P-04-260

Oskarshamn site investigation

Drill hole KLX02:

Extensometer measurement of the coefficient of thermal expansion of rock

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October 2004

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Keywords: Rock mechanics, Coefficient of thermal expansion, Temperature change, Density, Porosity.

Abstract

The coefficient of thermal expansion and the wet density has been determined on specimens from drill hole KLX02. The specimens were sampled from three levels in the drill hole at a depth of approximately 320, 500 and 740 m. The investigated rock type is mapped as Ävrö granite. The coefficient of thermal expansion has been determined in the temperature interval 20-80°C. The results indicated that the thermal expansion was almost linear, and the coefficient of thermal expansion for the investigated specimens range between 4.3 and 10.6×10^{-6} mm/mm°C.

Sammanfattning

Längdutvidgningskoefficienten och våtdensiteten har bestämts på prover från borrhål KLX02. Proverna kommer från tre olika nivåer i borrhålet, på ett ungefärligt djup av 320, 500 och 740 m. Den undersökta bergarten är karterad som Ävrö granit. Längdutvidgning skoefficienten bestämdes inom temperaturintervallet 20-80°C. Resultaten indikerade att längdutvidgningen var nästan linjär och längdutvidgningskoefficienten för de undersökta proverna varierade mellan 4.3 and 10.6×10^{-6} mm/mm°C.

Contents

1 Introduction

This document reports the data collected at the Laxemar site, which is one of the activities performed as part of the site investigation at Oskarshamn. The work was carried out in accordance with the activity plan AP PS 400–03-092 (SKB internal controlling document).

The purpose of the measurement is to determine the coefficient of thermal expansion at different temperatures.

The cores are sampled from borehole KLX02 in the Laxemar area (Figure 1-1). They were sampled 2 December 2003 by Thomas Janson, Tyréns AB and Urban Åkesson, The Swedish National Testing and Research Institute (SP). The specimens were taken from three levels at depths of approximately 320, 500 and 740 m. The rock cores were transported by SKB and arrived to SP in Febuary 2004. The testing was performed in September 2004 (see Appendix 1).

Figure 1-1. *The Laxemar investigation area.*

2 Objective and scope

The purpose is to determine the linear coefficient of thermal expansion for rock cores in water-saturated condition in the interval +20-80°C.

These parameters will be used in a rock mechanical model for the Laxemar site area, performed by SKB. The specimens and the results will be presented in tables, diagrams and spreadsheets.

3 Equipment

Following equipment have been used for the analyses:

- Extensometer (DEMEC inv no 102266) for measurement of the thermal expansion. Calibration of the instrument was done for each temperature interval(see Appendix 1). The uncertainty of the extensometer is $\pm 3.97\times10^{-6}$ mm/mm (strain), which equals an uncertainty of a single measurement of the coefficient of thermal expansion of $\pm 0.2\times10^{-6}$ mm/mm^{o}C for a temperature difference of 20°C.
- Reference bar in invar steel for calibrate the extensometer.
- Heating chamber (inv no 102284) with an accuracy of ± 0.7°C at 80°C for heating up the specimens.
- A covered plastic box filled with water for keeping the specimens water saturated.

4 Execution

Determination of the coefficient of thermal expansion was made in accordance with SKB's method description SKB MD 191.002, Version 2.0 (SKB internal controlling document). The Department of Building Technology and Mechanics (BM) at SP performed the test.

4.1 Description of the samples

From the Laxemar area specimens were sampled from three levels, approximately between 320, 500 and 740 m, in drill hole KLX02. The sampled rock type is mapped as Ävrö granite. 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).

Rock type	Identification	Sampling depth, according to the marks on the drill-core boxes (Sec up)
Ävrö granite	KLX02-90L-1	314.70
Ävrö granite	KLX02-90L-2	320.30
Ävrö granite	KLX02-90L-3	320.55
Ävrö granite	KLX02-90L-4	321.00
Ävrö granite	KLX02-90L-5	321.97
Ävrö granite	KLX02-90L-6	322.23
Ävrö granite	KLX02-90L-7	493.12
Ävrö granite	KLX02-90L-8	493.38
Ävrö granite	KLX02-90L-9	493.64
Ävrö granite	KLX02-90L-10	505.40
Ävrö granite	KLX02-90L-11	507.06
Ävrö granite	KLX02-90L-12	507.32
Ävrö granite	KLX02-90L-13	736.99
Ävrö granite	KLX02-90L-14	737.25
Ävrö granite	KLX02-90L-15	741.09
Ävrö granite	KLX02-90L-16	741.35
Ävrö granite	KLX02-90L-17	741.61
Ävrö granite	KLX02-90L-18	741.87

4.2 Testing

The execution procedure followed the prescription in SKB MD 191.002, Version 2.0 and SKB MD 160.002, Version 2.0. (SKB internal controlling document) and the following steps were performed:

Item	Activity
1	The specimens were cut according to the marks on the rock cores.
2	Two measuring points with a distance of 200 mm were glued on the specimens.
3	The specimens were photographed in JPEG-format.
4	The specimens were water saturated for seven days.
5	The wet density was determined (See Appendix 2)
6	The coefficient of thermal expansion was determined. The thermal expansion was measured at 20, 40, 60 and 80°C. On each temperature level was three to five measurements done with 24 h intervals in order to know that the expansion was completed for each temperature level (See Appendix 1). The coefficient of thermal expansion was determined between 20-80°C.

5 Results

The main results of the site investigation of KLX02 could be found in the database SICADA FN 236.

5.1 Description of the specimens and presentation of the results

The temperature of water for water saturation was 16.5°C and the density of the water was 998 kg/m^3. The coefficient of thermal expansion was determined between +20-80°C.

KLX02-90L-1 (314.7 m)

Figure 5-1. *Specimen KLX02-90L-1.*

The Figure 5-1 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The diagram show that the test has failed and the reason could either be bending of the specimen or that the demec studs were loose during the test. The coefficient of thermal expansion for specimen KLX02-90L-1 at 40°C was measured to be 6.0×10^{-6} mm/mm°C and the specimen had a wet density to 2,684 kg/m^3.

KLX02-90L-2 (320.3 m)

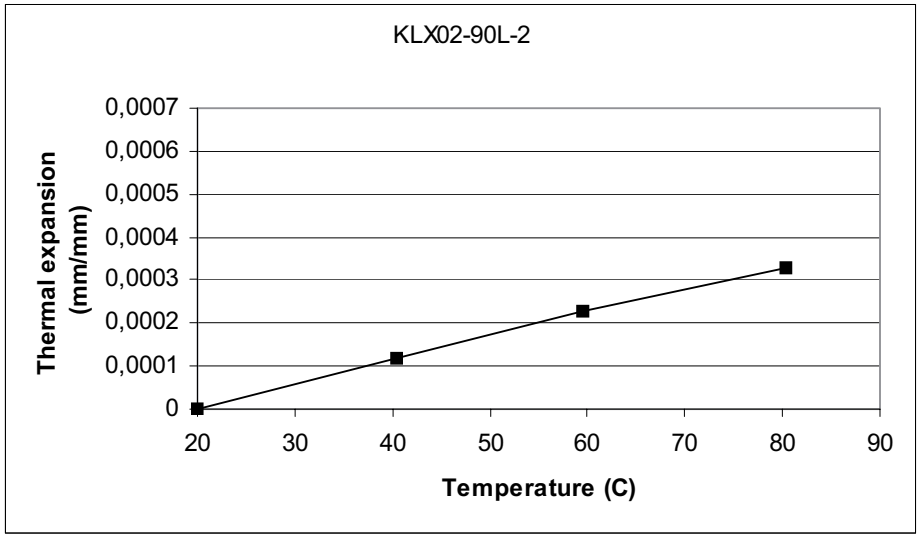


Figure 5-2. *Diagram showing the thermal expansion of specimen KLX02-90L-2 between 20 and 80°C, median values plotted.*

The Figure 5-2 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-2 was measured to be 5.5×10^{-6} mm/mm°C and the specimen had a wet density of 2,689 kg/m^3.

KLX02-90L-3 (320.55 m)

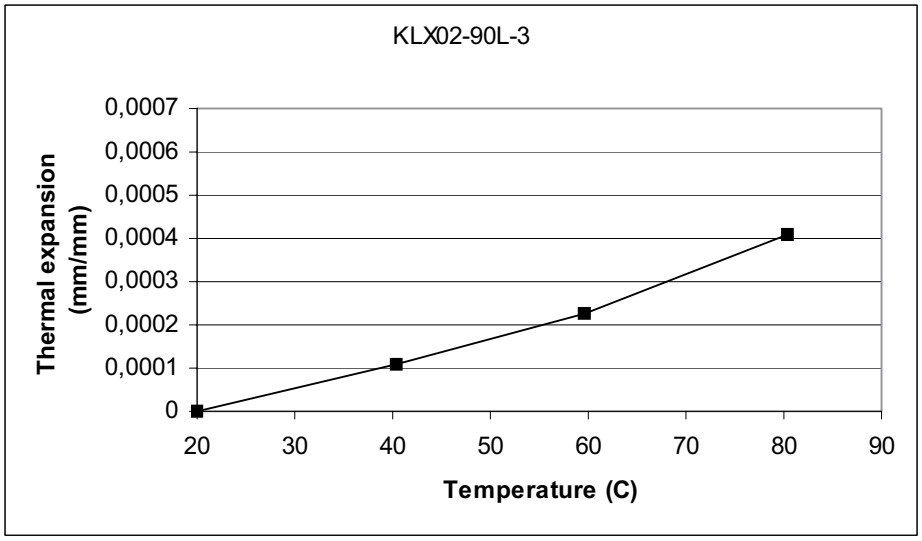


Figure 5-3. *Diagram showing the thermal expansion of specimen KLX02-90L-3 between 20 and 80°C, median values plotted.*

The Figure 5-3 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-3 was measured to be 6.8×10^{-6} mm/mm°C and the specimen had a wet density of 2,686 kg/m^3.

