P-04-198

Forsmark site investigation

Drill hole KFM04A: Extensometer measurement of the coefficient of thermal expansion of rock

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August 2004

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Keywords: AP PF 400-04-59, Field note no Forsmark 303, Rock mechanics, Coefficient of thermal expansion, Temperature change, Density, Porosity.

Abstract

The coefficient of thermal expansion and the wet density have been determined on fifteen specimens from drill hole KFM04A. The specimens were sampled on three levels in the drill hole at a depth of approximately 160 m, 580 m and 810 m. The investigated rock type is mapped as a fine-grained granite for level 1 (160 m), and medium grained granite for level 2 (580 m) and level 3 (810 m). The coefficient of thermal expansion has been determined within the temperature interval 20-80 ºC. The results indicated that the thermal expansion was almost linear and the coefficient of thermal expansion range between 4 and 14 x 10^{-6} mm/mm ˚C.

Contents

1 Introduction

This document reports the data collected within the activity “Undersökningar i Forsmarksområdet. KFM04A. Bergmekaniska och tekniska laboratoriebestämningar”, which is one of the activities performed as part of the site investigation at Forsmark. The work was carried out in accordance with activity plan AP PF 400-04-59 (SKB internal controlling document).

The principle of the measurements is to determine the coefficient of thermal expansion on drill core samples at different temperatures.

The cores are sampled from drill hole KFM04A in the Forsmark area (Figure 1-1). They were sampled 20 January 2004 by Thomas Janson, Tyréns AB, and Urban Åkesson, The Swedish National Testing and Research Institute (SP). Specimens were collected from three levels at depths of approximately 160 m, 580 m and 810 m. The rock cores were transported by SKB from Forsmark and arrived at SP 28 April 2004. The testing was performed during July 2004.

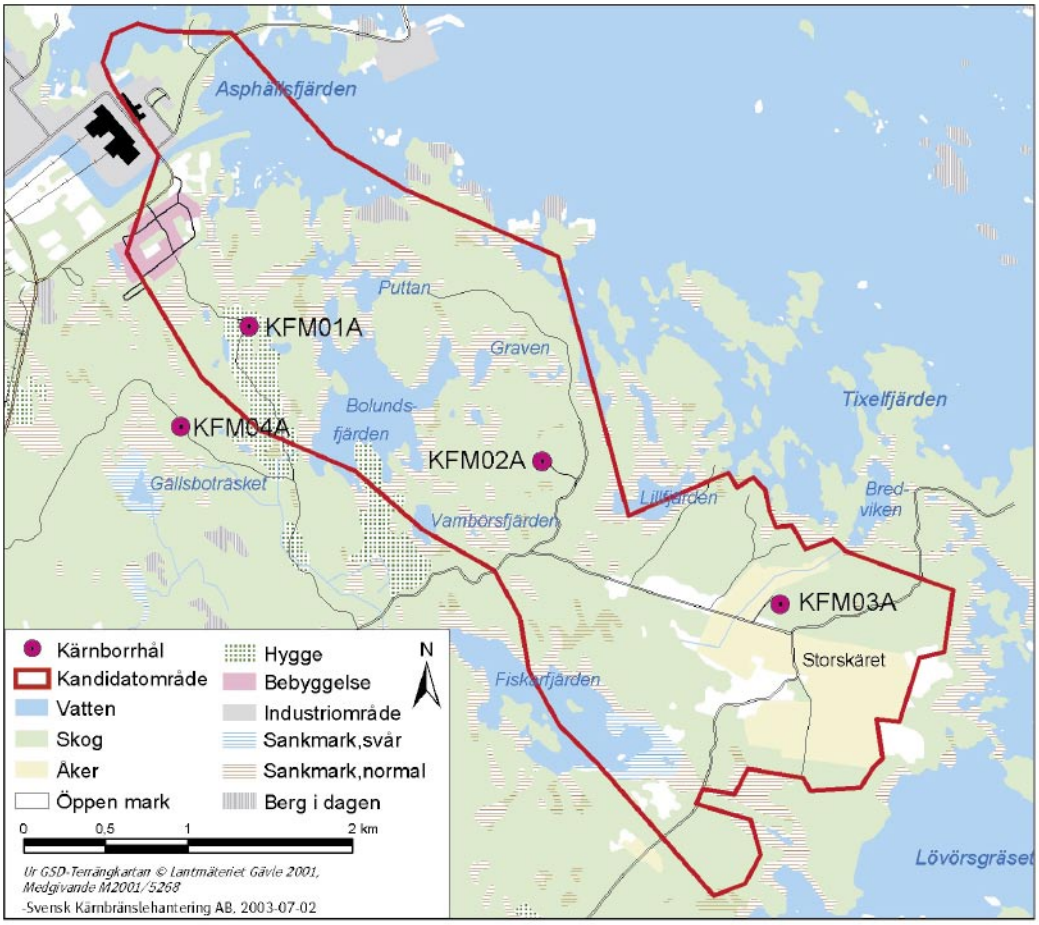


Figure 1-1. *Location of drill hole KFM04A at the Forsmark investigation area.*

2 Objective and scope

The purpose is to determine the linear coefficient of thermal expansion for rock cores at water-saturated conditions between +20-80 ºC.

These parameters will be included in the site descriptive model of rock mechanics for the Forsmark area, performed by SKB. The specimens and the results will be presented in tables, diagrams and spreadsheets.

3 Equipment

The following equipment has been used for the analyses:

- Extensometer (DEMEC inv no 102266) for measurements of the thermal expansion. Calibration of the instrument was done before the measurements on every new temperature level (see Appendix 1). The uncertainty of the extensometer is ± 3.97 x 10^{-6} mm/mm (strain) which for these samples equals an uncertainty of a single measurement of the coefficient of thermal expansion of ± 0.4 x 10^{-6} mm/mm ^{o}C for a temperature difference of 20 degrees C.
- Reference bar in invar steel for calibration of the extensometer.
- Heating chamber (inv no 102284) with an accuracy of ± 0.7 ºC at 80 ºC 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 1.9 (SKB internal controlling document). The department of Building Technology and Mechanics (BM) at SP performed the test.

4.1 Description of the samples

In the Forsmark area, specimens were sampled from three levels in drill hole KFM04A. The core drilled part of the borehole starts at a depth of 100 m, and the sampled levels were selected at the approximate depths of 160 m, 580 m and 810 m. Eighteen specimens, with a length of 240 mm and a diameter of 50 mm, were sampled. The sampled rock types are a fine-grained granite (level 1) and a medium-grained granite (level 2 and 3). Table 4-1 shows the rock types and identification marks of the specimens.

Table 4-1. Rock types and identification marks (Rock-type classification according to Boremap, July 2004).

