density, and degree of saturation at five depths in direction 245°.

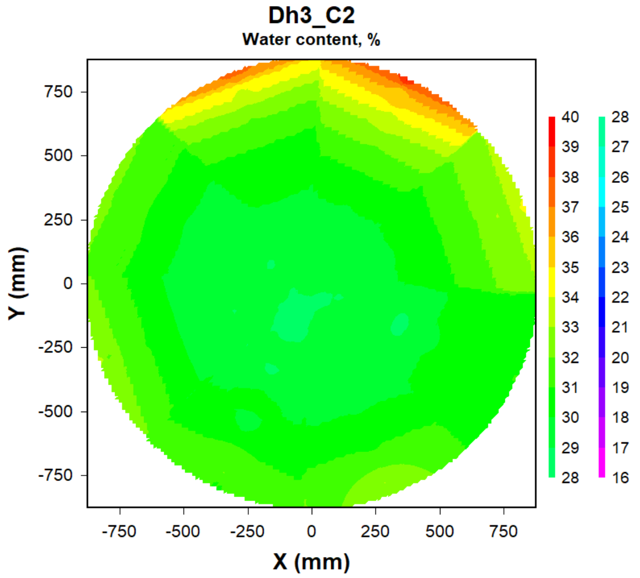


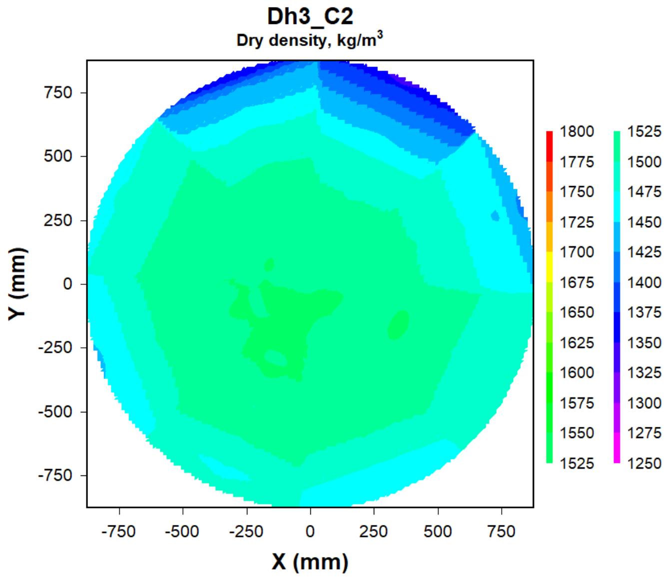


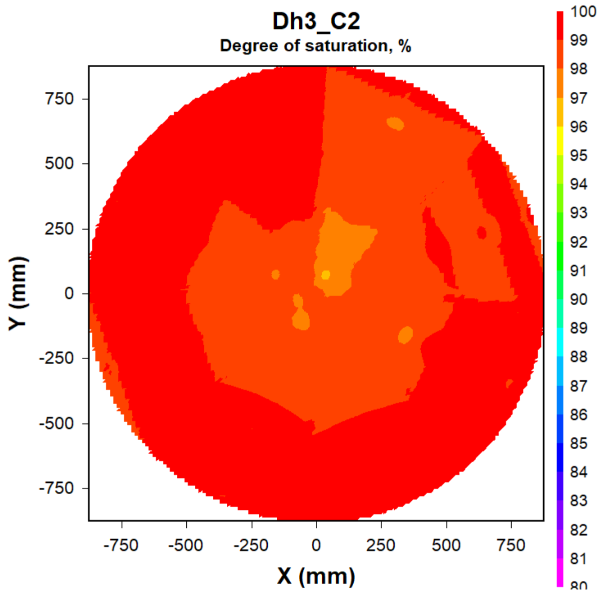


Appendix 2-3d Dh3, Block C2.

Water content, dry density, and degree of saturation distribution.

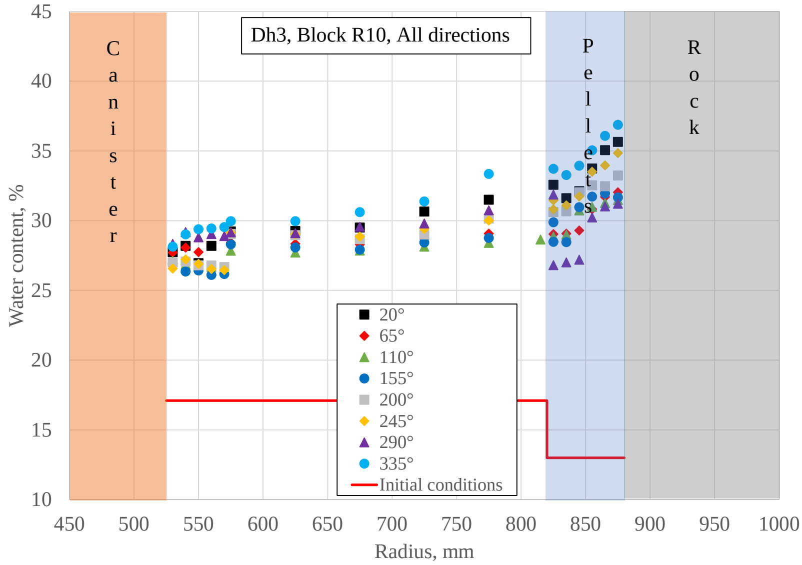


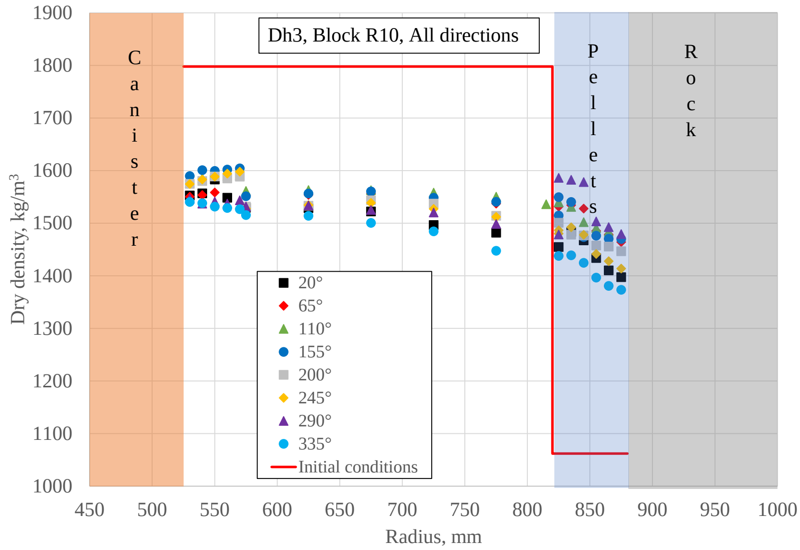


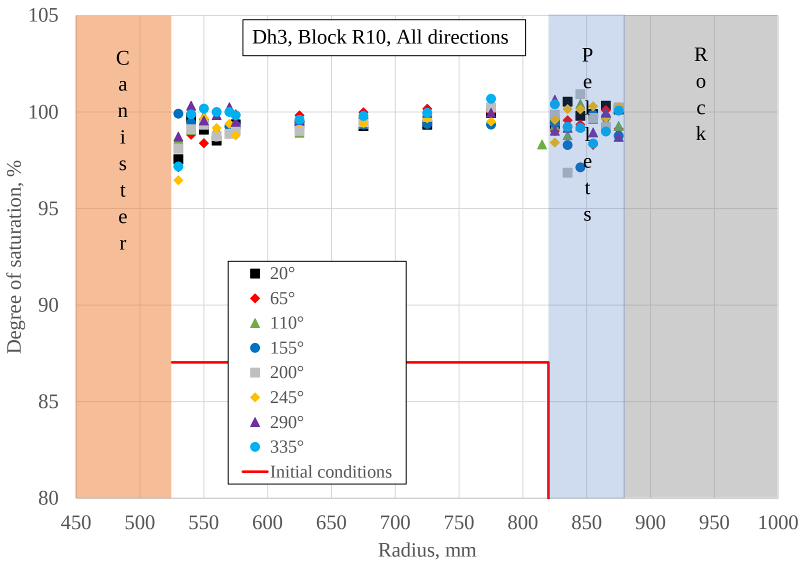


Appendix 2-4a Dh3, Block R10.

Water content, dry density, and degree of saturation in eight directions.

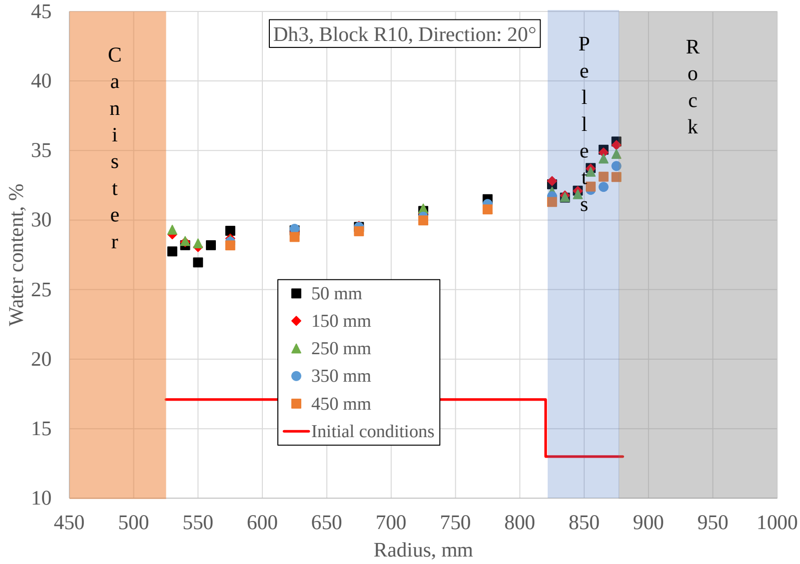


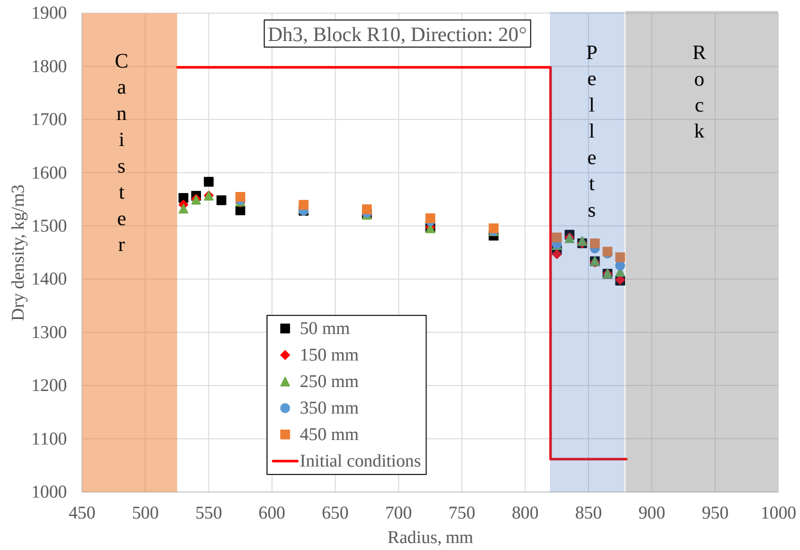


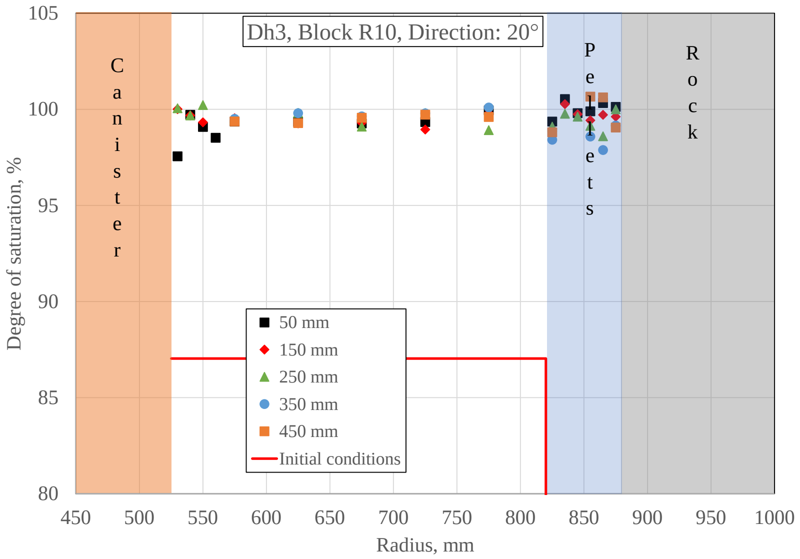


Appendix 2-4b Dh3, Block R10.

Water content, dry density, and degree of saturation at five depths in direction 20°.

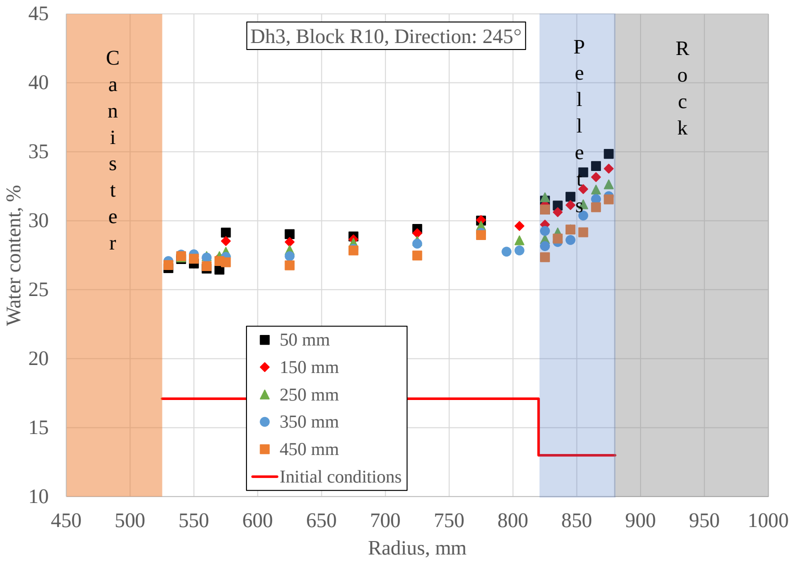


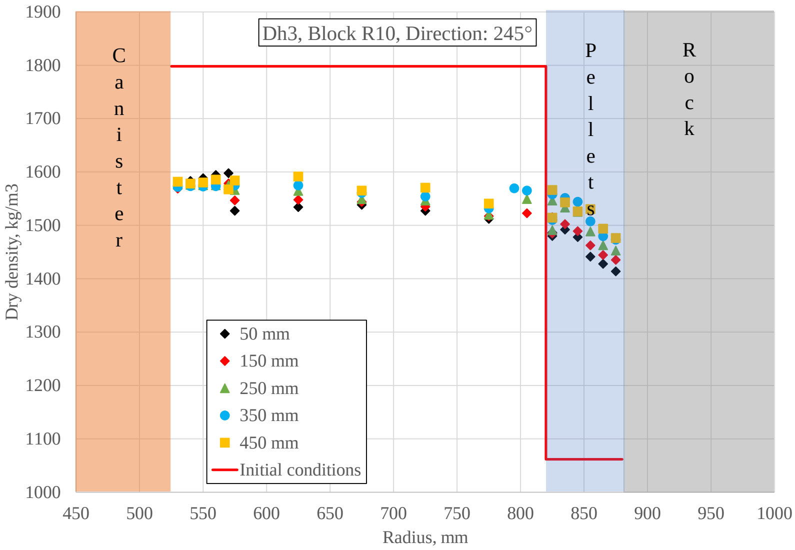


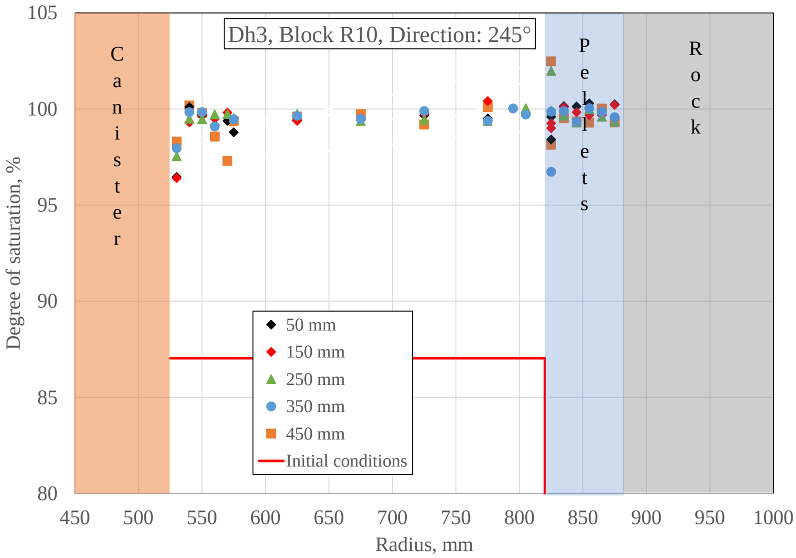


Appendix 2-4c Dh3, Block R10.

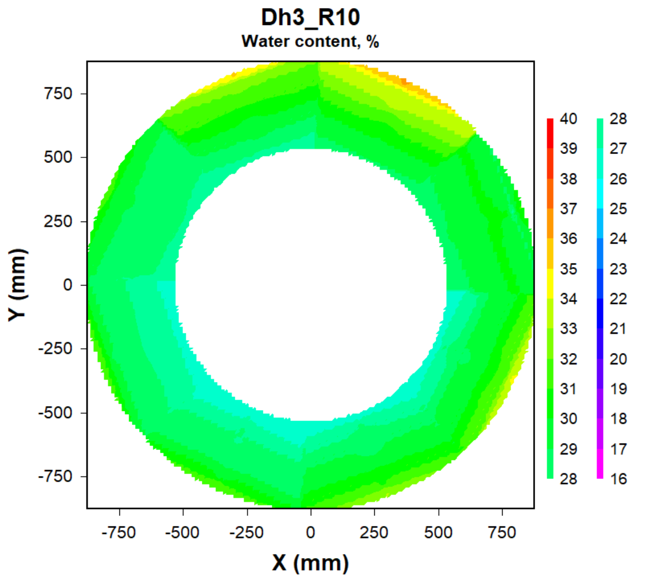
Water content, dry density, and degree of saturation at five depths in direction 245°.

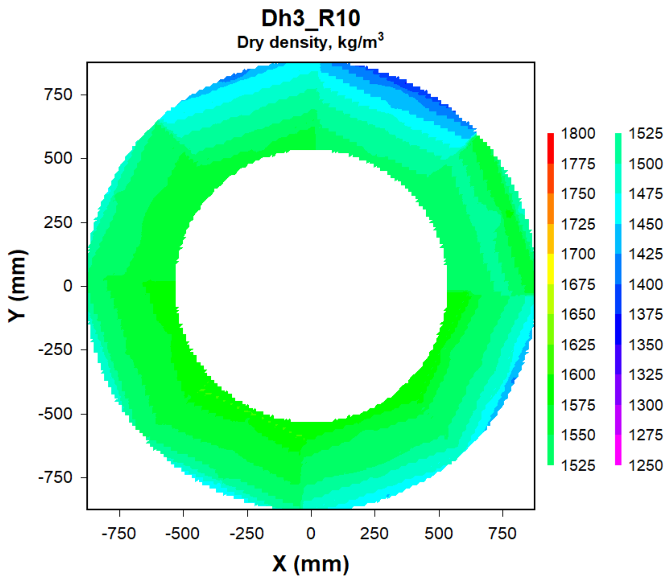


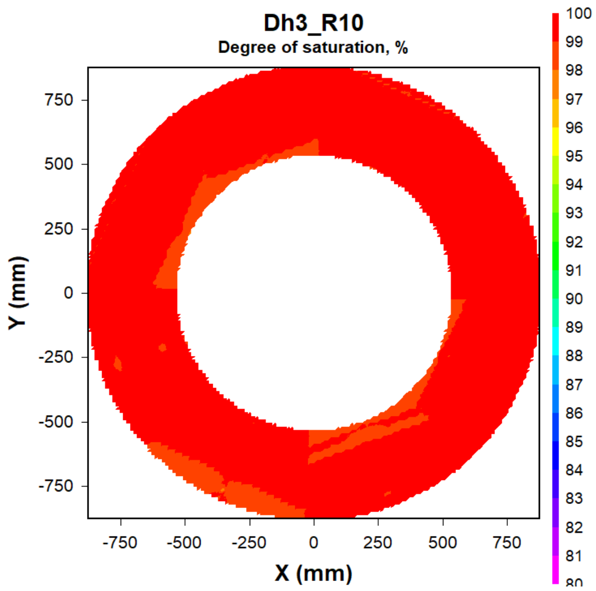




Appendix 2-4d Dh3, Block R10.
Water content, dry density, and degree of saturation distribution.

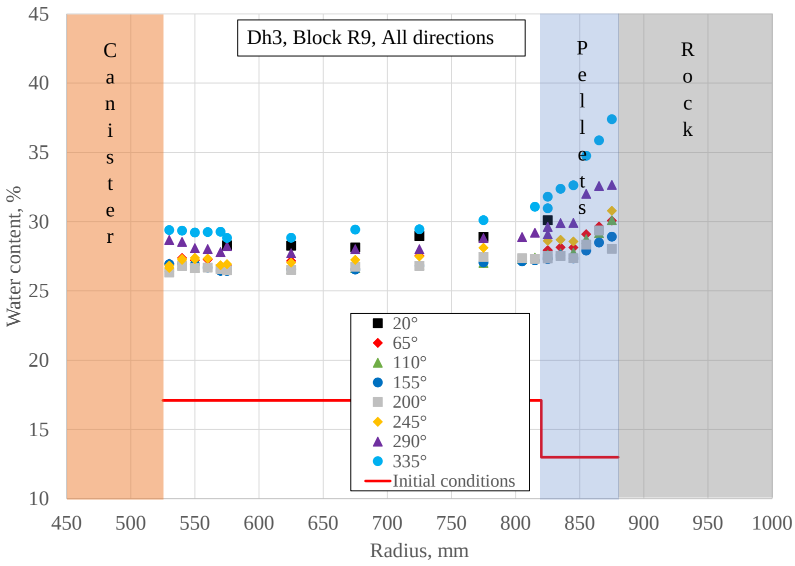


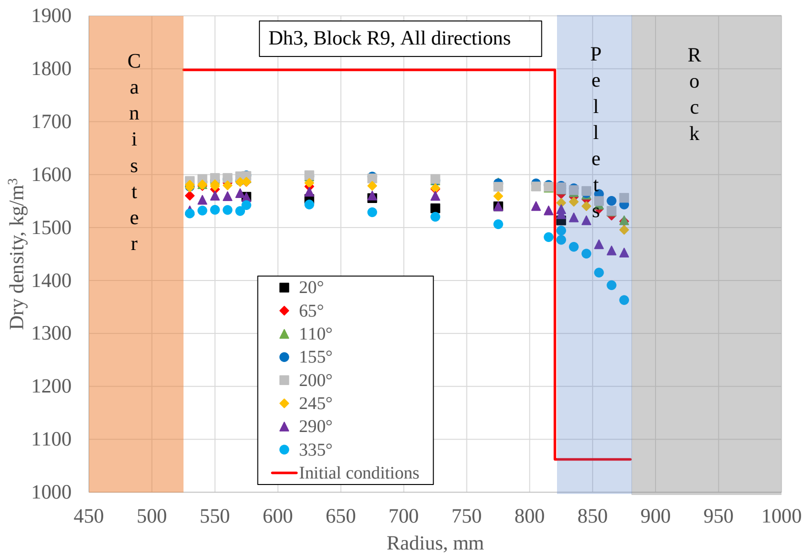


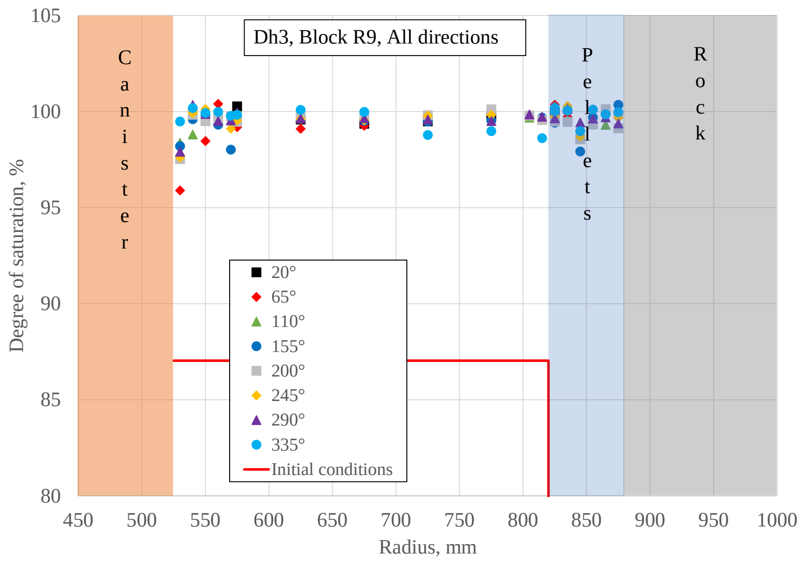


Appendix 2-5a Dh3, Block R9.

Water content, dry density, and degree of saturation in eight directions.

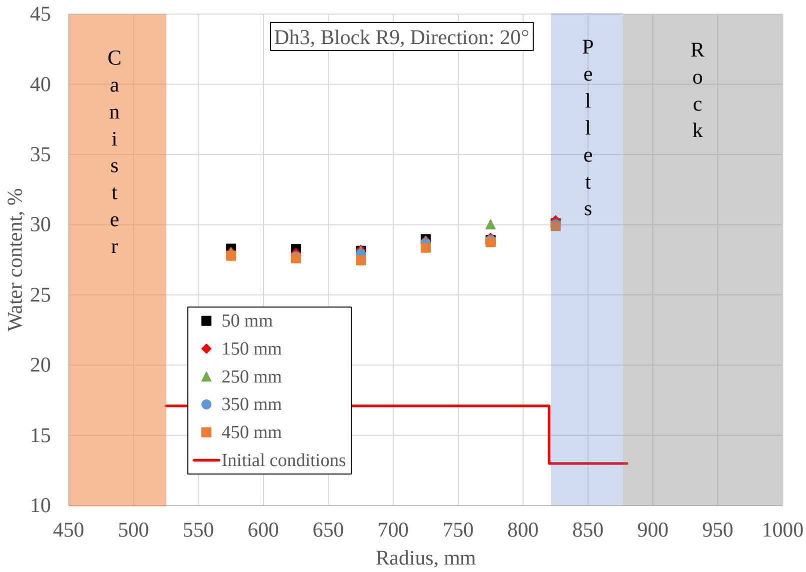


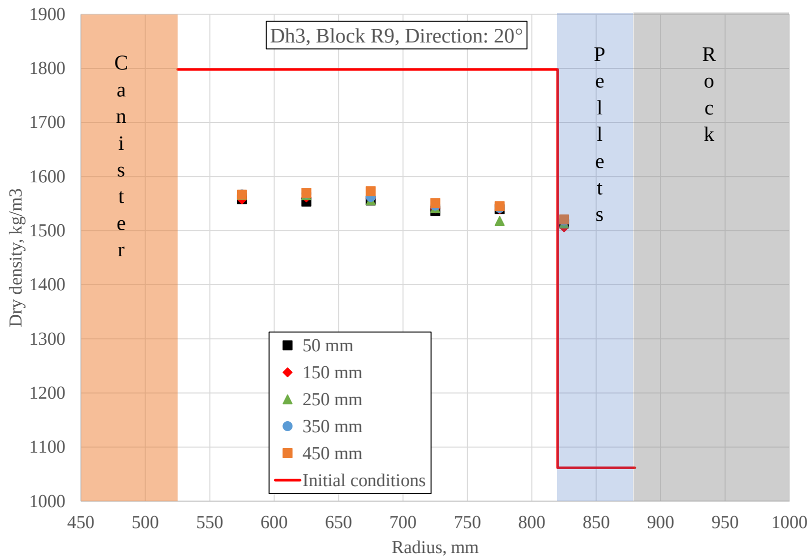


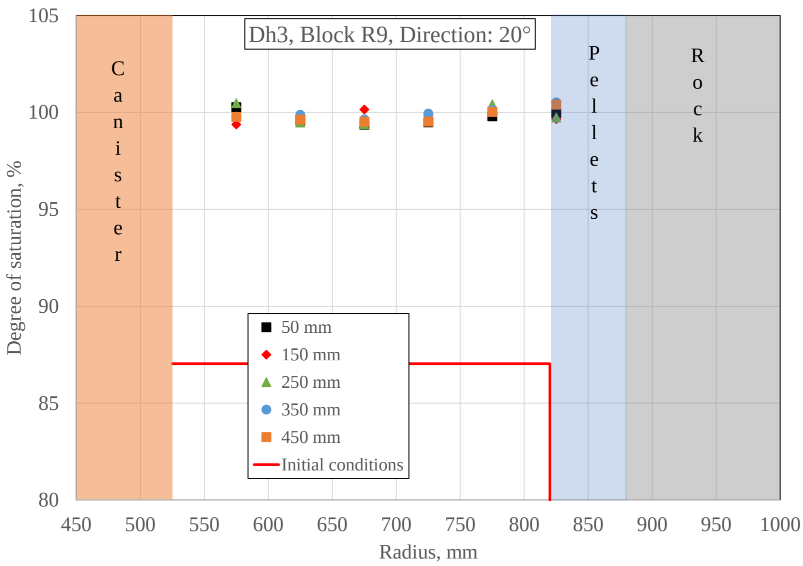


Appendix 2-5b Dh3, Block R9.

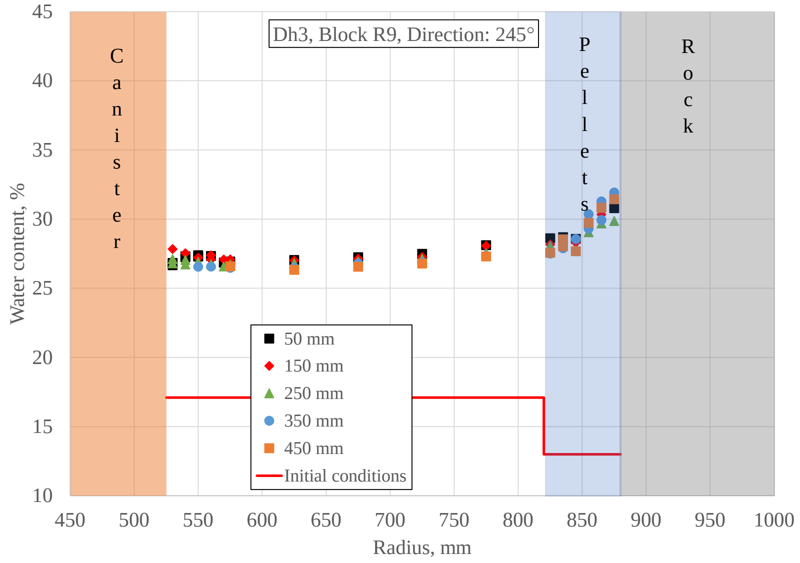
Water content, dry density, and degree of saturation at five depths in direction 20°.

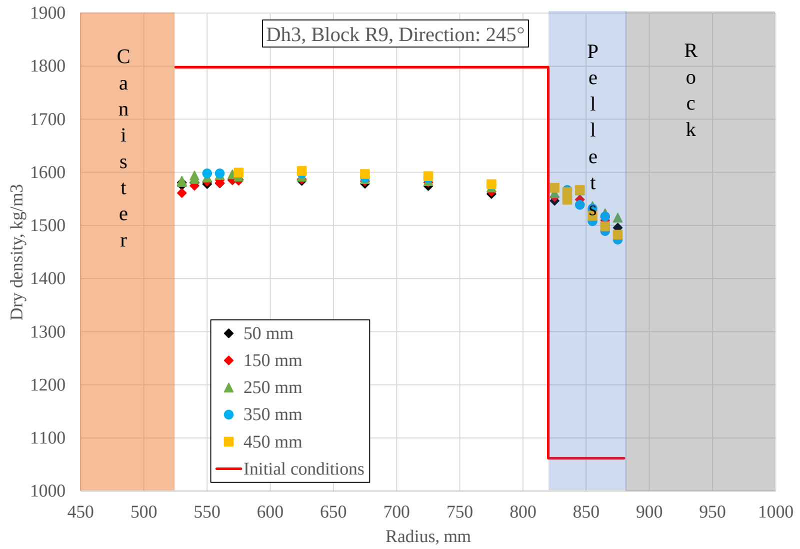


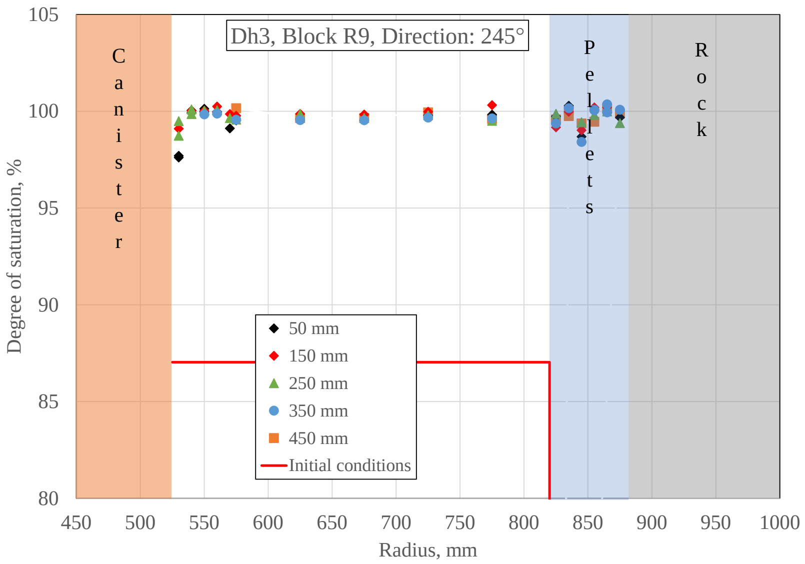




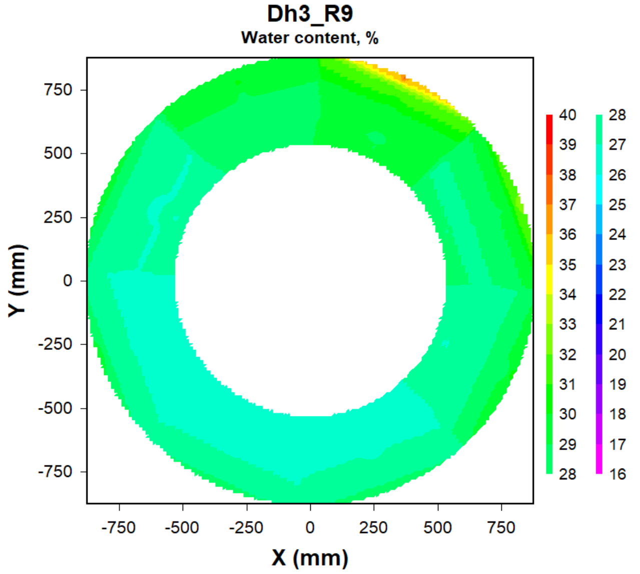
Appendix 2-5c Dh3, Block R9.
Water content, dry density, and degree of saturation at five depths in direction 245°.

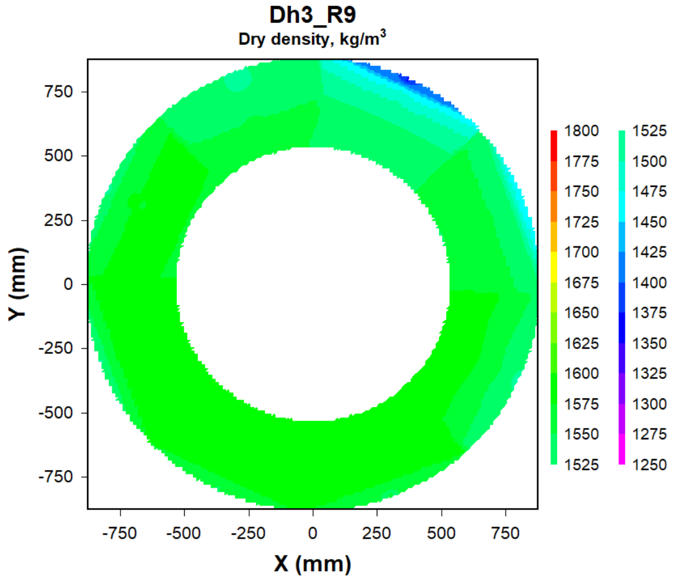


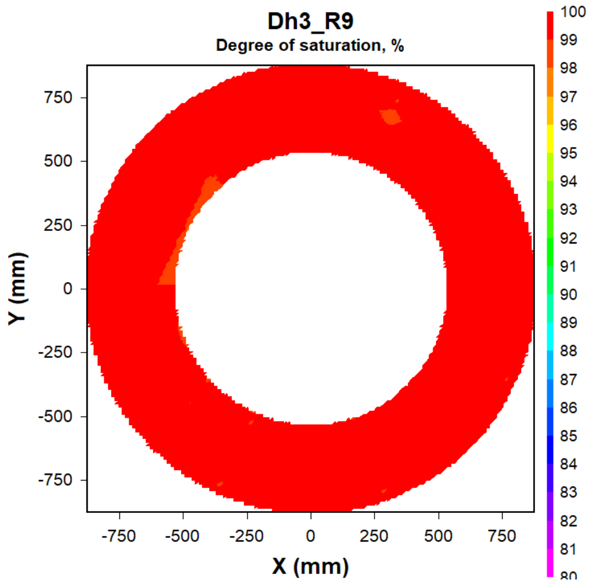




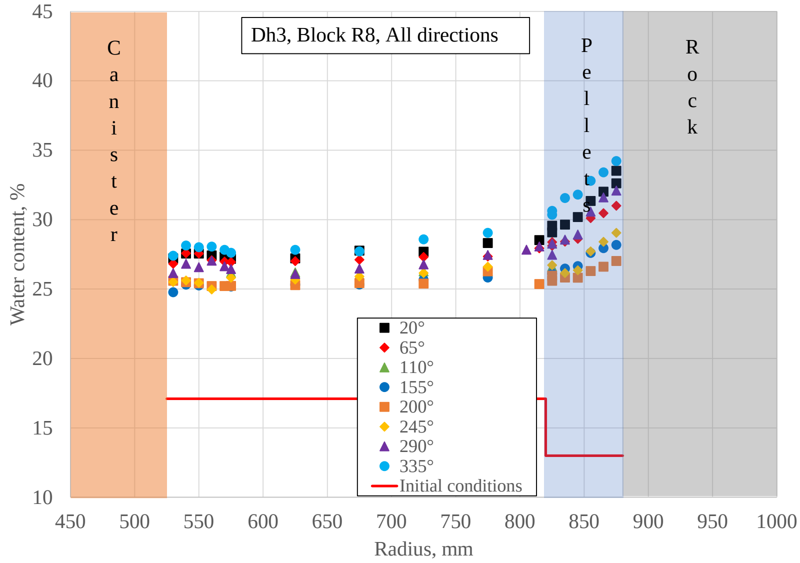
Appendix 2-5d Dh3, Block R9.
Water content, dry density, and degree of saturation distribution.

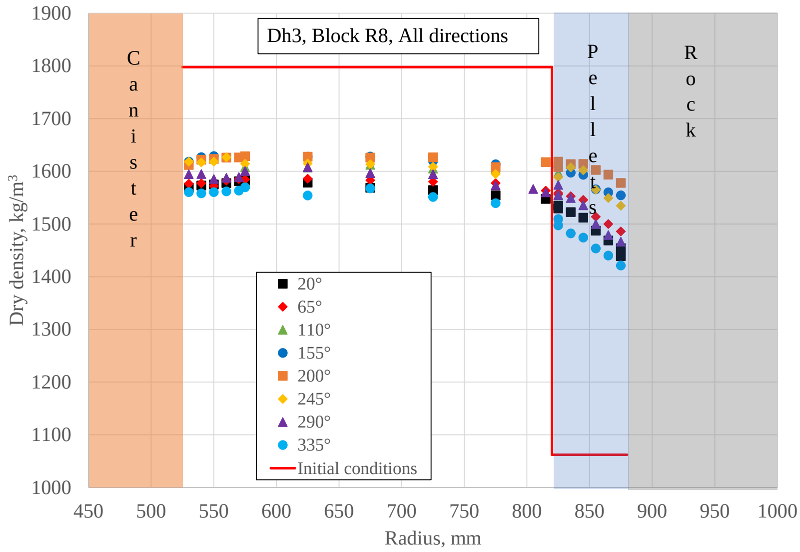


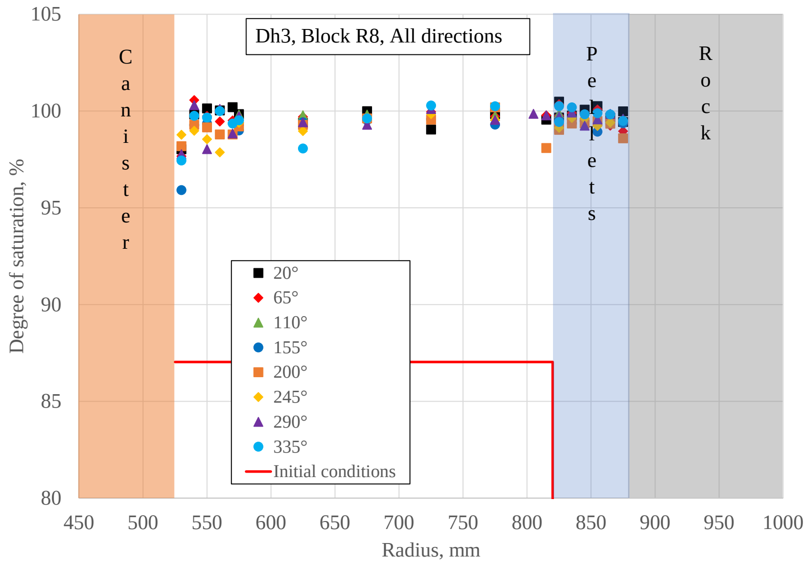




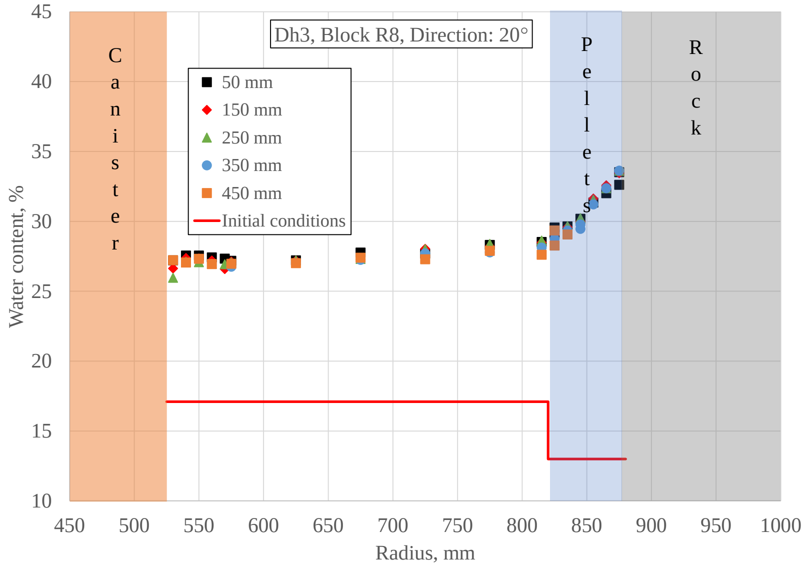
Appendix 2-6a Dh3, Block R8.
Water content, dry density, and degree of saturation in eight directions.

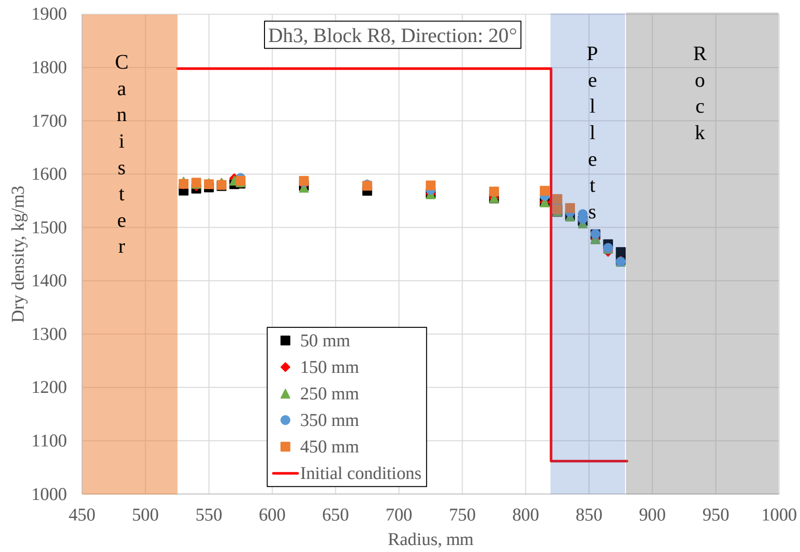


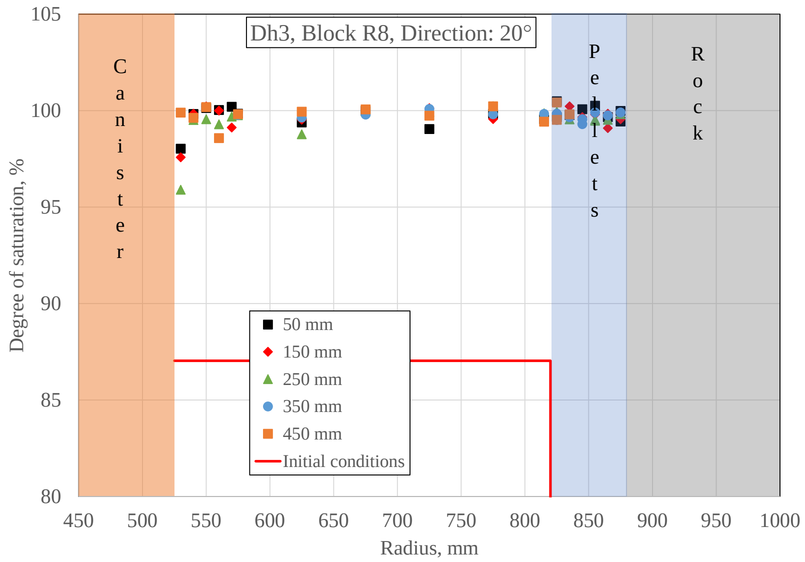




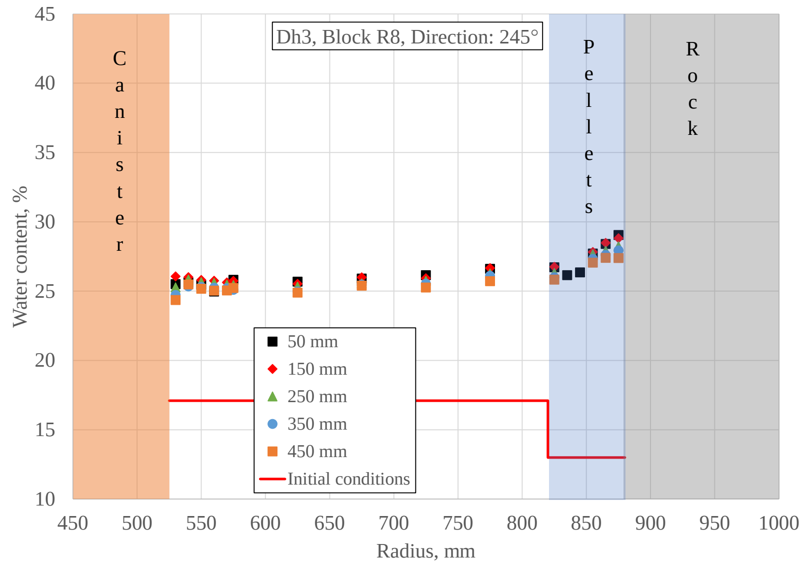
Appendix 2-6b Dh3, Block R8.
Water content, dry density, and degree of saturation at five depths in direction 20°.

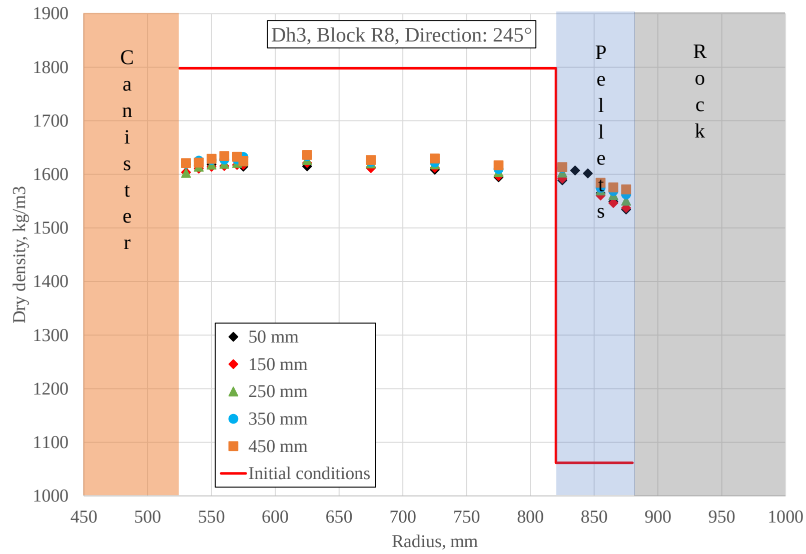


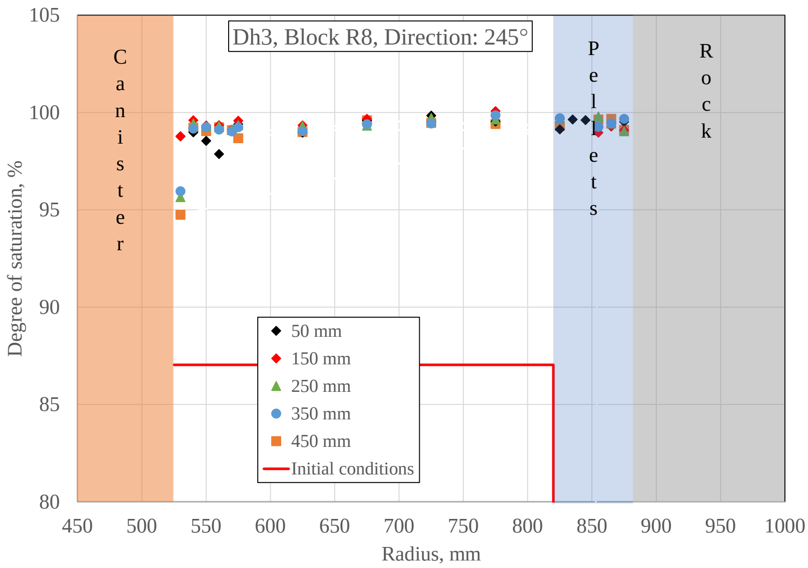




Appendix 2-6c Dh3, Block R8.
Water content, dry density, and degree of saturation at five depths in direction 245°.

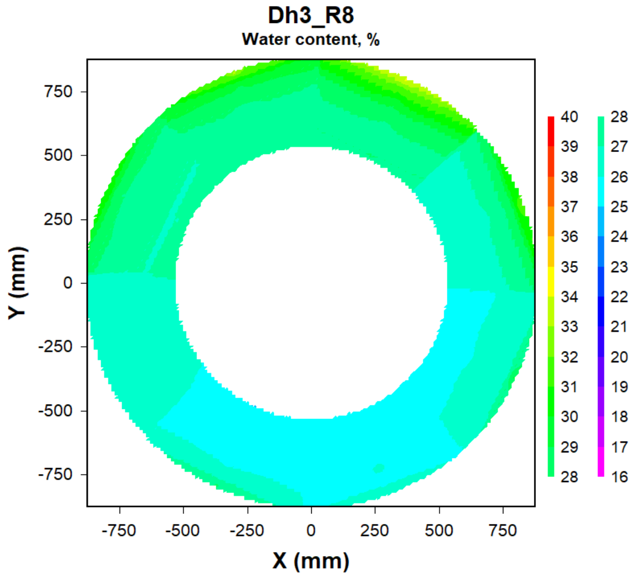


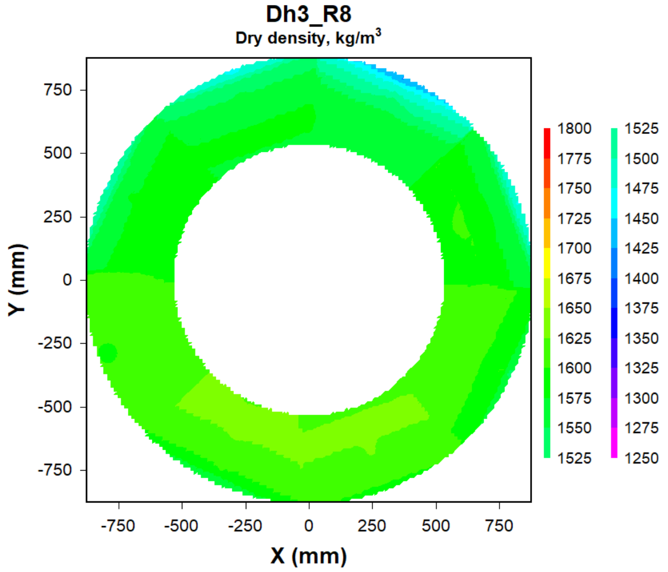


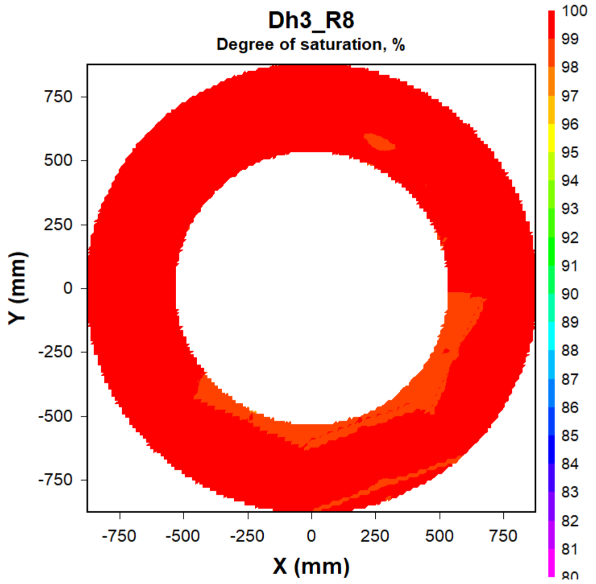


Appendix 2-6d Dh3, Block R8.

Water content, dry density, and degree of saturation distribution.

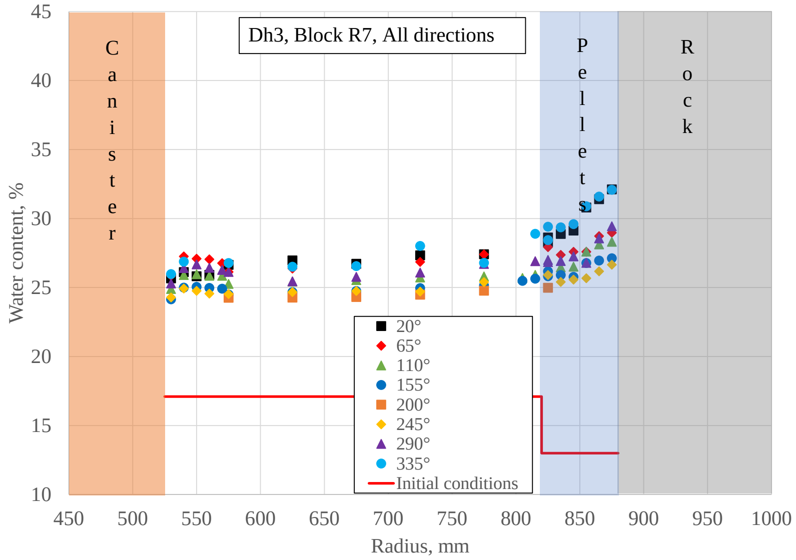


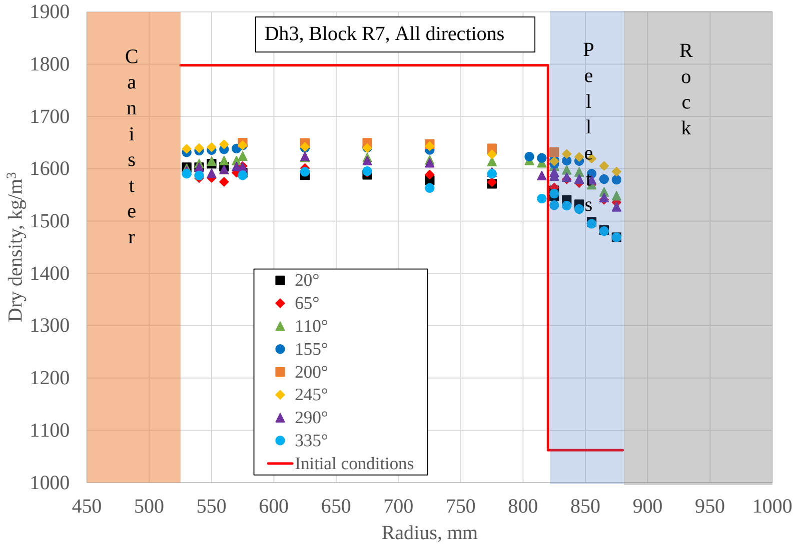


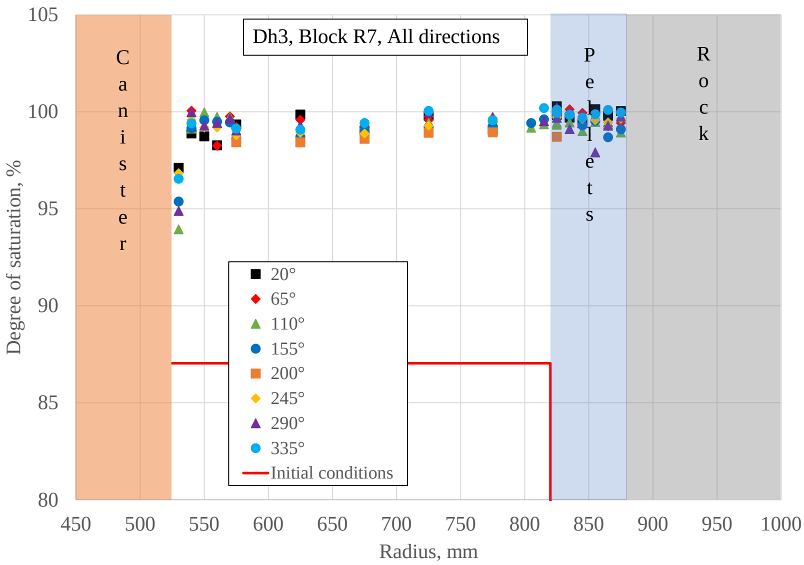


Appendix 2-7a Dh3, Block R7.

Water content, dry density, and degree of saturation in eight directions.

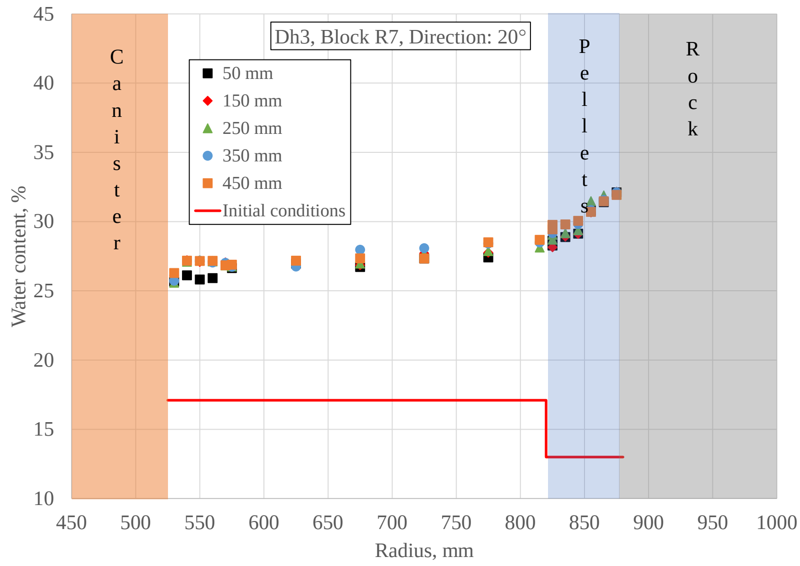


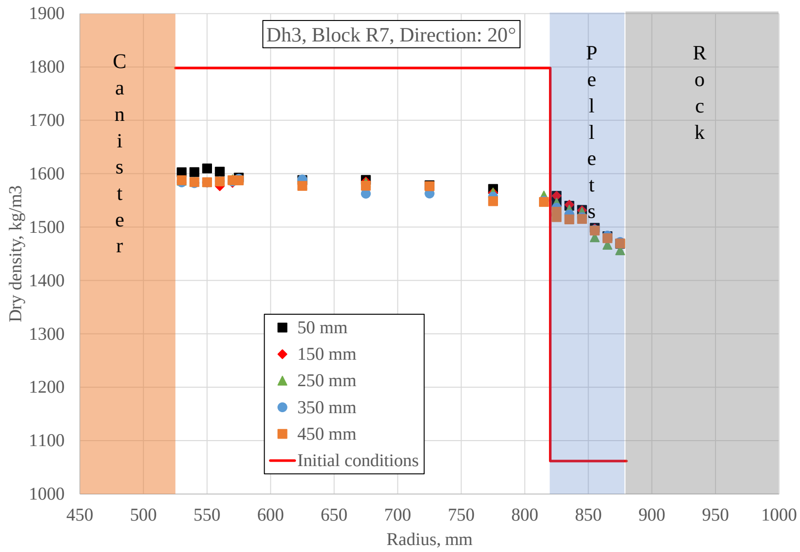


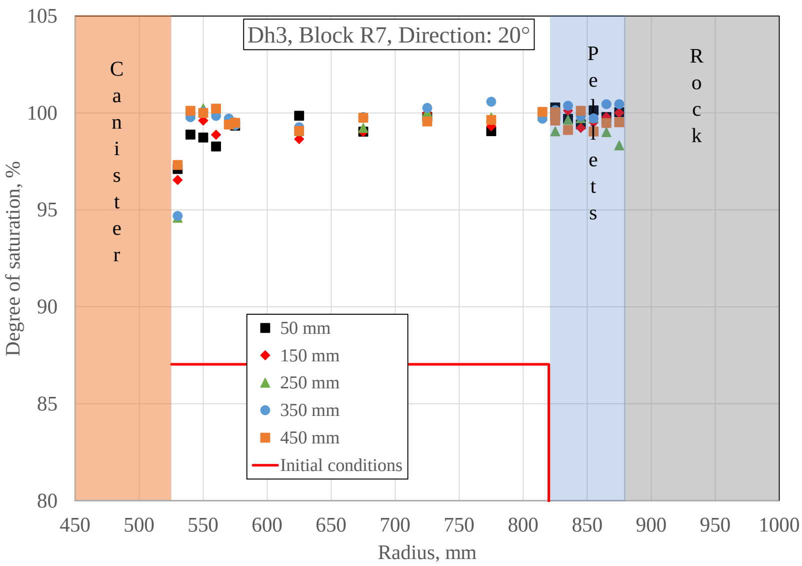


Appendix 2-7b Dh3, Block R7.

Water content, dry density, and degree of saturation at five depths in direction 20°.

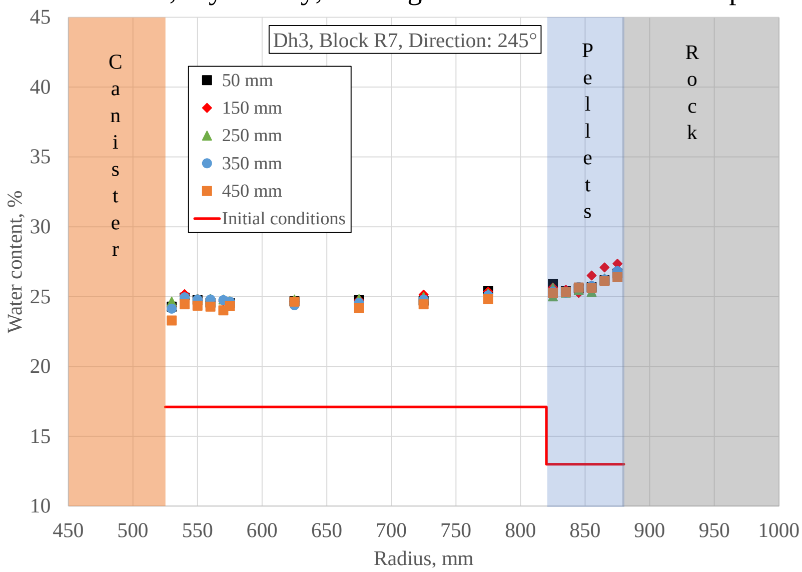


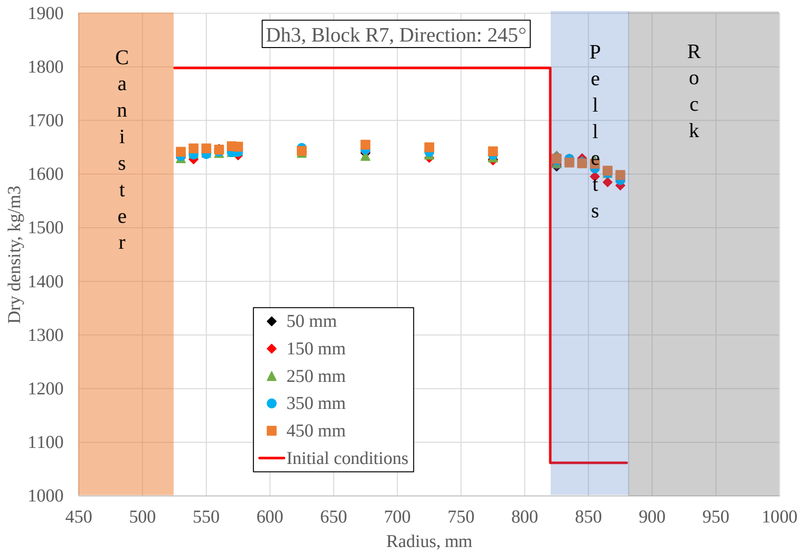


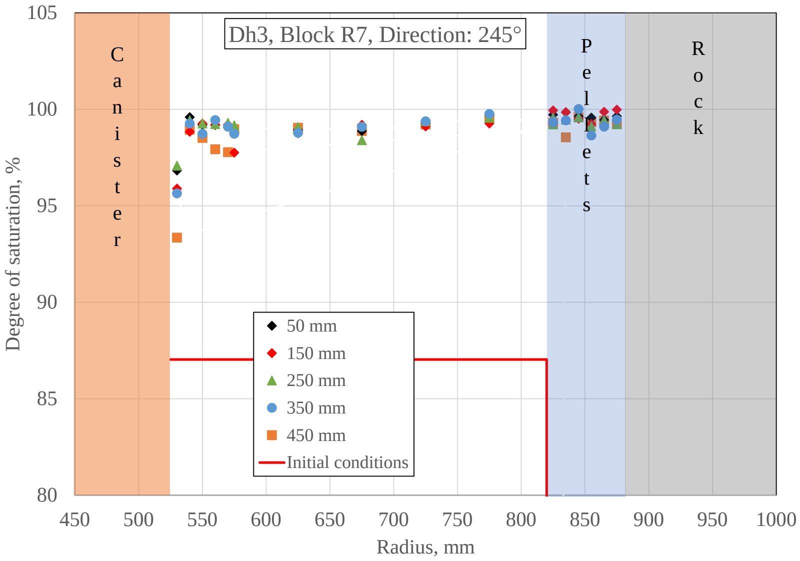


Appendix 2-7c Dh3, Block R7.

Water content, dry density, and degree of saturation at five depths in direction 245°.

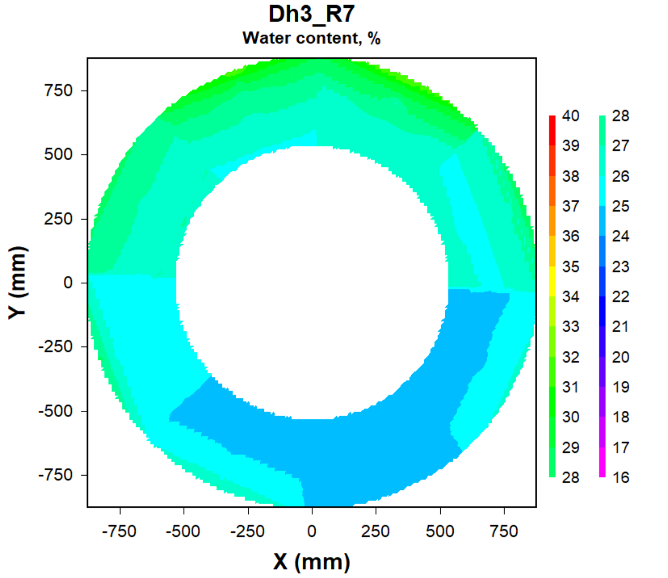


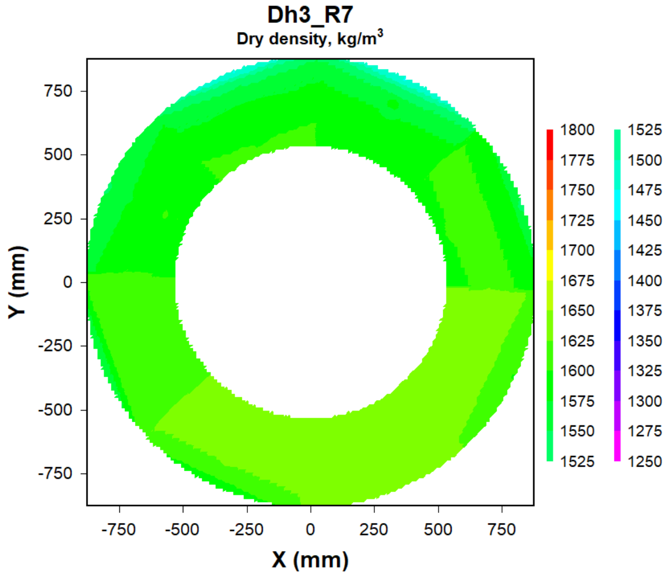


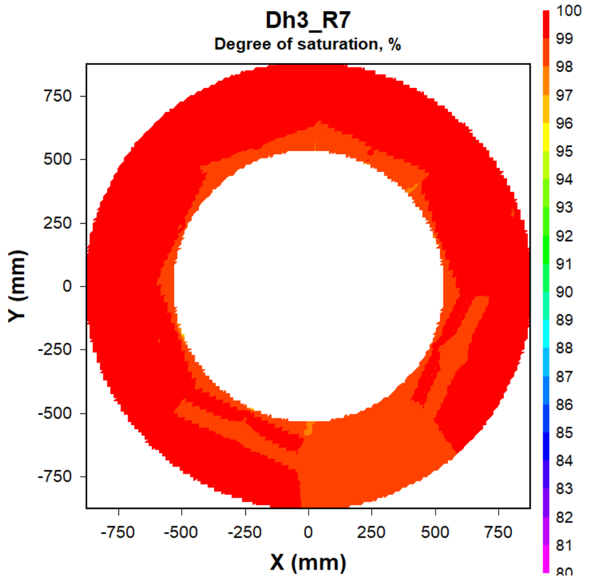


Appendix 2-7d Dh3, Block R7.

Water content, dry density, and degree of saturation distribution.

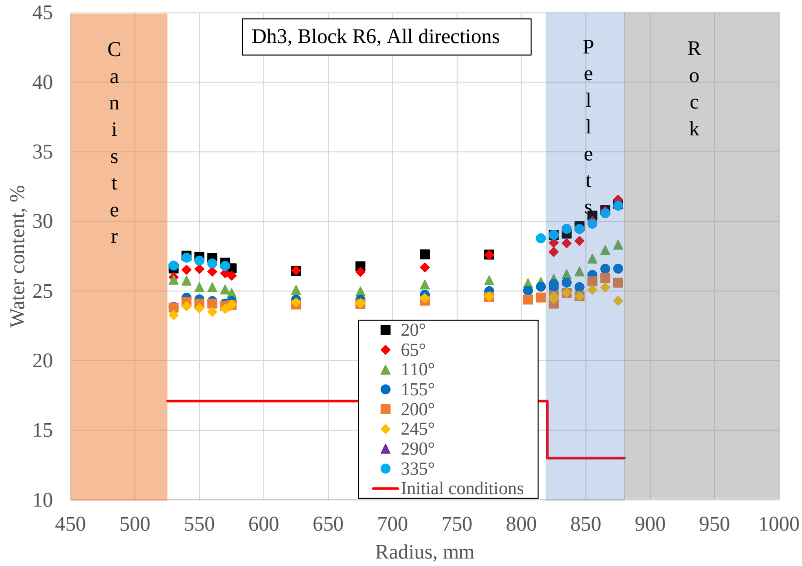


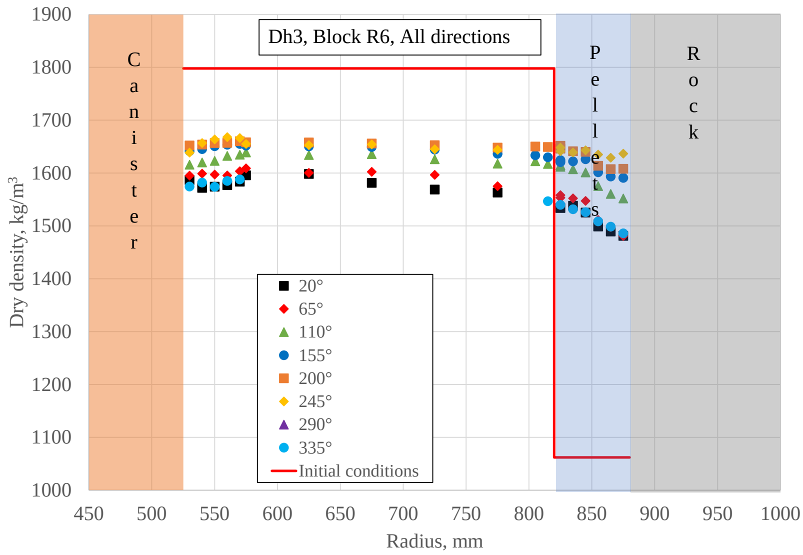


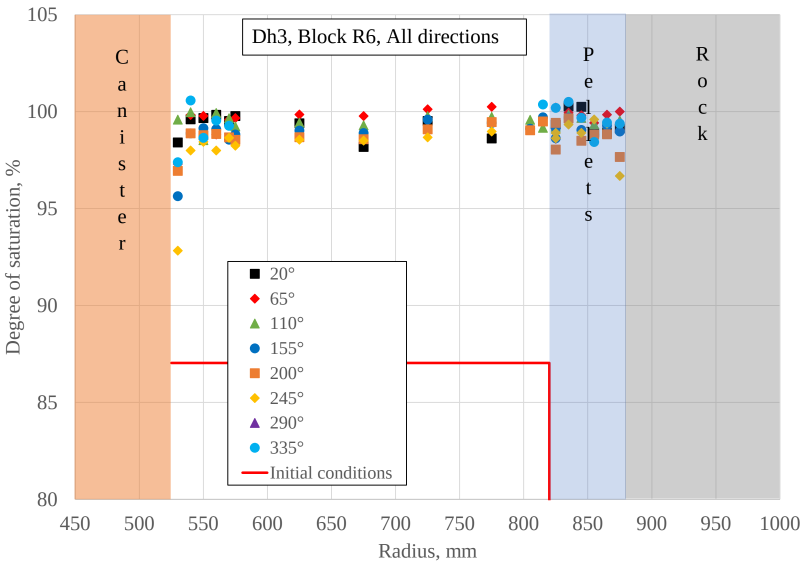


Appendix 2-8a Dh3, Block R6.

Water content, dry density, and degree of saturation in eight directions.

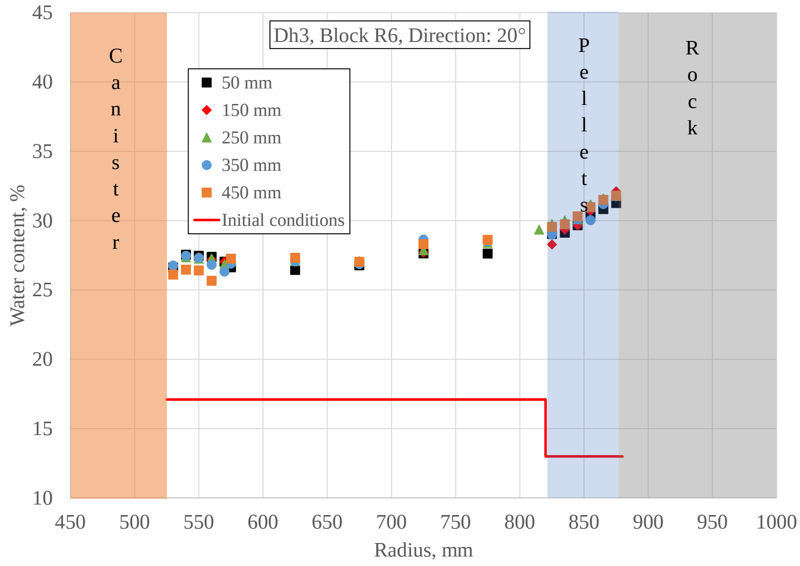


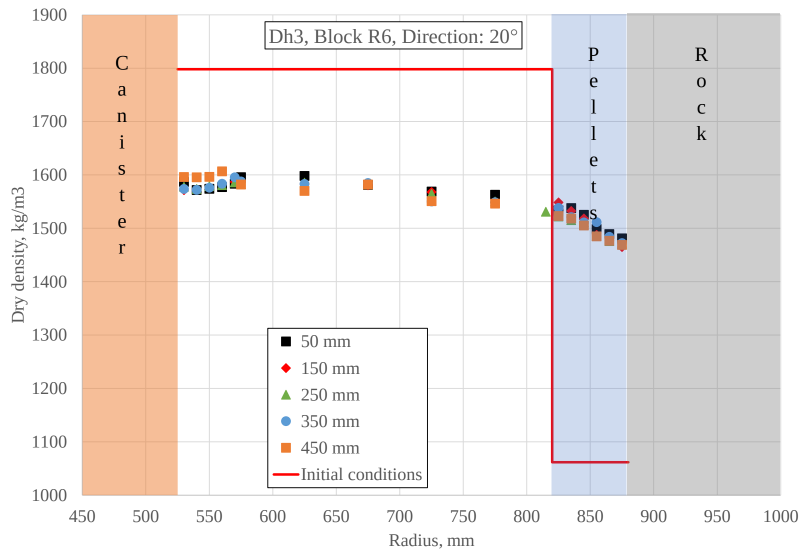


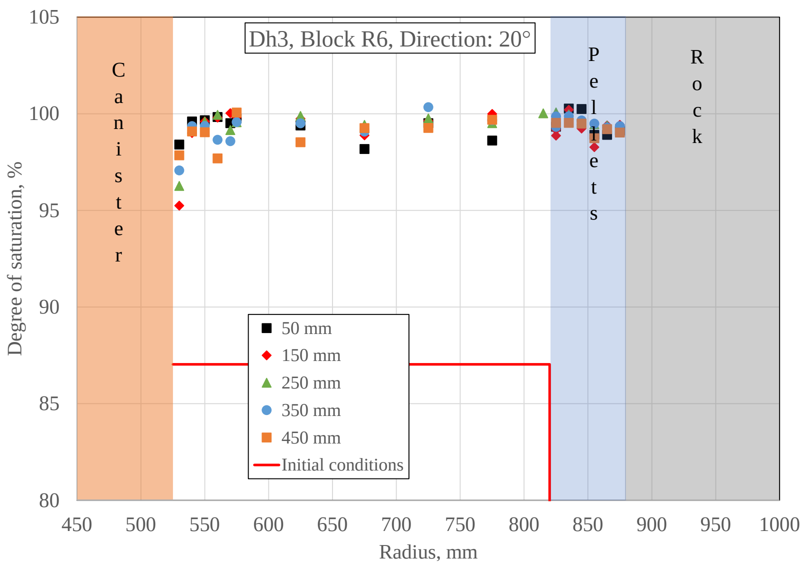


Appendix 2-8b Dh3, Block R6.

Water content, dry density, and degree of saturation at five depths in direction 20°.

