P-04-269

Oskarshamn site investigation

Drill hole KLX04A

Extensometer measurement of the coefficient of thermal expansion of rock

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Swedish National Testing and Research Institute

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 KLX04A. The specimens were sampled from three levels in the drill hole at a depth of approximately 310, 560 and 740 m. The main rock type was 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 4.6 and 10.0 × 10^{-6} mm/mm°C.

Sammanfattning

Längdutvidgningskoefficienten och våtdensiteten har bestämts på prover från borrhål KLX04A. Proverna kommer från tre olika nivåer i borrhålet, på ett ungefärligt djup av 310, 560 och 740 m. Huvudbergarten är karterad som Ävrö granit. Längdutvidgnings-koefficienten bestämdes inom temperaturintervallet 20–80°C. Resultaten indikerade att längdutvidgningen var nästan linjär och längdutvidgningskoefficienten för de undersökta proverna varierade mellan 4.6 och 10.0 × 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 400-04-073 Ver 1.0 (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 KLX04A in the Laxemar area (Figure 1-1). They were sampled 2 July 2004 by Thomas Janson, Tyréns AB and Rolf Christiansson, SKB. The specimens were taken from three levels at depths of approximately 310, 560 and 740 m. The rock cores were transported by SKB and arrived to SP in August 2004. The testing was performed in September 2004 (see Appendix 1).

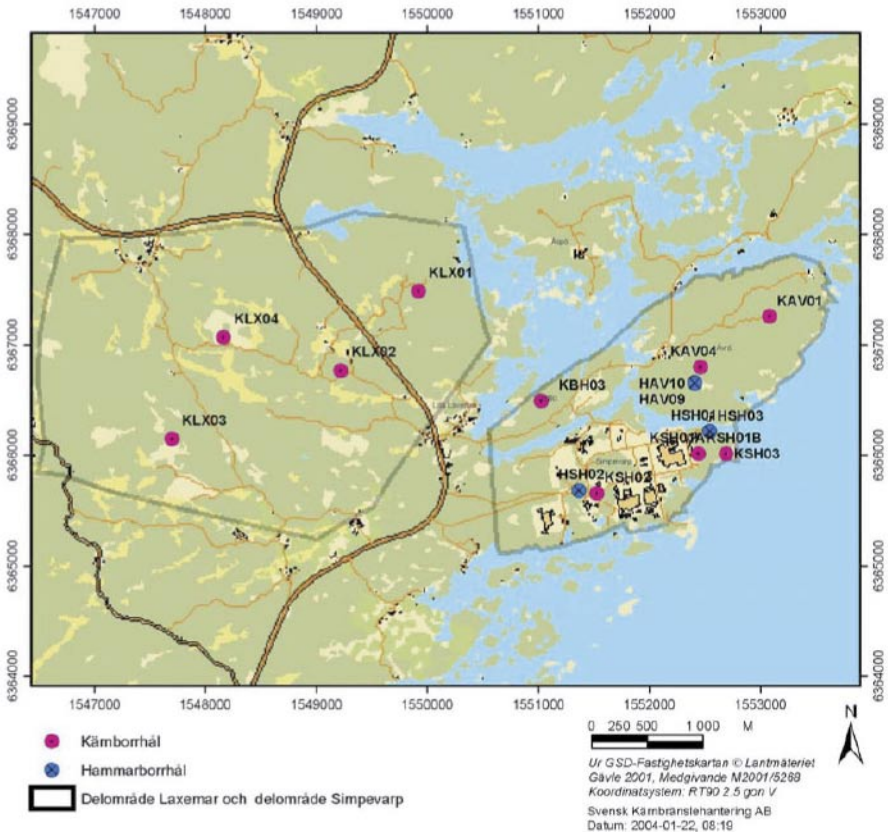


Figure 1-1. *The Laxemar investigation area.*

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 Oskarshamn 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 $\pm 3.97 \times 10^{-6}$ mm/mm (strain), which equals an uncertainty of a single measurement of the coefficient of thermal expansion of $\pm 0.2 \times 10^{-6}$ mm/mm°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 310, 560 and 740 m, in drill hole KLX04A. The sampled rock type was 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 bore map (Sec low)
Ävrö granite	KLX04A-90L-1	309.15
Ävrö granite	KLX04A-90L-2	313.03
Ävrö granite	KLX04A-90L-3	313.28
Ävrö granite	KLX04A-90L-4	305.53
Ävrö granite	KLX04A-90L-5	306.13
Ävrö granite	KLX04A-90L-6	306.38
Ävrö granite	KLX04A-90L-7	560.84
Ävrö granite	KLX04A-90L-8	561.14
Ävrö granite	KLX04A-90L-9	562.51
Ävrö granite	KLX04A-90L-10	562.76
Ävrö granite	KLX04A-90L-11	564.48
Ävrö granite	KLX04A-90L-12	564.73
Ävrö granite	KLX04A-90L-13	737.37
Ävrö granite	KLX04A-90L-14	737.62
Ävrö granite	KLX04A-90L-15	737.94
Ävrö granite	KLX04A-90L-16	738.19
Ävrö granite	KLX04A-90L-17	738.51
Ävrö granite	KLX04A-90L-18	738.76

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 KLX04A could be found in the database SICADA FN 428.

5.1 Description of the specimens and presentation of the results

The temperature of water for water saturation was 17.1°C and the density of the water was 999 kg/m^3. The coefficient of thermal expansion was determined between +20-80°C.

KLX04A-90L-1 (309.15 m)

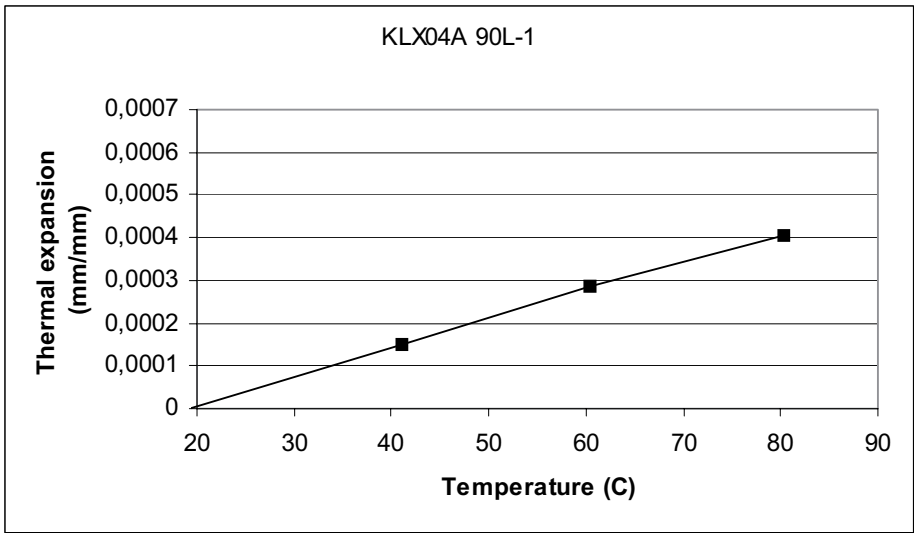


Figure 5-1. *Diagram showing the thermal expansion of specimen KLX04-90L-1 between 20 and 80°C, median values plotted.*

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 coefficient of thermal expansion for specimen KLX04A-90L-1 was measured to be 6.6 × 10^{-6} mm/mm°C and the specimen had a wet density to 2,671 kg/m^3.