Identification	Sampling depth, according to the marks on the drill-core boxes (Sec low)	Rock type
KFM04A-90L-1	157.37	Fine-grained granite
KFM04A-90L-2	157.75	Fine-grained granite
KFM04A-90L-3	158.30	Fine-grained granite
KFM04A-90L-4	158.56	Fine-grained granite
KFM04A-90L-5	158.78	Fine-grained granite
KFM04A-90L-6	159.05	Fine-grained granite
KFM04A-90L-7	582.00	Medium-grained granite
KFM04A-90L-8	582.26	Medium-grained granite
KFM04A-90L-9	585.37	Medium-grained granite
KFM04A-90L-10	585.66	Medium-grained granite
KFM04A-90L-11	585.92	Medium-grained granite
KFM04A-90L-12	586.18	Medium-grained granite
KFM04A-90L-13	810.79	Medium-grained granite
KFM04A-90L-14	811.04	Medium-grained granite
KFM04A-90L-15	811.29	Medium-grained granite
KFM04A-90L-16	812.17	Medium-grained granite
KFM04A-90L-17	812.42	Medium grained granite
KFM04A-90L-18	812.67	Medium grained granite

4.2 Testing

The execution procedure followed the prescription in SKB MD 191.002, version 1.9 and SKB MD 160.002, version 1.9 (SKB internal controlling documents) and the following steps were performed:

Item	Activity
1	The specimens were cut according to the marks on the rock cores.
2	The specimens were photographed in JPEG-format.
3	Two studs were glued with a distance of 200 mm on the specimens.
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 ºC. On each temperature level three to five measurements were done with 24 h intervals in order to ensure that the expansion was completed for each temperature level (See Appendix 1). The coefficient of thermal expansion was determined between 20-80 ºC.

5 Results

The results of the extensometer measurements on drill core samples from borehole KFM04A at Forsmark are stored in the database SICADA under field note no Forsmark 303.

5.1 Description of the specimens and presentation of the results

The temperature of the water used for water saturation was 19.9 ºC and the density of the water was 998 kg/m^3. The coefficient of thermal expansion was determined between +20-80 ˚C.

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 KFM04A-90L-1 was measured to be 14.4 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2660 kg/m^3.

KFM04A-90L-1 (157.37)

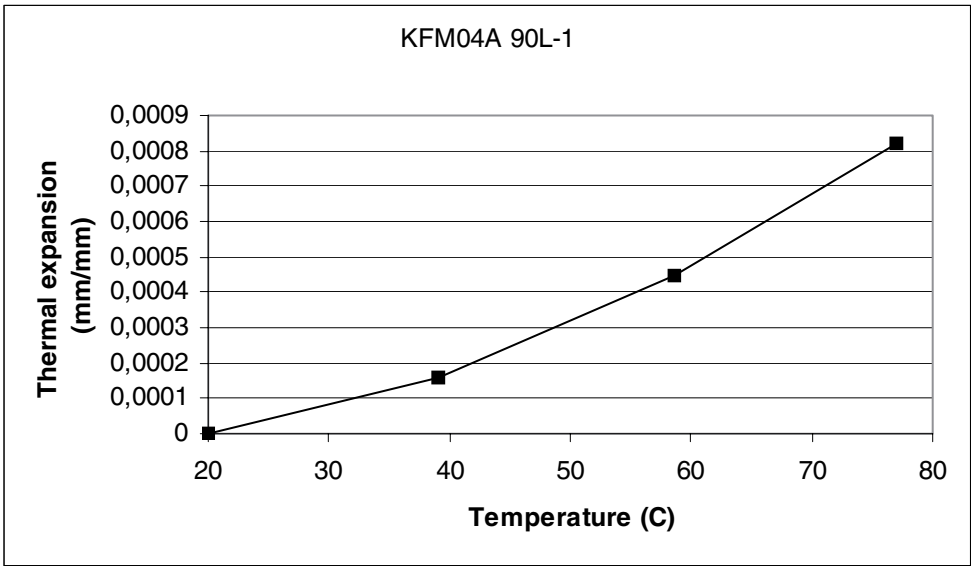
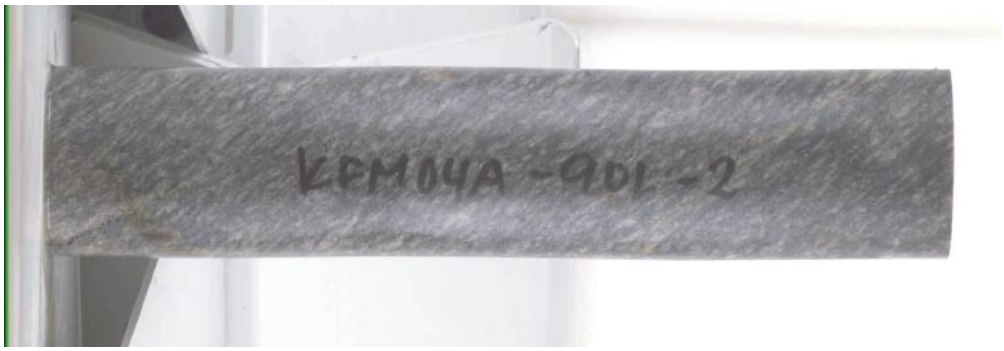


Figure 5-1. *Specimen KFM04A-90L-1.*

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 KFM04A-90L-2 was measured to be 5.9 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2703 kg/m^3.

KFM04A-90L-2 (157.75)



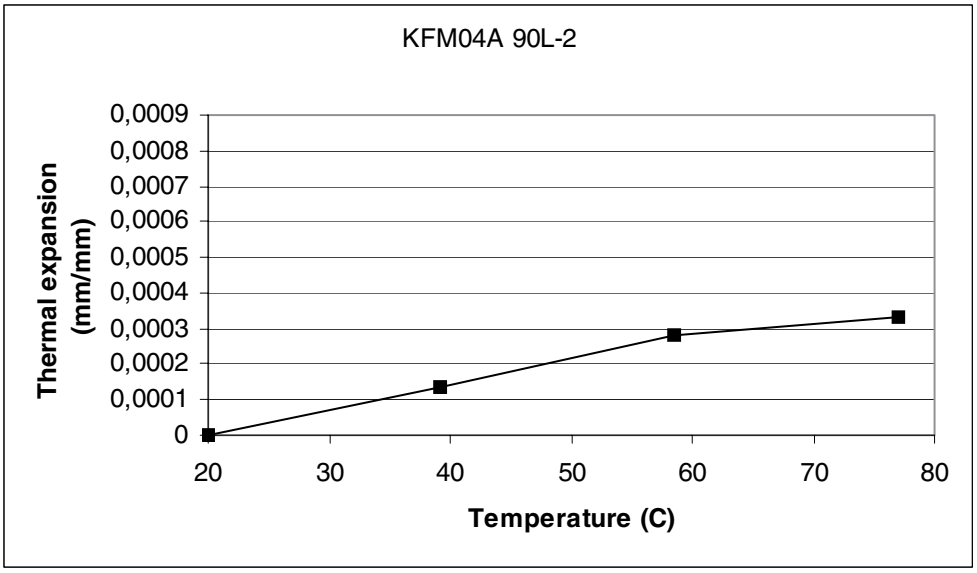


Figure 5-2. *Specimen KFM04A-90L-2.*

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 KFM04A-90L-3 was measured to be 5.2 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2680 kg/m^3.

