P-04-259

Oskarshamn site investigation

Drill hole KLX02

Determining of porosity by water saturation and density by buoyancy technique

M Savukoski
SP Swedish National Testing and Research Institute

October 2004

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

ISSN 1651-4416
SKB P-04-259

Oskarshamn site investigation

Drill hole KLX02

Determining of porosity by water saturation and density by buoyancy technique

M Savukoski
SP Swedish National Testing and Research Institute

October 2004

Keywords: Rock Mechanics, Petro Physics, Density, Porosity.

Abstract

The density and porosity has been determined on 15 specimens (each divided in two pieces) from drill hole KLX02. The specimens were sampled on three levels in the drill hole: 310, 500, and 740 m. The investigated rock types are mapped as Ävrö granite for level 1, 2 and 3 (310, 500 and 740 m), between 680 and 960 m the granite contains a large amount of dioritoid-gabbro.The results for dry density varied between 2,670 and 2,690 kg/m^3, for wet density the results varied between 2,670 and 2,700 kg/m^3 and the results for porosity varied between 0.3 and 0.6%.

Sammanfattning

Densiteten och porositeten har bestämts på 15 provkroppar (varje provkropp delad i två delar) från borrhål KLX02. Proverna togs från tre nivåer i borrhålet: 310, 500 och 740 m. De undersökta bergartstyperna är karterade som Ävrögranit för nivå 1, 2 och 3 (310, 500 och 740 m), mellan 680 och 960 m finns en stor andel dioritoid gabbro i graniten. Resultaten för den torra densiteten varierade mellan 2 670 och 2 700 kg/m^3, för den våta densiteten varierade resultaten mellan 2 670 och 2 700 kg/m^3 och resultaten för porositeten varierade mellan 0,3 och 0,6 %.

Contents

1 Introduction

The purpose is to determine the porosity and the water saturated and dry density of the samples.

The cores are sampled from borehole KLX02 in the Laxemar area. Thomas Janson, Tyréns AB, and Urban Åkesson, Swedish National Testing and Research Institute (SP) sampled them 2 December 2003. Specimens were taken from 3 levels in the rock core: level 1 between 314 and 315, level 2 between 492 and 502 m, level 3 between 738 and 741 m. The samples were selected based on the preliminary core logging, and with the strategy to primarily investigate the properties of the dominant rock properties. The rock cores were transported from Laxemar and arrived to SP February 2004. The testing was started in August 2004 and ended in September 2004.

Figure 1-1. *Location of the drill hole KLX02 at the Laxemar site.*

2 Objective and scope

The purpose of the testing is to determine the density and porosity of intact rock cores. The parameters are used in the rock mechanics and thermal site descriptive model, which will be established for the candidate area selected for site investigations at Simpevarp.

The samples are taken from the borehole KLX02 in Laxemar, which is an old borehole with a depth of about 1,700 m. The samples in this report are taken at 3 different main levels.

3 Equipment

Following equipment have been used for the analyses:

- Thermometer (inv no 100877) for measurement of water temperature. Calibrated 2004-03-11. Uncertainty of measurement ± 0,4°C.
- Scale (inv no 102291) for weight measurement. Calibrated in March 2004. Uncertainty of measurement ± 0.2 g.
- Heating chamber (inv no 102289) for drying the specimens. Calibrated 2004-08-31. Uncertainty of measurement ± 5°C.
- A covered plastic box filled with water for water saturation of the samples.
- A dessicator for cooling samples in.

Uncertainty of method as expanded uncertainty with covering factor 2 (95% confidence interval):

Density	± 4 kg/m^3
Porosity	± 0.09%
Waterabsorption	± 0.05%

4 Execution

Determination of the porosity and density was made in accordance with SKB's method description SKB MD 160.002e-version 2.0 (SKB internal controlling document). This includes determination of density in accordance to /ISRM, 1979/, volume 16, number 2, water saturation by /EN 13755/ and in accordance to Activity plan AP PS 400-03-092 (internal controlling document of SKB). The Department of Building Technology and Mechanics (BM) at SP performed the test.