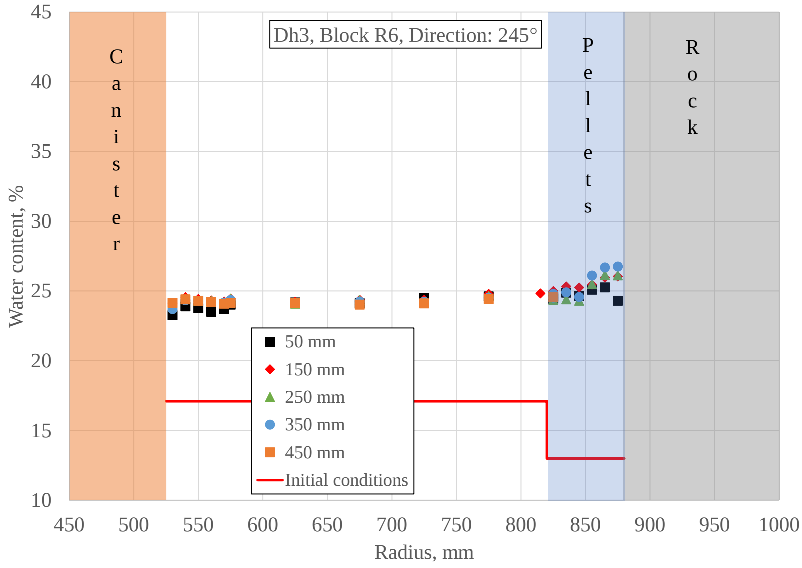


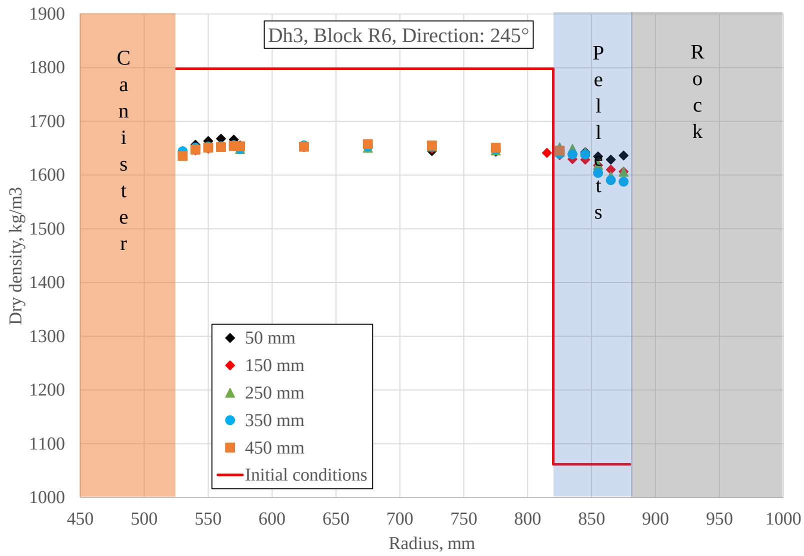


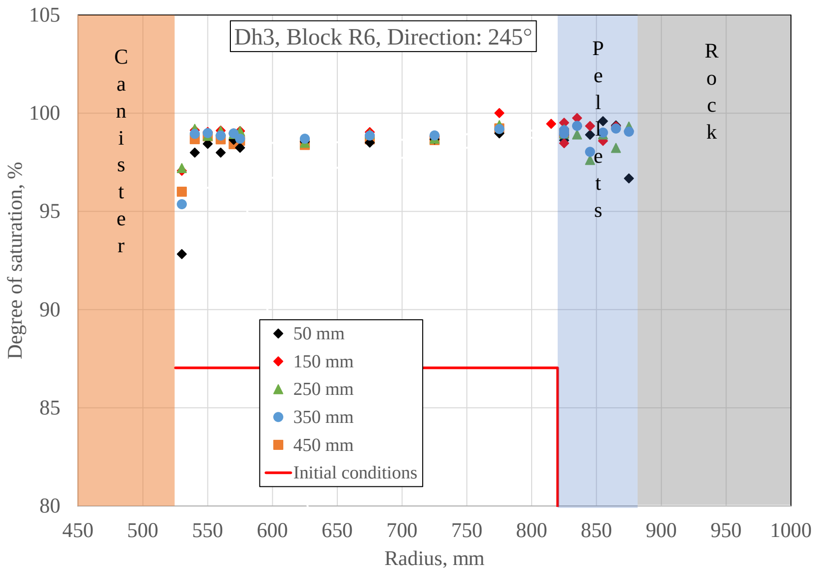


Appendix 2-8c Dh3, Block R6.

Water content, dry density, and degree of saturation at five depths in direction 245°.

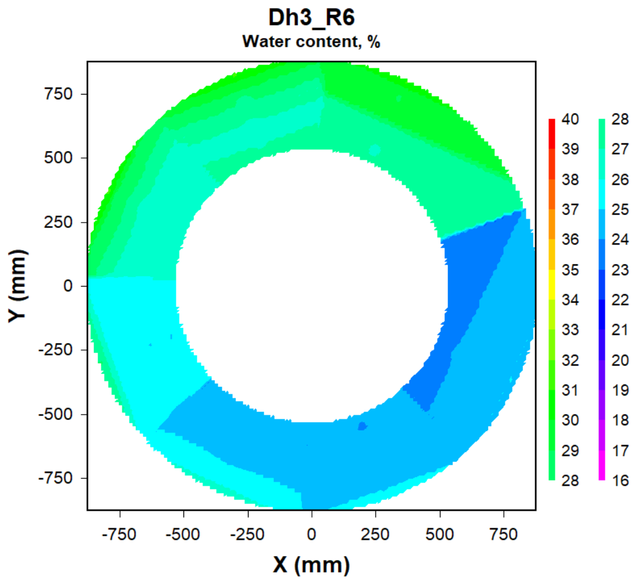


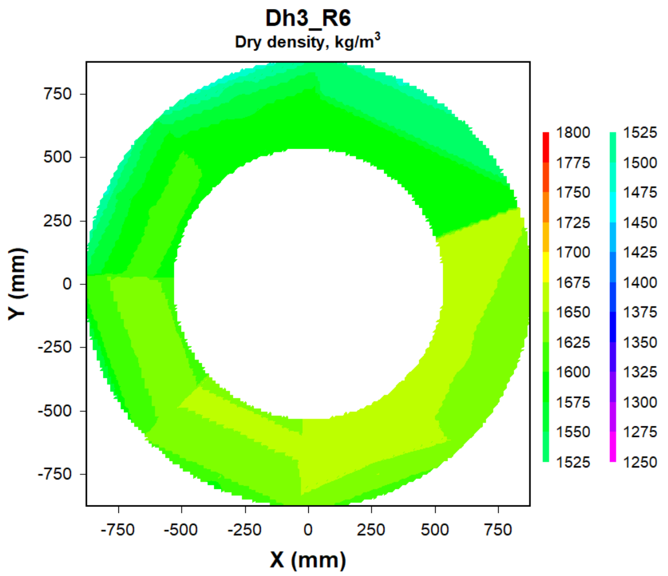


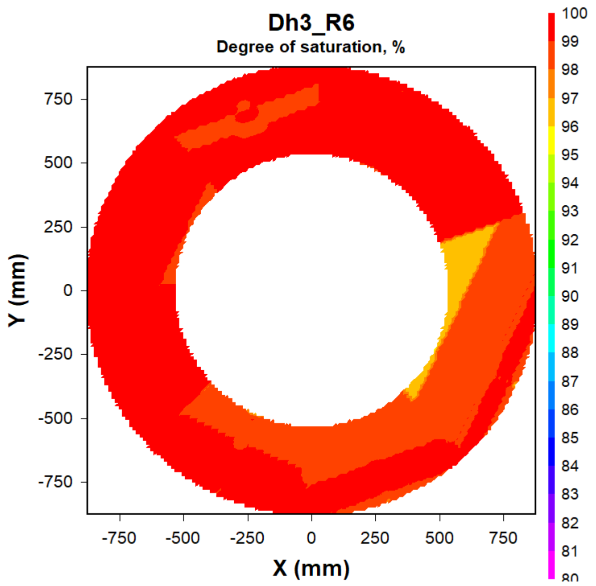


Appendix 2-8d Dh3, Block R6.

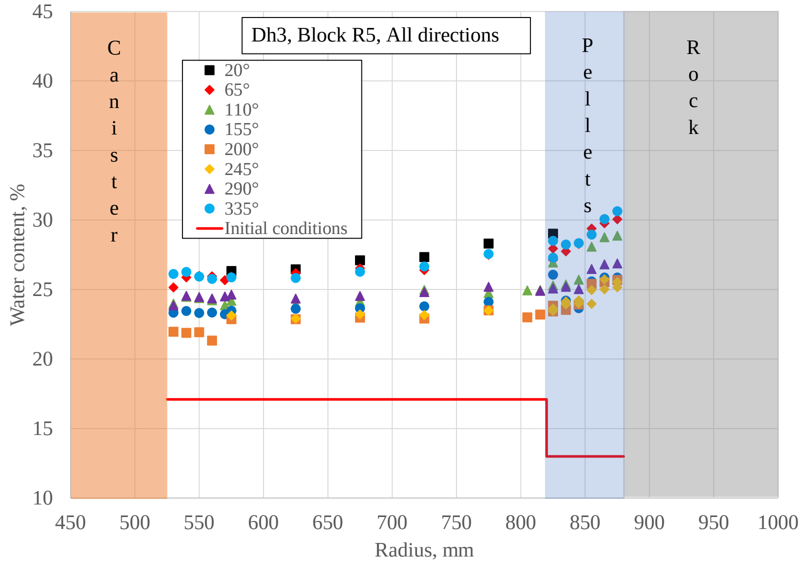
Water content, dry density, and degree of saturation distribution.

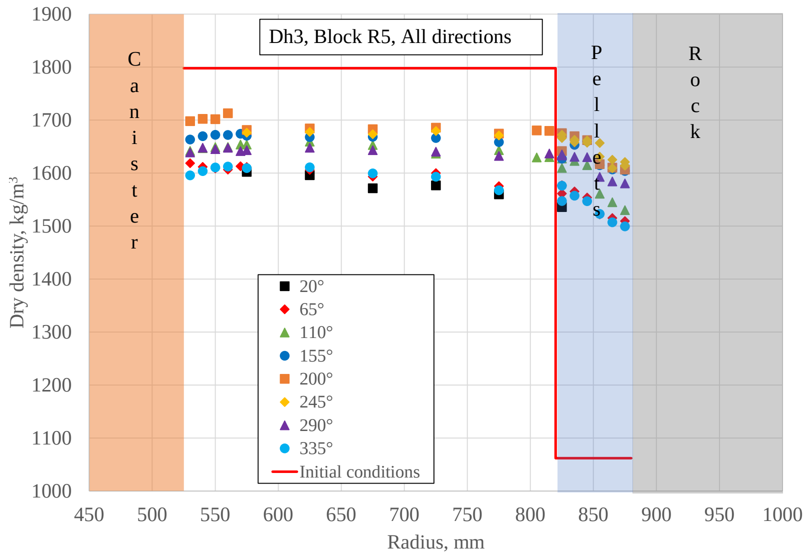


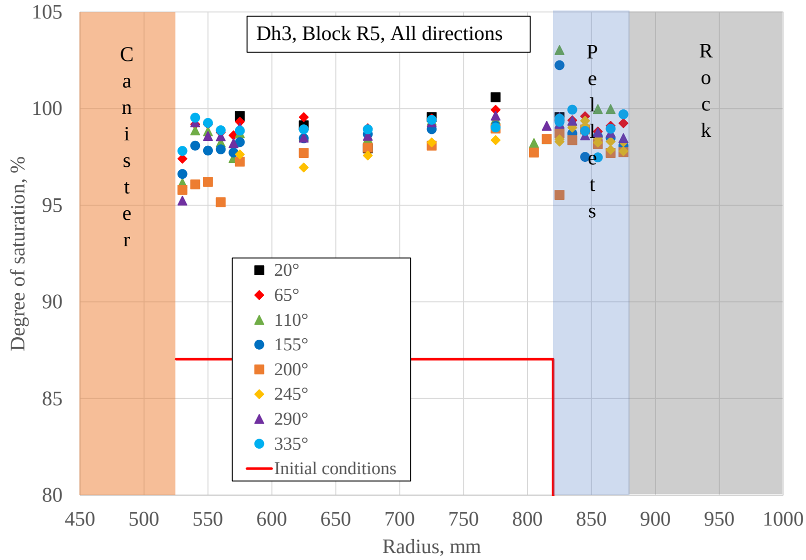




Appendix 2-9a Dh3, Block R5.
Water content, dry density, and degree of saturation in eight directions.

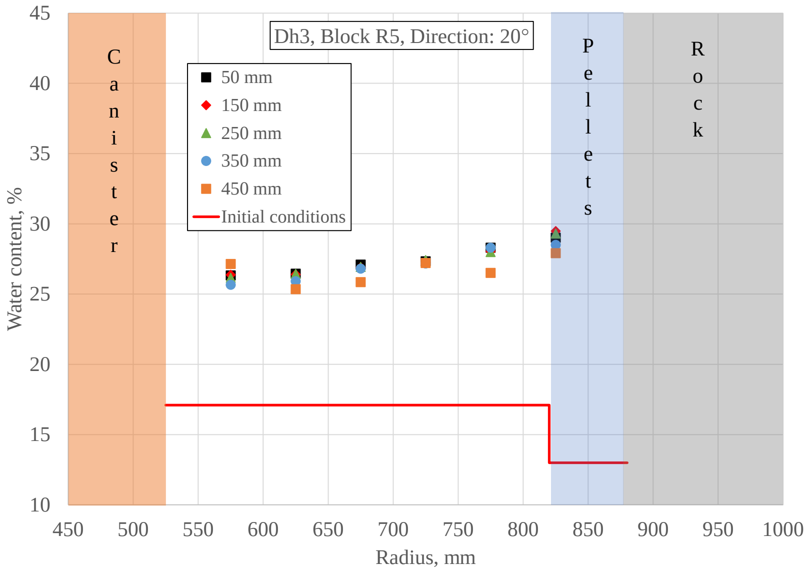


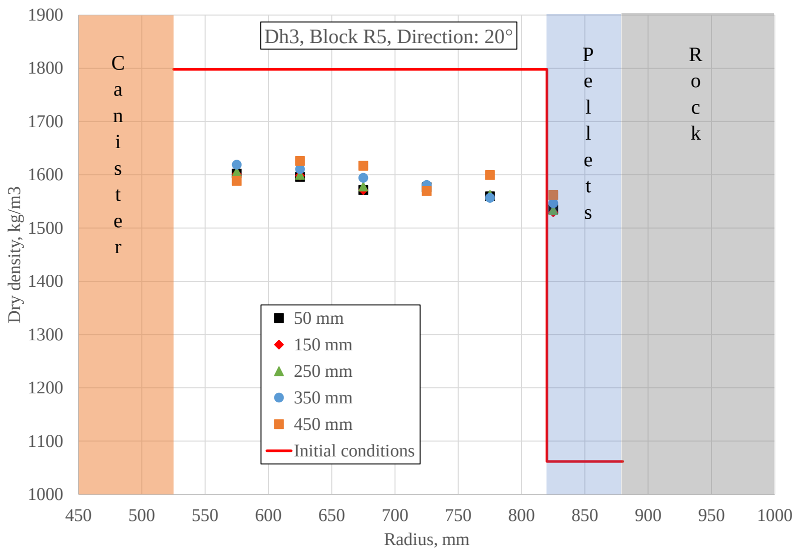


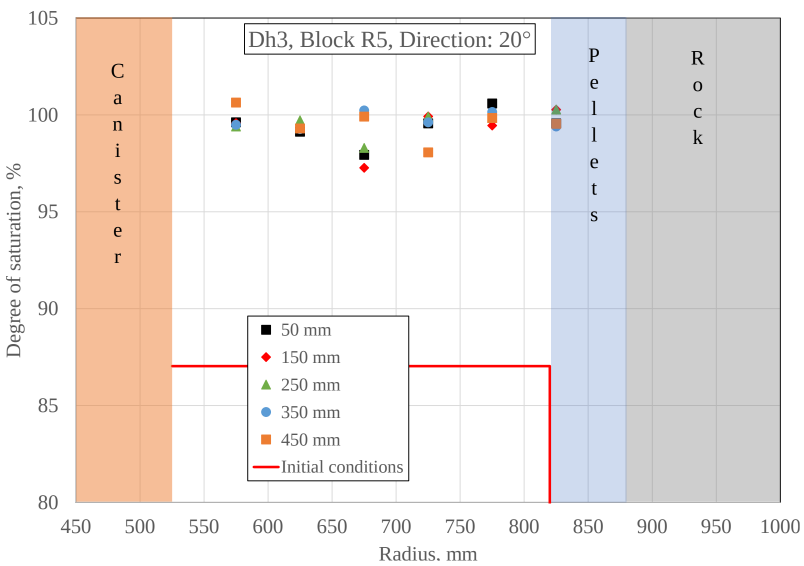


Appendix 2-9b Dh3, Block R5.

Water content, dry density, and degree of saturation at five depths in direction 20°.

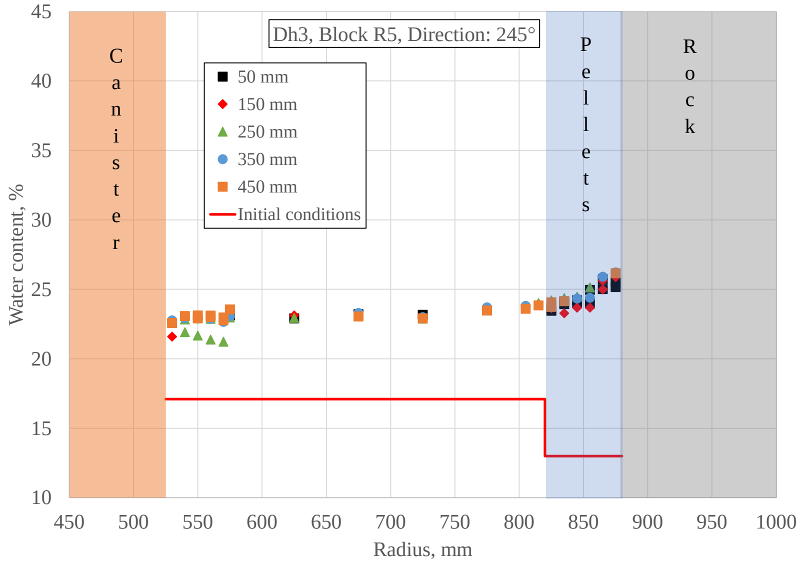


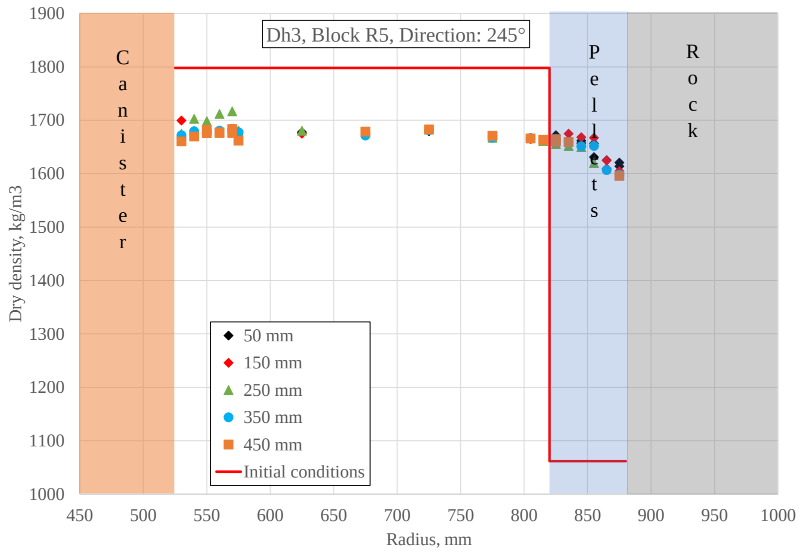


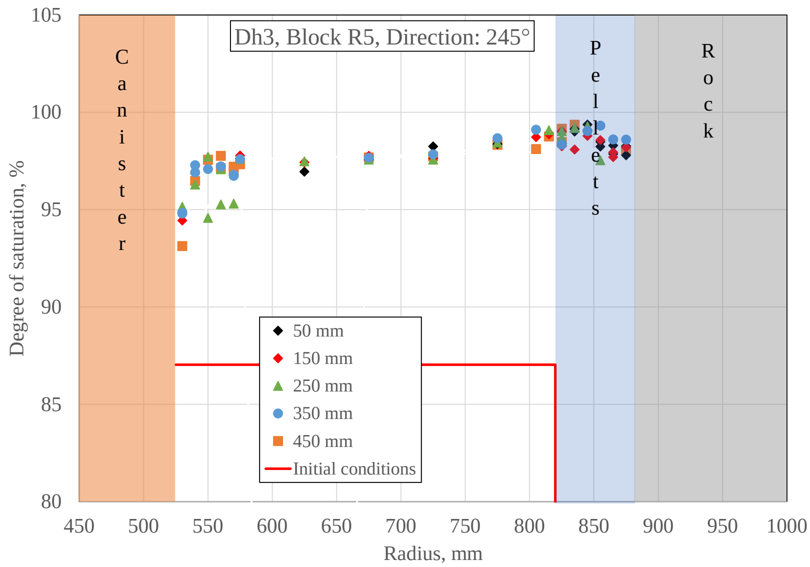


Appendix 2-9c Dh3, Block R5.

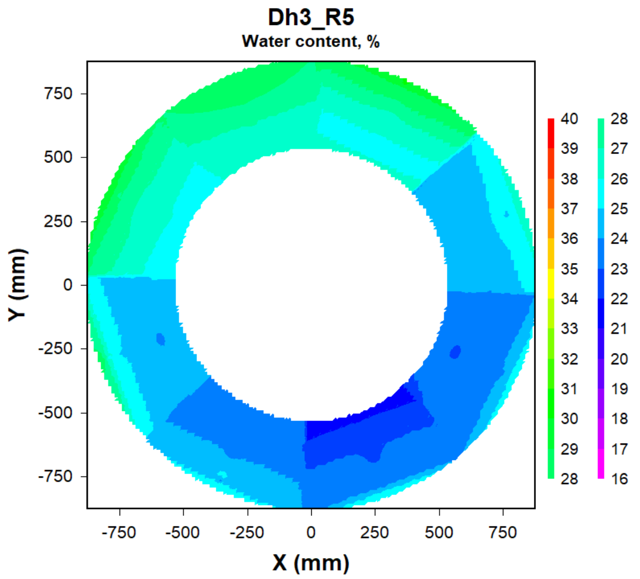
Water content, dry density, and degree of saturation at five depths in direction 245°.

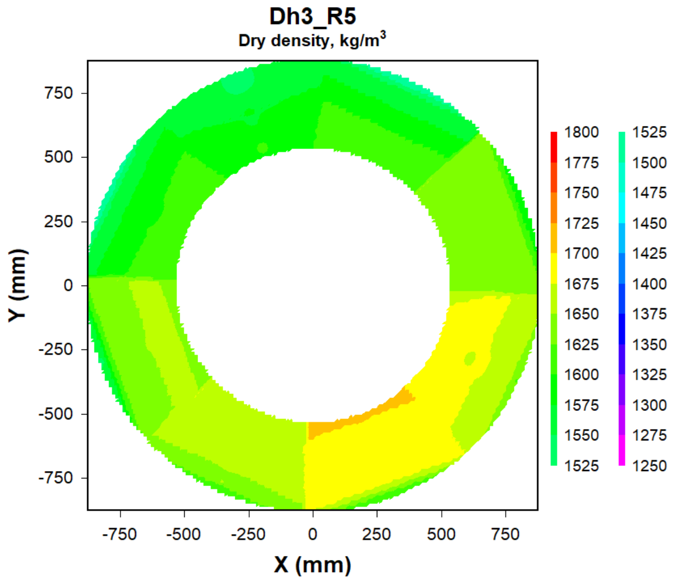


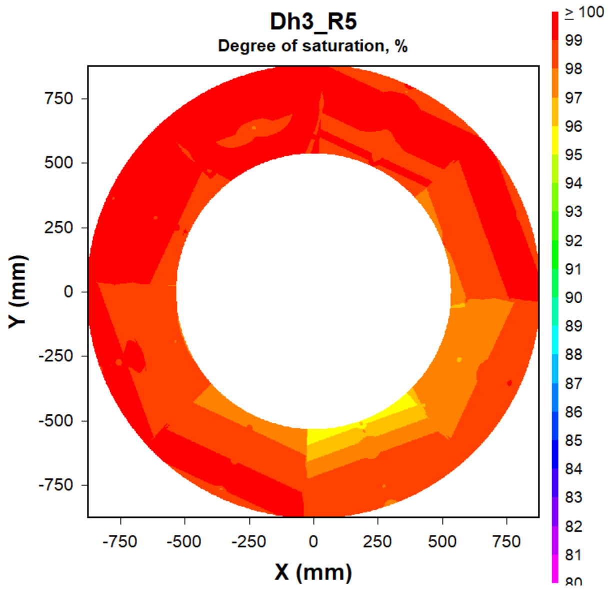




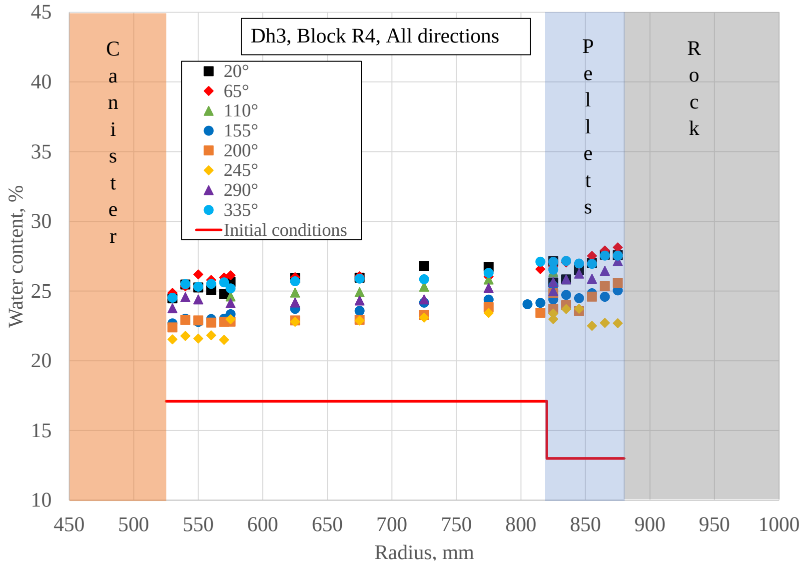
Appendix 2-9d Dh3, Block R5.
Water content, dry density, and degree of saturation distribution.

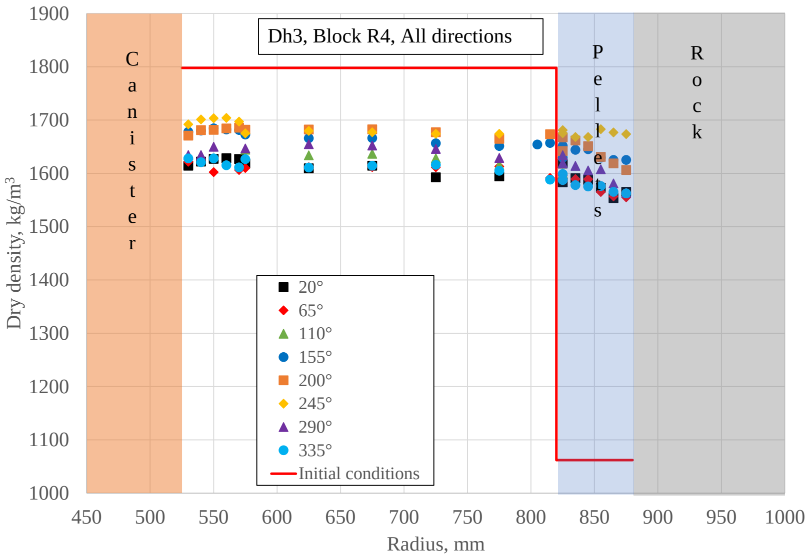


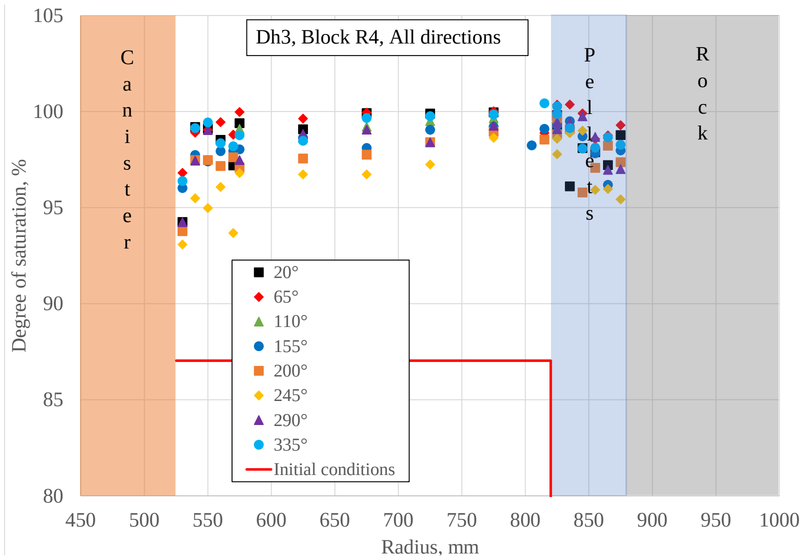




Appendix 2-10a Dh3, Block R4.
Water content, dry density, and degree of saturation in eight directions.

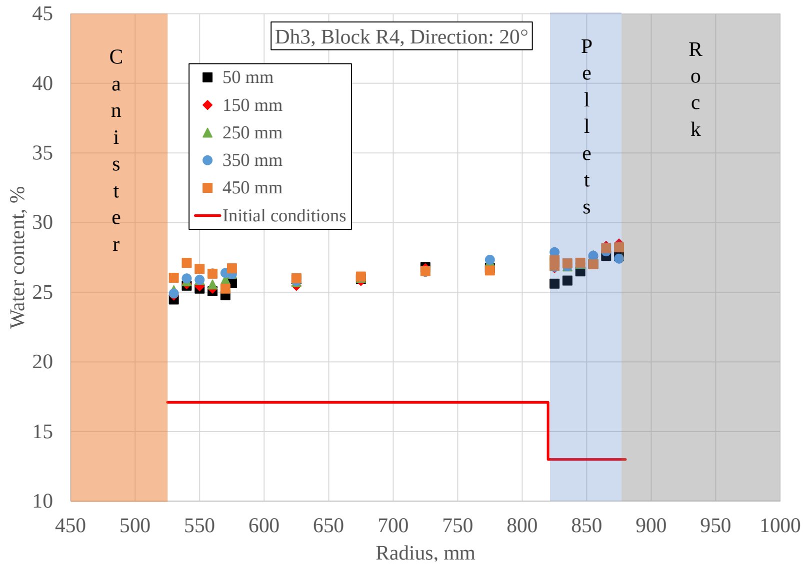


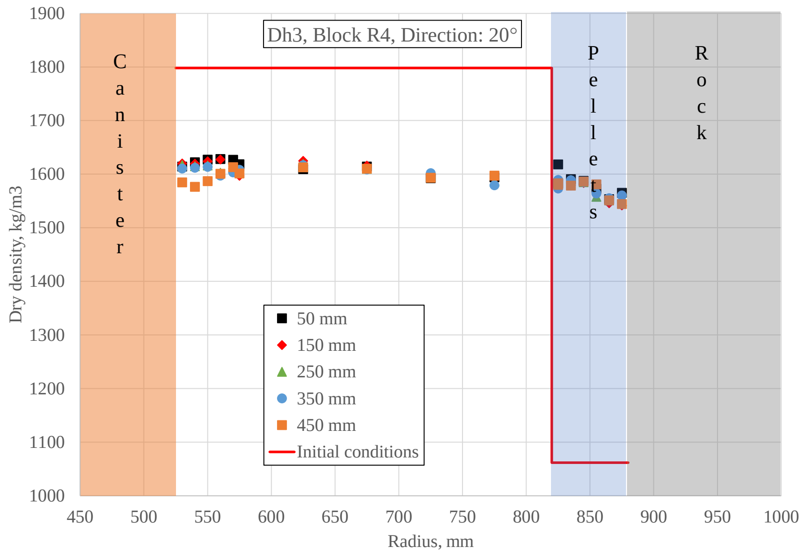


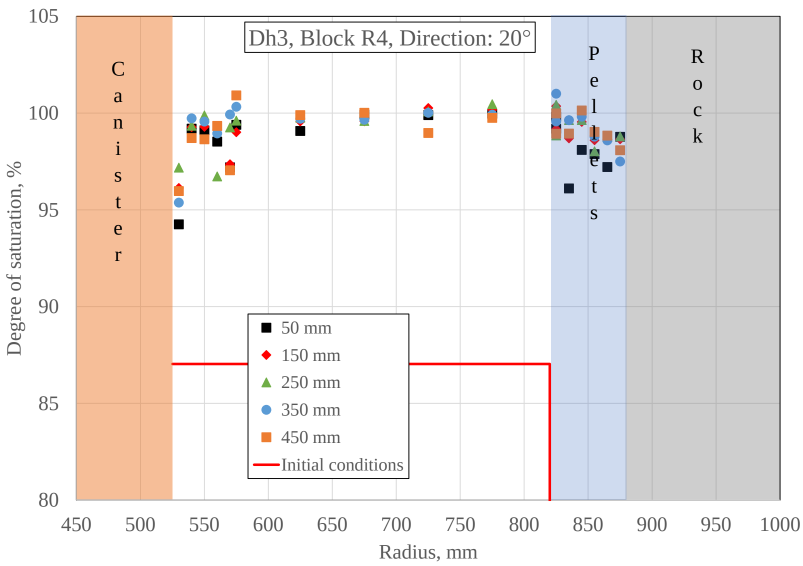


Appendix 2-10b Dh3, Block R4.

Water content, dry density, and degree of saturation at five depths in direction 20°.

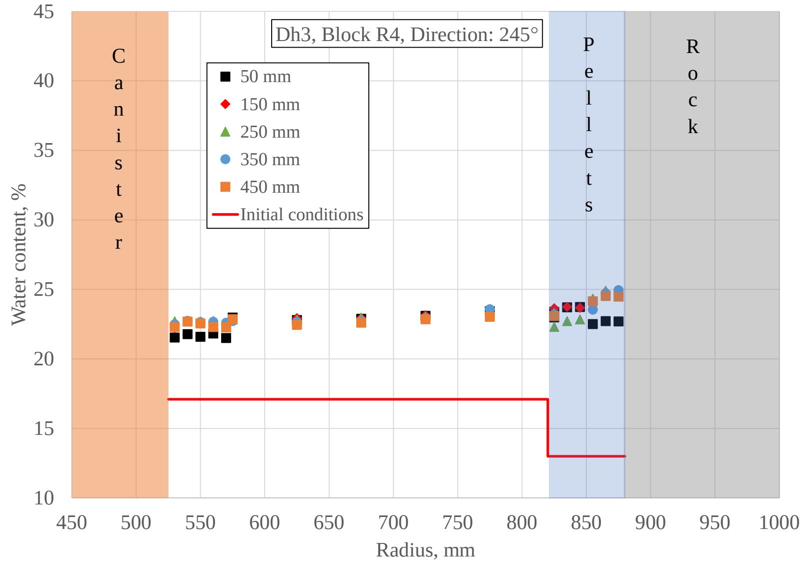


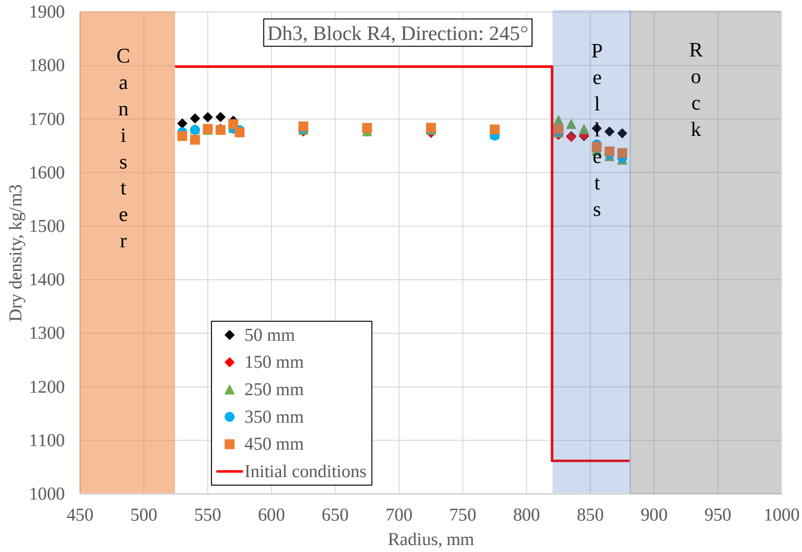


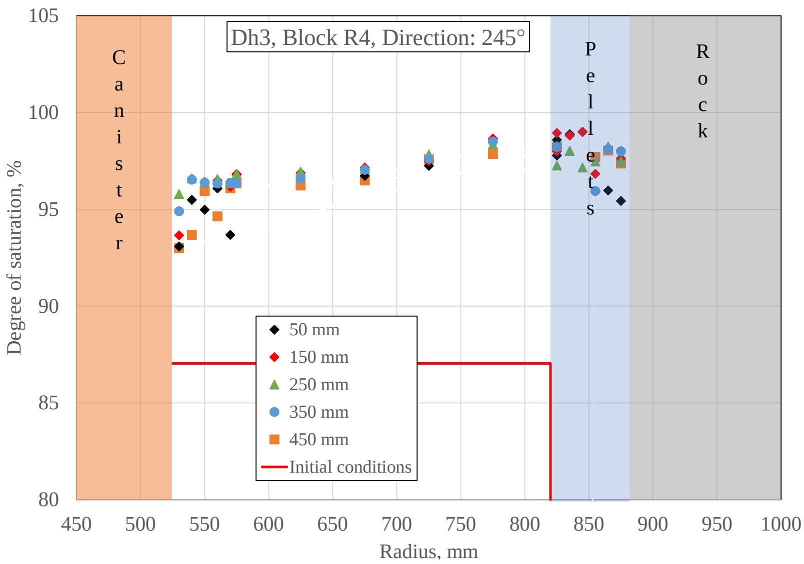


Appendix 2-10c Dh3, Block R4.

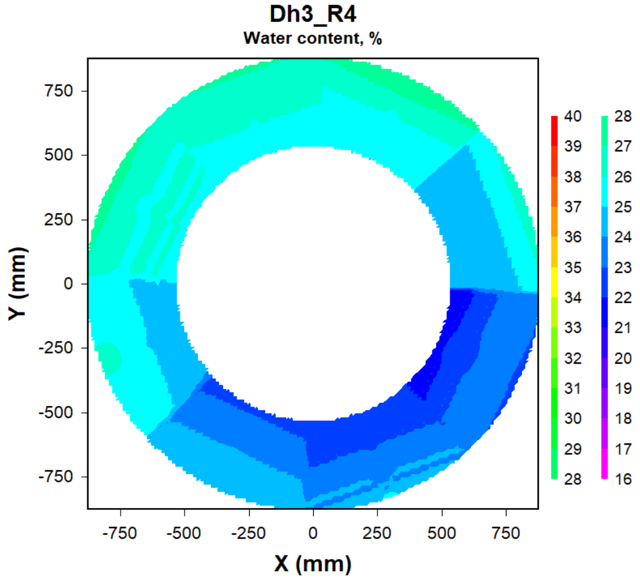
Water content, dry density, and degree of saturation at five depths in direction 245°.

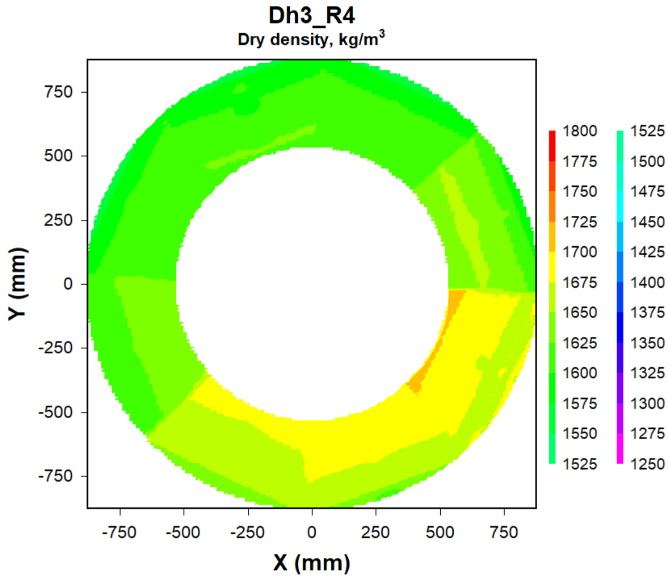


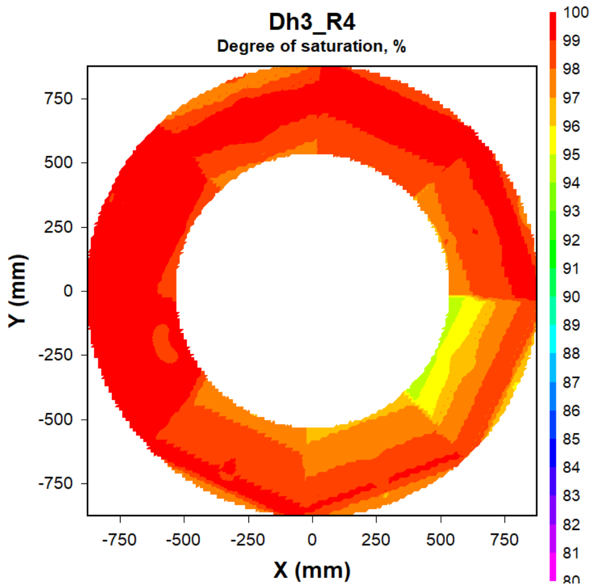




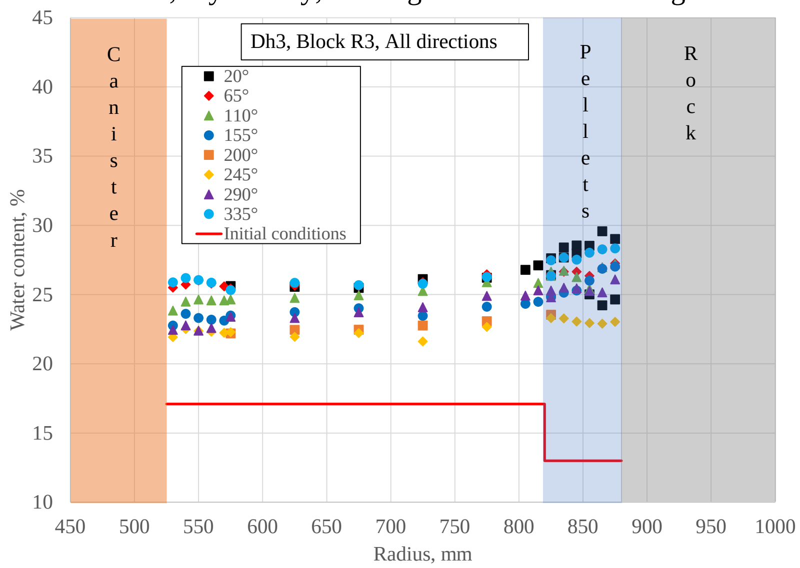
Appendix 2-10d Dh3, Block R4.
Water content, dry density, and degree of saturation distribution.

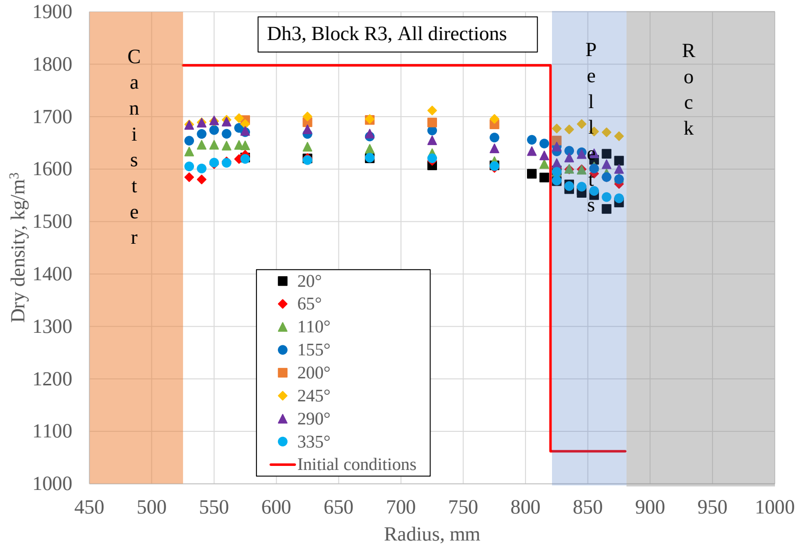


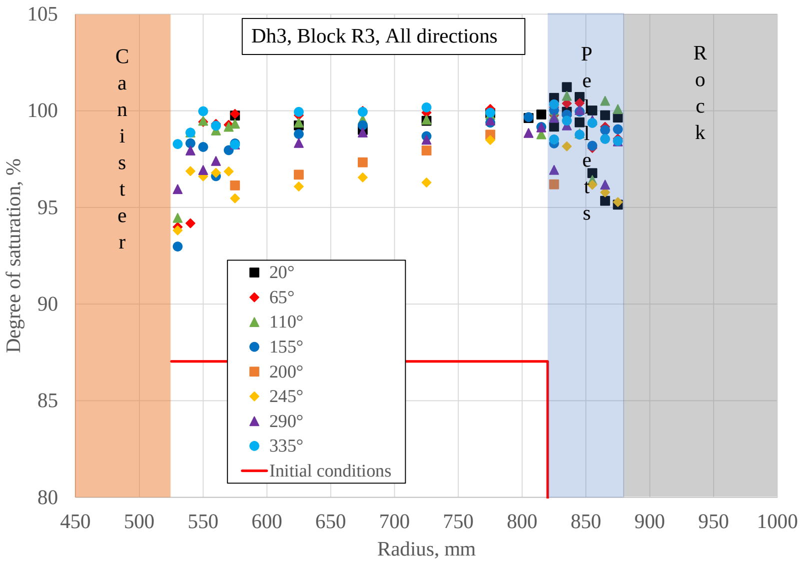




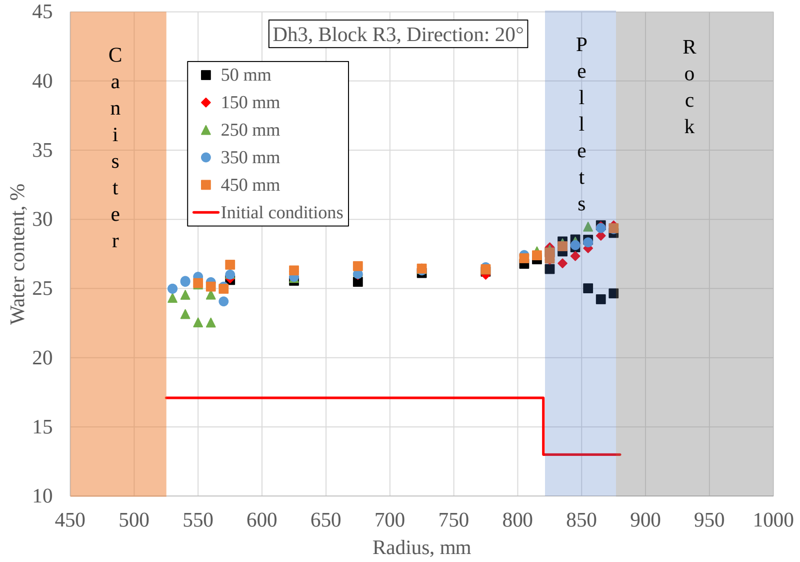
Appendix 2-11a Dh3, Block R3.
Water content, dry density, and degree of saturation in eight directions.

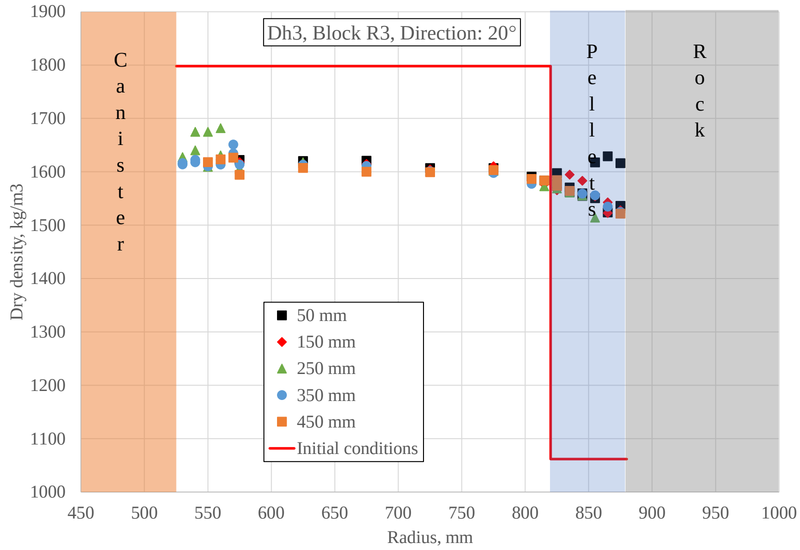


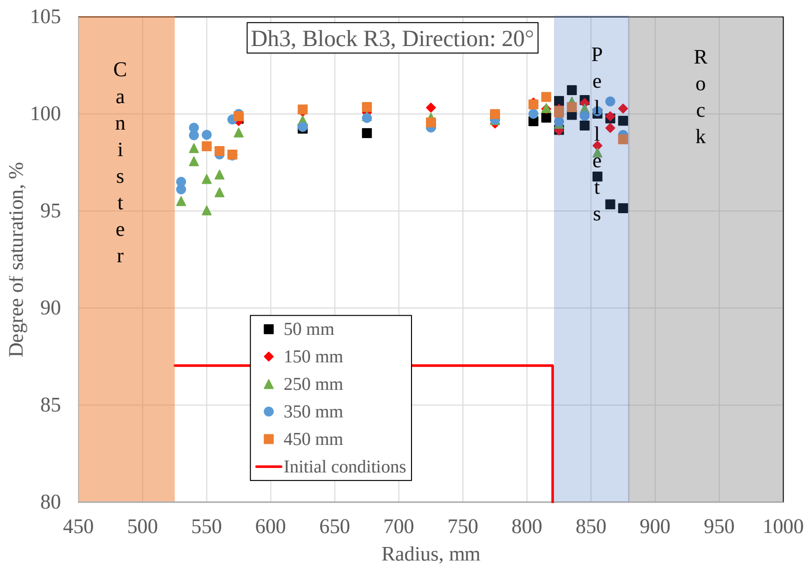




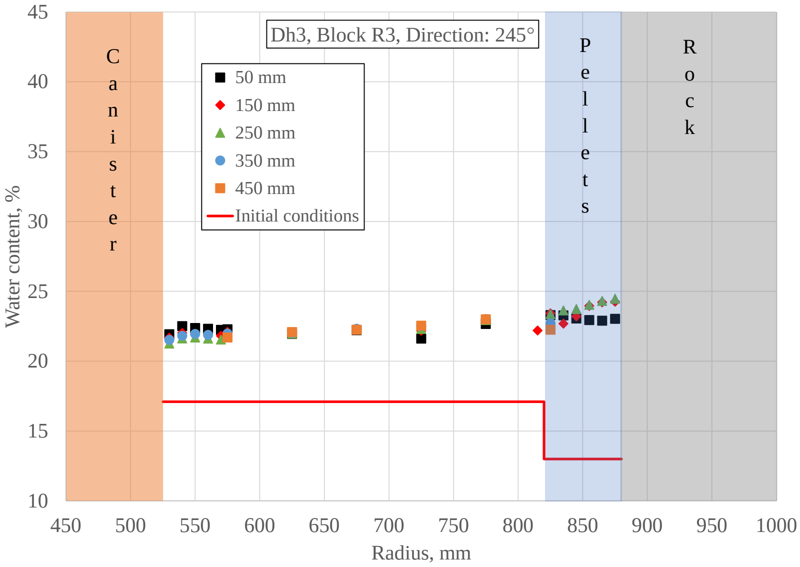
Appendix 2-11b Dh3, Block R3.
Water content, dry density, and degree of saturation at five depths in direction 20°.

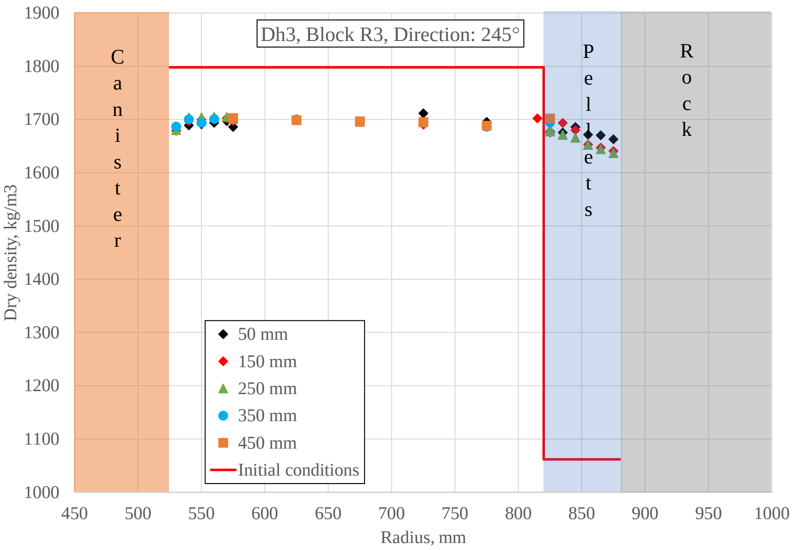


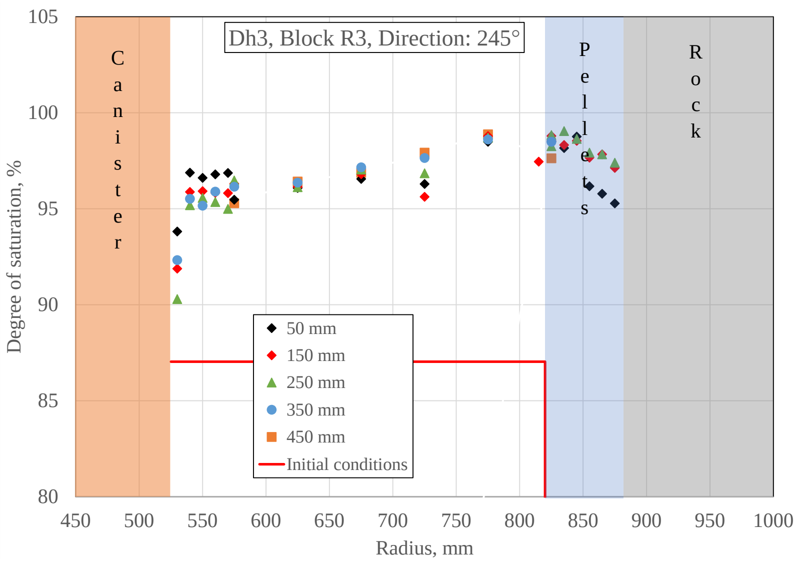




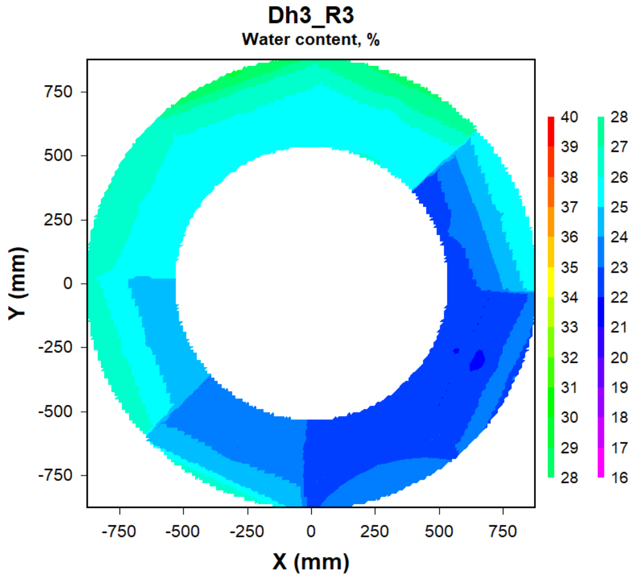
Appendix 2-11c Dh3, Block R3.
Water content, dry density, and degree of saturation at five depths in direction 245°.

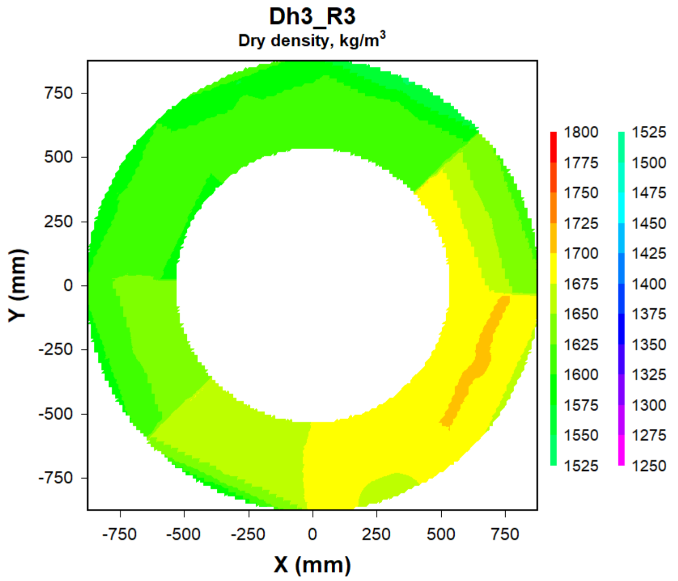


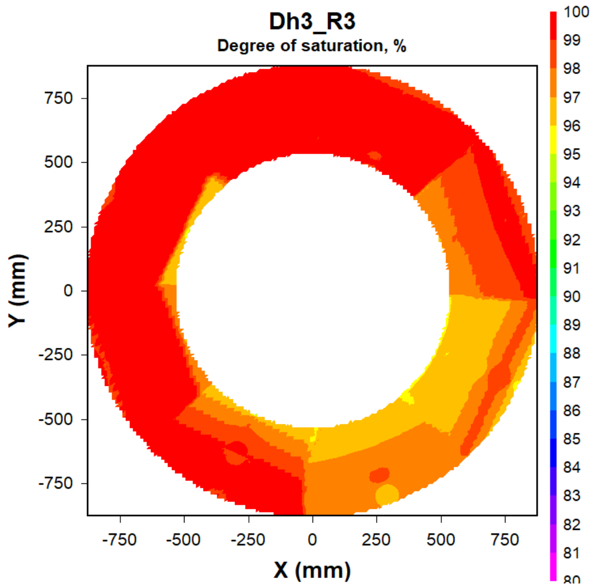




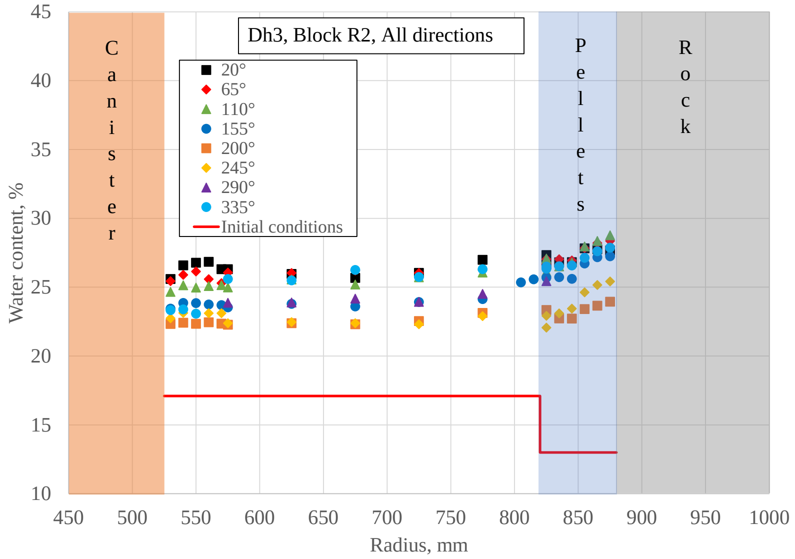
Appendix 2-11d Dh3, Block R3.
Water content, dry density, and degree of saturation distribution.

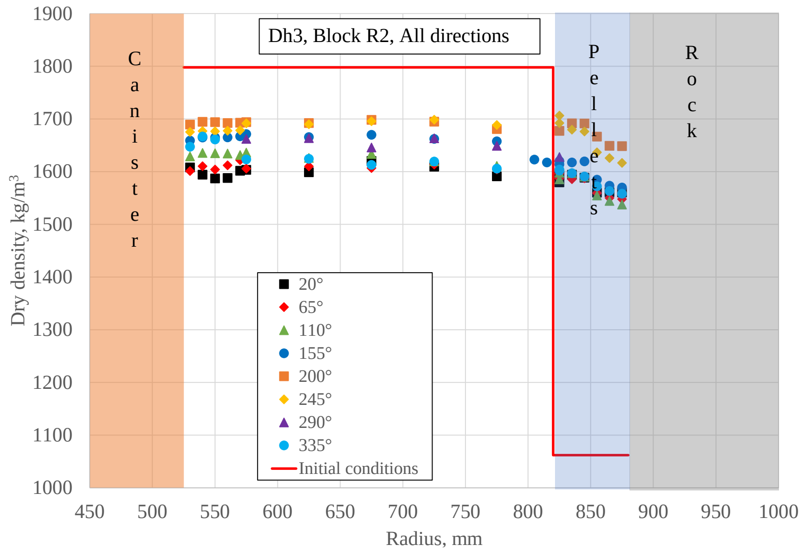


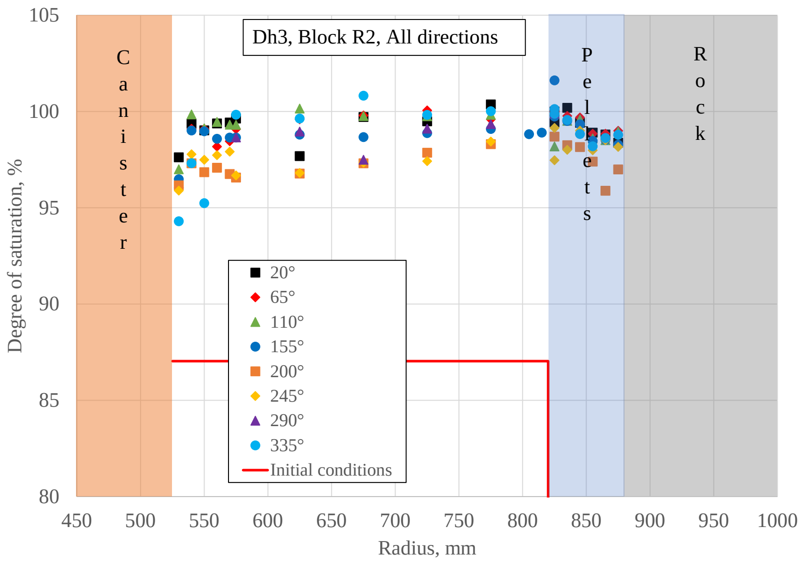




Appendix 2-12a Dh3, Block R2.
Water content, dry density, and degree of saturation in eight directions.

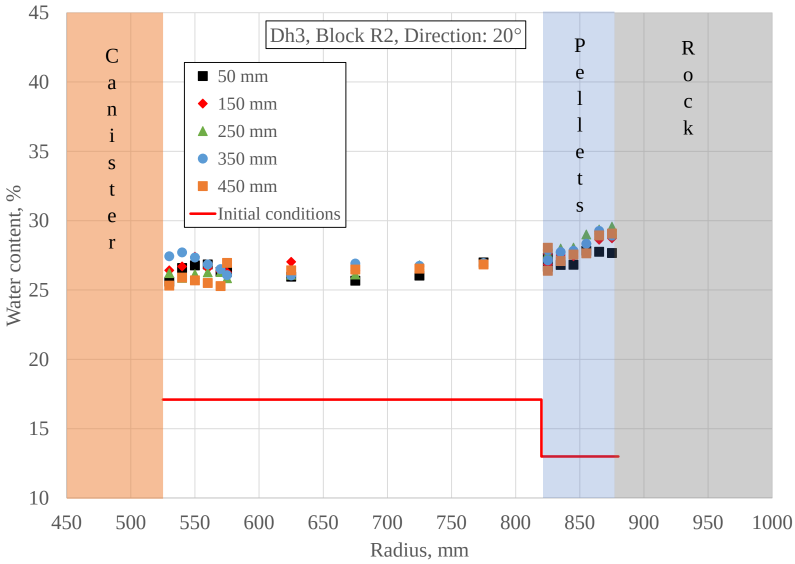


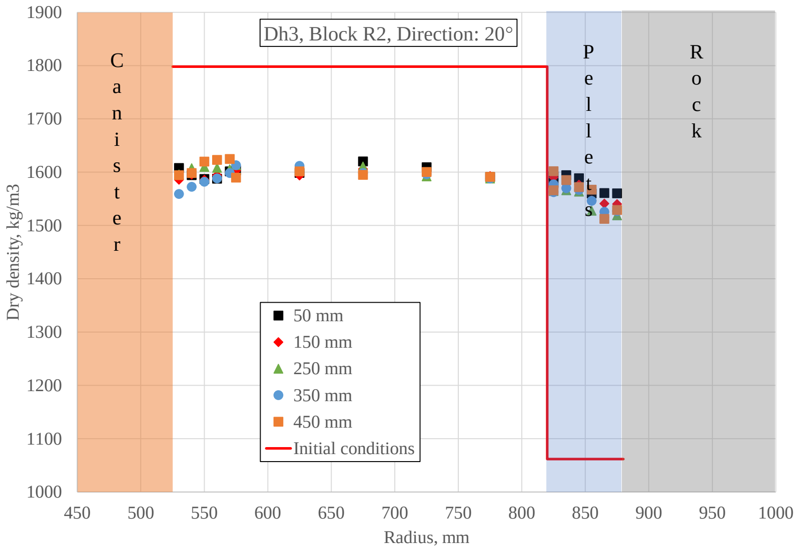


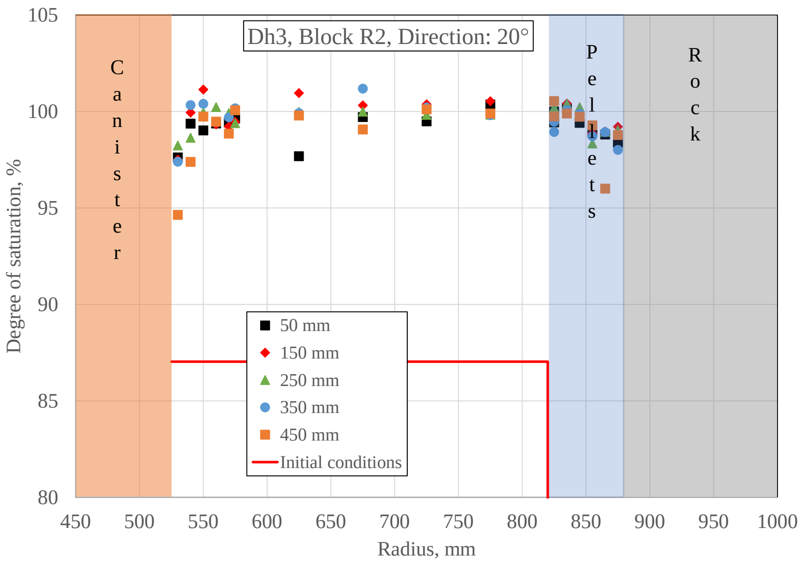


Appendix 2-12b Dh3, Block R2.

Water content, dry density, and degree of saturation at five depths in direction 20°.

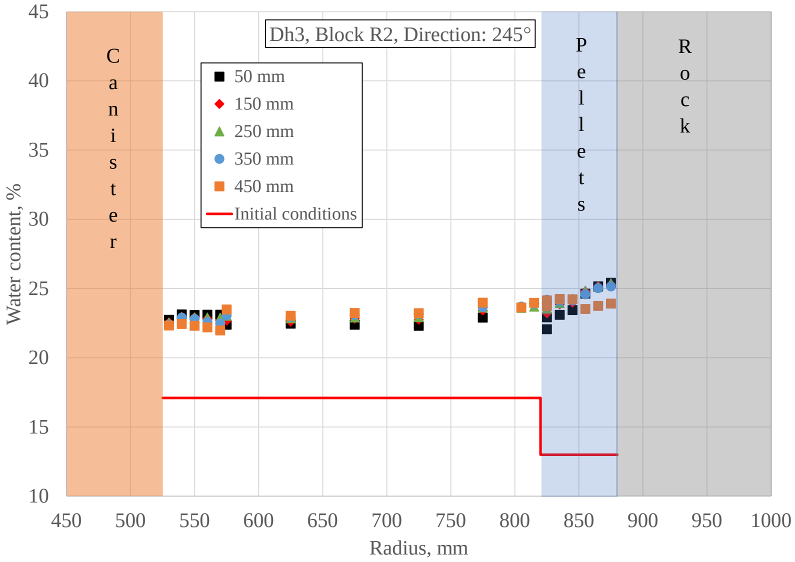


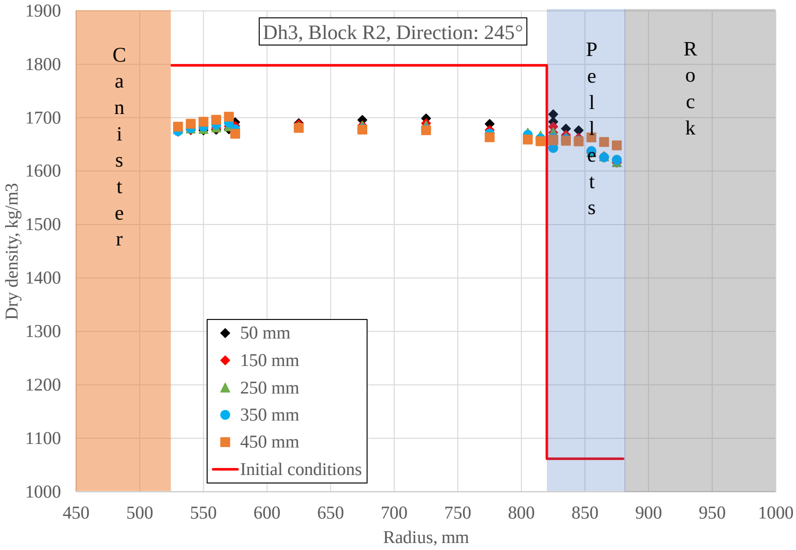


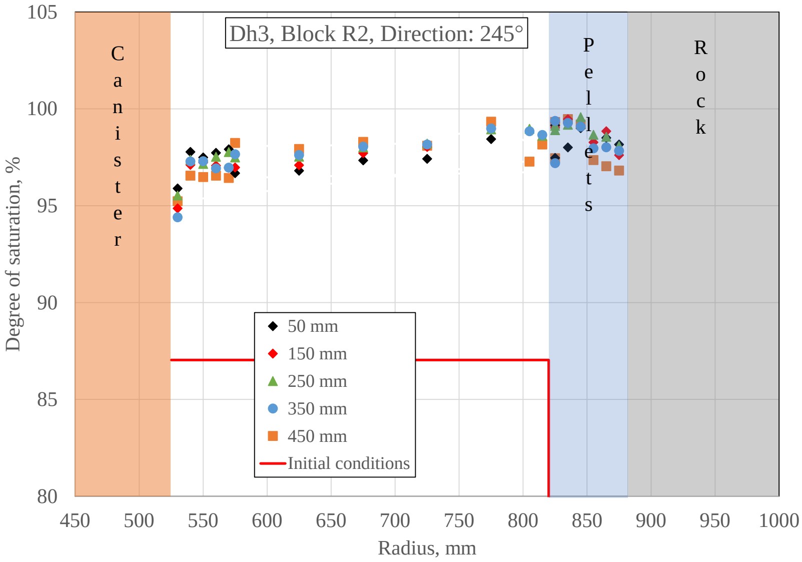


Appendix 2-12c Dh3, Block R2.

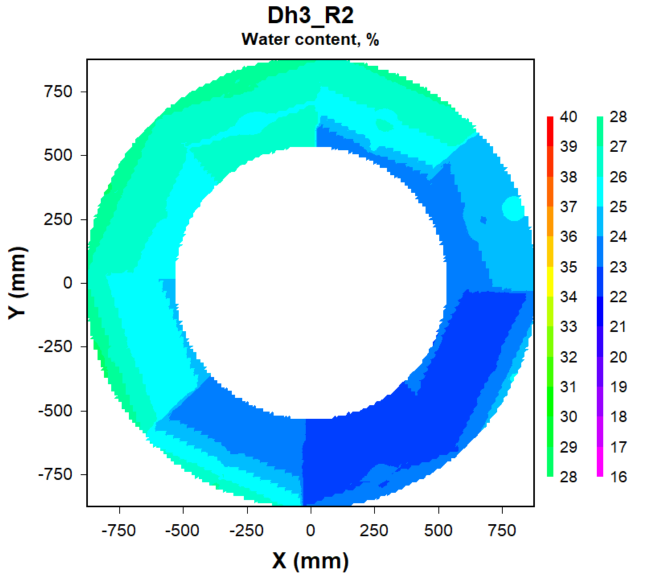
Water content, dry density, and degree of saturation at five depths in direction 245°.

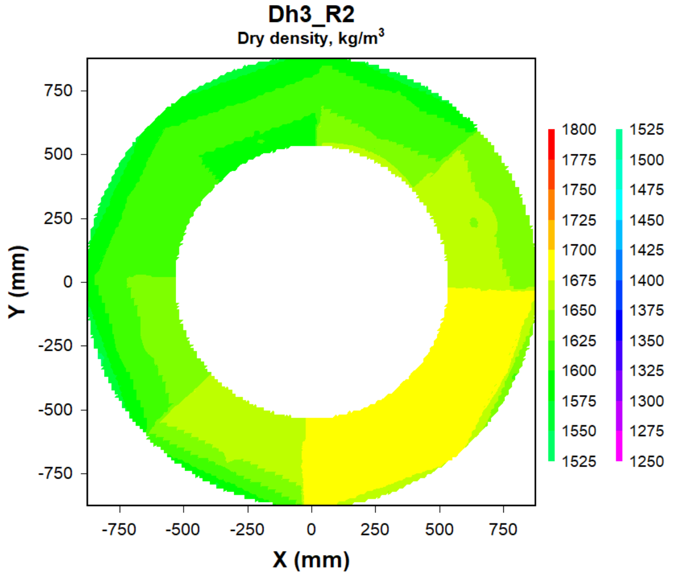


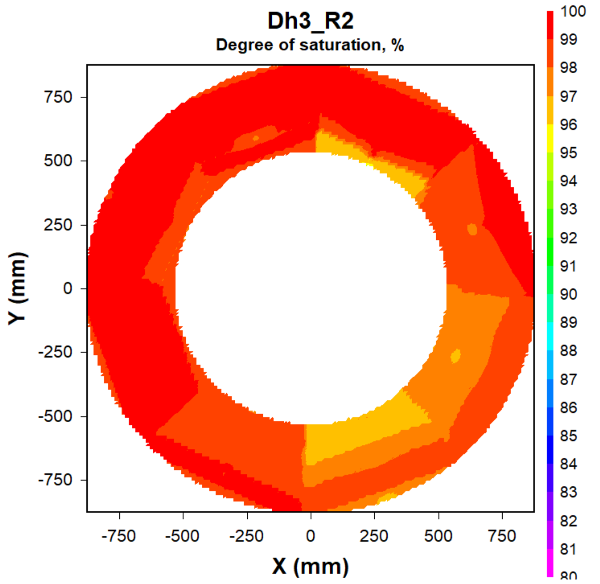




Appendix 2-12d Dh3, Block R2.
Water content, dry density, and degree of saturation distribution.

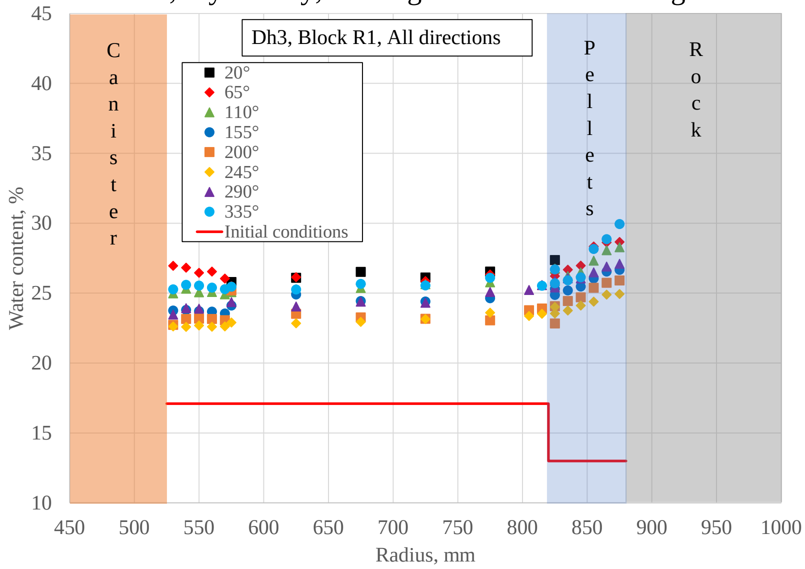


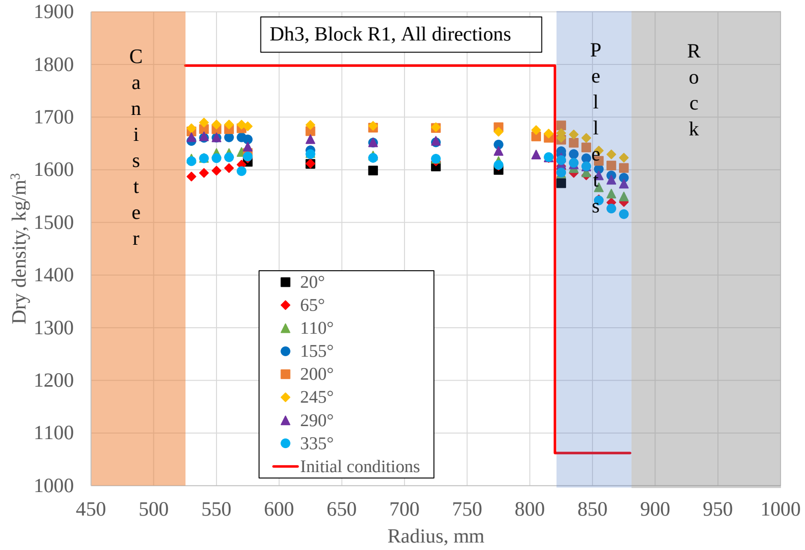


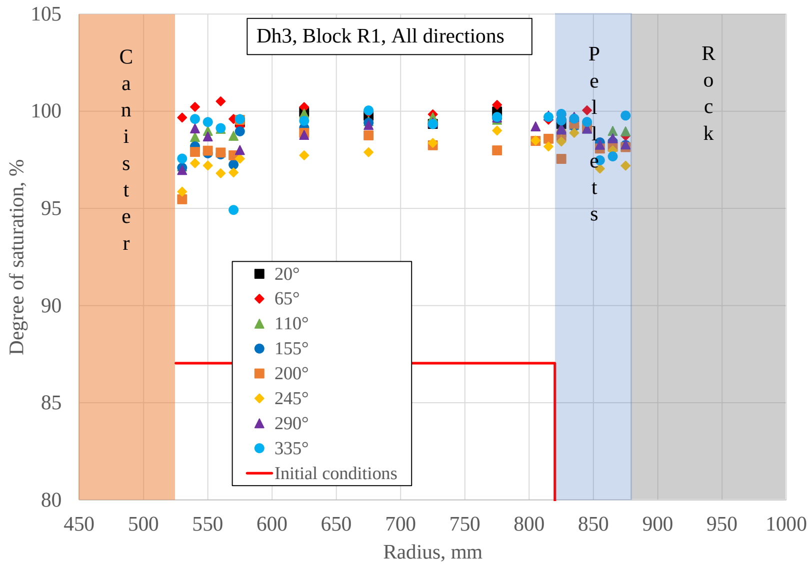


Appendix 2-13a Dh3, Block R1.

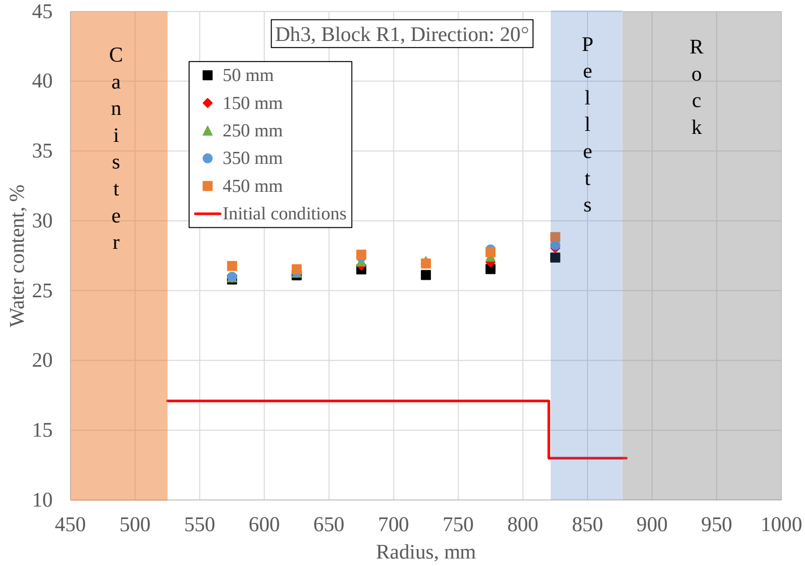
Water content, dry density, and degree of saturation in eight directions.

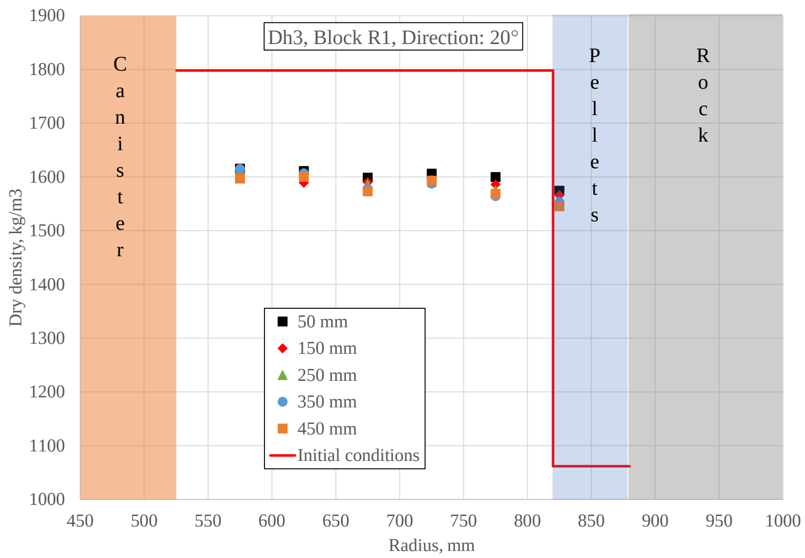


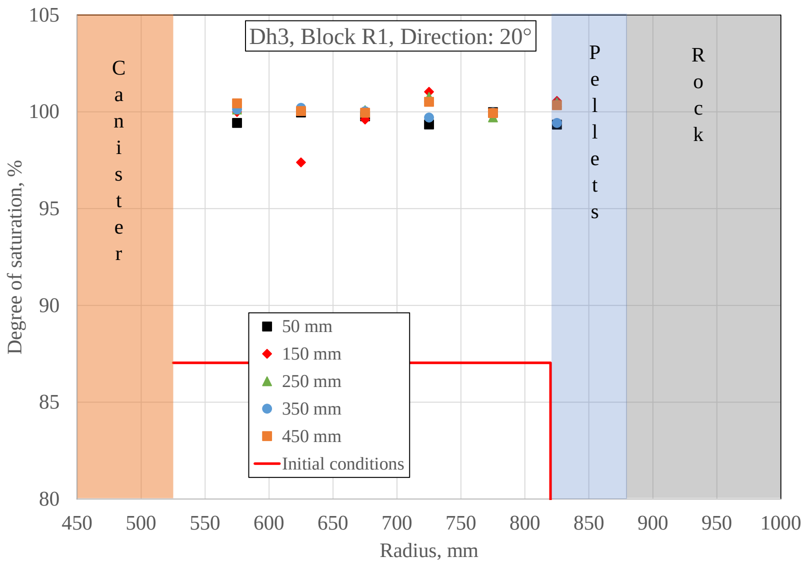




Appendix 2-13b Dh3, Block R1.
Water content, dry density, and degree of saturation at five depths in direction 20°.