KFM04A-90L-3 (158.30)

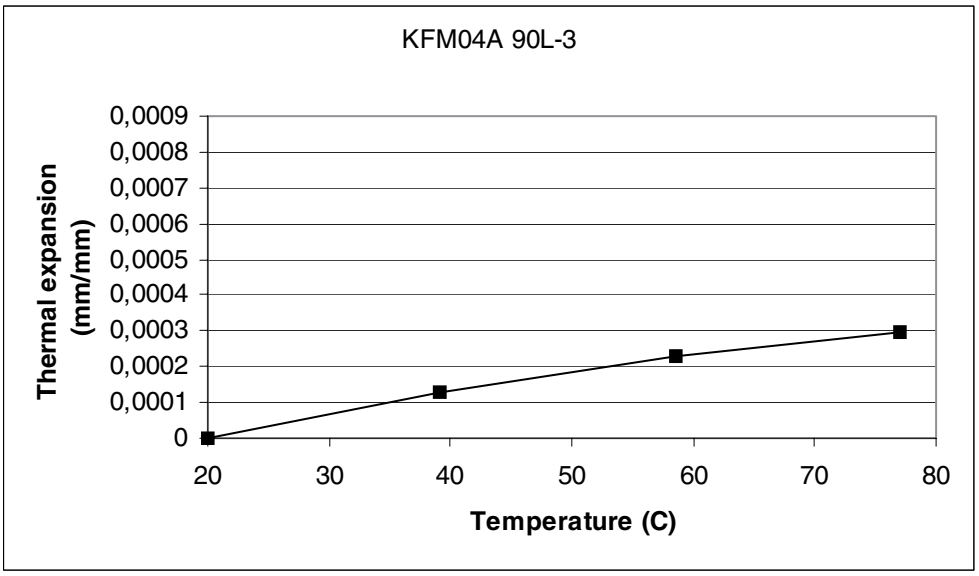


Figure 5-3. *Specimen KFM04A-90L-3.*

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 KFM04A-90L-4 was measured to be 6.2 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2695 kg/m^3.

KFM04A-90L-4 (158.56)

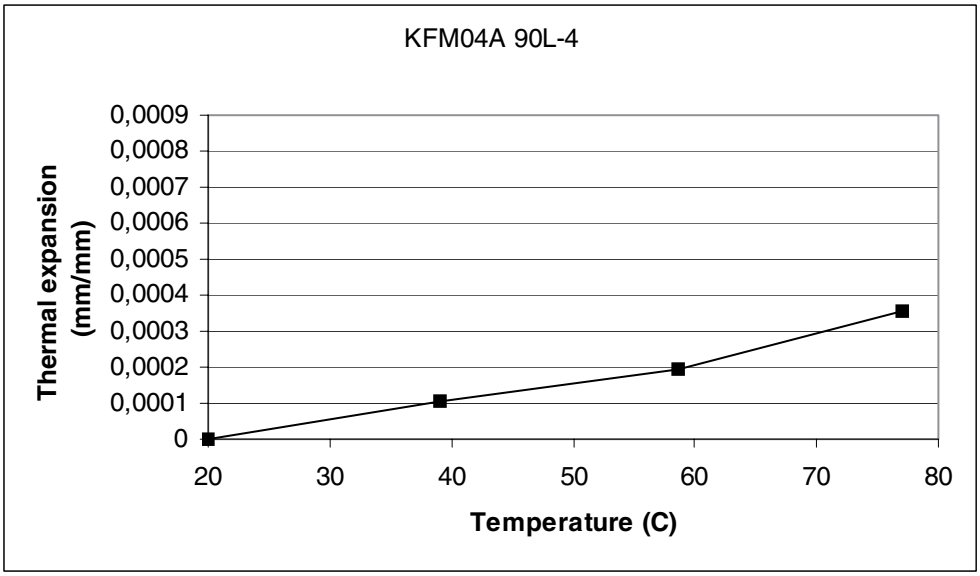


Figure 5-4. *Specimen KFM04A-90L-4.*

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 KFM04A-90L-5 was measured to be 8.5 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2691 kg/m^3.

KFM04A-90L-5 (158.78)

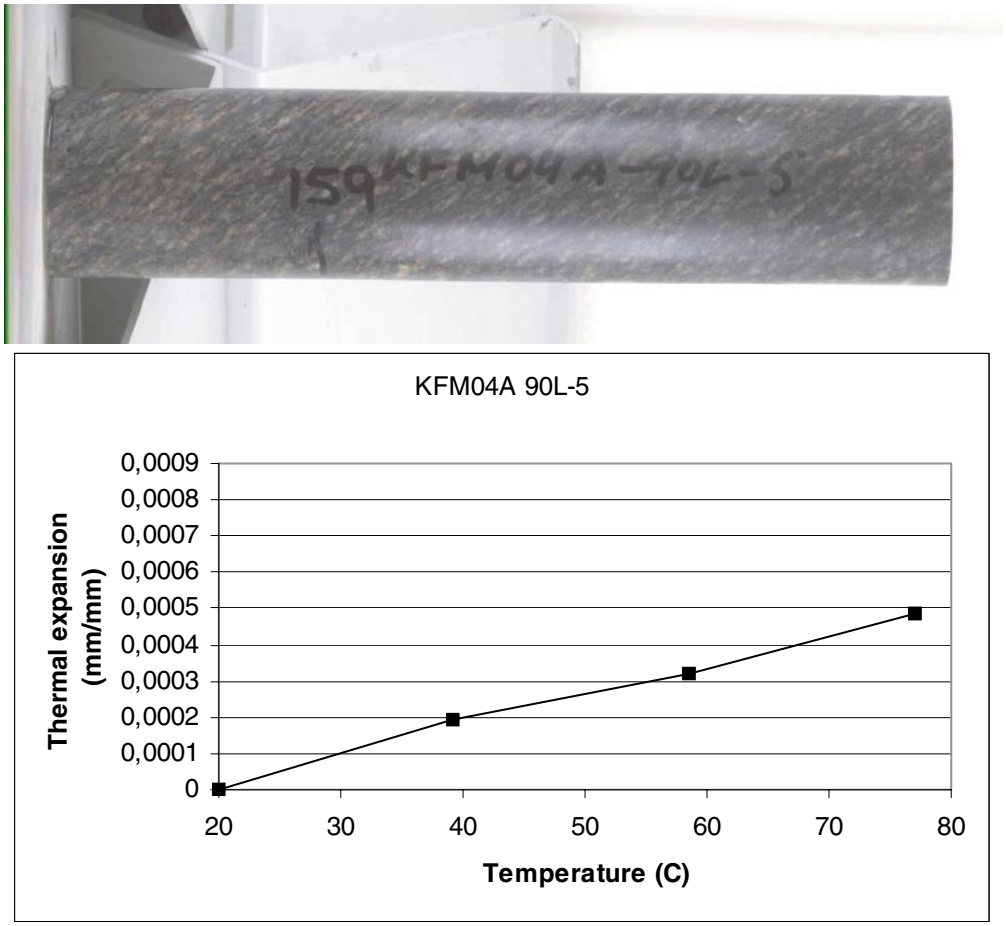


Figure 5-5. *Specimen KFM04A-90L-5.*

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 KFM04A-90L-6 was measured to be 8.5 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2691 kg/m^3.