KLX02-90L-4 (321.0 m)

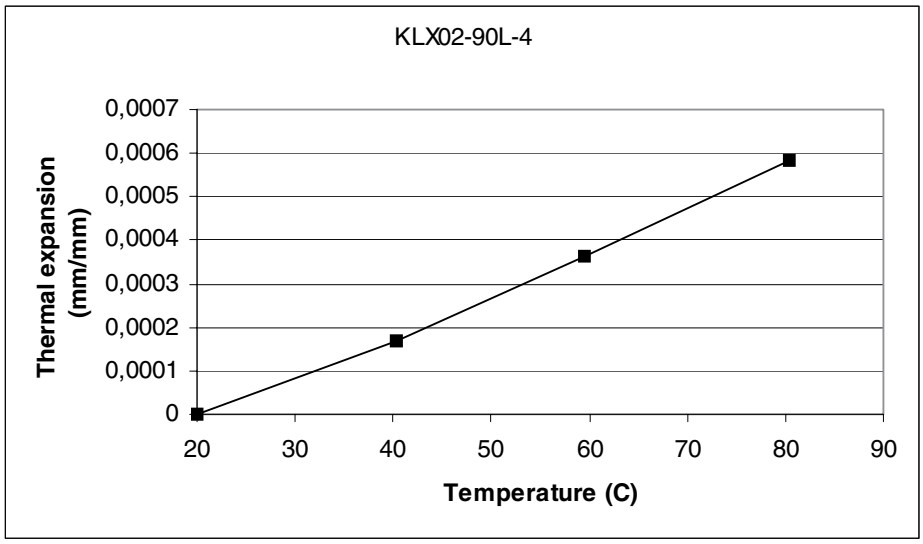


Figure 5-4. *Diagram showing the thermal expansion of specimen KLX02-90L-4 between 20 and 80°C, median values plotted.*

The Figure 5-4 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-4 was measured to be 9.7×10^{-6} mm/mm°C and the specimen had a wet density of 2,682 kg/m^3.

KLX02-90L-5 (321.97 m)

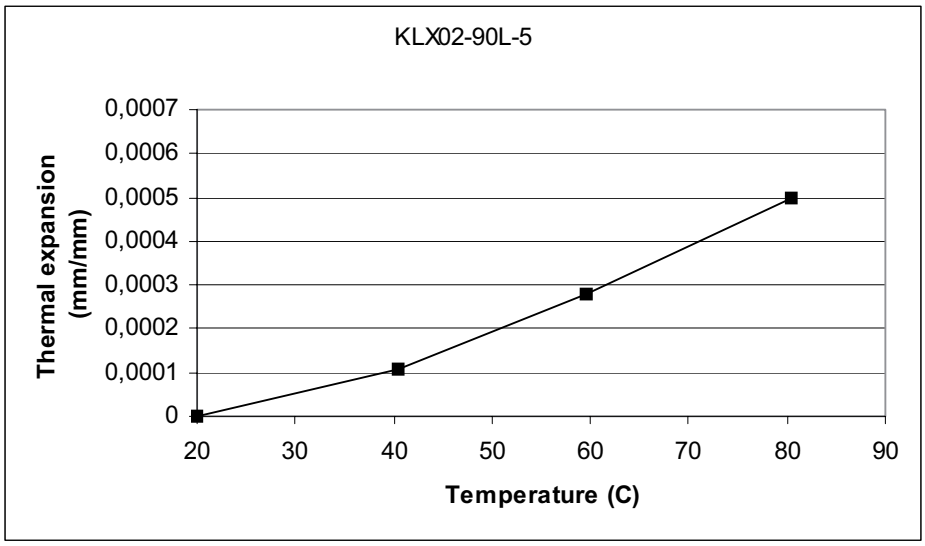


Figure 5-5. *Diagram showing the thermal expansion of specimen KLX02-90L-5 between 20 and 80°C, median values plotted.*

The Figure 5-5 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-5 was measured to be 8.3×10^{-6} mm/mm°C and the specimen had a wet density of 2,673 kg/m^3.

KLX02-90L-6 (322.23 m)

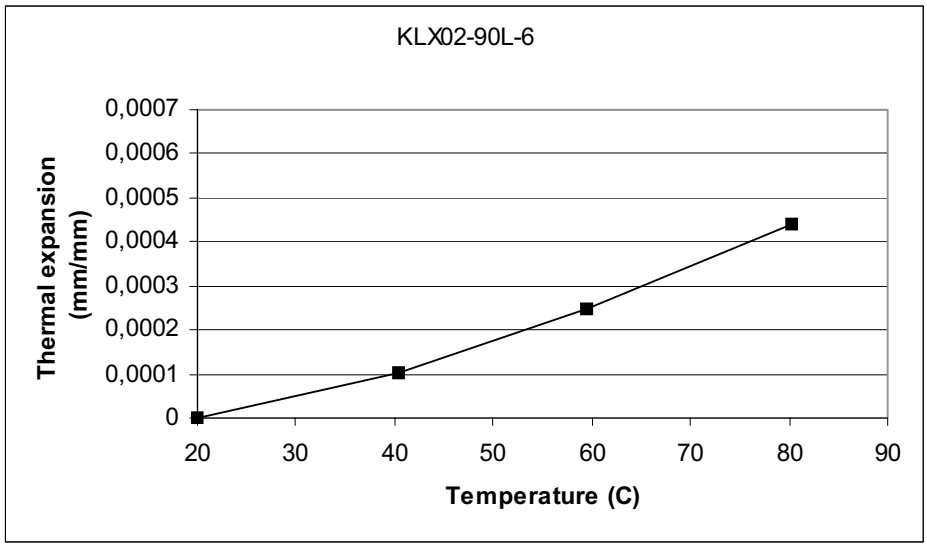
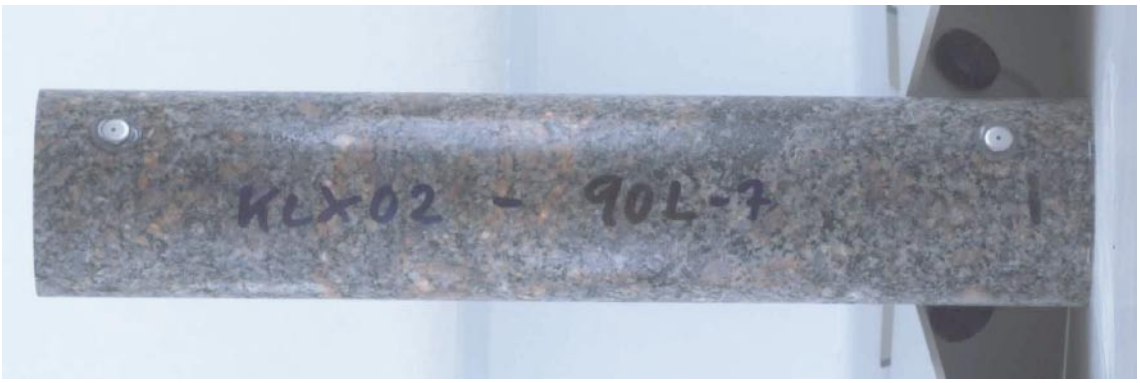


Figure 5-6. *Diagram showing the thermal expansion of specimen KLX02-90L-6 between 20 and 80°C, median values plotted.*

The Figure 5-6 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-6 was measured to be 7.3×10^{-6} mm/mm°C and the specimen had a wet density of 2,678 kg/m^3.

KLX02-90L-7 (493.12 m)



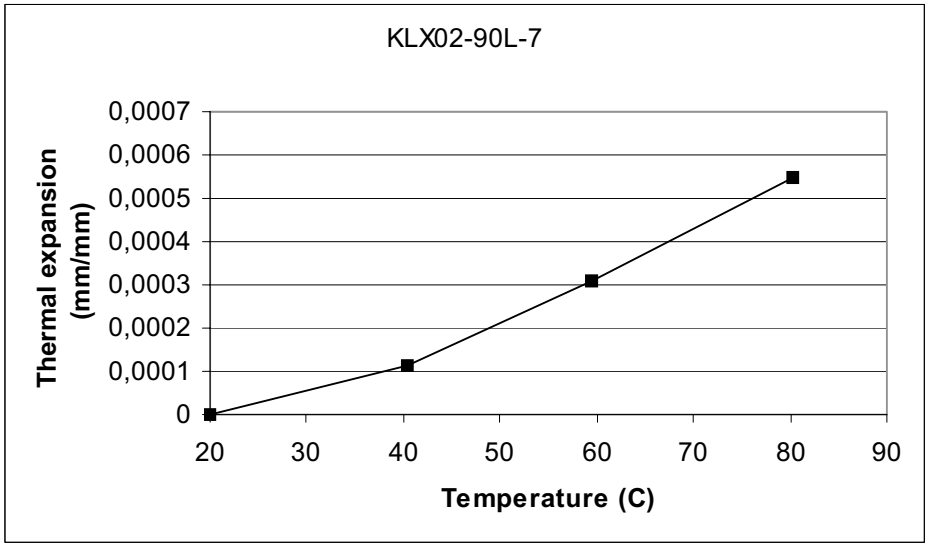


Figure 5-7. *Diagram showing the thermal expansion of specimen KLX02-90L-7 between 20 and 80°C, median values plotted.*

The Figure 5-7 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-7 was measured to be 9.1×10^{-6} mm/mm°C, and the specimen had a wet density of 2,727 kg/m^3.