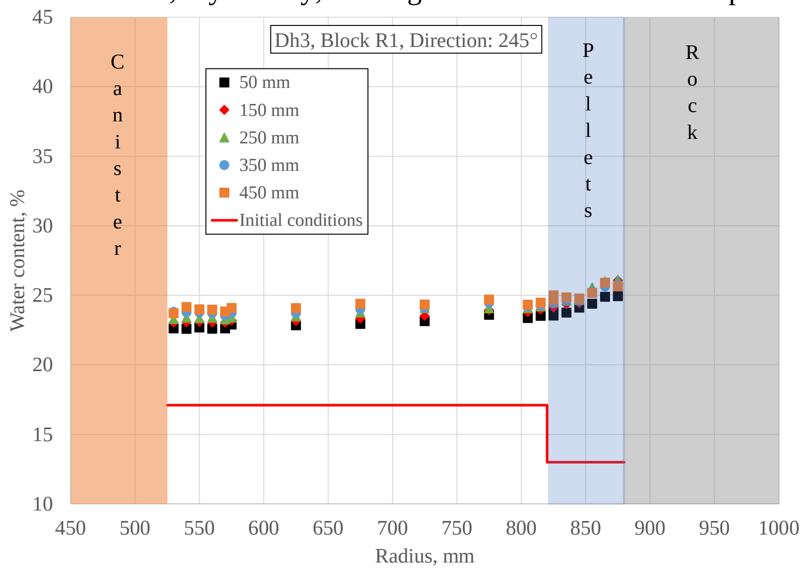


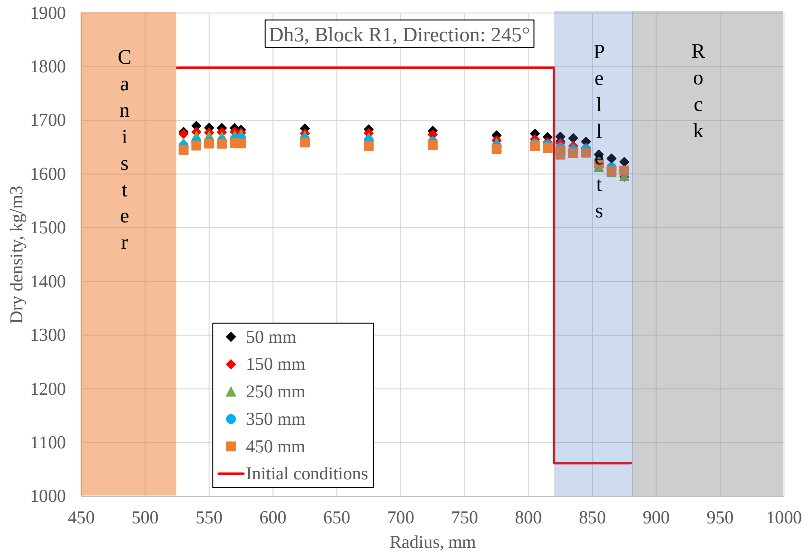


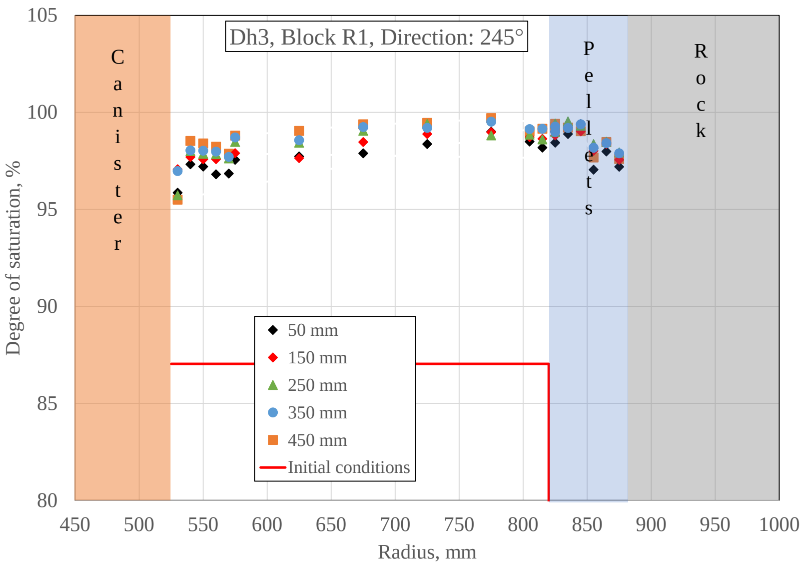


Appendix 2-13c Dh3, Block R1.

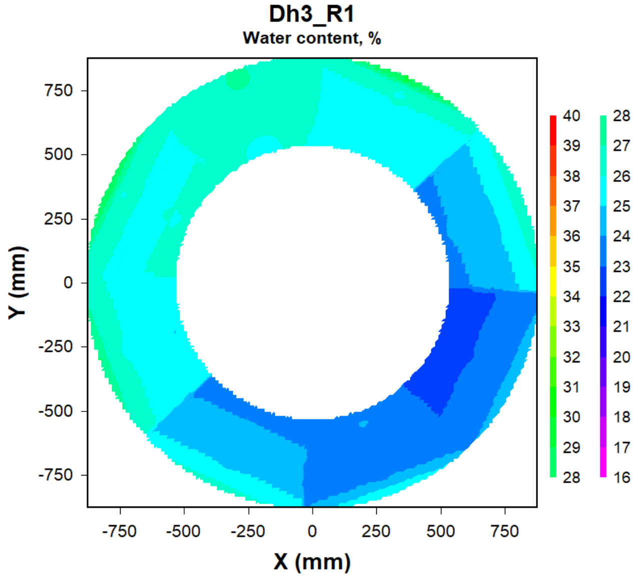
Water content, dry density, and degree of saturation at five depths in direction 245°.

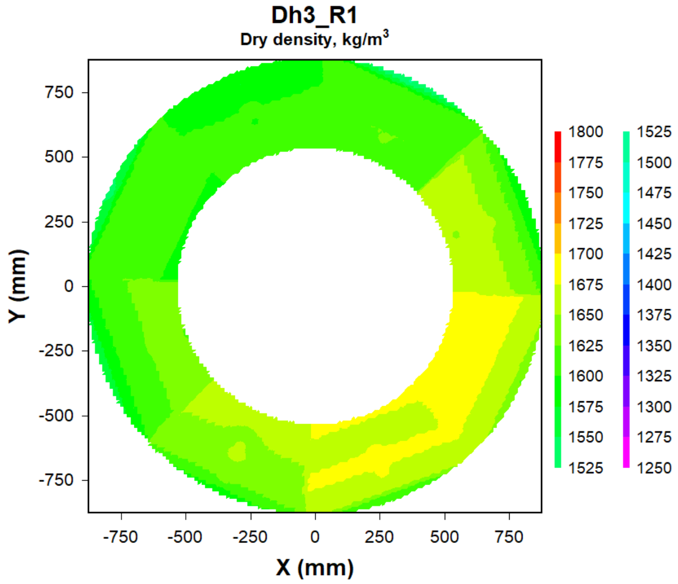


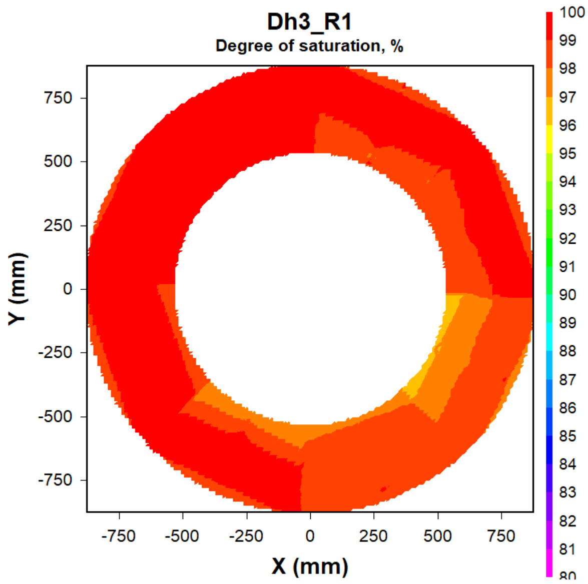




Appendix 2-13d Dh3, Block R1.
Water content, dry density, and degree of saturation distribution.

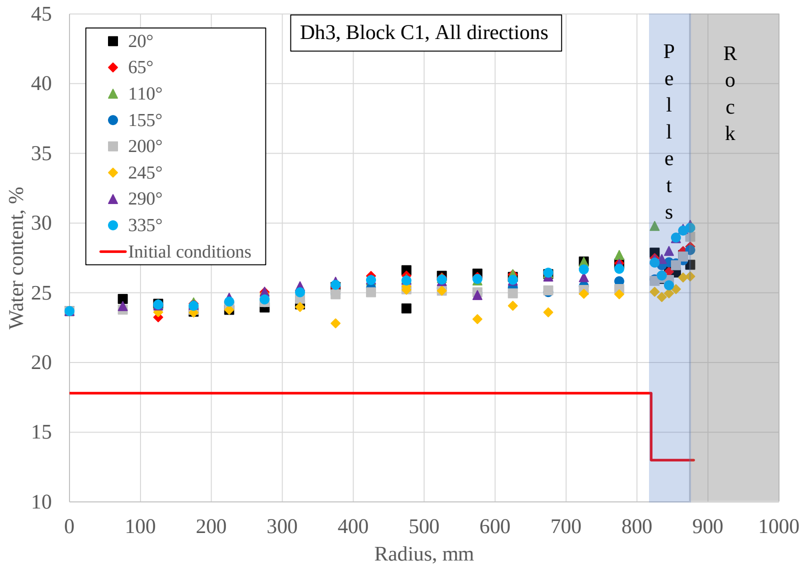


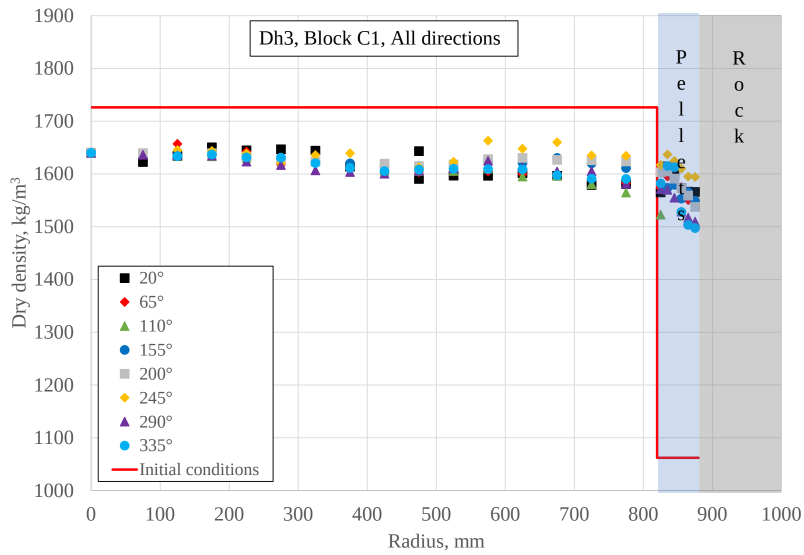


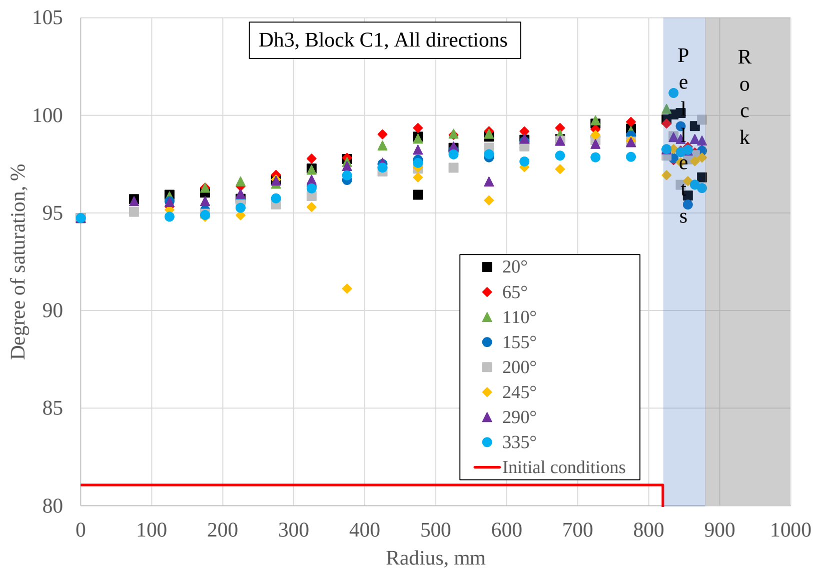


Appendix 2-14a Dh3, Block C1.

Water content, dry density, and degree of saturation in eight directions.

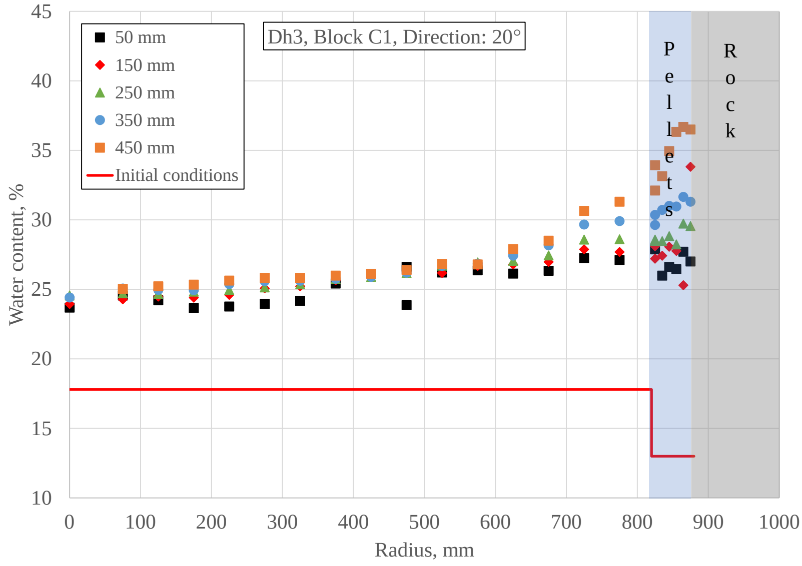


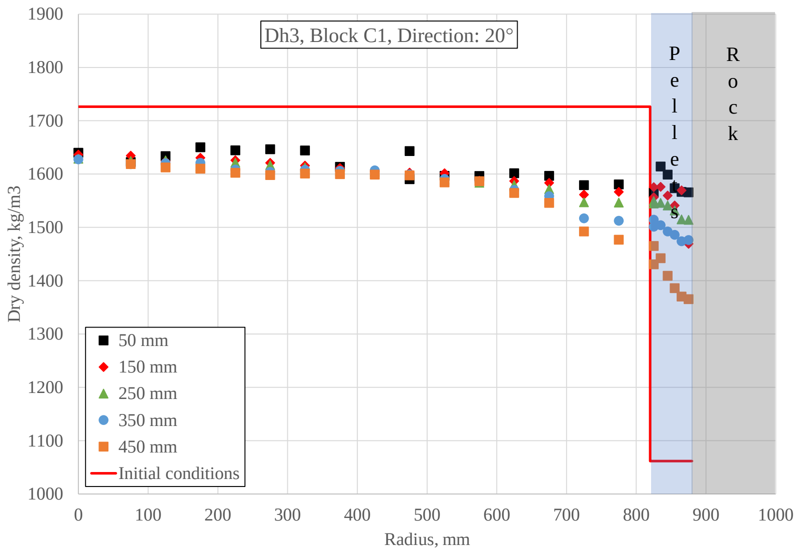


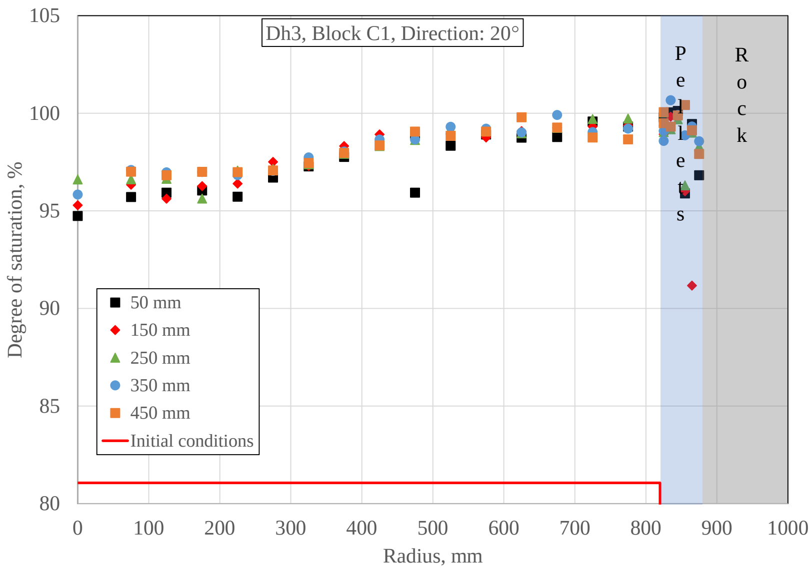


Appendix 2-14b Dh3, Block C1.

Water content, dry density, and degree of saturation at five depths in direction 20°.

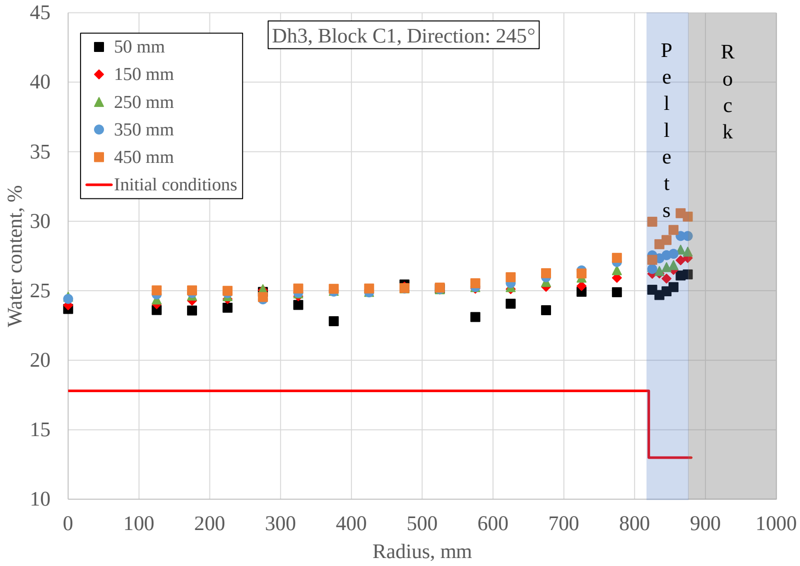


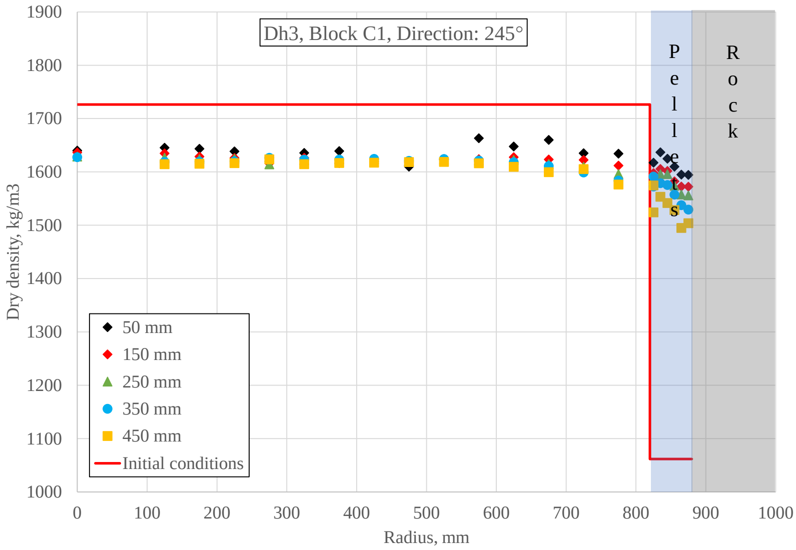


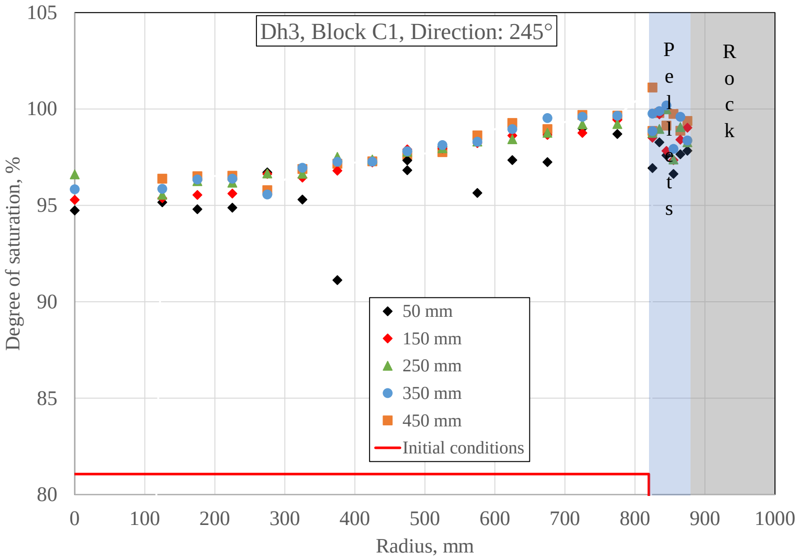


Appendix 2-14c Dh3, Block C1.

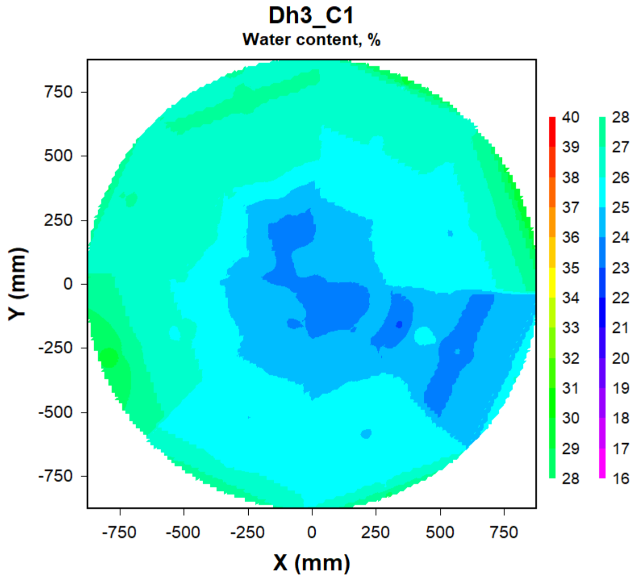
Water content, dry density, and degree of saturation at five depths in direction 245°.

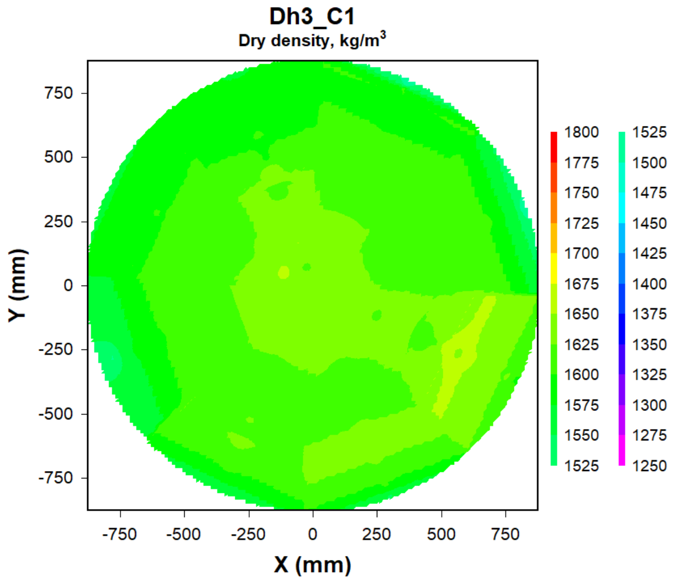


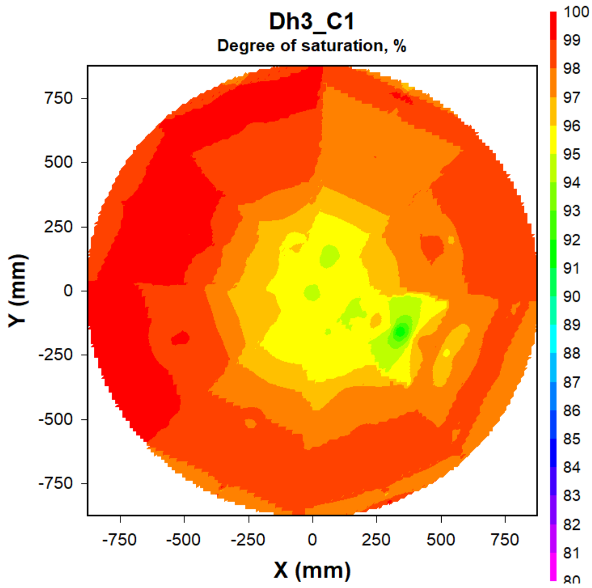




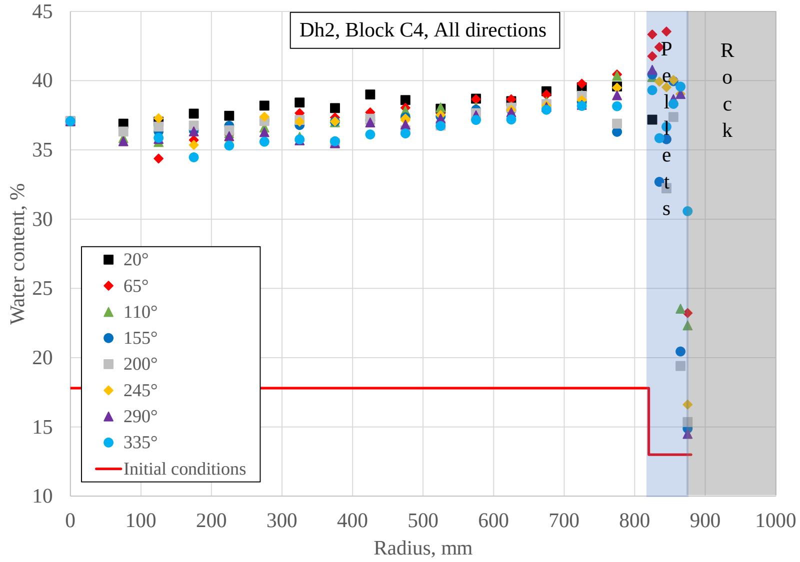
Appendix 2-14d Dh3, Block C1.
Water content, dry density, and degree of saturation distribution.

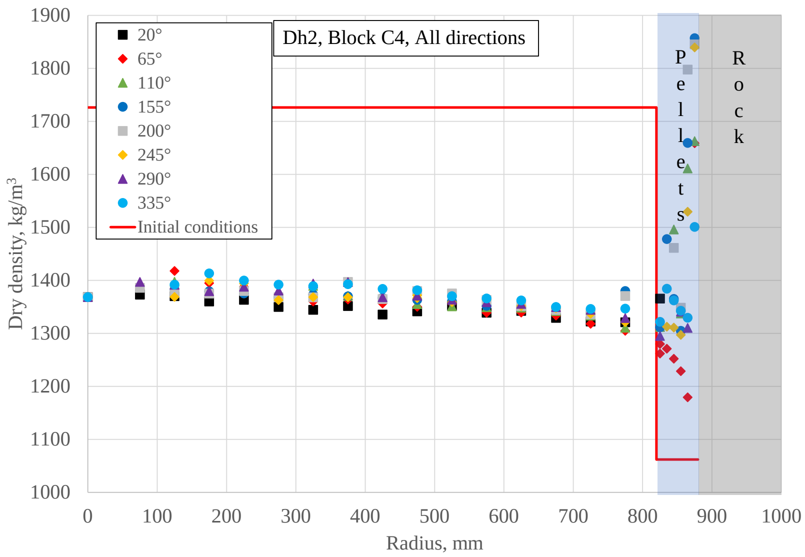


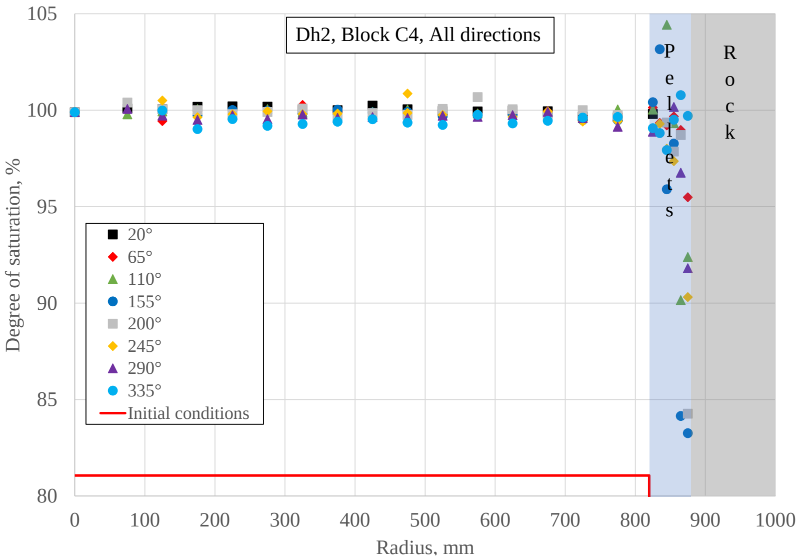




Appendix 3-1a Dh2, Block C4.
Water content, dry density, and degree of saturation in eight directions.

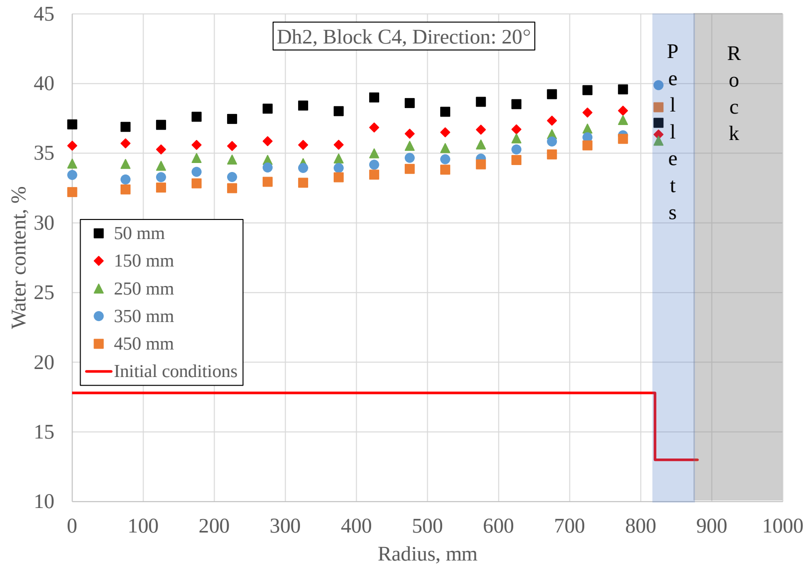


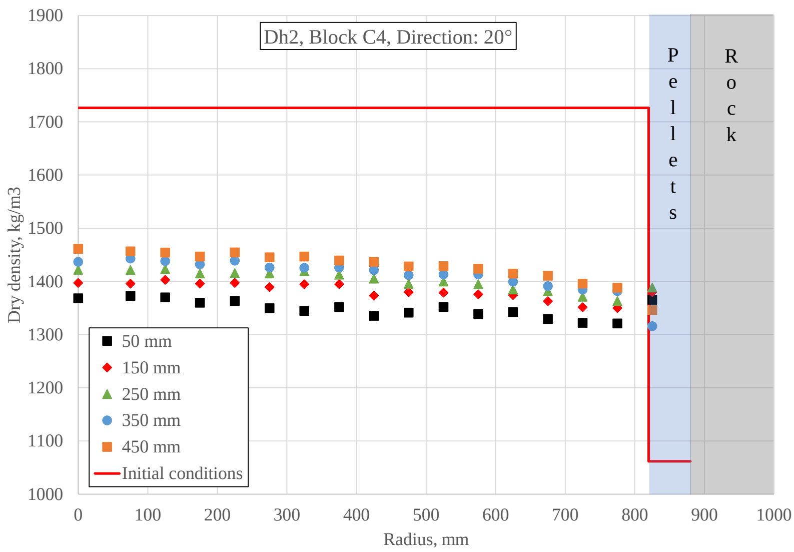


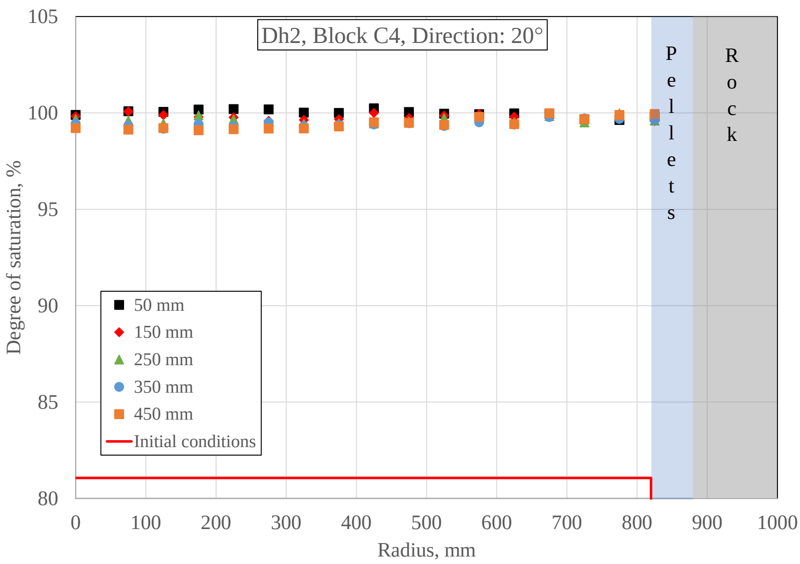


Appendix 3-1b Dh2, Block C4.

Water content, dry density, and degree of saturation at five depths in direction 20°.

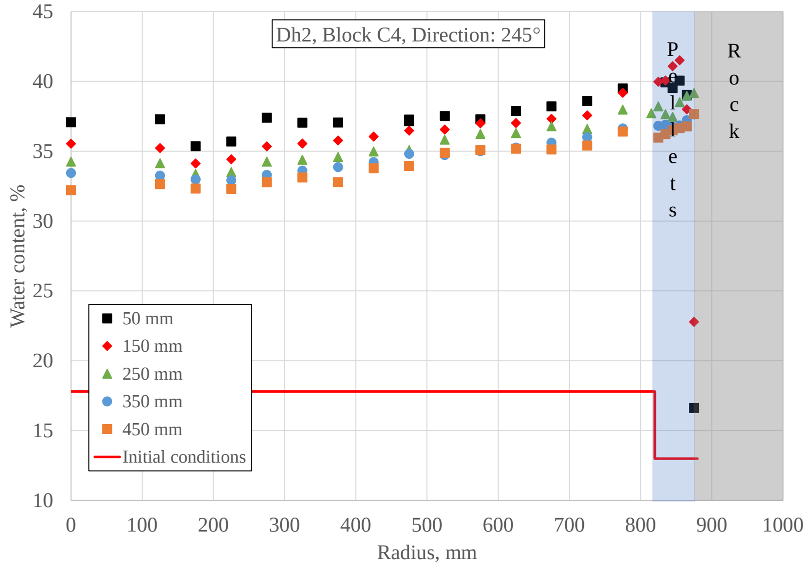


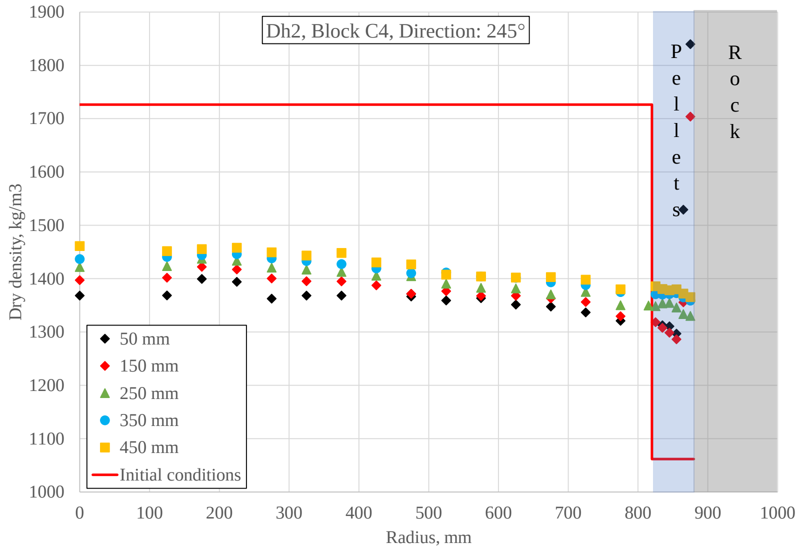


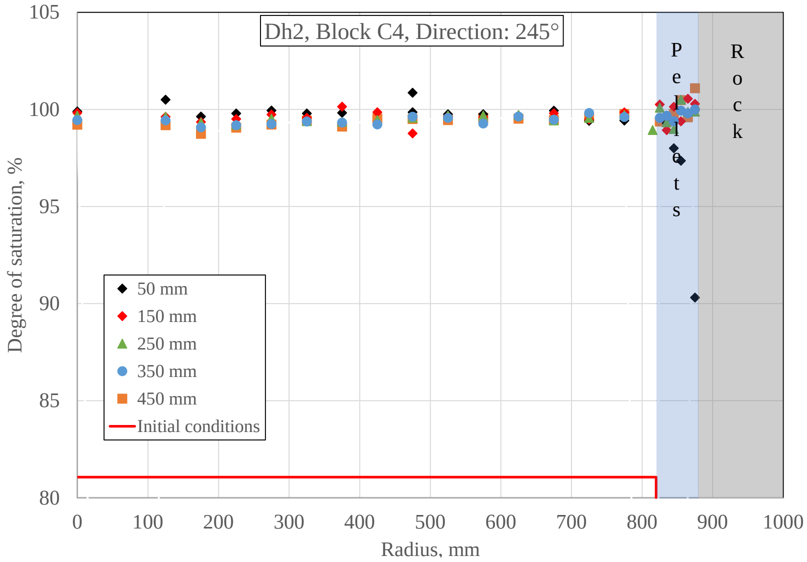


Appendix 3-1c Dh2, Block C4.

Water content, dry density, and degree of saturation at five depths in direction 245°.

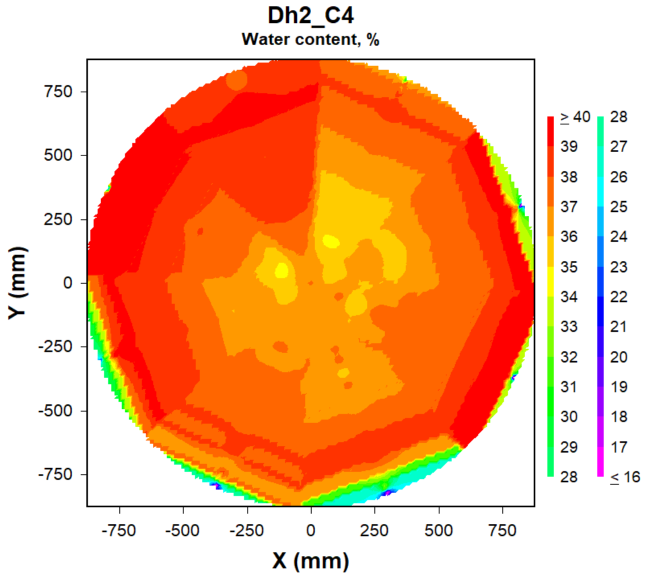


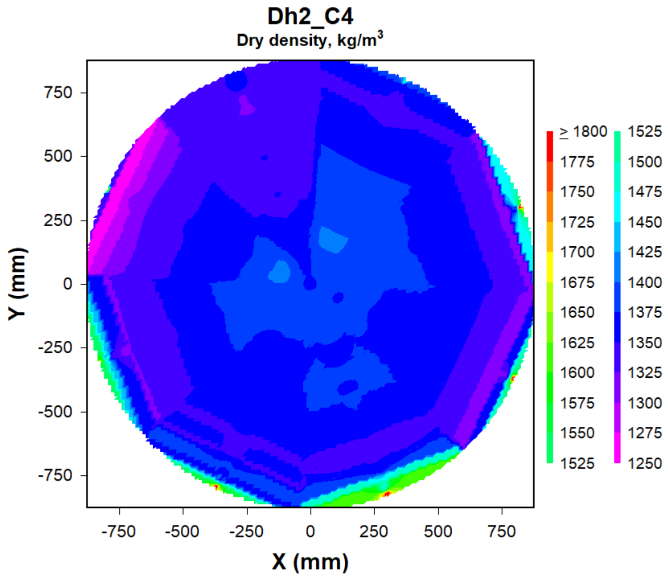


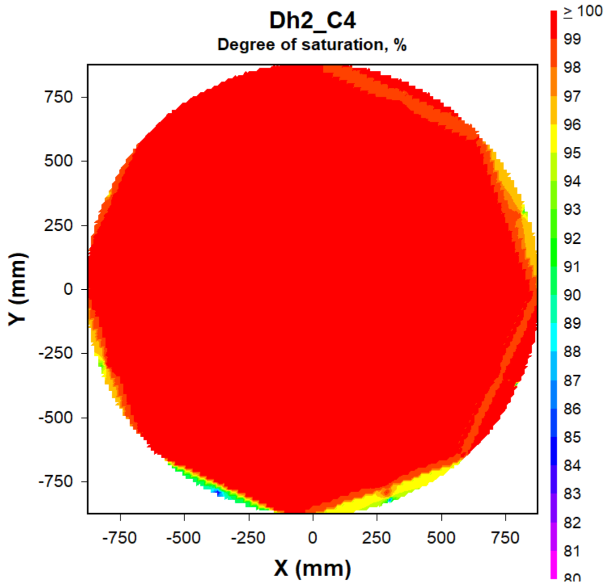


Appendix 3-1d Dh2, Block C4.

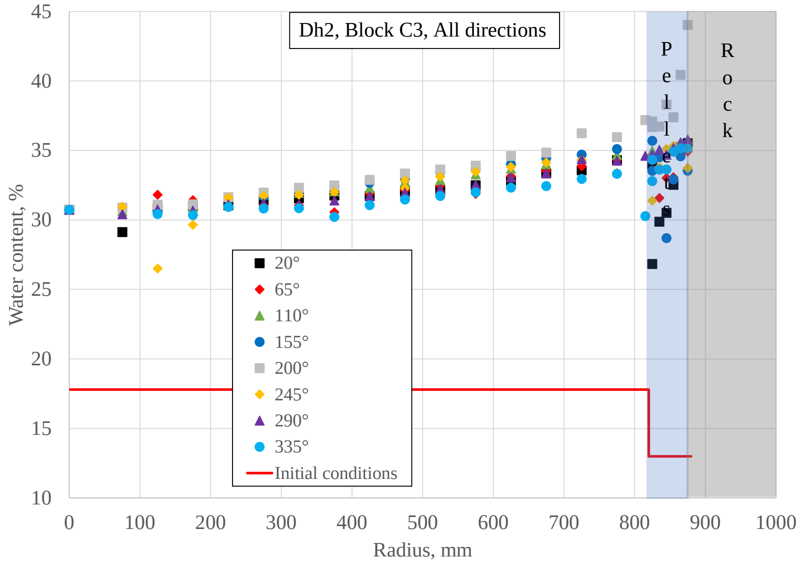
Water content, dry density, and degree of saturation distribution.

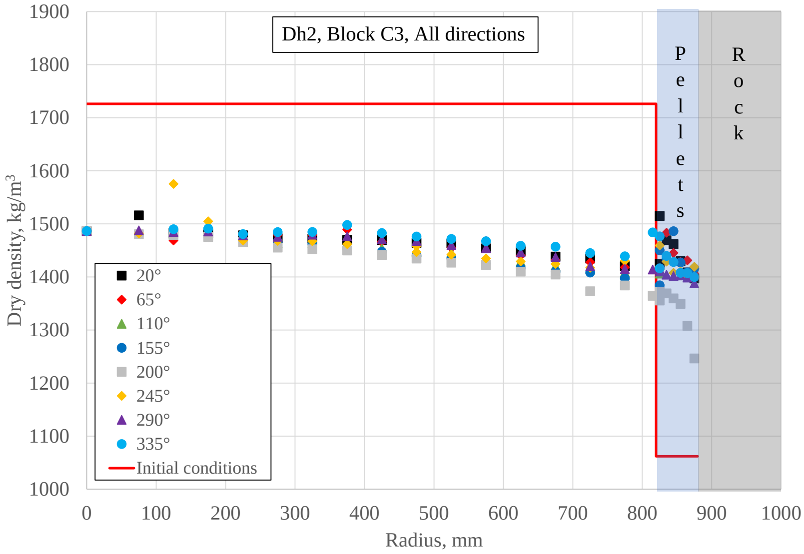


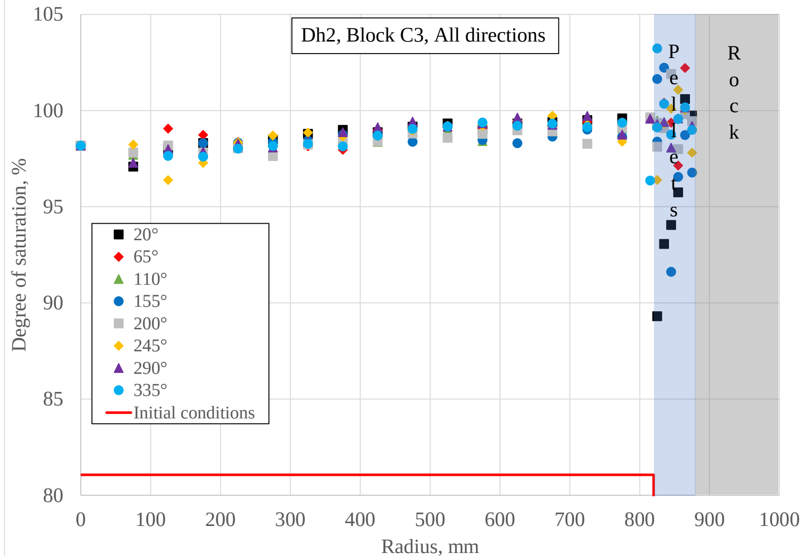




Appendix 3-2a Dh2, Block C3.
Water content, dry density, and degree of saturation in eight directions.

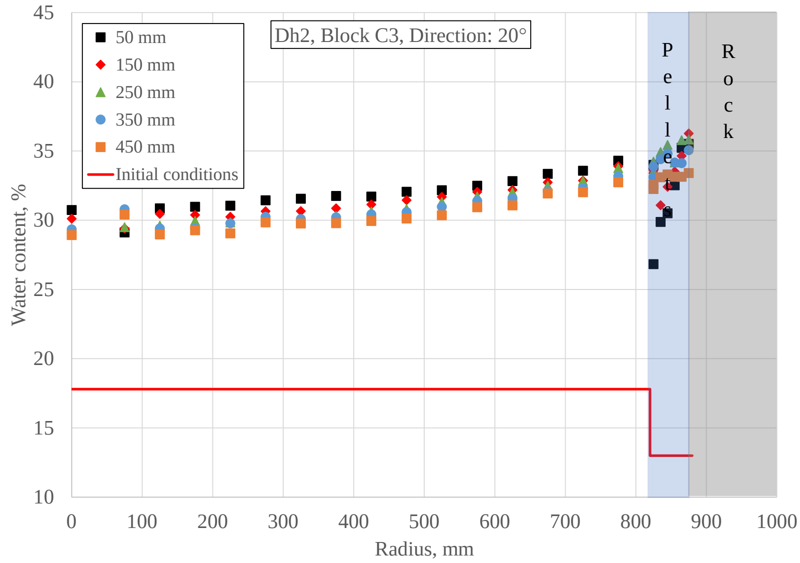


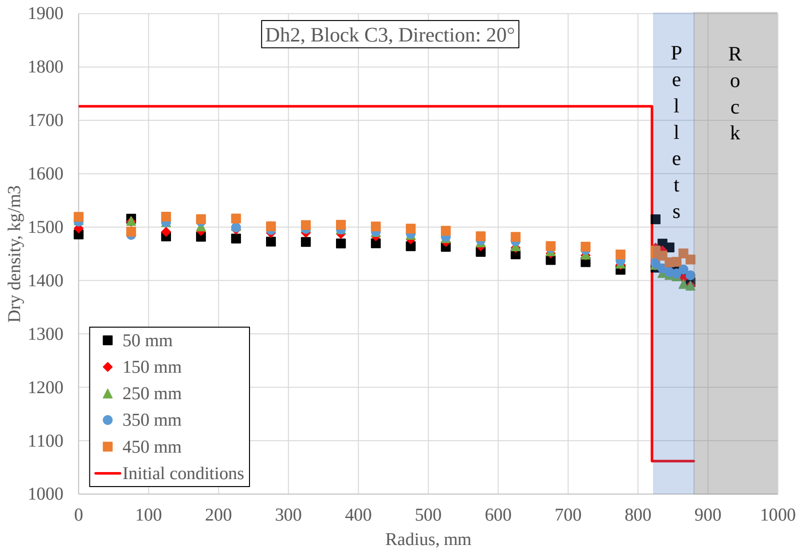


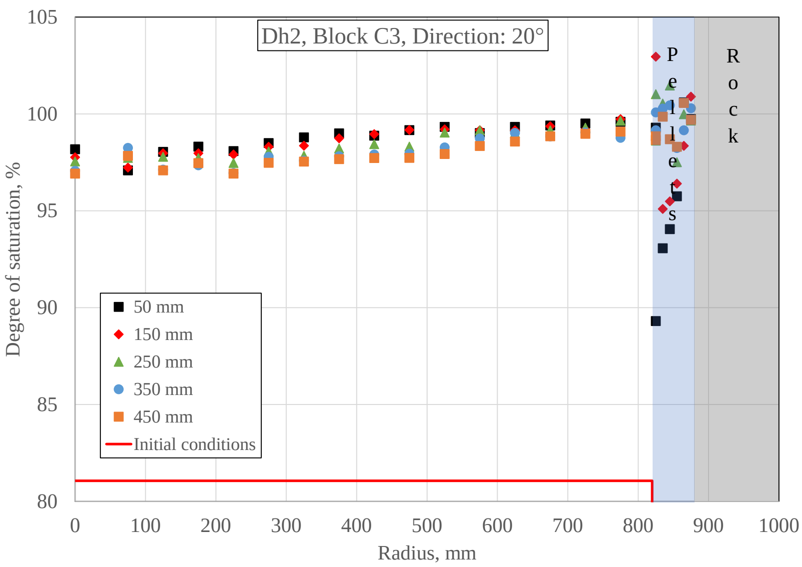


Appendix 3-2b Dh2, Block C3.

Water content, dry density, and degree of saturation at five depths in direction 20°.

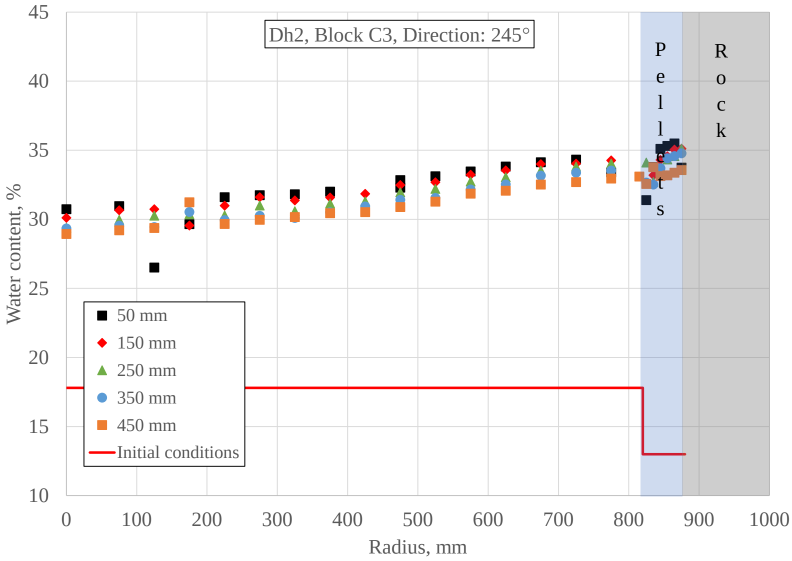


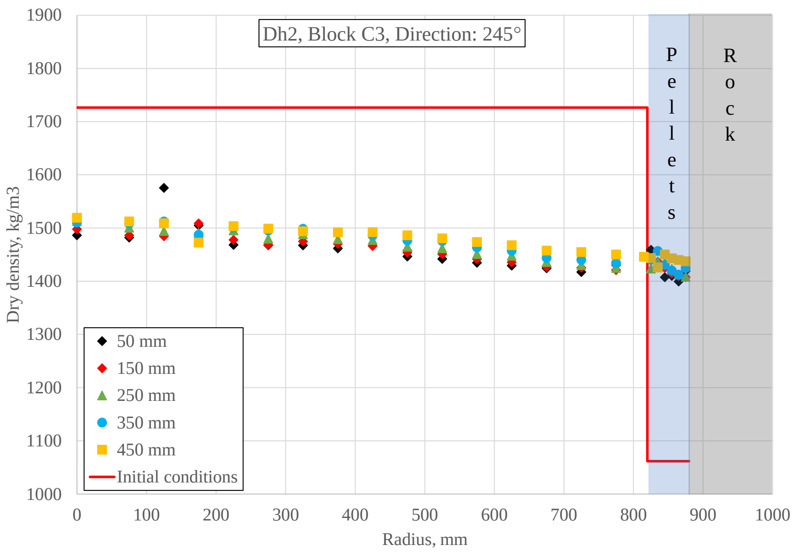


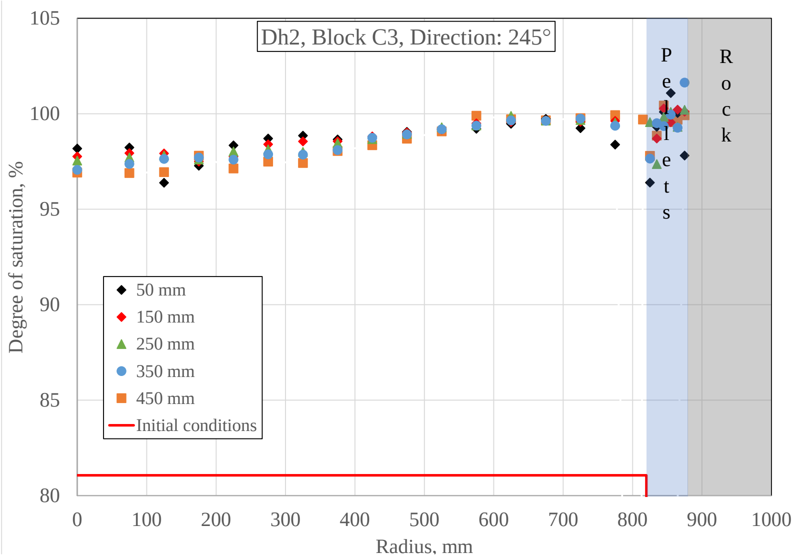


Appendix 3-2c Dh2, Block C3.

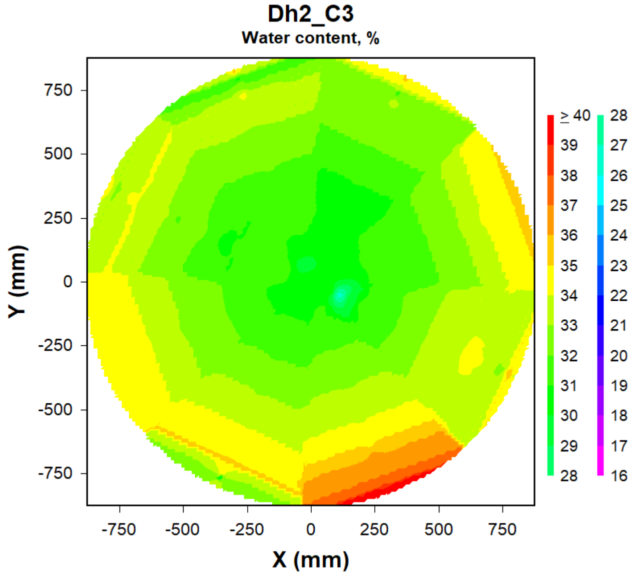
Water content, dry density, and degree of saturation at five depths in direction 245°.

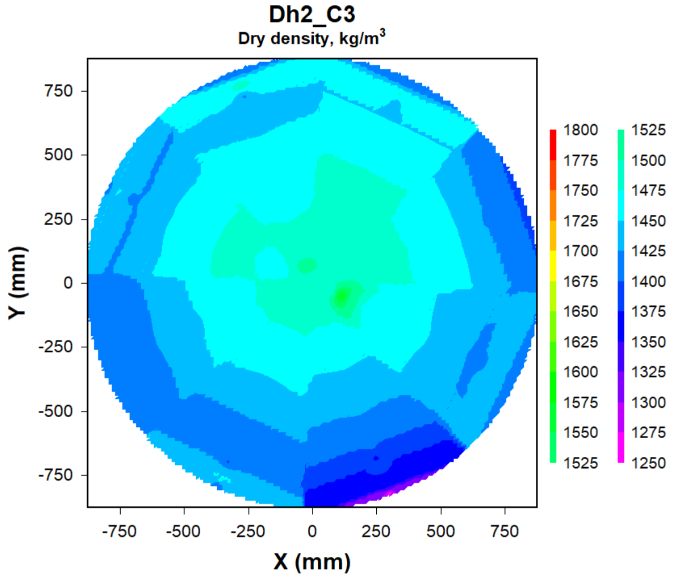


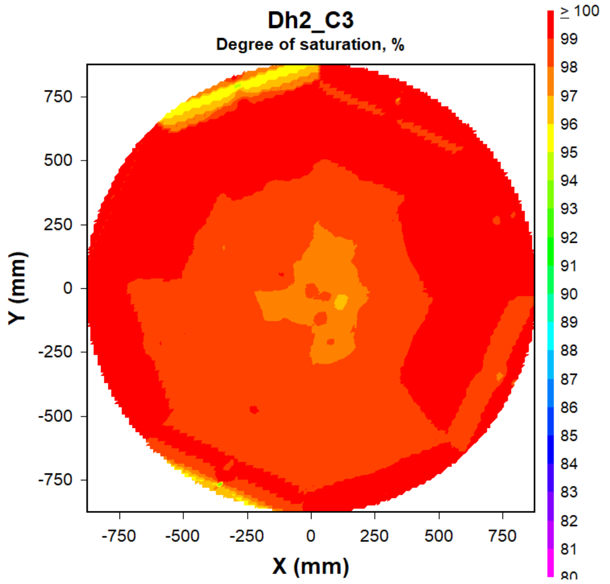




Appendix 3-2d Dh2, Block C3.
Water content, dry density, and degree of saturation distribution.

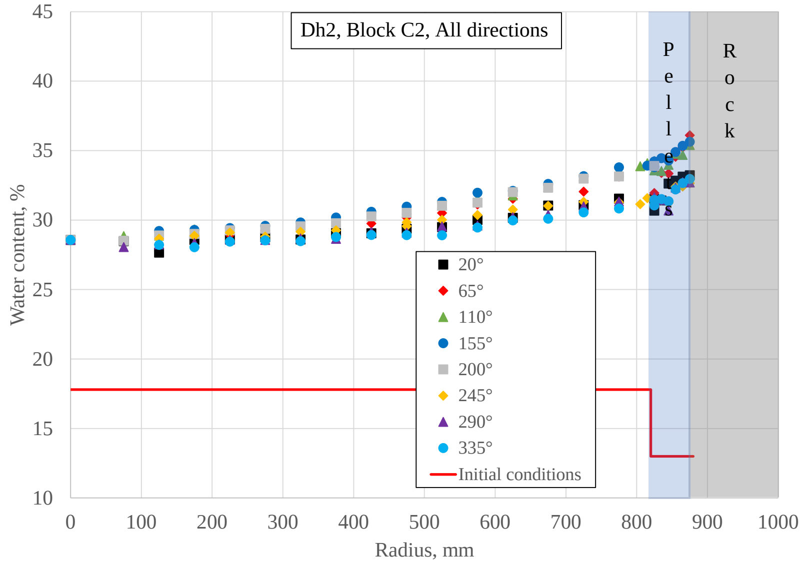


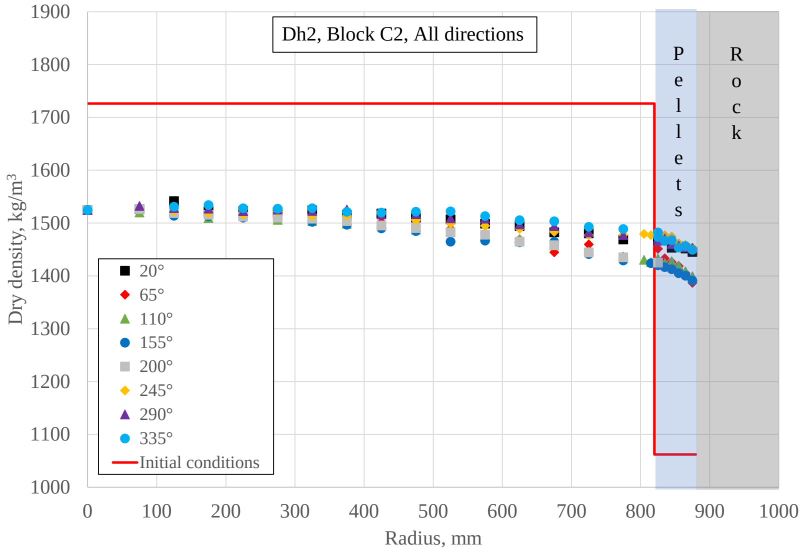


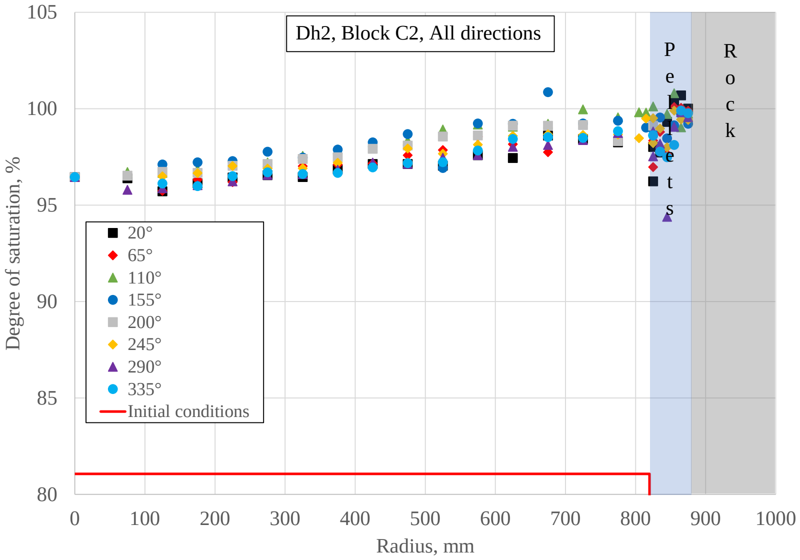


Appendix 3-3a Dh2, Block C2.

Water content, dry density, and degree of saturation in eight directions.

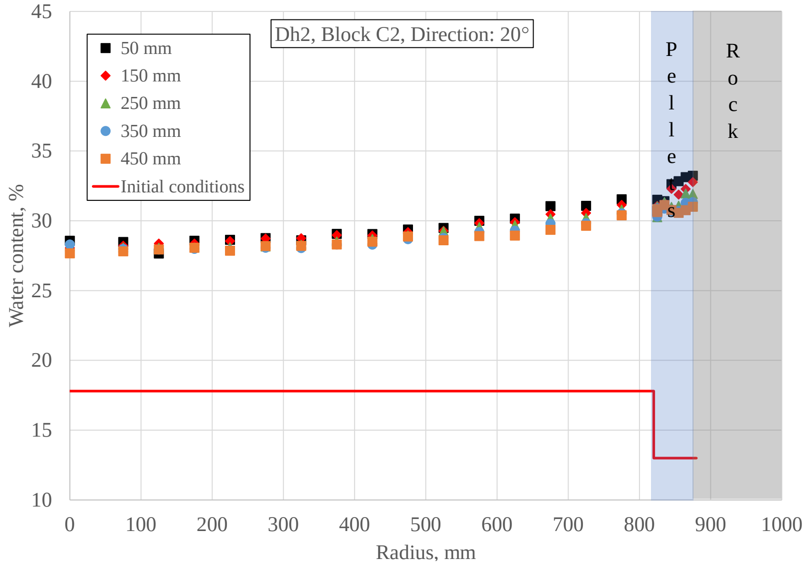


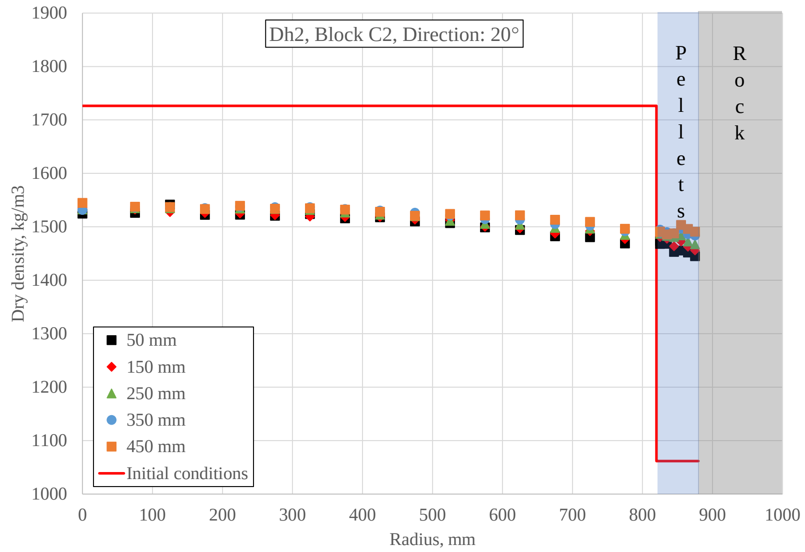


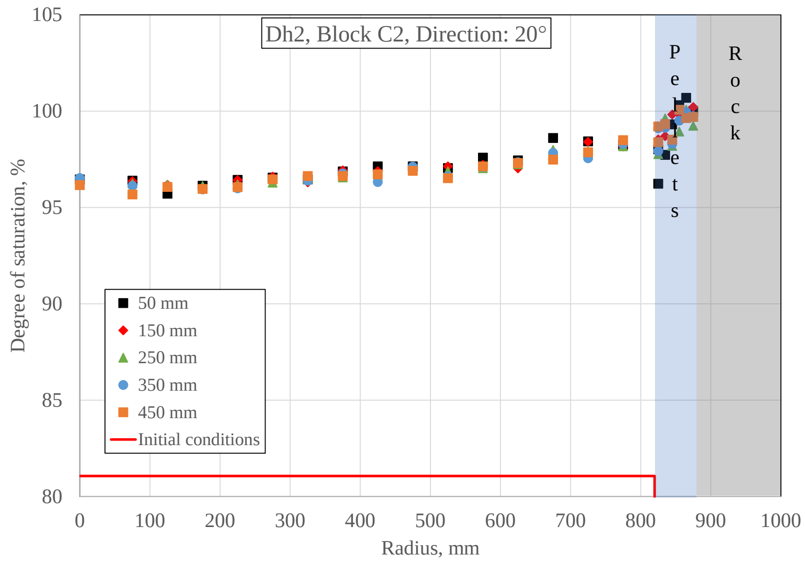


Appendix 3-3b Dh2, Block C2.

Water content, dry density, and degree of saturation at five depths in direction 20°.

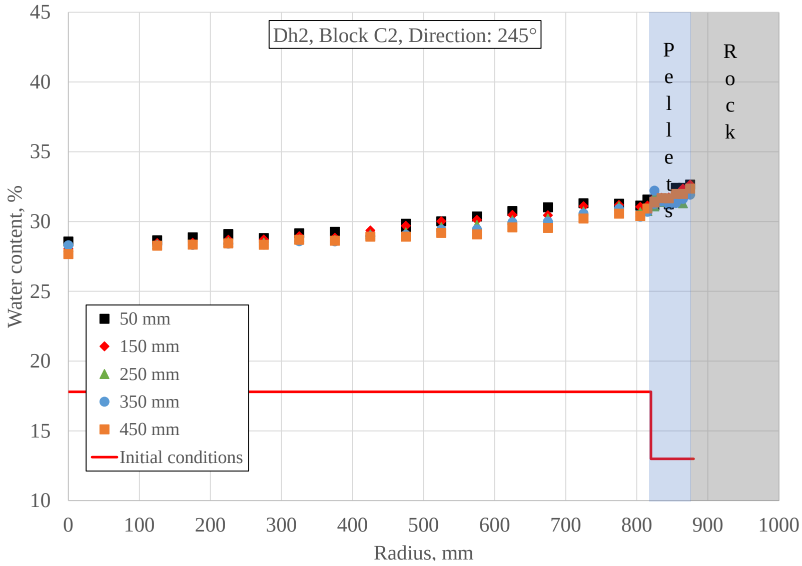


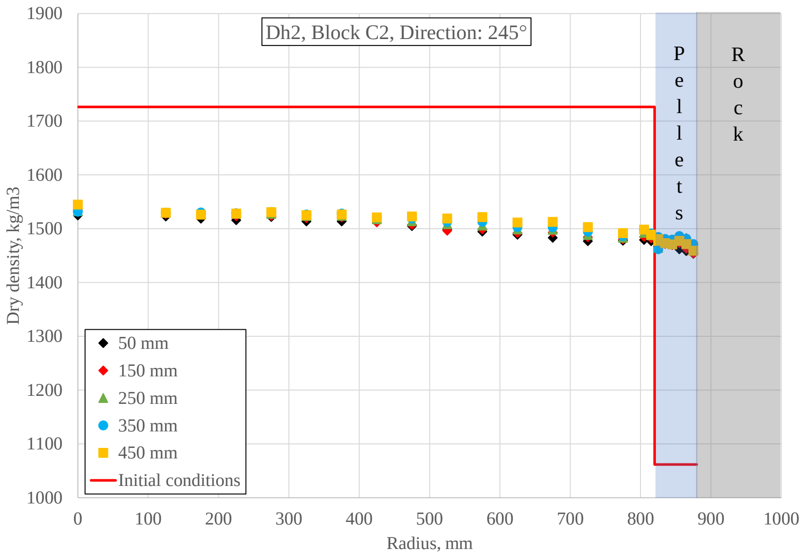


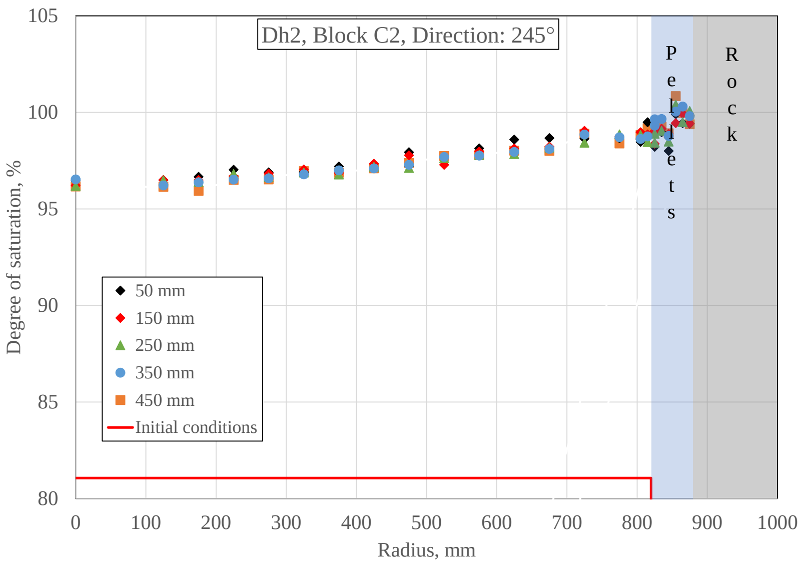


Appendix 3-3c Dh2, Block C2.

Water content, dry density, and degree of saturation at five depths in direction 245°.

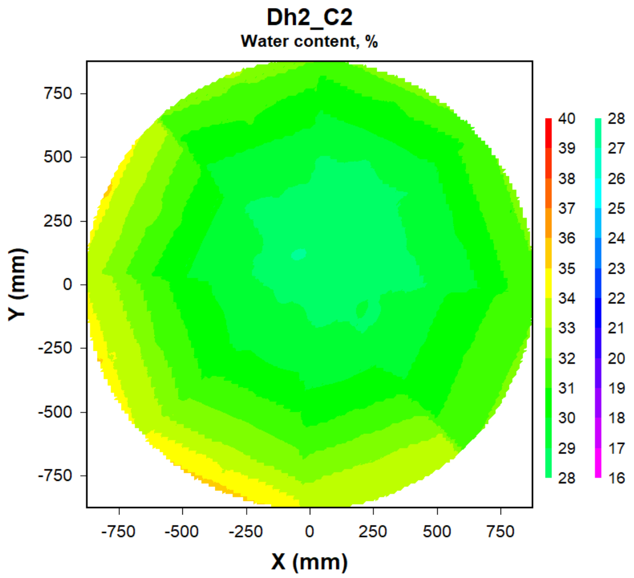


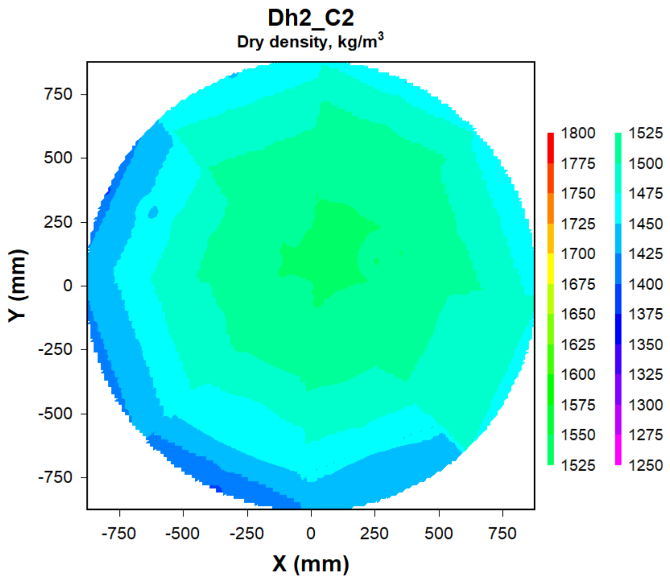


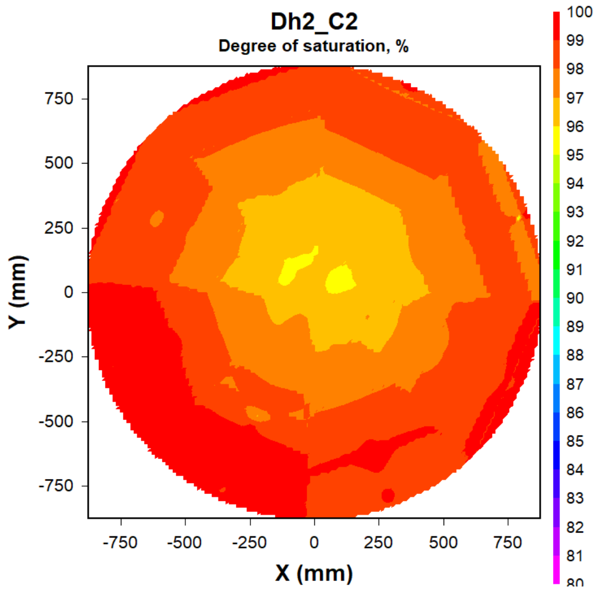


Appendix 3-3d Dh2, Block C2.

Water content, dry density, and degree of saturation distribution.

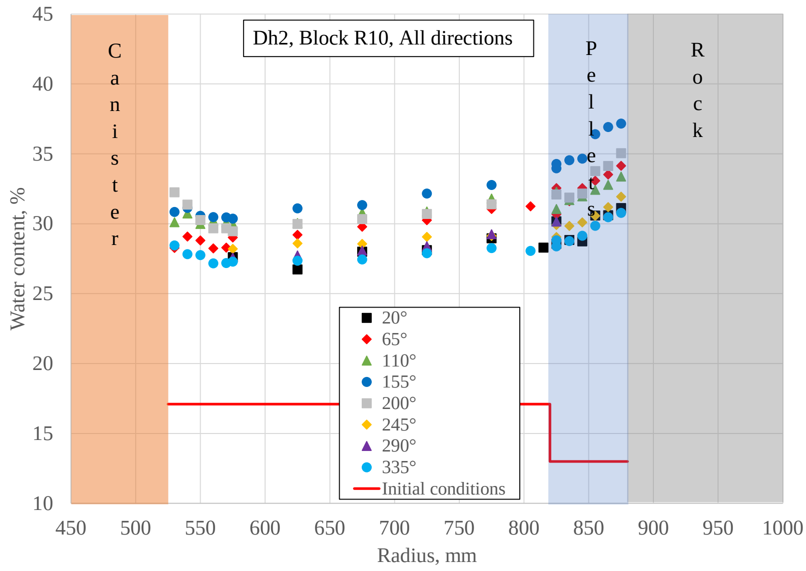


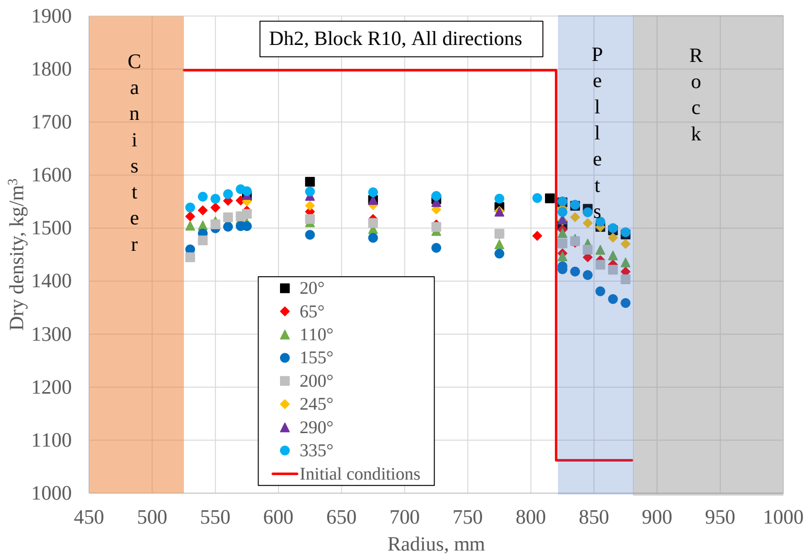


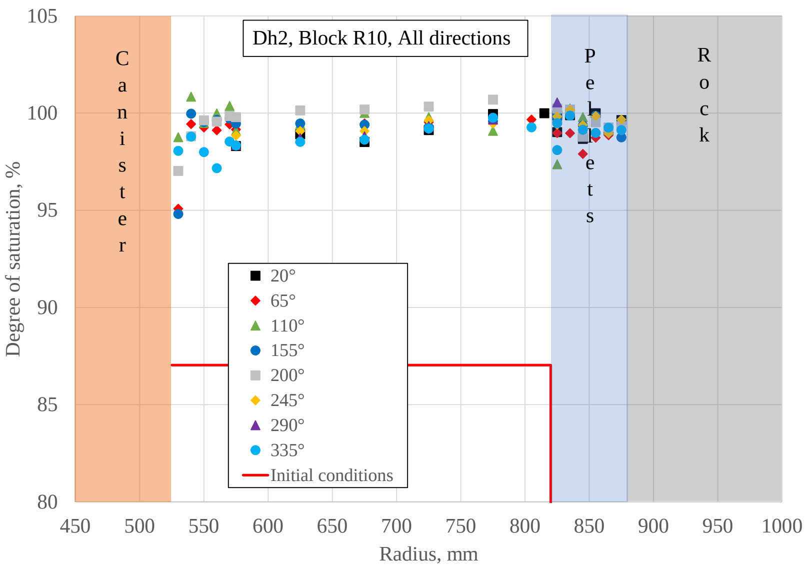


Appendix 3-4a Dh2, Block R10.

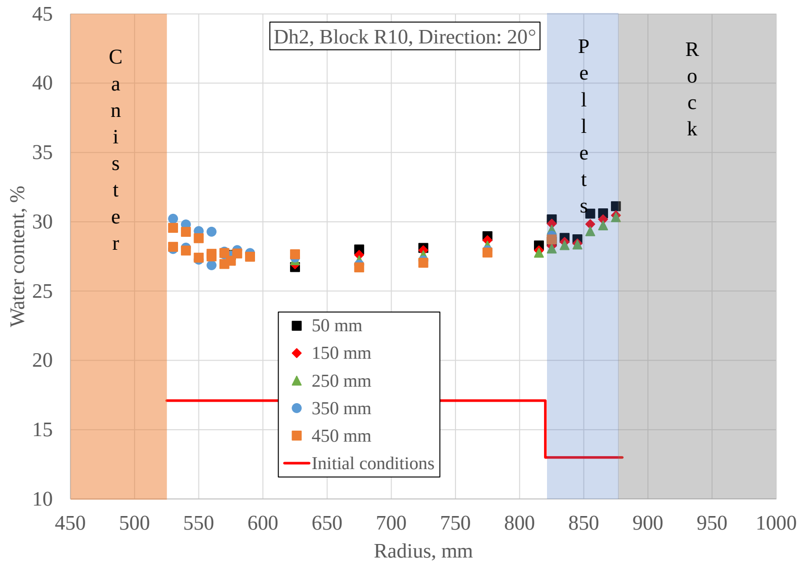
Water content, dry density, and degree of saturation in eight directions.