KFM04A-90L-6 (159.05)

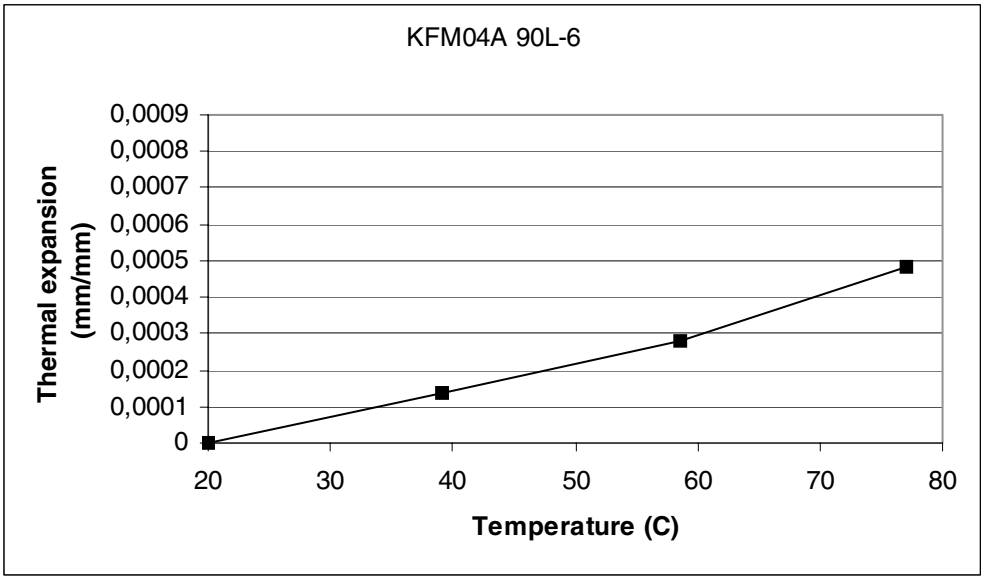


Figure 5-6. *Specimen KFM04A-90L-6.*

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 KFM04A-90L-7 was measured to be 6.2 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2659 kg/m^3.

KFM04A-90L-7 (582.00)

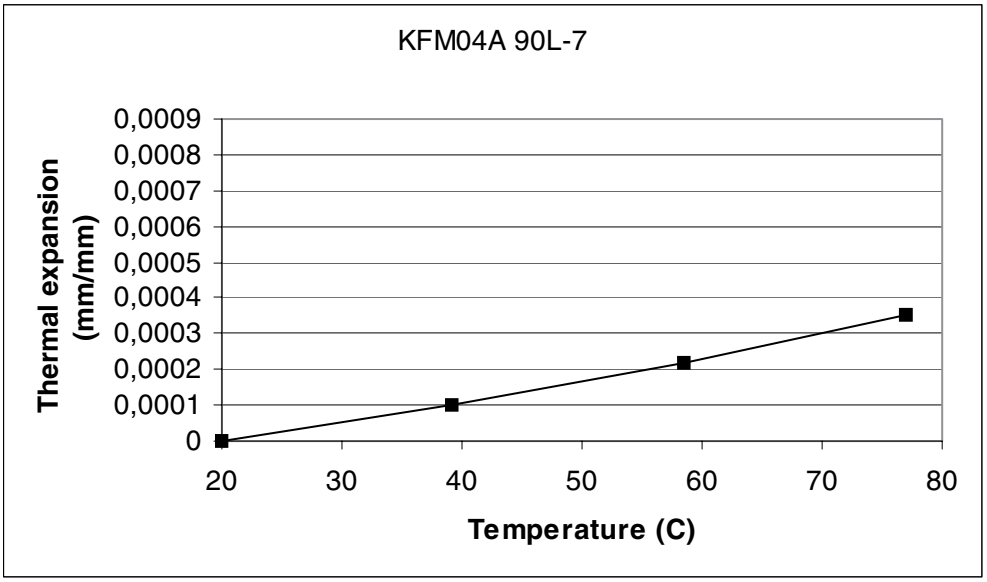


Figure 5-7. *Specimen KFM04A-90L-7.*

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 KFM04A-90L-8 was measured to be 4.7 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2654 kg/m^3.

KFM04A-90L-8 (582.26)

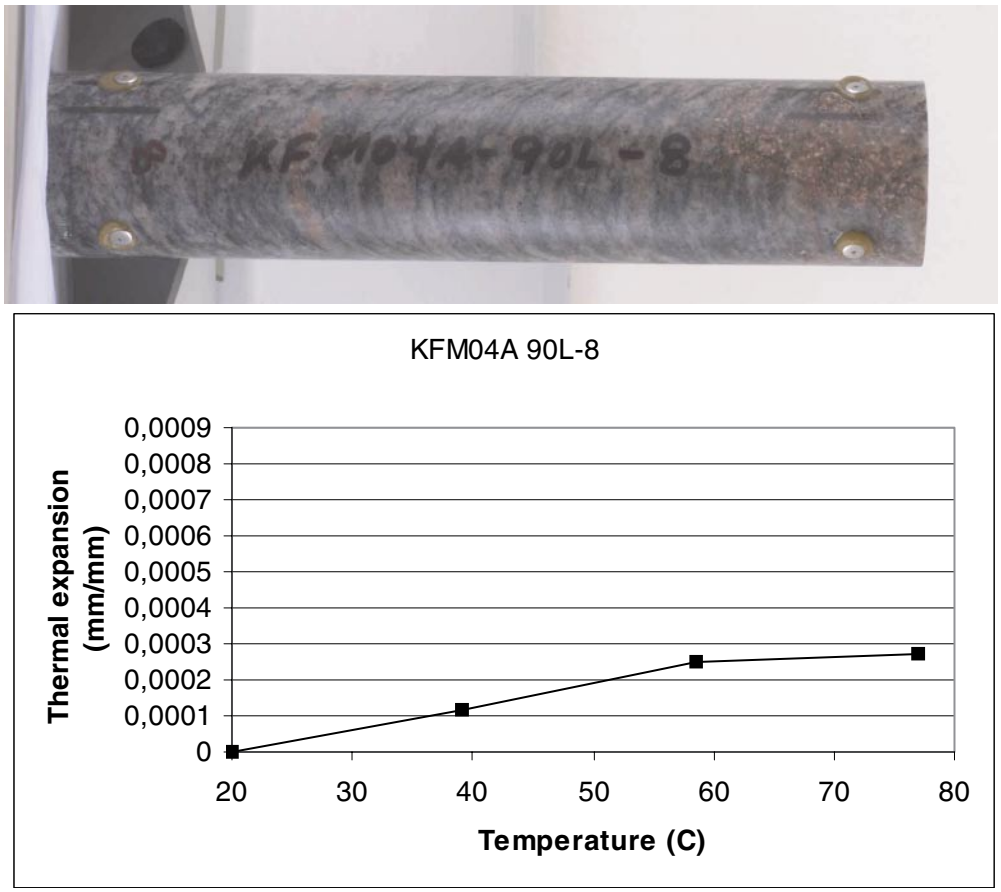


Figure 5-8. *Specimen KFM04A-90L-8.*

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 KFM04A-90L-9 was measured to be 7.3 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2660 kg/m^3.