KLX04A-90L-2 (313.03 m)

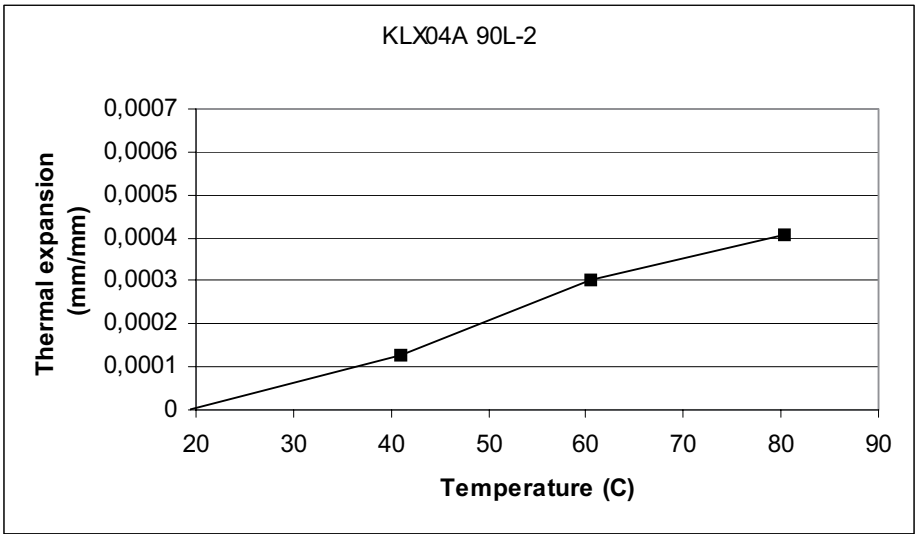


Figure 5-2. *Diagram showing the thermal expansion of specimen KLX04-90L-2 between 20 and 80°C, median values plotted.*

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 KLX04-90L-2 was measured to be 6.6×10^{-6} mm/mm°C and the specimen had a wet density of 2,675 kg/m^3.

KLX04A-90L-3 (313.28 m)

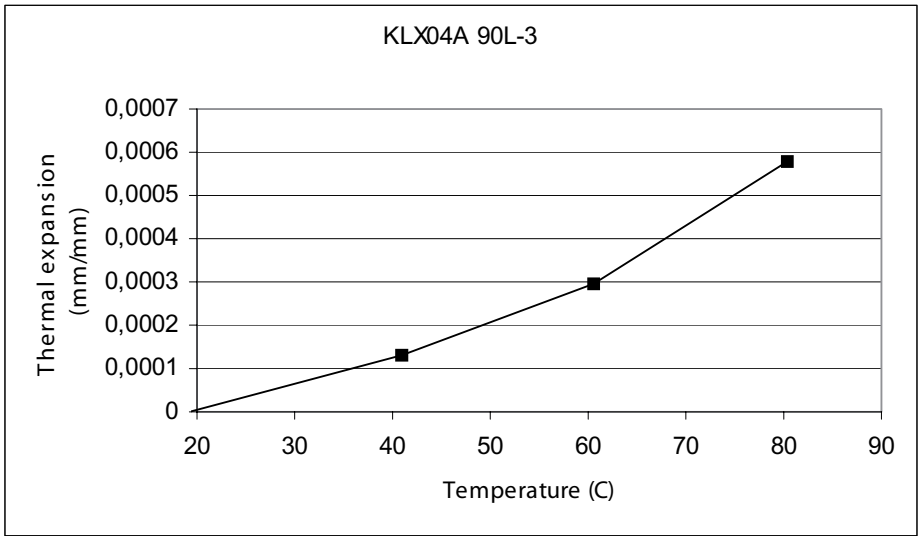
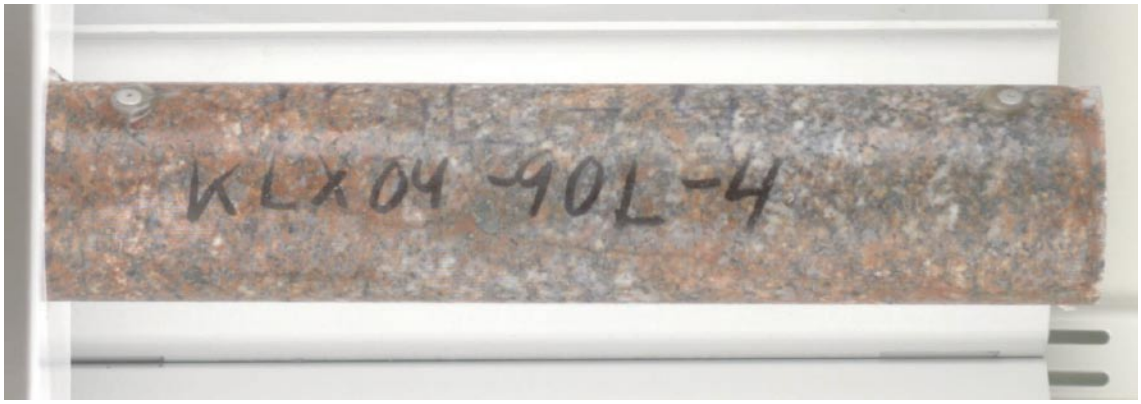


Figure 5-3. *Diagram showing the thermal expansion of specimen KLX04A-90L-3 between 20 and 80°C, median values plotted.*

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 KLX04A-90L-3 was measured to be 9.5×10^{-6} mm/mm°C and the specimen had a wet density of 2,677 kg/m^3.

KLX04A-90L-4 (305.53 m)



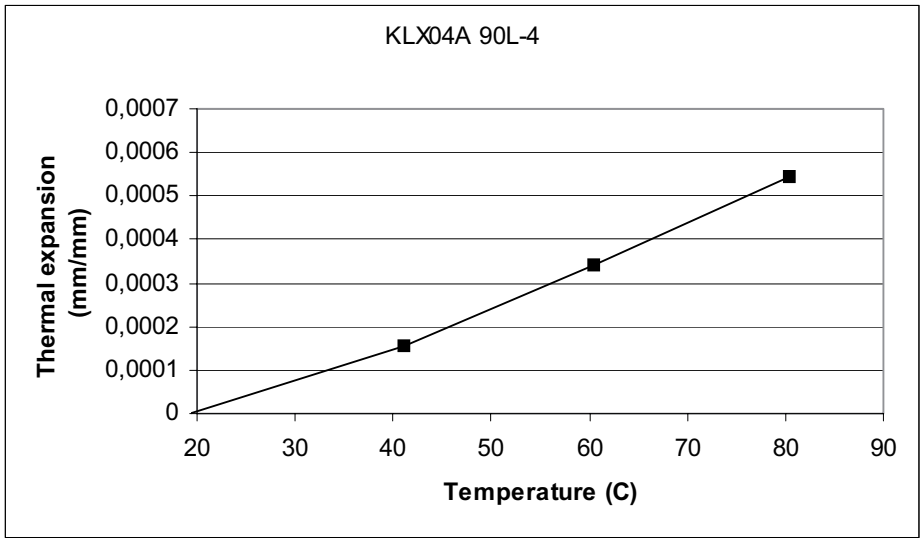


Figure 5-4. *Diagram showing the thermal expansion of specimen KLX04A-90L-4 between 20 and 80°C, median values plotted.*

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 KLX04A-90L-4 was measured to be 8.9×10^{-6} mm/mm°C and the specimen had a wet density of 2,664 kg/m^3.