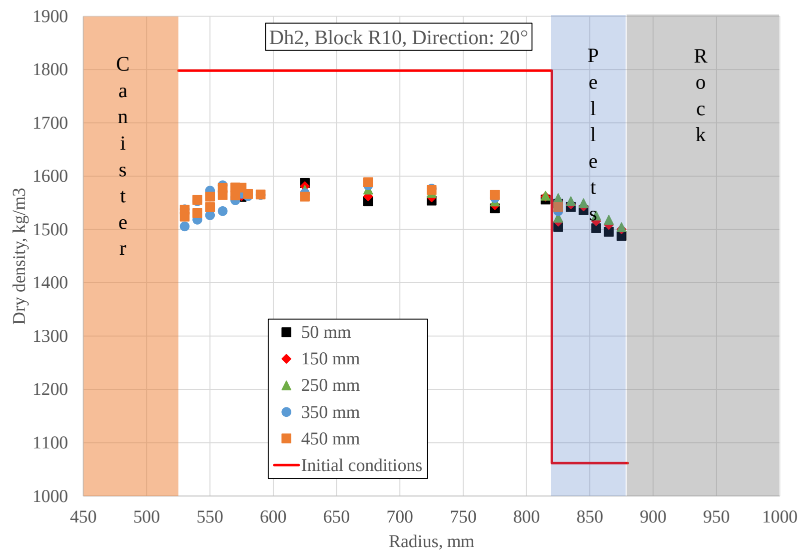


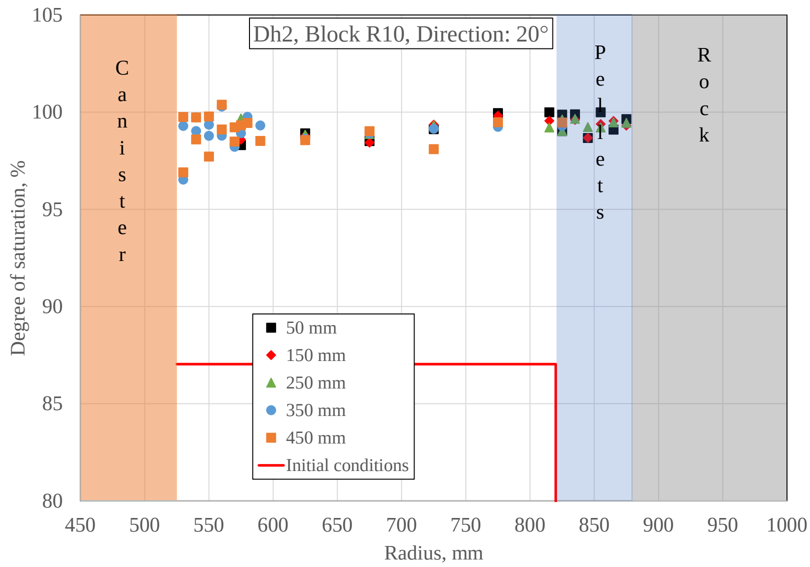




Appendix 3-4b Dh2, Block R10.
Water content, dry density, and degree of saturation at five depths in direction 20°.

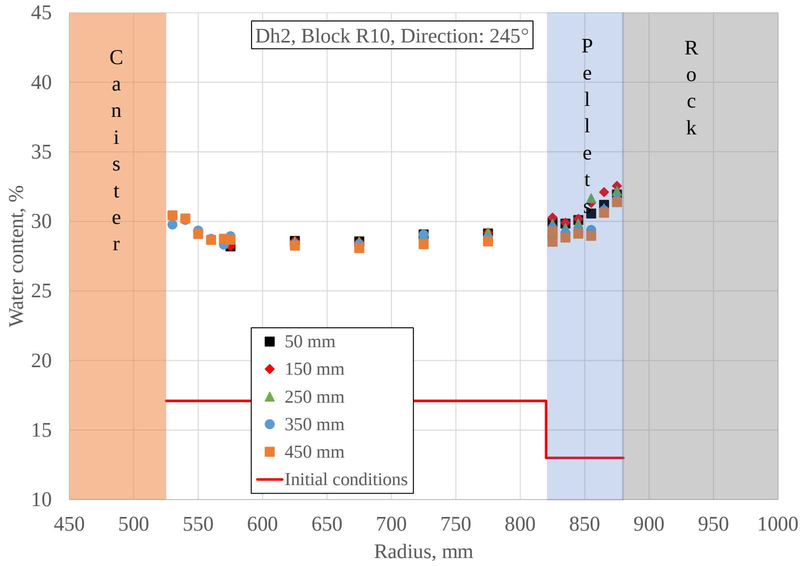


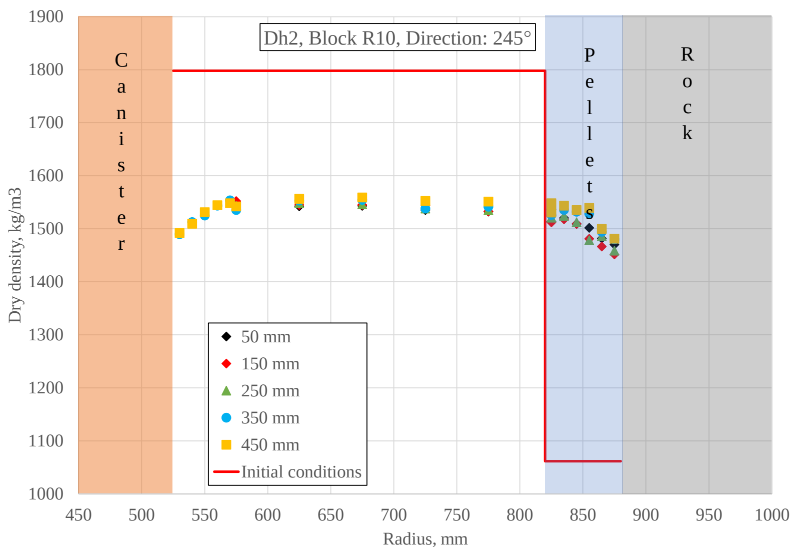


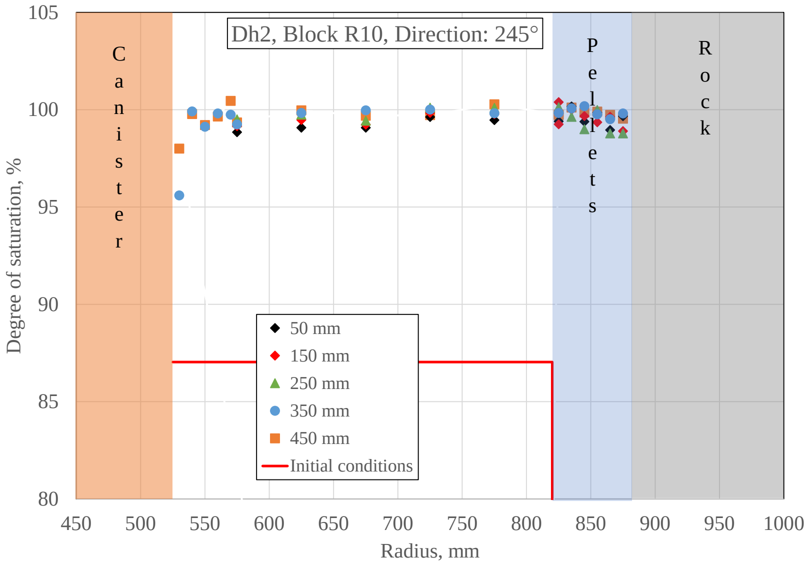


Appendix 3-4c Dh2, Block R10.

Water content, dry density, and degree of saturation at five depths in direction 245°.

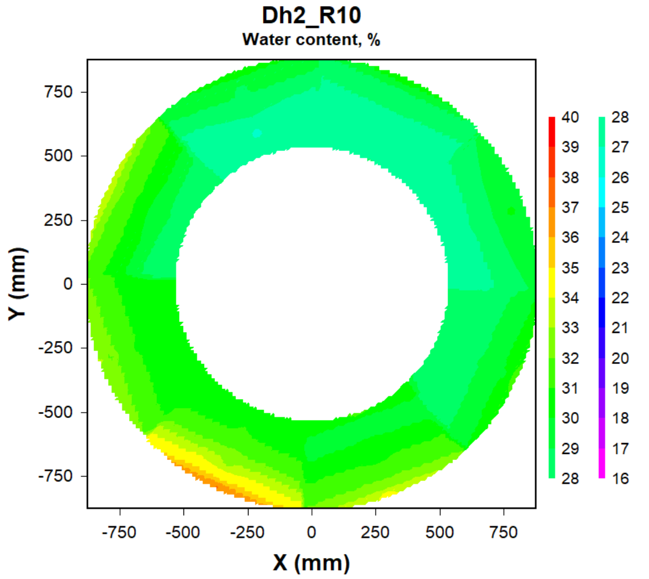


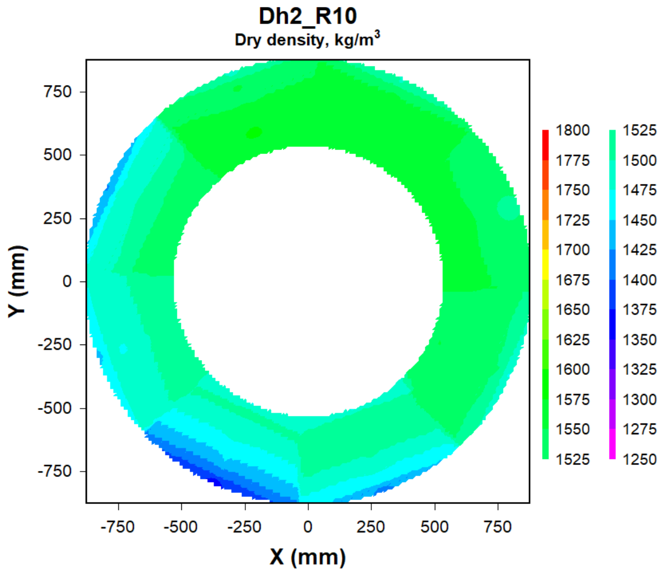


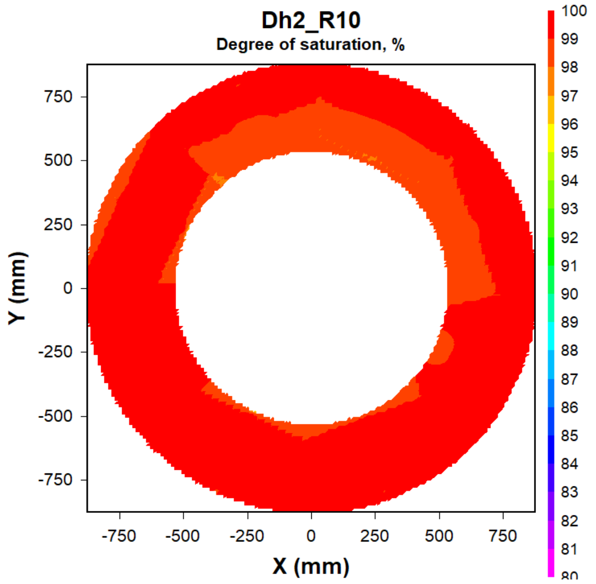


Appendix 3-4d Dh2, Block R10.

Water content, dry density, and degree of saturation distribution.

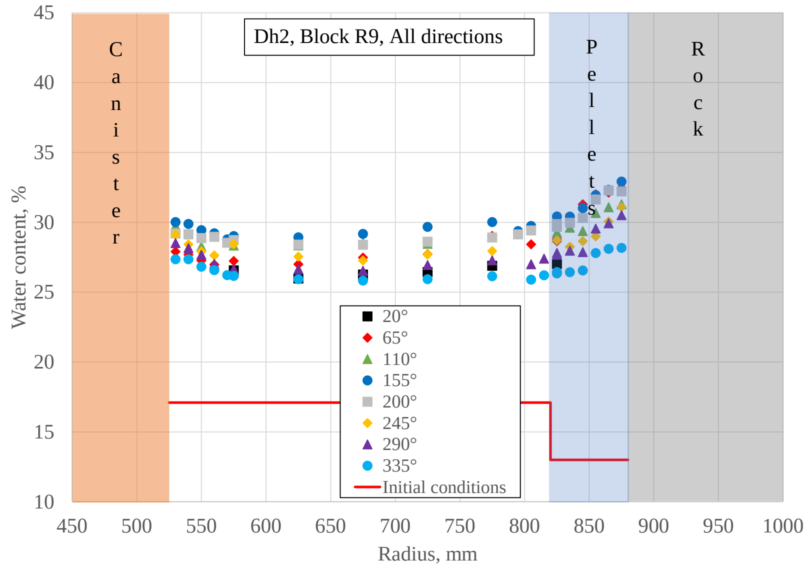


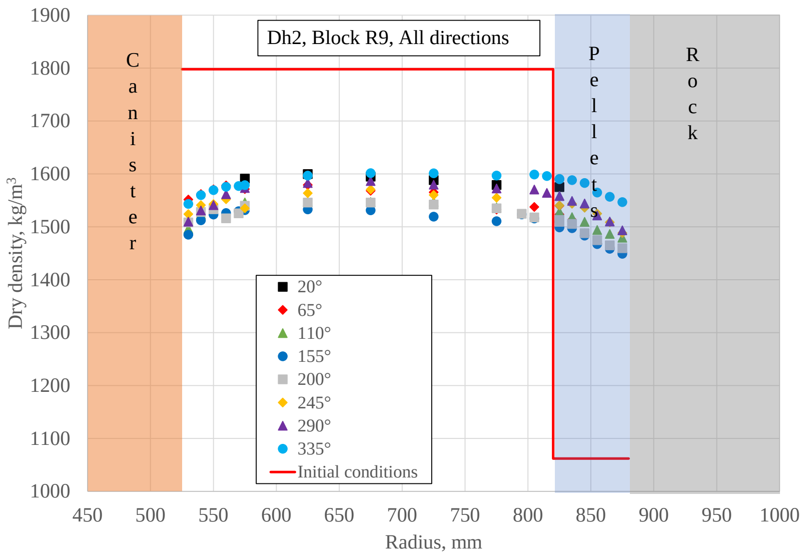


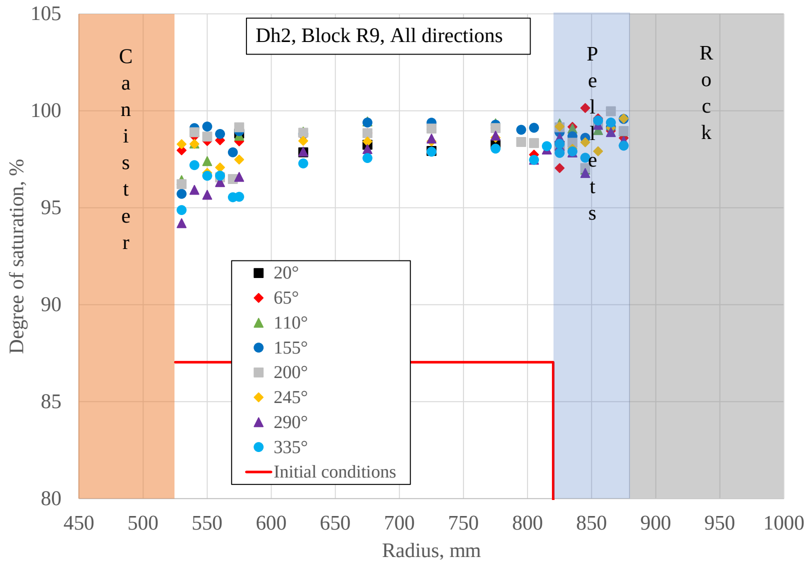


Appendix 3-5a Dh2, Block R9.

Water content, dry density, and degree of saturation in eight directions.

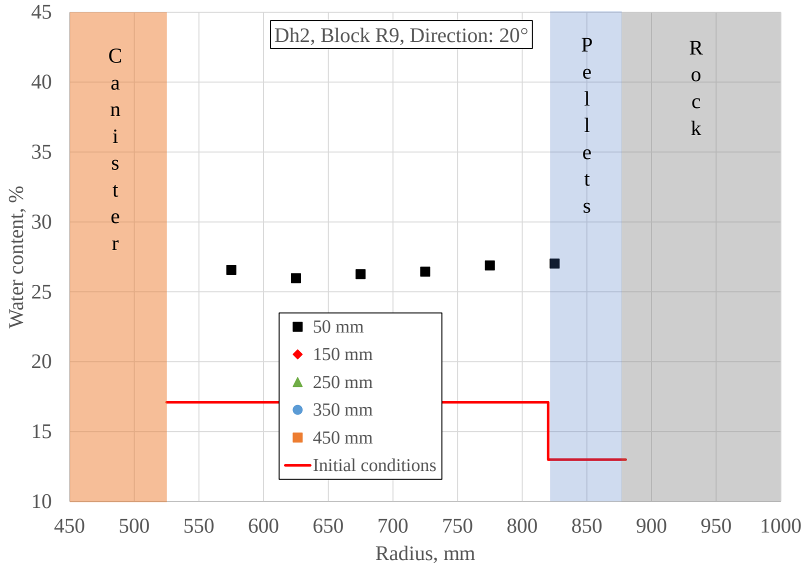


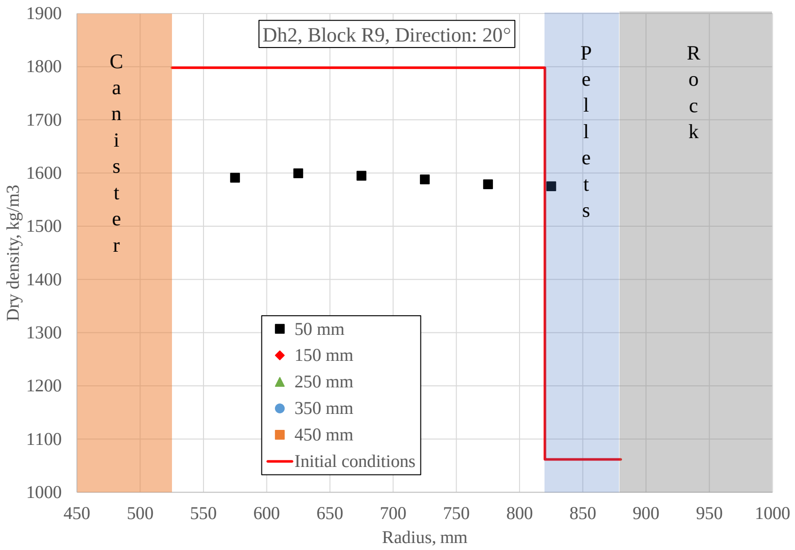


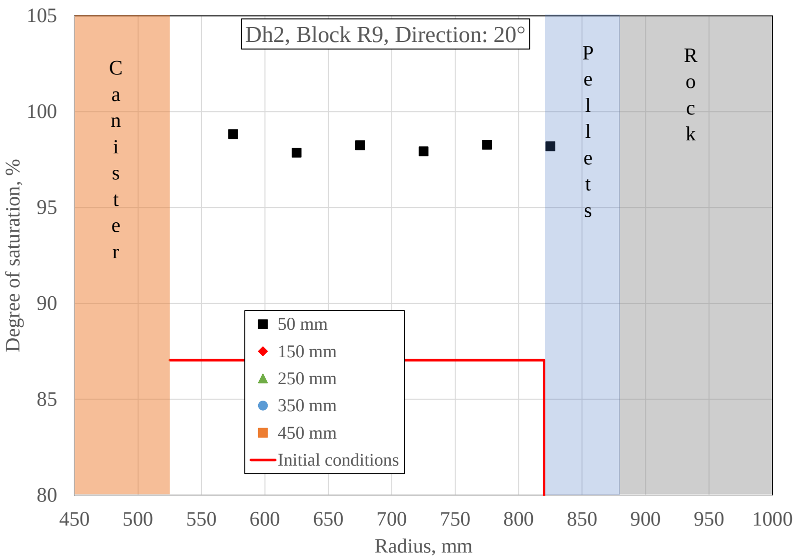


Appendix 3-5b Dh2, Block R9.

Water content, dry density, and degree of saturation at five depths in direction 20°.

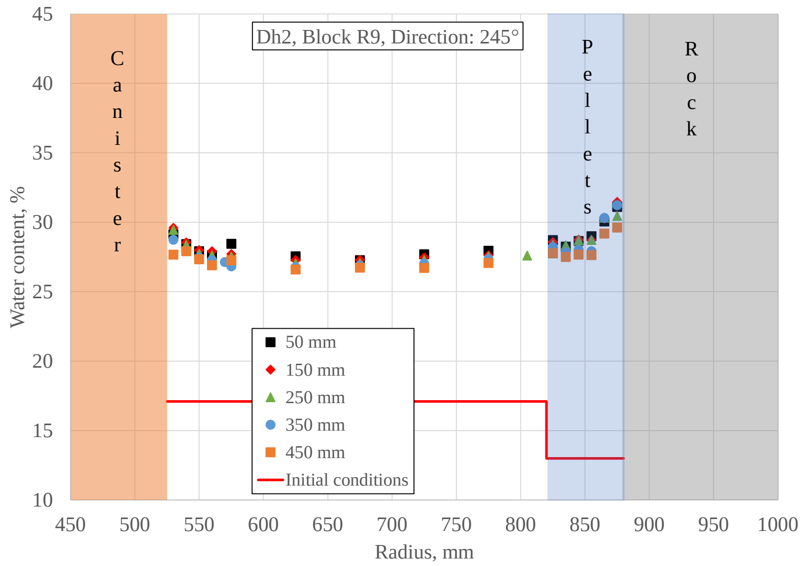


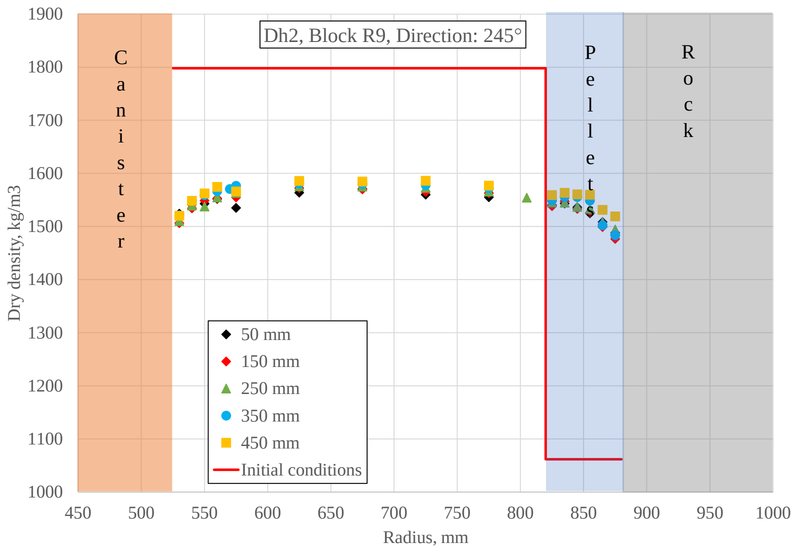


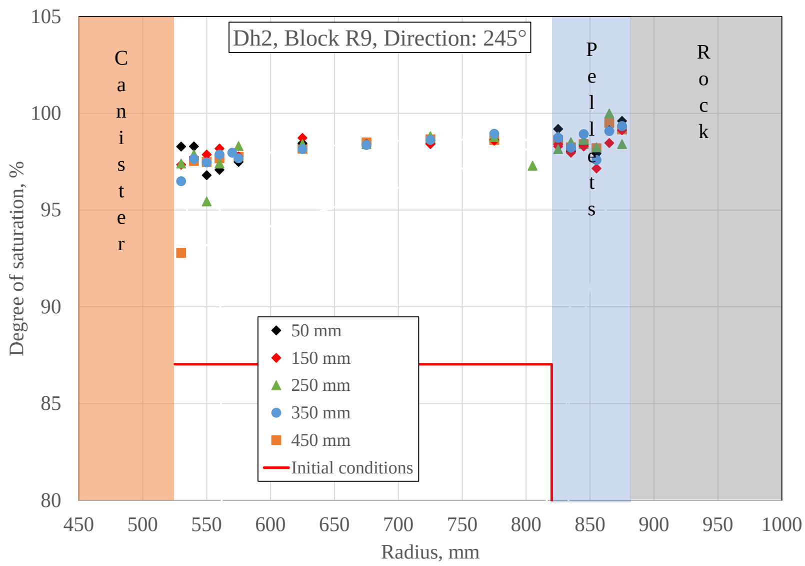


Appendix 3-5c Dh2, Block R9.

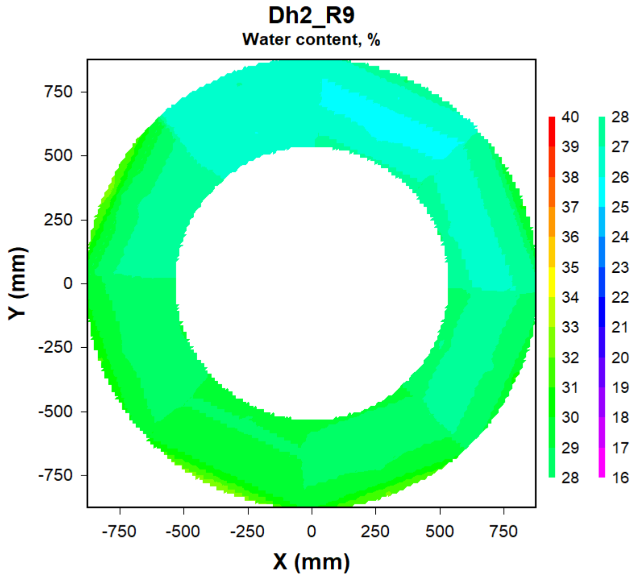
Water content, dry density, and degree of saturation at five depths in direction 245°.

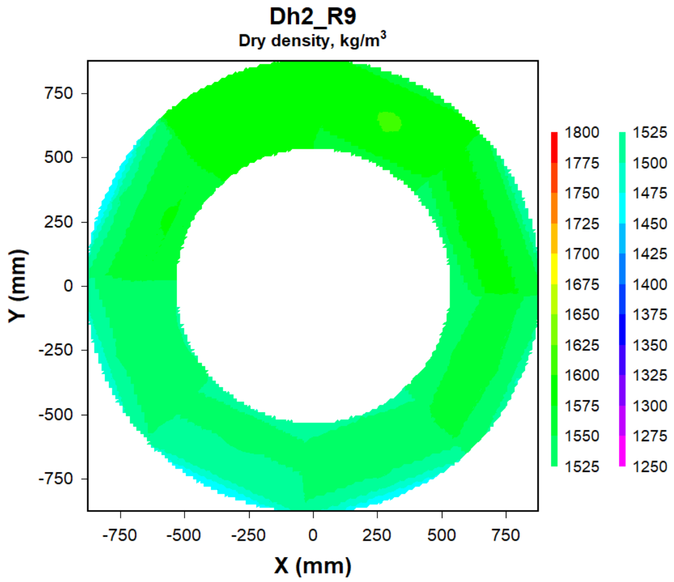


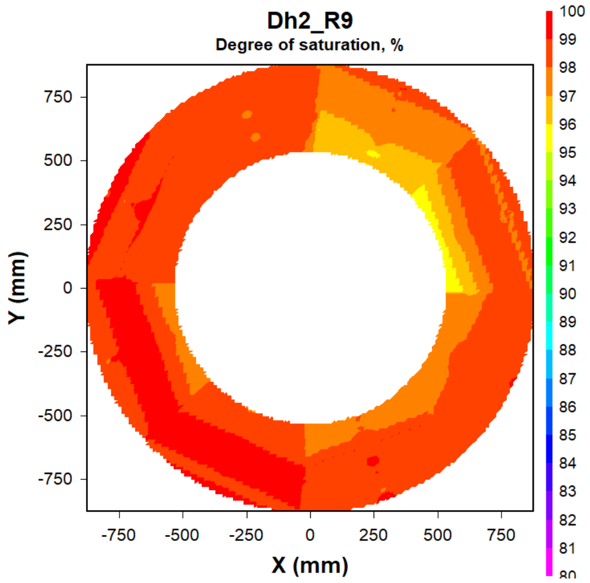




Appendix 3-5d Dh2, Block R9.
Water content, dry density, and degree of saturation distribution.

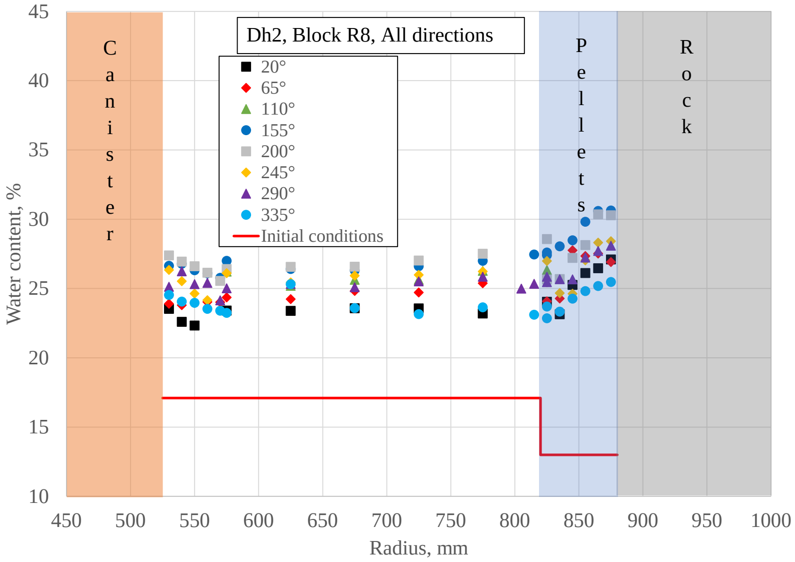


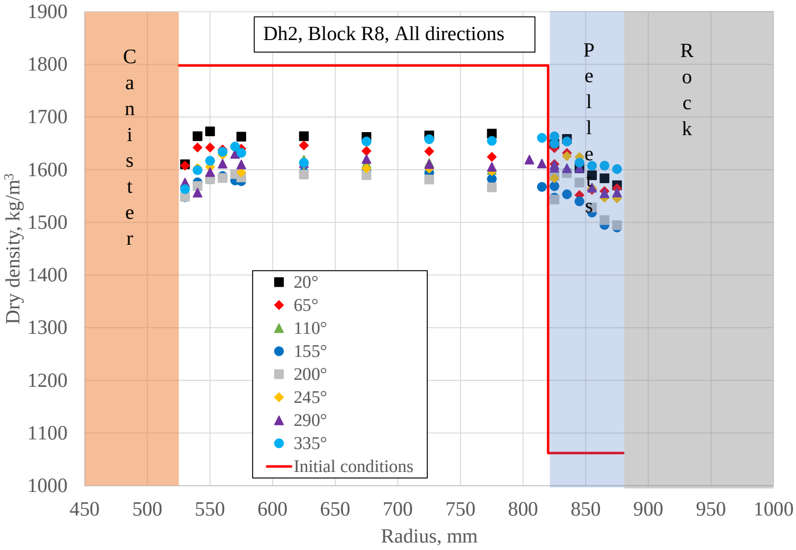


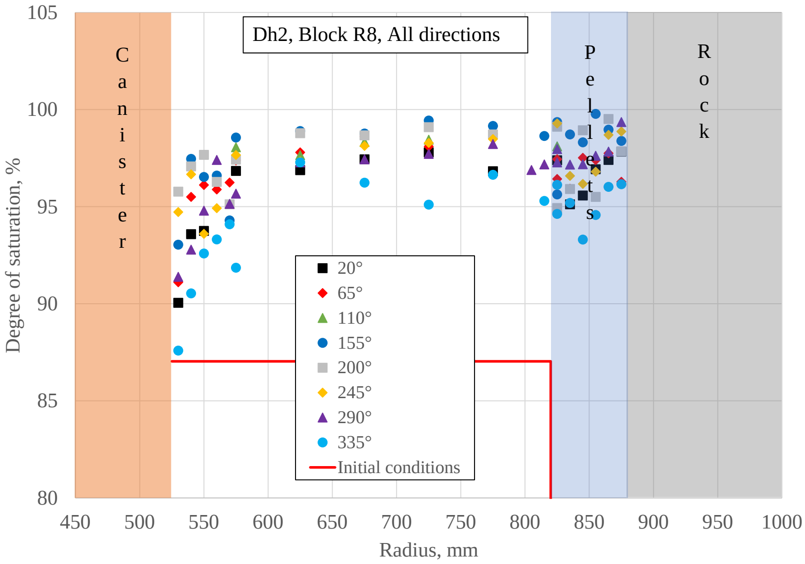


Appendix 3-6a Dh2, Block R8.

Water content, dry density, and degree of saturation in eight directions.

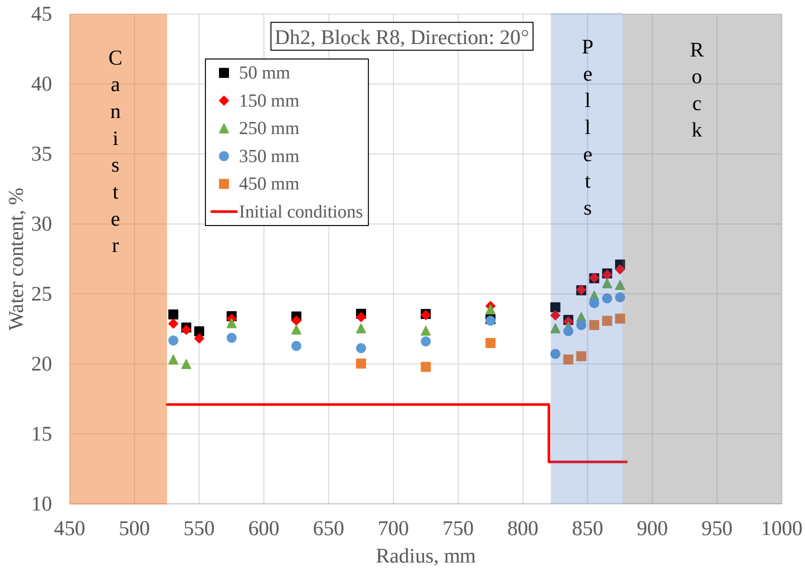


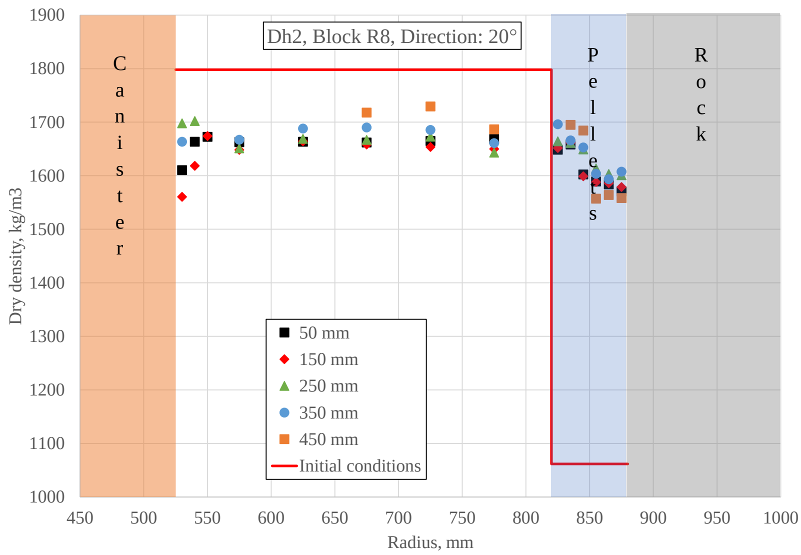


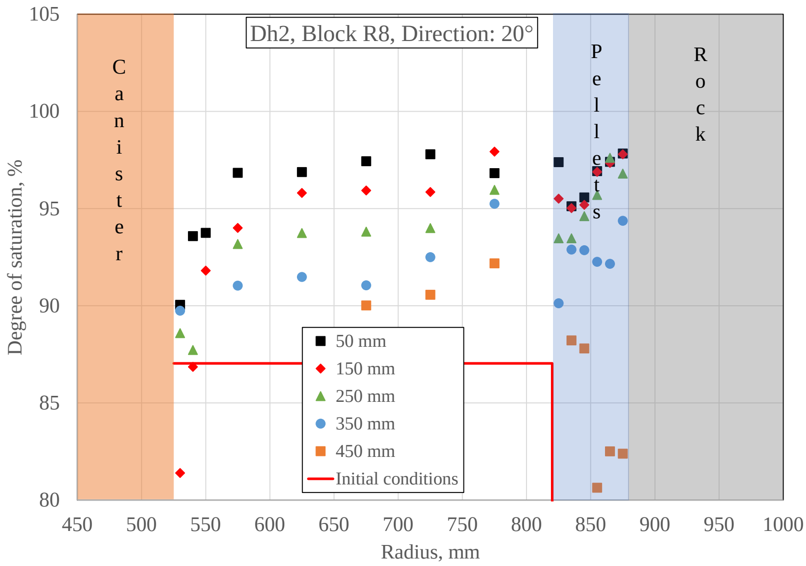


Appendix 3-6b Dh2, Block R8.

Water content, dry density, and degree of saturation at five depths in direction 20°.

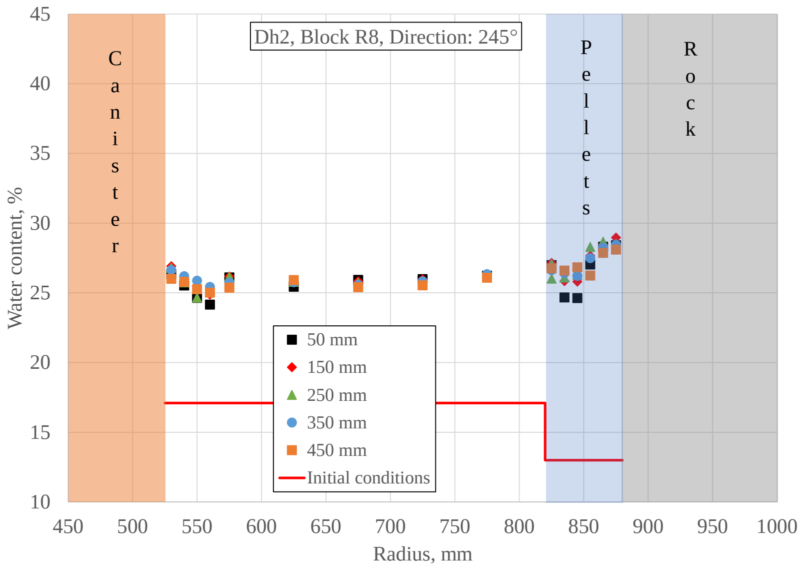


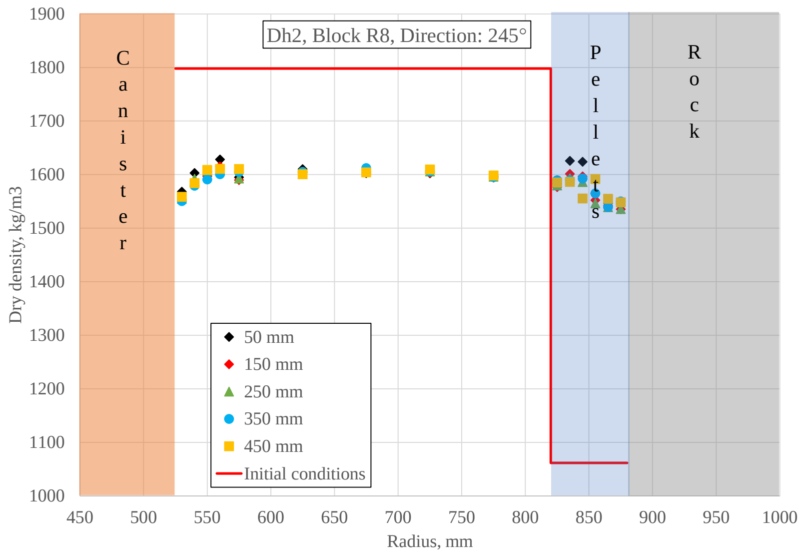


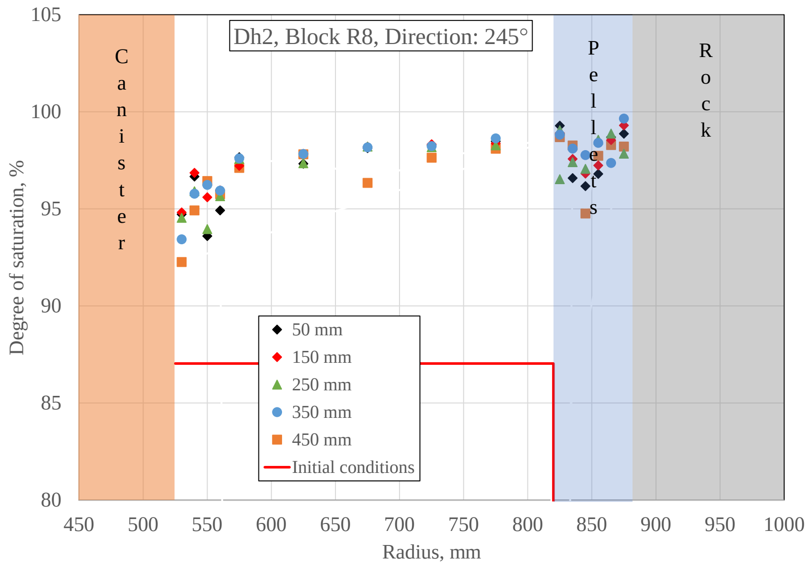


Appendix 3-6c Dh2, Block R8.

Water content, dry density, and degree of saturation at five depths in direction 245°.

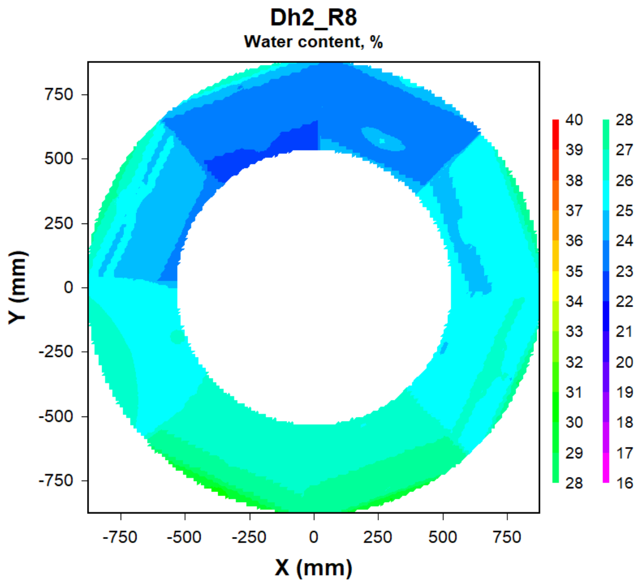


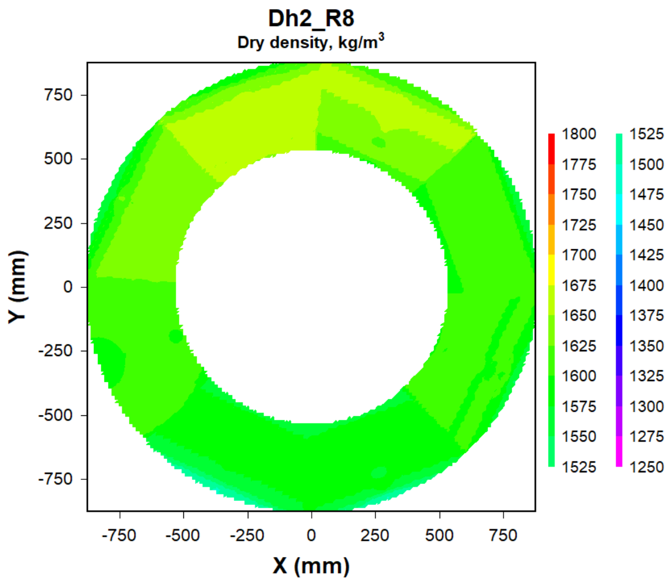


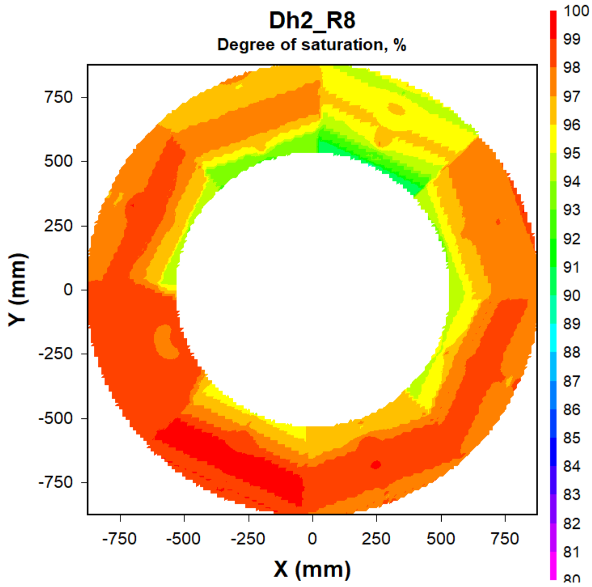


Appendix 3-6d Dh2, Block R8.

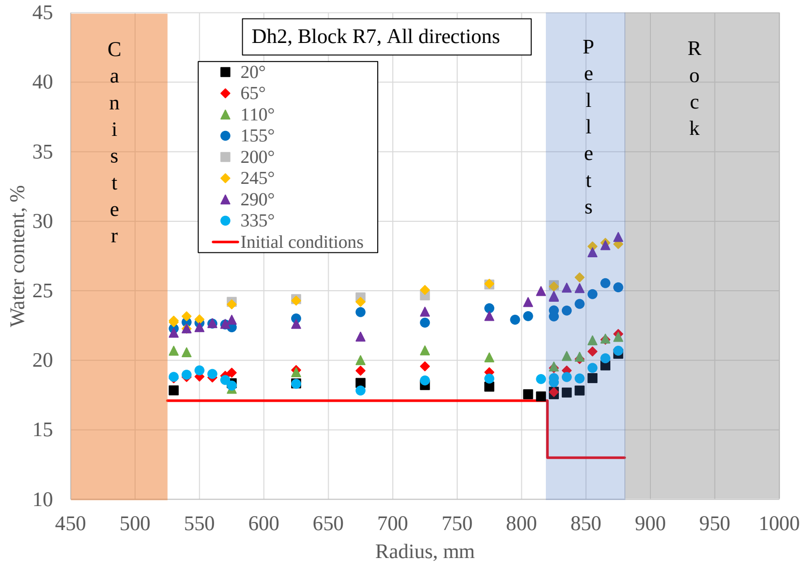
Water content, dry density, and degree of saturation distribution.

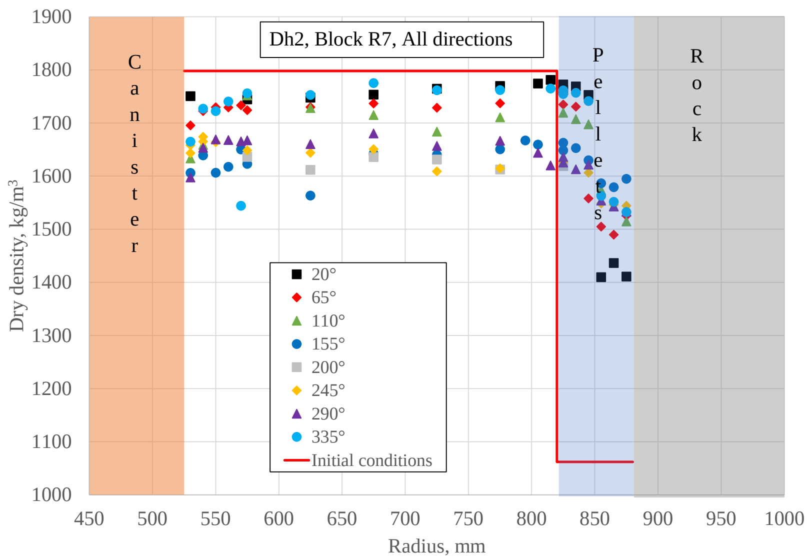


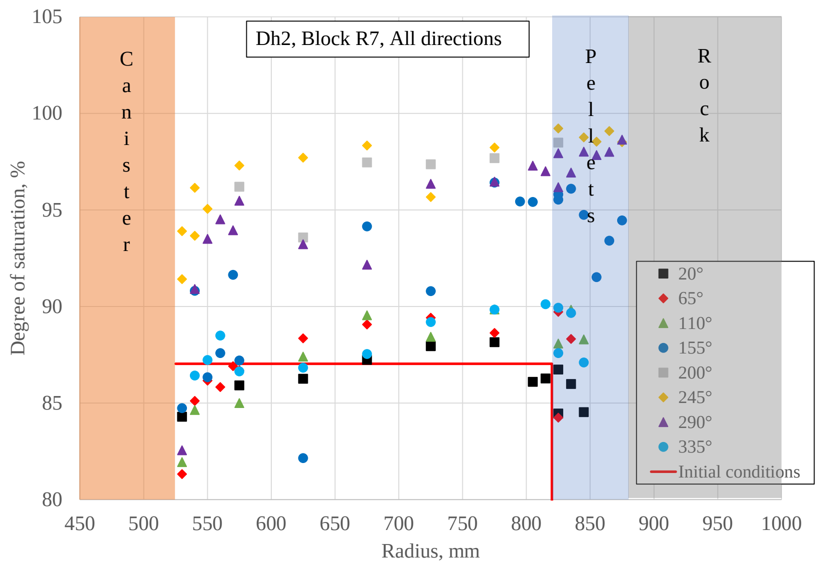




Appendix 3-7a Dh2, Block R7.
Water content, dry density, and degree of saturation in eight directions.

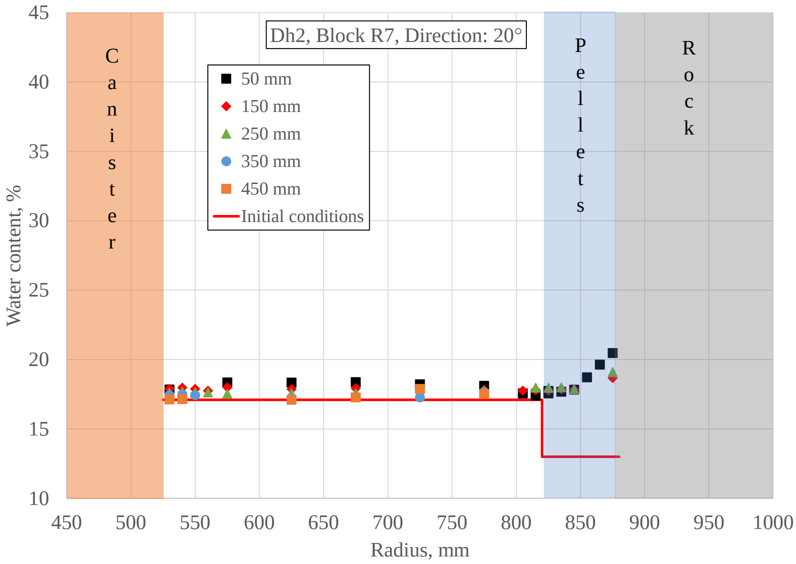


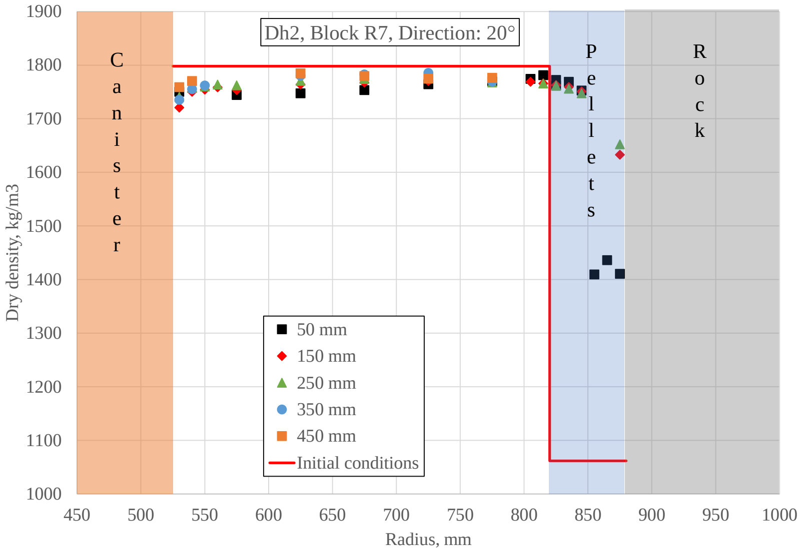


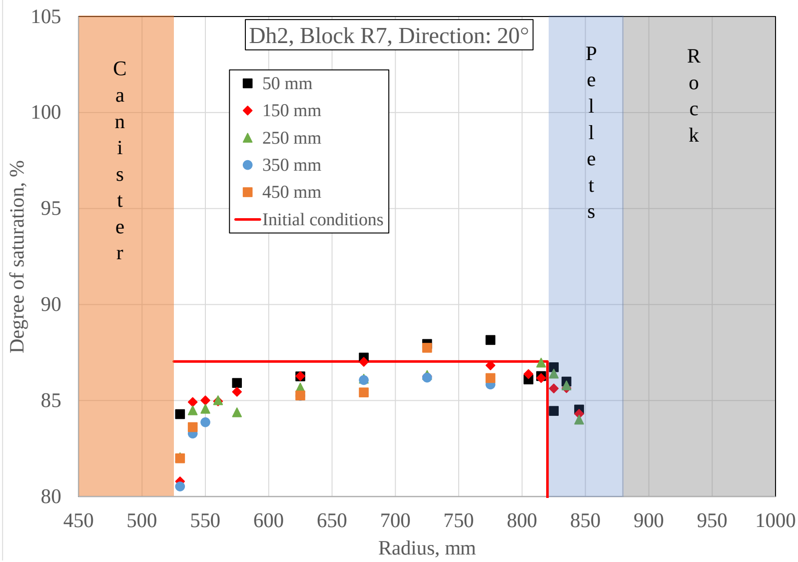


Appendix 3-7b Dh2, Block R7.

Water content, dry density, and degree of saturation at five depths in direction 20°.

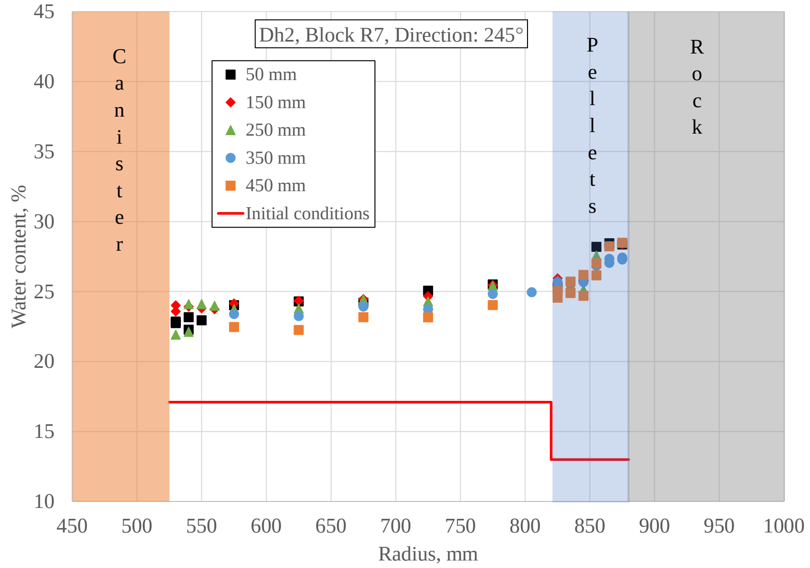


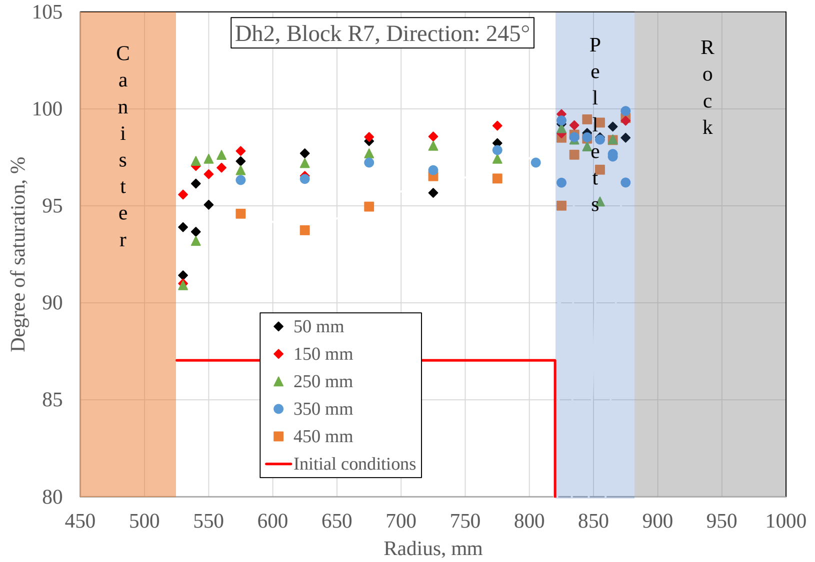




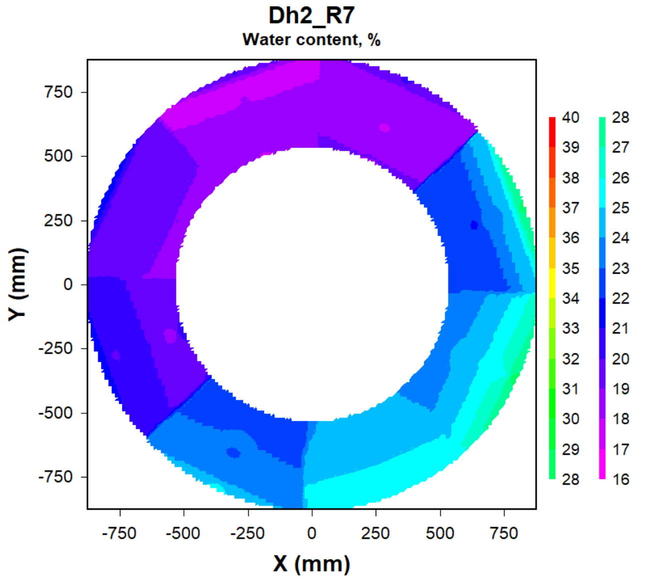
Appendix 3-7c Dh2, Block R7.

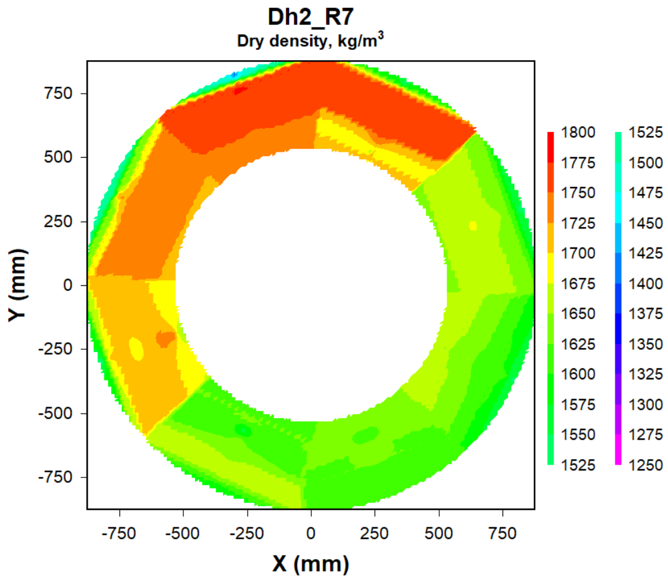
Water content, dry density, and degree of saturation at five depths in direction 245°.

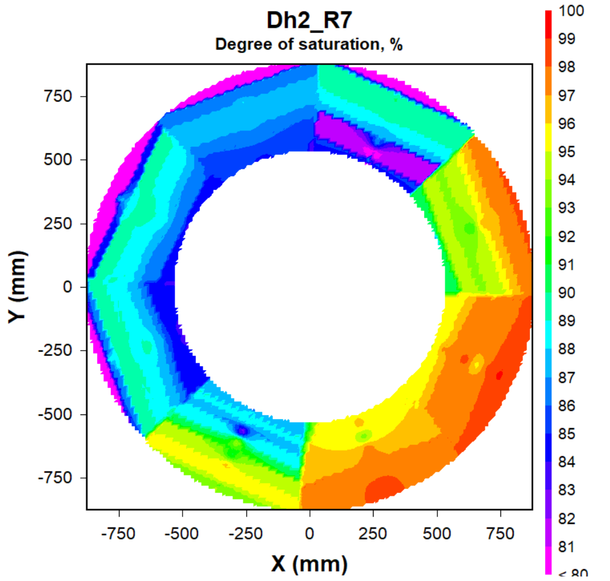




Appendix 3-7d Dh2, Block R7.
Water content, dry density, and degree of saturation distribution.

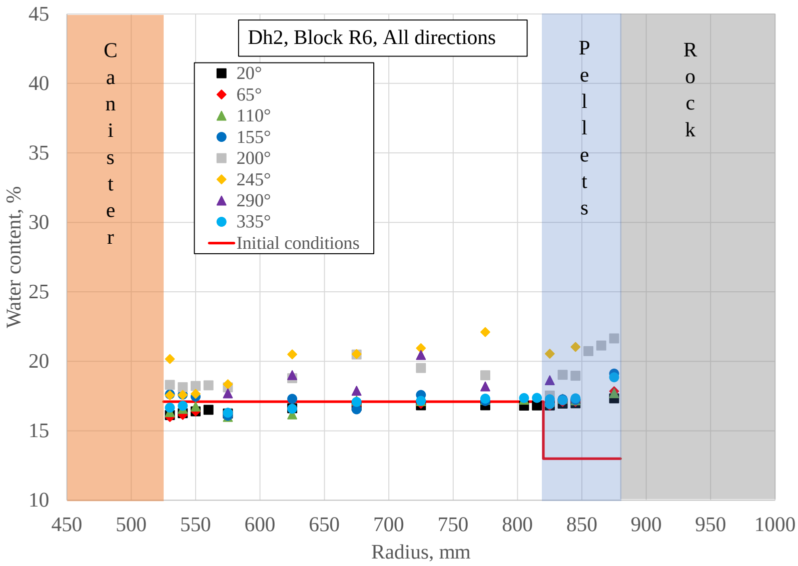


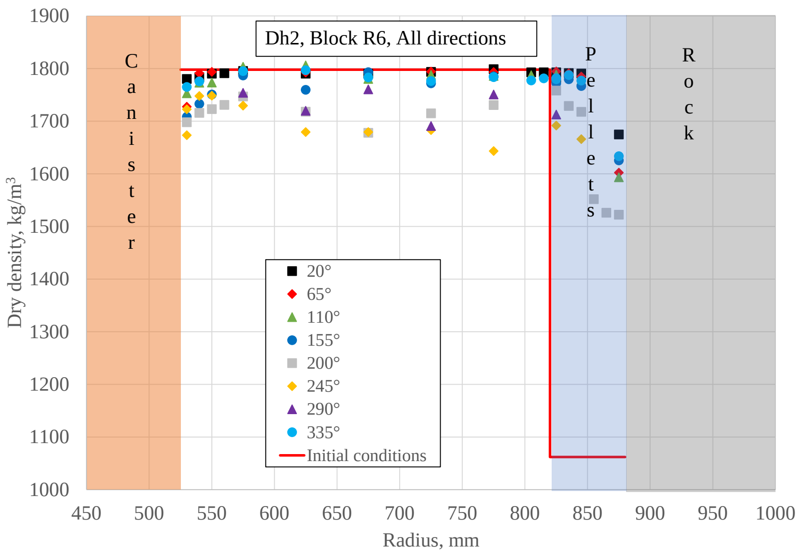


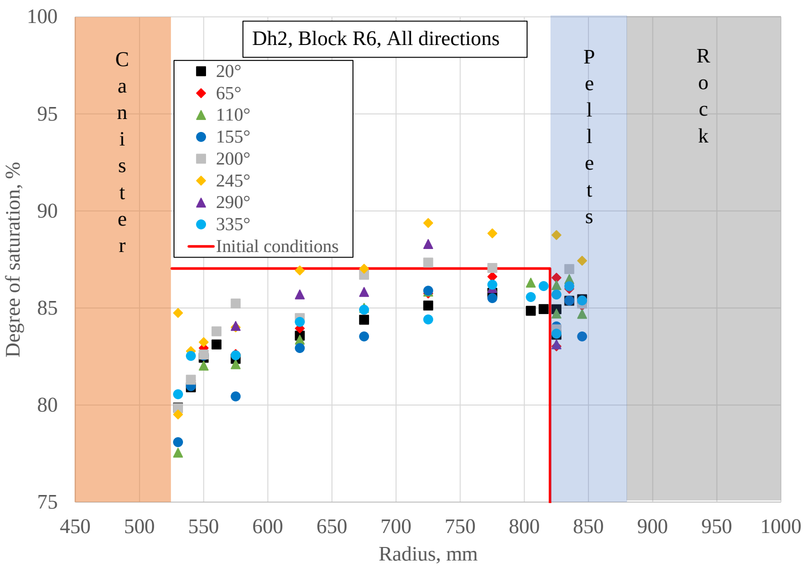


Appendix 3-8a Dh2, Block R6.

Water content, dry density, and degree of saturation in eight directions.

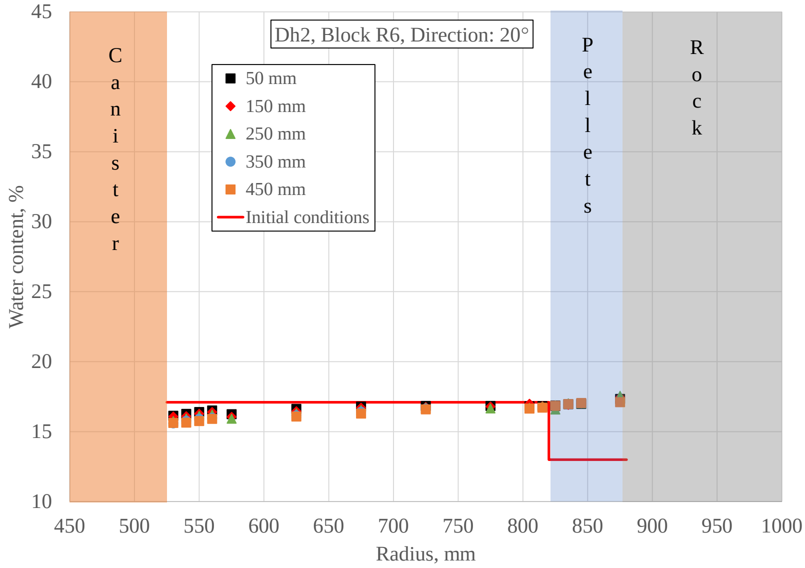


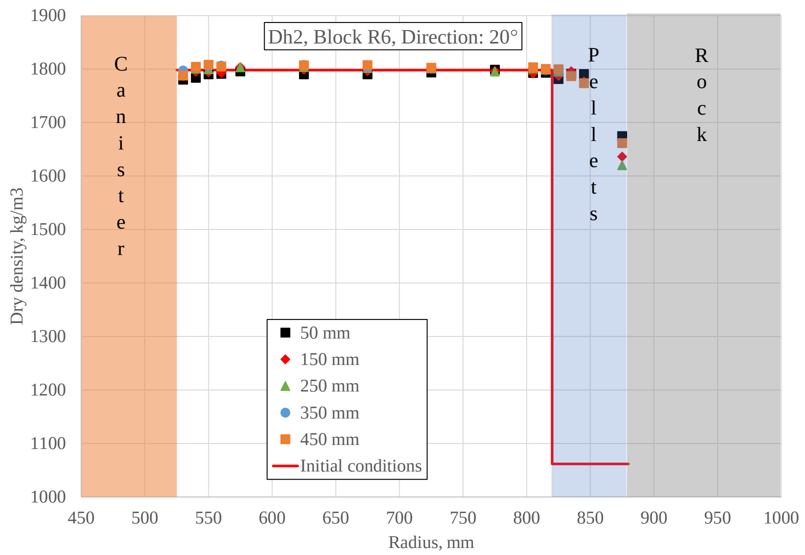


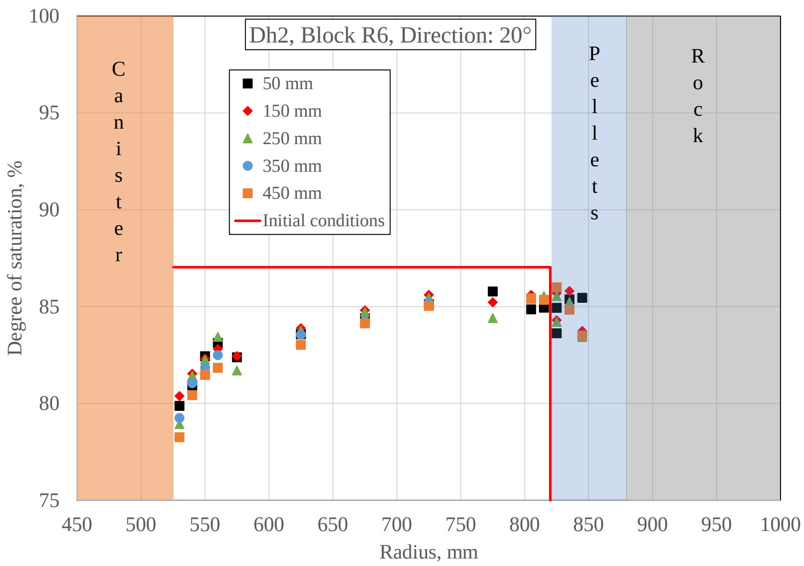


Appendix 3-8b Dh2, Block R6.

Water content, dry density, and degree of saturation at five depths in direction 20°.

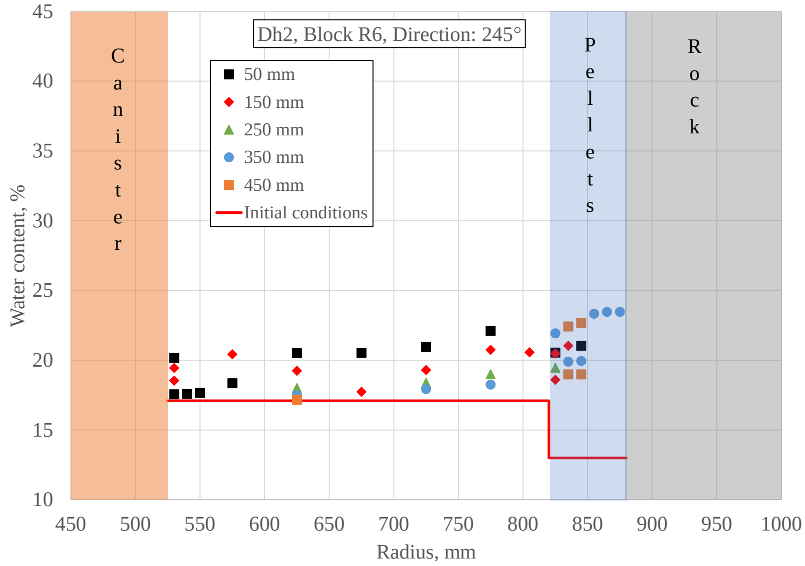


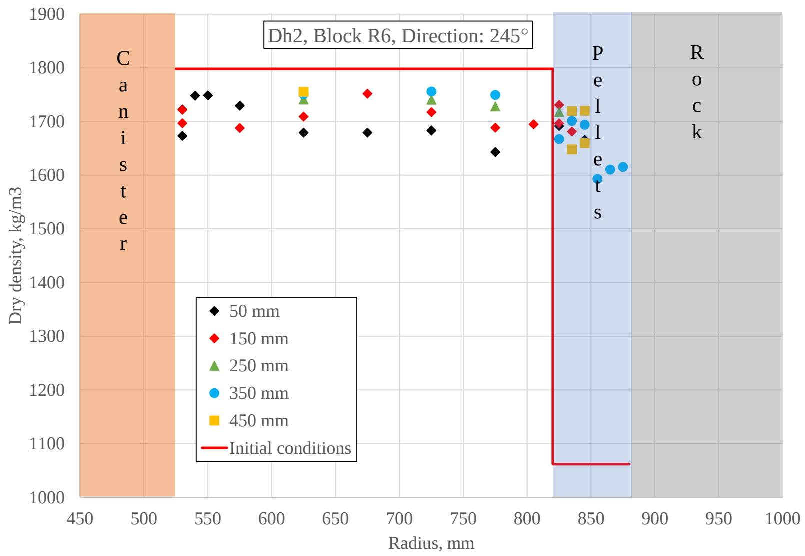


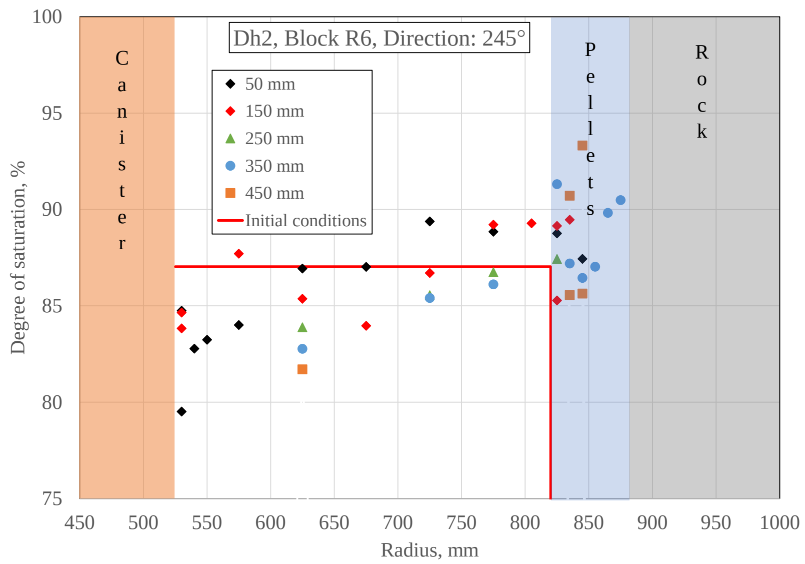


Appendix 3-8c Dh2, Block R6.

Water content, dry density, and degree of saturation at five depths in direction 245°.

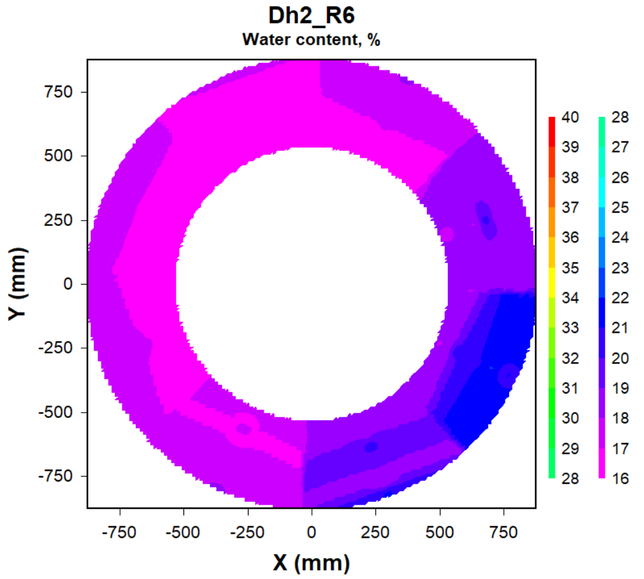


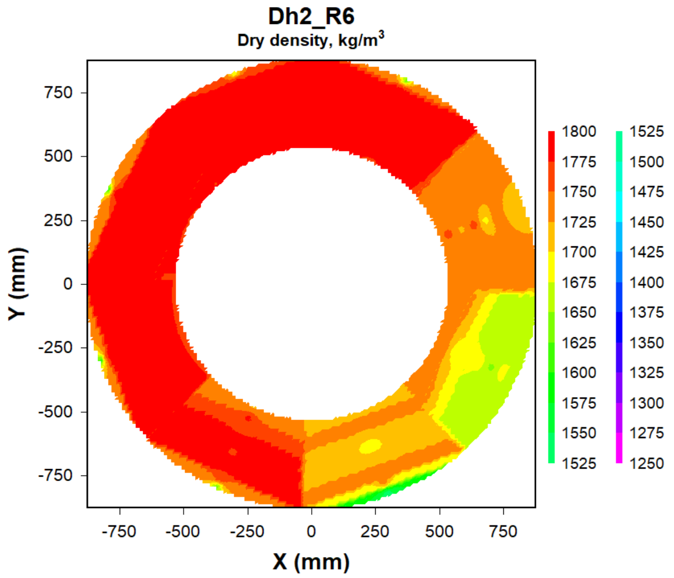


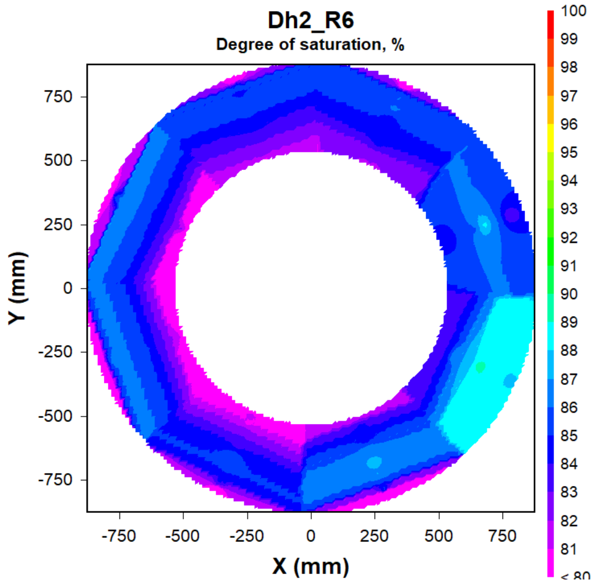


Appendix 3-8d Dh2, Block R6.

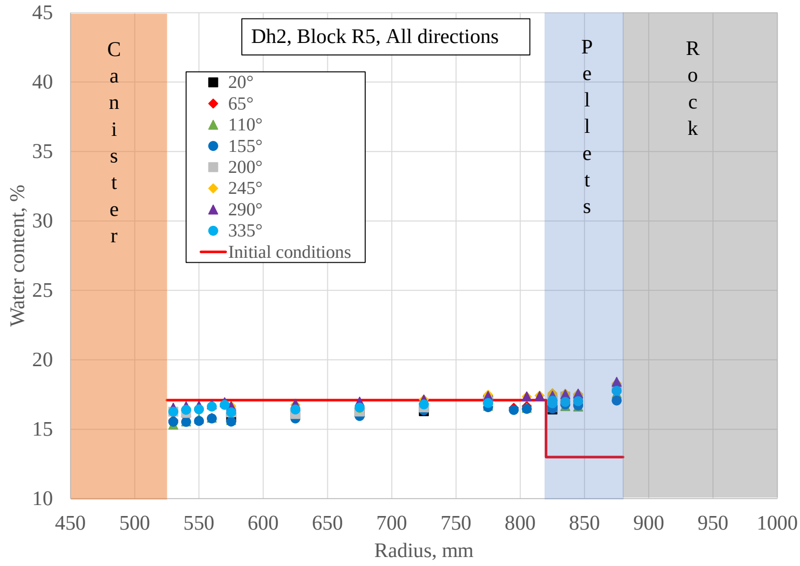
Water content, dry density, and degree of saturation distribution.

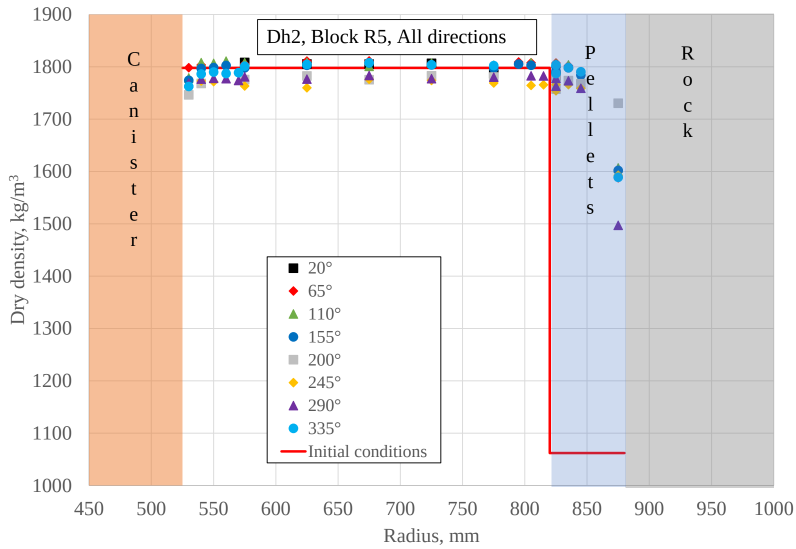


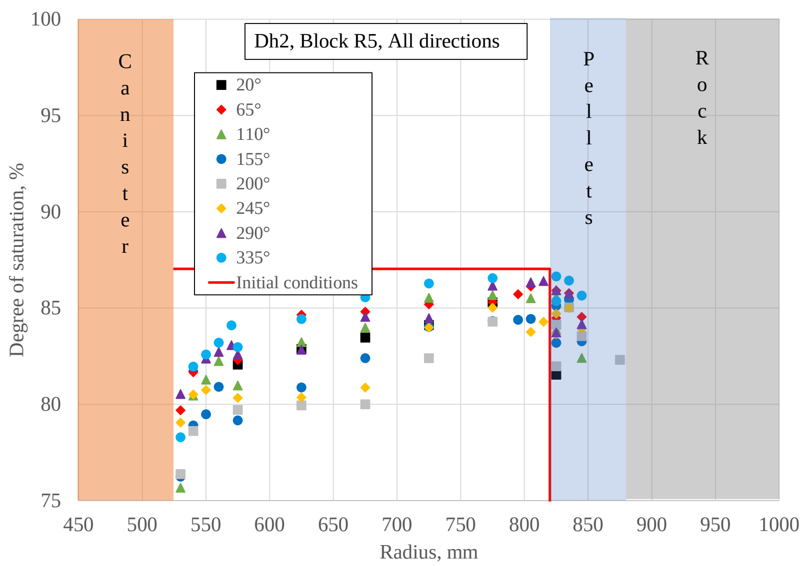




Appendix 3-9a Dh2, Block R5.
Water content, dry density, and degree of saturation in eight directions.