4.1 Description of the samples

From the Laxemar area, in Sweden, specimens were sampled from 3 levels in drill hole KLX02. Level 1 range between 314 and 315, level 2 between 492 and 503 m and level 3 between 738 and 741 m. Table 4-1 show the rock type and identification marks of the specimens.

Table 4-1. Rock type and identification marks (Rock-type classification according to Boremap).

Identification	Sampling depth (Seclow)	Rock type
KLX02-90V-1	314.39	Ävrö granite
KLX02-90V-2	314.45	Ävrö granite
KLX02-90V-3	314.51	Ävrö granite
KLX02-90V-4	314.57	Ävrö granite
KLX02-90V-5	314.63	Ävrö granite
KLX02-90V-7	492.36	Ävrö granite
KLX02-90V-8	492.42	Ävrö granite
KLX02-90V-9	502.01	Ävrö granite
KLX02-90V-10	502.07	Ävrö granite
KLX02-90V-11	502.13	Ävrö granite
KLX02-90V-13	738.28	Ävrö granite
KLX02-90V-14	738.34	Ävrö granite
KLX02-90V-15	740.08	Ävrö granite
KLX02-90V-16	740.14	Ävrö granite
KLX02-90V-17	740.20	Ävrö granite

4.2 Testing

The execution procedure followed the prescription in SKB MD 160.002e-version 2.0 (SKB internal controlling document), see Table 4-2.

Table 4-2. Execution procedure with activities.

Activity no	Activity
1	The specimens were cut according to the marks on the rock cores. Every specimen was cut in two pieces, marked A and B and about 25 mm thick each. The same specimens were used to test Thermal properties: heat conductivity and heat capacity determing using the TPS method.
2	The specimens were water saturated in normal air pressure for at least seven days.
3	The specimens were weighted in tapwater (See Appendix 3).
4	The specimens were photographed in JPEG-format.
5	The specimens were surface dried with a towel and weighted.
6	The water saturated density was determined (See Appendix 3).
7	The samples were sent from SP Building and Mechanics to SP Fire Technology for measurement of thermal properties.
8	The samples were sent back from SP Fire Technology to SP Building and Mechanics.
9	The specimens were dried in a heating chamber at 105°C.
10	The specimens were transported to a dessicator for cooling.
11	The dry density and porosity was determined (See Appendix 3).

5 Results

The main results of the site investigation of KLX02 could be found in the database SICADA FN236. The data from SICADA should be used for modelling.

Protocols, calculations and pictures can be found in Appendix 1–2.

5.1 Description and presentation of the specimen

The temperature of water for water saturation was 22°C and the density of the water was 998 kg/m^3. The specimens were dried in 105°C for one week after water saturation. Table 5-1 show the identification marks, porosity, dry and wet density.

Table 5-1. Summary of the results for porosity, dry density and wet density of the specimens from level 1, seclow 314 to 315 m. The result for each specimen is a mean value of subsample A and B.

Specimen	Sampling depth, according to the marks on the drill-core boxes (Seclow) (m)	Porosity (%)	Dry density (kg/m^3)	Wet density (kg/m^3)
KLX02-90V-1	314.39	0.4	2,690	2,700
KLX02-90V-2	314.45	0.4	2,680	2,680
KLX02-90V-3	314.51	0.3	2,680	2,680
KLX02-90V-4	314.57	0.3	2,680	2,690
KLX02-90V-5	314.63	0.3	2,680	2,690
Mean value		0.4	2,680	2,690
Standard deviation		0.1	10	10

Table 5-2. Summary of the results for porosity, dry density and wet density of the specimens from level 2, seclow 492 to 503 m. The result for each specimen is a mean value of subsample A and B.

Specimen	Sampling depth, according to the marks on the drill-core boxes (Seclow) (m)	Porosity (%)	Dry density (kg/m^3)	Wet density (kg/m^3)
KLX02-90V-7	492.36	0.3	2,690	2,690
KLX02-90V-8	492.42	0.4	2,690	2,690
KLX02-90V-9	502.01	0.5	2,690	2,690
KLX02-90V-10	502.07	0.5	2,680	2,680
KLX02-90V-11	502.13	0.5	2,670	2,670
Mean value		0.4	2,680	2,690
Standard deviation		0.1	9	8

Table 5-3. Summary of the results for porosity, dry density and wet density of the specimens from level 3 seclow 738 m to 741 m. The result for each specimen is a mean value of subsample A and B.