KLX04A-90L-5 (306,13 m)

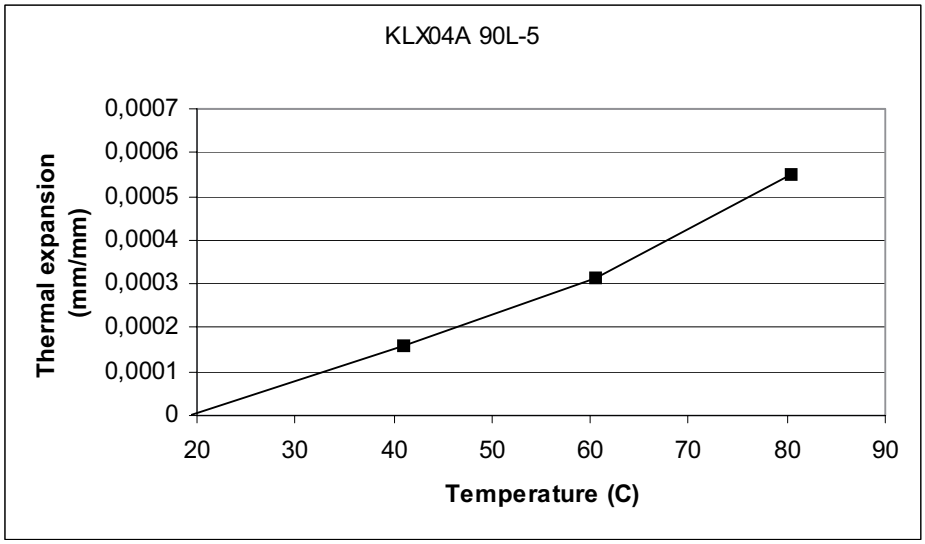


Figure 5-5. *Diagram showing the thermal expansion of specimen KLX04A-90L-5 between 20 and 80°C, median values plotted.*

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 KLX04A-90L-5 was measured to be 9.0×10^{-6} mm/mm°C and the specimen had a wet density of 2,669 kg/m^3.

KLX04A-90L-6 (306.38 m)

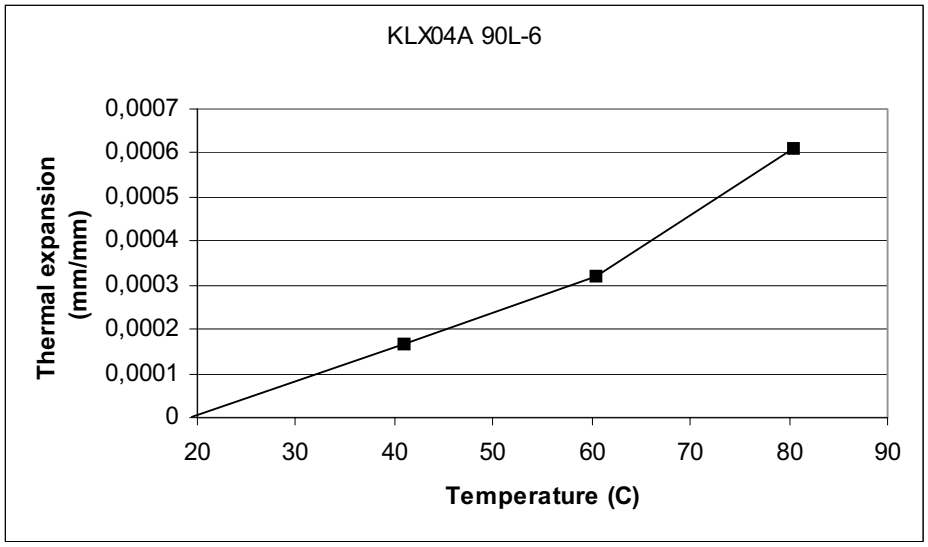
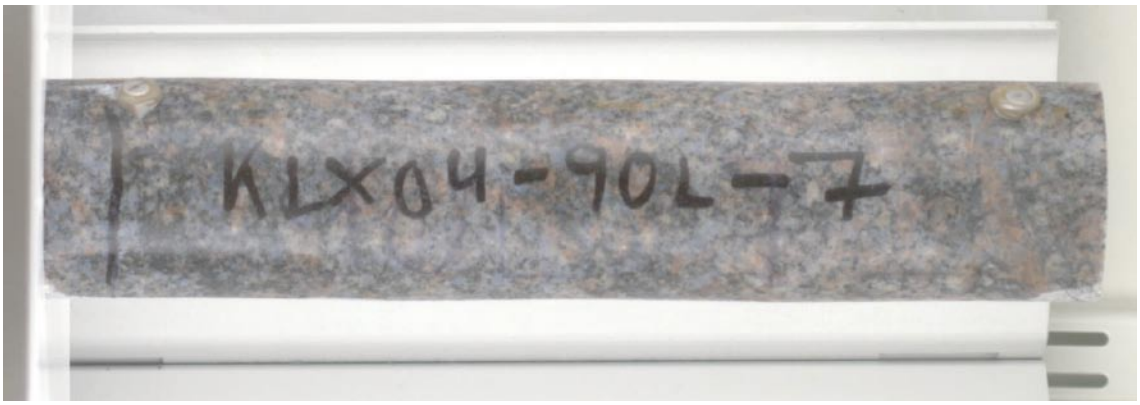


Figure 5-6. *Diagram showing the thermal expansion of specimen KLX04A-90L-6 between 20 and 80°C, median values plotted.*

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 KLX04A-90L-6 was measured to be 10.0×10^{-6} mm/mm°C and the specimen had a wet density of 2,670 kg/m^3.

KLX04A-90L-7 (560.84 m)



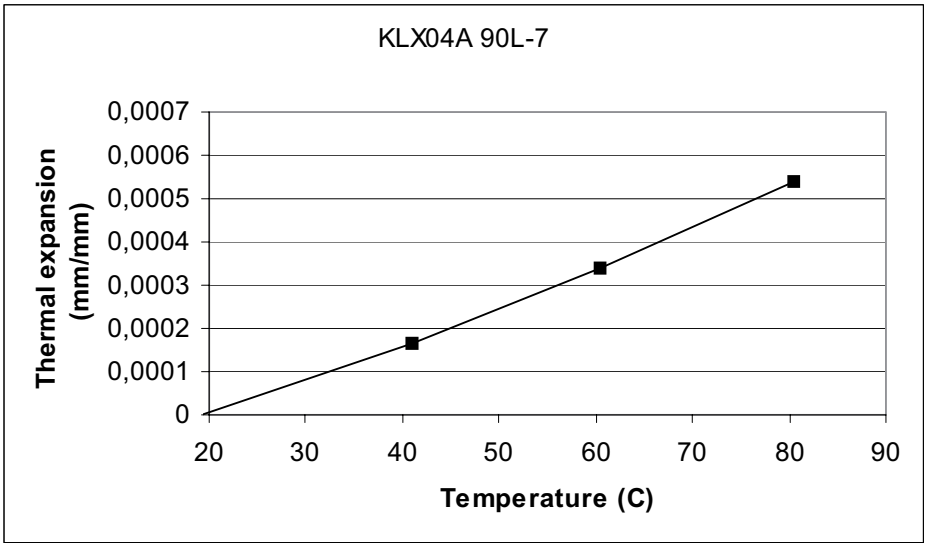


Figure 5-7. *Diagram showing the thermal expansion of specimen KLX04A-90L-7 between 20 and 80°C, median values plotted.*

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 KLX04A-90L-7 was measured to be 8.8×10^{-6} mm/mm°C, and the specimen had a wet density of 2,685 kg/m^3.

KLX04A-90L-8 (561.14 m)

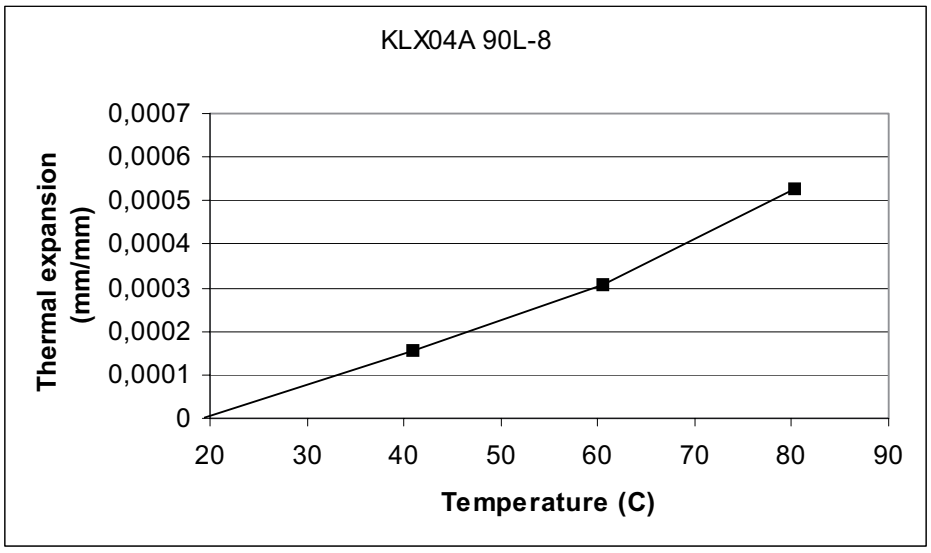


Figure 5-8. *Diagram showing the thermal expansion of specimen KLX02-90L-8 between 20 and 80°C, median values plotted.*

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 KLX04A-90L-8 was measured to be 8.6×10^{-6} mm/mm°C and the specimen had a wet density of 2,677 kg/m^3.