KFM04A-90L-9 (585.37)

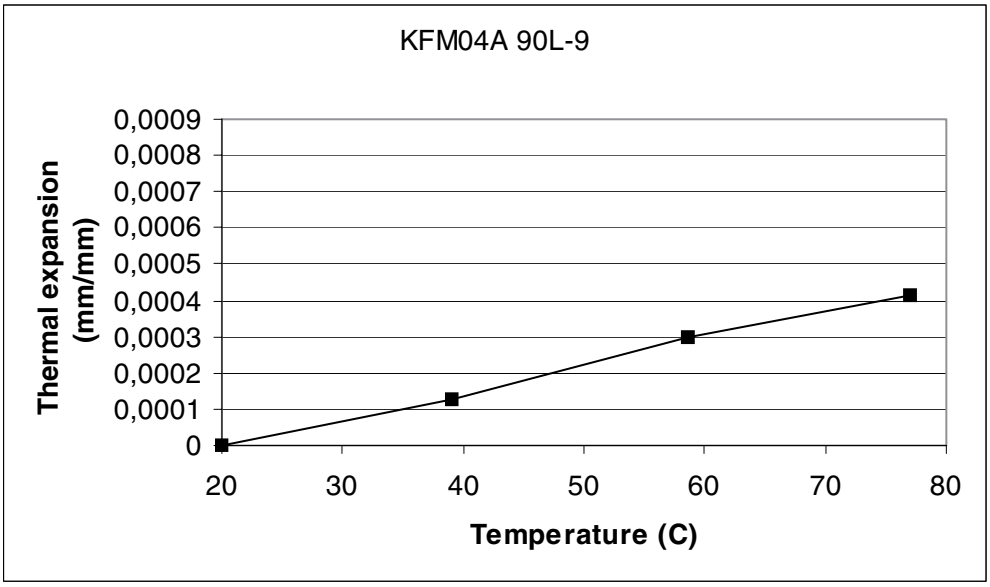


Figure 5-9. *Specimen KFM04A-90L-9.*

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 KFM04A-90L-10 was measured to be 8.5 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2651 kg/m^3.

KFM04A-90L-10 (585.66)

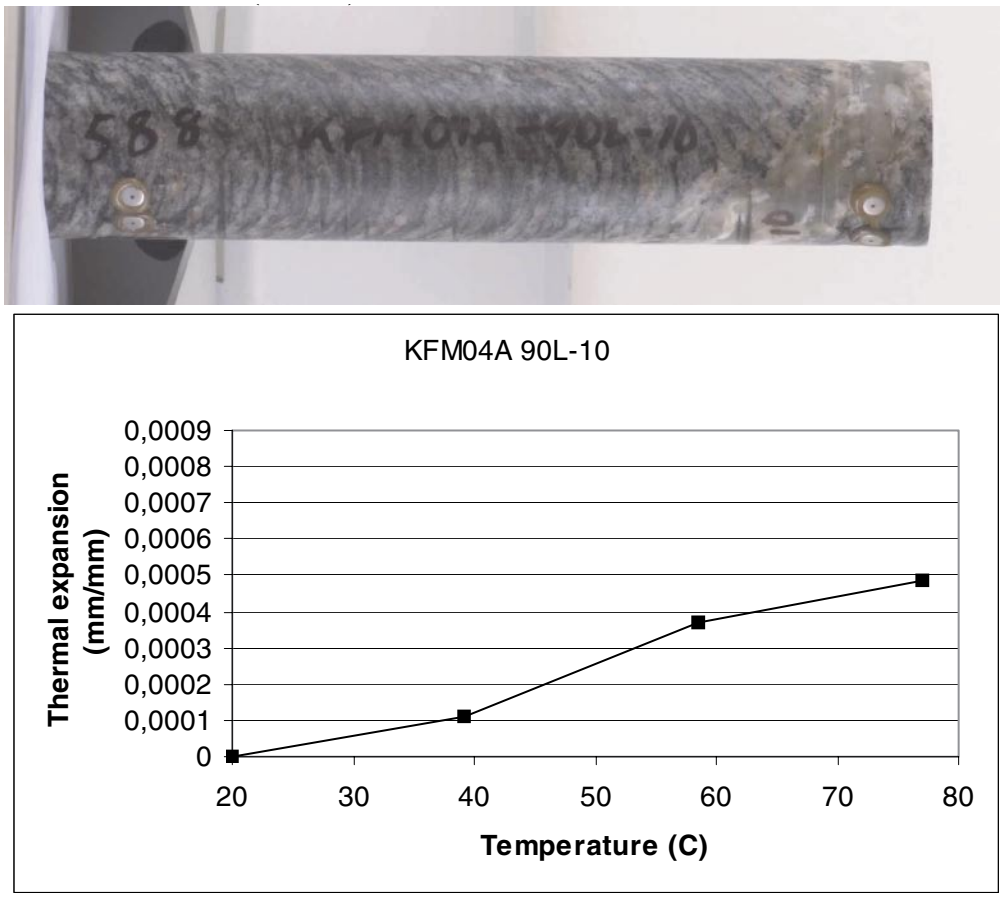


Figure 5-10. *Specimen KFM04A-90L-10.*

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 KFM04A-90L-11 was measured to be 4.9 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2656 kg/m^3.

KFM04A-90L-11 (585.92)