KLX02-90L-8 (493.38 m)

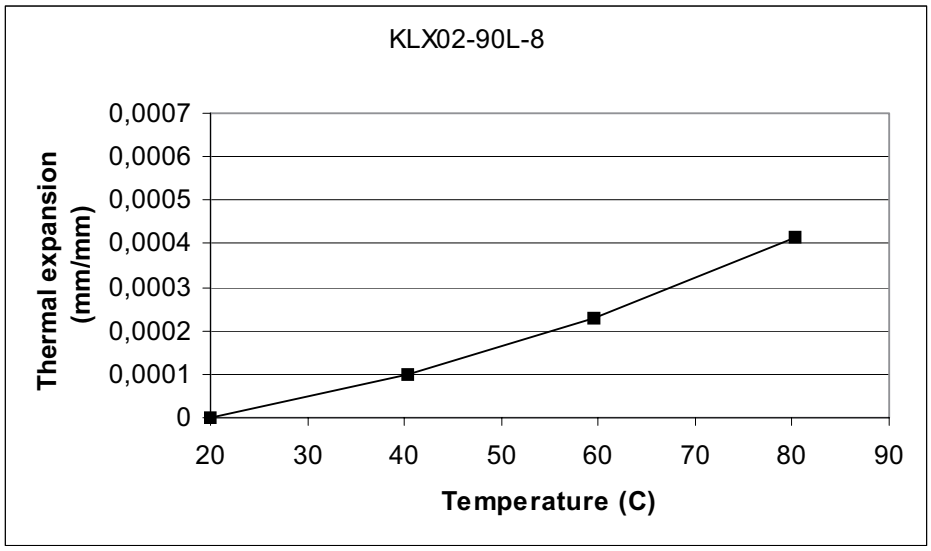
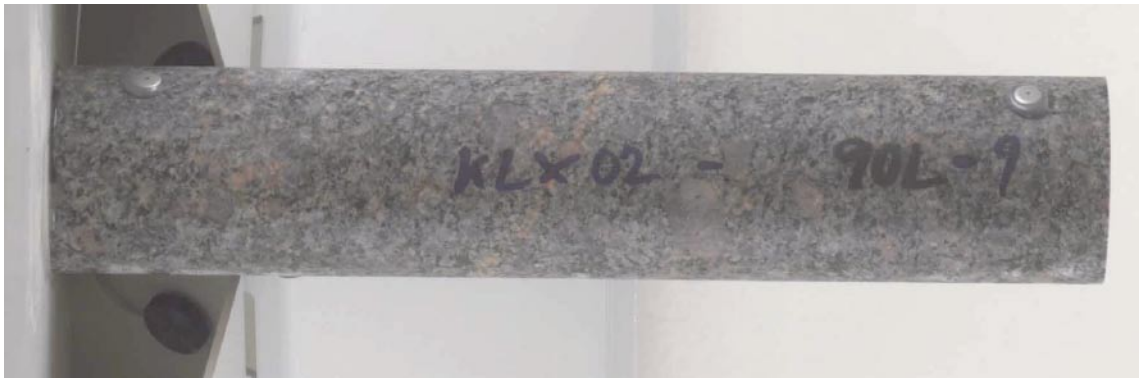


Figure 5-8. *Diagram showing the thermal expansion of specimen KLX02-90L-8 between 20 and 80°C, median values plotted.*

The Figure 5-8 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-8 was measured to be 6.9×10^{-6} mm/mm°C and the specimen had a wet density of 2,723 kg/m^3.

KLX02-90L-9 (493.64 m)



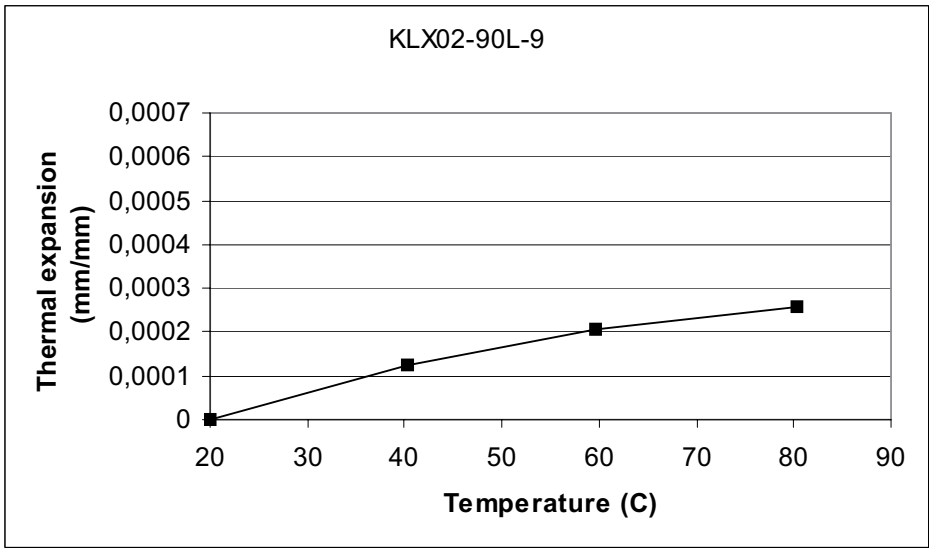
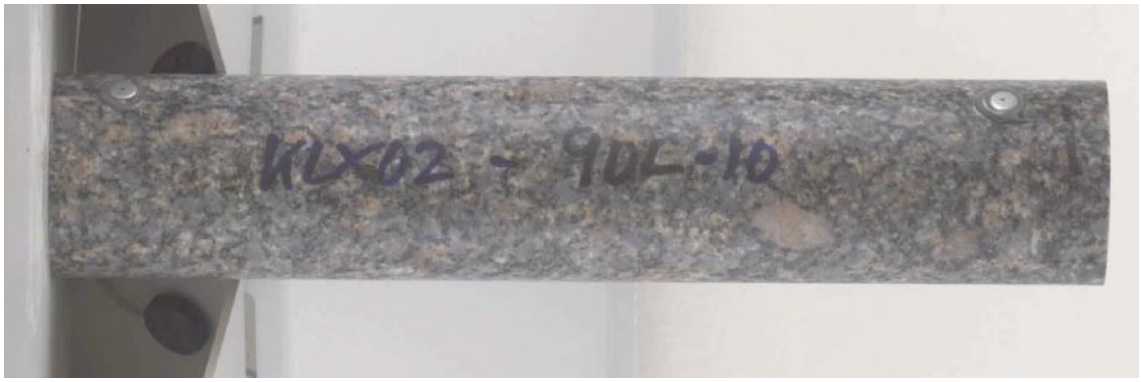


Figure 5-9. *Diagram showing the thermal expansion of specimen KLX02-90L-9 between 20 and 80°C, median values plotted.*

The Figure 5-9 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-9 was measured to be 4.3×10^{-6} mm/mm°C and the specimen had a wet density of 2,724 kg/m^3.

KLX02-90L-10 (505.4 m)