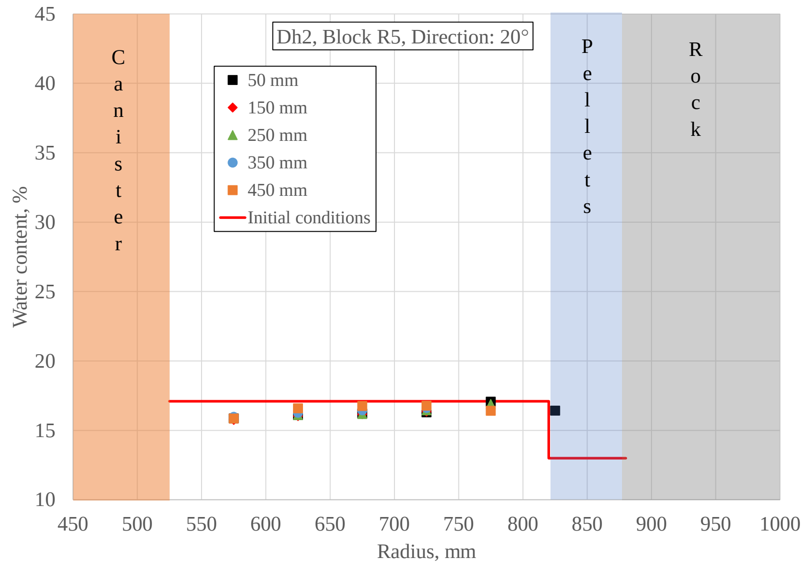


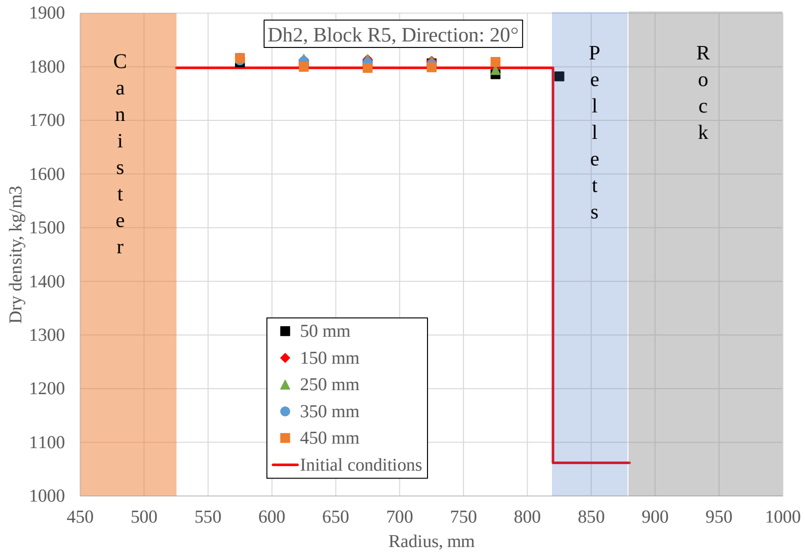


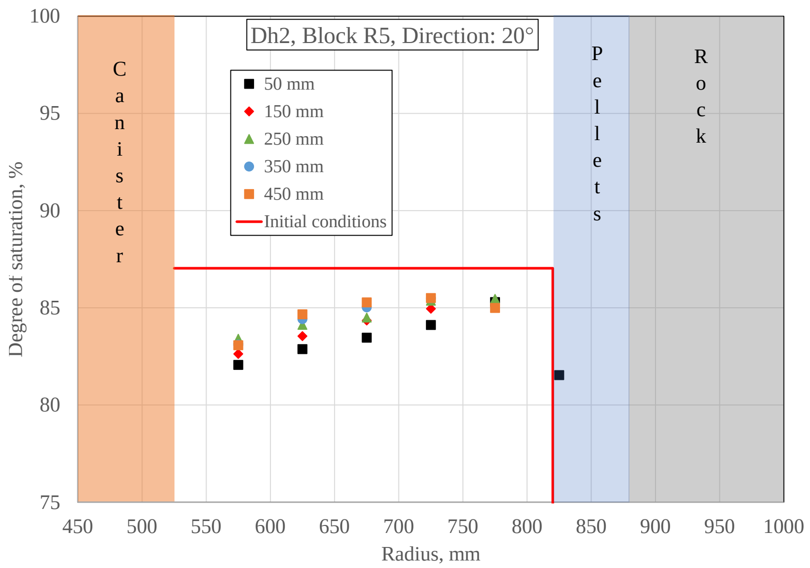


Appendix 3-9b Dh2, Block R5.

Water content, dry density, and degree of saturation at five depths in direction 20°.

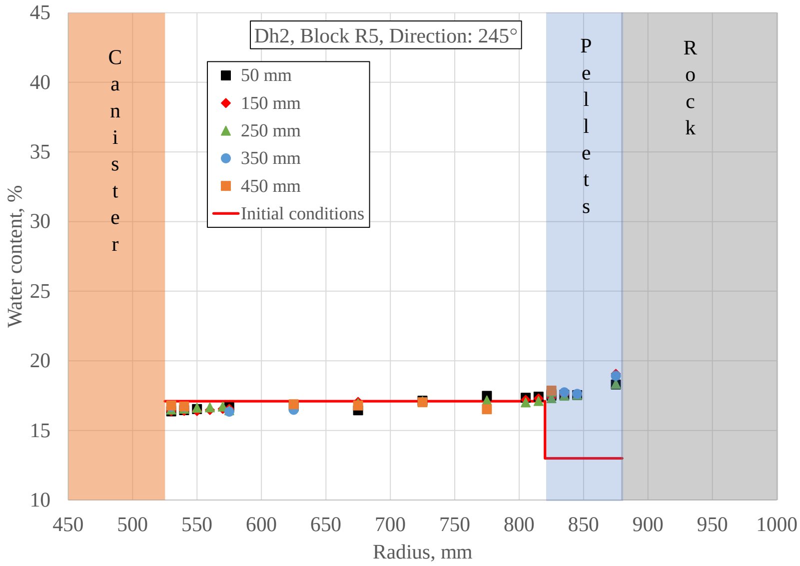


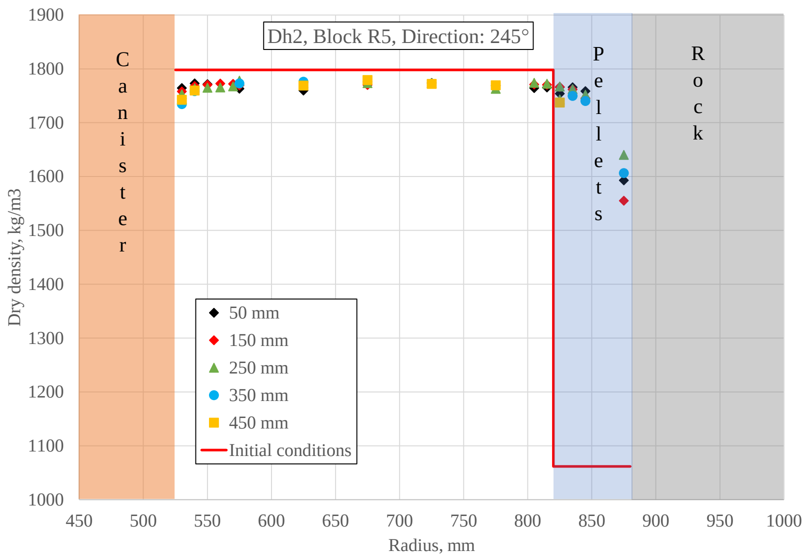


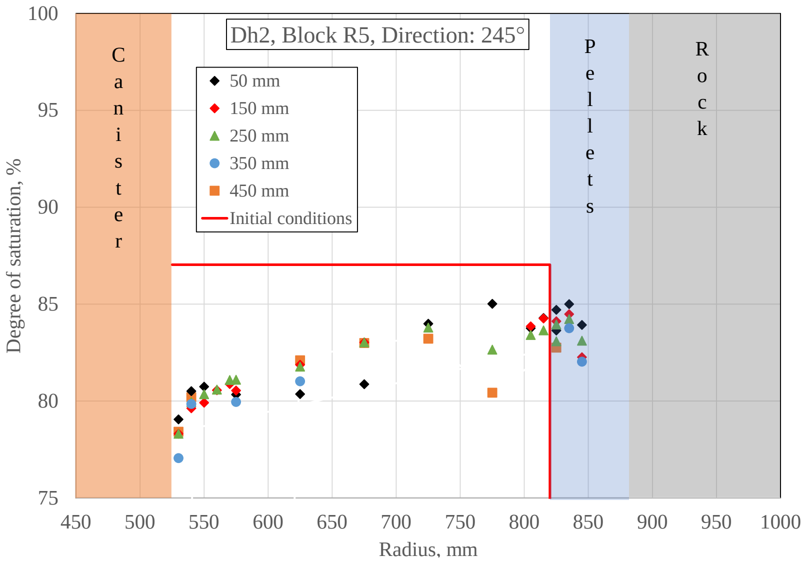


Appendix 3-9c Dh2, Block R5.

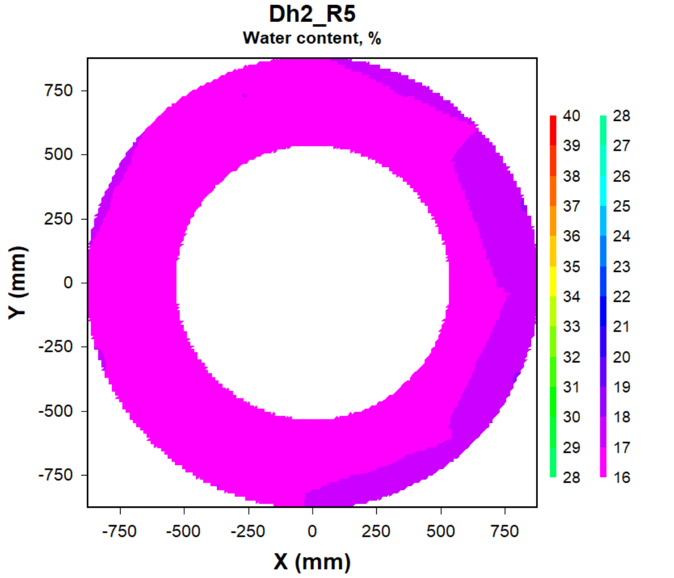
Water content, dry density, and degree of saturation at five depths in direction 245°.

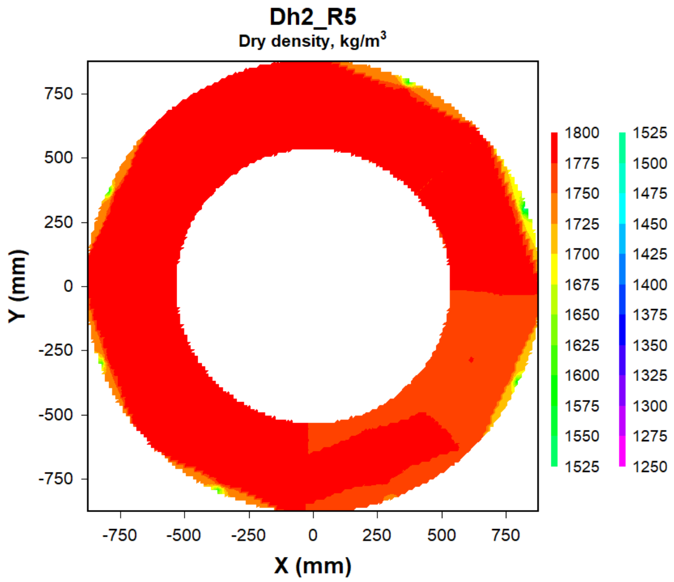


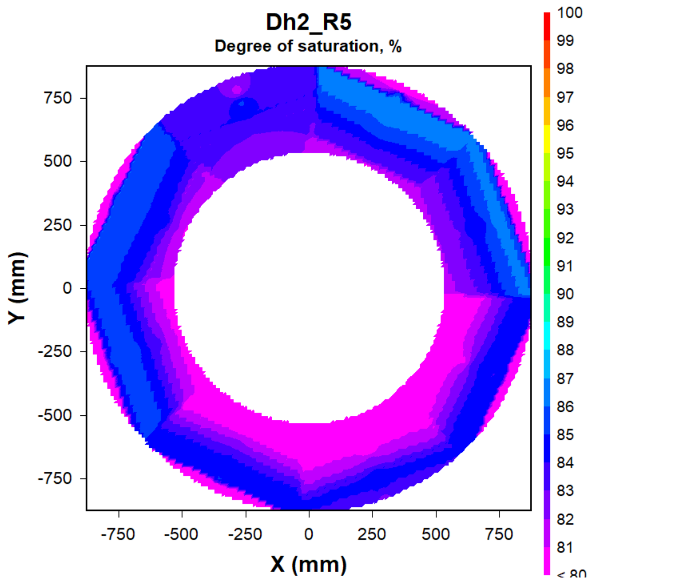




Appendix 3-9d Dh2, Block R5.
Water content, dry density, and degree of saturation distribution.

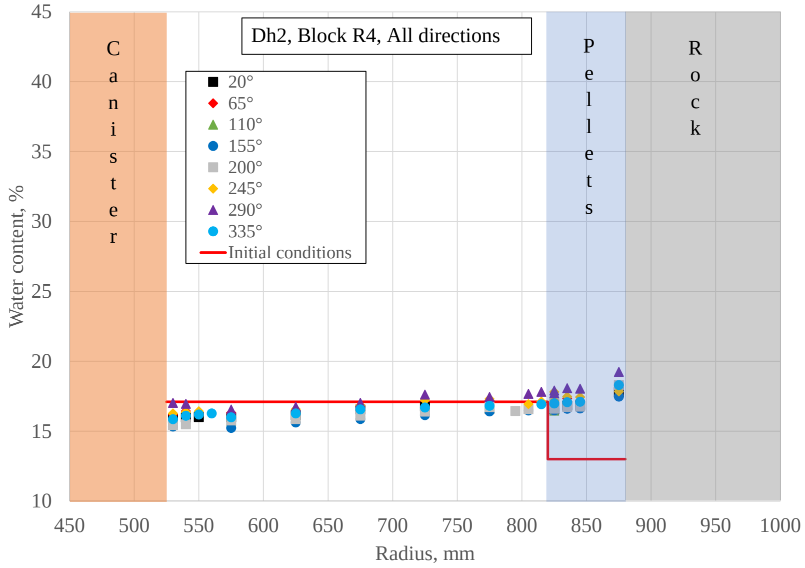


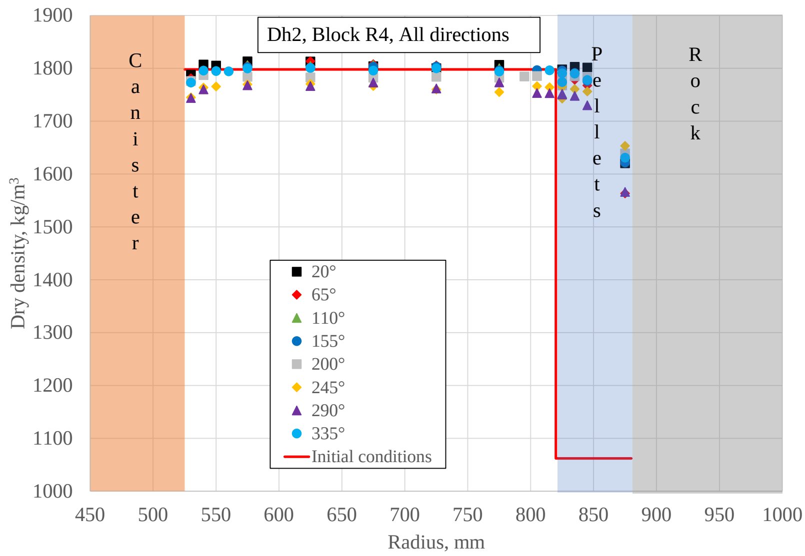


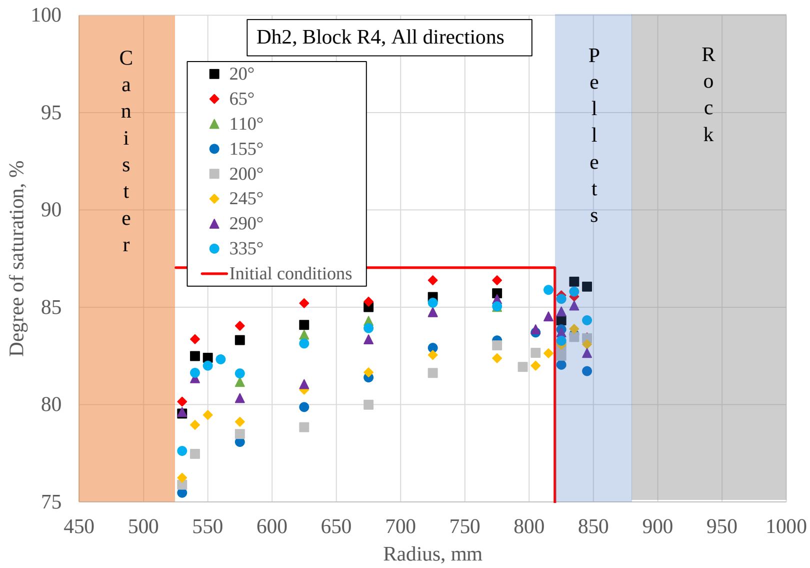


Appendix 3-10a Dh2, Block R4.

Water content, dry density, and degree of saturation in eight directions.

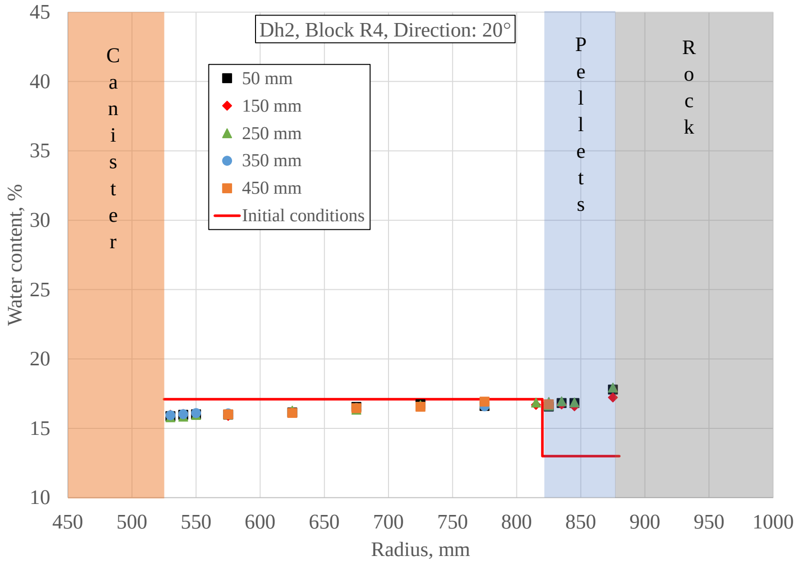


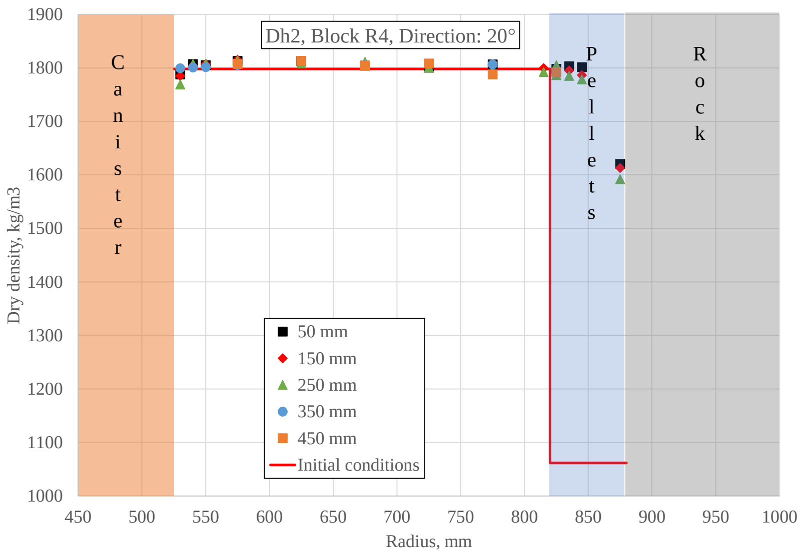


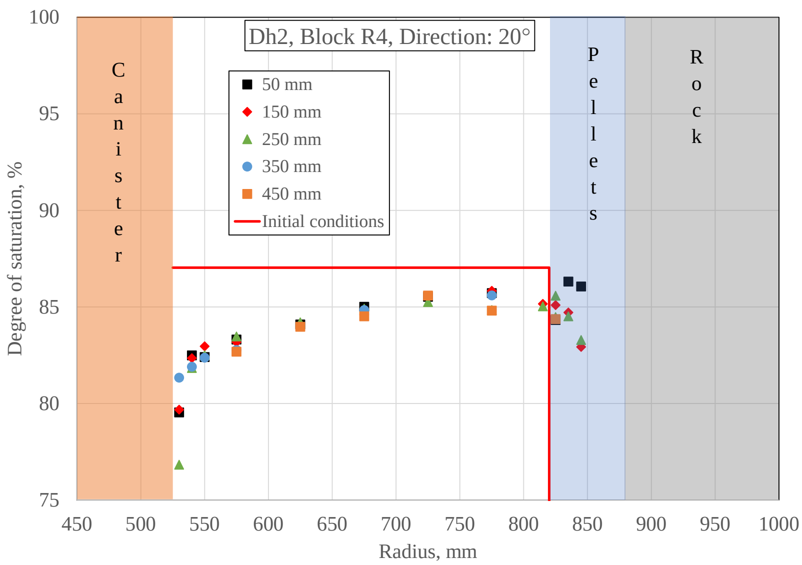


Appendix 3-10b Dh2, Block R4.

Water content, dry density, and degree of saturation at five depths in direction 20°.

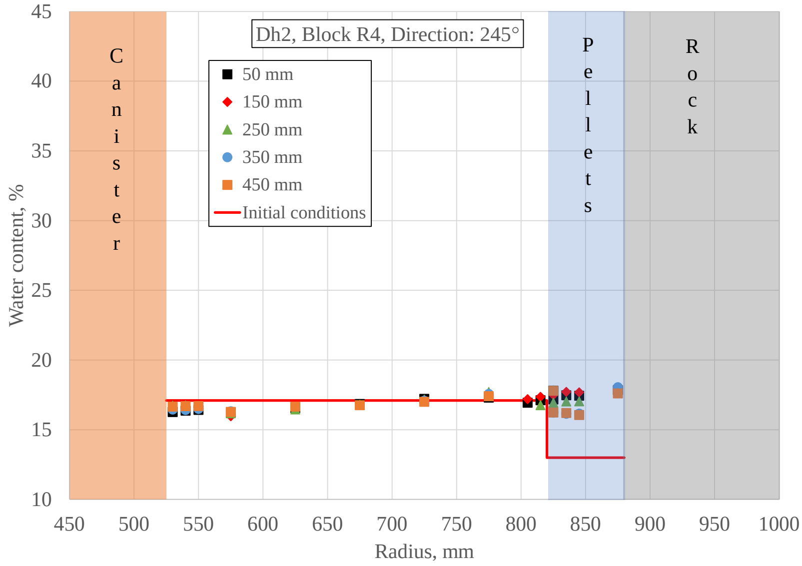


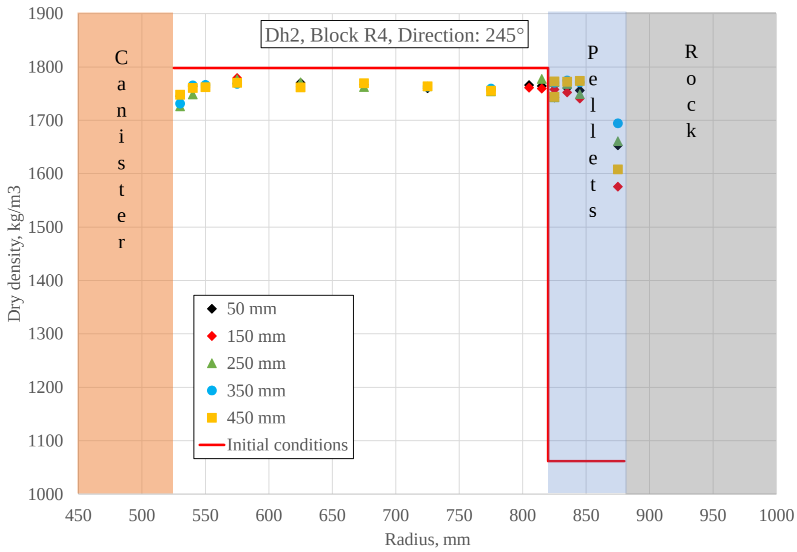


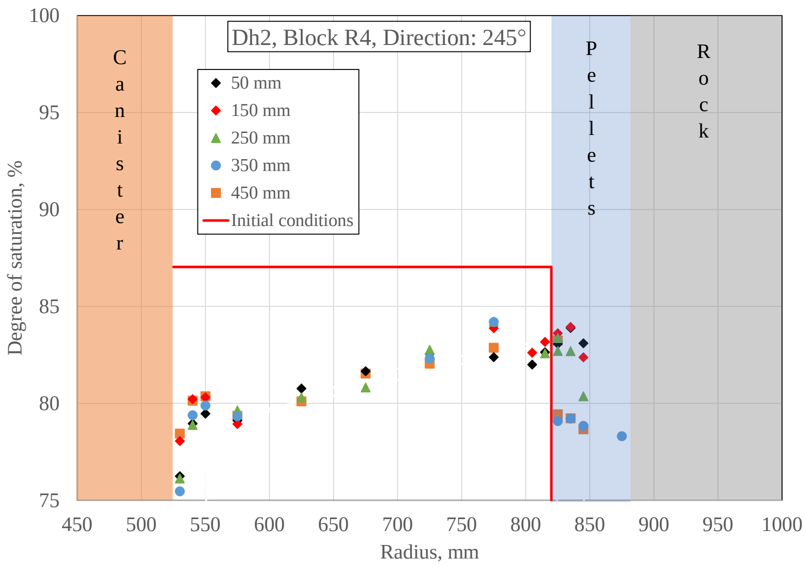


Appendix 3-10c Dh2, Block R4.

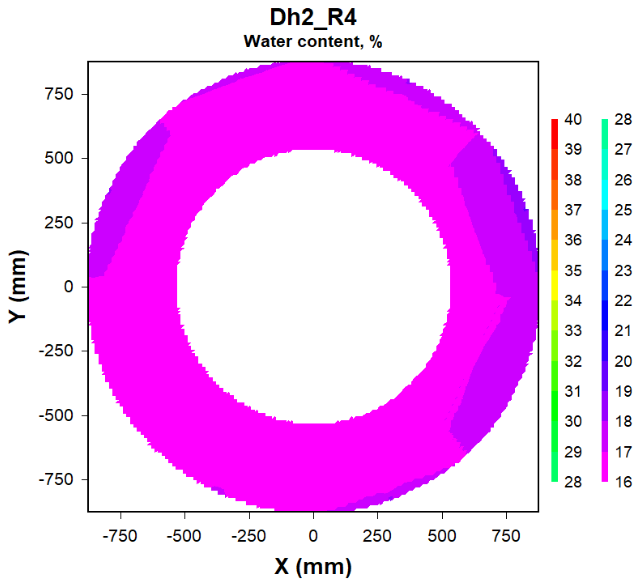
Water content, dry density, and degree of saturation at five depths in direction 245°.

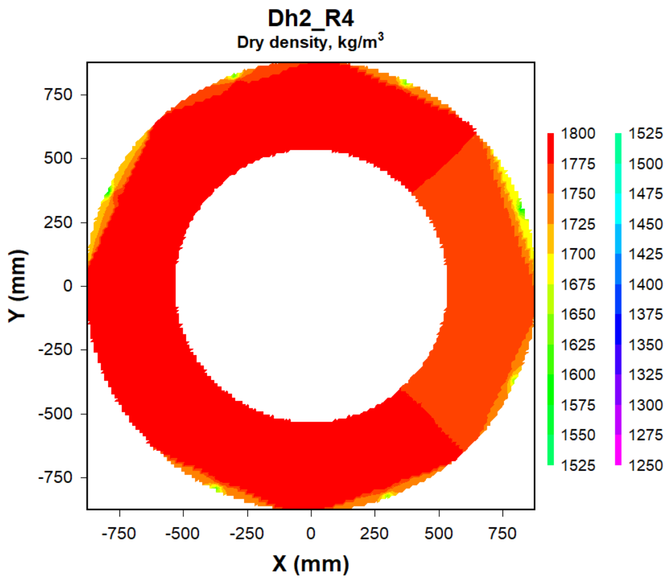


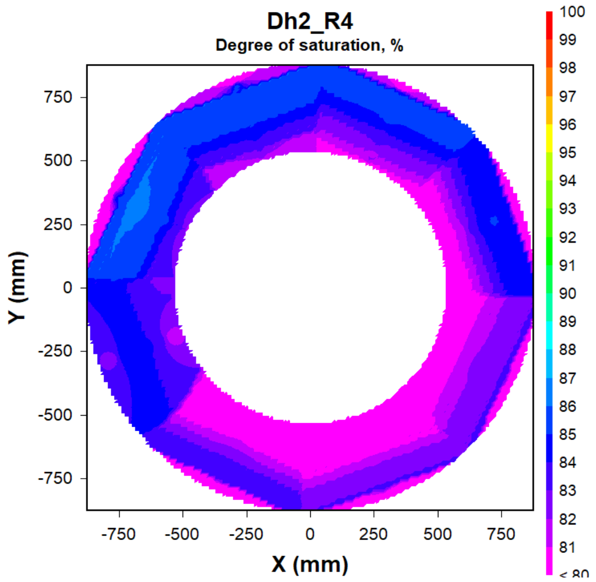




Appendix 3-10d Dh2, Block R4.
Water content, dry density, and degree of saturation distribution.

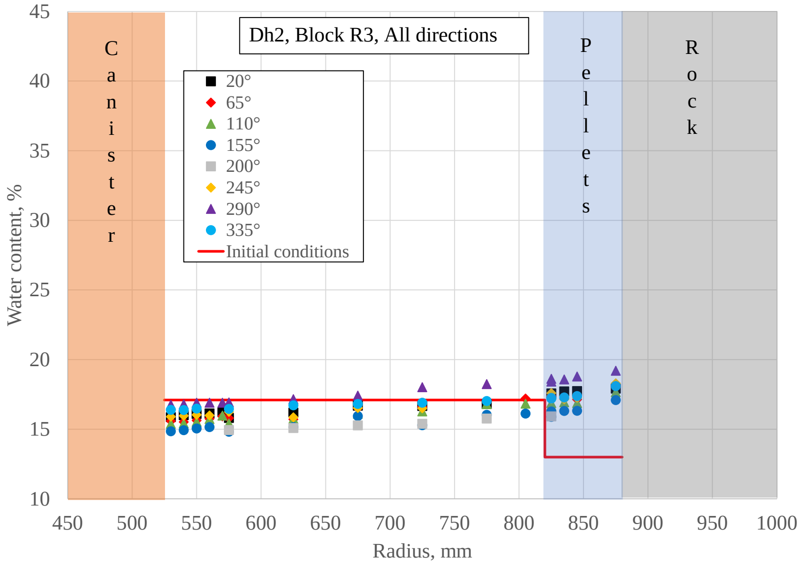


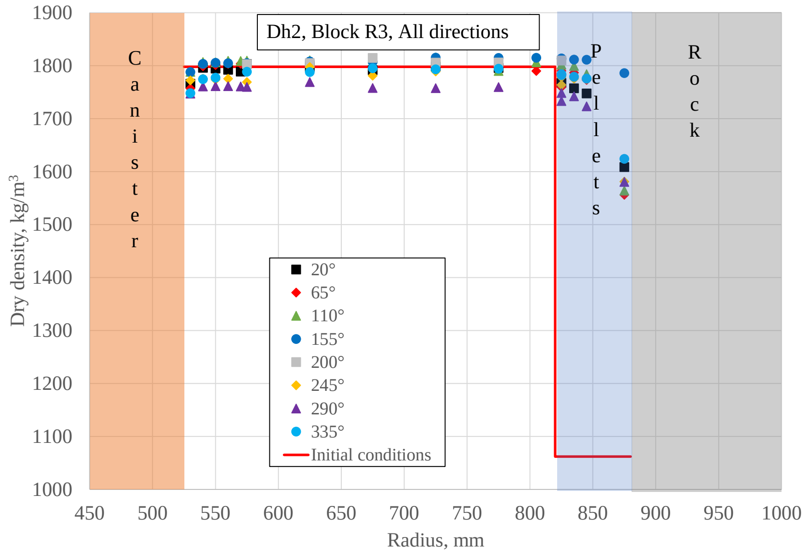


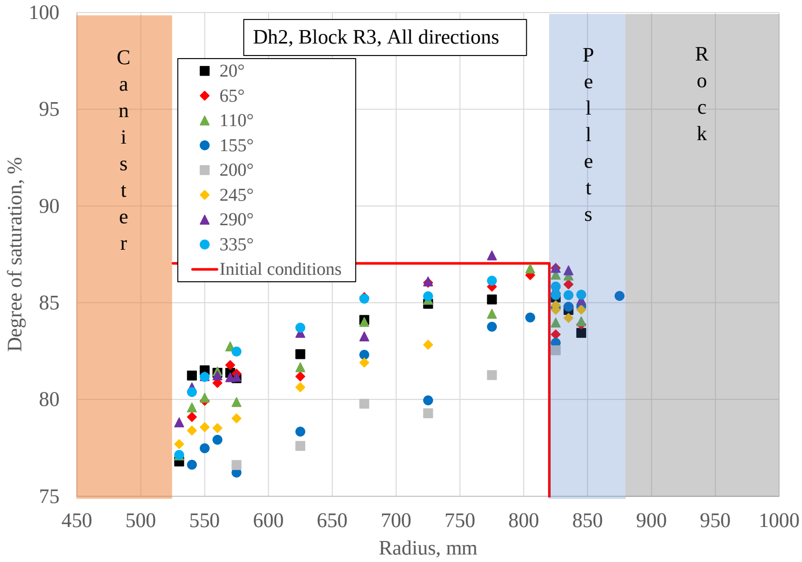


Appendix 3-11a Dh2, Block R3.

Water content, dry density, and degree of saturation in eight directions.

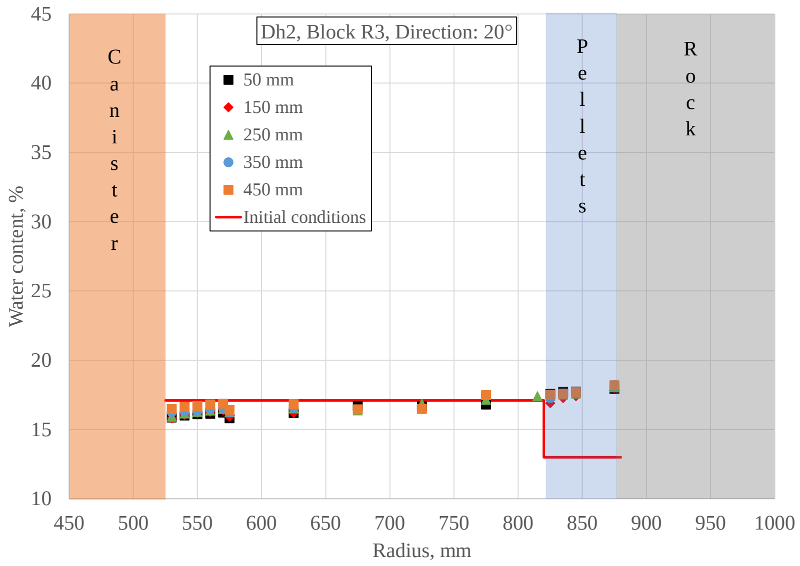


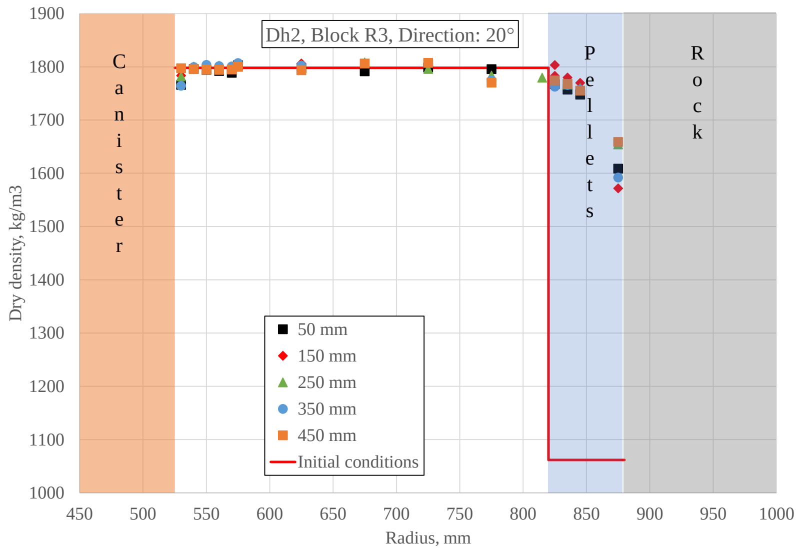


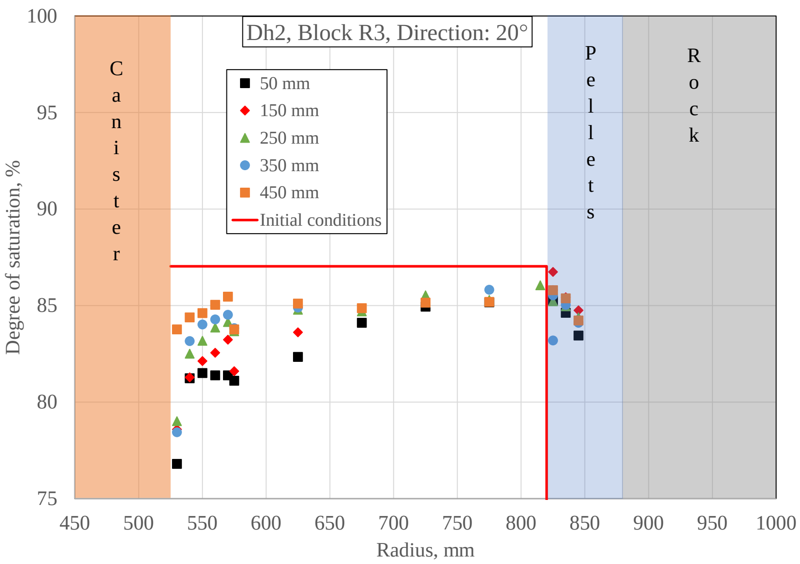


Appendix 3-11b Dh2, Block R3.

Water content, dry density, and degree of saturation at five depths in direction 20°.

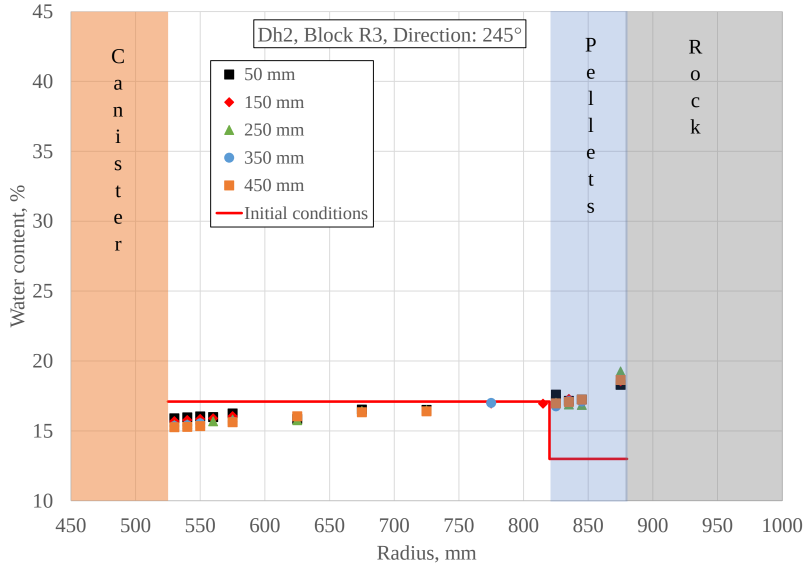


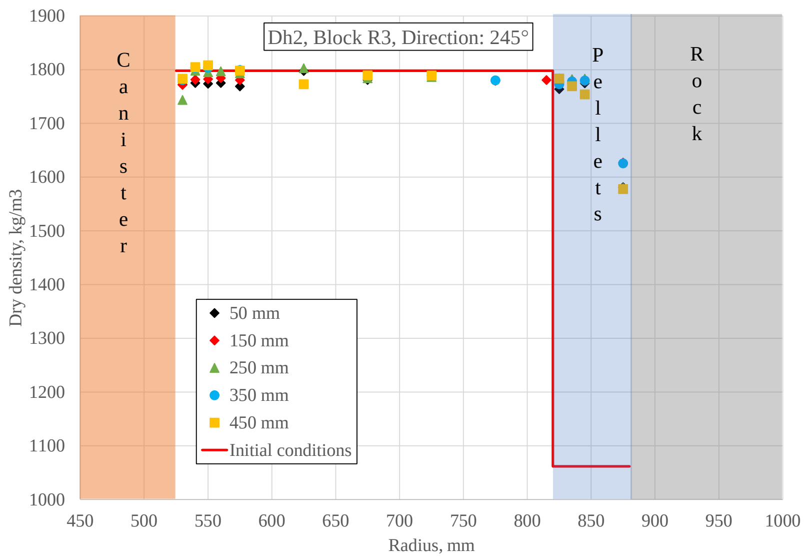


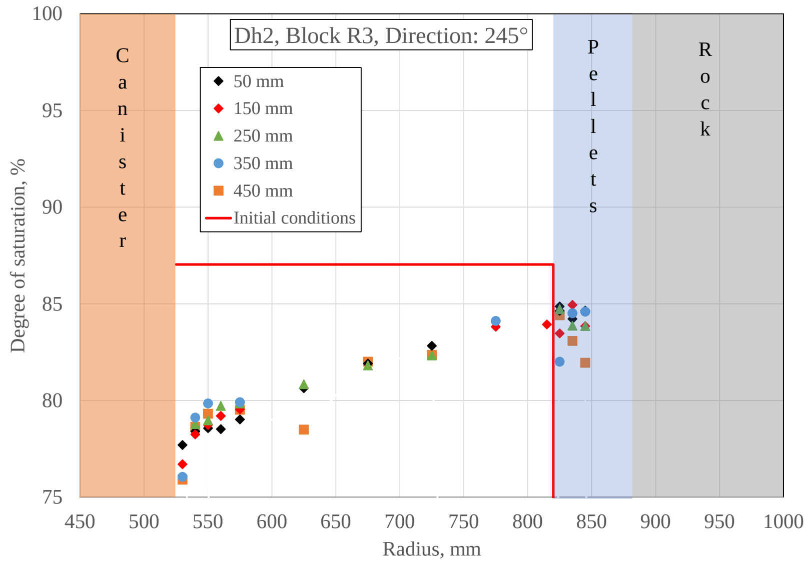


Appendix 3-11c Dh2, Block R3.

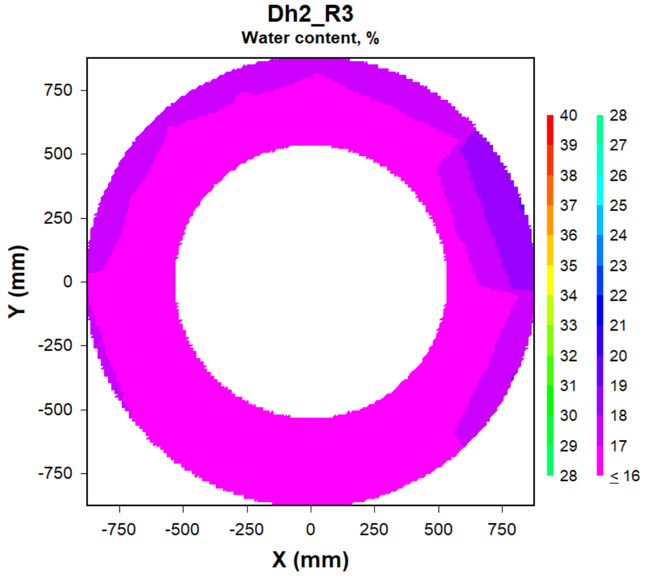
Water content, dry density, and degree of saturation at five depths in direction 245°.

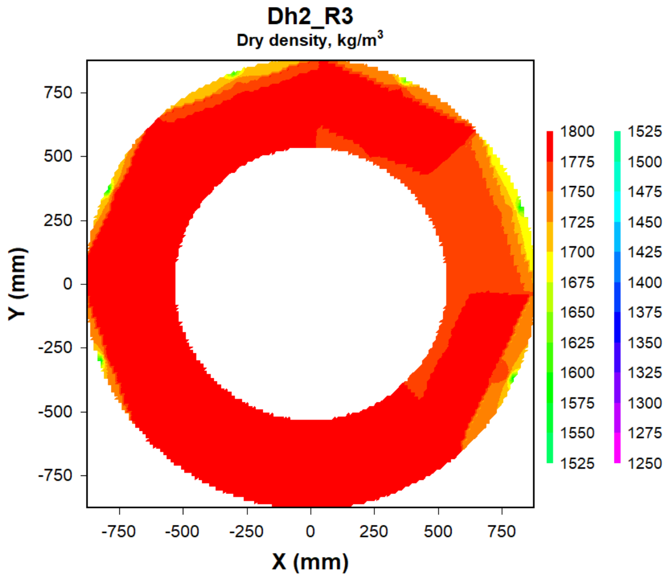


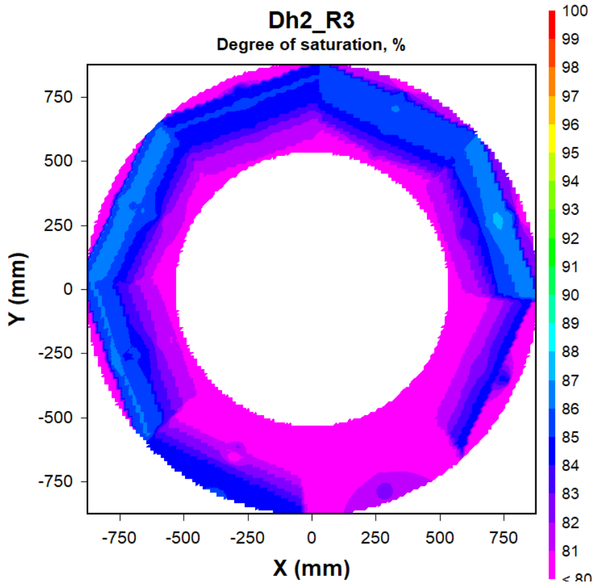




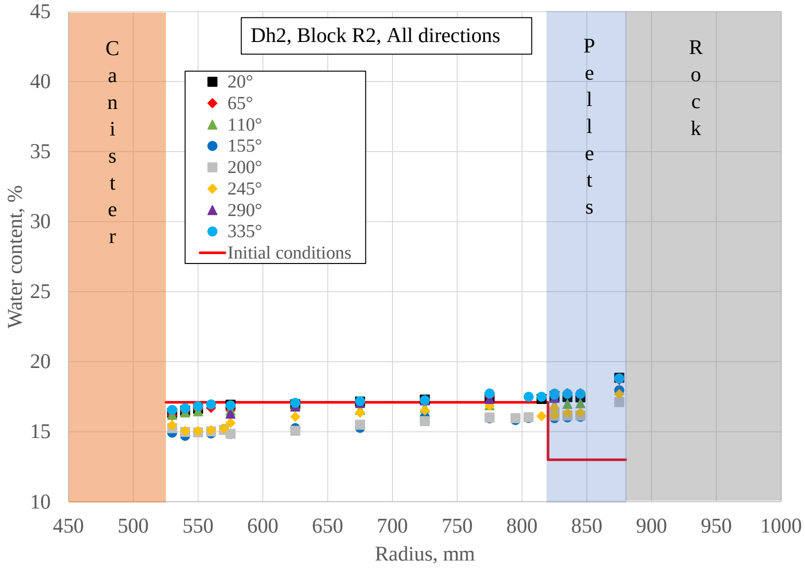
Appendix 3-11d Dh2, Block R3.
Water content, dry density, and degree of saturation distribution.

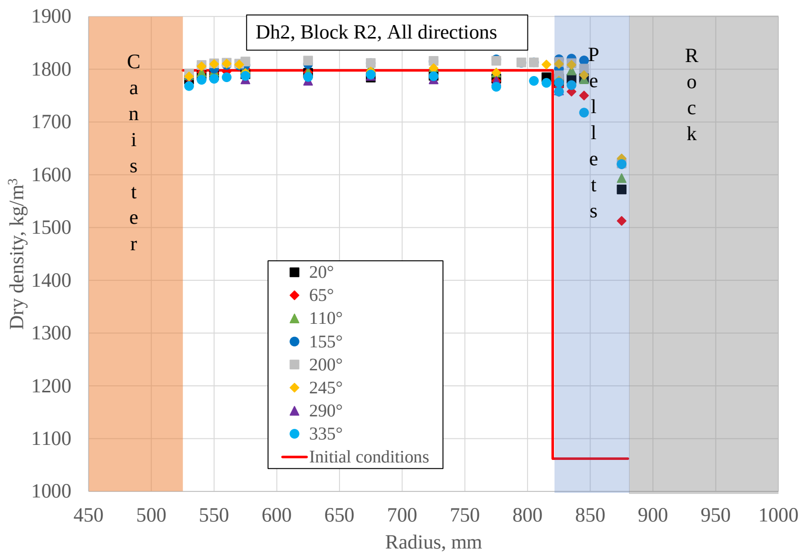


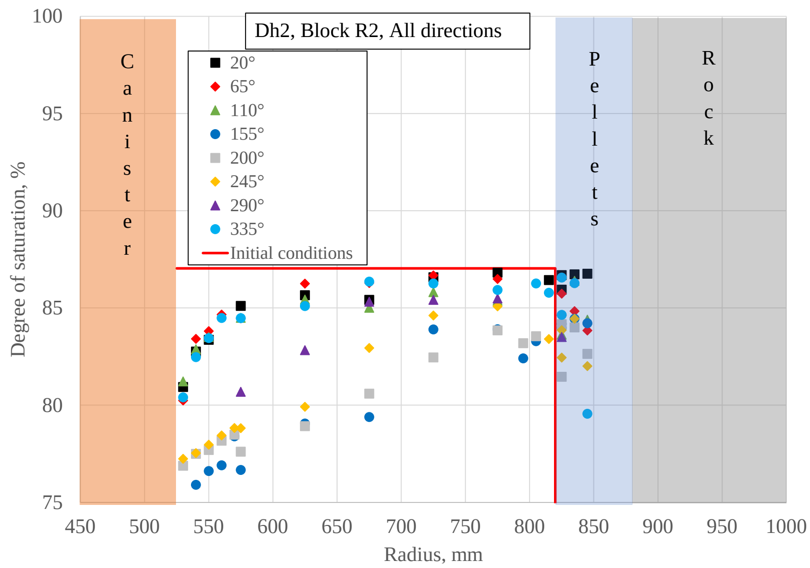




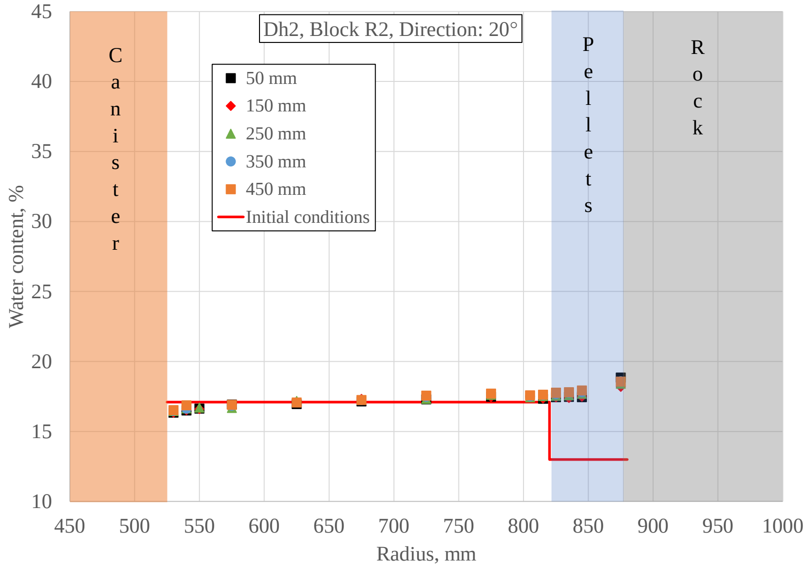
Appendix 3-12a Dh2, Block R2.
Water content, dry density, and degree of saturation in eight directions.

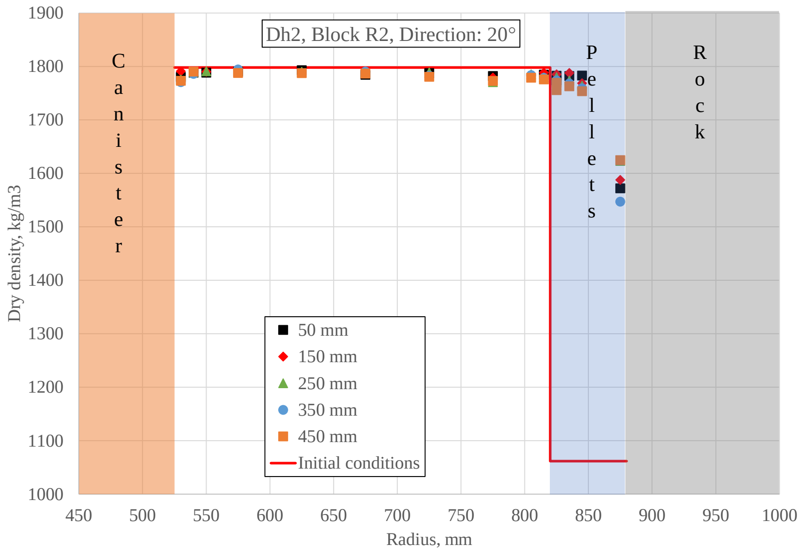


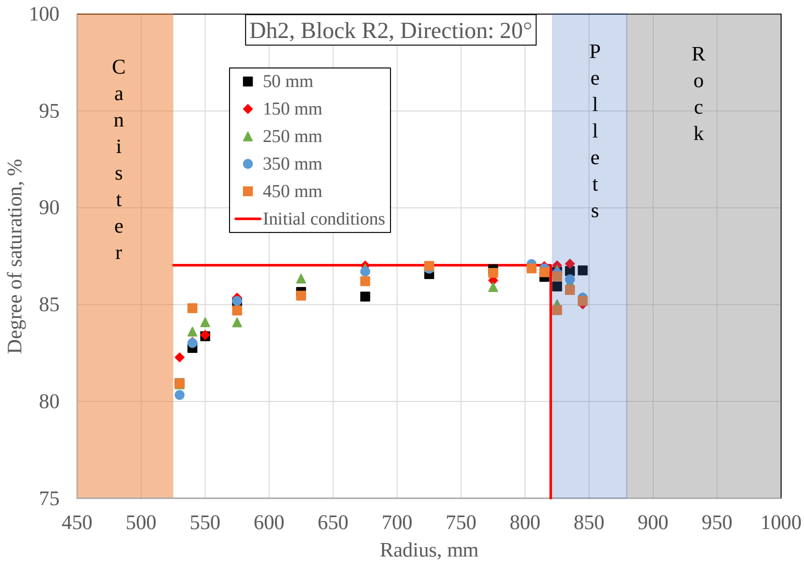




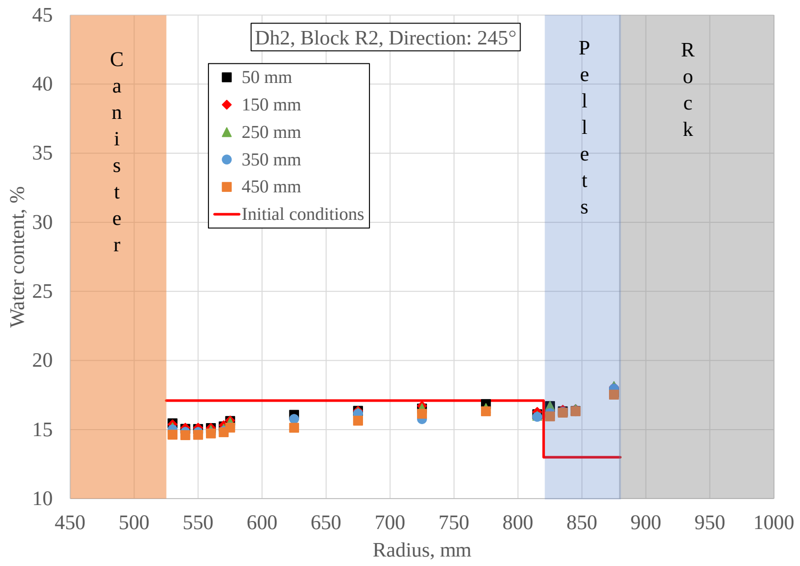
Appendix 3-12b Dh2, Block R2.
Water content, dry density, and degree of saturation at five depths in direction 20°.

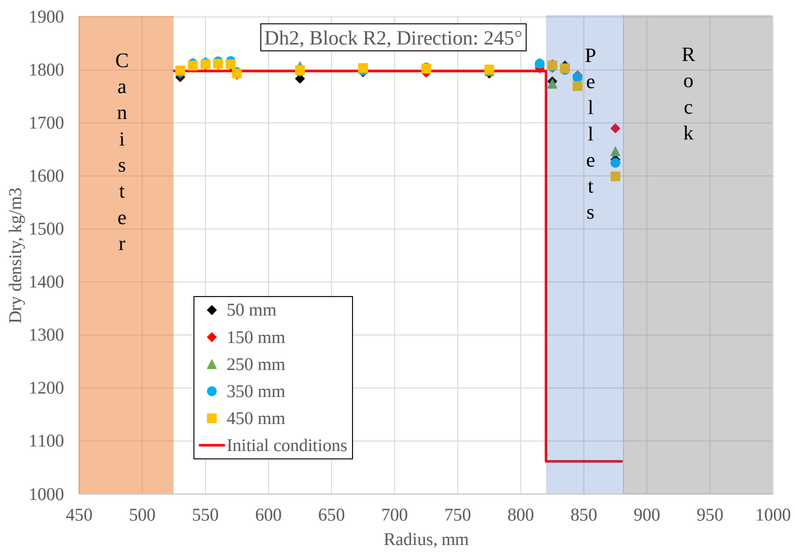


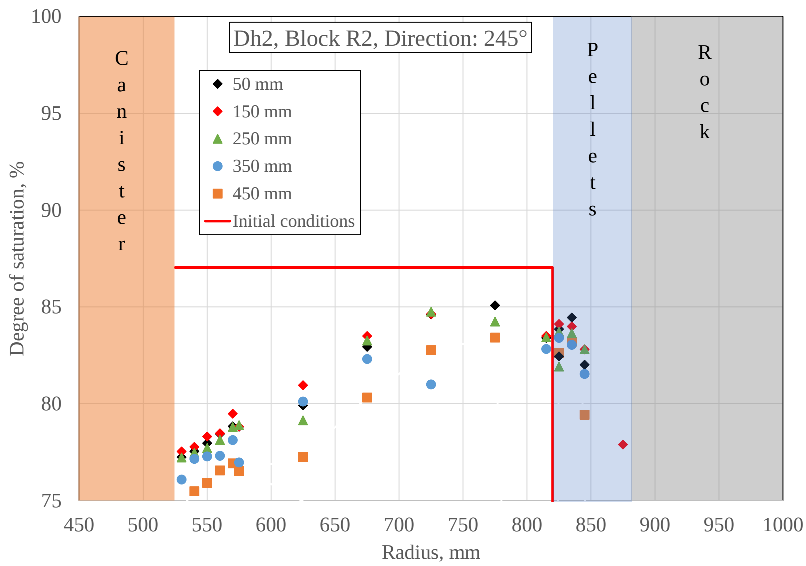




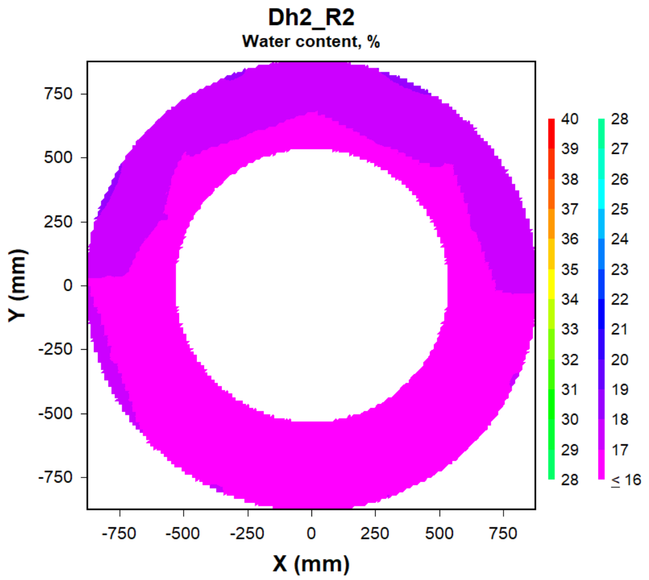
Appendix 3-12c Dh2, Block R2.
Water content, dry density, and degree of saturation at five depths in direction 245°.

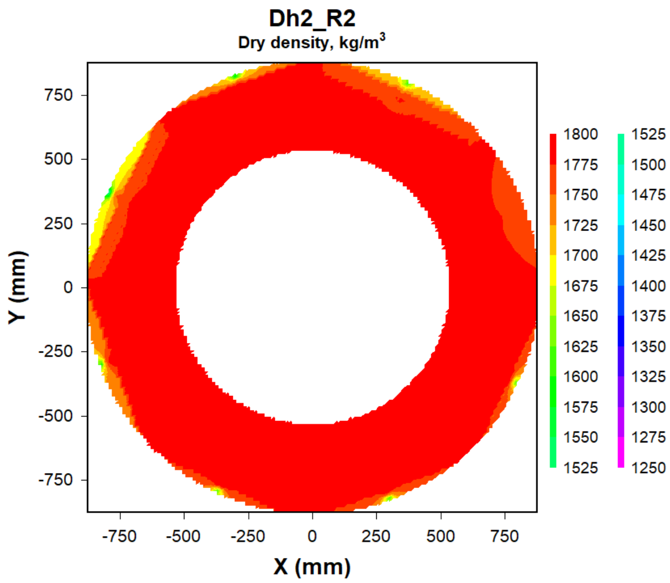


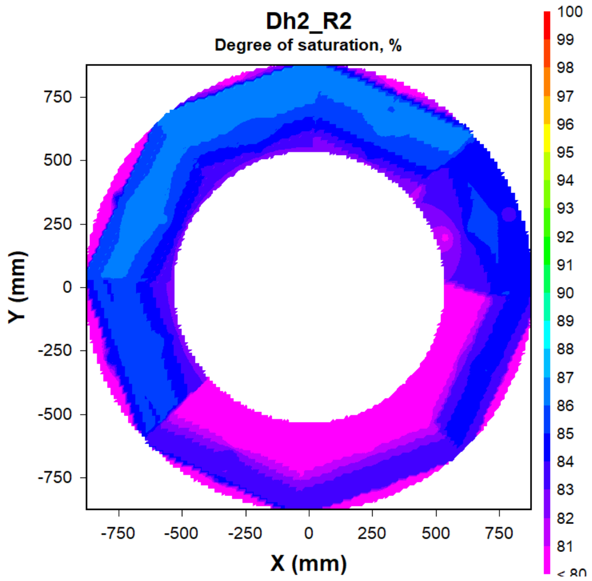




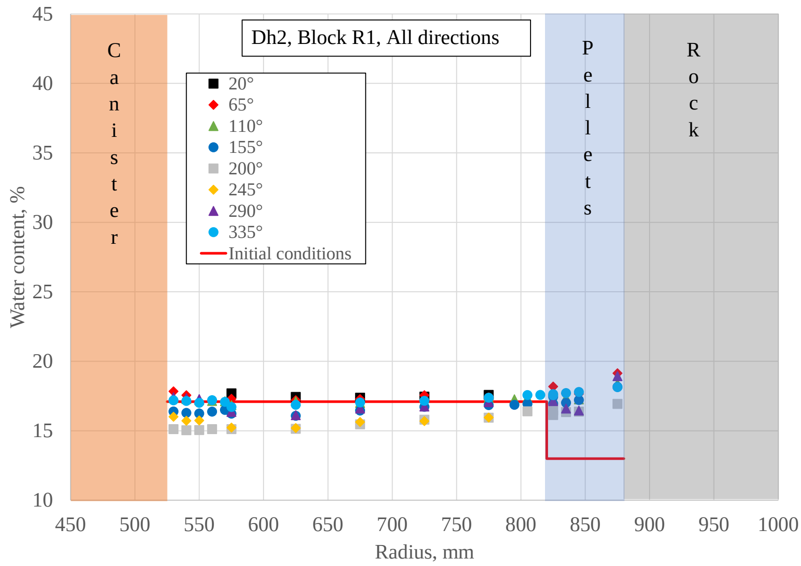
Appendix 3-12d Dh2, Block R2.
Water content, dry density, and degree of saturation distribution.

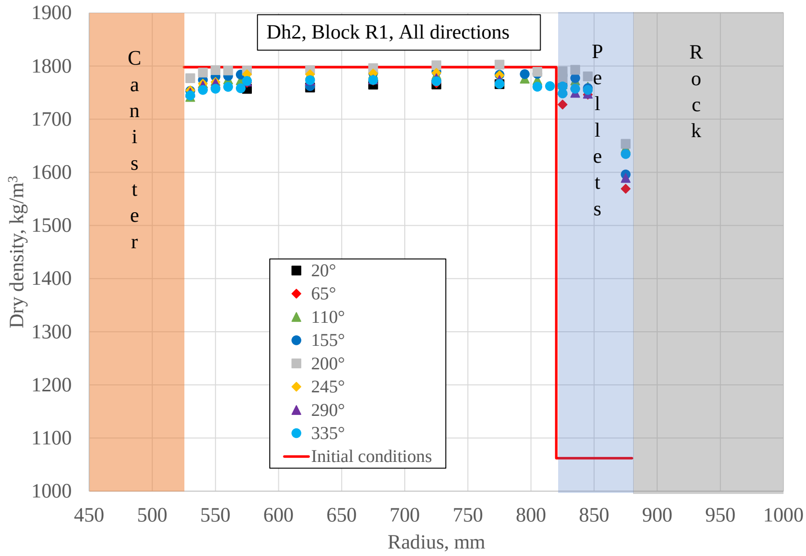


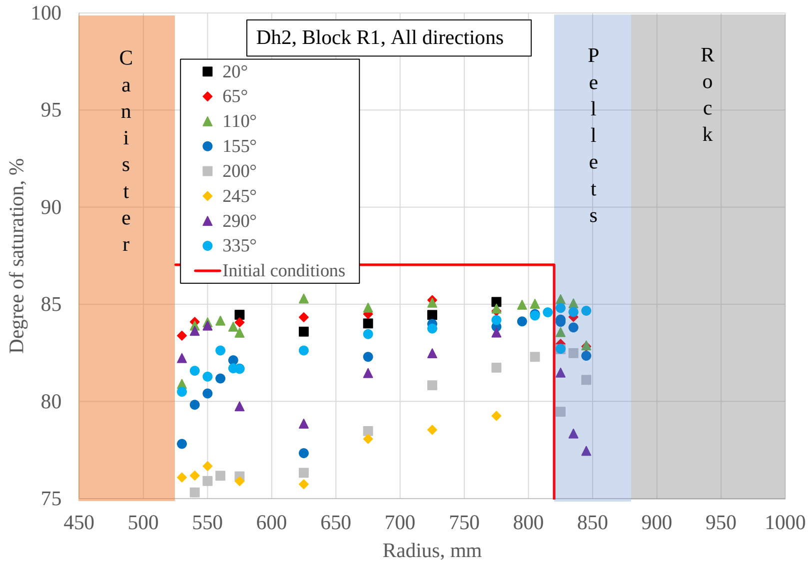




Appendix 3-13a Dh2, Block R1.
Water content, dry density, and degree of saturation in eight directions.

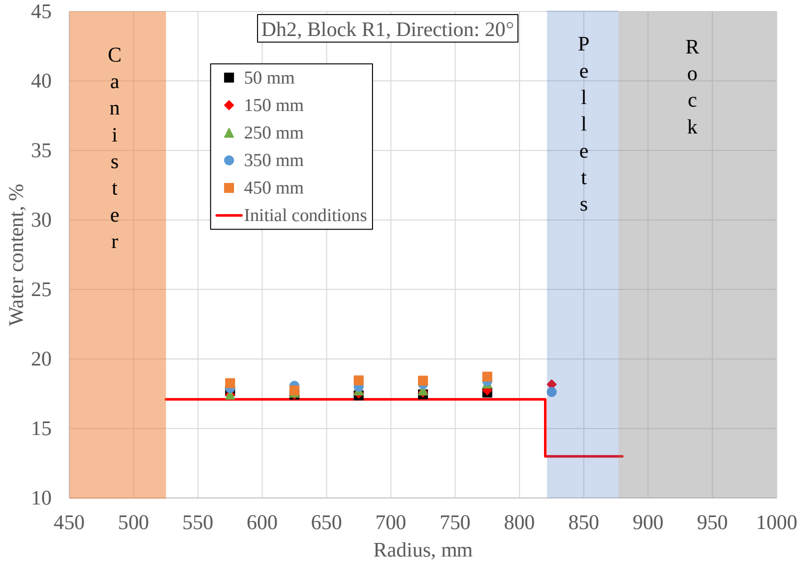


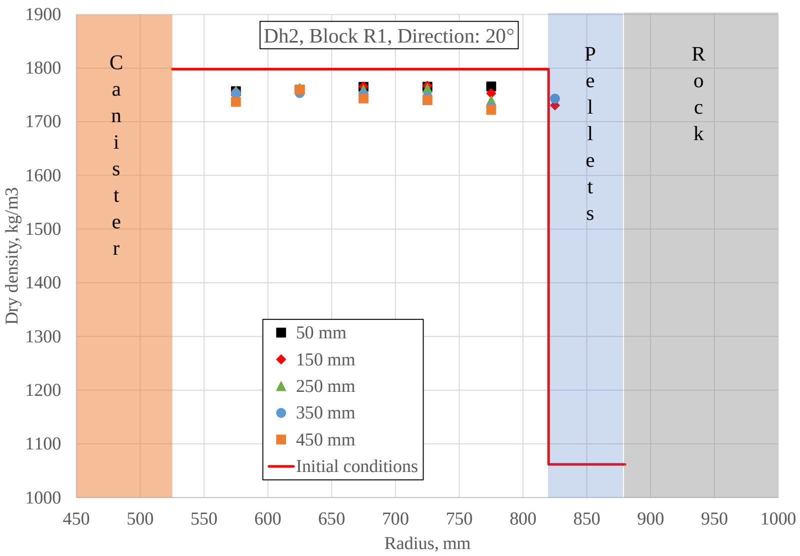


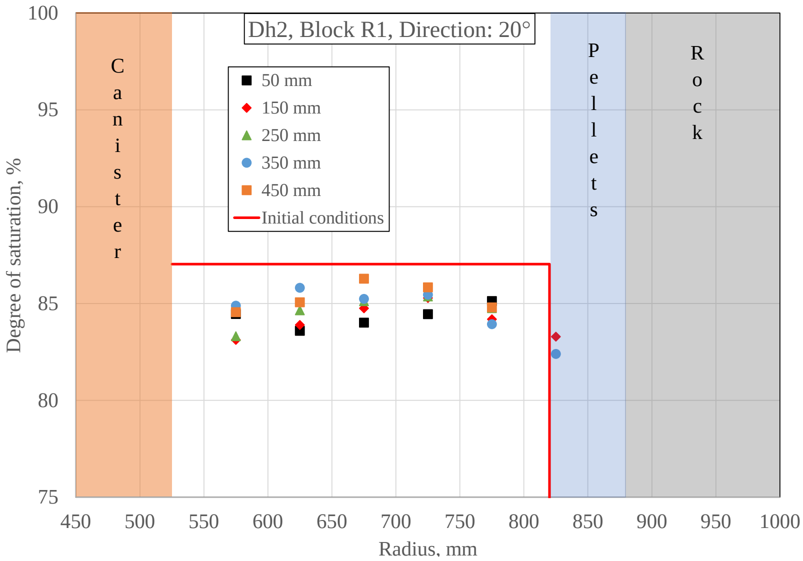


Appendix 3-13b Dh2, Block R1.

Water content, dry density, and degree of saturation at five depths in direction 20°.

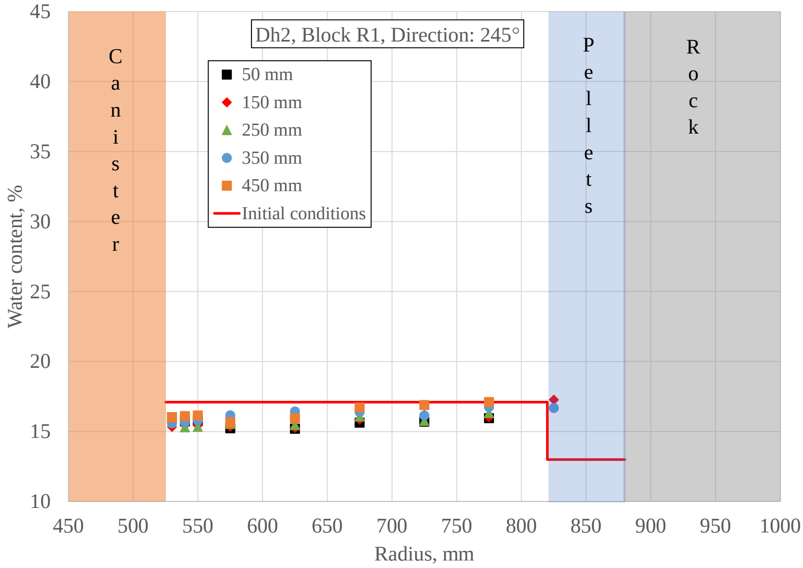


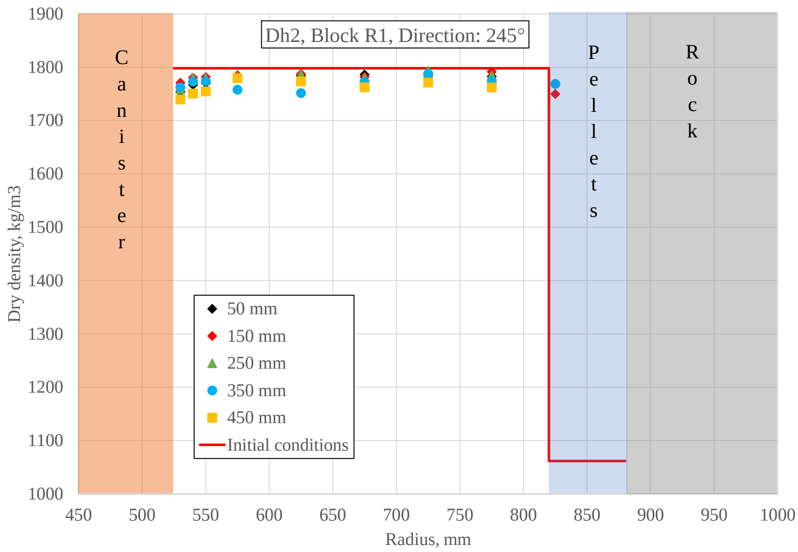


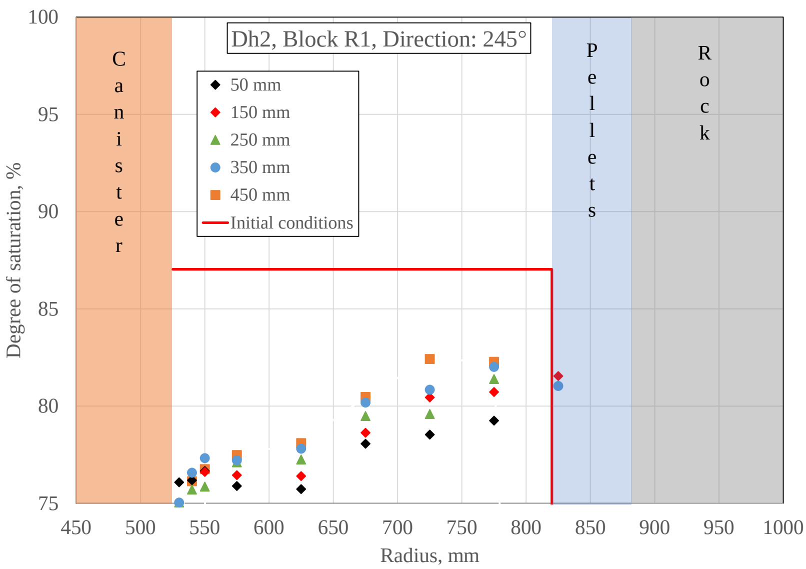


Appendix 3-13c Dh2, Block R1.

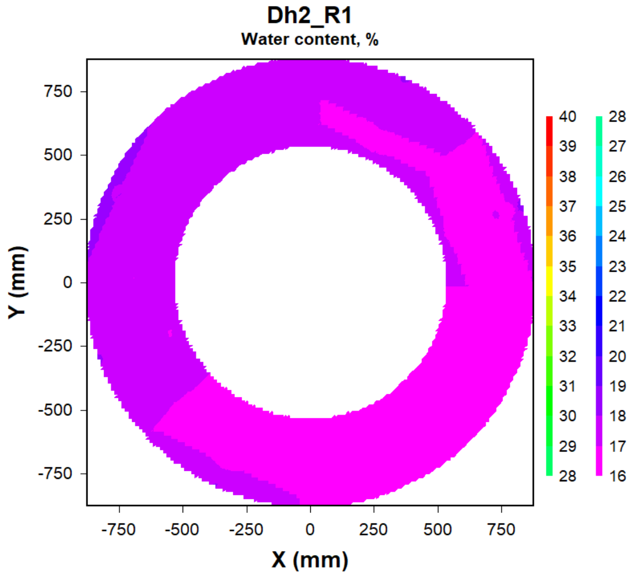
Water content, dry density, and degree of saturation at five depths in direction 245°.

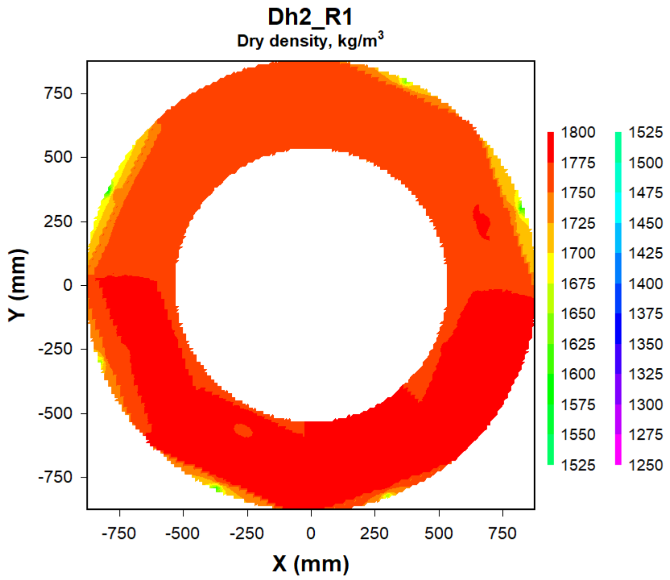


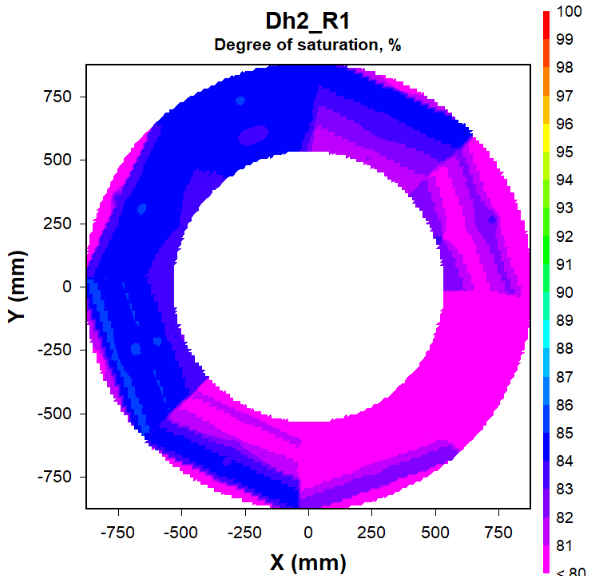




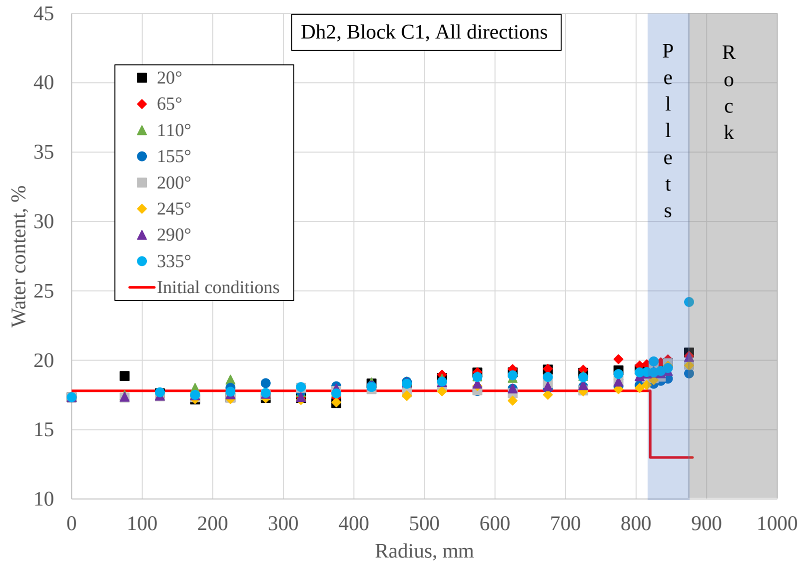
Appendix 3-13d Dh2, Block R1.
Water content, dry density, and degree of saturation distribution.