KLX04A-90L-9 (562.51 m)

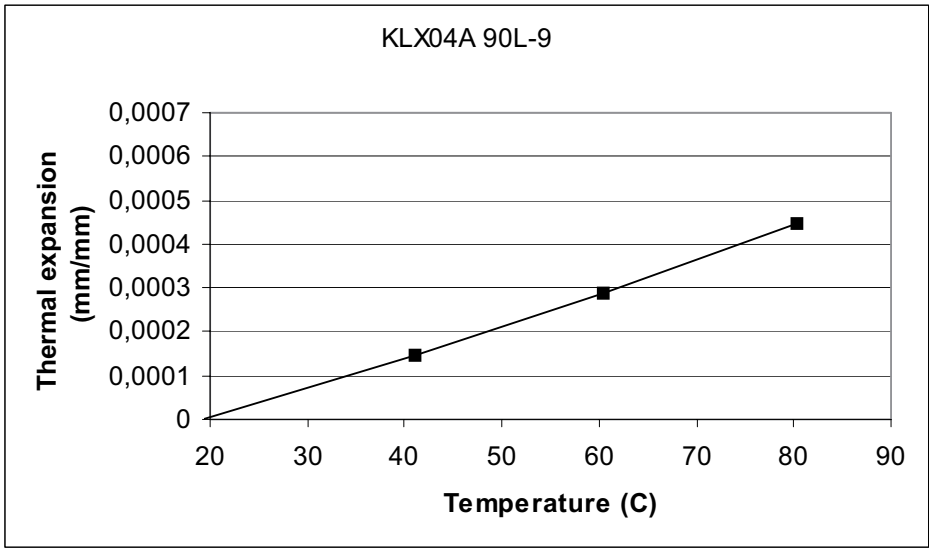


Figure 5-9. *Diagram showing the thermal expansion of specimen KLX04A-90L-9 between 20 and 80°C, median values plotted.*

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 KLX04A-90L-9 was measured to be 7.3×10^{-6} mm/mm°C and the specimen had a wet density of 2,719 kg/m^3.

KLX04A-90L-10 (562.76 m)

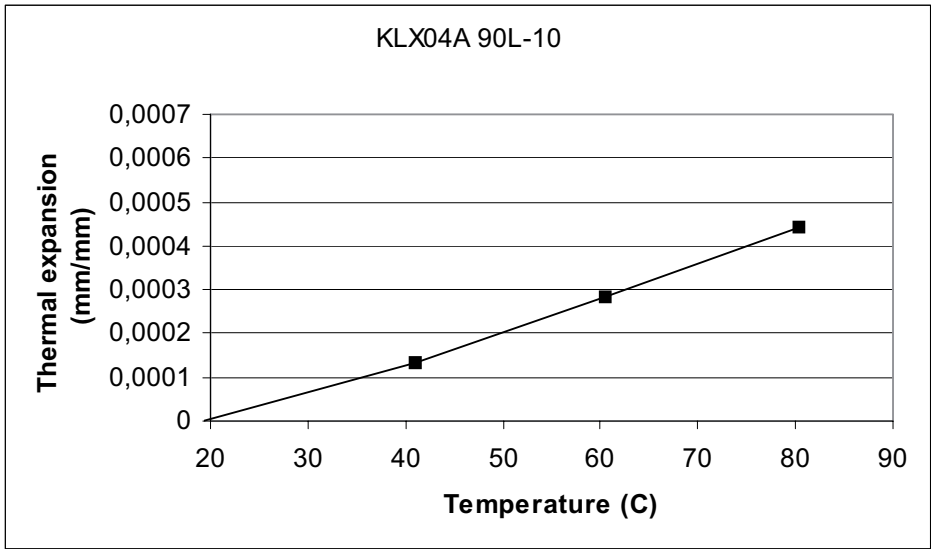


Figure 5-10. *Diagram showing the thermal expansion of specimen KLX04A-90L-10 between 20 and 80°C, median values plotted.*

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 coefficient of thermal expansion for specimen KLX04A-90L-10 was measured to be 7.2×10^{-6} mm/mm°C and the specimen had a wet density of 2,733 kg/m^3.

KLX04A-90L-11 (564.48 m)

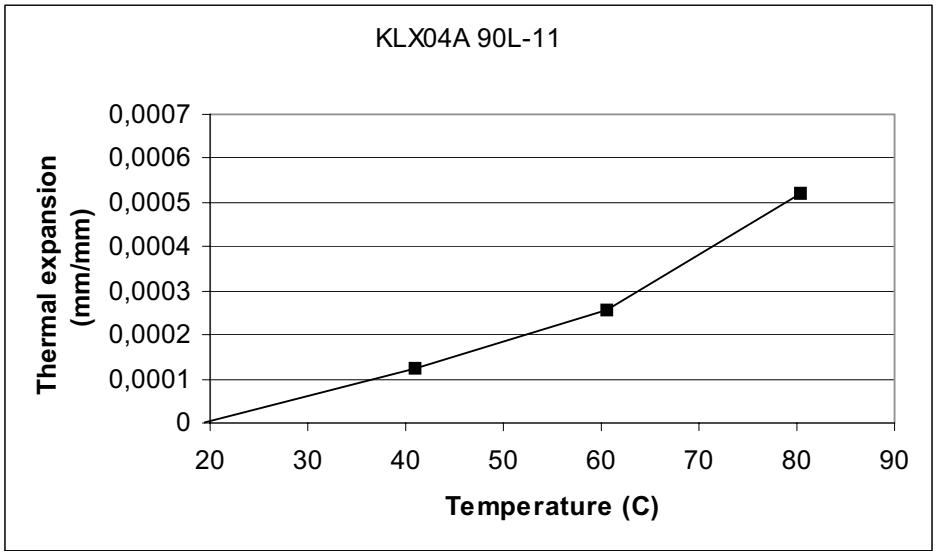


Figure 5-11. *Diagram showing the thermal expansion of specimen KLX02-90L-11 between 20 and 80°C, median values plotted.*

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 KLX04A-90L-11 was measured to be 8.5×10^{-6} mm/mm°C and the specimen had a wet density of 2,724 kg/m^3.

KLX0A4-90L-12 (564.73 m)

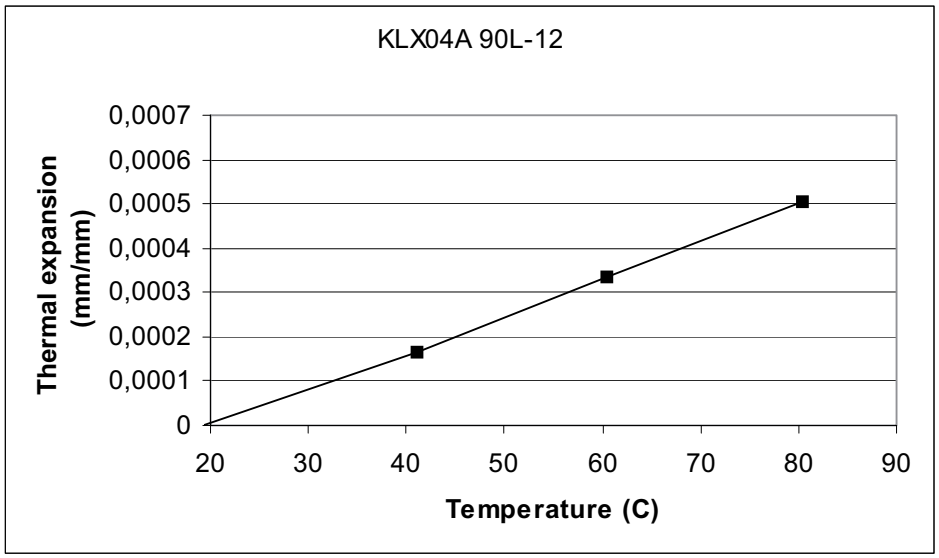


Figure 5-12. *Diagram showing the thermal expansion of specimen KLX04A-90L-12 between 20 and 80°C, median values plotted.*

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 KLX04A-90L-12 was measured to be 8.3×10^{-6} mm/mm°C and the specimen had a wet density of 2,760 kg/m^3.