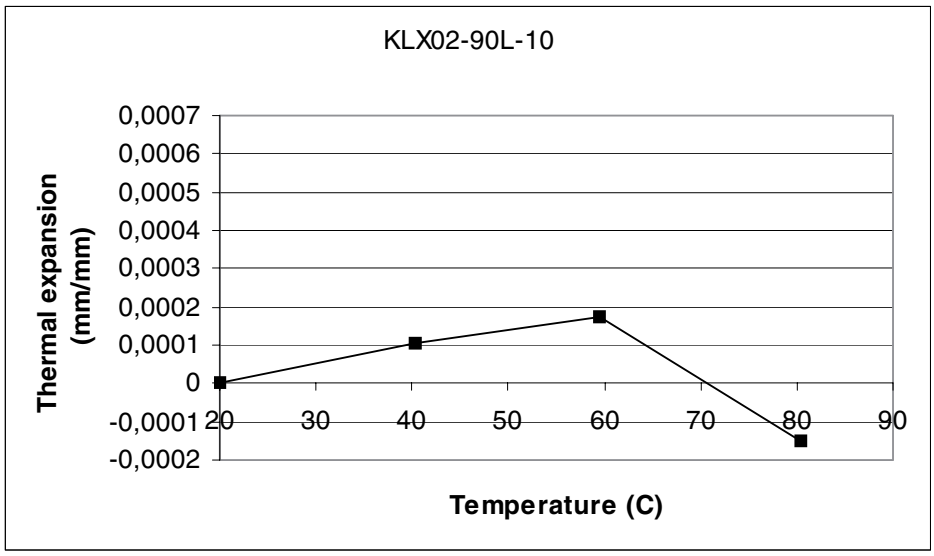
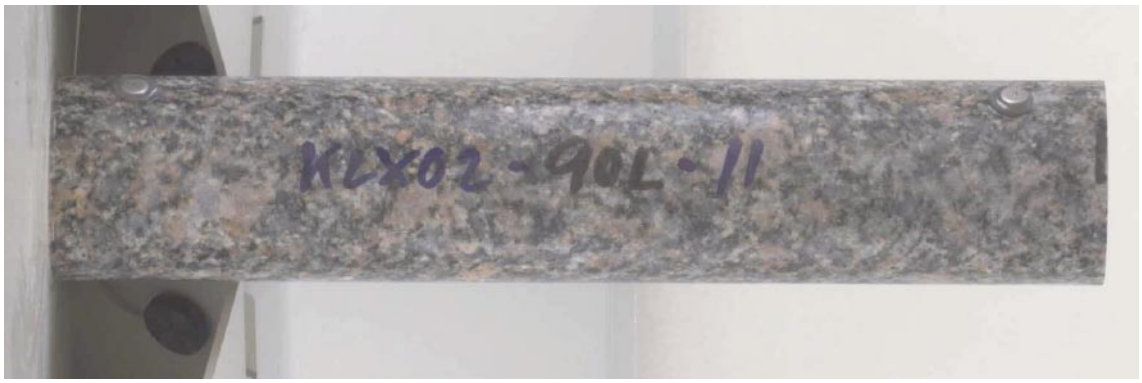


Figure 5-10. *Diagram showing the thermal expansion of specimen KLX02-90L-10 between 20 and 80°C, median values plotted.*

The Figure 5-10 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The diagram show that the test has failed and the reason could either be bending of the specimen or that the demec studs were loose during the test. The coefficient of thermal expansion for specimen KLX02-90L-10 at 60°C was measured to be 4.5×10^{-6} mm/mm°C and the specimen had a wet density of 2,689 kg/m^3.

KLX02-90L-11 (507.06 m)



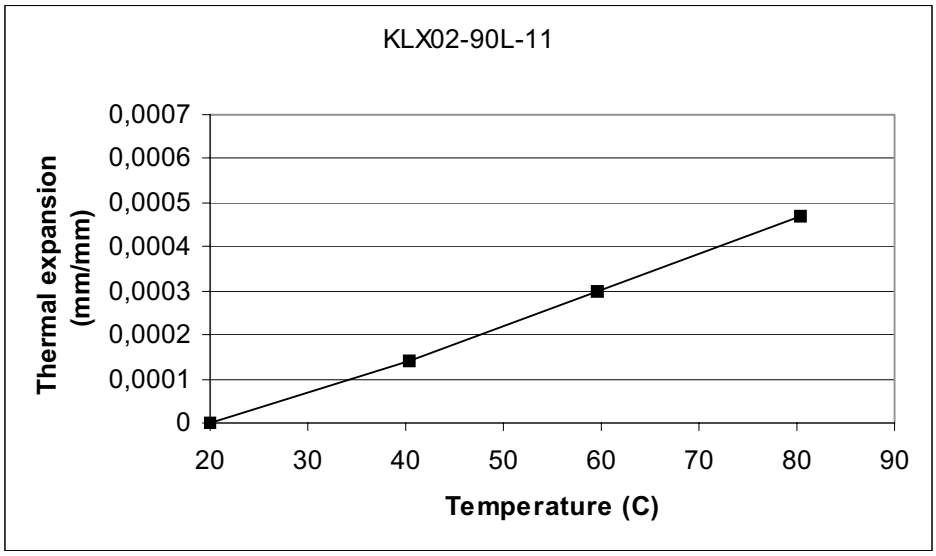
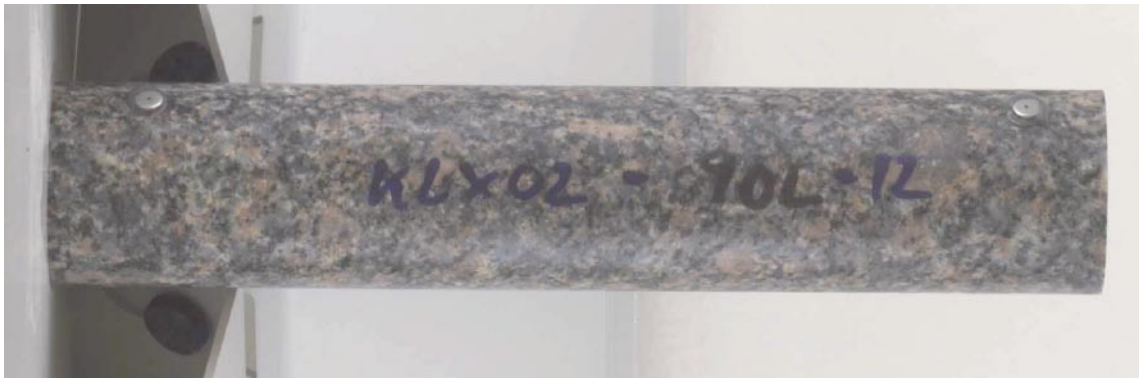


Figure 5-11. *Diagram showing the thermal expansion of specimen KLX02-90L-11 between 20 and 80°C, median values plotted.*

The Figure 5-11 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-11 was measured to be 7.8×10^{-6} mm/mm°C and the specimen had a wet density of 2,686 kg/m^3.

KLX02-90L-12 (507.32 m)



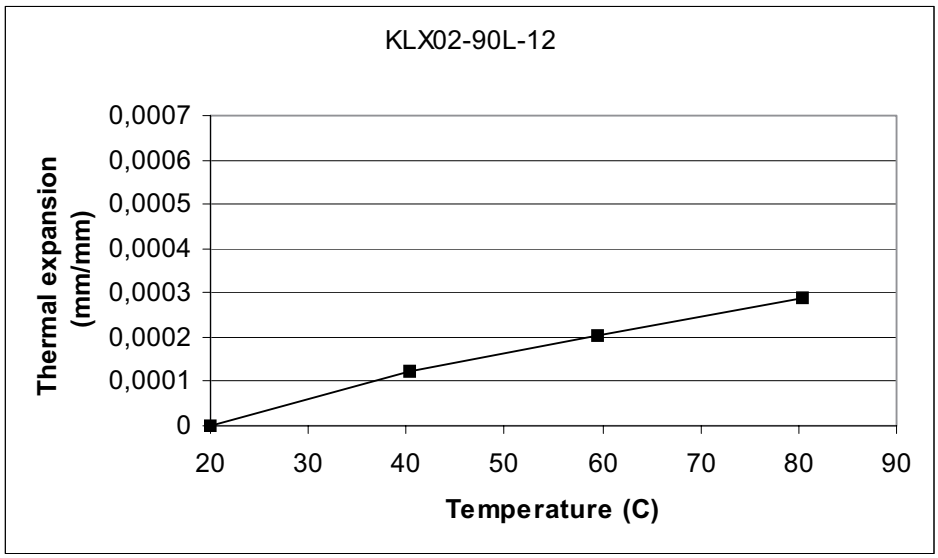
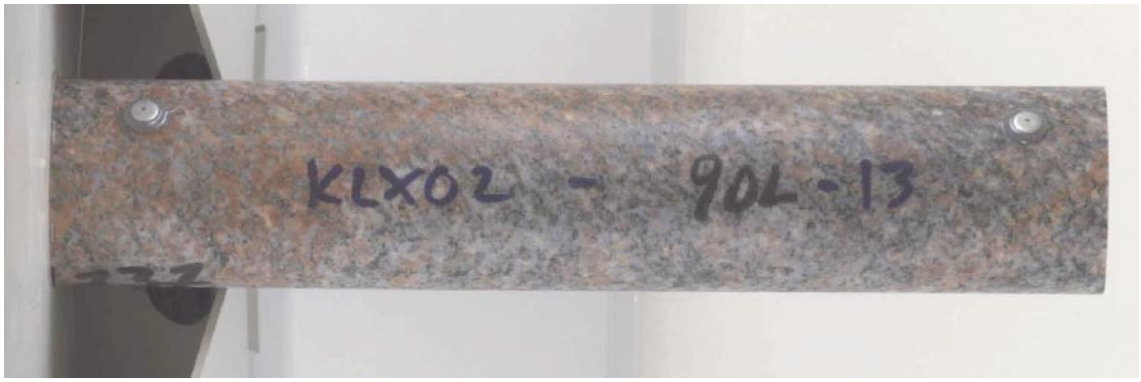


Figure 5-12. *Diagram showing the thermal expansion of specimen KLX02-90L-12 between 20 and 80°C, median values plotted.*

The Figure 5-12 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-12 was measured to be 4.8×10^{-6} mm/mm°C and the specimen had a wet density of 2,687 kg/m^3.