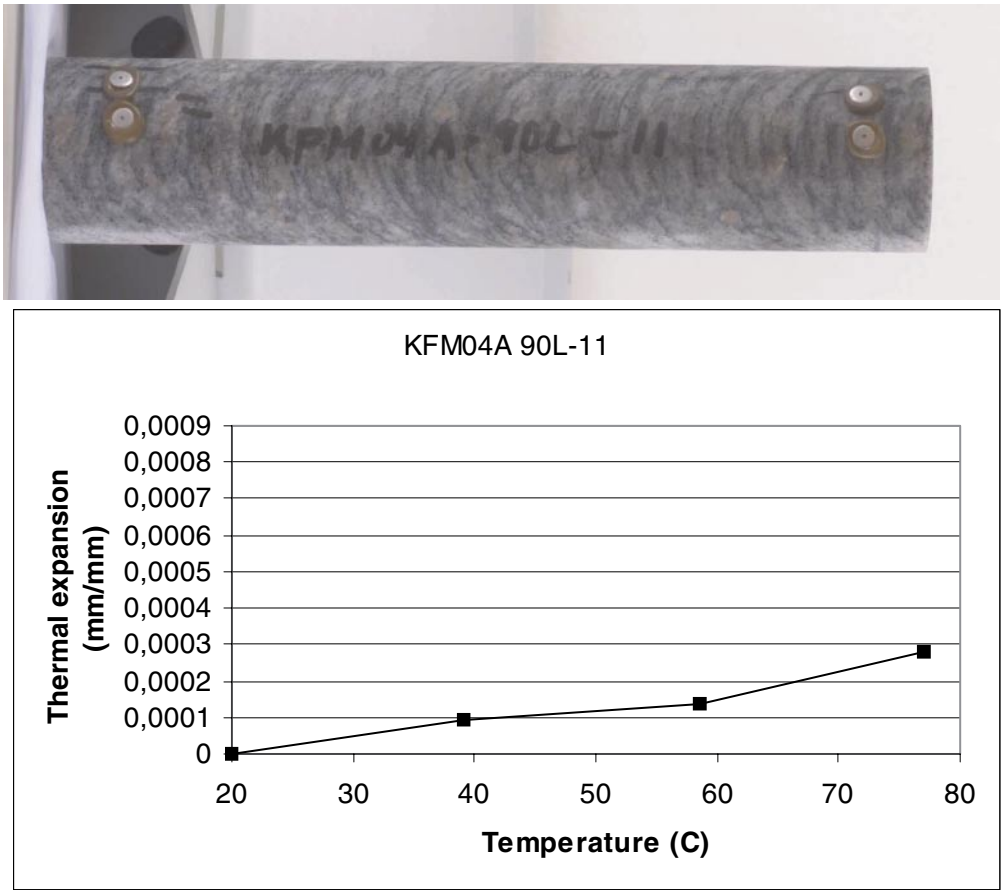


Figure 5-11. *Specimen KFM04A-90L-11.*

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 KFM04A-90L-12 was measured to be 8.7x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2656 kg/m^3.

KFM04A-90L-12 (586.18)

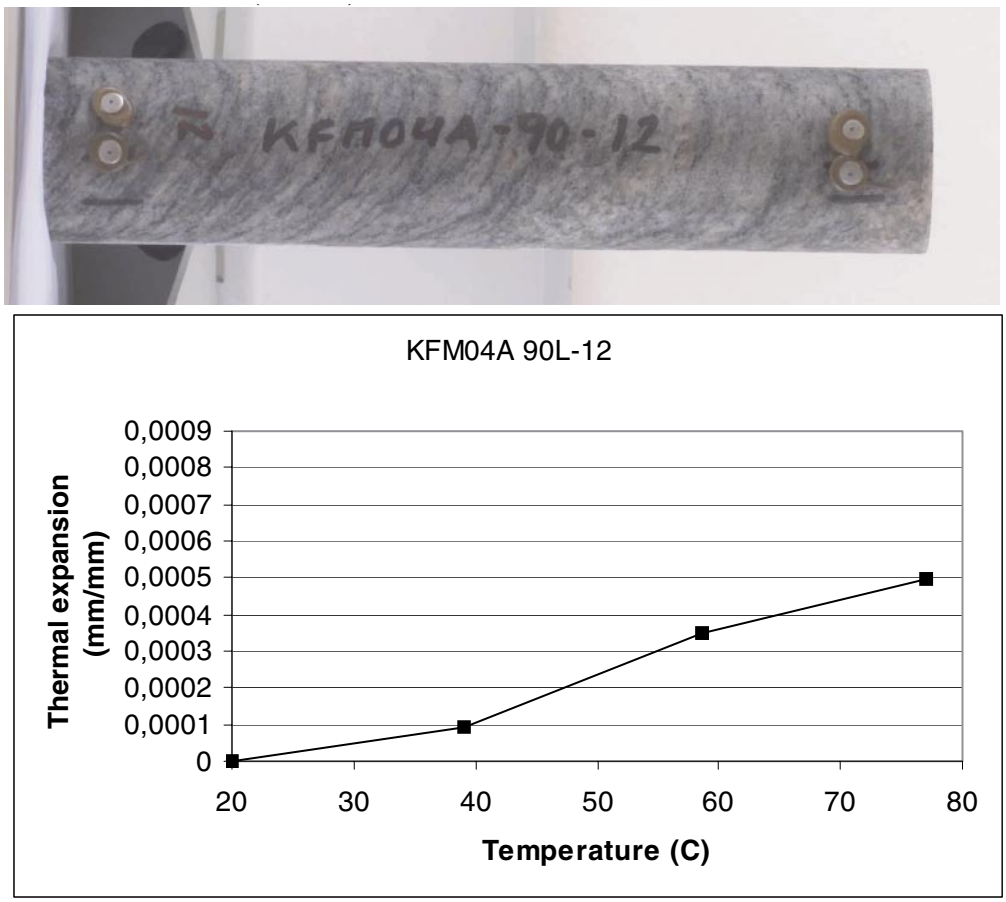
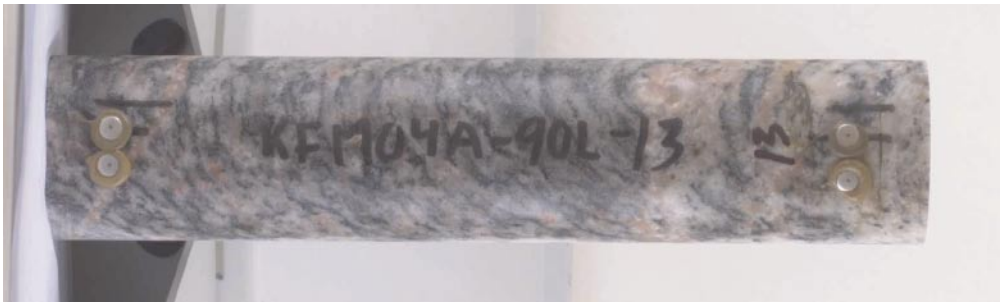


Figure 5-12. *Specimen KFM04A-90L-12.*

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 KFM04A-90L-13 was measured to be 8.9 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2652 kg/m^3.

KFM04A-90L-13 (810.79)



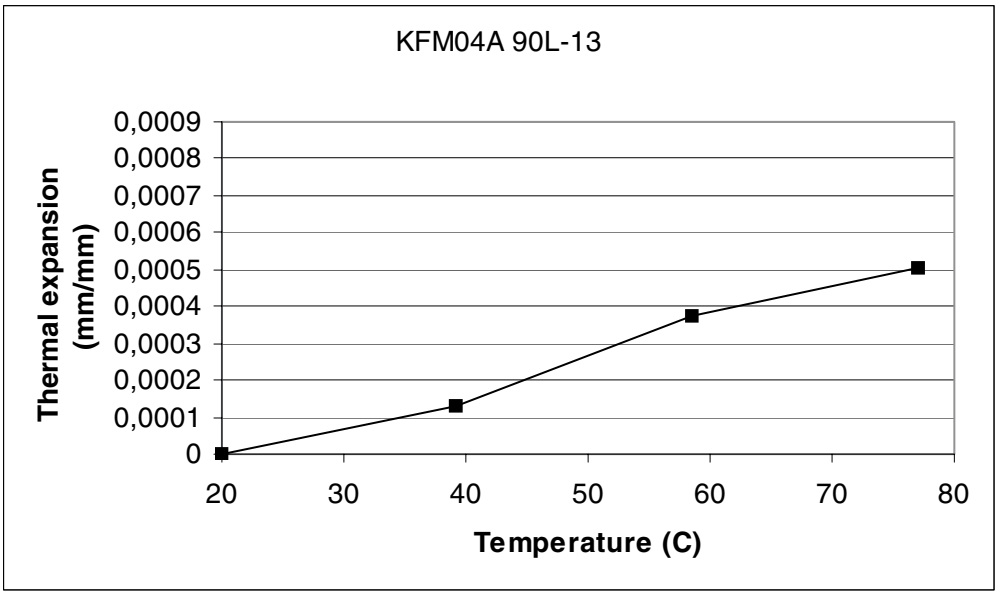


Figure 5-13. *Specimen KFM04A-90L-13.*

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 KFM04A-90L-14 was measured to be 8.3 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2656 kg/m^3.