KLX04A-90L-13 (737.37 m)

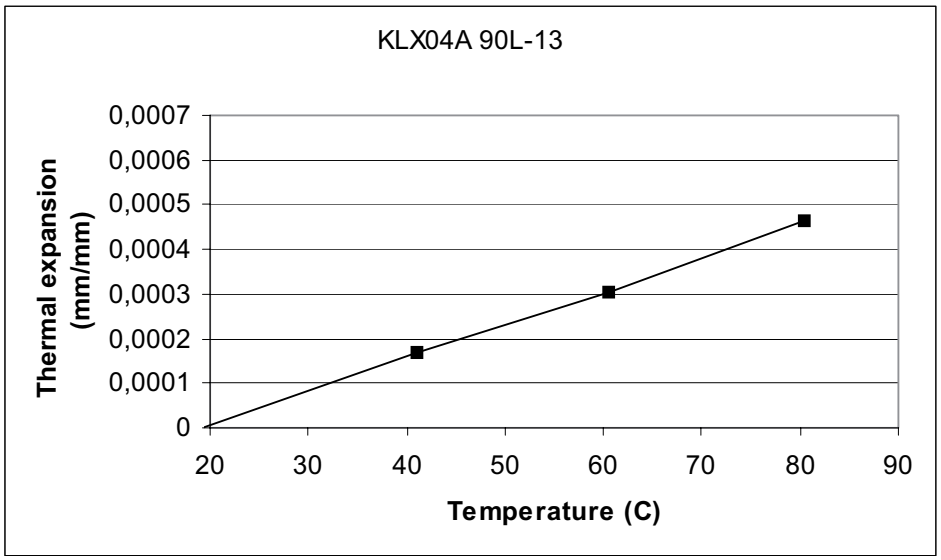


Figure 5-13. *Diagram showing the thermal expansion of specimen KLX04A-90L-13 between 20 and 80°C, median values plotted.*

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 KLX04A-90L-13 was measured to be 7.6×10^{-6} mm/mm°C and the specimen had a wet density of 2,684 kg/m^3.

KLX04A-90L-14 (737.62 m)

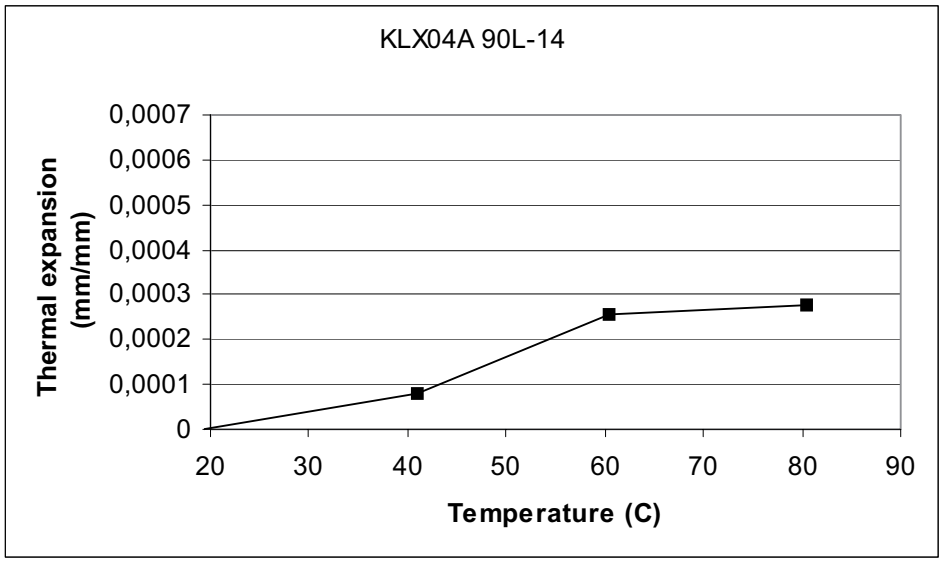


Figure 5-14. *Diagram showing the thermal expansion of specimen KLX02-90L-14 between 20 and 80°C, median values plotted.*

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 KLX04A-90L-14 was measured to be 4.6×10^{-6} mm/mm°C and the specimen had a wet density of 2,683 kg/m^3.

KLX04A-90L-15 (737.94 m)

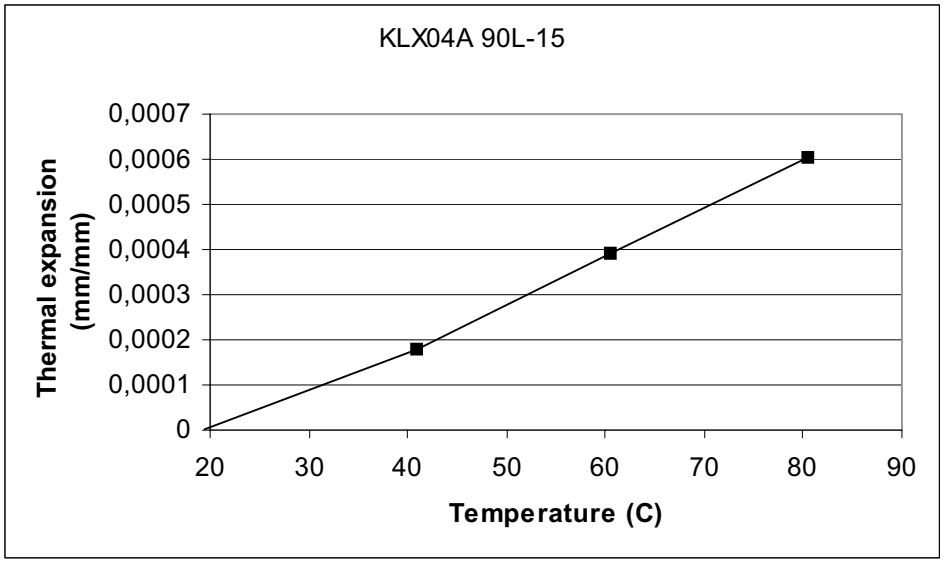


Figure 5-15. *Diagram showing the thermal expansion of specimen KLX04A-90L-15 between 20 and 80°C, median values plotted.*

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 KLX04A-90L-15 was measured to be 9.9×10^{-6} mm/mm°C and the specimen had a wet density of 2,676 kg/m^3.