Specimen	Sampling depth, according to the marks on the drill-core boxes (Seclow) (m)	Porosity (%)	Dry density (kg/m³)	Wet density (kg/m³)
KLX02-90V-13	738.28	0.6	2,670	2,670
KLX02-90V-14	738.34	0.6	2,670	2,670
KLX02-90V-15	740.08	0.5	2,680	2,680
KLX02-90V-16	740.14	0.5	2,670	2,680
KLX02-90V-17	740.20	0.5	2,680	2,680
Mean value		0.5	2,670	2,680
Standard deviation		0.1	7	7

5.2 Results for the entire test series

Results for the entire test series are shown in the diagrams below. They are divided into 3 diagrams, i.e. dry density, wet density and porosity, see Figures 5-1, 5-2, 5-3.

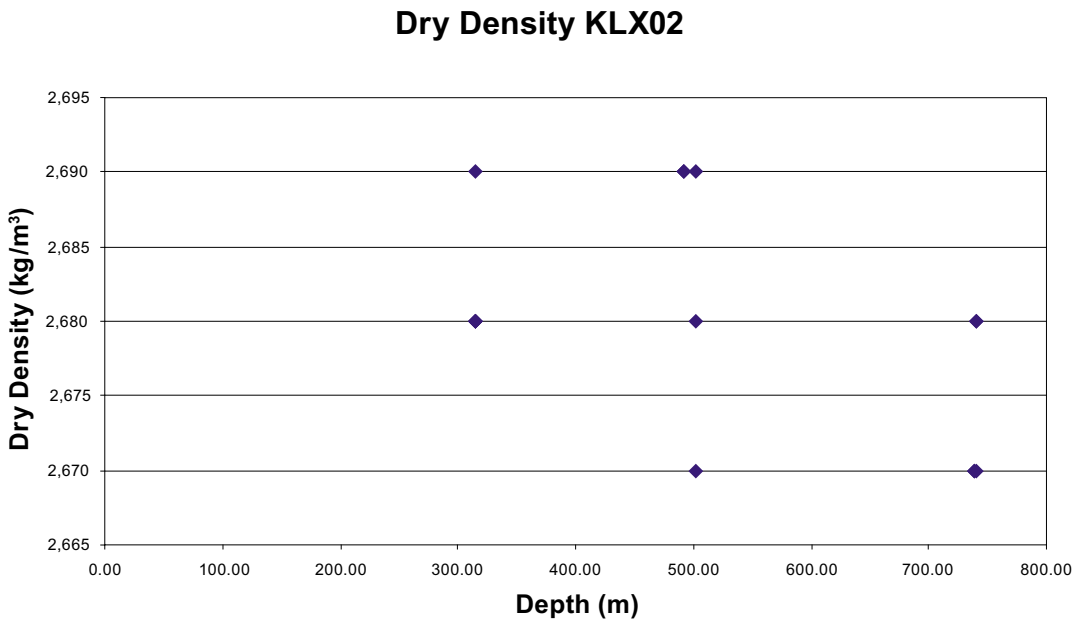


Figure 5-1. *Density (dry) versus depth, depth is where the samples are taken in the borehole.*