KLX02-90L-13 (736.99 m)



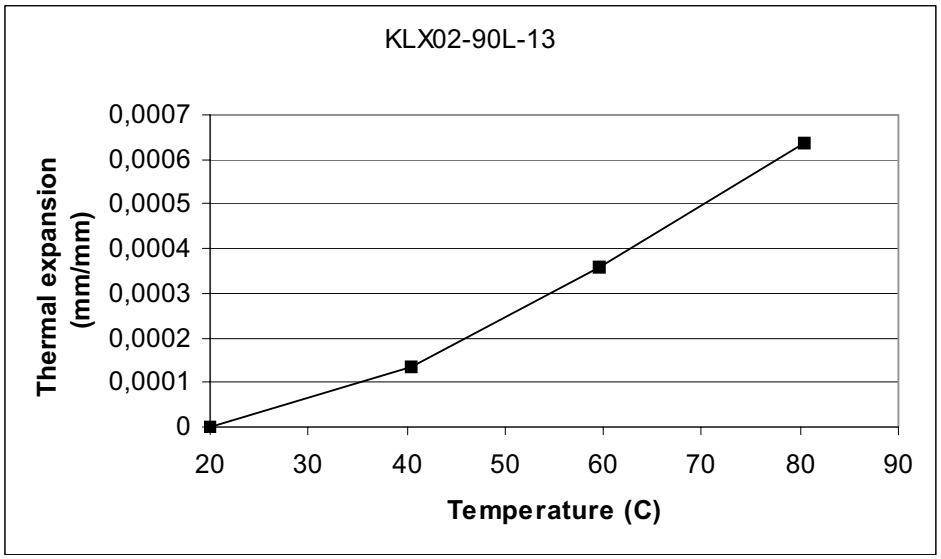
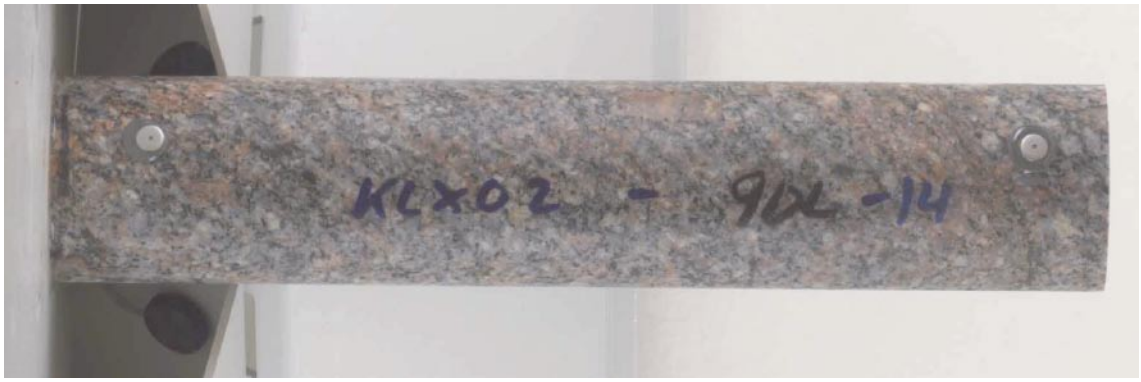


Figure 5-13. *Diagram showing the thermal expansion of specimen KLX02-90L-13 between 20 and 80°C, median values plotted.*

The Figure 5-13 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-13 was measured to be 10.6×10^{-6} mm/mm°C and the specimen had a wet density of 2,673 kg/m^3.

KLX02-90L-14 (737.25 m)



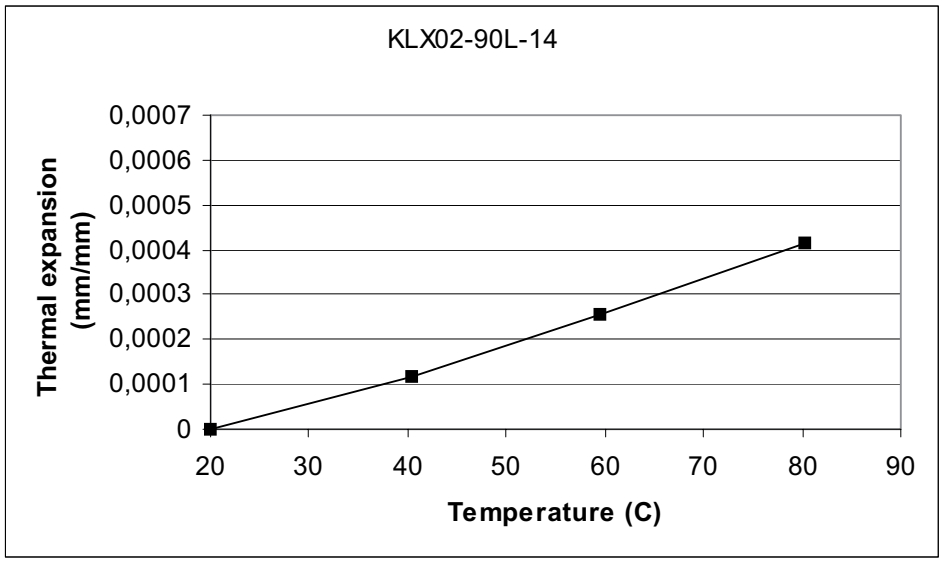
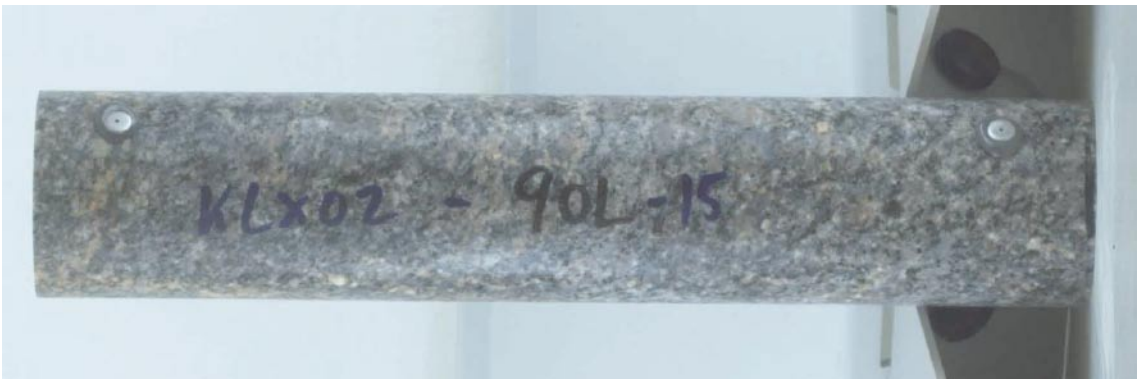


Figure 5-14. *Diagram showing the thermal expansion of specimen KLX02-90L-14 between 20 and 80°C, median values plotted.*

The Figure 5-14 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-14 was measured to be 6.9×10^{-6} mm/mm°C and the specimen had a wet density of 2,672 kg/m^3.

KLX02-90L-15 (741.09 m)



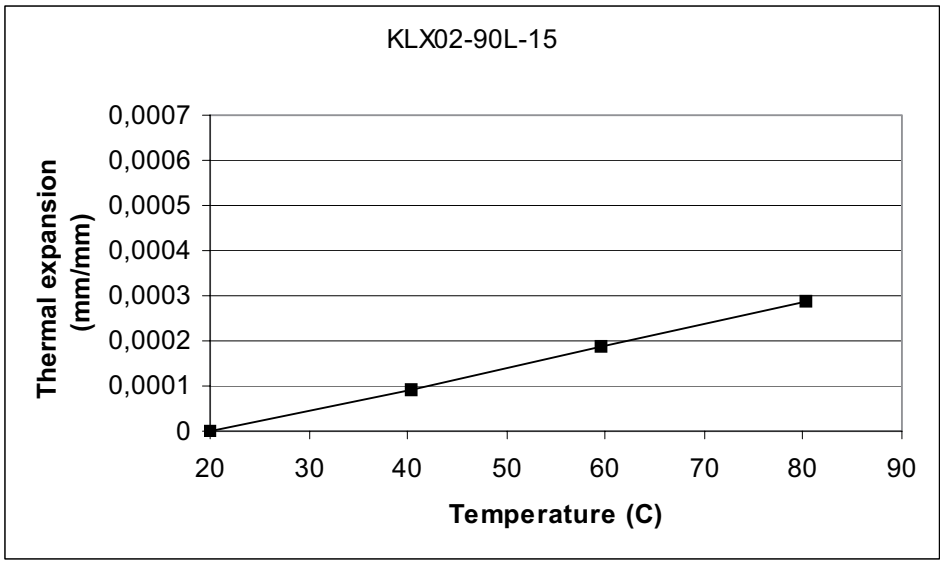


Figure 5-15. *Diagram showing the thermal expansion of specimen KLX02-90L-15 between 20 and 80°C, median values plotted.*

The Figure 5-15 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-15 was measured to be 4.8×10^{-6} mm/mm°C and the specimen had a wet density of 2,685 kg/m^3.