KLX04A-90L-16 (738.19 m)

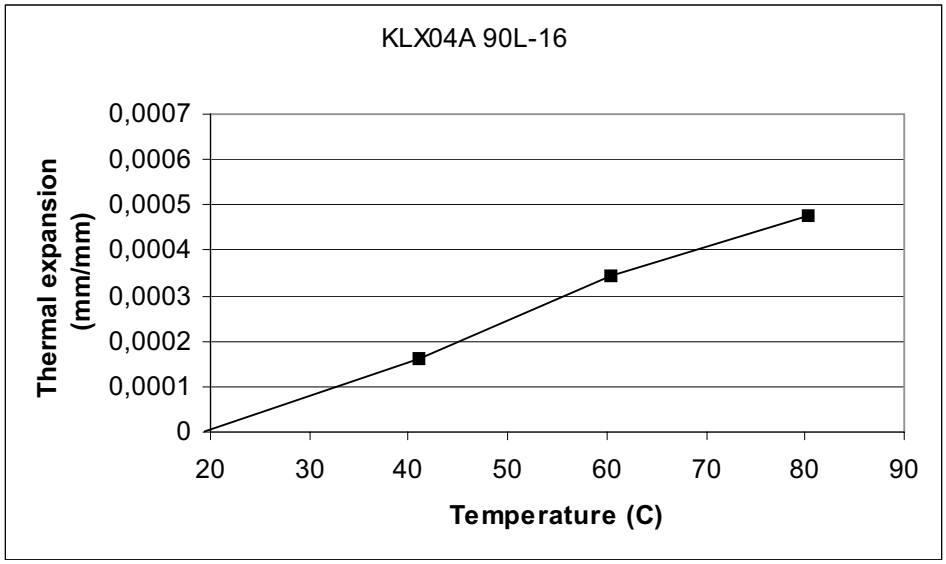


Figure 5-16. *Diagram showing the thermal expansion of specimen KLX04A-90L-16 between 20 and 80°C, median values plotted.*

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 KLX04A-90L-16 was measured to be 7.8×10^{-6} mm/mm°C and the specimen had a wet density of 2,678 kg/m^3.

KLX04A-90L-17 (738.51 m)

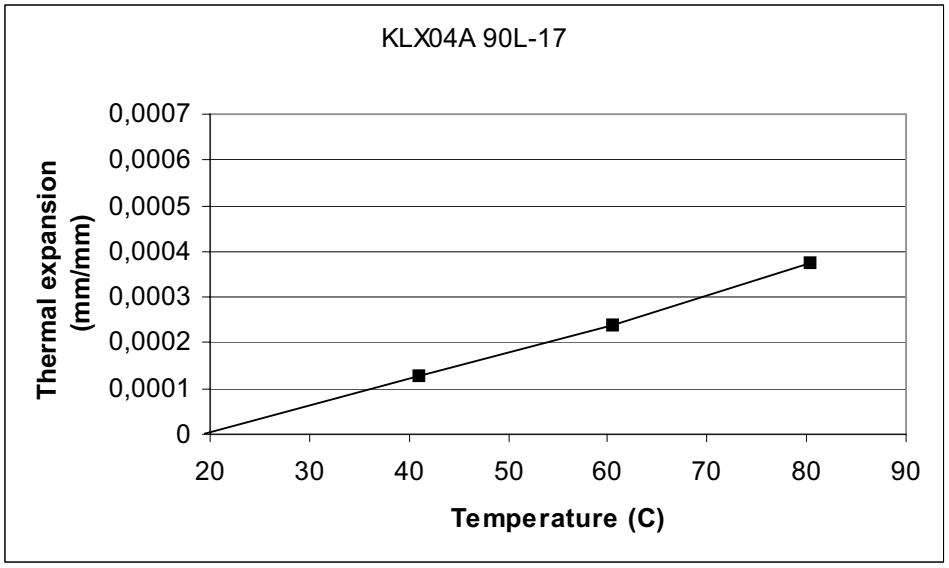


Figure 5-17. *Diagram showing the thermal expansion of specimen KLX04A-90L-17 between 20 and 80°C, median values plotted.*

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 KLX04A-90L-17 was measured to be 6.1×10^{-6} mm/mm°C and the specimen had a wet density of 2,681 kg/m^3.

KLX04A-90L-18 (738.76 m)

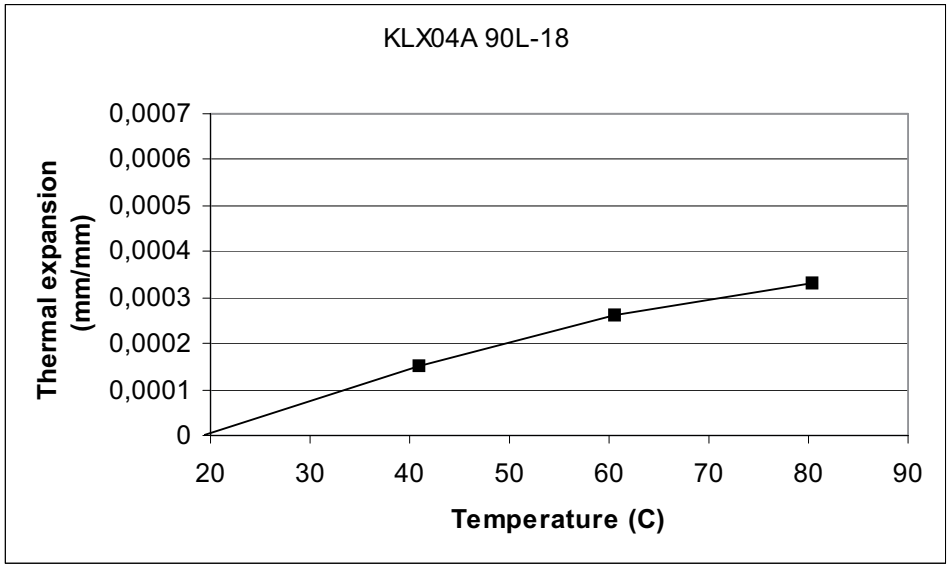


Figure 5-18. *Diagram showing the thermal expansion of specimen KLX04A-90L-18 between 20 and 80°C, median values plotted.*

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 coefficient of thermal expansion for specimen KLX04A-90L-18 at was measured to be 5.5×10^{-6} mm/mm°C and the specimen had a wet density to 2,677 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	Coefficient of thermal expansion between 20 and 80°C (mm/mm°C)	Wet density (kg/m^3)
KLX04A-90L-1	6.6×10^{-6}	2,671
KLX04A-90L-2	6.6×10^{-6}	2,675
KLX04A-90L-3	9.5×10^{-6}	2,677
KLX04A-90L-4	8.9×10^{-6}	2,664
KLX04A-90L-5	9.0×10^{-6}	2,669
KLX04A-90L-6	10.0×10^{-6}	2,670
Median	8.9×10^{-6}	
Maximum value	10.0×10^{-6}	
Minimum value	6.6×10^{-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	Coefficient of thermal expansion between 20 and 80°C (mm/mm°C)	Wet density (kg/m^3)
KLX04A-90L-7	8.8×10^{-6}	2,685
KLX04A-90L-8	8.6×10^{-6}	2,677
KLX04A-90L-9	7.3×10^{-6}	2,719
KLX04A-90L-10	7.2×10^{-6}	2,733
KLX04A-90L-11	8.5×10^{-6}	2,724
KLX04A-90L-12	8.3×10^{-6}	2,760
Median	8.4×10^{-6}	
Maximum value	8.8×10^{-6}	
Minimum value	7.2×10^{-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	Coefficient of thermal expansion between 20 and 80°C (mm/mm°C)	Wet density (kg/m^3)
KLX04A-90L-13	7.6×10^{-6}	2,673
KLX04-A90L-14	4.6×10^{-6}	2,672
KLX04A-90L-15	9.9×10^{-6}	2,685
KLX04A-90L-16	7.8×10^{-6}	2,683
KLX04A-90L-17	6.1×10^{-6}	2,689
KLX04A-90L-18	5.5×10^{-6}	2,687
Median	6.9×10^{-6}	
Maximum value	9.9×10^{-6}	
Minimum value	4.6×10^{-6}	

5.3 Discussion

The variation between the specimens is approximately 5.4×10^{-6} mm/mm°C, which is approximately 27 times the uncertainty of the measurement (0.2×10^{-6} mm/mm°C). It has not been observed any lost of demec studs. The diagrams show that the thermal expansion have been rather linear for all specimens, except for specimen KLX04A-90L-14 where thermal expansion decreases considerably after 60°C. This could be due to bowing of the specimen, since any lost of demec studs has been observed. For the other specimens, it is suggested that the variation of the results are related to the difference in geological properties.