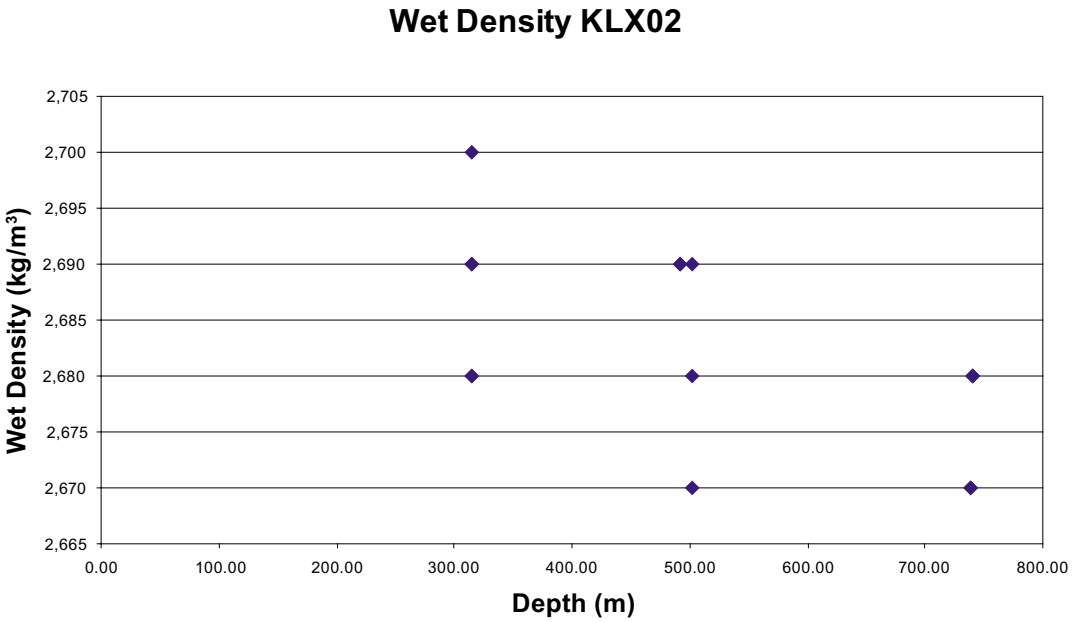


Figure 5-2. *Density (wet) versus depth, depth is where the samples are taken in the borehole.*

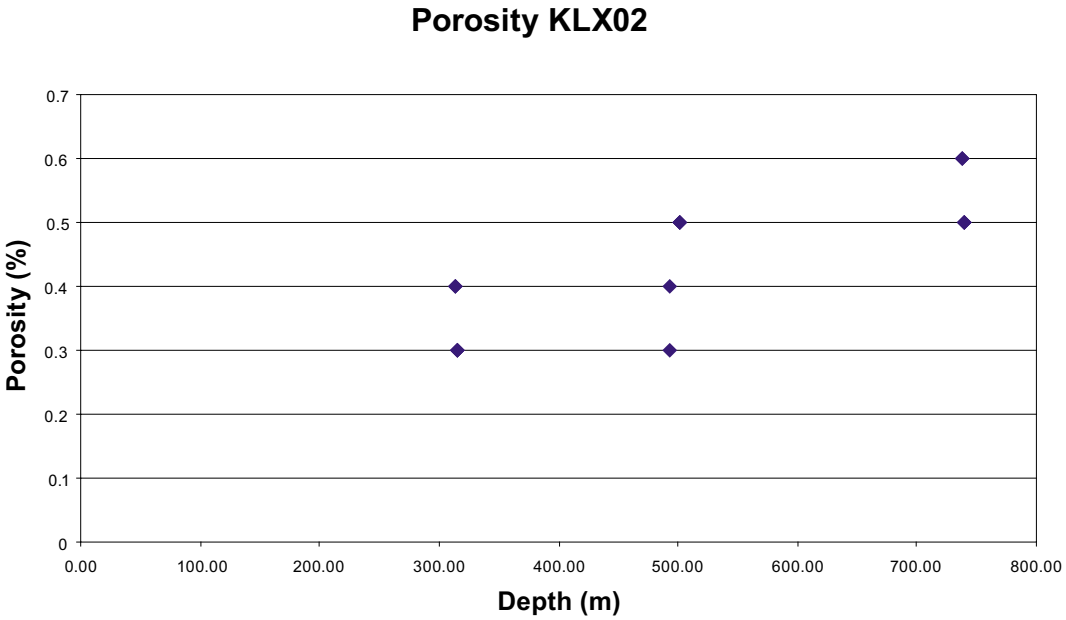


Figure 5-3. *Porosity versus depth, depth is where the samples are taken in the borehole.*

5.3 Discussion

The tests were performed in accordance with the method descriptions. The activity plan was followed without deviations.