KFM04A-90L-14 (811.04)

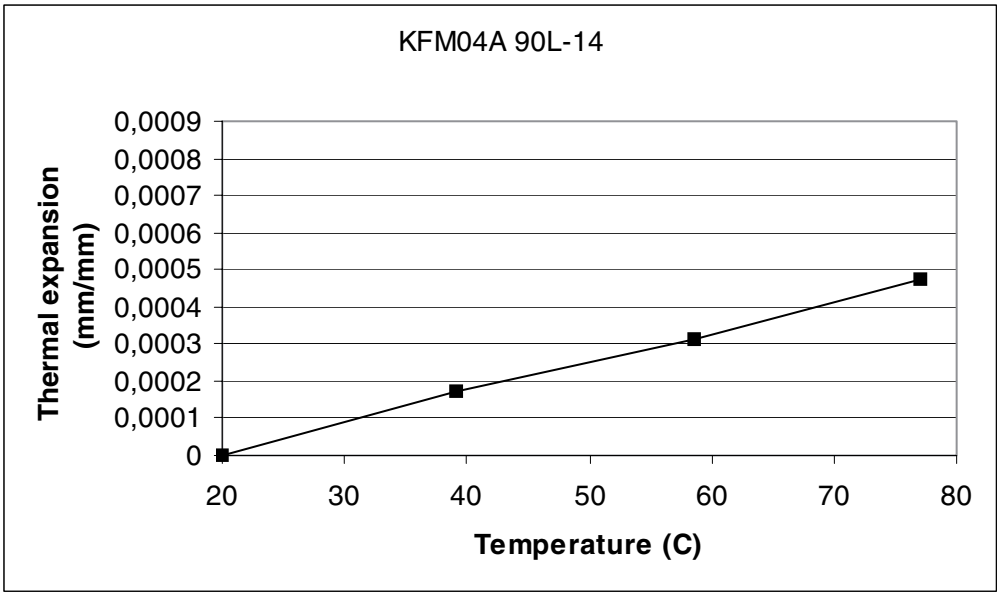
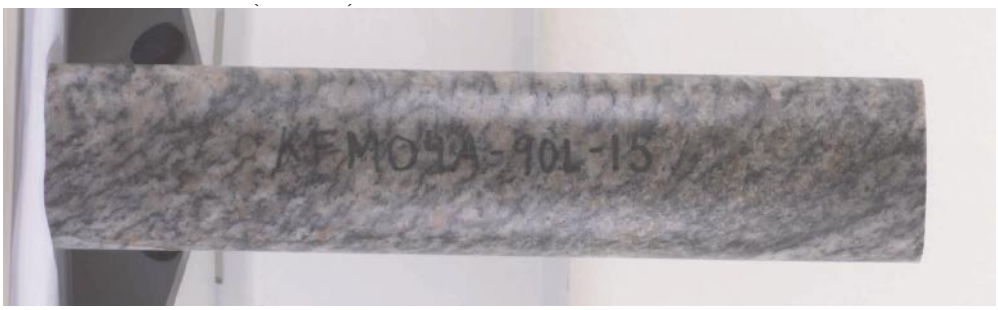


Figure 5-14. *Specimen KFM04A-90L-14.*

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 KFM04A-90L-15 was measured to be 3.9 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2659 kg/m^3.

KFM04A-90L-15 (811.29)



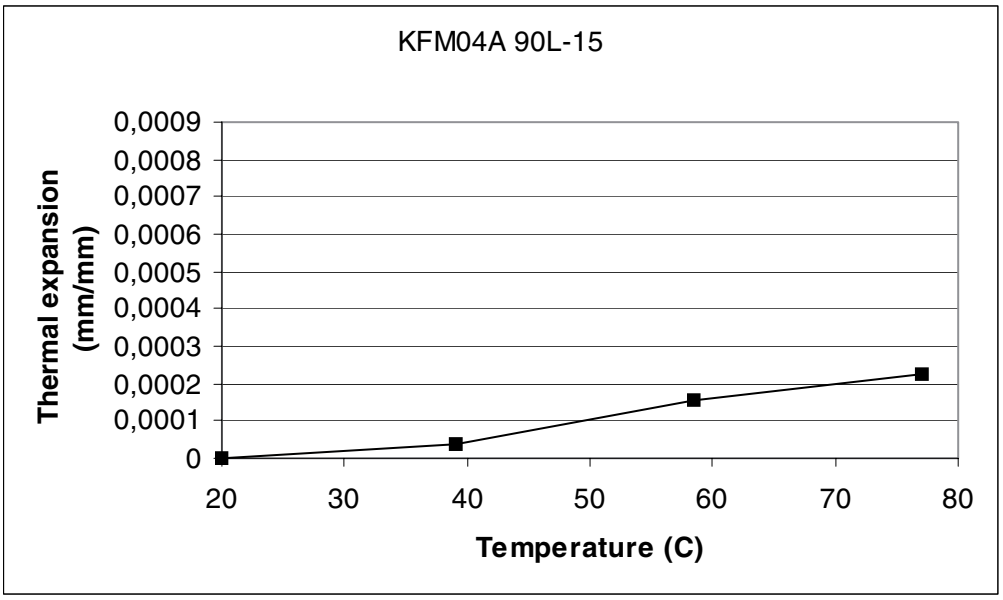


Figure 5-15. *Specimen KFM04A-90L-15.*

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 KFM04A-90L-16 was measured to be 10.9 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2657 kg/m^3.

KFM04A-90L-16 (812.17)