References

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

Appendix 1

Determination of the linear coefficient of thermal expansion

Uppdragsnummer:	P402277
Borrhål:	KLXO4
Metod:	
Provkroppar som provas se nästa blad	

Provberedning	**Datum**	**Sign**
Sågning:	8/13/04	Lej
Foto:	10/13/04	UÅ
Vattenmättnad start datum:	8/20/04	Lej
Vägning vattenmättat yttorrt tillstånd:		
Provning start:	8/27/04	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: **P402277**
Borrhål: **KLXO4**

					Median
Mättemperatur	**19,3** C	C	C	19,3 C	19,3
			värde i grön kolumn använd vid beräkning		

Prov ID	Skalvärde/datum	Skalvärde/datum	Skalvärde/datum	Skalvärde/datum	**Median**
1				380	380,00
2				107	107,00
3				–73	–73,00
4				27	27,00
5				12	12,00
6				–17	–17,00
7				8	8,00
8				–2238	–2238,00
9				–1872	–1872,00
10				106	106,00
11				164	164,00
12				31	31,00
13				–38	–38,00
14				4	4,00
15				93	93,00
16				7	7,00
17				–945	–945,00
18				–499	–499,00

Provningsprotokoll längdutvidgningskoefficient

Uppdrags nummer: **P402277**

Borrhål: **KLXO4**

									Median
Mättemperatur	**40,2**	C	41,3	C	41	C		C	41
					värdet i grön kolumn används vid beräkning				
Prov ID	Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		**Median**
1	408	04/08/30	432	04/08/31	418				418
2	131		140		139				139
3	–49		–37		–40				–40
4	45		66		66				66
5	18		52		53				52
6	43		23		25				25
7	42		52		50				50
8	–2162		–2200		–2199				–2199
9	–1826		–1836		–1835				–1835
10	138		140		140				140
11	195		196		195				195
12	71		73		75				73
13	1		4		5				4
14	24		24		25				24
15	132		138		140				138
16	47		48		50				48
17	–913		–913		–915				–913
18	–462		–461		–459				–461

Provningsprotokoll längdutvidgningskoefficient

Uppdrags nummer: **P402277**
Borrhål: **KLXO4**

									Median
Mättemperatur	**60,6**	C	60,4	C	60,5	C	60,5	C	60,5
					värdet i grön kolumn används vid beräkning				
Prov ID	Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		**Median**
1	454	04/09/02	455	04/09/03	451	04/09/06	449		452,5
2	181		184		182		184		183
3	–4		–1		4		4		1,5
4	105		109		117		117		113
5	85		90		93		92		91
6	61		62		70		66		64
7	91		93		95		94		93,5
8	–2167		–2167		–2153		–2154		–2160,5
9	–1802		–1799		–1795		–1799		–1799
10	173		175		180		180		177,5
11	223		226		231		232		228,5
12	110		113		118		118		115,5
13	38		39		40		39		39
14	57		67		70		72		68,5
15	180		186		197		197		191,5
16	85		90		98		97		93,5
17	–885		–887		–883		–884		–884,5
18	–430		–434		–433		–434		–433,5

Provningsprotokoll längdutvidgningskoefficient

Uppdrags nummer: **P402277**

Borrhål: **KLXO4**

									Median
Mättemperatur	**60,6**	C	60,4	C	60,5	C	60,5	C	60,5
					värdet i grön kolumn används vid beräkning				
Prov ID	Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		**Median**
1	454	04/09/02	455	04/09/03	451	04/09/06	449		452,5
2	181		184		182		184		183
3	–4		–1		4		4		1,5
4	105		109		117		117		113
5	85		90		93		92		91
6	61		62		70		66		64
7	91		93		95		94		93,5
8	–2167		–2167		–2153		–2154		–2160,5
9	–1802		–1799		–1795		–1799		–1799
10	173		175		180		180		177,5
11	223		226		231		232		228,5
12	110		113		118		118		115,5
13	38		39		40		39		39
14	57		67		70		72		68,5
15	180		186		197		197		191,5
16	85		90		98		97		93,5
17	–885		–887		–883		–884		–884,5
18	–430		–434		–433		–434		–433,5

Provningsprotokoll längdutvidgningskoefficient

Uppdrags nummer: **P402277**
Borrhål: **KLXO4**

									Median
Mättemperatur	**80,5**	C	80,3	C	80,3	C	80,5	C	80,4
					värdet i grön kolumn används vid beräkning				
Prov ID	Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		**Median**
1	482	04/09/08	479	04/09/09	482	04/09/10	483		482
2	196		205		223		213		209
3	68		73		73		73		73
4	159		163		165		167		164
5	142		149		152		151		150
6	133		135		138		140		136,5
7	136		144		143		144		143,5
8	–2106		–2110		–2105		–2098		–2105,5
9	–1761		–1763		–1759		–1756		–1760
10	218		217		215		219		217,5
11	288		296		297		295		295,5
12	157		156		159		160		158
13	78		79		80		79		79
14	74		74		73		78		74
15	244		244		247		248		245,5
16	128		124		126		127		126,5
17	–849		–850		–852		–851		–850,5
18	–410		–411		–419		–419		–415

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479 Tempdifferens 21,7

1 skaldel motsvarar 3,97 mikrostrain = 3,97x10^{-6} strain

Borrhål/nivå: KLXO4 Delta l = längdförändringen i mm = strain x l

Prov id	Skalvärde start	Skalvärde vid mätning datum temperatur	Differens skaldelar	strain (mm/mm)	Delta l	l	Längdutvidg-ningskoeff mm/mm per grader C	Längdutv mm/mm
1	380	418	38	0,00015086	0,030172	200,0	0,00000695	0,000151
2	107	139	32	0,00012704	0,025408	200,0	0,00000585	0,000127
3	–73	–40	33	0,00013101	0,026202	200,0	0,00000604	0,000131
4	27	66	39	0,00015483	0,030966	200,0	0,00000714	0,000155
5	12	52	40	0,0001588	0,03176	200,0	0,00000732	0,000159
6	–17	25	42	0,00016674	0,033348	200,0	0,00000768	0,000167
7	8	50	42	0,00016674	0,033348	200,0	0,00000768	0,000167
8	–2238	–2199	39	0,00015483	0,030966	200,0	0,00000714	0,000155
9	–1872	–1835	37	0,00014689	0,029378	200,0	0,00000677	0,000147
10	106	140	34	0,00013498	0,026996	200,0	0,00000622	0,000135
11	164	195	31	0,00012307	0,024614	200,0	0,00000567	0,000123
12	31	73	42	0,00016674	0,033348	200,0	0,00000768	0,000167
13	–38	4	42	0,00016674	0,033348	200,0	0,00000768	0,000167
14	4	24	20	0,0000794	0,01588	200,0	0,00000366	0,000079
15	93	138	45	0,00017865	0,03573	200,0	0,00000823	0,000179
16	7	48	41	0,00016277	0,032554	200,0	0,00000750	0,000163
17	–945	–913	32	0,00012704	0,025408	200,0	0,00000585	0,000127
18	–499	–461	38	0,00015086	0,030172	200,0	0,00000695	0,000151