References

ISRM, 1979. Volume 16, Number 2.

EN 13755. Natural stone test methods – Determination of water absorption at atm ospheric pressure.

Appendix 1

Results and pictures

Table 1. Level 1, 314–315 m, specimen KLX02-090V-1 to KLX02-090V-5.

KLX02-90V-1 (314.39)

The dry density for specimen KLX02-90V-1A was measured to be 2,720 kg/m^3 and the porosity to 0.3% and the dry density for specimen KLX02-90V-1B was measured to be 2,670 kg/m^3 and the porosity to 0.4%.

Figure 1. *Specimen KLX02-90V-1.*

KLX02-90V-2 (314.45)

The dry density for specimen KLX02-90V-2A was measured to be 2,680 kg/m^3 and the porosity to 0.5% and the dry density for specimen KLX02-90V-2B was measured to be 2,670 kg/m^3 and the porosity to 0.3%.

Figure 2. *Specimen KLX02-90V-2.*

KLX02-90V-3 (314.51)

The dry density for specimen KLX02-90V-3A was measured to be 2,680 kg/m^3 and the porosity to 0.3% and the dry density for specimen KLX02-90V-3B was measured to be 2,680 kg/m^3 and the porosity to 0.3%.

Figure 3. *Specimen KLX02-90V-3.*

KLX02-90V-4 (314.57)

The dry density for specimen KLX02-90V-4A was measured to be 2,680 kg/m^3 and the porosity to 0.4% and the dry density for specimen KLX02-90V-4B was measured to be 2,680 kg/m^3 and the porosity to 0.3 %.

Figure 4. *Specimen KLX02-90V-4.*

KLX02-90V-5 (314.63)

The dry density for specimen KLX02-90V-5A was measured to be 2,690 kg/m^3 and the porosity to 0.3% and the dry density for specimen KLX02-90V-5B was measured to be 2,680 kg/m^3 and the porosity to 0.3%.

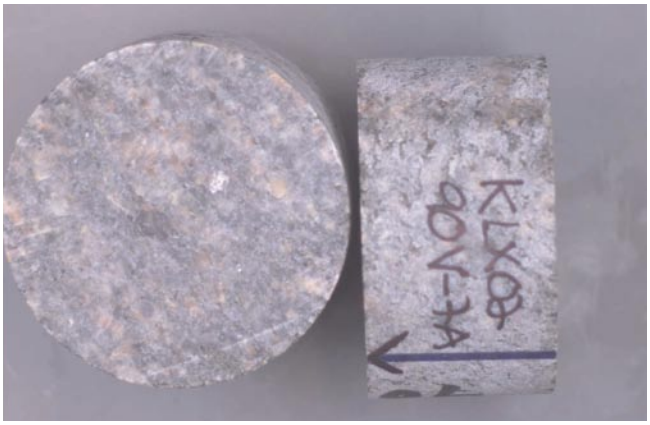
Figure 5. *Specimen KLX02-90V-5.*

Table 2. Level 2, 492–503 m, specimen KLX02-090V-7 to KLX02-090V-11.

KLX02-90V-7 (492.36)

The dry density for specimen KLX02-90V-7A was measured to be 2,690 kg/m^3 and the porosity to 0.3% and the dry density for specimen KLX02-90V-7B was measured to be 2,690 kg/m^3 and the porosity to 0.3%.

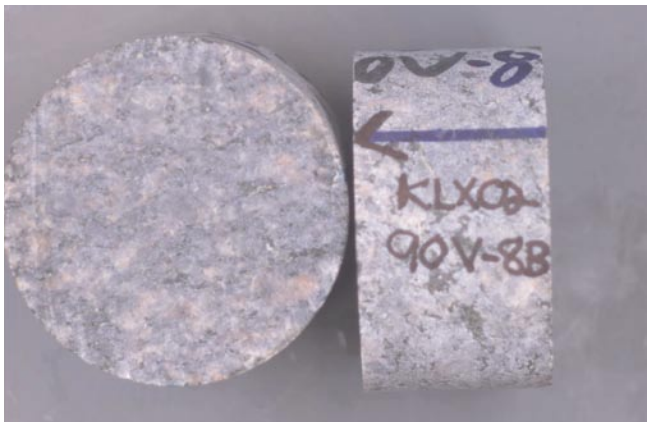
Figure 6. *Specimen KLX02-90V-7.*



KLX02-90V-8 (492.42)