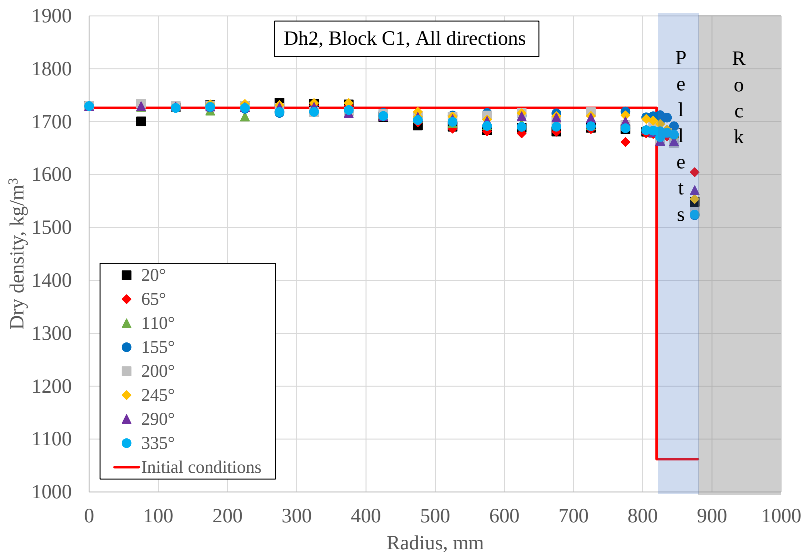


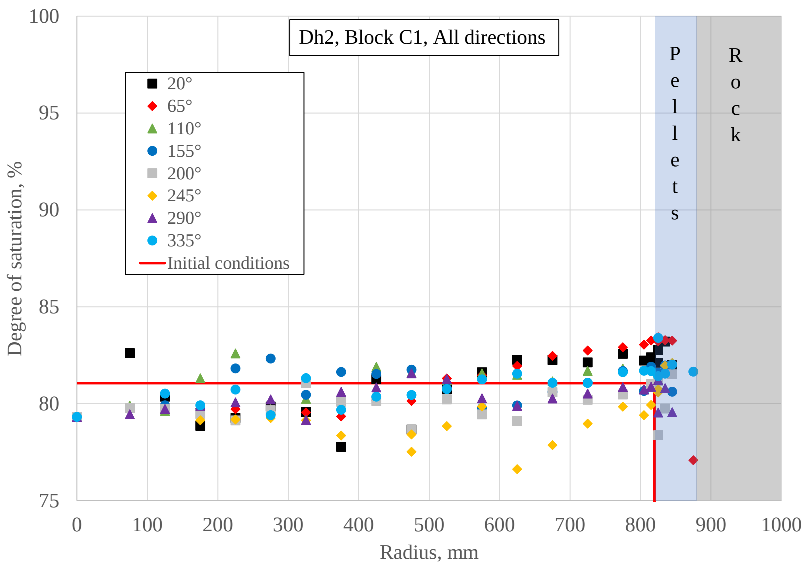




Appendix 3-14a Dh2, Block C1.
Water content, dry density, and degree of saturation in eight directions.

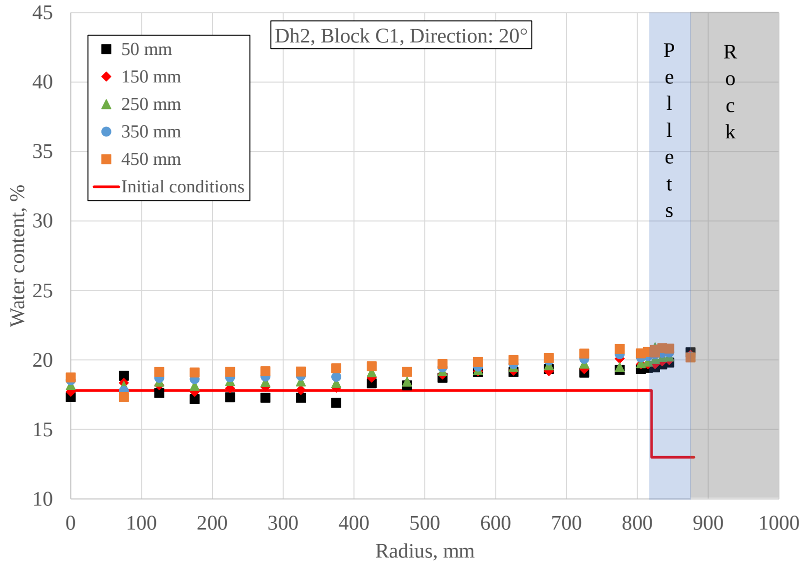


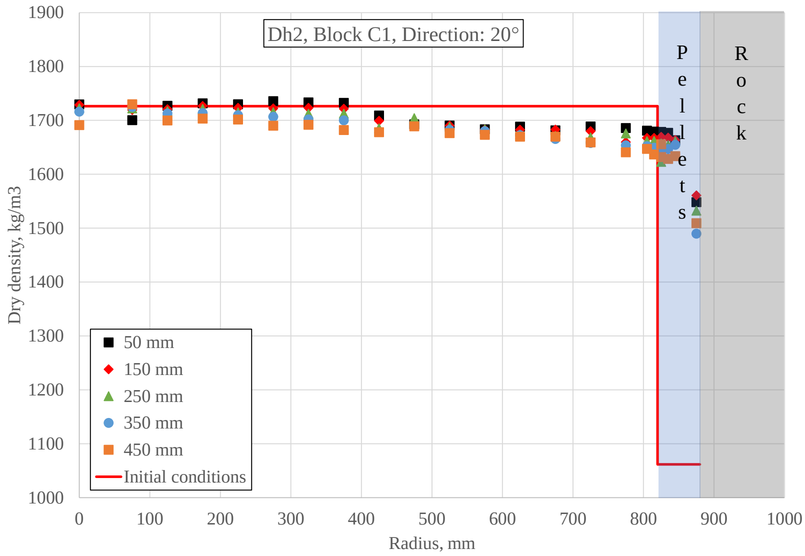


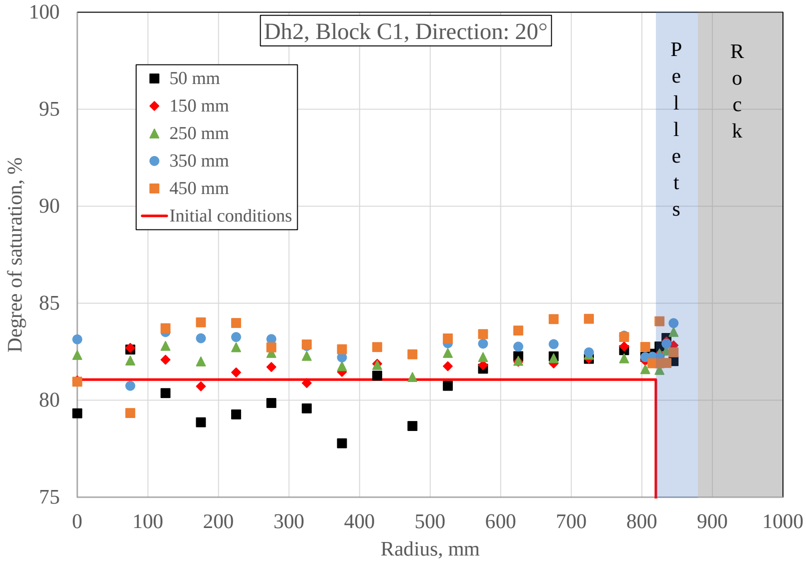


Appendix 3-14b Dh2, Block C1.

Water content, dry density, and degree of saturation at five depths in direction 20°.

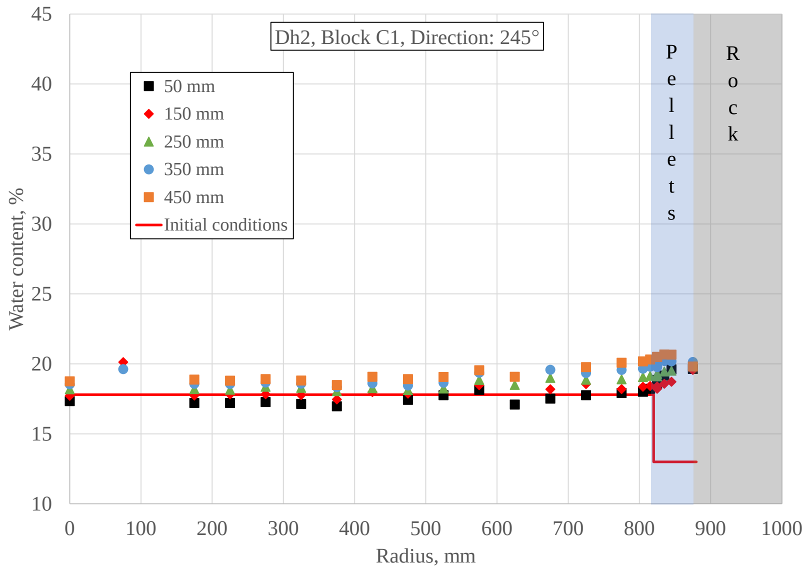


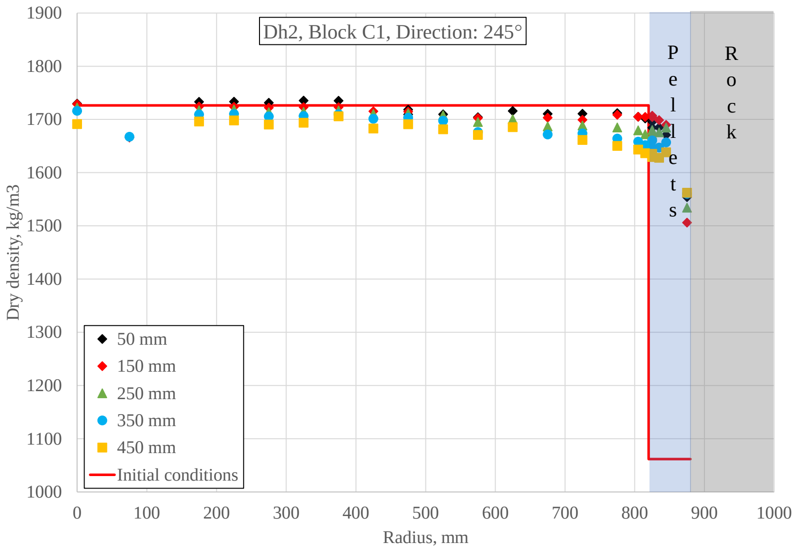


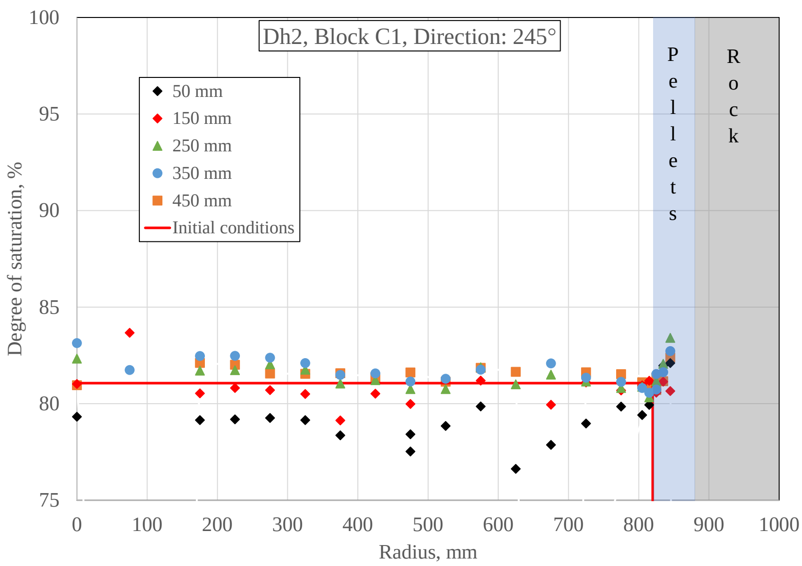


Appendix 3-14c Dh2, Block C1.

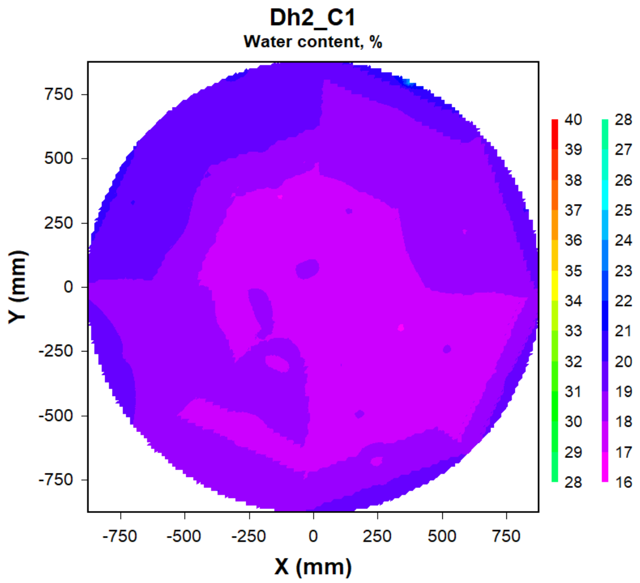
Water content, dry density, and degree of saturation at five depths in direction 245°.

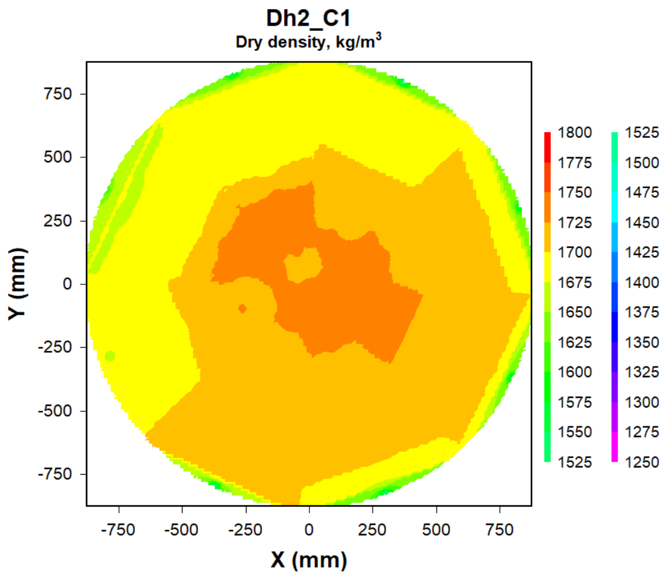


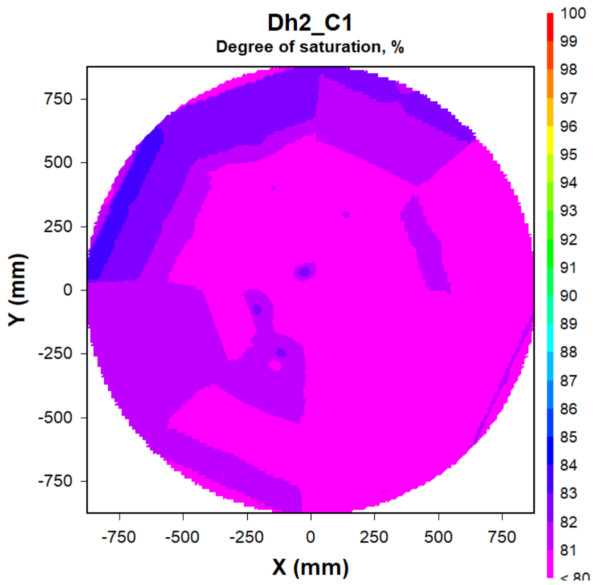




Appendix 3-14d Dh2, Block C1.
Water content, dry density, and degree of saturation distribution.

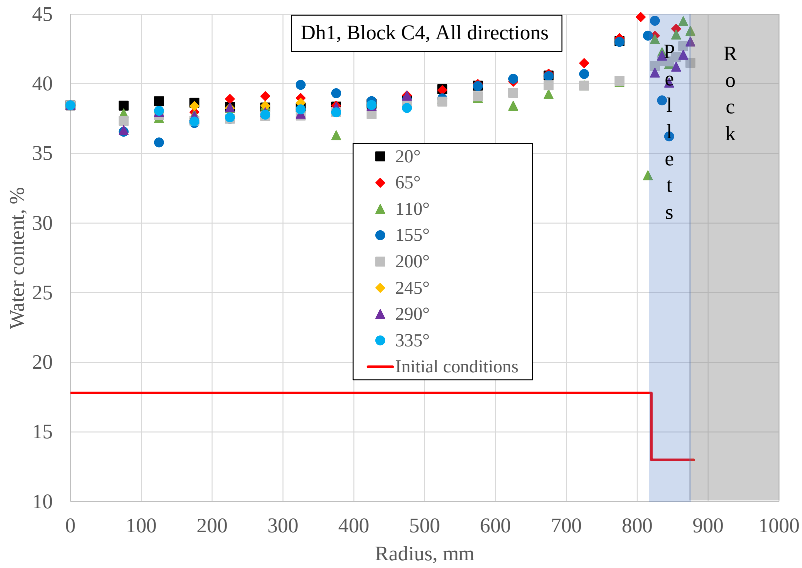


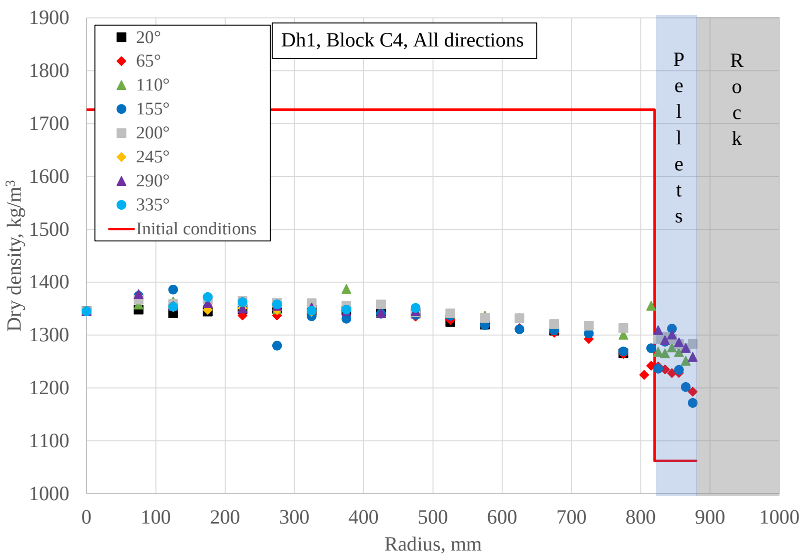


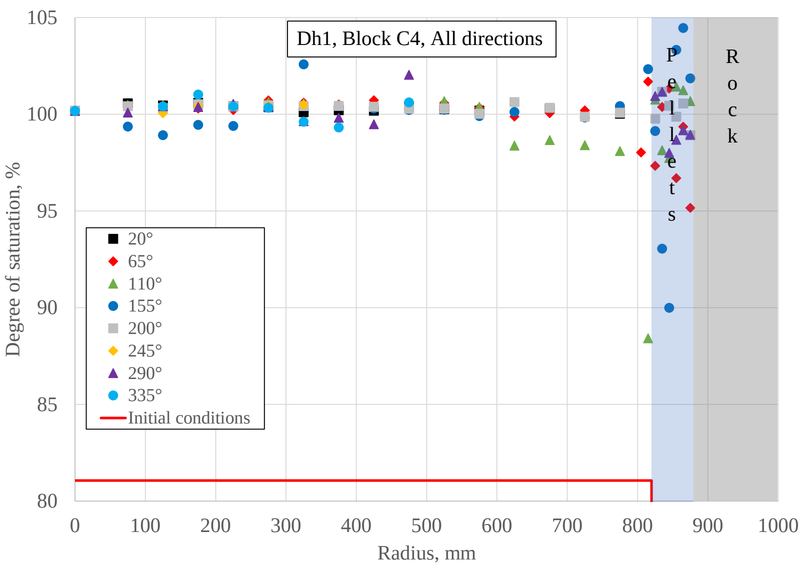


Appendix 4-1a Dh1, Block C4.

Water content, dry density, and degree of saturation in eight directions.

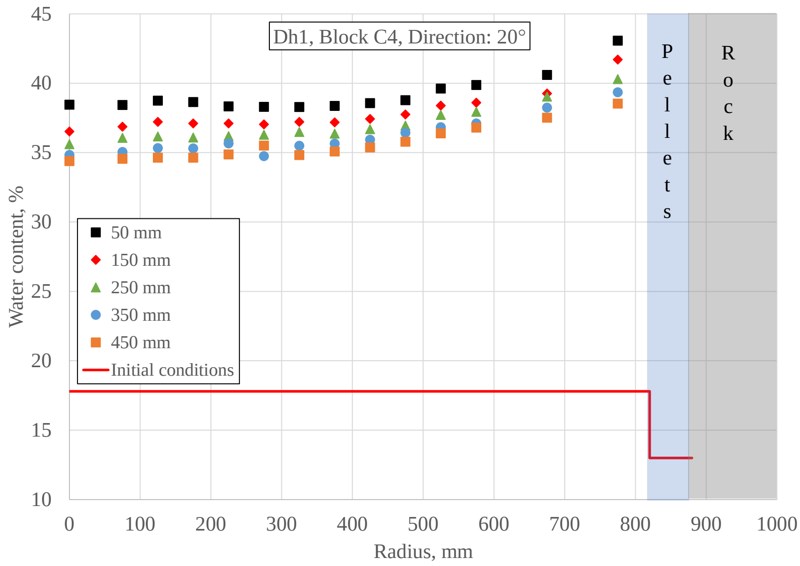


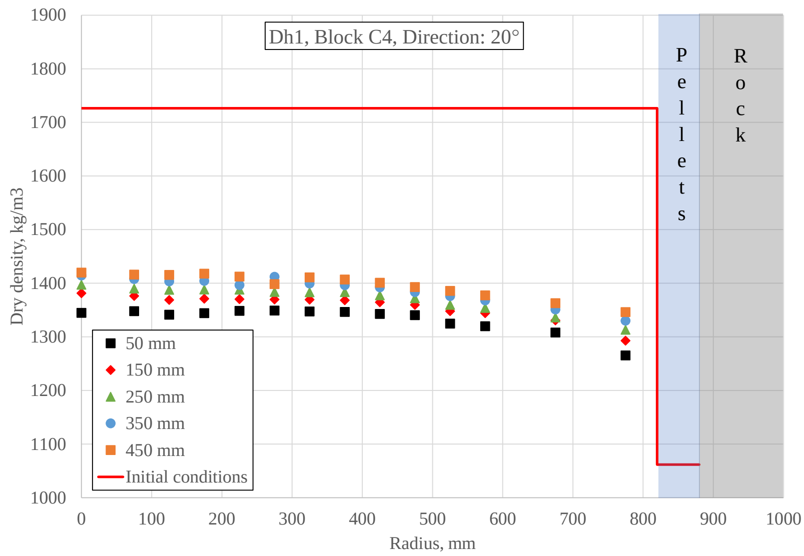


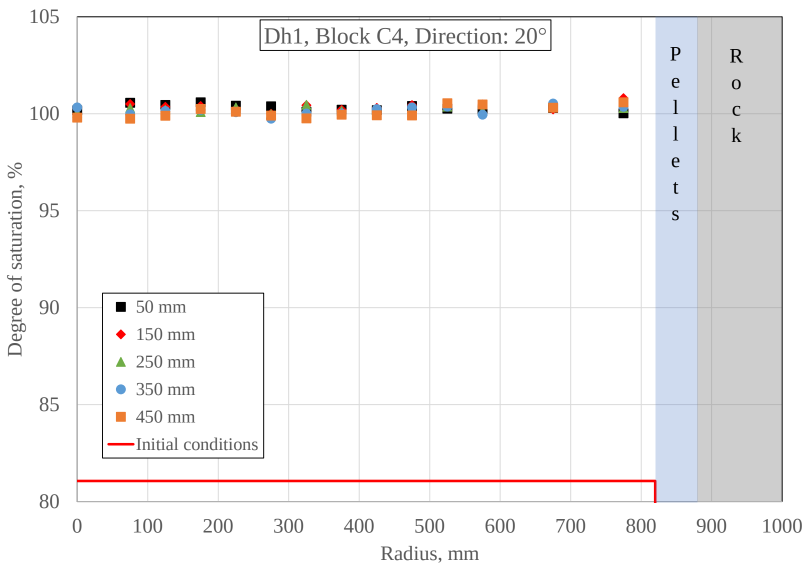


Appendix 4-1b Dh1, Block C4.

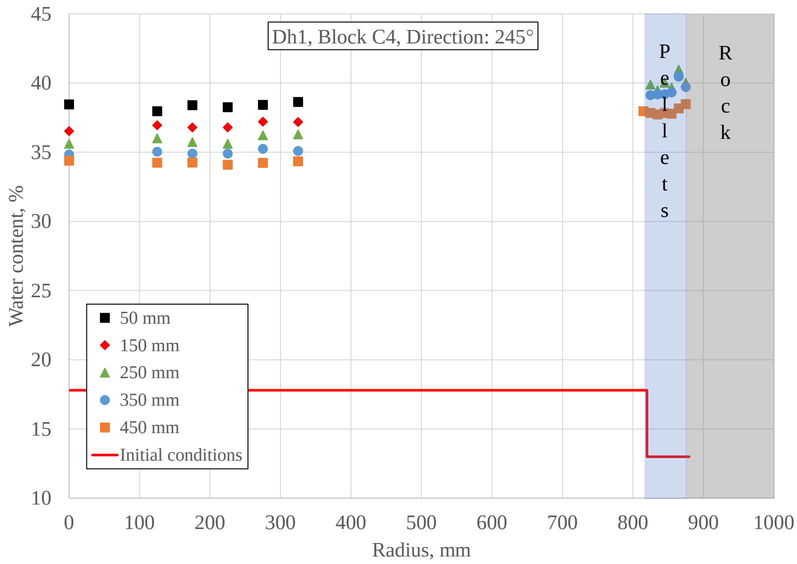
Water content, dry density, and degree of saturation at five depths in direction 20°.

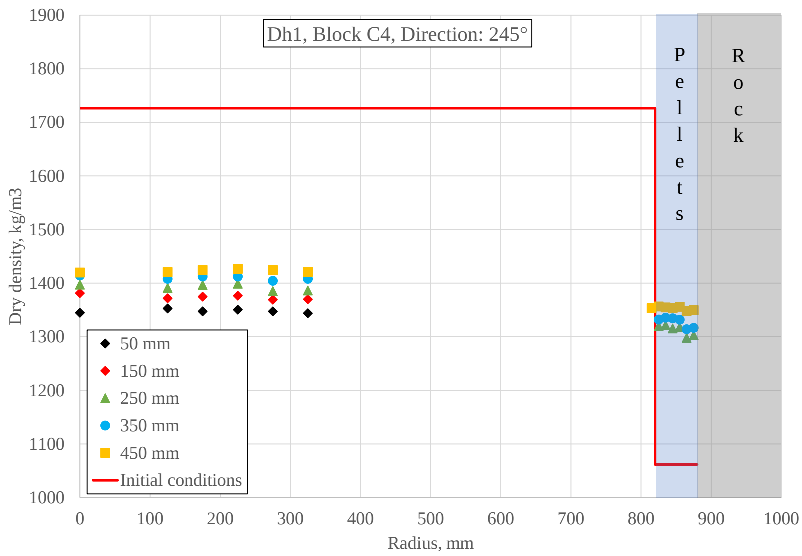


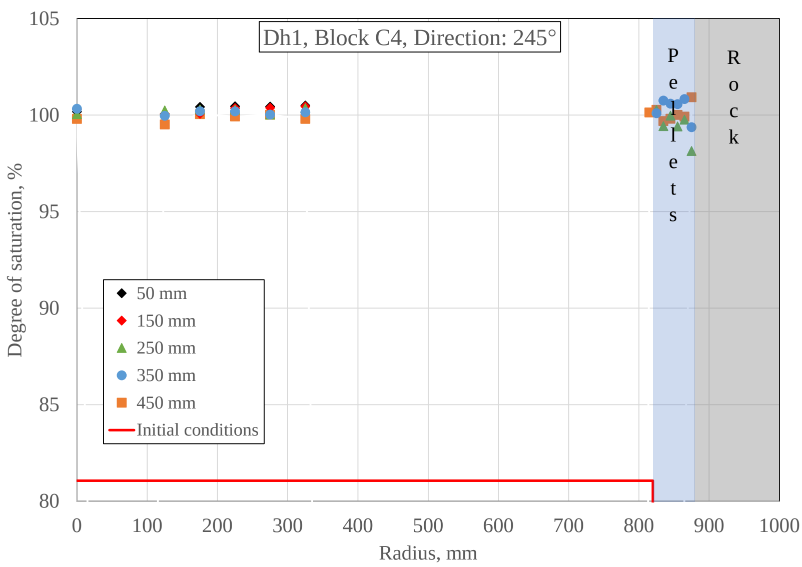




Appendix 4-1c Dh1, Block C4.
Water content, dry density, and degree of saturation at five depths in direction 245°.

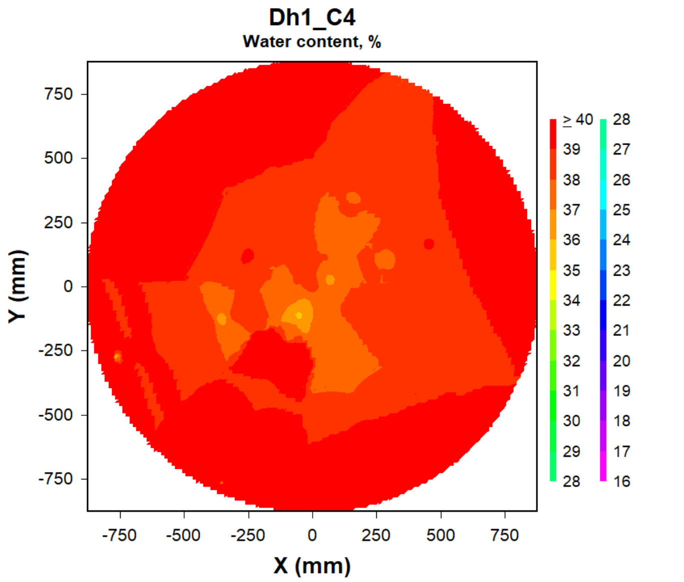


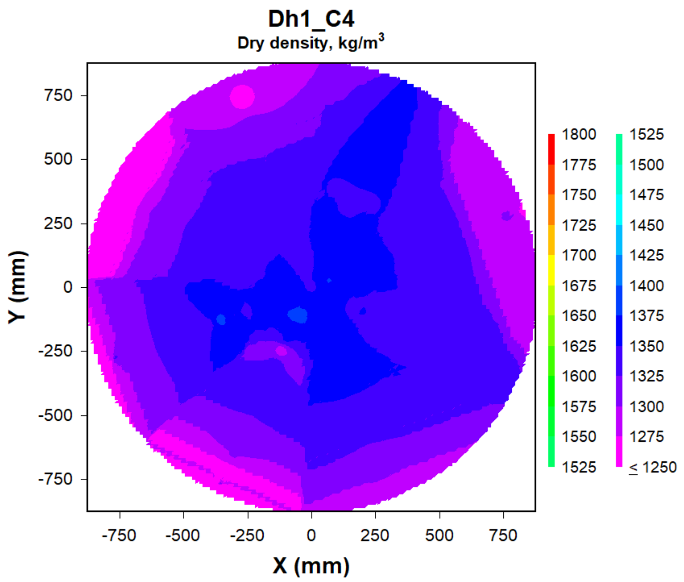


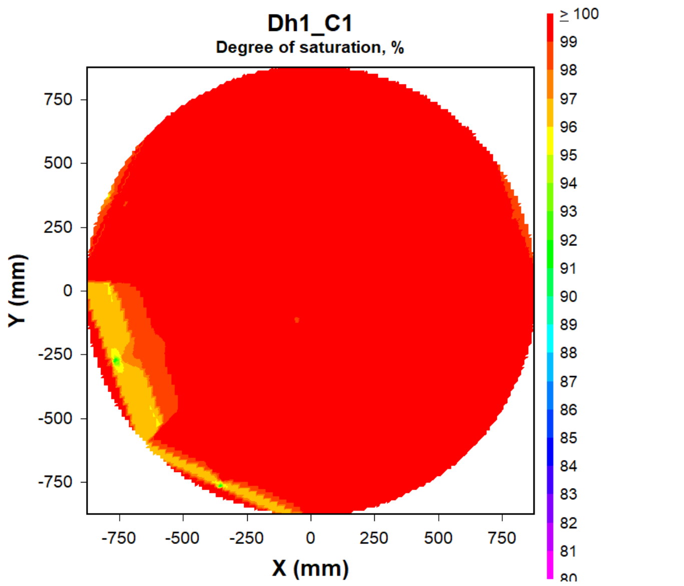


Appendix 4-1d Dh1, Block C4.

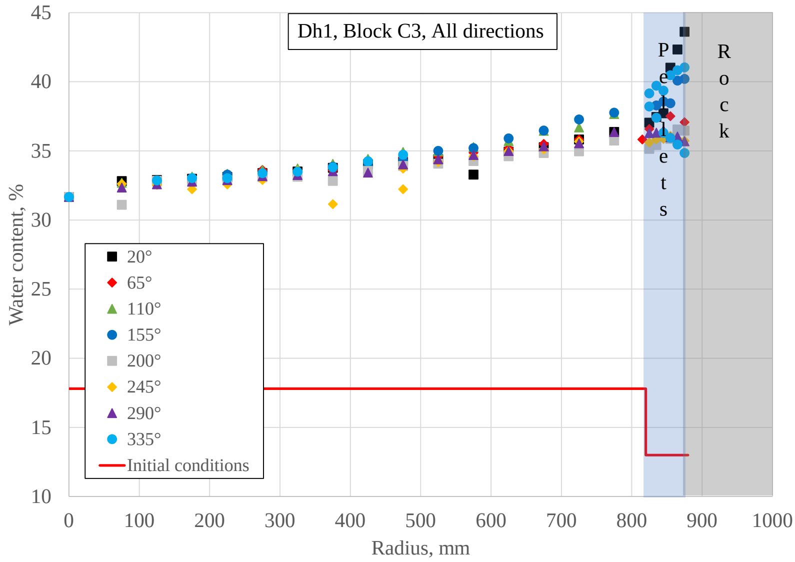
Water content, dry density, and degree of saturation distribution.

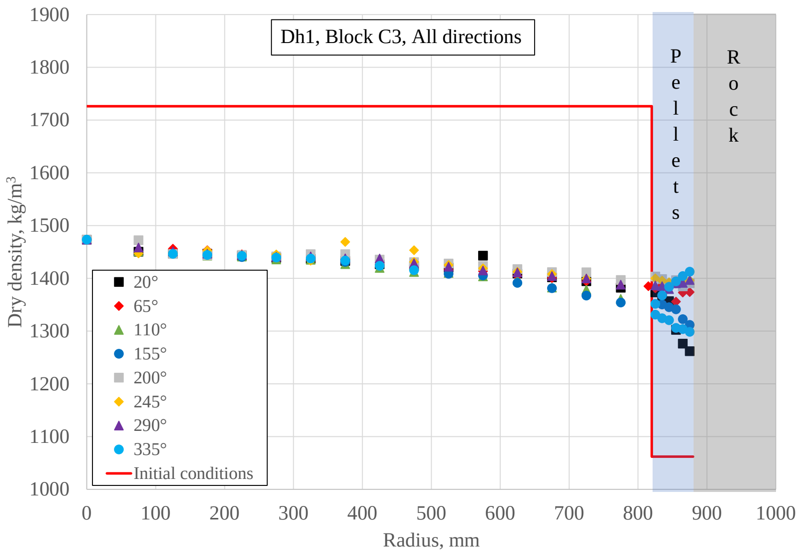


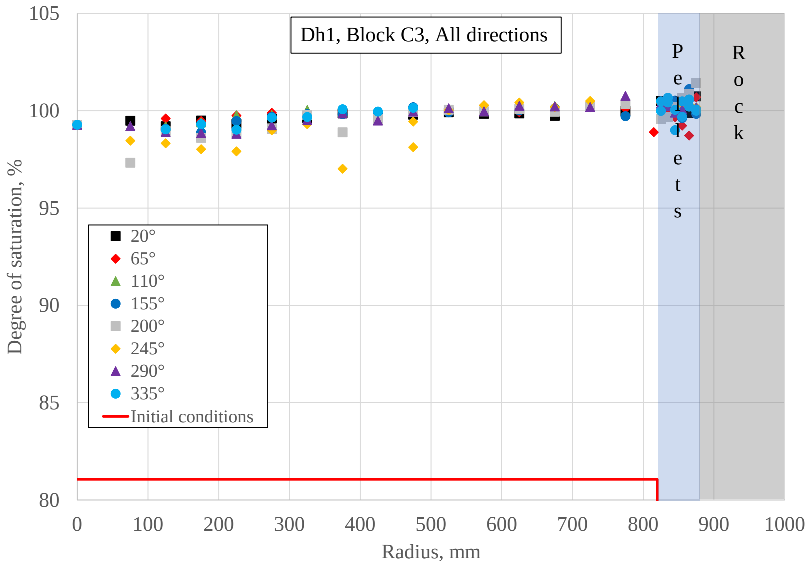




Appendix 4-2a Dh1, Block C3.
Water content, dry density, and degree of saturation in eight directions.

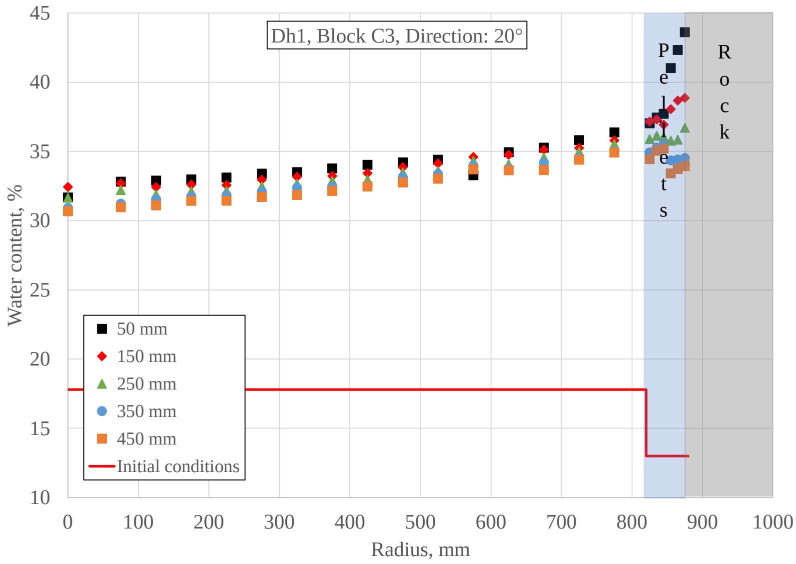


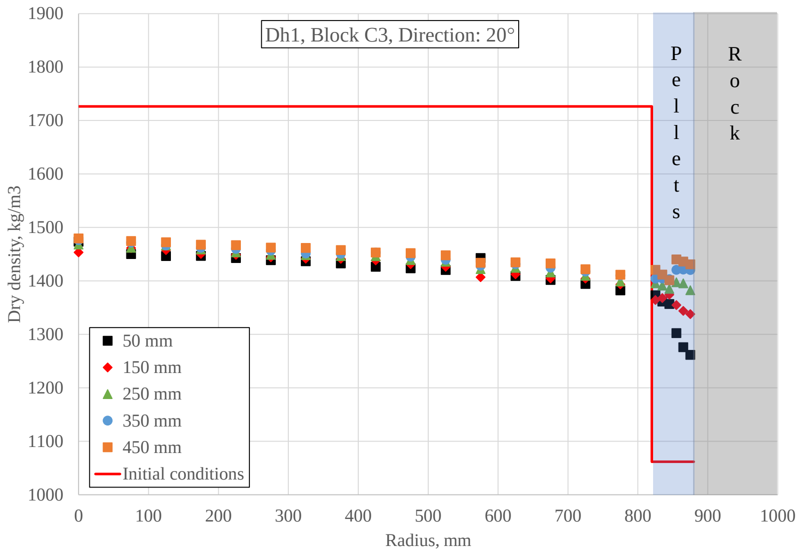


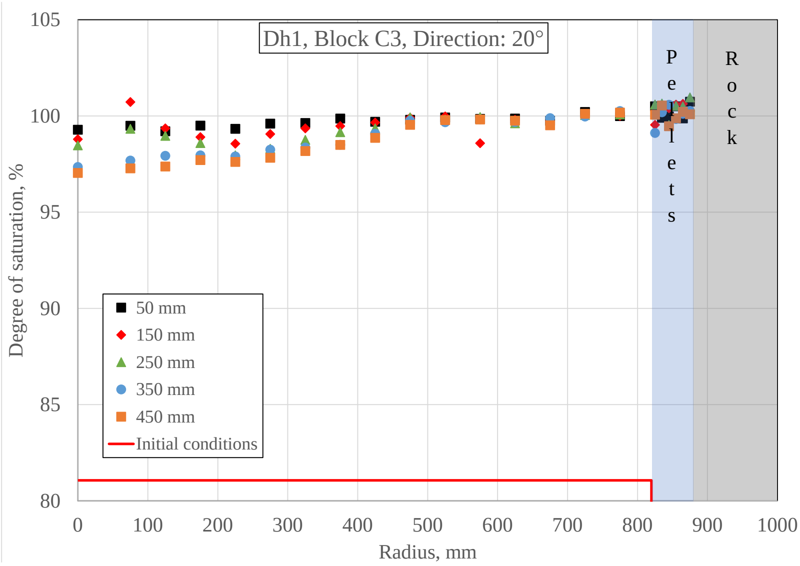


Appendix 4-2b Dh1, Block C3.

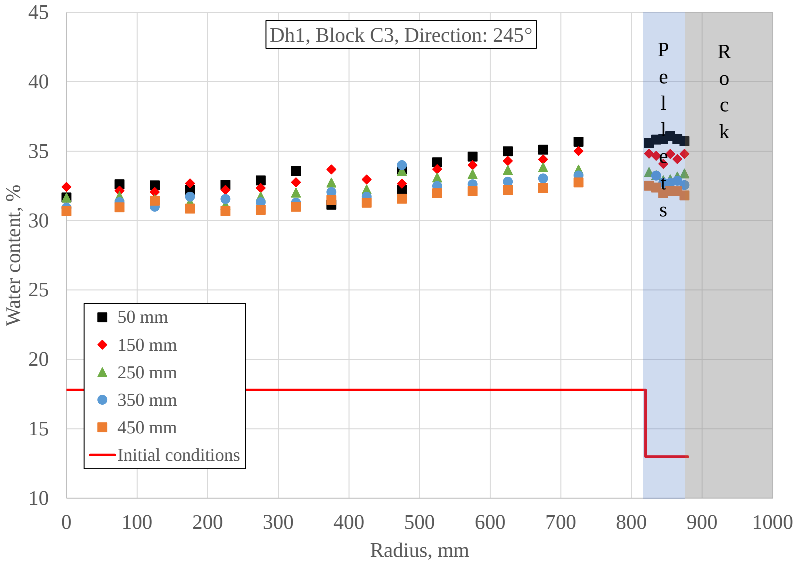
Water content, dry density, and degree of saturation at five depths in direction 20°.

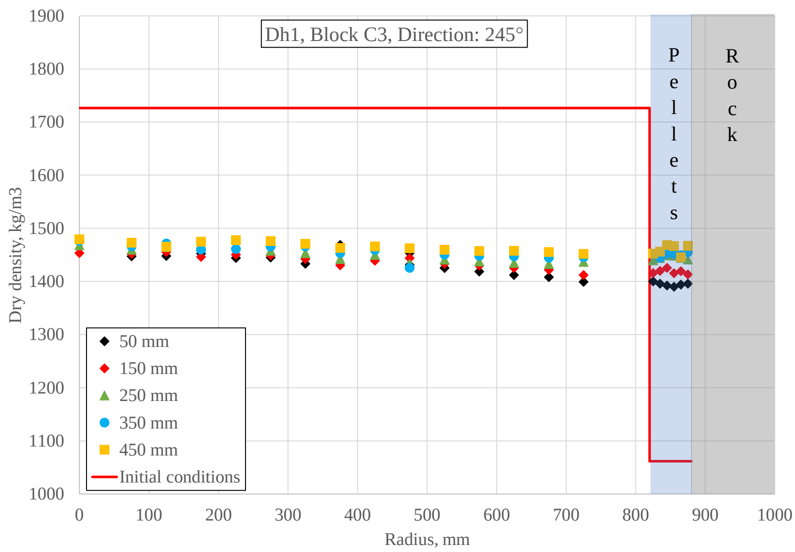


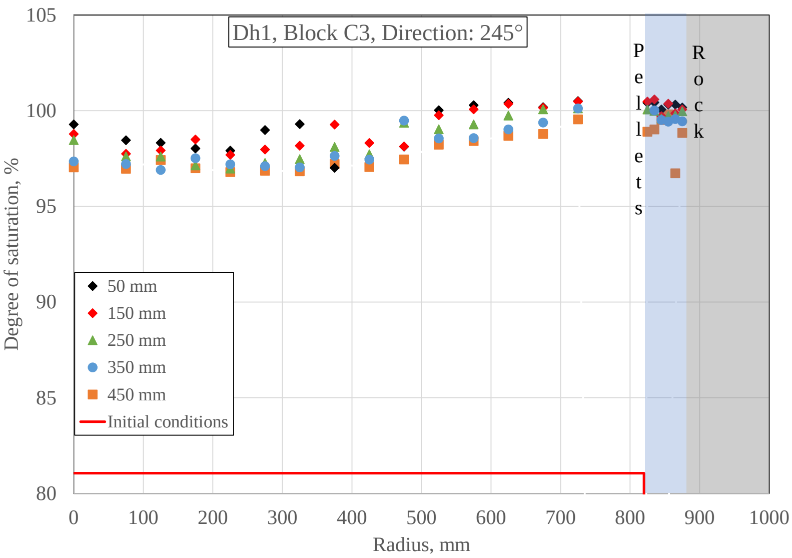




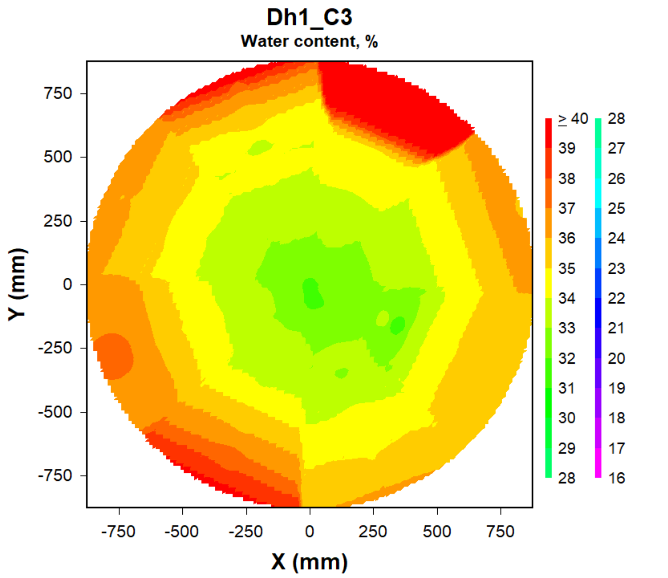
Appendix 4-2c Dh1, Block C3.
Water content, dry density, and degree of saturation at five depths in direction 245°.

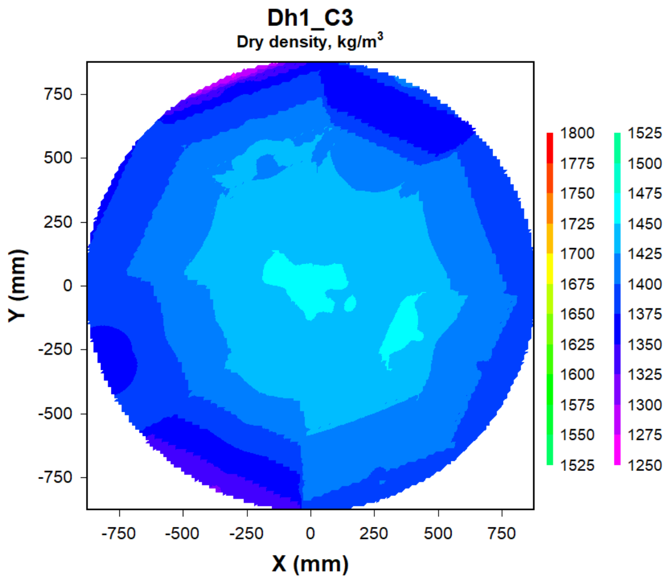


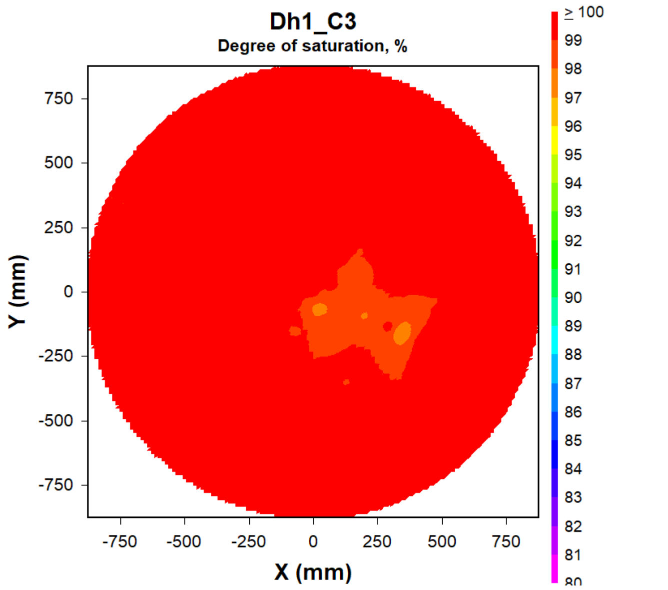




Appendix 4-2d Dh1, Block C3.
Water content, dry density, and degree of saturation distribution.

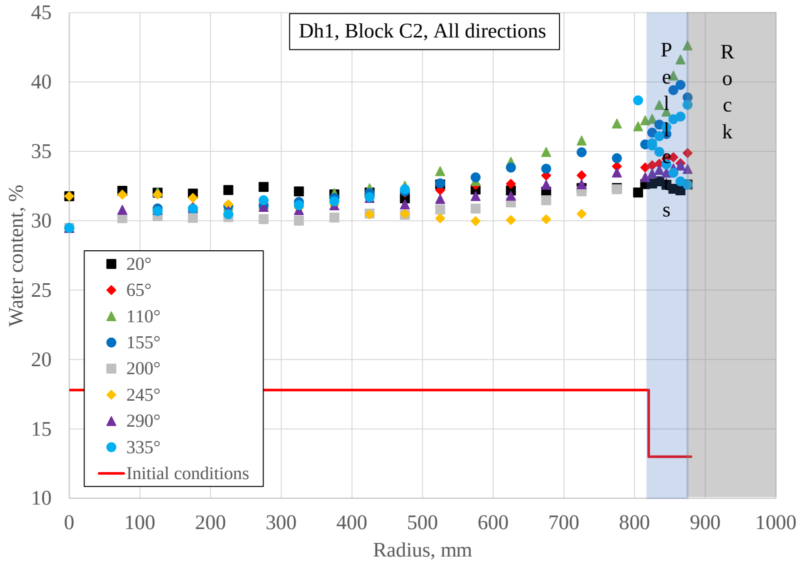


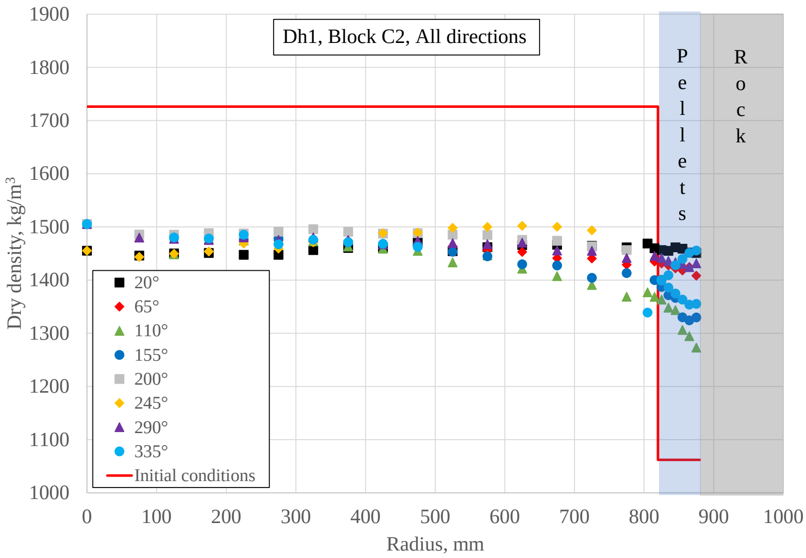


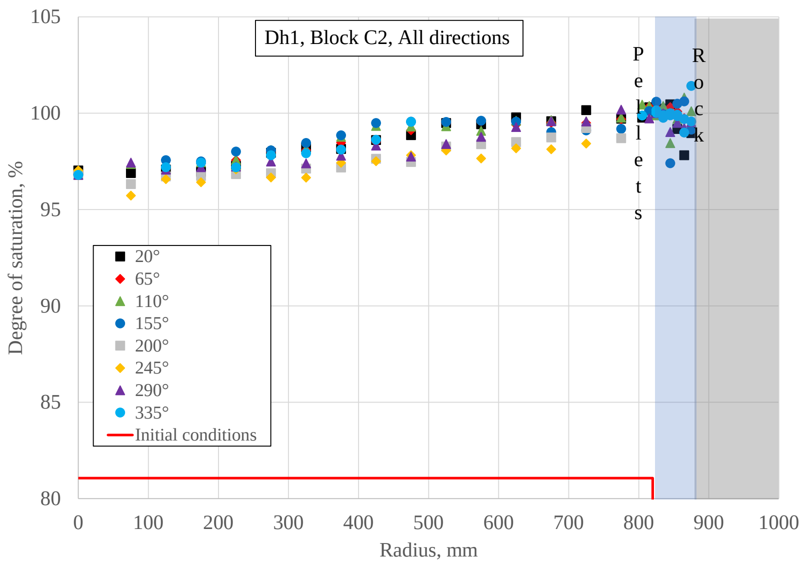


Appendix 4-3a Dh1, Block C2.

Water content, dry density, and degree of saturation in eight directions.

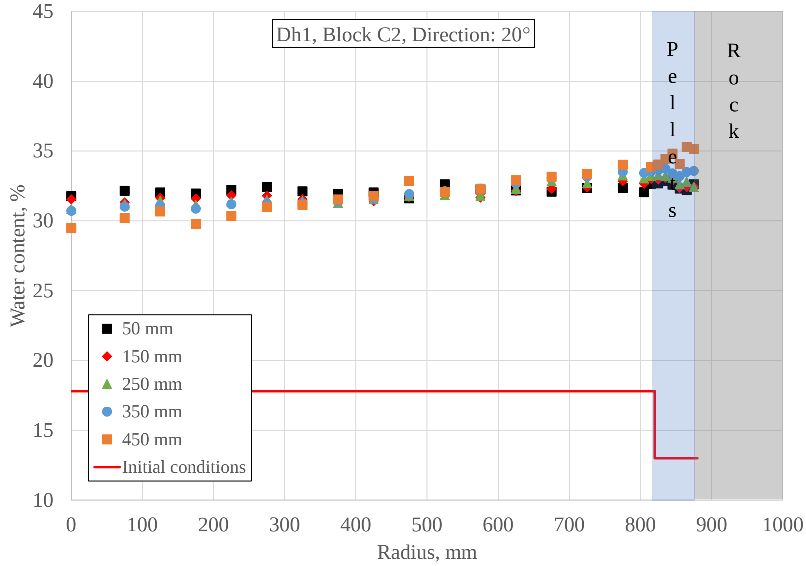


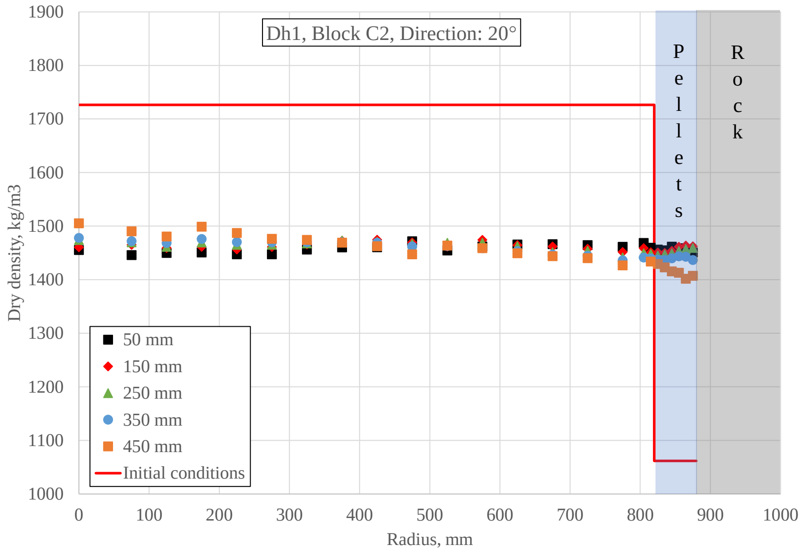


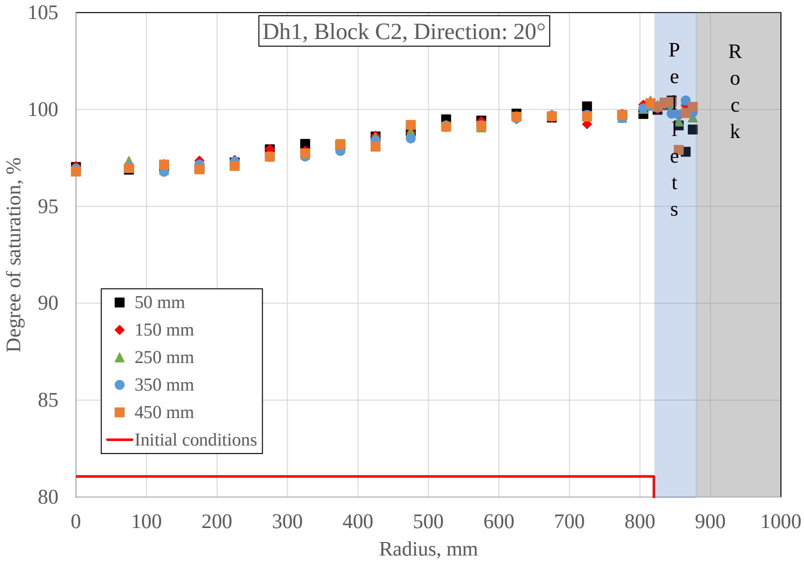


Appendix 4-3b Dh1, Block C2.

Water content, dry density, and degree of saturation at five depths in direction 20°.

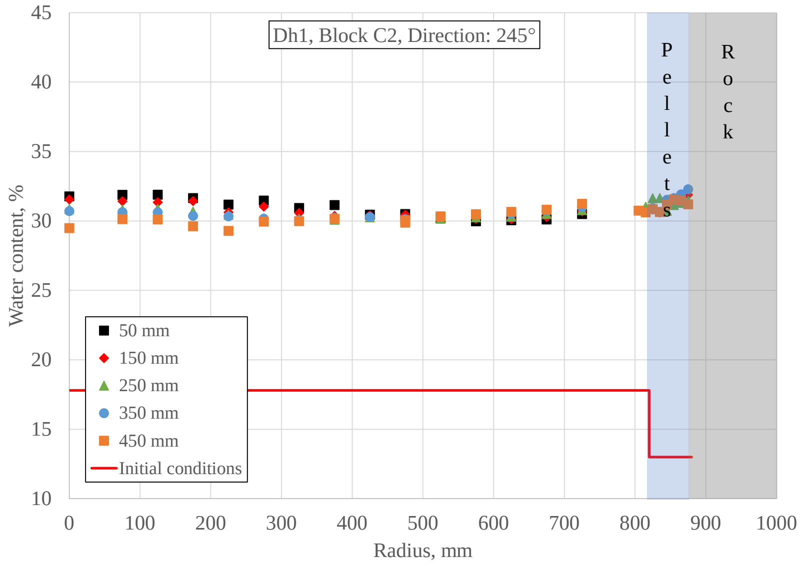


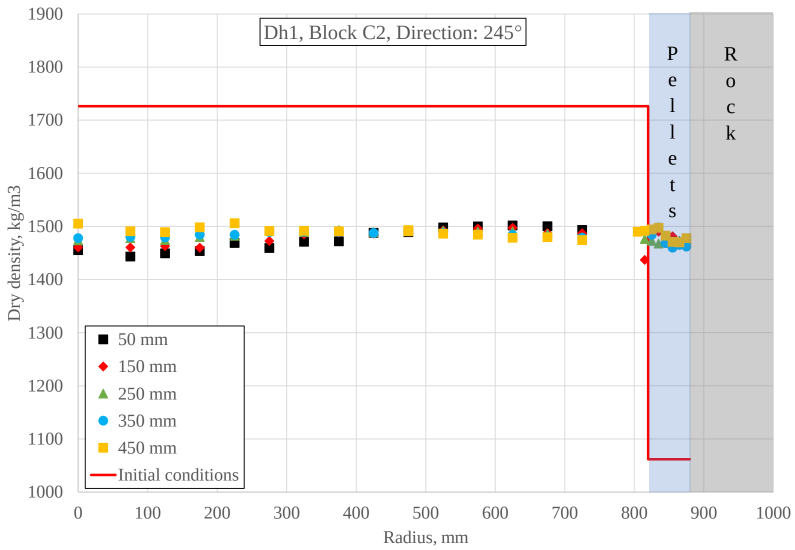


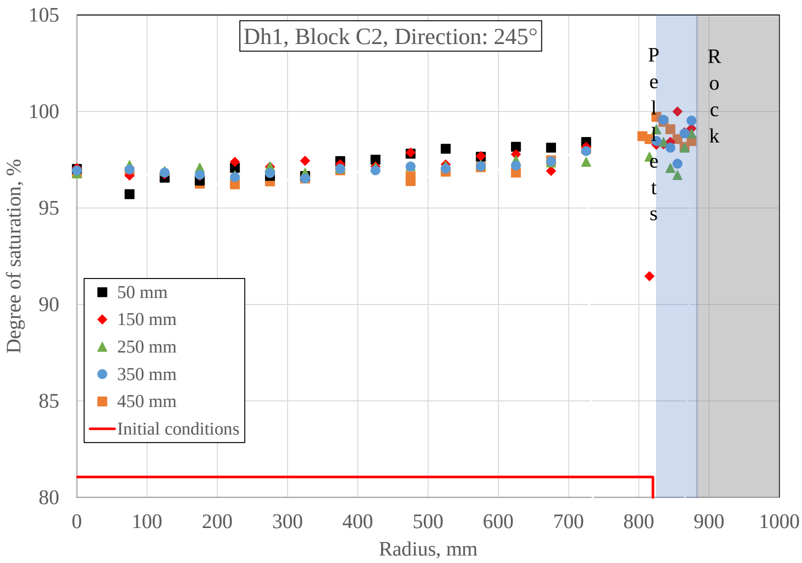


Appendix 4-3c Dh1, Block C2.

Water content, dry density, and degree of saturation at five depths in direction 245°.

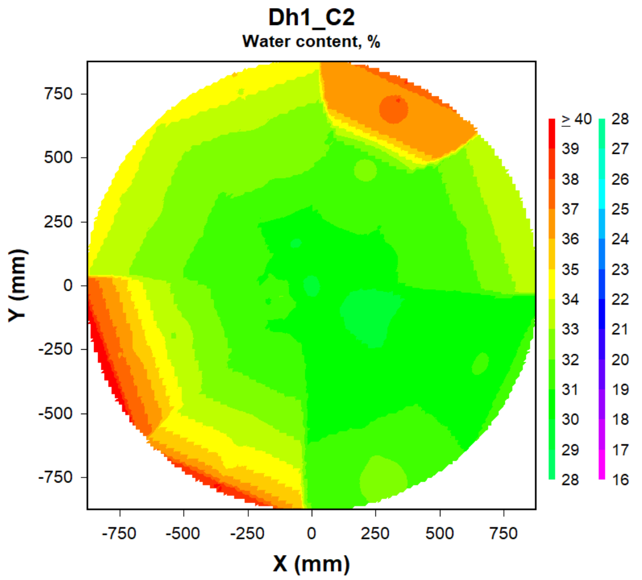


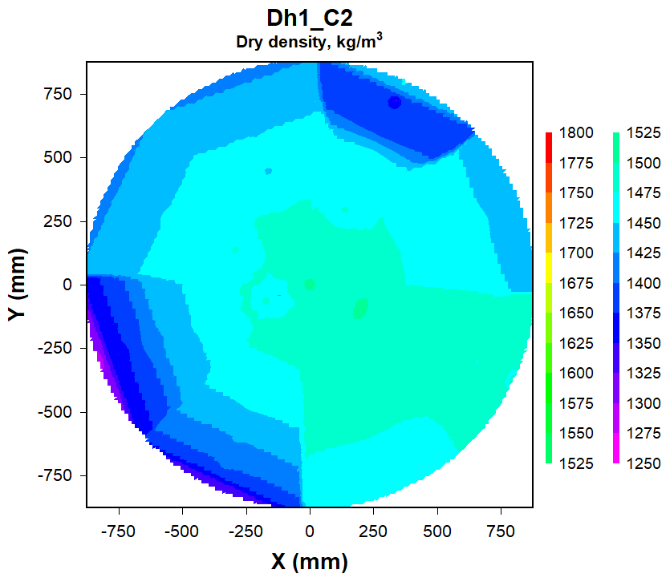


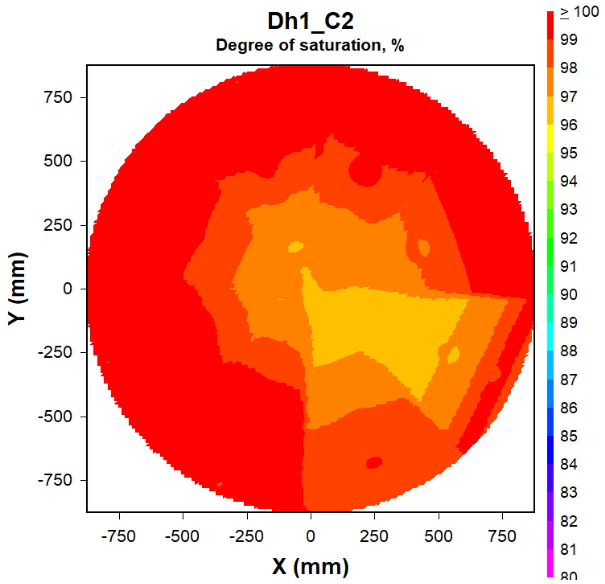


Appendix 4-3d Dh1, Block C2.

Water content, dry density, and degree of saturation distribution.

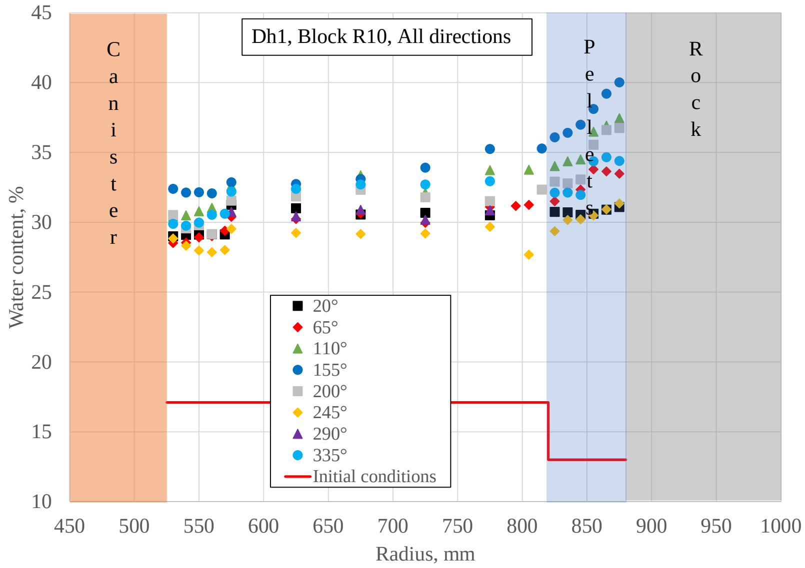


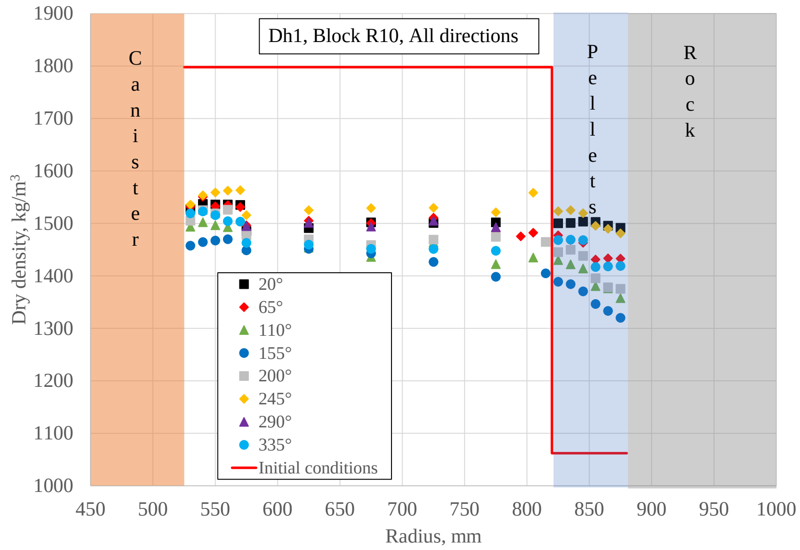


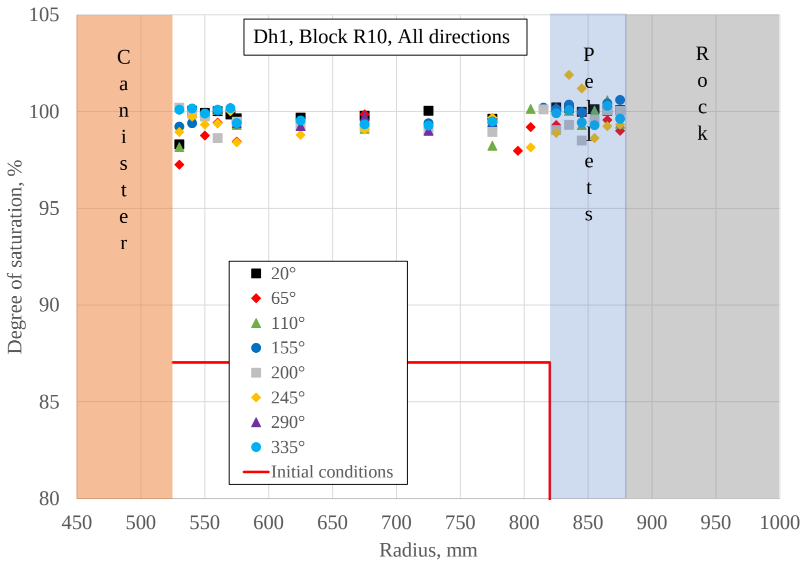


Appendix 4-4a Dh1, Block R10.

Water content, dry density, and degree of saturation in eight directions.

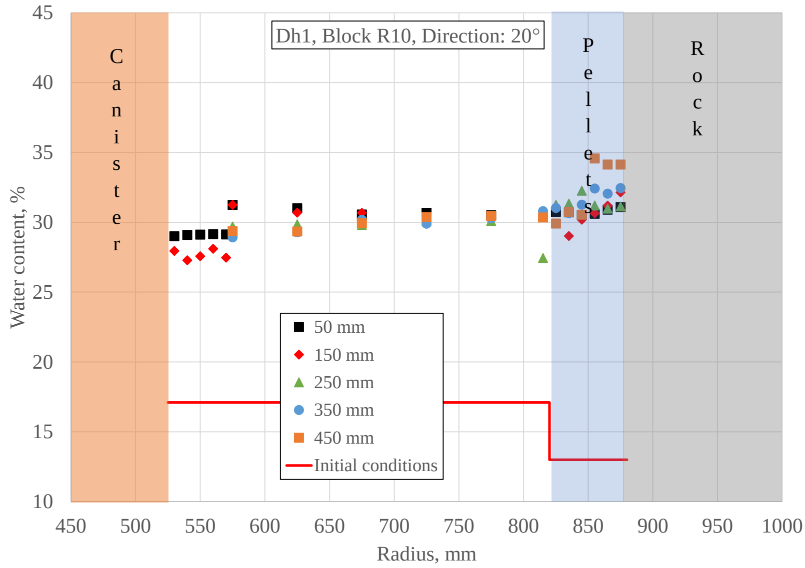


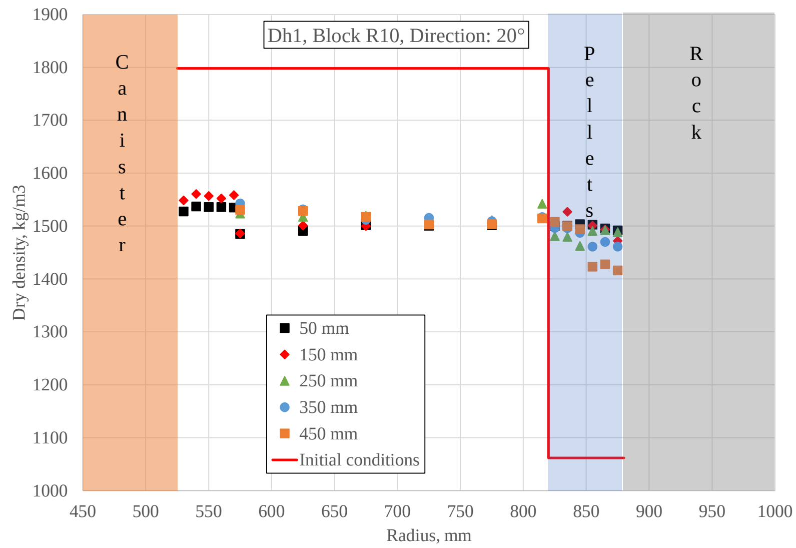


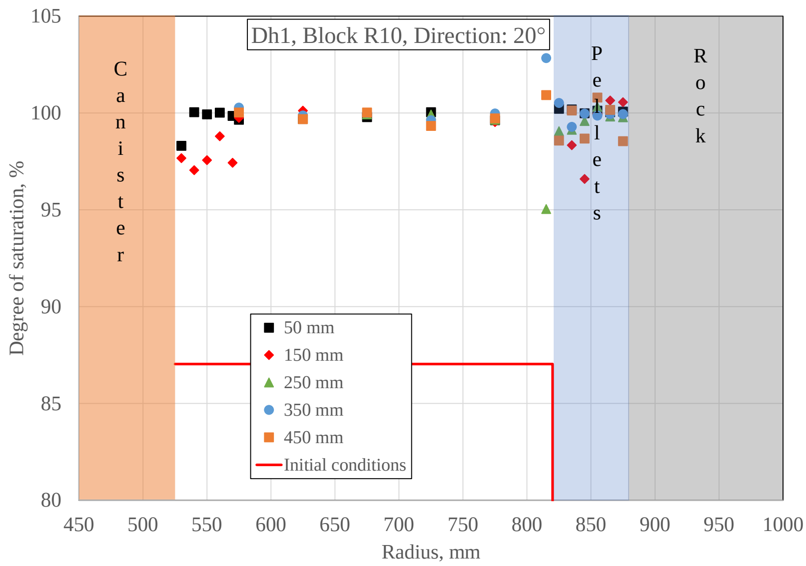


Appendix 4-4b Dh1, Block R10.

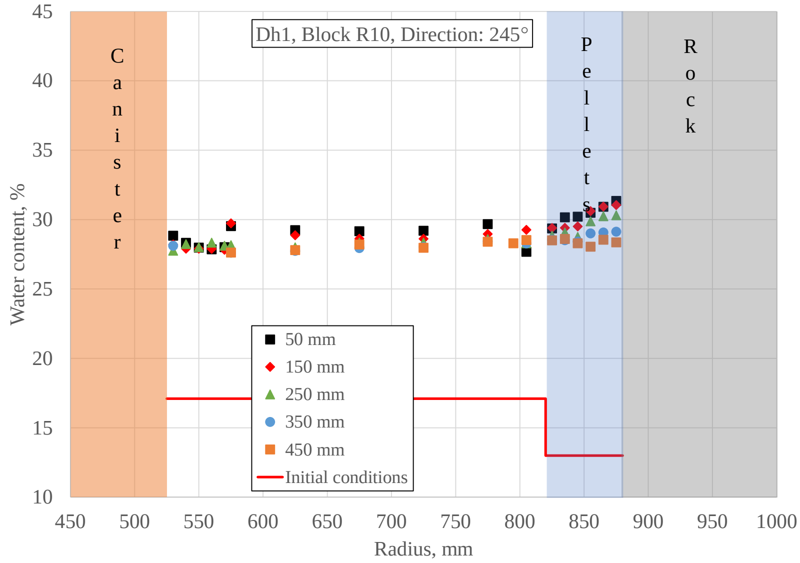
Water content, dry density, and degree of saturation at five depths in direction 20°.

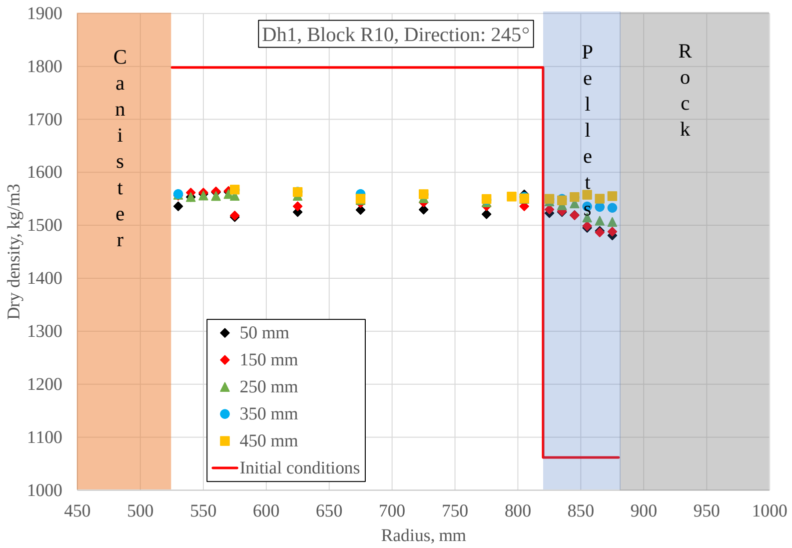


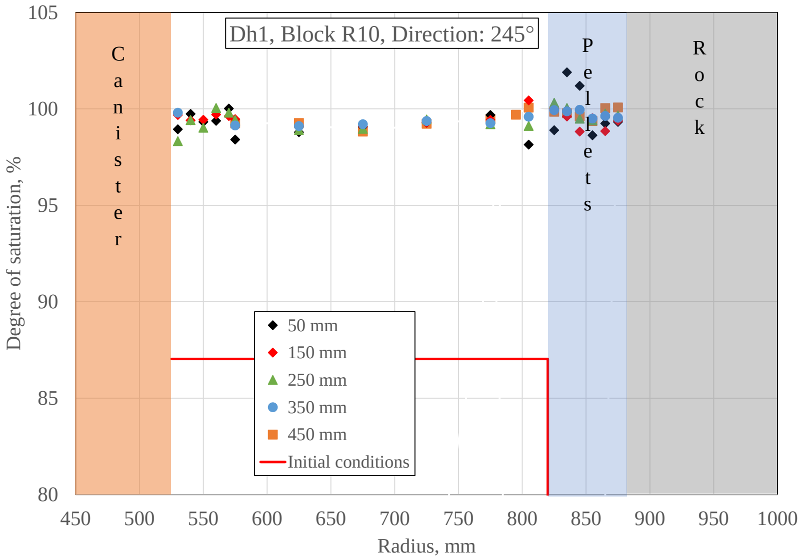




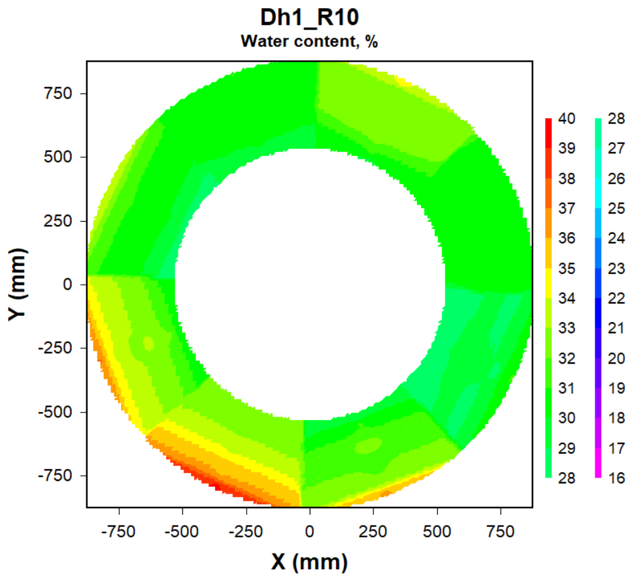
Appendix 4-4c Dh1, Block R10.
Water content, dry density, and degree of saturation at five depths in direction 245°.