använder sista mätvärdet på 20 grader

använder median på 40 gradersmätn

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479 Tempdifferens 41,2

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

Borrhål/nivå: KLXO4 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	380	452,5	72,5	0,000287825	0,057565	200,0	0,00000699	0,000288
2	107	183	76	0,00030172	0,060344	200,0	0,00000732	0,000302
3	–73	1,5	74,5	0,000295765	0,059153	200,0	0,00000718	0,000296
4	27	113	86	0,00034142	0,068284	200,0	0,00000829	0,000341
5	12	91	79	0,00031363	0,062726	200,0	0,00000761	0,000314
6	–17	64	81	0,00032157	0,064314	200,0	0,00000781	0,000322
7	8	93,5	85,5	0,000339435	0,067887	200,0	0,00000824	0,000339
8	–2238	–2160,5	77,5	0,000307675	0,061535	200,0	0,00000747	0,000308
9	–1872	–1799	73	0,00028981	0,057962	200,0	0,00000703	0,000290
10	106	177,5	71,5	0,000283855	0,056771	200,0	0,00000689	0,000284
11	164	228,5	64,5	0,000256065	0,051213	200,0	0,00000622	0,000256
12	31	115,5	84,5	0,000335465	0,067093	200,0	0,00000814	0,000335
13	–38	39	77	0,00030569	0,061138	200,0	0,00000742	0,000306
14	4	68,5	64,5	0,000256065	0,051213	200,0	0,00000622	0,000256
15	93	191,5	98,5	0,000391045	0,078209	200,0	0,00000949	0,000391
16	7	93,5	86,5	0,000343405	0,068681	200,0	0,00000834	0,000343
17	–945	–884,5	60,5	0,000240185	0,048037	200,0	0,00000583	0,000240
18	–499	–433,5	65,5	0,000260035	0,052007	200,0	0,00000631	0,000260

använder sista mätvärdet på 20 grader

använder median på 60 gradersmätn

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479 Tempdifferens 61,1

1 skaldel motsvarar 3,97 mikrostrain = 3,97x10^{-6} strain

Borrhål/nivå: KLXO4 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	380	482	102	0,00040494	0,080988	200,0	0,00000663	0,000405
2	107	209	102	0,00040494	0,080988	200,0	0,00000663	0,000405
3	–73	73	146	0,00057962	0,115924	200,0	0,00000949	0,000580
4	27	164	137	0,00054389	0,108778	200,0	0,00000890	0,000544
5	12	150	138	0,00054786	0,109572	200,0	0,00000897	0,000548
6	–17	136,5	153,5	0,000609395	0,121879	200,0	0,00000997	0,000609
7	8	143,5	135,5	0,000537935	0,107587	200,0	0,00000880	0,000538
8	–2238	–2105,5	132,5	0,000526025	0,105205	200,0	0,00000861	0,000526
9	–1872	–1760	112	0,00044464	0,088928	200,0	0,00000728	0,000445
10	106	217,5	111,5	0,000442655	0,088531	200,0	0,00000724	0,000443
11	164	295,5	131,5	0,000522055	0,104411	200,0	0,00000854	0,000522
12	31	158	127	0,00050419	0,100838	200,0	0,00000825	0,000504
13	–38	79	117	0,00046449	0,092898	200,0	0,00000760	0,000465
14	4	74	70	0,0002779	0,05558	200,0	0,00000455	0,000278
15	93	245,5	152,5	0,000605425	0,121085	200,0	0,00000991	0,000605
16	7	126,5	119,5	0,000474415	0,094883	200,0	0,00000776	0,000474
17	–945	–850,5	94,5	0,000375165	0,075033	200,0	0,00000614	0,000375
18	–499	–415	84	0,00033348	0,066696	200,0	0,00000546	0,000333

använder sista mätvärdet på 20 grader

använder median på 80 gradersmätn

Sammanställning

Längdutvidgningskoeff	Borrhål:	KLXO4			Längdutvidgning				
Temperatur/mm/mm per grader C	19,3	41	60,5	80,4	Temperatur/mm/mm	19,3	41	60,5	80,4
KLX04A 90L-1	0	6,95207E–06	6,98604E–06	6,6275E–06	1	0	0,00015086	0,000287825	0,00040494
KLX04A 90L-2	0	5,85438E–06	7,3233E–06	6,6275E–06	2	0	0,00012704	0,00030172	0,00040494
KLX04A 90L-3	0	6,03733E–06	7,17876E–06	9,48642E–06	3	0	0,00013101	0,000295765	0,00057962
KLX04A 90L-4	0	7,13502E–06	8,28689E–06	8,90164E–06	4	0	0,00015483	0,00034142	0,00054389
KLX04A 90L-5	0	7,31797E–06	7,61238E–06	8,96661E–06	5	0	0,0001588	0,00031363	0,00054786
KLX04A 90L-6	0	7,68387E–06	7,8051E–06	9,97373E–06	6	0	0,00016674	0,00032157	0,000609395
KLX04A 90L-7	0	7,68387E–06	8,23871E–06	8,80417E–06	7	0	0,00016674	0,000339435	0,000537935
KLX04A 90L-8	0	7,13502E–06	7,46784E–06	8,60925E–06	8	0	0,00015483	0,000307675	0,000526025
KLX04A 90L-9	0	6,76912E–06	7,03422E–06	7,27725E–06	9	0	0,00014689	0,00028981	0,00044464
KLX04A 90L-10	0	6,22028E–06	6,88968E–06	7,24476E–06	10	0	0,00013498	0,000283855	0,000442655
KLX04A 90L-11	0	5,67143E–06	6,21517E–06	8,54427E–06	11	0	0,00012307	0,000256065	0,000522055
KLX04A 90L-12	0	7,68387E–06	8,14235E–06	8,25188E–06	12	0	0,00016674	0,000335465	0,00050419
KLX04A 90L-13	0	7,68387E–06	7,41966E–06	7,60213E–06	13	0	0,00016674	0,00030569	0,00046449
KLX04A 90L-14	0	3,65899E–06	6,21517E–06	4,54828E–06	14	0	0,0000794	0,000256065	0,0002779
KLX04A 90L-15	0	8,23272E–06	9,49138E–06	9,90876E–06	15	0	0,00017865	0,000391045	0,000605425
KLX04A 90L-16	0	7,50092E–06	8,33507E–06	7,76457E–06	16	0	0,00016277	0,000343405	0,000474415
KLX04A 90L-17	0	5,85438E–06	5,82973E–06	6,14018E–06	17	0	0,00012704	0,000240185	0,000375165
KLX04A 90L-18	0	6,95207E–06	6,31153E–06	5,45794E–06	18	0	0,00015086	0,000260035	0,00033348

Appendix 2

Determination of wet density

VattenmättnadsdensitetKLXO4A

Uppdrags nr: P402277
Metod: EN 13755, ISRM (1973), avsnitt 3 samt SKB MD 160.002 version 1.0
Provad av: Lej
Datum: 9/16/04

	Provmärkning:	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	KLXO4-1	800,16	1278,01		478,42	1279,55	267,45	0,000	2,671
2	2	798,93	1274,98		476,62	1276,51	267,82	0,000	2,675
3	3	800,19	1276,44		476,82	1277,97	268,02	0,000	2,677
4	4	796,10	1273,51		477,98	1275,04	266,75	0,000	2,664
5	5	798,12	1275,31		477,76	1276,84	267,25	0,000	2,669
6	6	798,75	1276,2		478,02	1277,73	267,30	0,000	2,670
7	7	799,02	1272,41		473,96	1273,94	268,79	0,000	2,685
8	8	796,76	1270,98		474,79	1272,51	268,01	0,000	2,677
9	9	817,65	1292,28		475,20	1293,83	272,27	0,000	2,719
10	10	824,47	1299,2		475,30	1300,76	273,67	0,000	2,733
11	11	820,50	1295,47		475,54	1297,03	272,75	0,000	2,724
12	12	837,57	1312,6		475,60	1314,18	276,32	0,000	2,760
13	13	803,43	1279,62		476,76	1281,16	268,72	0,000	2,684
14	14	803,14	1279,46		476,89	1281,00	268,61	0,000	2,683
15	15	800,02	1276,5		477,05	1278,03	267,90	0,000	2,676
16	16	801,75	1278,51		477,33	1280,05	268,17	0,000	2,678
17	17	802,20	1278,63		477,00	1280,17	268,38	0,000	2,681
18	18	800,55	1276,97		476,99	1278,50	268,03	0,000	2,677
19					0,00	0,00			
20					0,00	0,00			
21					0,00	0,00			

Vattnets temperatur (ºC):	17,1	Våg, inv.nr:	102291
Vattnets desitet (g/cm^3):	0,9988	Termometer, inv.nr:	102080