KLX02-90L-16 (741.35 m)

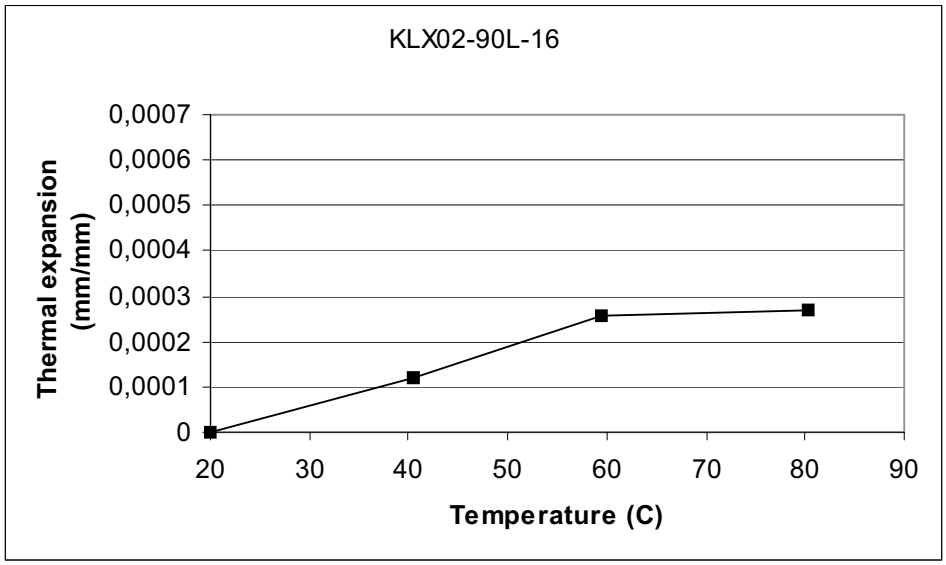


Figure 5-16. *Diagram showing the thermal expansion of specimen KLX02-90L-16 between 20 and 80°C, median values plotted.*

The Figure 5-16 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-16 was measured to be 4.5×10^{-6} mm/mm°C and the specimen had a wet density of 2,683 kg/m^3.

KLX02-90L-17 (741.61 m)

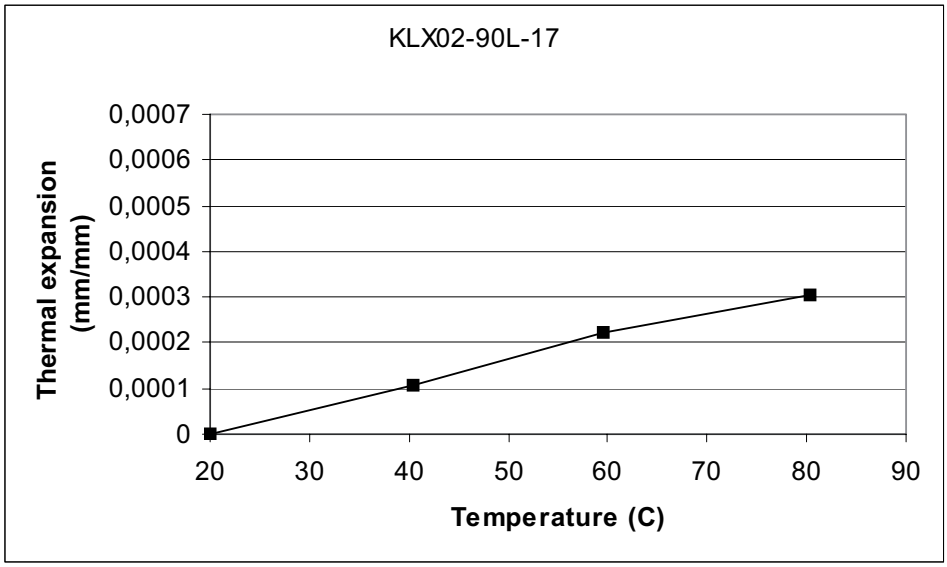
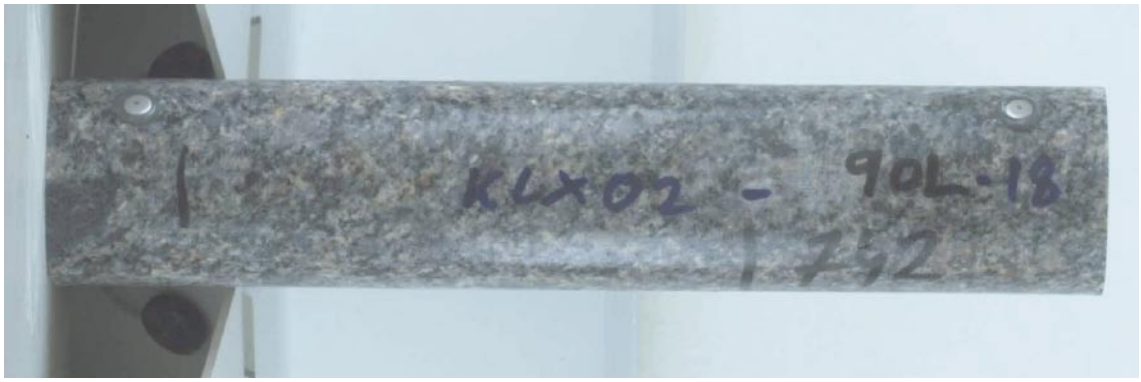


Figure 5-17. *Diagram showing the thermal expansion of specimen KLX02-90L-17 between 20 and 80°C, median values plotted.*

The Figure 5-17 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The coefficient of thermal expansion for specimen KLX02-90L-17 was measured to be 5.1×10^{-6} mm/mm°C and the specimen had a wet density of 2,689 kg/m^3.

KLX02-90L-18 (741.87 m)



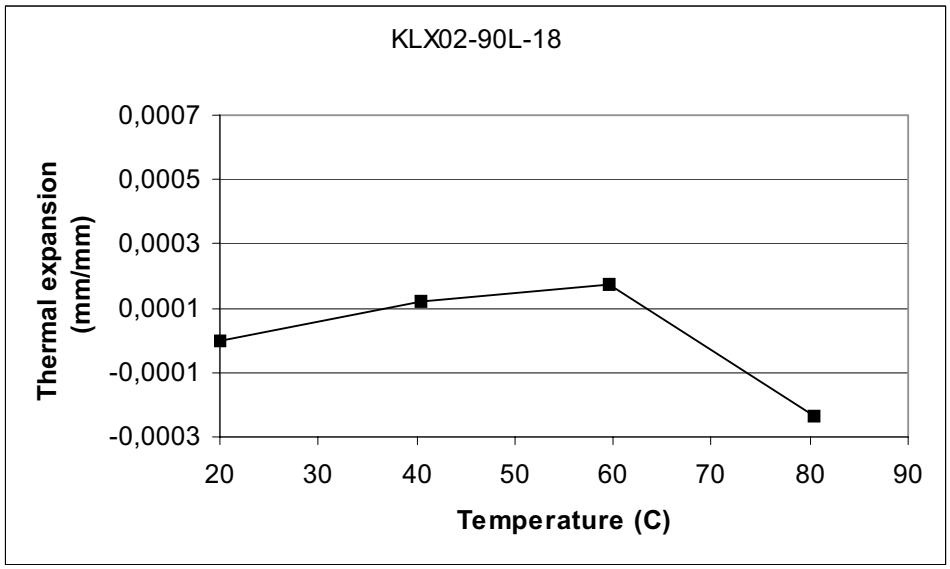


Figure 5-18. *Diagram showing the thermal expansion of specimen KLX02-90L-18 between 20 and 80°C, median values plotted.*

The Figure 5-18 shows a picture of the specimen and a diagram for the thermal expansion in the interval 20, 40, 60, 80°C. The diagram show that the test has failed and the reason could either be bending of the specimen or that the demec studs were loose during the test. The coefficient of thermal expansion for specimen KLX02-90L-18 at 60°C was measured to be 4.5×10^{-6} mm/mm°C and the specimen had a wet density to 2,687 kg/m^3.

5.2 Results for the entire test series

Table 5-1. Summary of the results for the coefficient of thermal expansion (median values) and wet density of the tested specimens at Level 1. Specimen KLX-90L-1 is excluded when the median, maximum and minimum value are calculated.

Specimen	Coefficient of thermal expansion between 20 and 80°C (mm/mm°C)	Wet density (kg/m^3)
KLX02-90L-1	Failed, see Figure 5.1-1	2,684
KLX02-90L-2	5.5×10^{-6}	2,689
KLX02-90L-3	6.8×10^{-6}	2,686
KLX02-90L-4	9.7×10^{-6}	2,682
KLX02-90L-5	8.3×10^{-6}	2,673
KLX02-90L-6	7.3×10^{-6}	2,678
Median	7.3×10^{-6}	
Maximum value	9.7×10^{-6}	
Minimum value	5.5×10^{-6}	

Table 5-2. Summary of the results for the coefficient of thermal expansion (median values) and wet density of the tested specimens at Level 2. Specimen KLX-90L-10 is excluded when the median, maximum and minimum value are calculated.

Specimen	Coefficient of thermal expansion between 20 and 80°C (mm/mm°C)	Wet density (kg/m^3)
KLX02-90L-7	9.1 $\times10^{-6}$	2,727
KLX02-90L-8	6.9×10^{-6}	2,723
KLX02-90L-9	4.3×10^{-6}	2,724
KLX02-90L-10	Failed, See Figure 5-10	2,689
KLX02-90L-11	7.8×10^{-6}	2,686
KLX02-90L-12	4.8×10^{-6}	2,687
Median	6.9×10^{-6}	
Maximum value	9.1×10^{-6}	
Minimum value	4.3×10^{-6}	

Table 5-3. Summary of the results for the coefficient of thermal expansion (median values) and wet density of the tested specimens at Level 3. Specimen KLX-90L-18 is excluded when the median, maximum and minimum value are calculated.