The dry density for specimen KLX02-90V-8A was measured to be 2,690 kg/m^3 and the porosity to 0.4% and the dry density for specimen KLX02-90V-8B was measured to be 2,680 kg/m^3 and the porosity to 0.4%.

Figure 7. *Specimen KLX02-90V-8.*



KLX02-90V-9 (502.01)

The dry density for specimen KLX02-90V-9A was measured to be 2,690 kg/m^3 and the porosity to 0.5% and the dry density for specimen KLX02-90V-9B was measured to be 2,680 kg/m^3 and the porosity to 0.5%.

Figure 8. *Specimen KLX02-90V-9.*

KLX02-90V-10 (502.07)

The dry density for specimen KLX02-90V-10A was measured to be 2,680 kg/m^3 and the porosity to 0.5% and the dry density for specimen KLX02-90V-10B was measured to be 2,680 kg/m^3 and the porosity to 0.5%.

Figure 9. *Specimen KLX02-90V-10.*

KLX02-90V-11 (502.13)

The dry density for specimen KLX02-90V-11A was measured to be 2,670 kg/m^3 and the porosity to 0.5% and the dry density for specimen KLX02-90V-11B was measured to be 2,670 kg/m^3 and the porosity to 0.5%.

Figure 10. *Specimen KLX02-90V-11.*

Table 3. Level 3, 738–741 m, specimen KLX02-090V-13 to KLX02-090V-17.

KLX02-90V-13 (738.28)

The dry density for specimen KLX02-90V-13A was measured to be 2,660 kg/m^3 and the porosity to 0.5% and the dry density for specimen KLX02-90V-13B was measured to be 2,670 kg/m^3 and the porosity to 0.6%.

Figure 11. *Specimen KLX02-90V-13.*

KLX02-90V-14 (738.34)

The dry density for specimen KLX02-90V-14A was measured to be 2,670 kg/m^3 and the porosity to 0.7% and the dry density for specimen KLX02-90V-14B was measured to be 2,670 kg/m^3 and the porosity to 0.6%.

Figure 12. *Specimen KLX02-90V-14.*

KLX02-90V-15 (740.08)

The dry density for specimen KLX02-90V-15A was measured to be 2,680 kg/m^3 and the porosity to 0.5% and the dry density for specimen KLX02-90V-15B was measured to be 2,670 kg/m^3 and the porosity to 0.5%.

Figure 13. *Specimen KLX02-90V-15.*

KLX02-90V-16 (740.14)

The dry density for specimen KLX02-90V-16A was measured to be 2,680 kg/m^3 and the porosity to 0.6% and the dry density for specimen KLX02-90V-16B was measured to be 2,670 kg/m^3 and the porosity to 0.5%.

Figure 14. *Specimen KLX02-90V-16.*

KLX02-90V-17 (740.20)

The dry density for specimen KLX02-90V-17A was measured to be 2,680 kg/m^3 and the porosity to 0.5% and the dry density for specimen KLX02-90V-17B was measured to be 2,670 kg/m^3 and the porosity to 0.5%.

Figure 15. *Specimen KLX02-90V-17.*

Appendix 2

Calculation for density and porosity

Densitet och porositet, SKB

Vattnets temperatur (°C): 22 Metod: /EN 13755; ISRM, 1979/, avsnitt 3 samt SKB MD 160.002 version 2.0