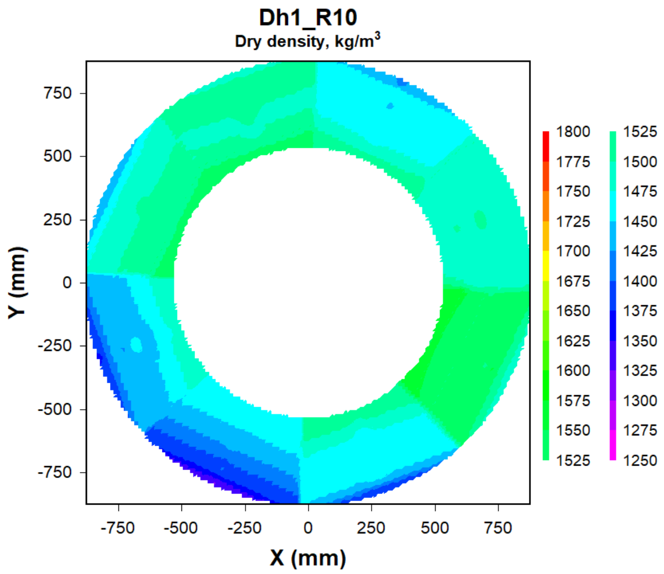


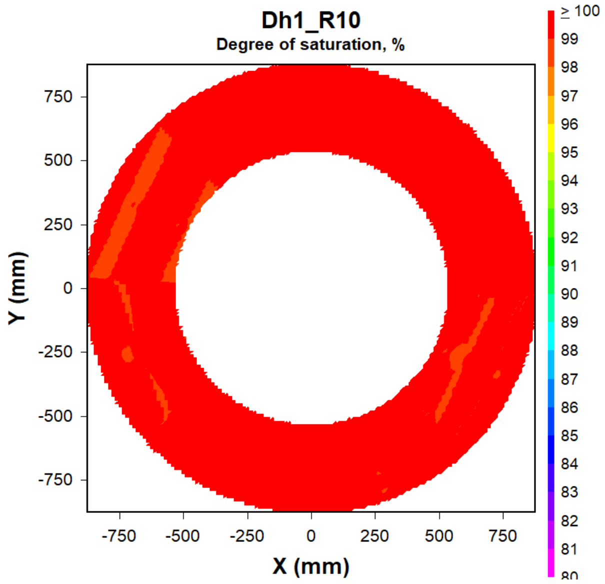




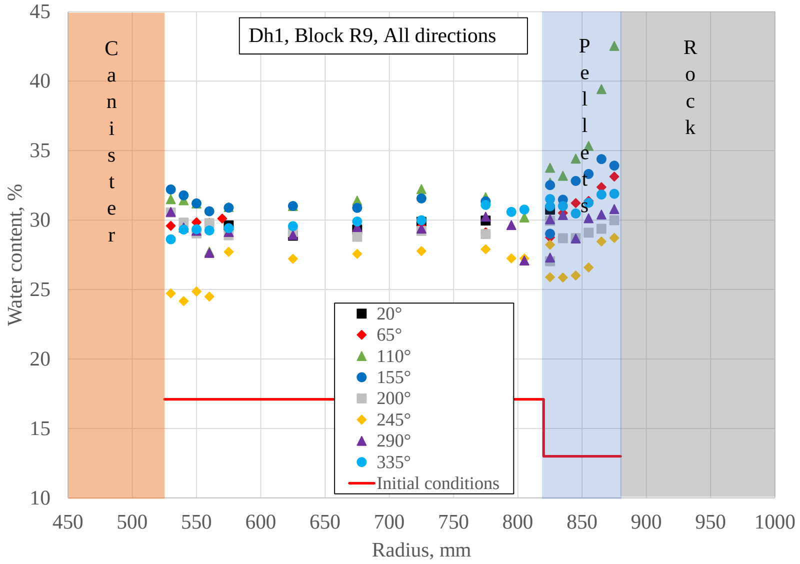
Appendix 4-4d Dh1, Block R10.
Water content, dry density, and degree of saturation distribution.

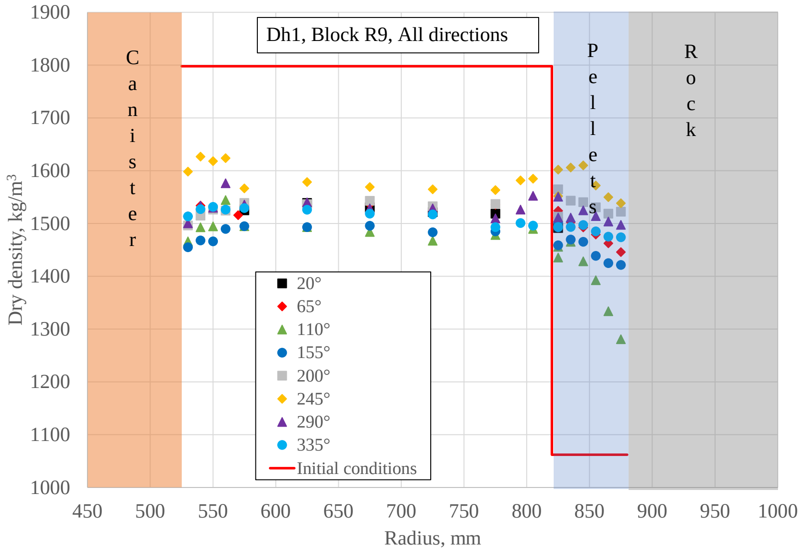


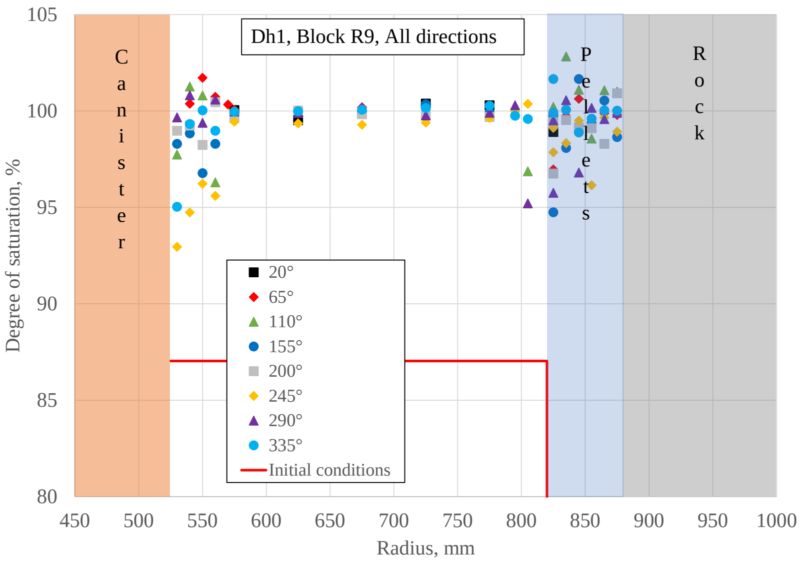




Appendix 4-5a Dh1, Block R9.
Water content, dry density, and degree of saturation in eight directions.

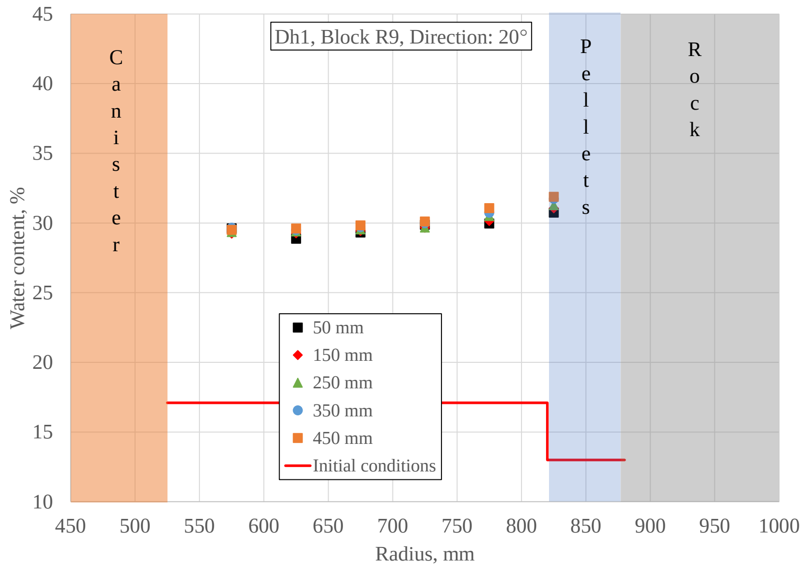


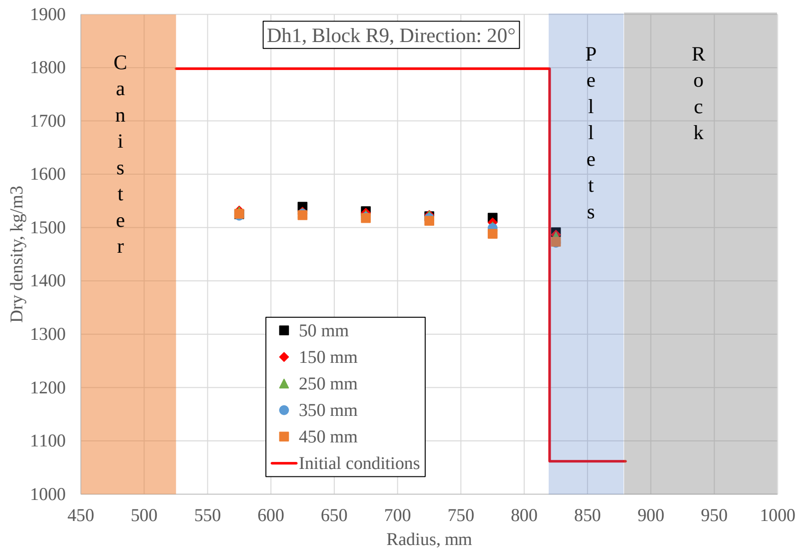


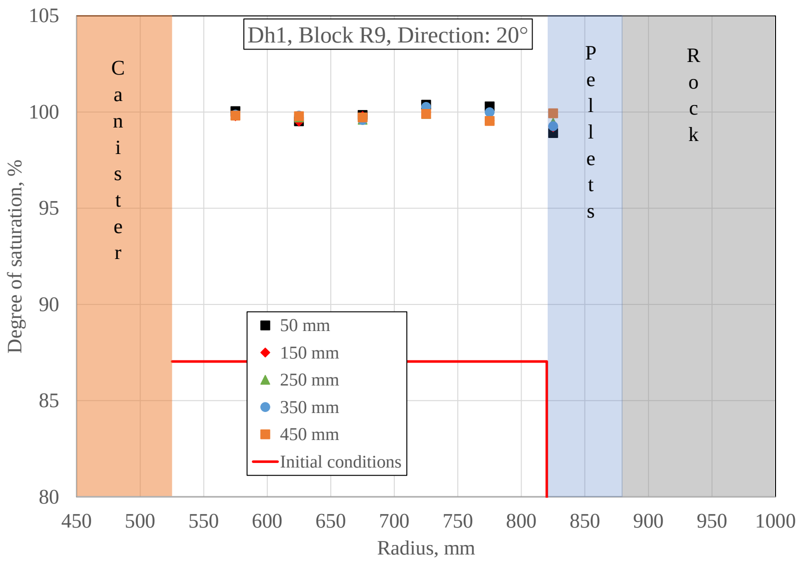


Appendix 4-5b Dh1, Block R9.

Water content, dry density, and degree of saturation at five depths in direction 20°.

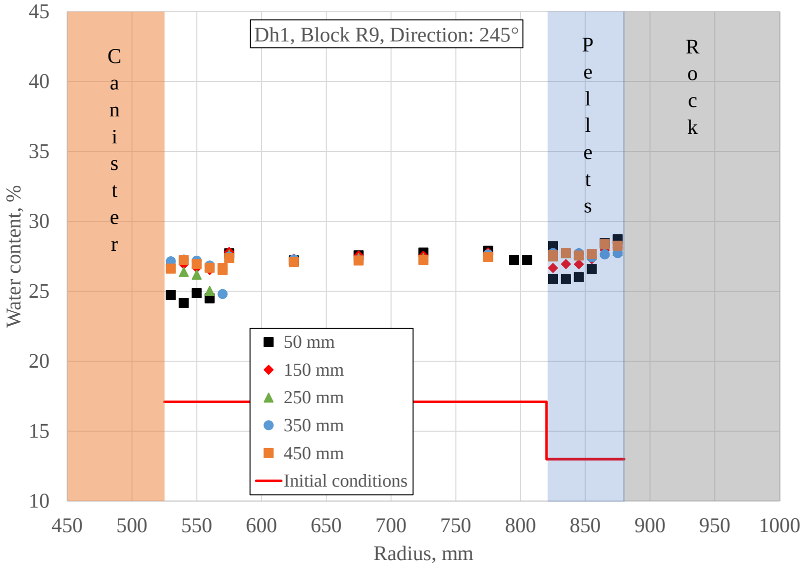


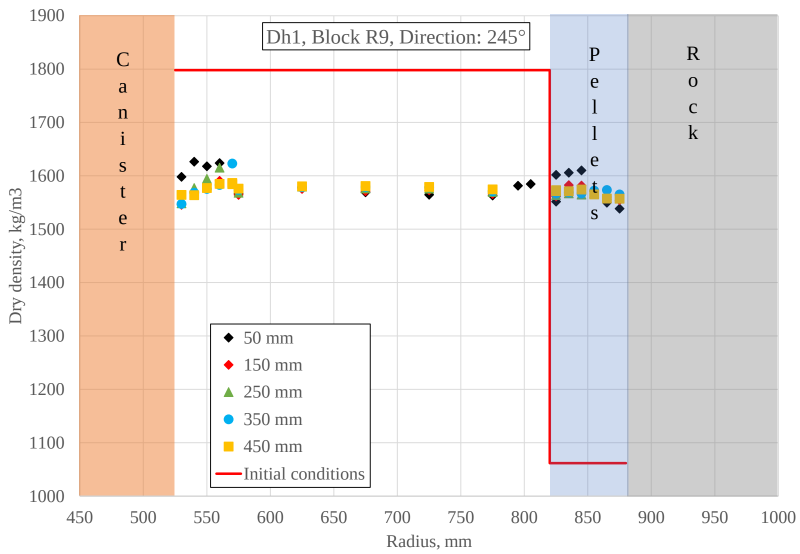


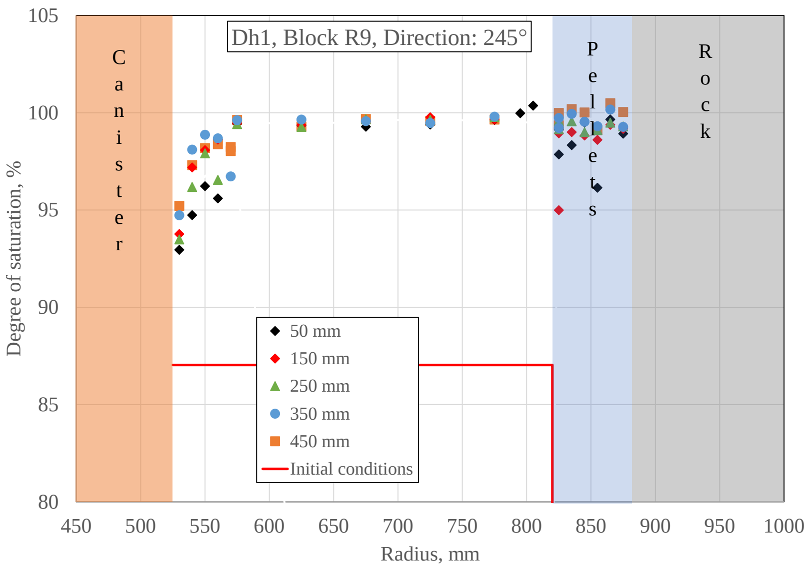


Appendix 4-5c Dh1, Block R9.

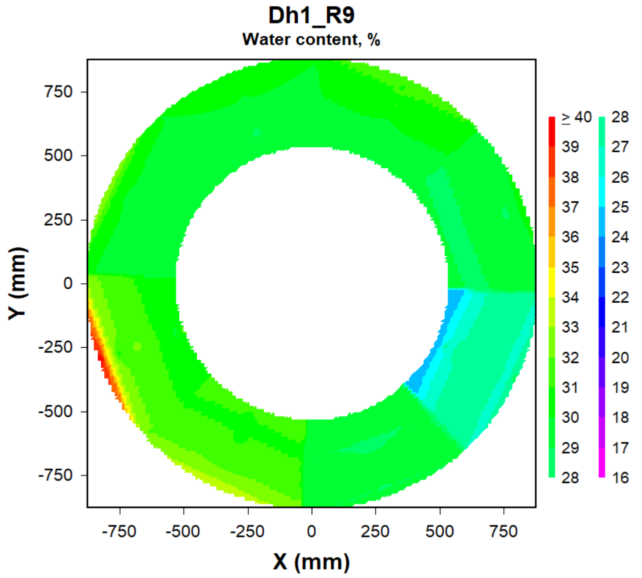
Water content, dry density, and degree of saturation at five depths in direction 245°.

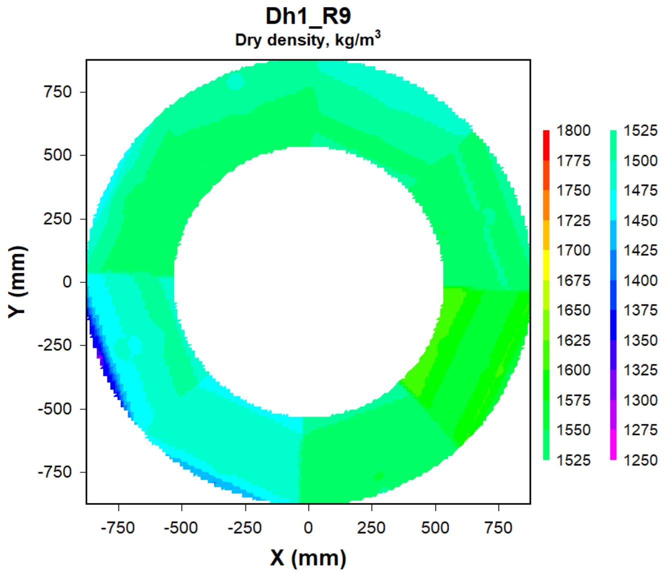


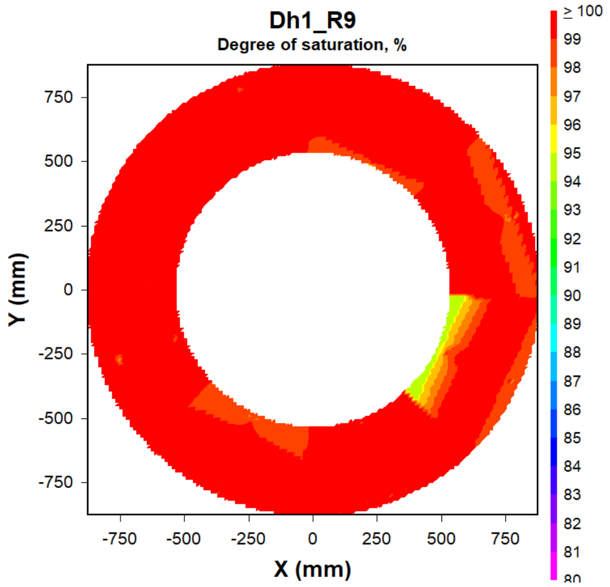




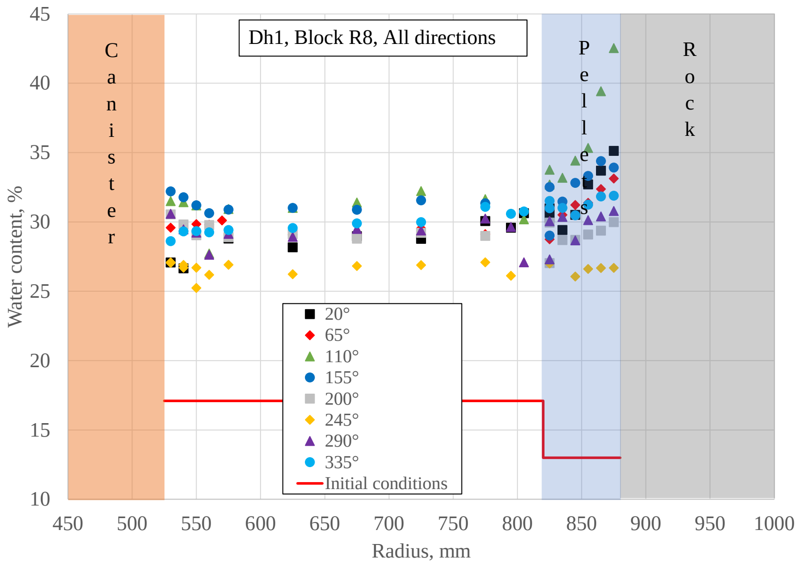
Appendix 4-5d Dh1, Block R9.
Water content, dry density, and degree of saturation distribution.

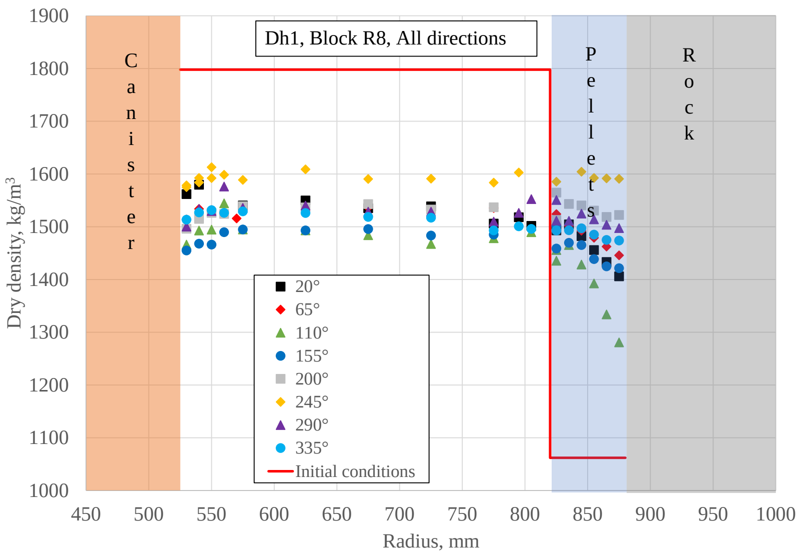


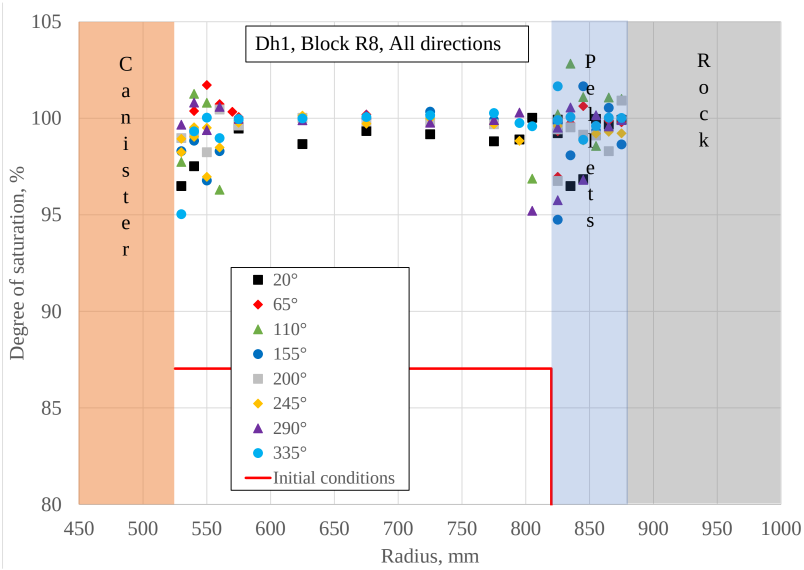




Appendix 4-6a Dh1, Block R8.
Water content, dry density, and degree of saturation in eight directions.

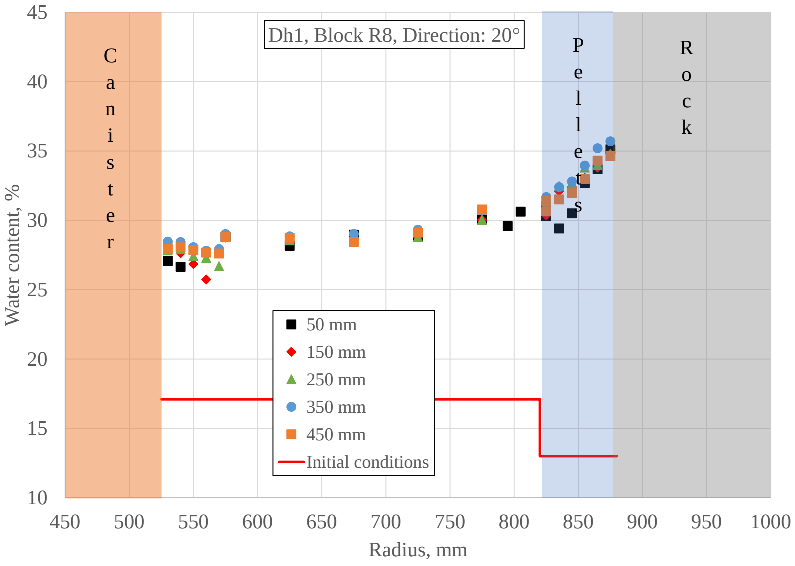


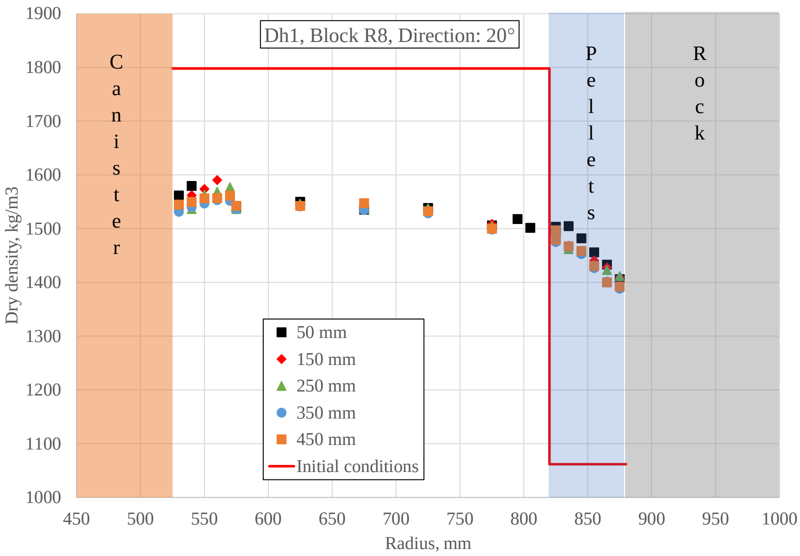


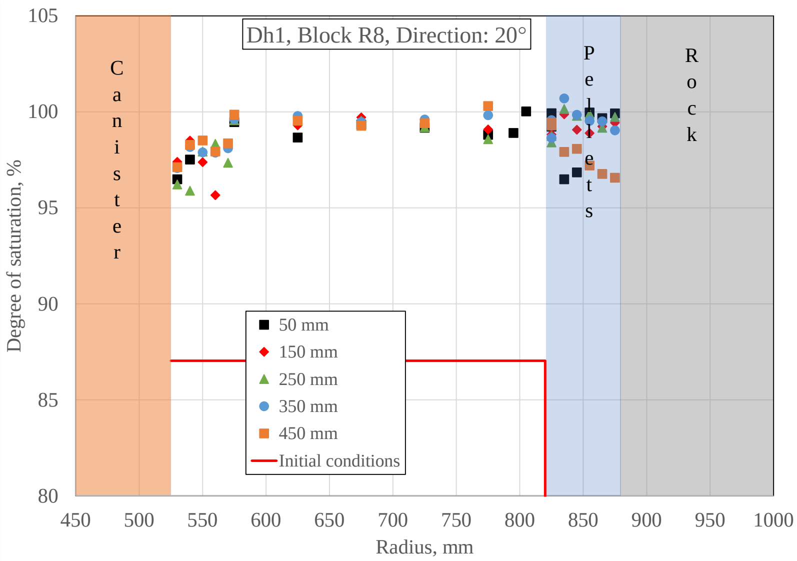


Appendix 4-6b Dh1, Block R8.

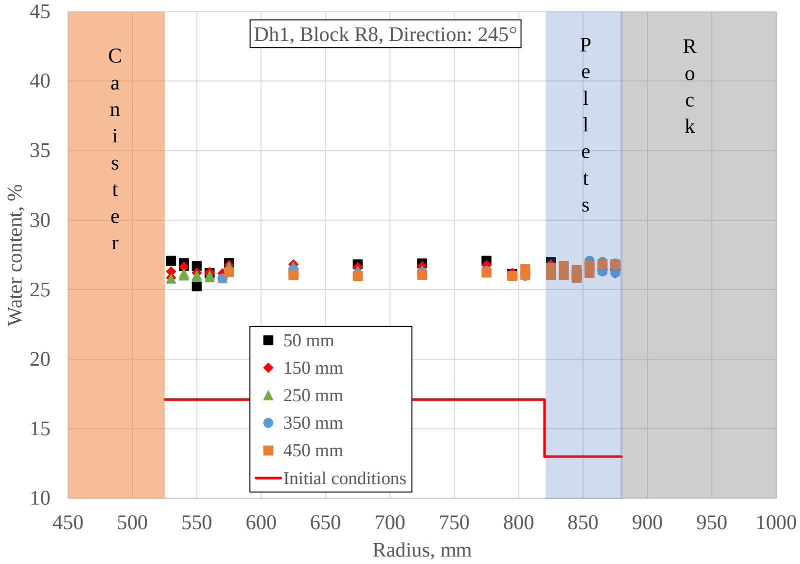
Water content, dry density, and degree of saturation at five depths in direction 20°.

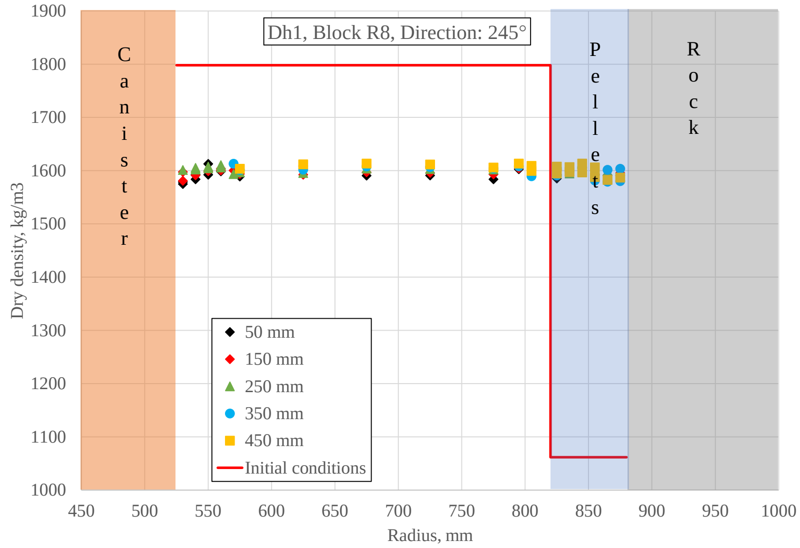


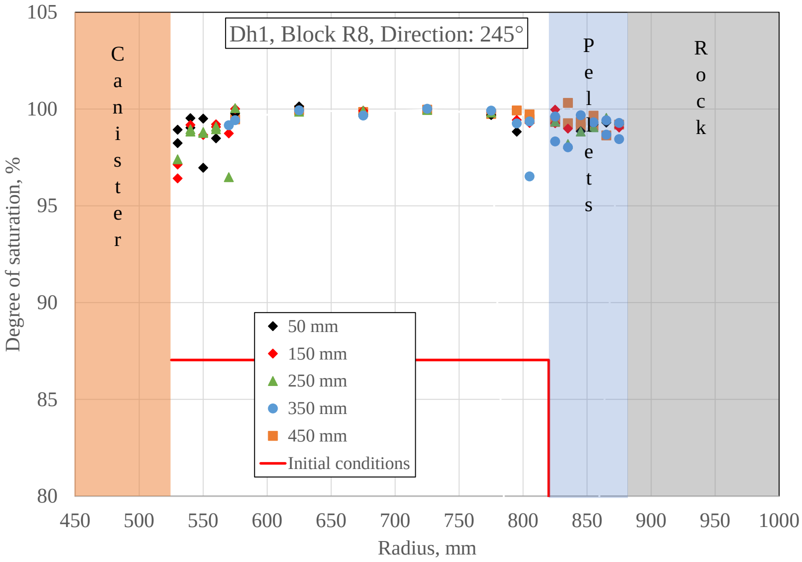




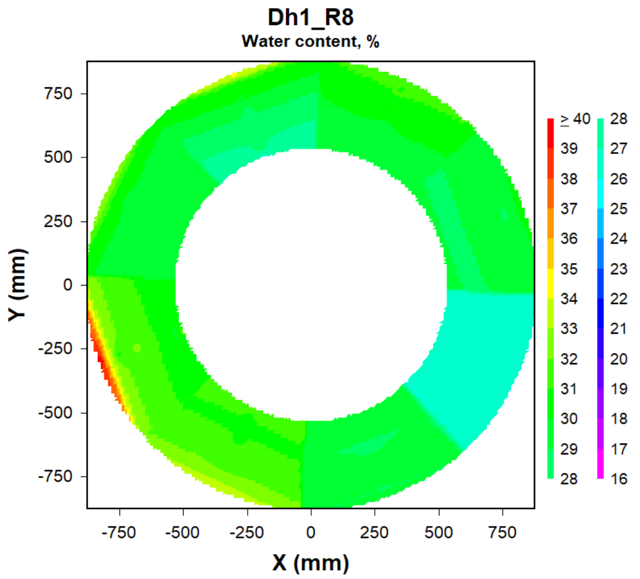
Appendix 4-6c Dh1, Block R8.
Water content, dry density, and degree of saturation at five depths in direction 245°.

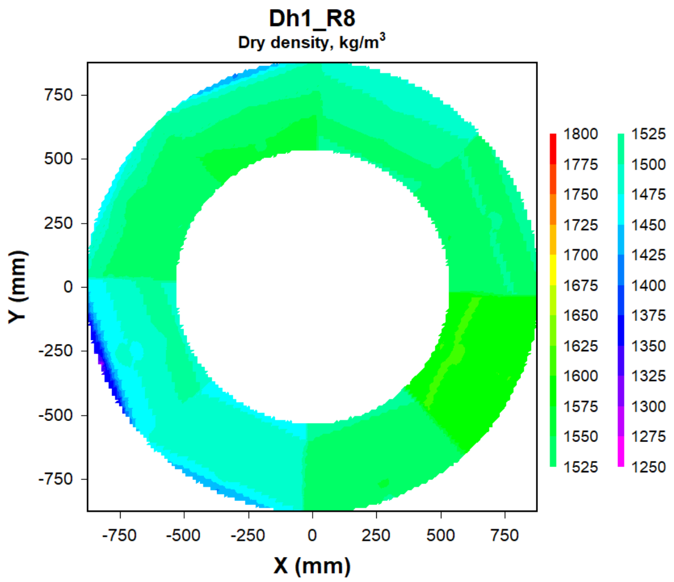


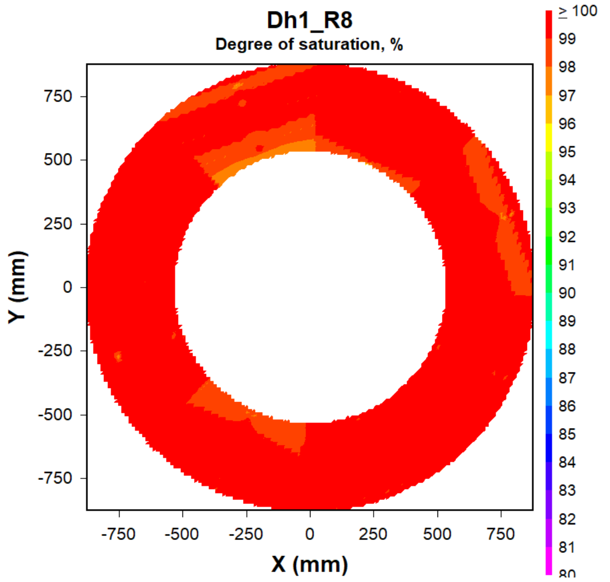




Appendix 4-6d Dh1, Block R8.
Water content, dry density, and degree of saturation distribution.

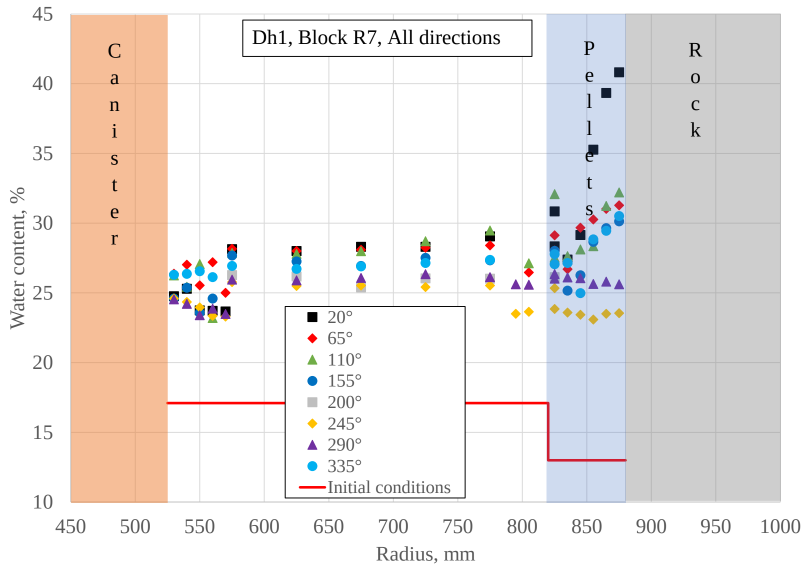


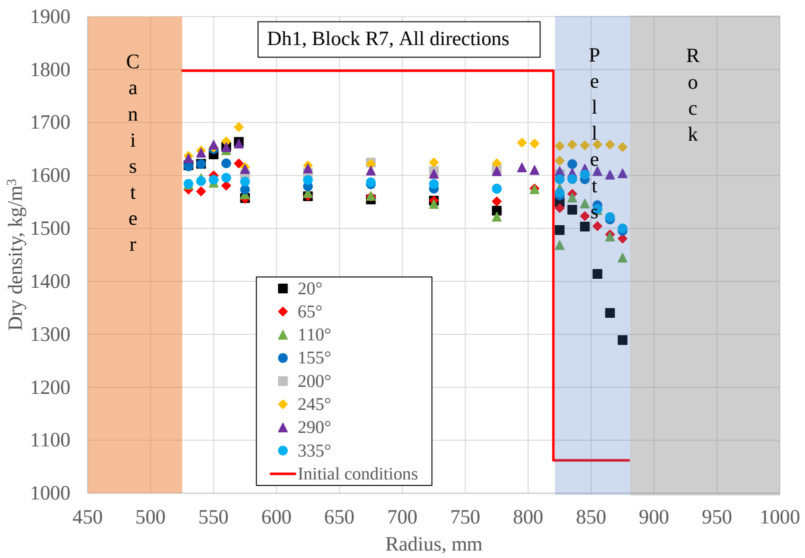


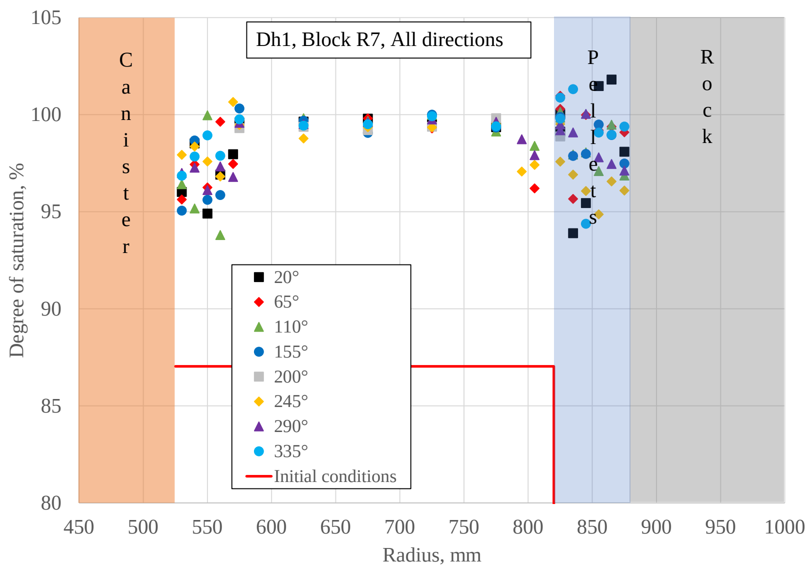


Appendix 4-7a Dh1, Block R7.

Water content, dry density, and degree of saturation in eight directions.

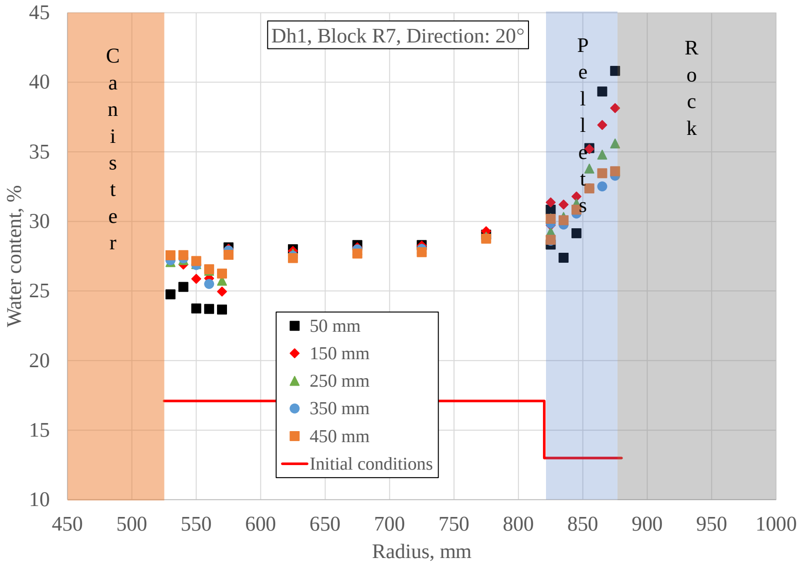


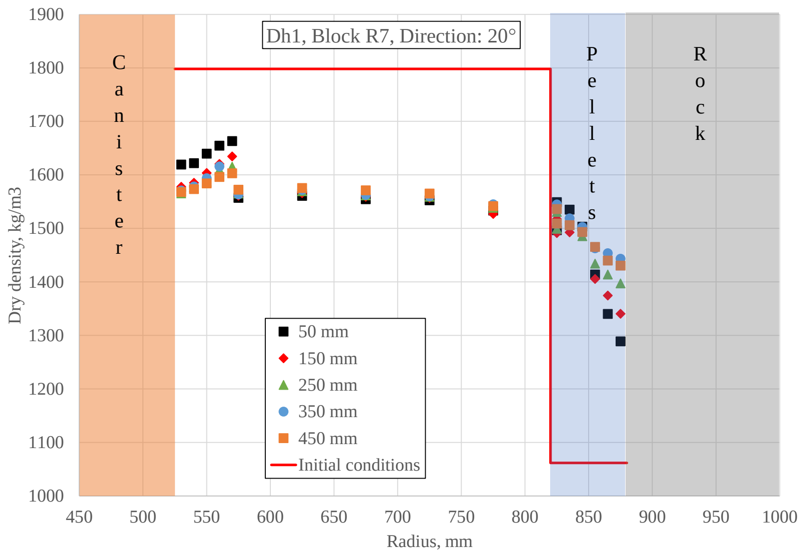


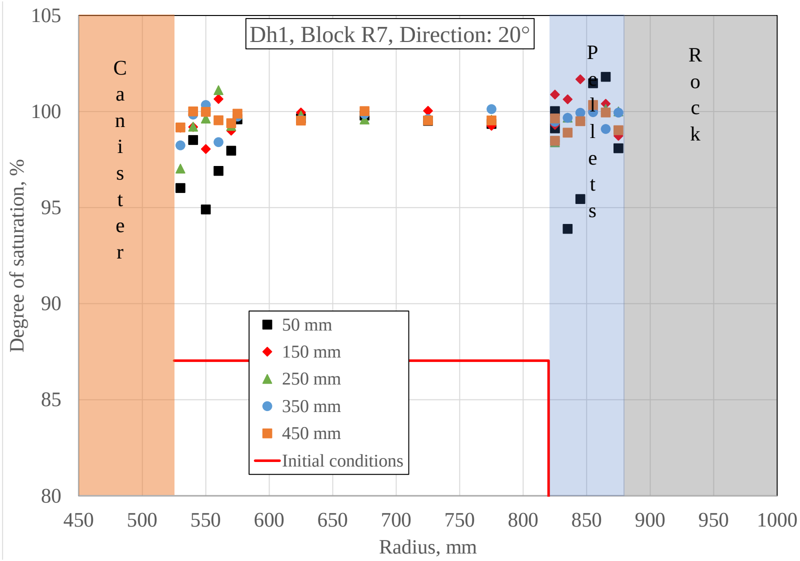


Appendix 4-7b Dh1, Block R7.

Water content, dry density, and degree of saturation at five depths in direction 20°.

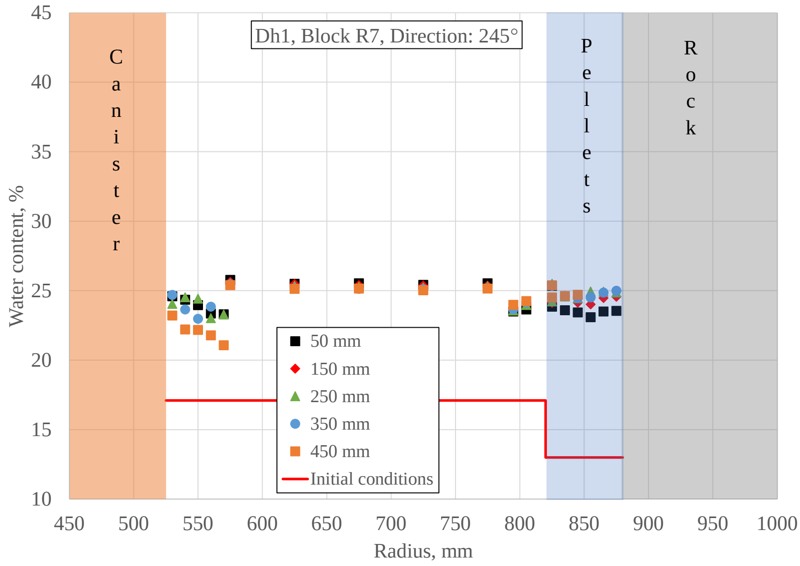


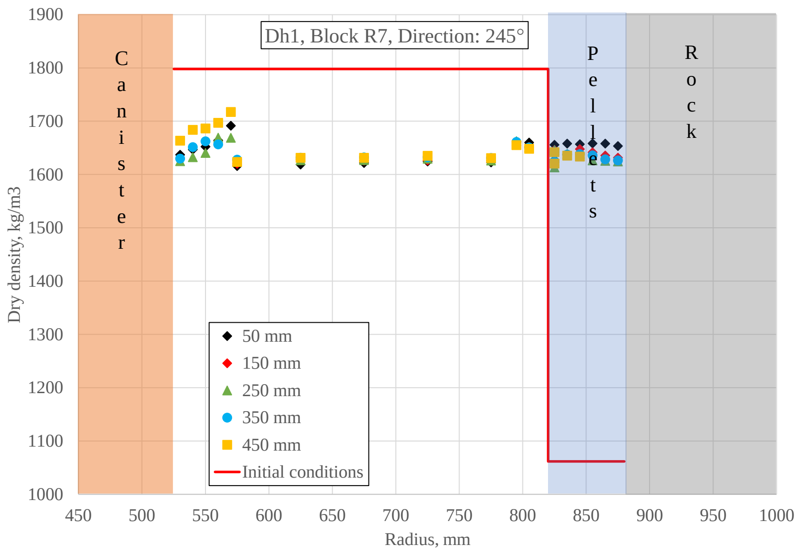


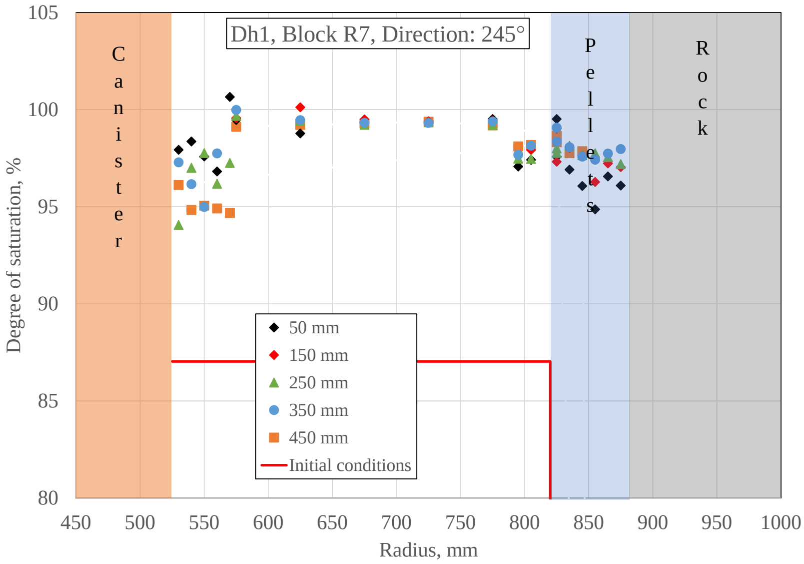


Appendix 4-7c Dh1, Block R7.

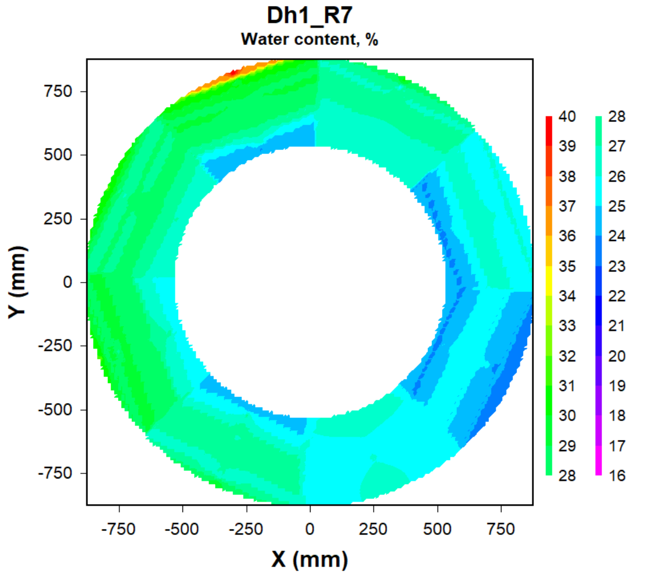
Water content, dry density, and degree of saturation at five depths in direction 245°.

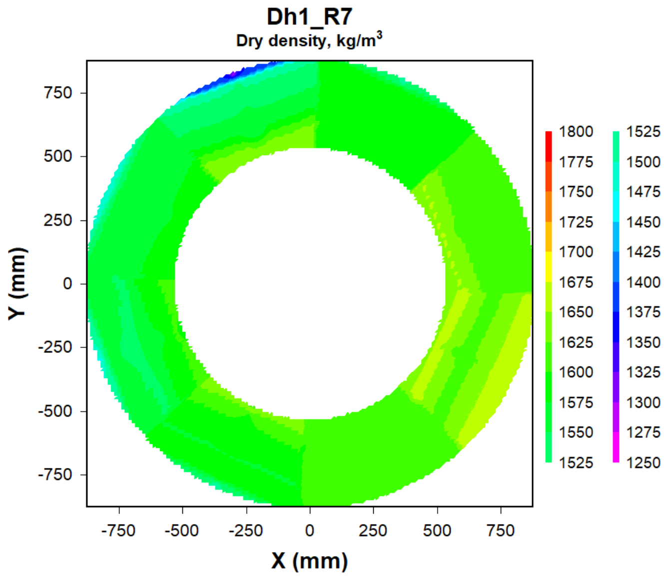


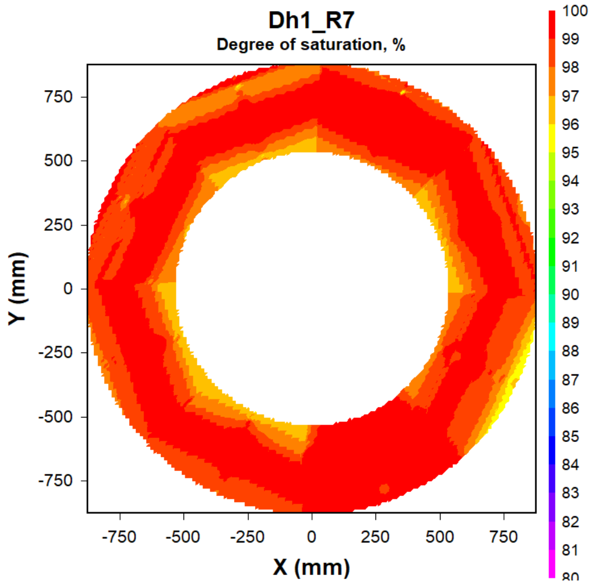




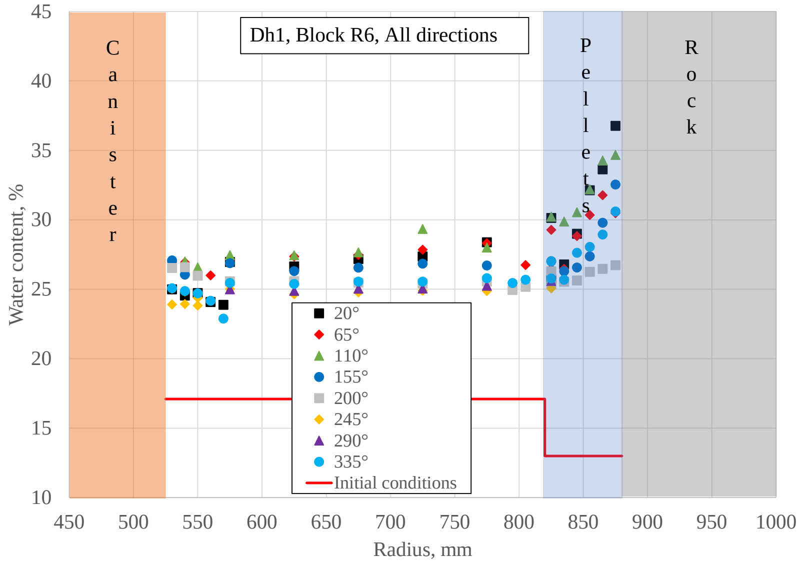
Appendix 4-7d Dh1, Block R7.
Water content, dry density, and degree of saturation distribution.

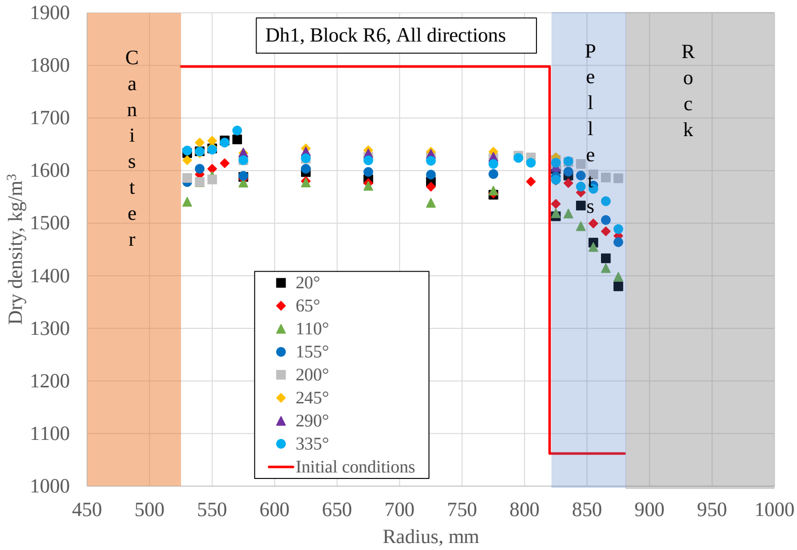


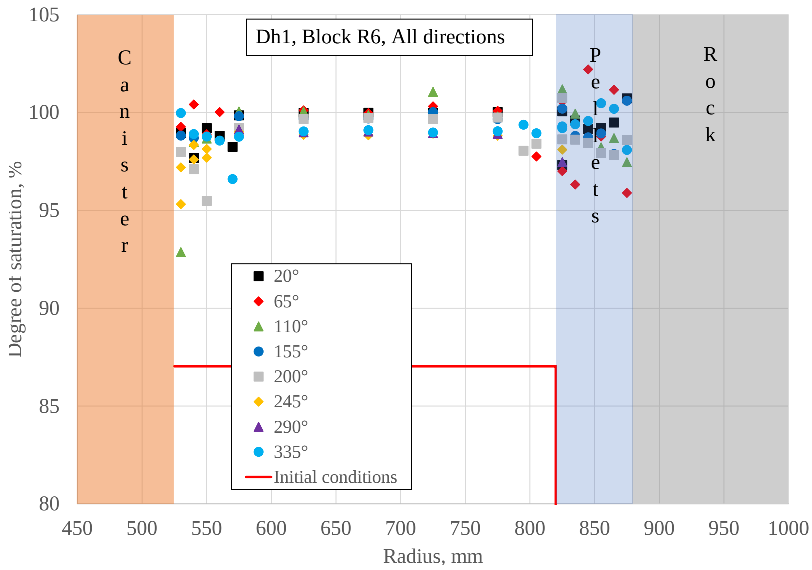




Appendix 4-8a Dh1, Block R6.
Water content, dry density, and degree of saturation in eight directions.

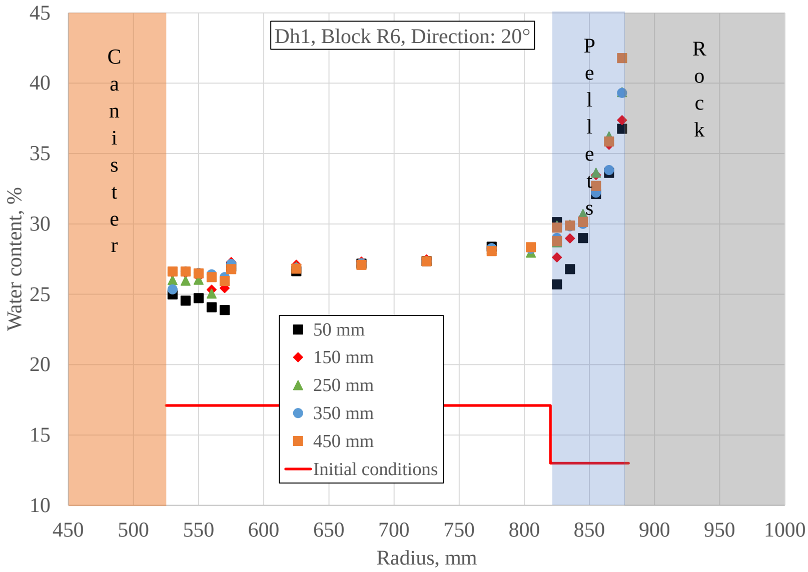


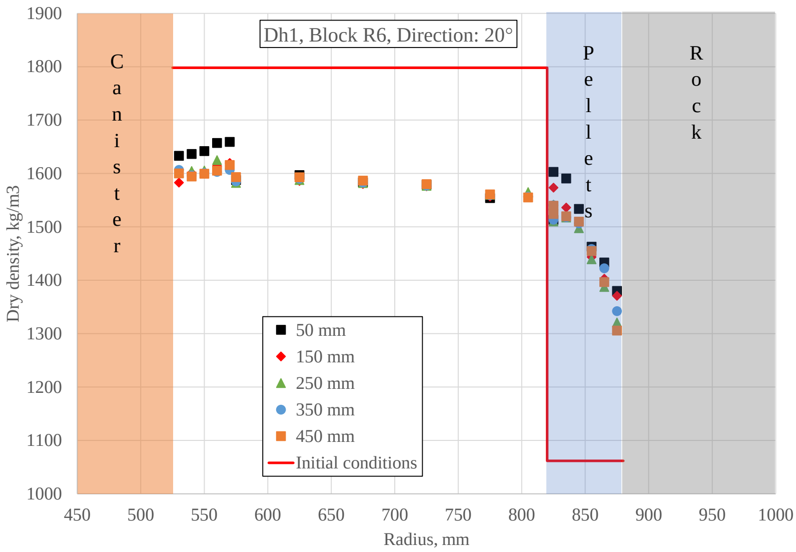


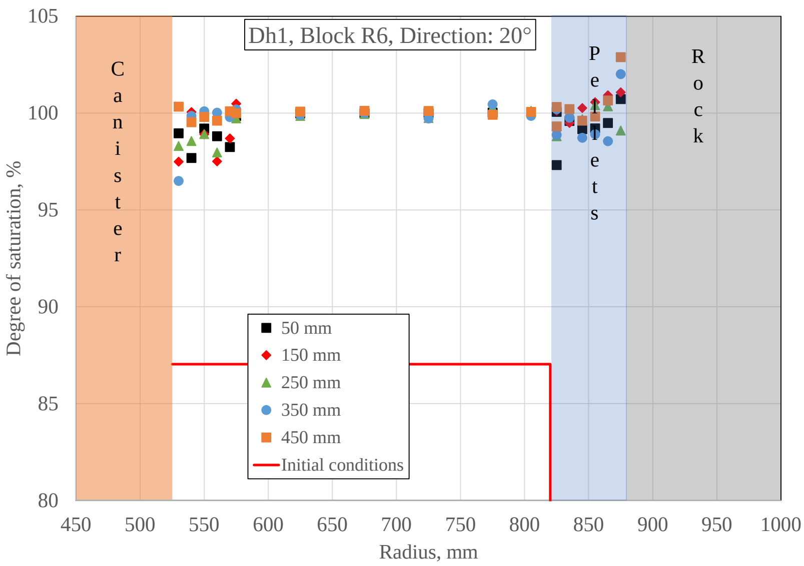


Appendix 4-8b Dh1, Block R6.

Water content, dry density, and degree of saturation at five depths in direction 20°.

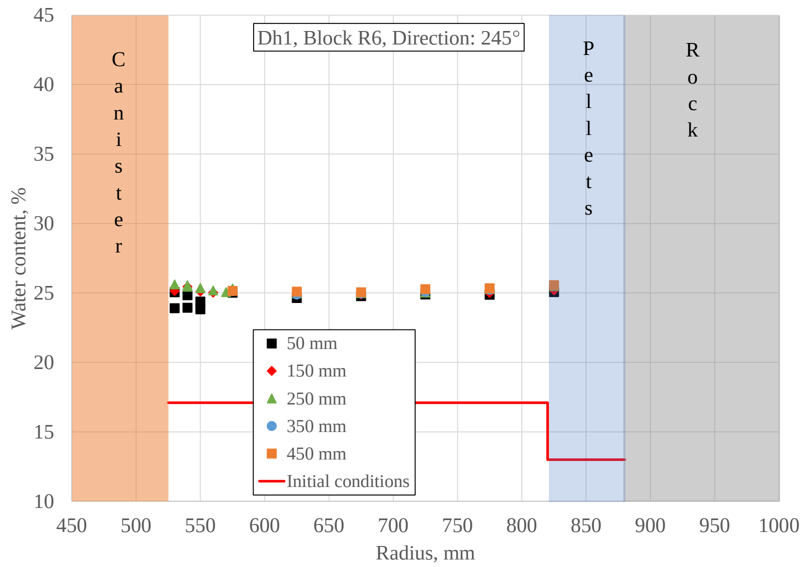


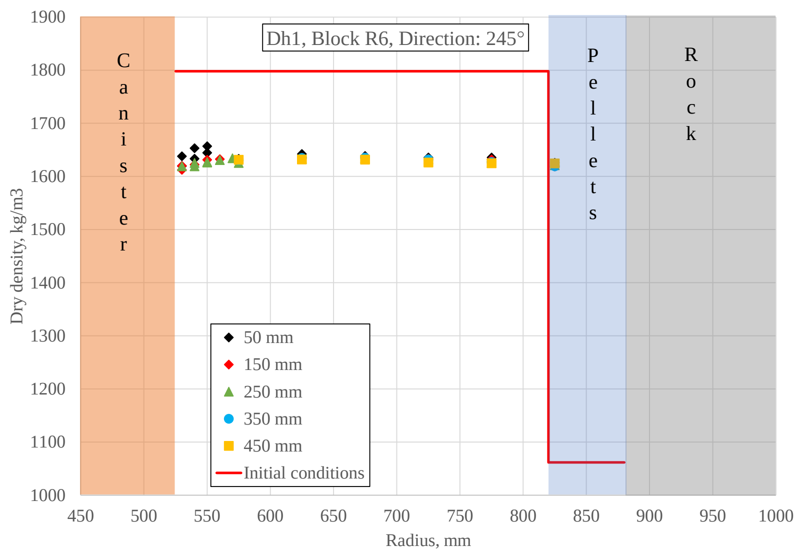


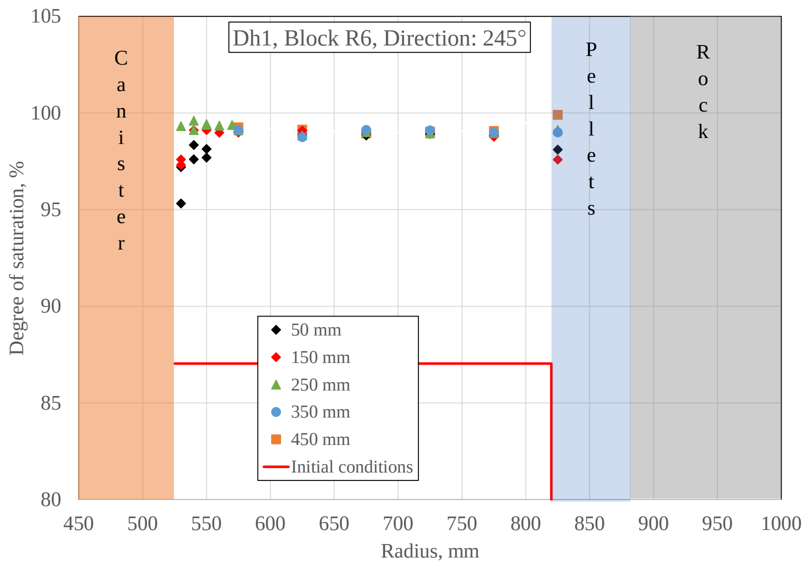


Appendix 4-8c Dh1, Block R6.

Water content, dry density, and degree of saturation at five depths in direction 245°.

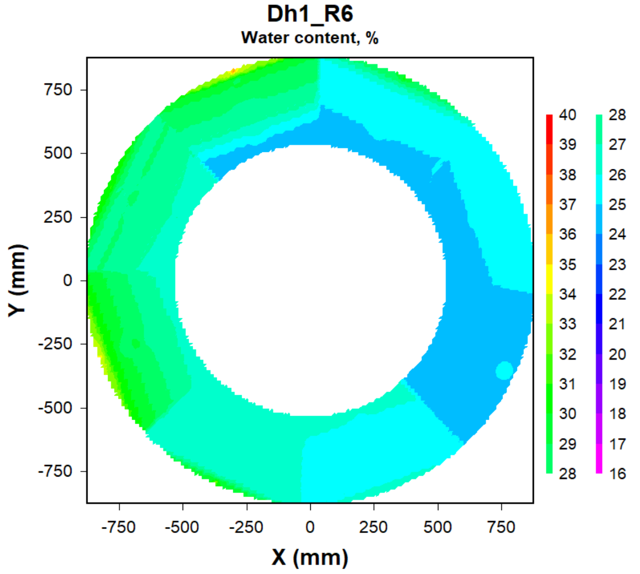


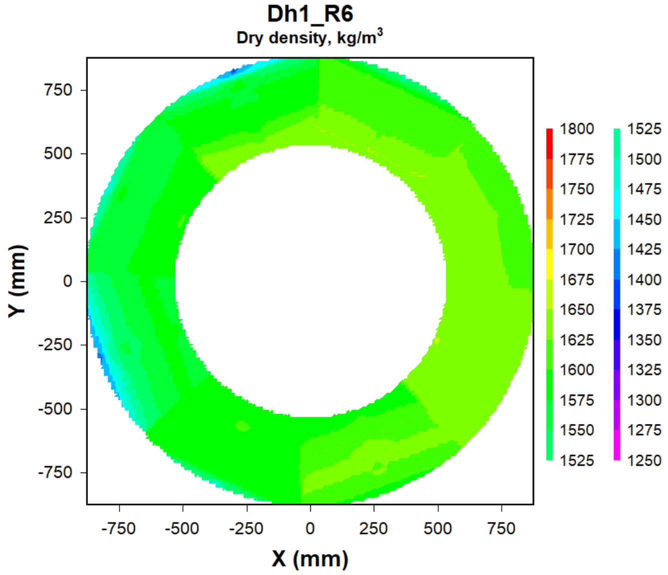


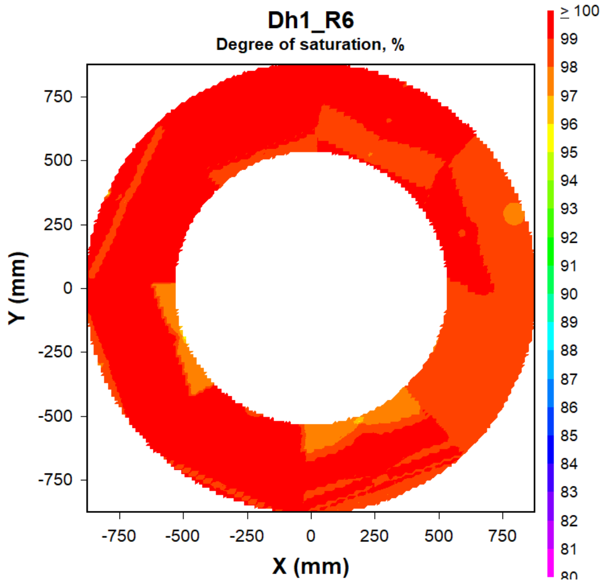


Appendix 4-8d Dh1, Block R6.

Water content, dry density, and degree of saturation distribution.

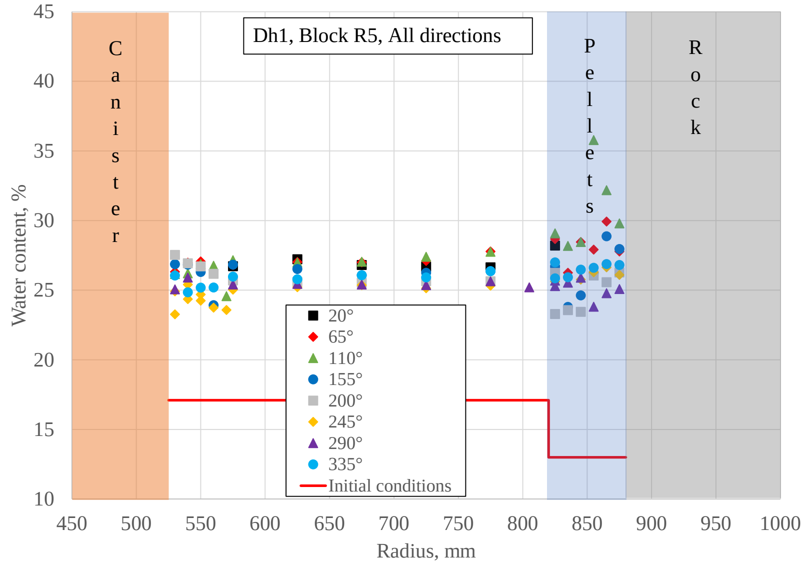


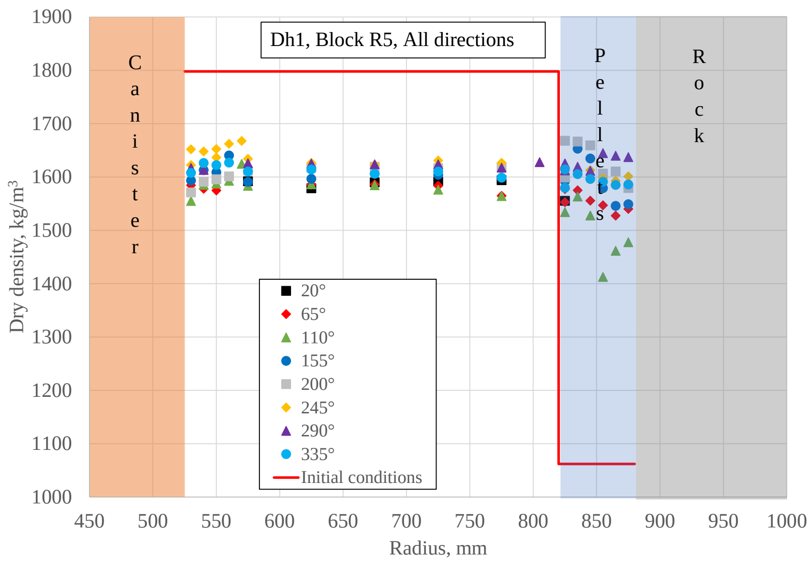


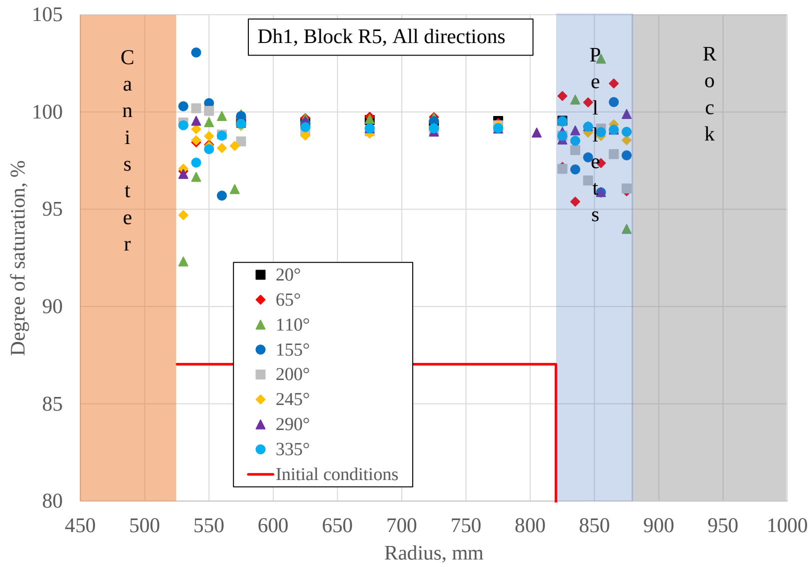


Appendix 4-9a Dh1, Block R5.

Water content, dry density, and degree of saturation in eight directions.

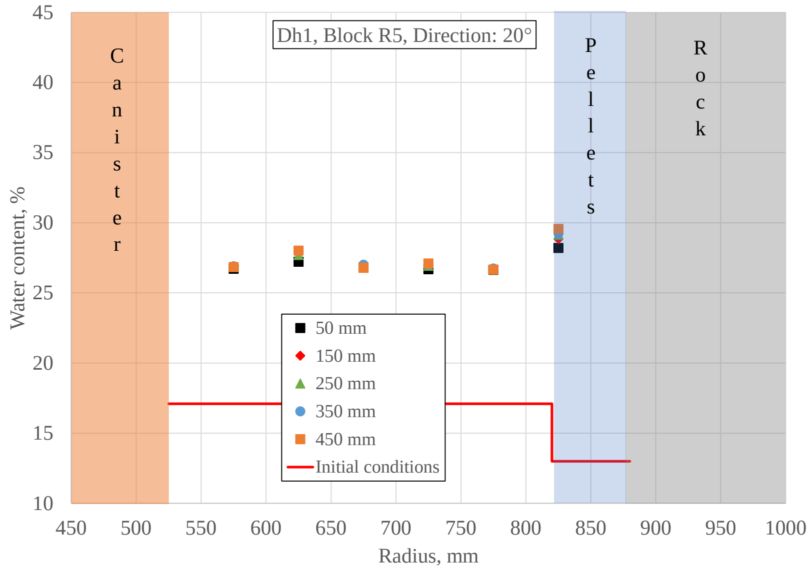


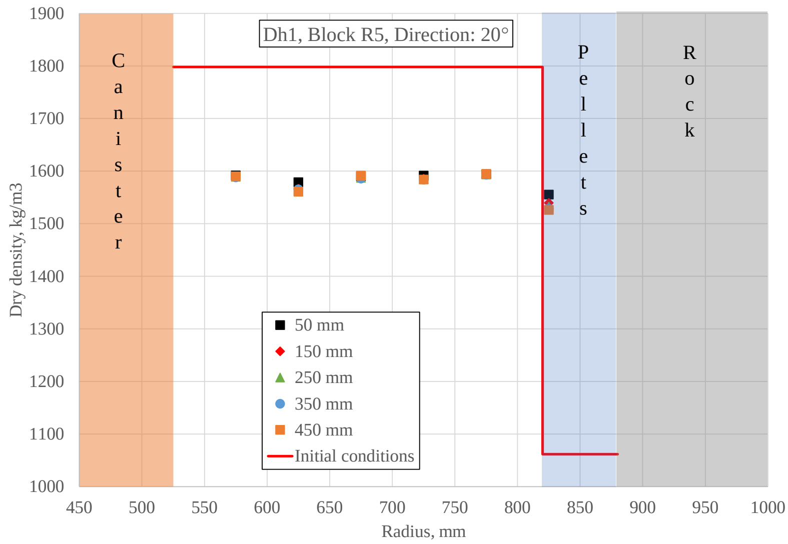


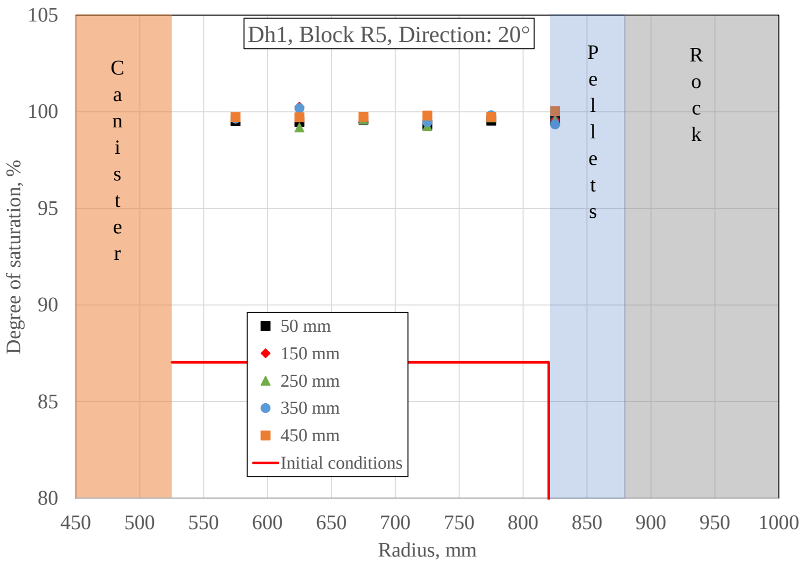


Appendix 4-9b Dh1, Block R5.

Water content, dry density, and degree of saturation at five depths in direction 20°.

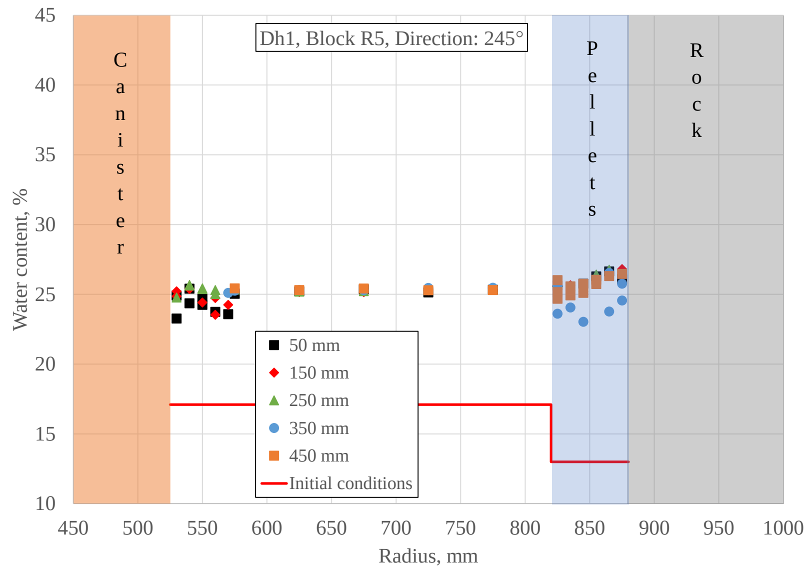


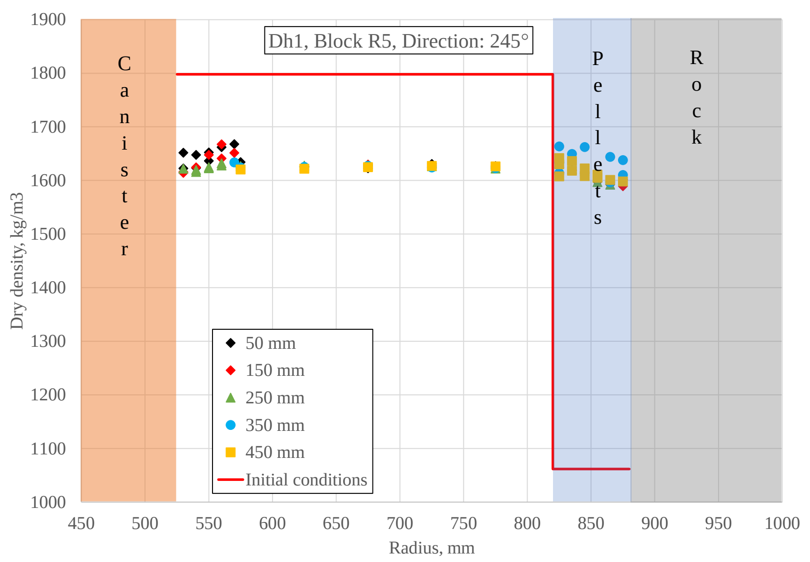


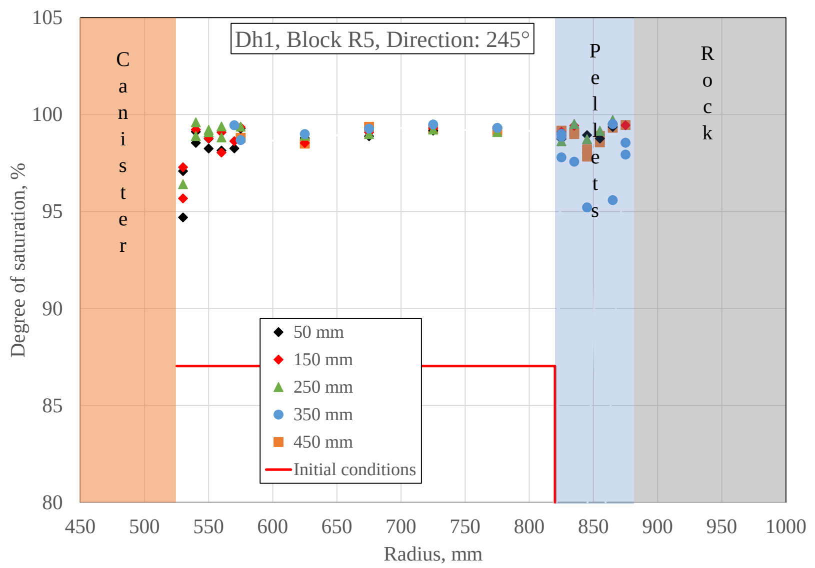


Appendix 4-9c Dh1, Block R5.