Specimen	Coefficient of thermal expansion between 20 and 80°C (mm/mm°C)	Wet density (kg/m^3)
KLX02-90L-13	10.6 $\times10^{-6}$	2,673
KLX02-90L-14	6.9×10^{-6}	2,672
KLX02-90L-15	4.8×10^{-6}	2,685
KLX02-90L-16	4.5×10^{-6}	2,683
KLX02-90L-17	5.1×10^{-6}	2,689
KLX02-90L-18	Failed, see Fig 5-18.	2,687
Median	5.1×10^{-6}	
Maximum value	10.6×10^{-6}	
Minimum value	4.5×10^{-6}	

5.3 Discussion

The test failed at three specimens (KLX02-90L-1, 10 and 18) and this could be due to either bending of the specimen or lost of the demec studs. Therefore are the results from these specimens not included in the SICADA FN 236.

The variation between the samples is approximately 6.3×10^{-6} mm/mm°C which is approximately 30 times the uncertainty of the measurement (0.2×10^{-6} mm/mm°C).

References

NT BUILD 479, Natural Building stones: Coefficient of thermal expansion.

Appendix 1

Determination of the linear coefficient of thermal expansion

Uppdragsnummer:	**P304311**	
Borrhål:	KLXO2	
Metod:		
Provkroppar som provas se nästa blad		
Provberedning	**Datum**	**Sign**
Sågning:	6/22/04	Lej
Foto:	8/16/04	UÅ
Vattenmättnad start datum:	8/17/04	Lej
Vägning vattenmättat yttorrt tillstånd:		
Provning start:	8/25/04	Lej
Vägning torrt tillstånd:		
Utrustning	**Inventarienummer**	**Kalibrerad datum**
Extensometer:	102266	5/5/03
Våg	102291	3/10/04
Torkskåp	102284	5/21/03
Termometer	102080	6/14/04
Övrigt		
Eventuella avvikelser under provning:		
	Datum	**Sign**
Proverna åter i kärnlådan:	9/17/04	Lej

Provningsprotokoll längdutvidgningskoefficient

Uppdrags nummer:		**P304311**				
Borrhål:		**KLXO2**				
						Median
Mättempe-ratur	**20,4**	**C**	**C**	**C**	**20,4**	**C**	**20,4**

Prov ID	Skalvärde/datum	Skalvärde/datum	Skalvärde/datum	Skalvärde/datum	Median
1				678	678,00
2				67	67,00
3				2	2,00
4				808	808,00
5				97	97,00
6				–32	–32,00
7				–53	–53,00
8				–175	–175,00
9				–304	–304,00
10				–559	–559,00
11				–121	–121,00
12				–952	–952,00
13				181	181,00
14				–244	–244,00
15				–77	–77,00
16				–118	–118,00
17				–102	–102,00
18				–138	–138,00

Provningsprotokoll längdutvidgningskoefficient

Uppdrags nummer:	**P304311**								
Borrhål:	**KLXO2**								
									Median
Mättempe-ratur	**40,6**	**C**	**40,4**	**C**	**40,2**	**C**		**C**	**40,4**

Prov ID	Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Skalvärde/datum	Median
1	708	04/08/26	709	04/08/27	706			708
2	97		96		97			97
3	27		29		30			29
4	849		850		852			850
5	124		123		124			124
6	–7		–6		–3			–6
7	–25		–32		–23			–25
8	–148		–151		–150			–150
9	–273		–274		–273			–273
10	–531		–532		–533			–532
11	–87		–86		–85			–86
12	–921		–921		–920			–921
13	215		215		217			215
14	–214		–215		–214			–214
15	–52		–54		–55			–54
16	–87		–88		–98			–88
17	–73		–75		–75			–75
18	–108		–109		110			–108

Provningsprotokoll längdutvidgningskoefficient

Uppdrags nummer:	**P304311**								
Borrhål:	**KLXO2**								
									Median
Mättemperatur	**59,7**	**C**	**59,5**	**C**	**59,6**	**C**	**59,5**	**C**	**59,55**

Prov ID	Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Median
1	706	04/09/01	702	04/09/02	701	04/09/03	694		701,5
2	119		123		125		132		124
3	55		58		60		65		59
4	887		898		900		912		899
5	152		166		168		176		167
6	23		29		31		33		30
7	15		23		27		32		25
8	–123		–118		–116		–109		–117
9	–246		–252		–252		–252		–252
10	–507		–510		–520		–534		–515
11	–51		–46		–45		–42		–45,5
12	–894		–902		–902		–900		–901
13	267		270		272		274		271
14	–181		–180		–180		–180		–180
15	–29		–30		–30		–33		–30
16	–58		–53		–54		–50		–53,5
17	–48		–46		–47		–43		–46,5
18	–92		–94		–94		–100		–94

Provningsprotokoll längdutvidgningskoefficient

Uppdrags nummer:	**P304311**								
Borrhål:	**KLXO2**								
									Median
Mättempe-ratur	**80,3**	**C**	**80,4**	**C**	**80,5**	**C**	**80,3**	**C**	**80,35**

Prov ID	Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Median
1	714	04/09/09	693	04/09/10	665	04/09/13	639		679
2	152		153		148		146		150
3	105		105		97		106		105
4	956		956		948		953		954,5
5	224		222		223		223		223
6	77		79		78		79		78,5
7	85		85		85		86		85
8	–70		–70		–71		–76		–70,5
9	–225		–238		–240		–241		–239
10	–588		–593		–602		–641		–597,5
11	–6		0		4		–9		–3
12	–882		–877		–884		–876		–879,5
13	337		341		342		342		341,5
14	–140		–140		–139		–140		–140
15	–2		–4		–5		–7		–4,5
16	–45		–49		–51		–55		–50
17	–13		–24		–27		–30		–25,5
18	–137		–207		–195		–200		–197,5

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479 Tempdifferens 20

1 skaldel motsvarar 3,97 mikrostrain = $3{,}97 \times 10^{-6}$ strain

Borrhål/nivå: KLXO2 Delta l = längdförändringen i mm = strain x l

Prov id	Skalvärde start	Skalvärde vid mätning Datum tempe-ratur	Differens skaldelar	Strain (mm/mm)	Delta l	l	Längdutvidg-ningskoeff mm/mm per grader C	Längdutv mm/mm
1	678	708	30	0,0001191	0,02382	200,0	0,00000596	0,000119
2	67	97	30	0,0001191	0,02382	200,0	0,00000596	0,000119
3	2	29	27	0,00010719	0,021438	200,0	0,00000536	0,000107
4	808	850	42	0,00016674	0,033348	200,0	0,00000834	0,000167
5	97	124	27	0,00010719	0,021438	200,0	0,00000536	0,000107
6	–32	–6	26	0,00010322	0,020644	200,0	0,00000516	0,000103
7	–53	–25	28	0,00011116	0,022232	200,0	0,00000556	0,000111
8	–175	–150	25	0,00009925	0,01985	200,0	0,00000496	0,000099
9	–304	–273	31	0,00012307	0,024614	200,0	0,00000615	0,000123
10	–559	–532	27	0,00010719	0,021438	200,0	0,00000536	0,000107
11	–121	–86	35	0,00013895	0,02779	200,0	0,00000695	0,000139
12	–952	–921	31	0,00012307	0,024614	200,0	0,00000615	0,000123
13	181	215	34	0,00013498	0,026996	200,0	0,00000675	0,000135
14	–244	–214	30	0,0001191	0,02382	200,0	0,00000596	0,000119
15	–77	–54	23	0,00009131	0,018262	200,0	0,00000457	0,000091
16	–118	–88	30	0,0001191	0,02382	200,0	0,00000596	0,000119
17	–102	–75	27	0,00010719	0,021438	200,0	0,00000536	0,000107
18	–138	–108	30	0,0001191	0,02382	200,0	0,00000596	0,000119
0	0	0	0	0	0	200,0	0,00000000	0,000000
0	0	0	0	0	0	200,0	0,00000000	0,000000
0	0	0	0	0	0	200,0	0,00000000	0,000000
0	0	0	0	0	0	200,0	0,00000000	0,000000
	använder sista mät-värdet på 20 grader							
		använder median på 40 gradersmätn						