Vattnets densitet (°C): 0.997 Borrhål: KLX02

	Provmärkning	Vikt i vatten, Msub (g)	Yttor vikt, Msat (g)	Torr vikt, Ms (g)	Bulk volume, V (cm^3)	Pore volume, Vv (cm^3)	Porosity, n (%)	Porosity AB (%)	Dry density, ρd (g/cm^3)	Dry density AB (g/cm^3)	Wet density (g/cm^3)	Wet density AB (g/cm^3)
1	KLXO2-1A	78.44	123.91	123.78	45.57	0.13	0.3	0.4	2.72	2.69	2.72	2.70
2	1B	75.96	121.26	121.07	45.40	0.19	0.4		2.67		2.67	
3	2A	76.45	121.65	121.41	45.30	0.24	0.5	0.4	2.68	2.68	2.69	2.68
4	2B	76.03	121.27	121.12	45.34	0.15	0.3		2.67		2.67	
5	3A	76.59	121.83	121.69	45.34	0.14	0.3	0.3	2.68	2.68	2.69	2.68
6	3B	75.78	120.7	120.55	45.02	0.15	0.3		2.68		2.68	
7	4A	77.58	123.4	123.23	45.92	0.17	0.4	0.3	2.68	2.68	2.69	2.69
8	4B	77.25	122.93	122.79	45.78	0.14	0.3		2.68		2.69	
9	5A	77.64	123.44	123.28	45.90	0.16	0.4	0.3	2.69	2.68	2.69	2.69
10	5B	77.48	123.39	123.25	46.01	0.14	0.3		2.68		2.68	
11	R6A	77.49	123.25	123.11	45.86	0.14	0.3	0.3	2.68	2.69	2.69	2.69
12	R6B	77.73	123.6	123.47	45.97	0.13	0.3		2.69		2.69	
13	7A	77.78	123.59	123.43	45.91	0.16	0.4	0.3	2.69	2.69	2.69	2.69
14	7B	78.22	124.23	124.07	46.11	0.16	0.3		2.69		2.69	
15	8A	78.21	124.17	123.99	46.06	0.18	0.4	0.4	2.69	2.69	2.70	2.69
16	8B	77.89	123.87	123.7	46.08	0.17	0.4		2.68		2.69	
17	9A	75.79	120.43	120.22	44.74	0.21	0.5	0.5	2.69	2.69	2.69	2.69
18	9B	75.58	120.19	119.98	44.71	0.21	0.5		2.68		2.69	
19	10A	75.18	119.78	119.57	44.70	0.21	0.5	0.5	2.68	2.68	2.68	2.68
20	10B	74.96	119.39	119.18	44.53	0.21	0.5		2.68		2.68	
21	11A	74.3	118.59	118.35	44.39	0.24	0.5	0.5	2.67	2.67	2.67	2.67
22	11B	74.92	119.49	119.27	44.67	0.22	0.5		2.67		2.68	
23	R12A	74.44	118.59	118.35	44.25	0.24	0.5	0.5	2.67	2.68	2.68	2.69
24	R12B	75.66	120.24	120.05	44.68	0.19	0.4		2.69		2.69	
25	13A	77.59	123.93	123.68	46.44	0.25	0.5	0.6	2.66	2.67	2.67	2.67
26	13B	77.51	123.67	123.39	46.26	0.28	0.6		2.67		2.67	
27	14A	77.34	123.44	123.14	46.20	0.30	0.7	0.6	2.67	2.67	2.67	2.68
28	14B	76.76	122.34	122.05	45.68	0.29	0.6		2.67		2.68	
29	15A	78.03	124.16	123.95	46.23	0.21	0.5	0.5	2.68	2.68	2.69	2.68
30	15B	77.99	124.25	124.01	46.36	0.24	0.5		2.67		2.68	
31	16A	78.13	124.34	124.08	46.31	0.26	0.6	0.5	2.68	2.68	2.68	2.68
32	16B	77.45	123.5	123.26	46.15	0.24	0.5		2.67		2.68	
33	17A	78.08	124.15	123.93	46.17	0.22	0.5	0.5	2.68	2.68	2.69	2.68
34	17B	77.73	123.88	123.65	46.25	0.23	0.5		2.67		2.68	
35	R18A	77.94	124.22	123.97	46.38	0.25	0.5	0.5	2.67	2.67	2.68	2.68
36	R18B	78.08	124.36	124.12	46.38	0.24	0.5		2.68		2.68	