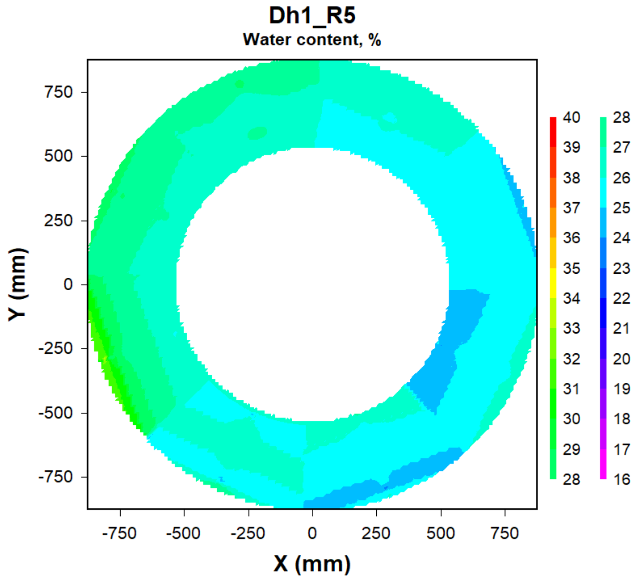
Water content, dry density, and degree of saturation at five depths in direction 245°.

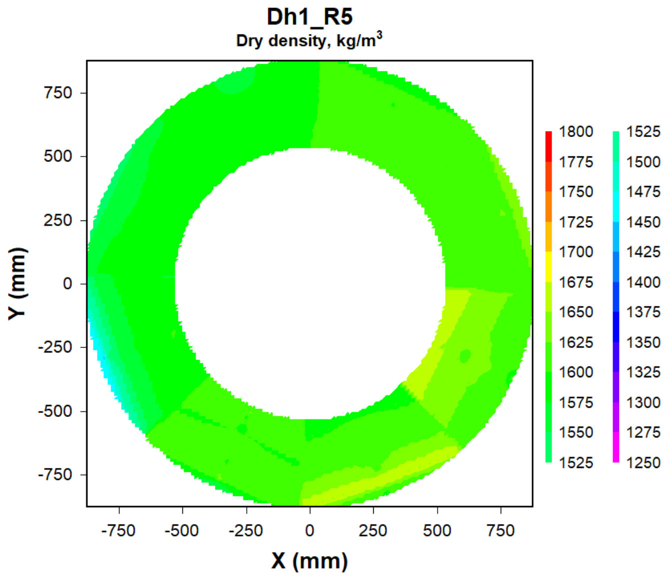


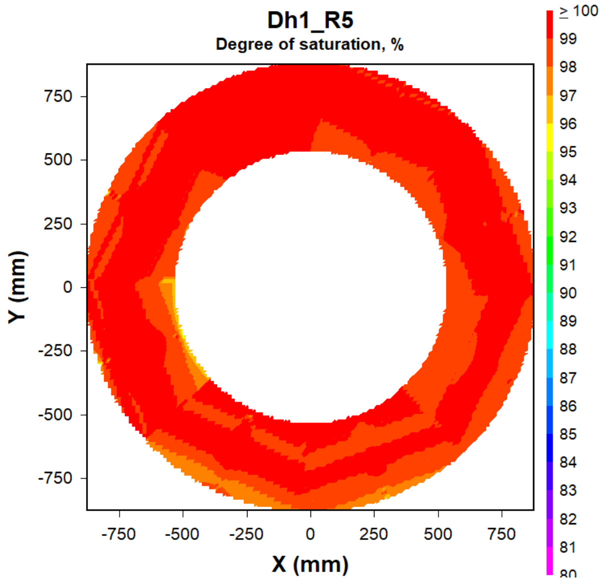




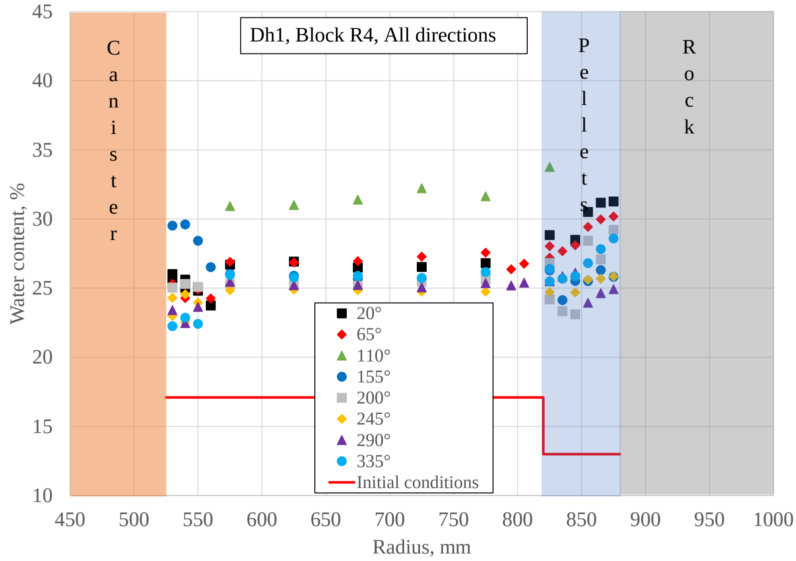
Appendix 4-9d Dh1, Block R5.
Water content, dry density, and degree of saturation distribution.

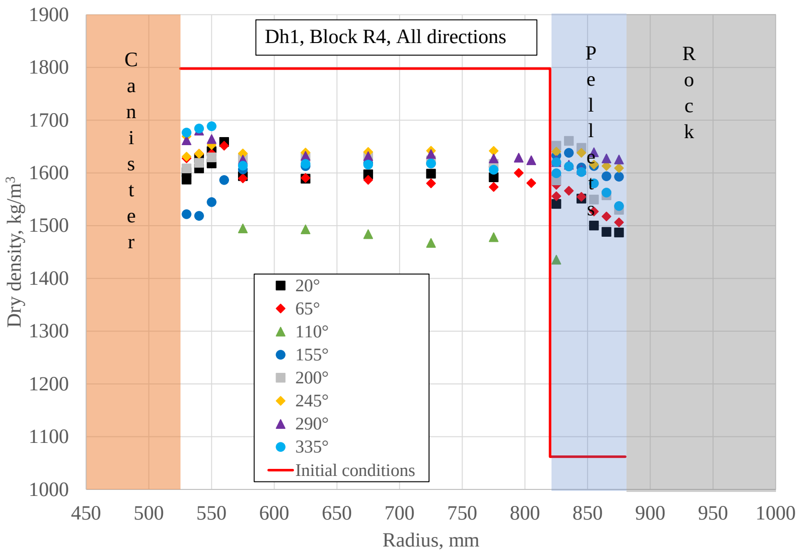


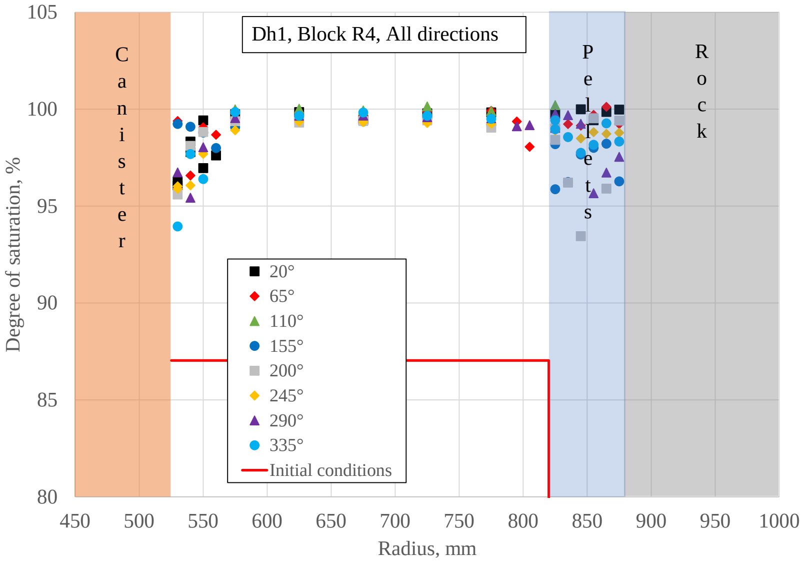




Appendix 4-10a Dh1, Block R4.
Water content, dry density, and degree of saturation in eight directions.

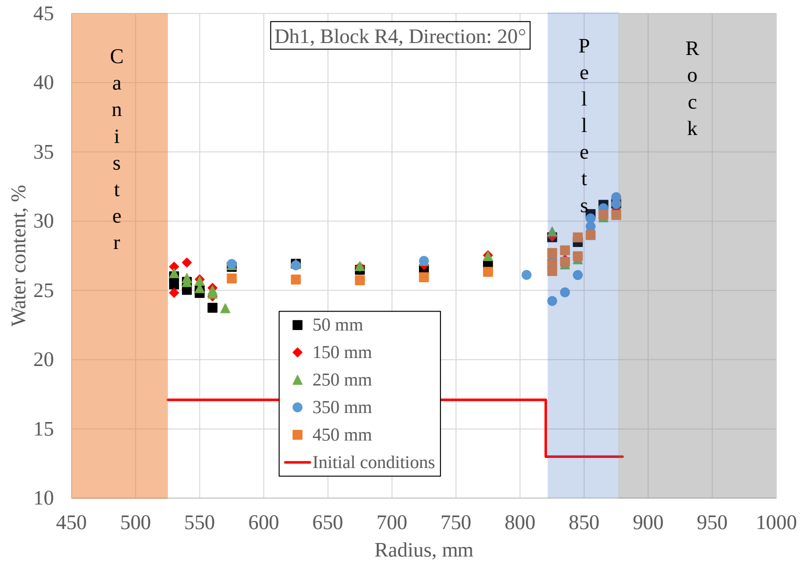


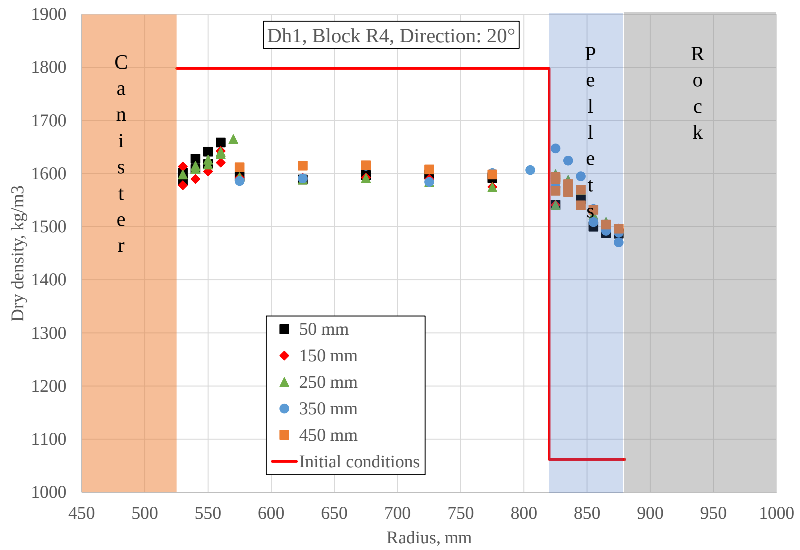


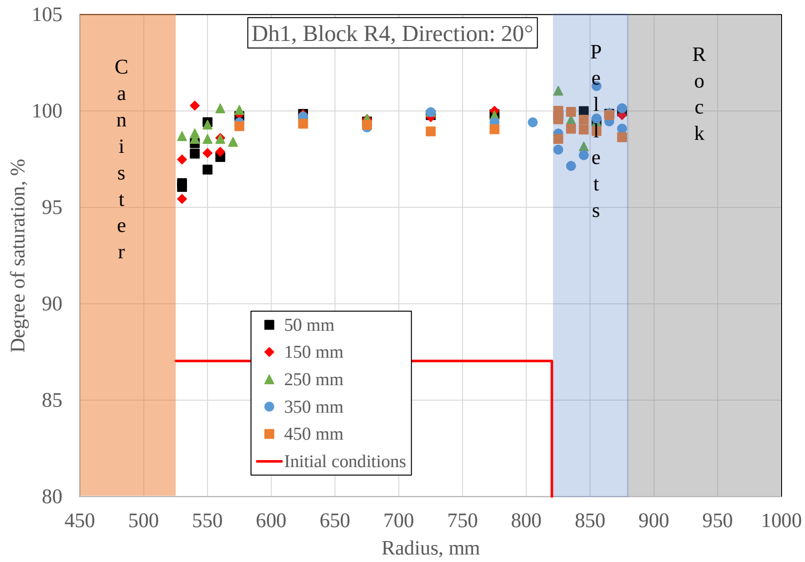


Appendix 4-10b Dh1, Block R4.

Water content, dry density, and degree of saturation at five depths in direction 20°.

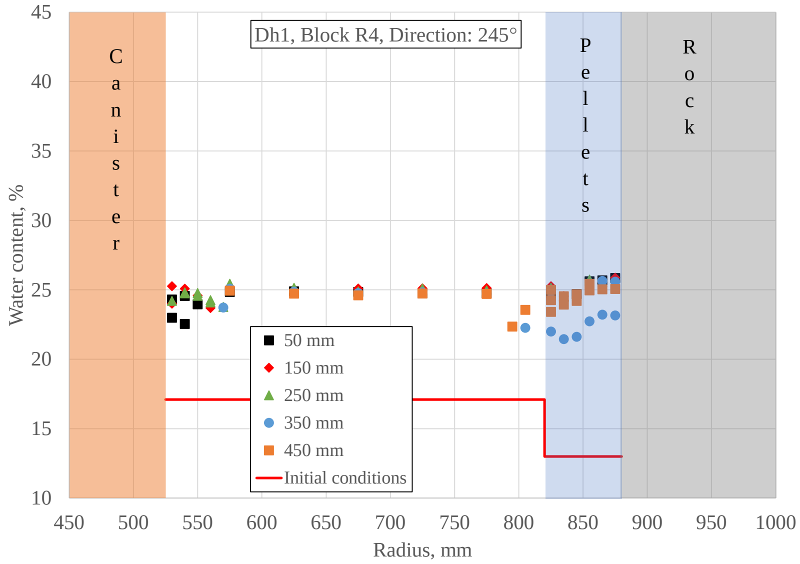


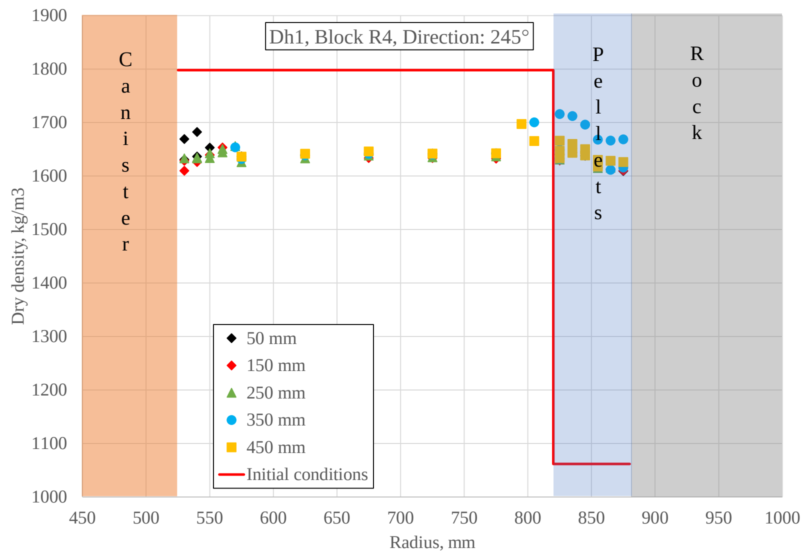


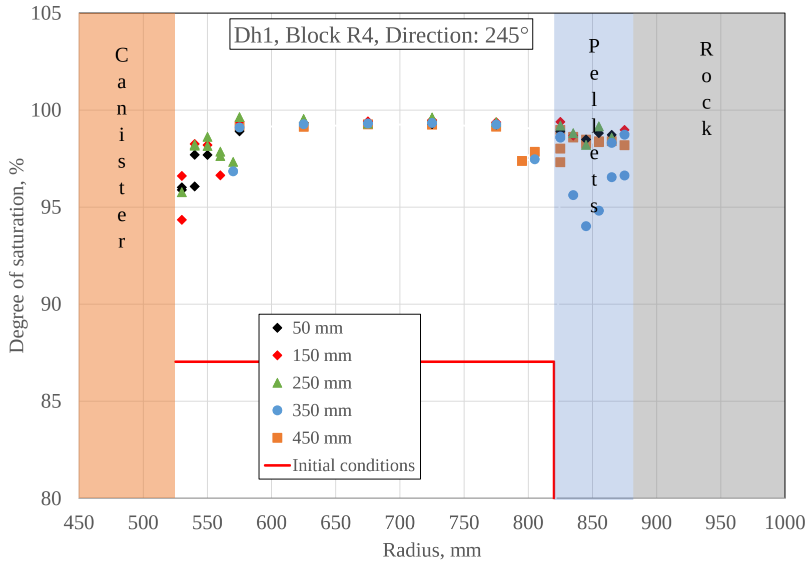


Appendix 4-10c Dh1, Block R4.

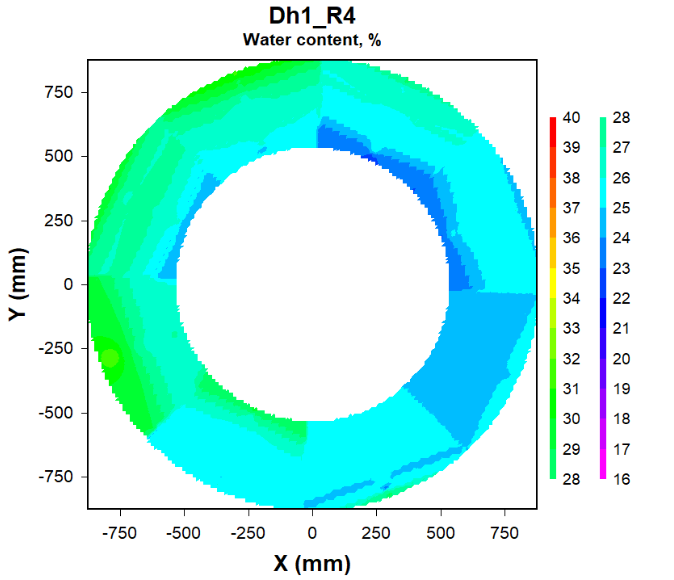
Water content, dry density, and degree of saturation at five depths in direction 245°.

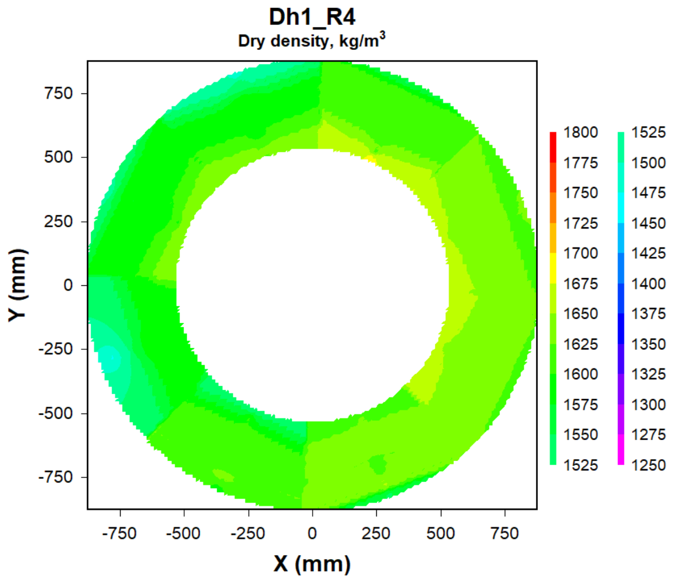


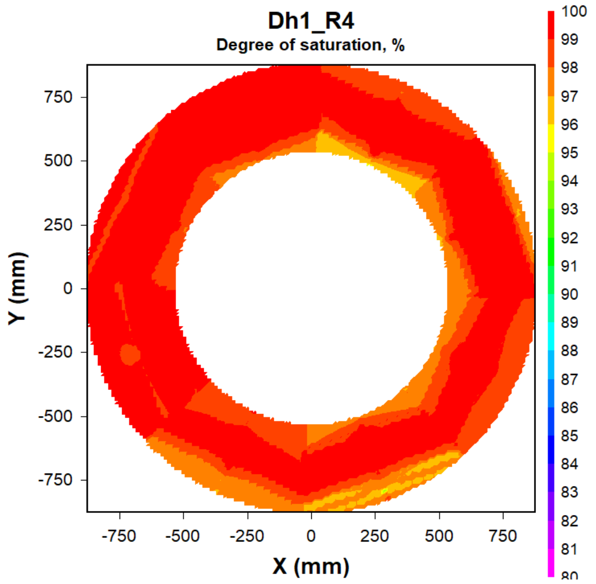




Appendix 4-10d Dh1, Block R4.
Water content, dry density, and degree of saturation distribution.

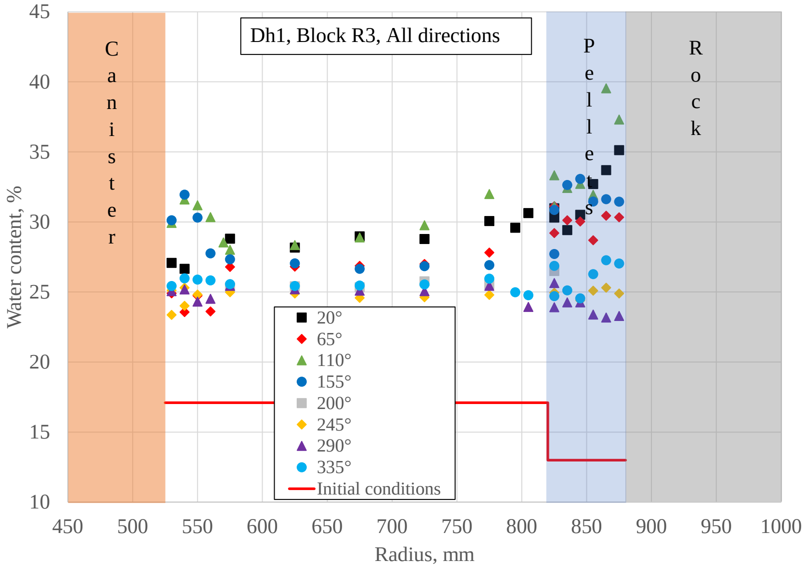


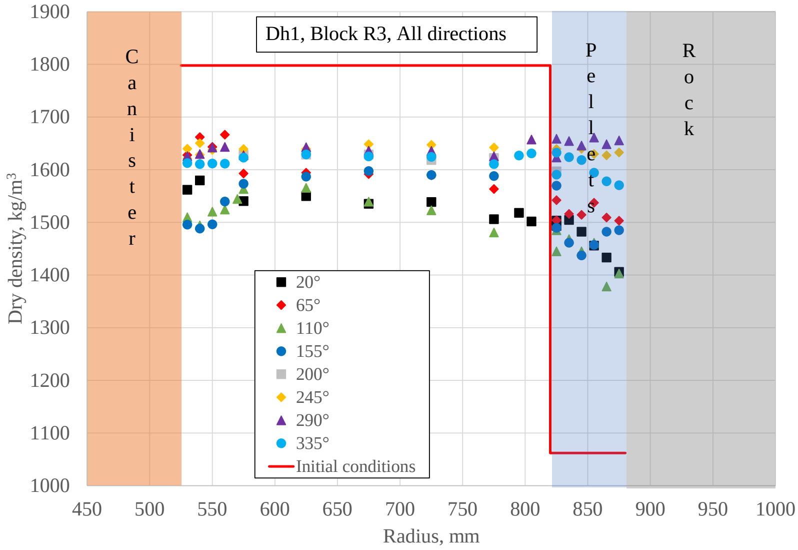


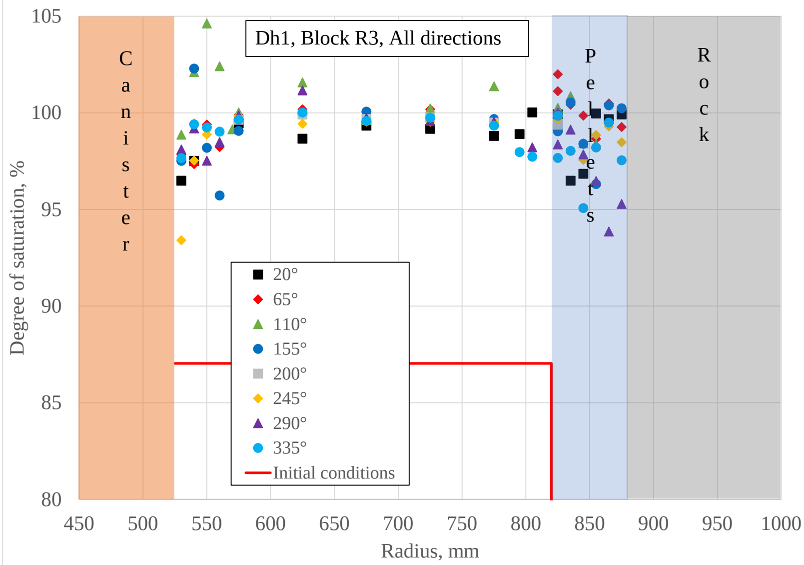


Appendix 4-11a Dh1, Block R3.

Water content, dry density, and degree of saturation in eight directions.

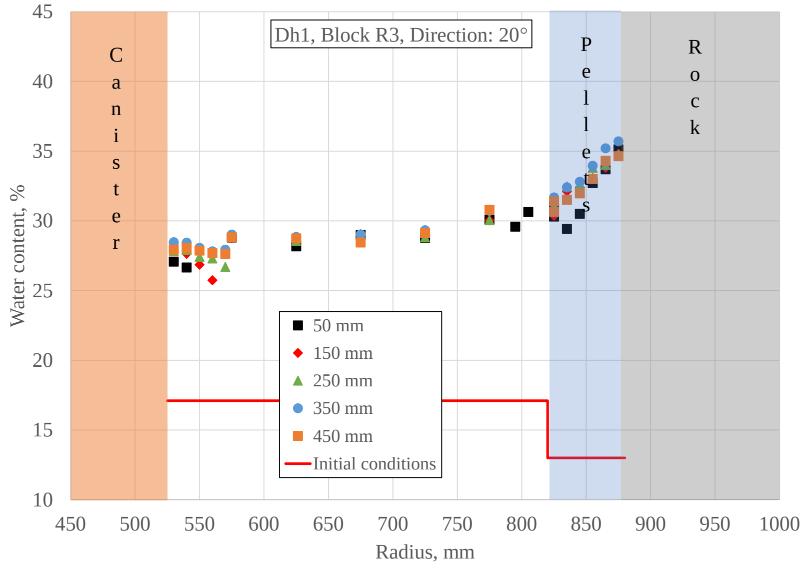


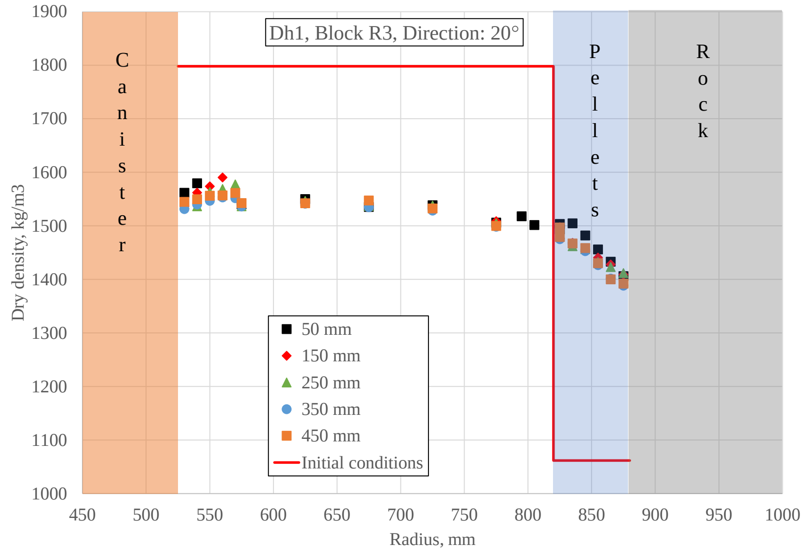


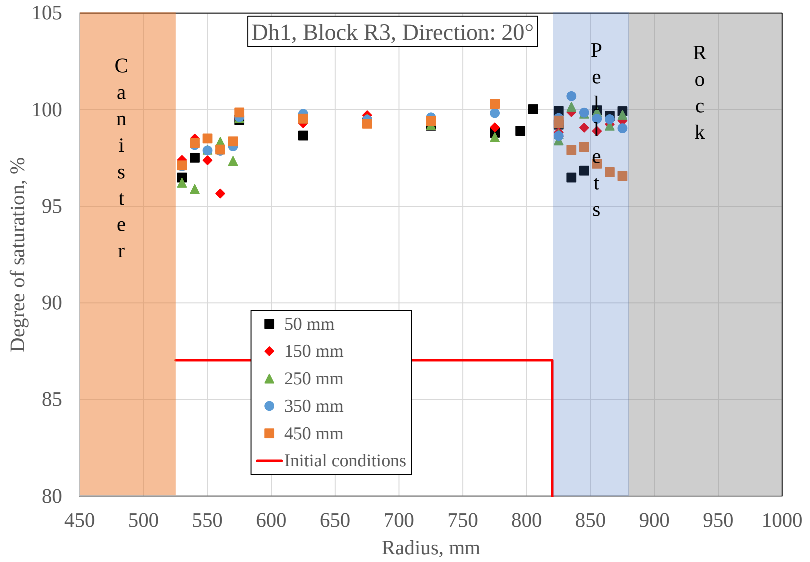


Appendix 4-11b Dh1, Block R3.

Water content, dry density, and degree of saturation at five depths in direction 20°.

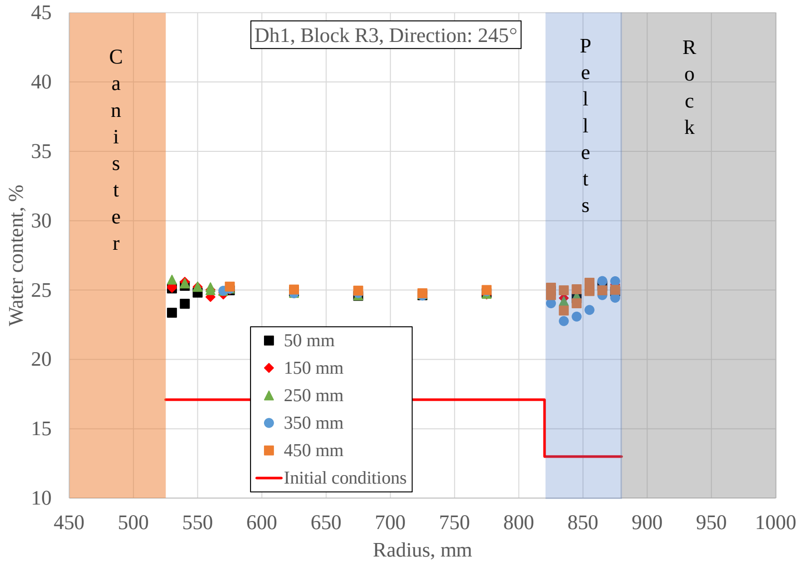


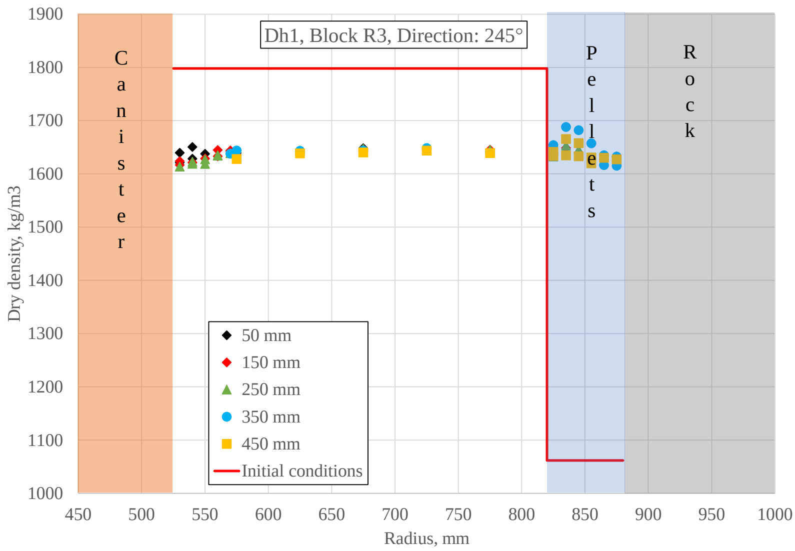


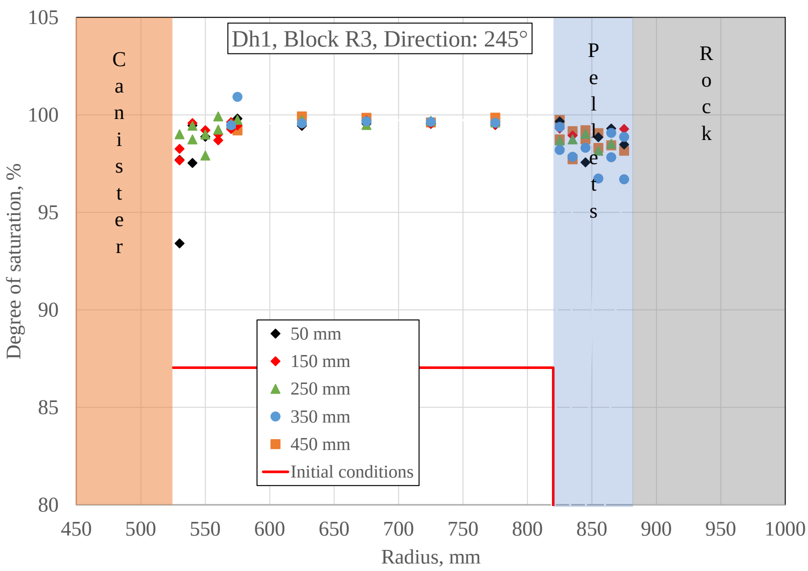


Appendix 4-11c Dh1, Block R3.

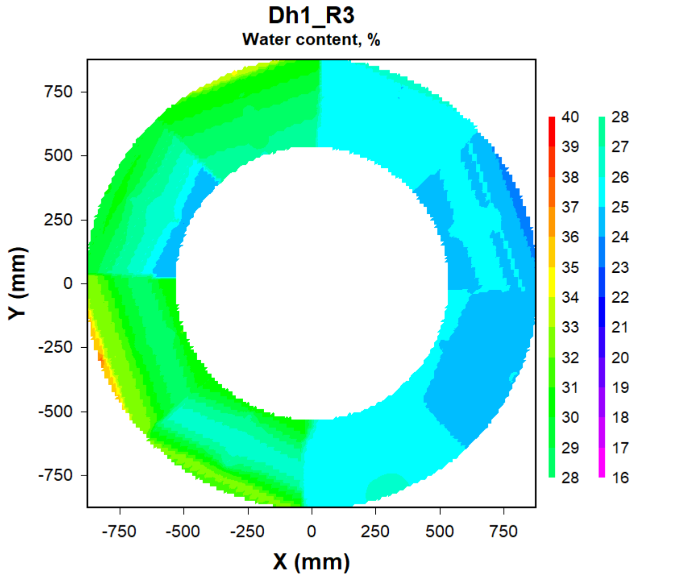
Water content, dry density, and degree of saturation at five depths in direction 245°.

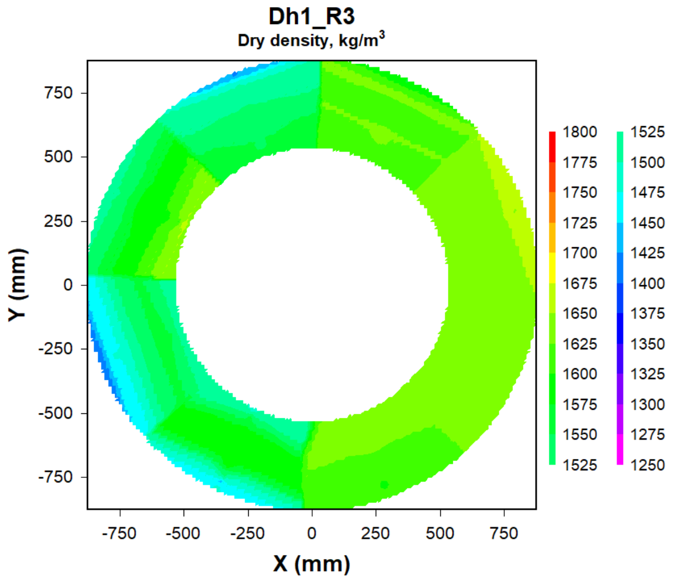


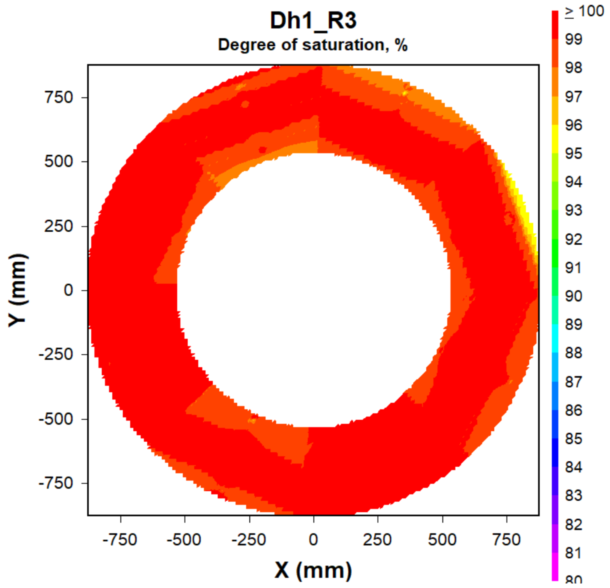




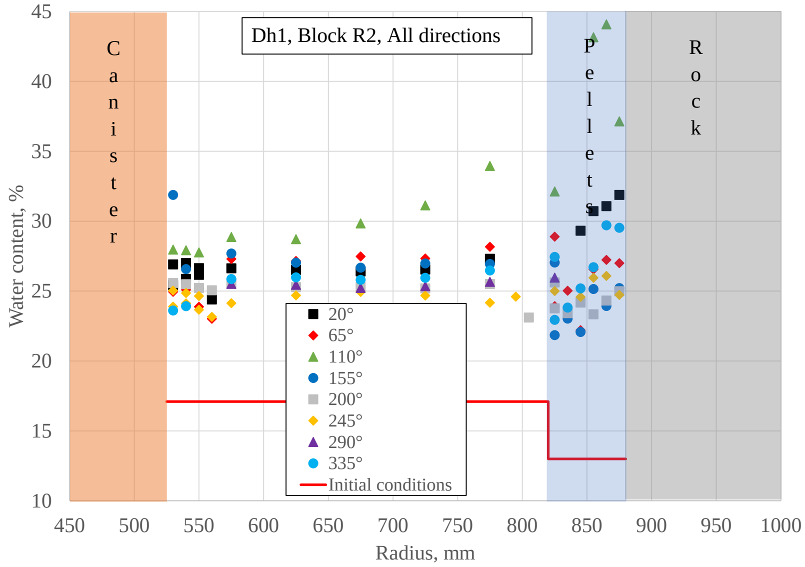
Appendix 4-11d Dh1, Block R3.
Water content, dry density, and degree of saturation distribution.

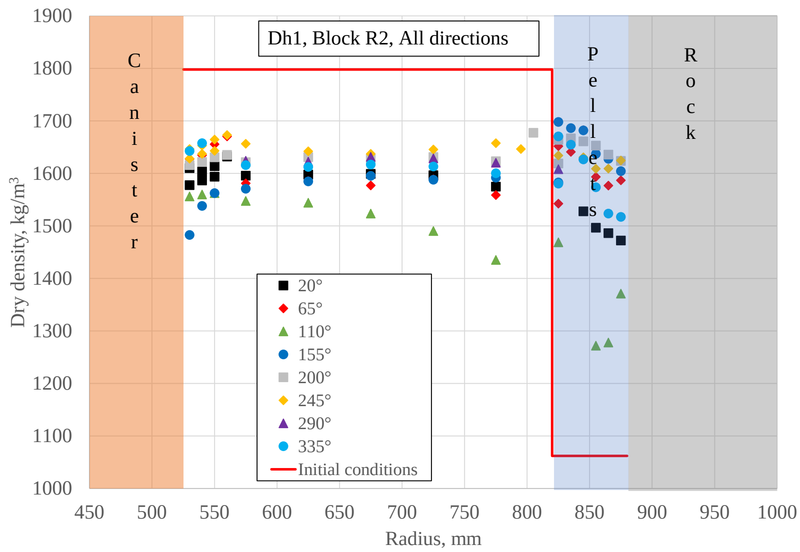


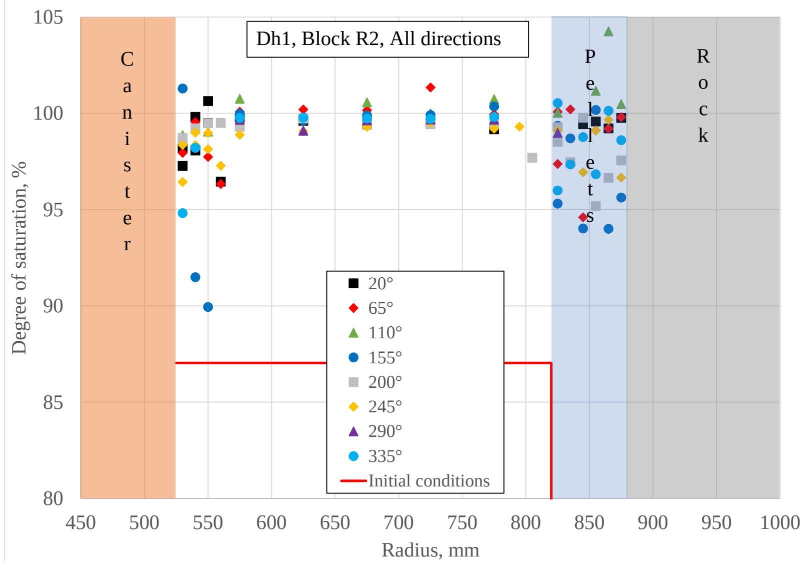




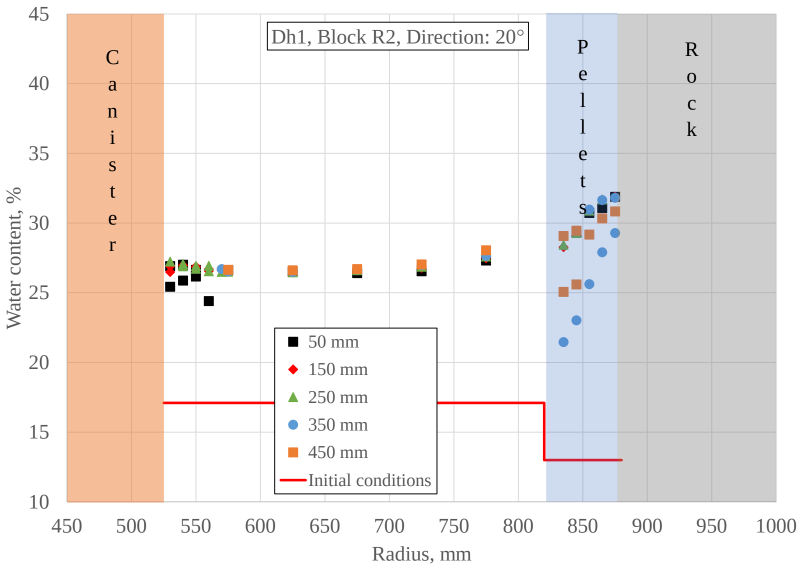
Appendix 4-12a Dh1, Block R2.
Water content, dry density, and degree of saturation in eight directions.

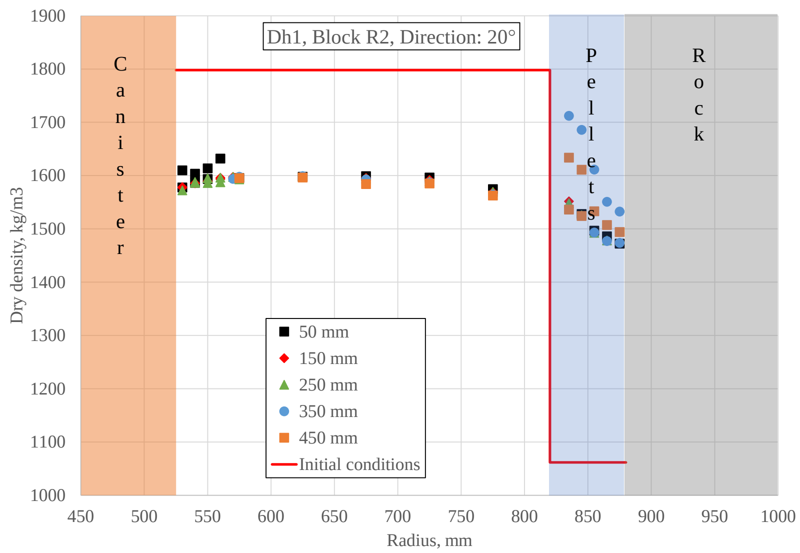


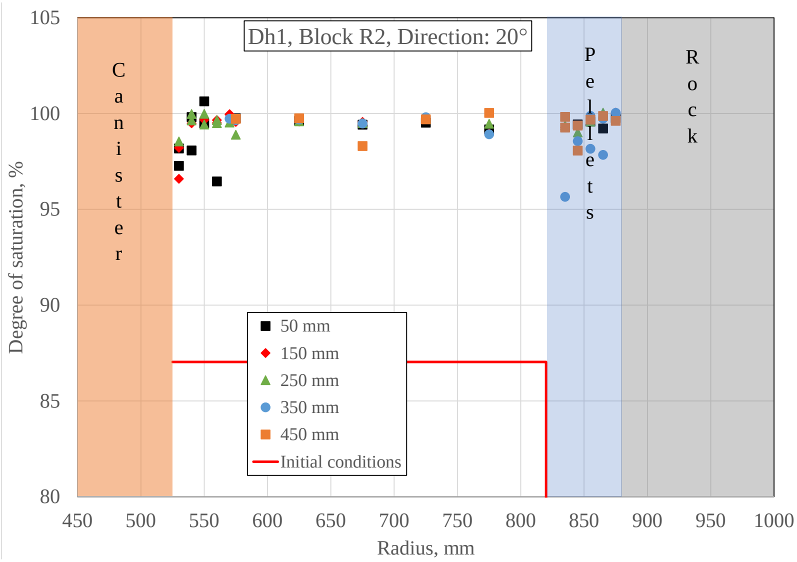




Appendix 4-12b Dh1, Block R2.
Water content, dry density, and degree of saturation at five depths in direction 20°.

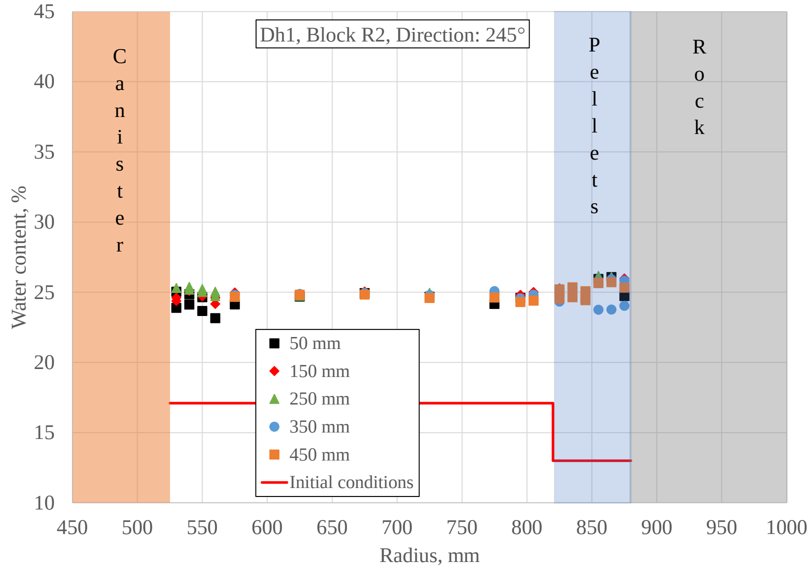


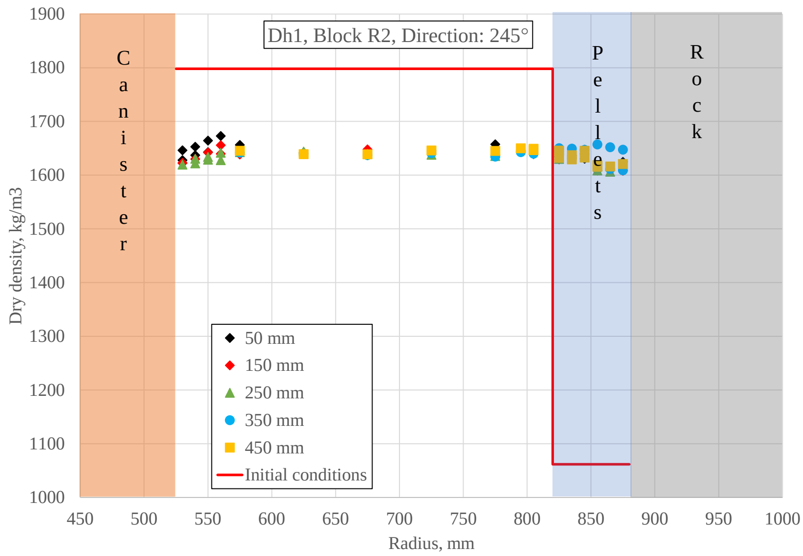


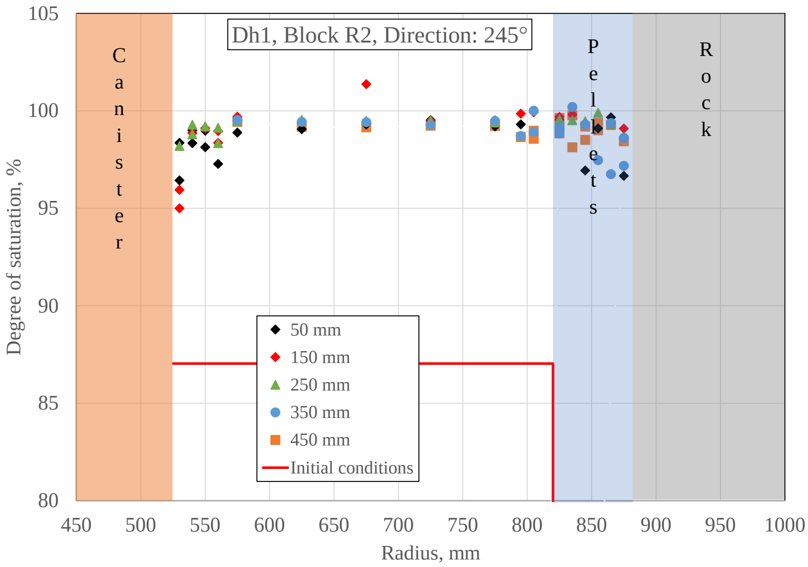


Appendix 4-12c Dh1, Block R2.

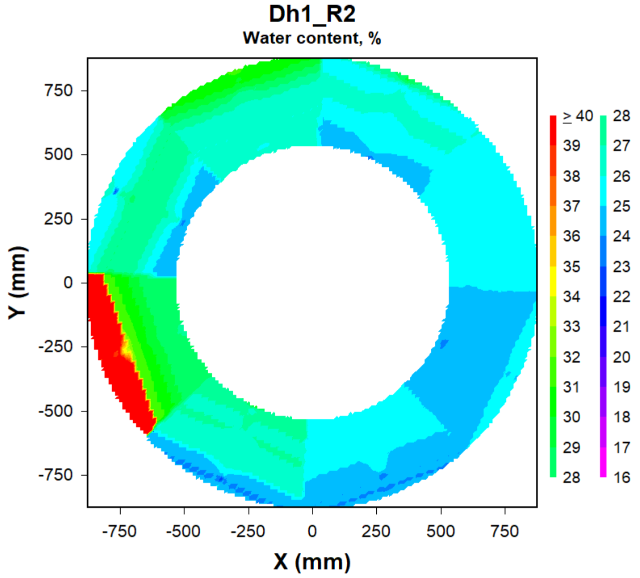
Water content, dry density, and degree of saturation at five depths in direction 245°.

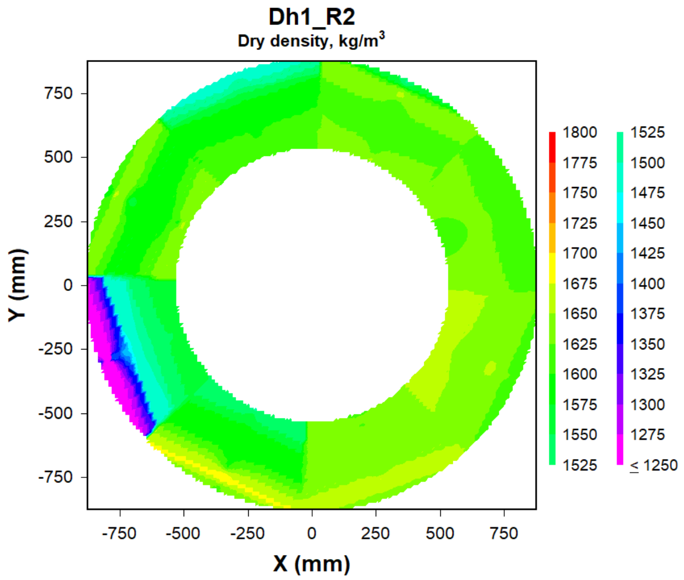


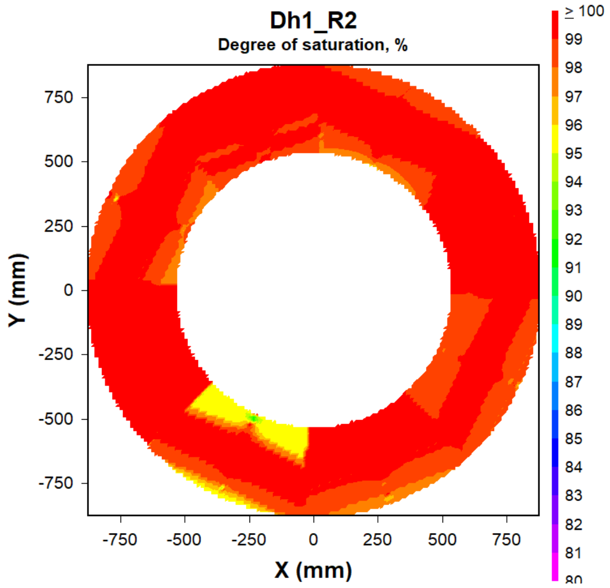




Appendix 4-12d Dh1, Block R2.
Water content, dry density, and degree of saturation distribution.

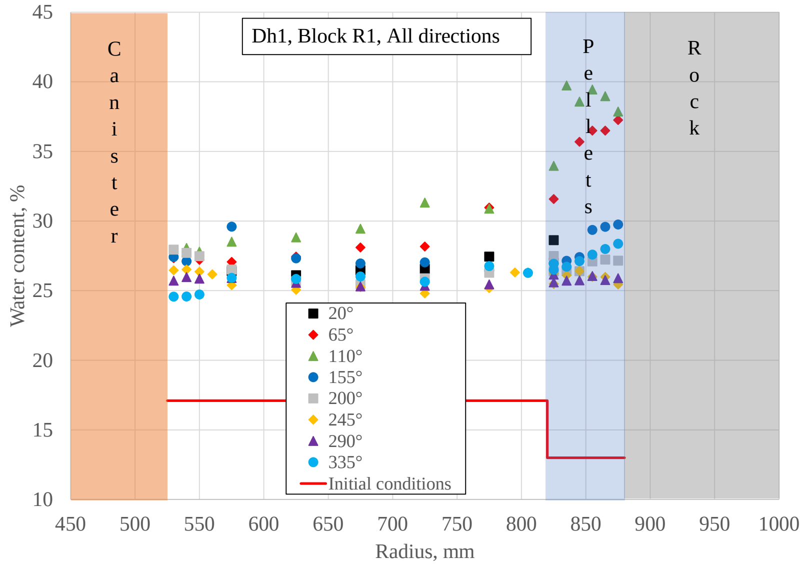


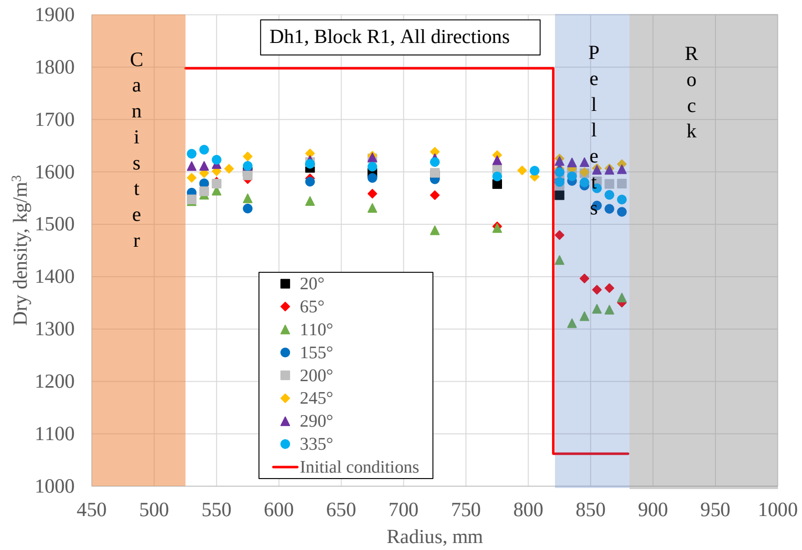


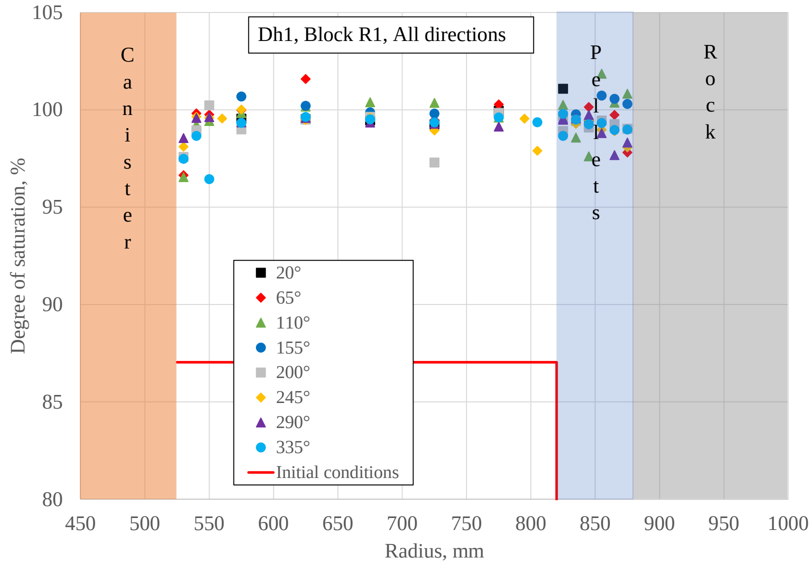


Appendix 4-13a Dh1, Block R1.

Water content, dry density, and degree of saturation in eight directions.

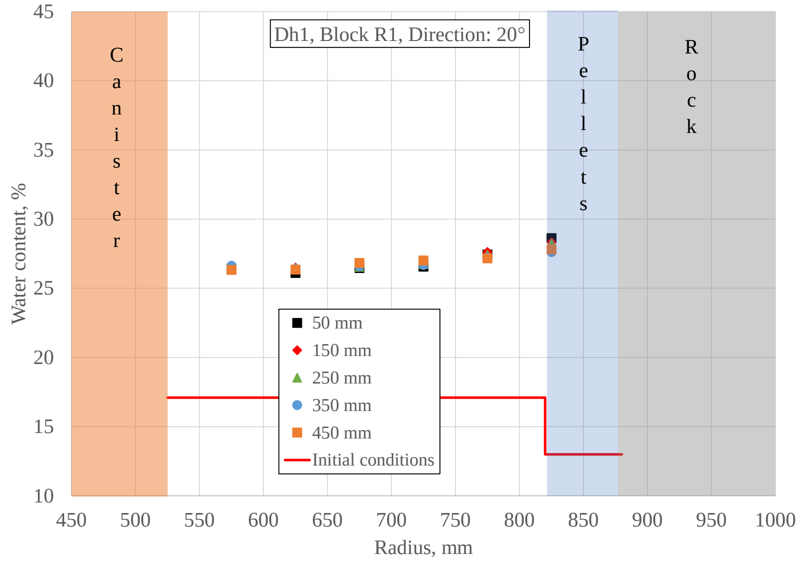


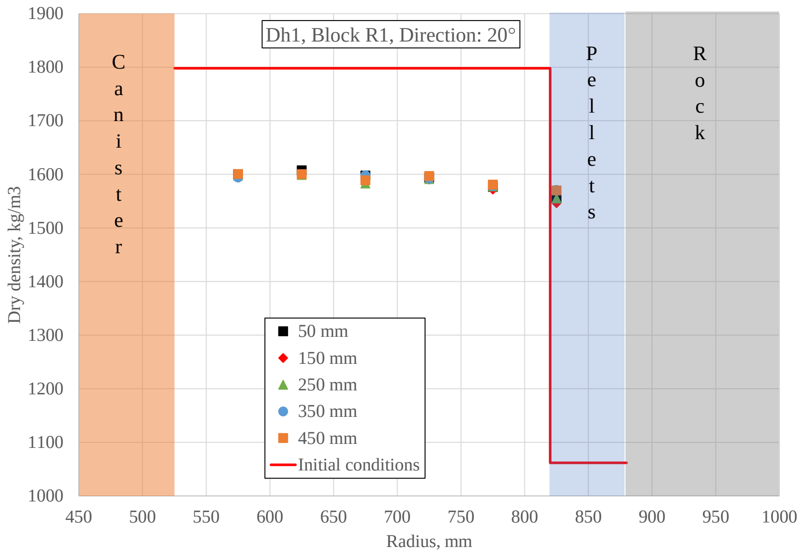


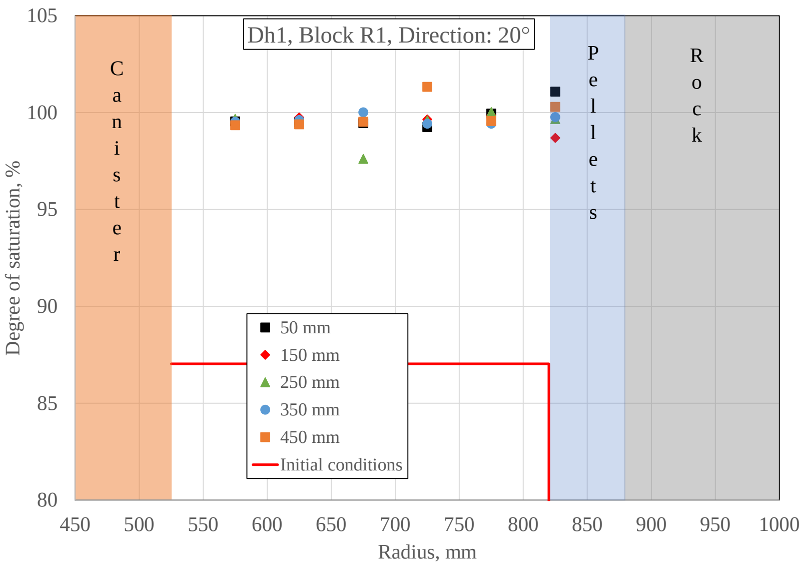


Appendix 4-13b Dh1, Block R1.

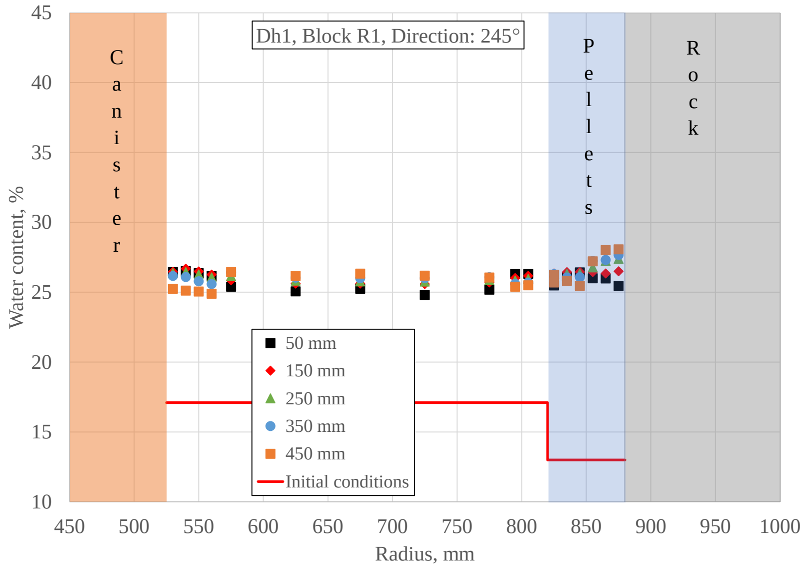
Water content, dry density, and degree of saturation at five depths in direction 20°.

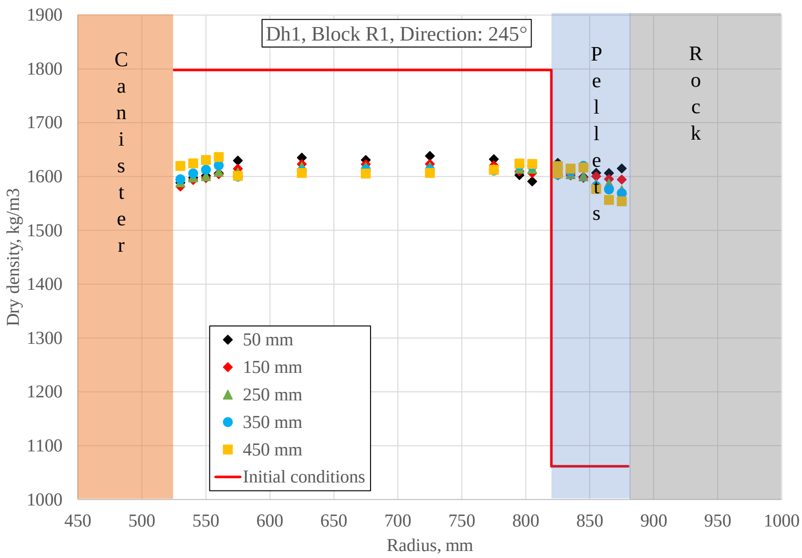


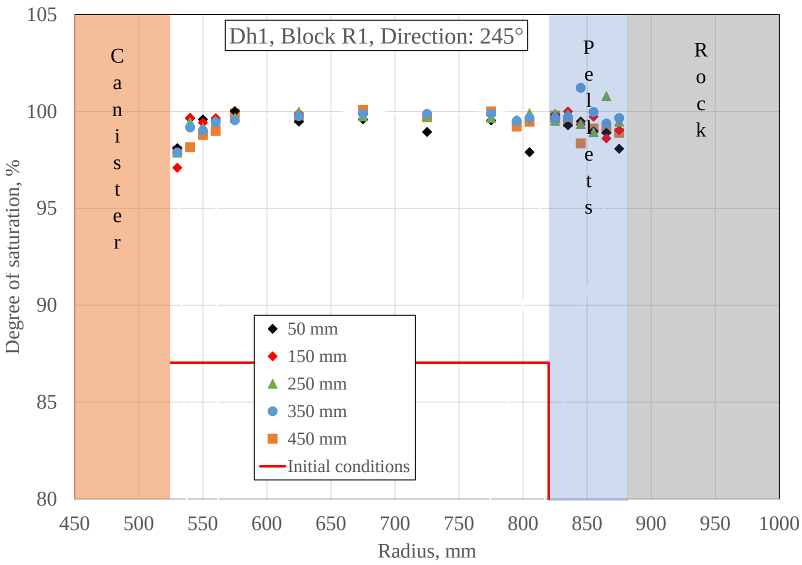




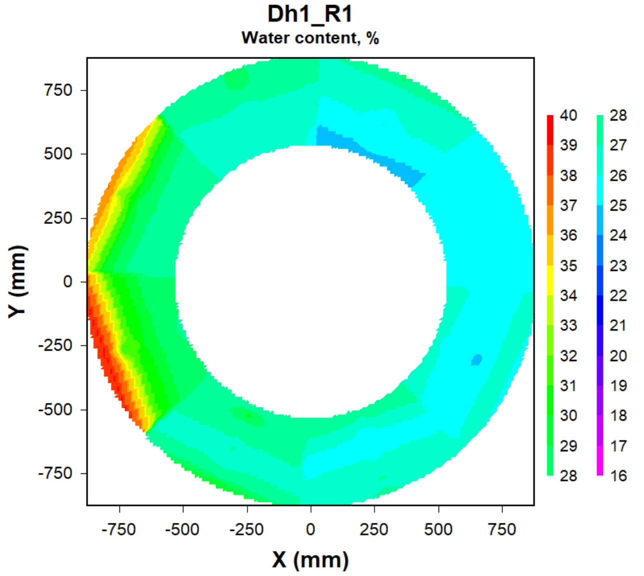
Appendix 4-13c Dh1, Block R1.
Water content, dry density, and degree of saturation at five depths in direction 245°.

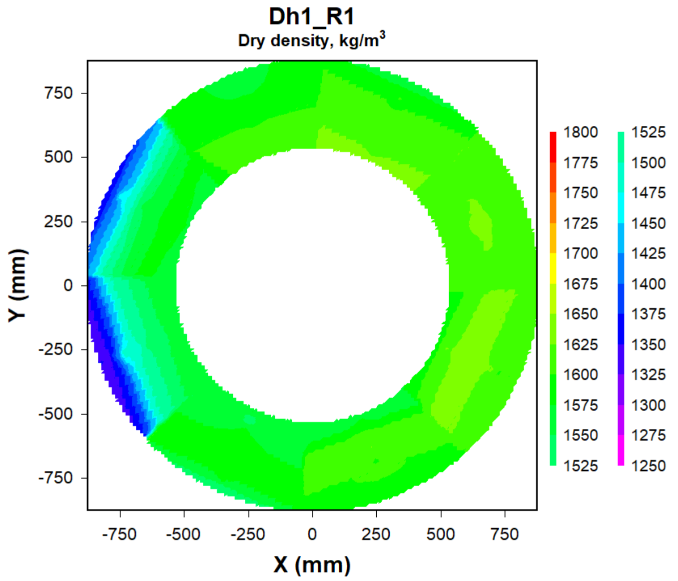


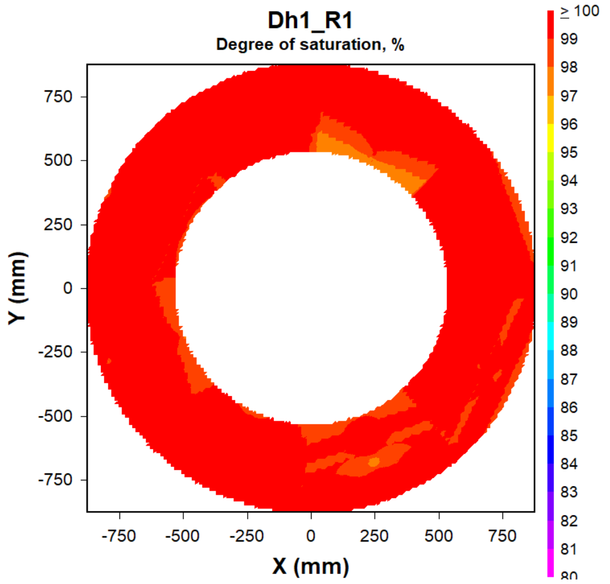




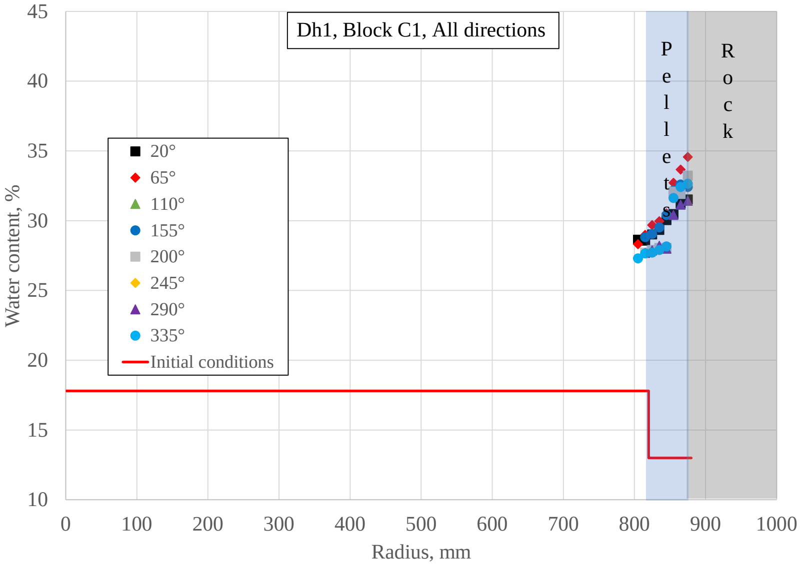
Appendix 4-13d Dh1, Block R1.
Water content, dry density, and degree of saturation distribution.

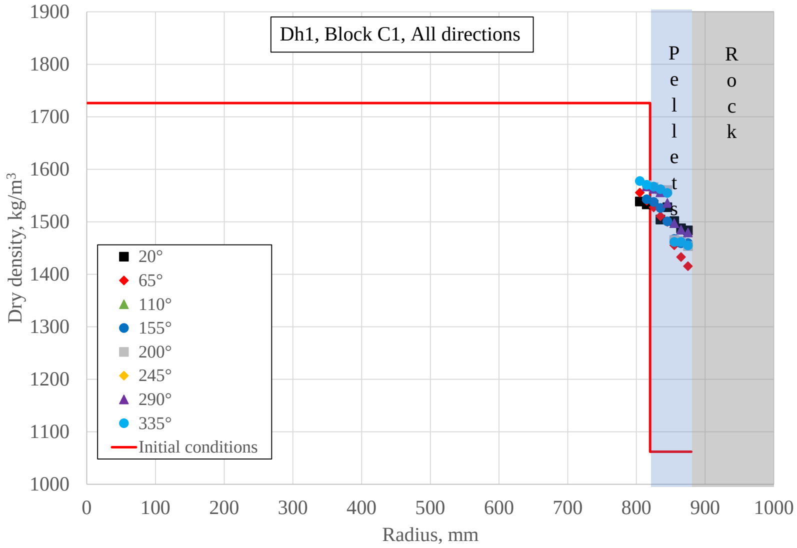


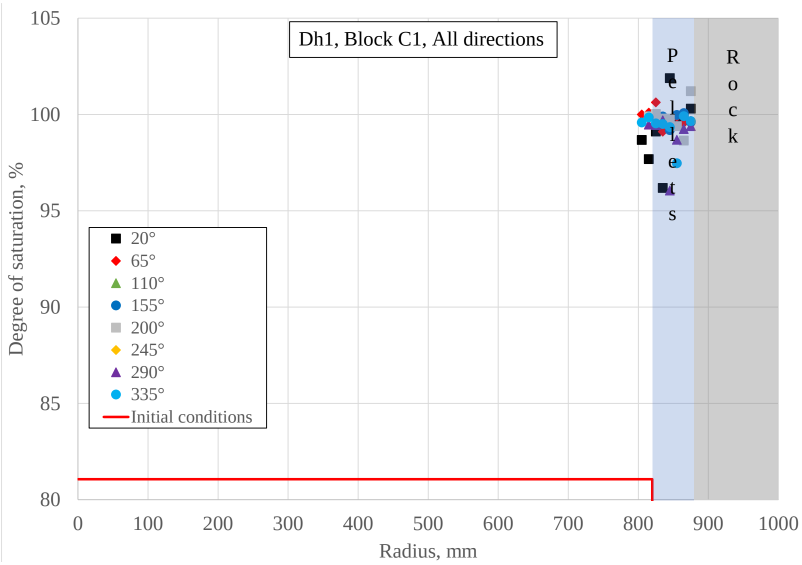




Appendix 4-14a Dh1, Block C1.
Water content, dry density, and degree of saturation in eight directions.

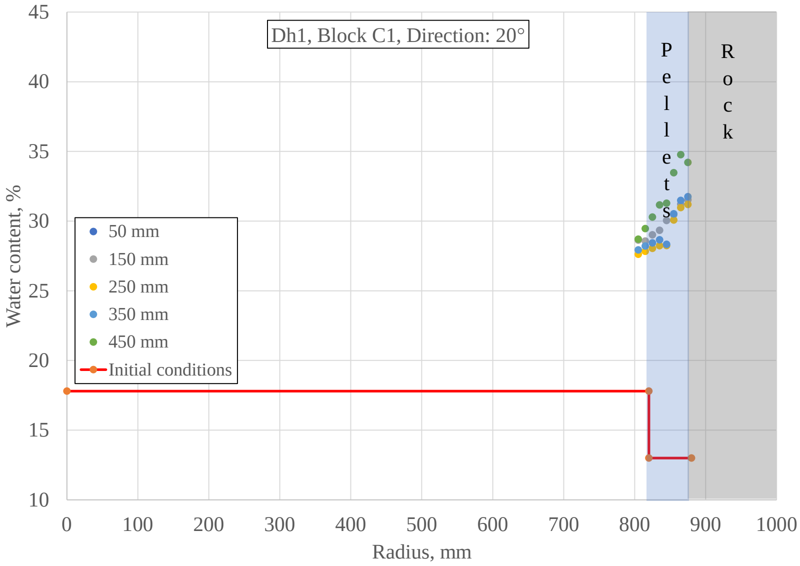


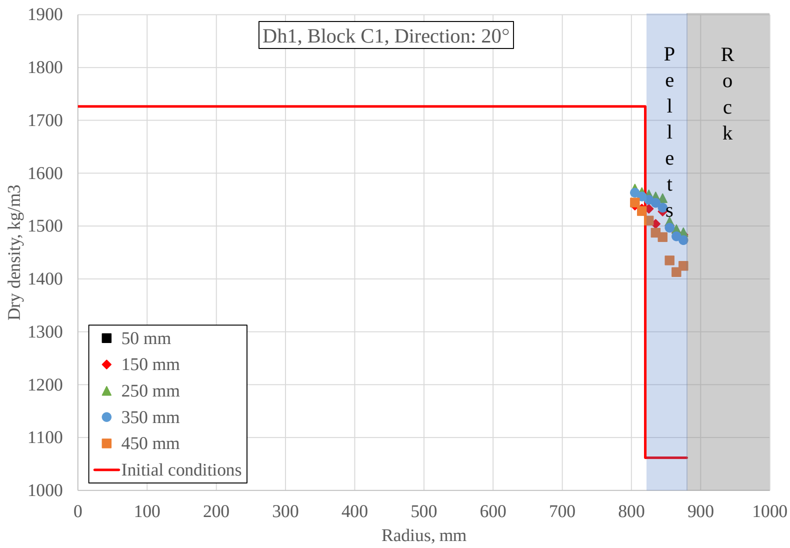


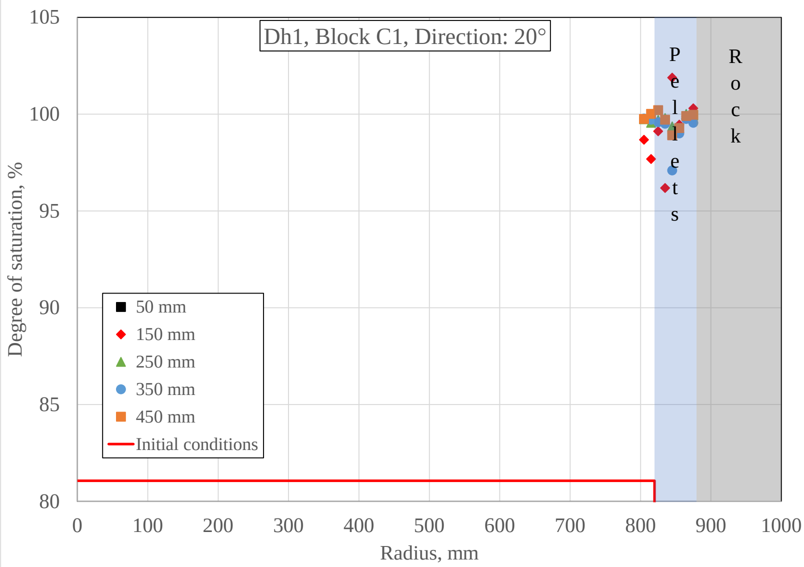


Appendix 4-14b Dh1, Block C1.

Water content, dry density, and degree of saturation at five depths in direction 20°.







Appendix 4-14d Dh1, Block C1.

Water content, dry density, and degree of saturation distribution. Note that the number of samples was limited for this block.