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479 Tempdifferens 39,15

1 skaldel motsvarar 3,97 mikrostrain = $3{,}97 \times 10^{-6}$ strain

Borrhål/nivå: KLXO2 Delta l = längdförändringen i mm = strain x l

Prov id	Skalvärde start	Skalvärde vid mätning Datum tempe-ratur	Differens skaldelar	Strain (mm/mm)	Delta l	l	Längdutvidg-ningskoeff mm/mm per grader C	Längdutv mm/mm
1	678	701,5	23,5	0,000093295	0,018659	200,0	0,00000238	0,000093
2	67	124	57	0,00022629	0,045258	200,0	0,00000578	0,000226
3	2	59	57	0,00022629	0,045258	200,0	0,00000578	0,000226
4	808	899	91	0,00036127	0,072254	200,0	0,00000923	0,000361
5	97	167	70	0,0002779	0,05558	200,0	0,00000710	0,000278
6	–32	30	62	0,00024614	0,049228	200,0	0,00000629	0,000246
7	–53	25	78	0,00030966	0,061932	200,0	0,00000791	0,000310
8	–175	–117	58	0,00023026	0,046052	200,0	0,00000588	0,000230
9	–304	–252	52	0,00020644	0,041288	200,0	0,00000527	0,000206
10	–559	–515	44	0,00017468	0,034936	200,0	0,00000446	0,000175
11	–121	–45,5	75,5	0,000299735	0,059947	200,0	0,00000766	0,000300
12	–952	–901	51	0,00020247	0,040494	200,0	0,00000517	0,000202
13	181	271	90	0,0003573	0,07146	200,0	0,00000913	0,000357
14	–244	–180	64	0,00025408	0,050816	200,0	0,00000649	0,000254
15	–77	–30	47	0,00018659	0,037318	200,0	0,00000477	0,000187
16	–118	–53,5	64,5	0,000256065	0,051213	200,0	0,00000654	0,000256
17	–102	–46,5	55,5	0,000220335	0,044067	200,0	0,00000563	0,000220
18	–138	–94	44	0,00017468	0,034936	200,0	0,00000446	0,000175
0	0	0	0	0	0	200,0	0,00000000	0,000000
0	0	0	0	0	0	200,0	0,00000000	0,000000
0	0	0	0	0	0	200,0	0,00000000	0,000000
0	0	0	0	0	0	200,0	0,00000000	0,000000
	använder sista mät-värdet på 20 grader							
		använder median på 60 gradersmätn						

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479 Tempdifferens 59,95

1 skaldel motsvarar 3,97 mikrostrain = $3{,}97 \times 10^{-6}$ strain

Borrhål/nivå: KLXO2 Delta l = längdförändringen i mm = strain x l

Prov id	Skalvärde start	Skalvärde vid mätning Datum tempe-ratur	Differens skaldelar	Strain (mm/mm)	Delta l	l	Längdutvidg-ningskoeff mm/mm per grader C	Längdutv mm/mm
1	678	679	1	0,00000397	0,000794	200,0	0,00000007	0,000004
2	67	150	83	0,00032951	0,065902	200,0	0,00000550	0,000330
3	2	105	103	0,00040891	0,081782	200,0	0,00000682	0,000409
4	808	954,5	146,5	0,000581605	0,116321	200,0	0,00000970	0,000582
5	97	223	126	0,00050022	0,100044	200,0	0,00000834	0,000500
6	–32	78,5	110,5	0,000438685	0,087737	200,0	0,00000732	0,000439
7	–53	85	138	0,00054786	0,109572	200,0	0,00000914	0,000548
8	–175	–70,5	104,5	0,000414865	0,082973	200,0	0,00000692	0,000415
9	–304	–239	65	0,00025805	0,05161	200,0	0,00000430	0,000258
10	–559	–597,5	–38,5	–0,000152845	–0,030569	200,0	–0,00000255	–0,000153
11	–121	–3	118	0,00046846	0,093692	200,0	0,00000781	0,000468
12	–952	–879,5	72,5	0,000287825	0,057565	200,0	0,00000480	0,000288
13	181	341,5	160,5	0,000637185	0,127437	200,0	0,00001063	0,000637
14	–244	–140	104	0,00041288	0,082576	200,0	0,00000689	0,000413
15	–77	–4,5	72,5	0,000287825	0,057565	200,0	0,00000480	0,000288
16	–118	–50	68	0,00026996	0,053992	200,0	0,00000450	0,000270
17	–102	–25,5	76,5	0,000303705	0,060741	200,0	0,00000507	0,000304
18	–138	–197,5	–59,5	–0,000236215	–0,047243	200,0	–0,00000394	–0,000236
0	0	0	0	0	0	200,0	0,00000000	0,000000
0	0	0	0	0	0	200,0	0,00000000	0,000000
0	0	0	0	0	0	200,0	0,00000000	0,000000
0	0	0	0	0	0	200,0	0,00000000	0,000000
	använder sista mät-värdet på 20 grader							
		använder median på 60 gradersmätn						

Längdutvidgnings-koeff	Borrhål: KLXO2				Längdutvidgning				
Temperatur/ mm/mm per grader C	20,4	40,4	59,55	80,35	Temperatur / mm/mm	20	40,4	59,55	80,35
KLX02-90L-1	0	0,000005955	0,000002383	0,0000000662	1	0	0,0001191	0,000093295	0,00000397
KLX02-90L-2	0	0,000005955	0,0000057801	0,0000054964	2	0	0,0001191	0,00022629	0,00032951
KLX02-90L-3	0	0,0000053595	0,0000057801	0,0000068209	3	0	0,00010719	0,00022629	0,00040891
KLX02-90L-4	0	0,000008337	0,0000092278	0,0000097015	4	0	0,00016674	0,00036127	0,000581605
KLX02-90L-5	0	0,0000053595	0,0000070983	0,000008344	5	0	0,00010719	0,0002779	0,00050022
KLX02-90L-6	0	0,000005161	0,0000062871	0,0000073175	6	0	0,00010322	0,00024614	0,000438685
KLX02-90L-7	0	0,000005558	0,0000079096	0,0000091386	7	0	0,00011116	0,00030966	0,00054786
KLX02-90L-8	0	0,0000049625	0,0000058815	0,0000069202	8	0	0,00009925	0,00023026	0,000414865
KLX02-90L-9	0	0,0000061535	0,0000052731	0,0000043044	9	0	0,00012307	0,00020644	0,00025805
KLX02-90L-10	0	0,0000053595	0,0000044618	–0,0000025495	10	0	0,00010719	0,00017468	–0,000152845
KLX02-90L-11	0	0,0000069475	0,0000076561	0,0000078142	11	0	0,00013895	0,000299735	0,00046846
KLX02-90L-12	0	0,0000061535	0,0000051716	0,0000048011	12	0	0,00012307	0,00020247	0,000287825
KLX02-90L-13	0	0,000006749	0,0000091264	0,0000106286	13	0	0,00013498	0,0003573	0,000637185
KLX02-90L-14	0	0,000005955	0,0000064899	0,0000068871	14	0	0,0001191	0,00025408	0,00041288
KLX02-90L-15	0	0,0000045655	0,000004766	0,0000048011	15	0	0,00009131	0,00018659	0,000287825
KLX02-90L-16	0	0,000005955	0,0000065406	0,0000045031	16	0	0,0001191	0,000256065	0,00026996
KLX02-90L-17	0	0,0000053595	0,000005628	0,000005066	17	0	0,00010719	0,000220335	0,000303705
KLX02-90L-18	0	0,000005955	0,0000044618	–0,0000039402	18	0	0,0001191	0,00017468	–0,000236215

Appendix 2

Determination of wet density

Vattenmättnadsdensitet

KLXO2 Uppdrags nr: P304311
Metod: EN 13755, ISRM (1973), avsnitt 3 samt SKB MD 160.002 version 1.0
Provad av: Lej
Datum: 9/16/04

	Prov-märkning:	Vikt i vatten, Msub (g)	Yttor vikt, Msat (g)	Yttorr vikt, Ms (g)	Bulk volume, V (cm^3)	Pore volume, Vv (cm^3)	Porosity, n (%)	Dry density, ρd (g/cm^3)	Wet density (g/cm^3)
1	KLXO2-1	711,96	1133,91		422,44	1135,22	268,73	0,000	2,684
2	2	714,37	1136,53		422,65	1137,84	269,22	0,000	2,689
3	3	712,66	1134,46		422,29	1135,77	268,96	0,000	2,686
4	4	710,80	1132,7		422,39	1134,00	268,48	0,000	2,682
5	5	707,95	1130,33		422,87	1131,63	267,61	0,000	2,673
6	6	710,07	1132,39		422,81	1133,69	268,14	0,000	2,678
7	7	734,52	1158,99		424,96	1160,32	273,04	0,000	2,727
8	8	732,78	1157,34		425,05	1158,67	272,60	0,000	2,723
9	9	733,84	1158,61		425,26	1159,94	272,76	0,000	2,724
10	10	697,05	1108,94		412,36	1110,22	269,23	0,000	2,689
11	11	696,33	1108,66		412,80	1109,94	268,88	0,000	2,686
12	12	695,21	1106,47		411,73	1107,74	269,04	0,000	2,687
13	13	710,69	1134,82		424,62	1136,13	267,56	0,000	2,673
14	14	710,62	1134,73		424,60	1136,04	267,56	0,000	2,672
15	15	716,83	1141,49		425,15	1142,80	268,80	0,000	2,685
16	16	716,69	1141,63		425,43	1142,94	268,66	0,000	2,683
17	17	719,77	1145,17		425,89	1146,49	269,20	0,000	2,689
18	18	718,72	1144,05		425,82	1145,37	268,98	0,000	2,687
19					0,00	0,00	#DIV/0!	#DIV/0!	#DIV/0!
20					0,00	0,00	#DIV/0!	#DIV/0!	#DIV/0!
21					0,00	0,00	#DIV/0!	#DIV/0!	#DIV/0!

Vattnets temperatur ºC):	16,5	Våg, inv.nr:	102291
Vattnets desitet (ºC):	0,99885	Termometer, inv.nr:	102080