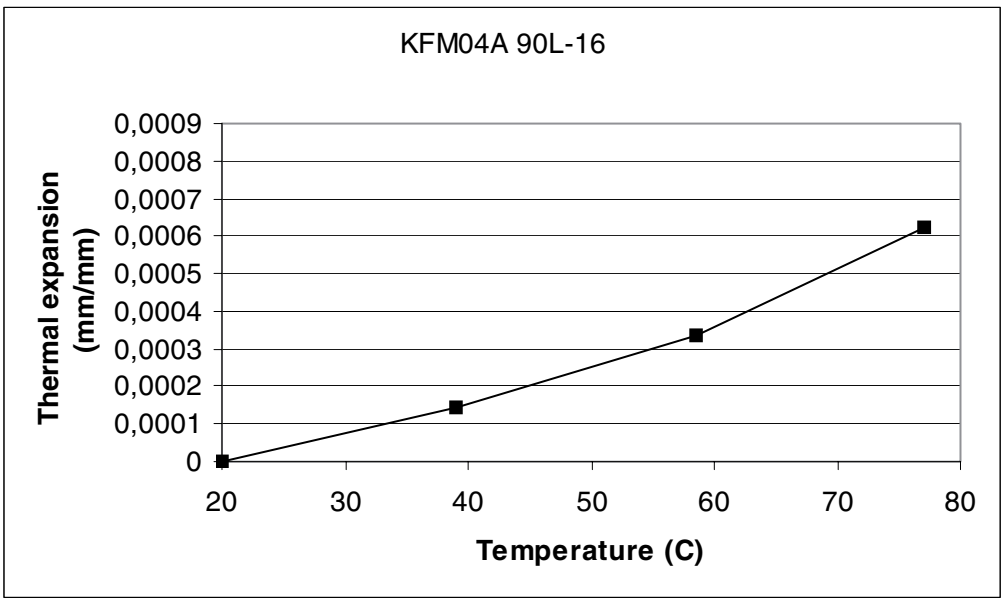
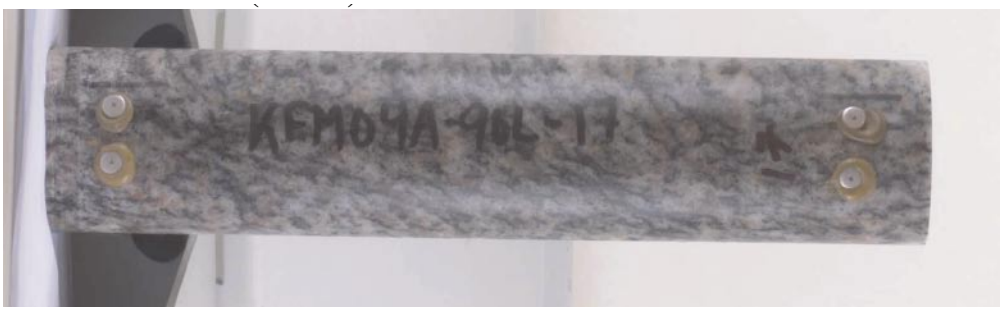


Figure 5-16. *Specimen KFM04A-90L-16.*

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 KFM04A-90L-17 was measured to be 8.1 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2659 kg/m^3.

KFM04A-90L-17 (812.42)



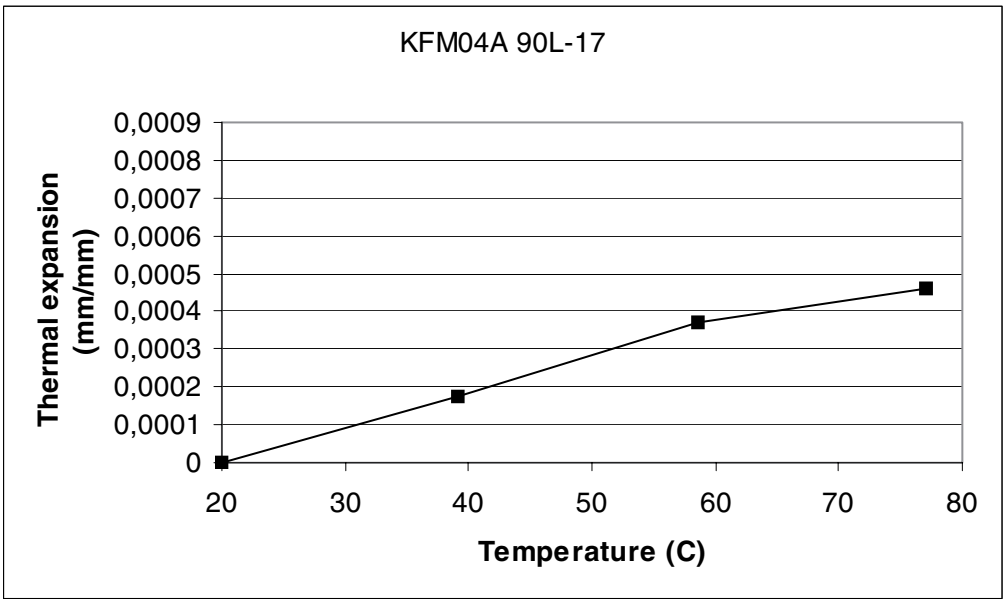


Figure 5-17. *Specimen KFM04A-90L-17.*

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 KFM04A-90L-18 was measured to be 12.6 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2660 kg/m^3.

KFM04A-90L-18 (812.67)

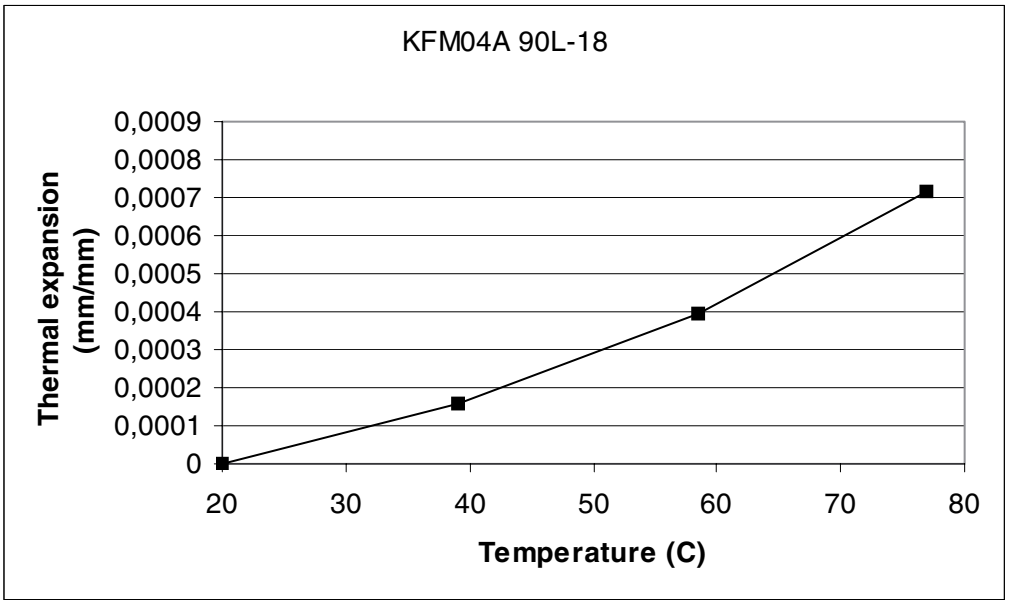


Figure 5-18. *Specimen KFM04A-90L-18.*

5.2 Results for the entire test series

Table 5-1. Summary of the results for the coefficient of thermal expansion and wet density of the tested specimens, level 1 (160 m).

Specimen	Coefficient of thermal expansion between 20 and 80 ˚C (mm/mm ˚C)	Wet density (Kg/m^3)
KFM04A-90L-1	14.4 x 10^{-6}	2660
KFM04A-90L-2	5.9x 10^{-6}	2703
KFM04A-90L-3	5.2 x 10^{-6}	2680
KFM04A-90L-4	6.2 x 10^{-6}	2695
KFM04A-90L-5	8.5 x 10^{-6}	2691
KFM04A-90L-6	8.5 x 10^{-6}	2691
Median	7.3 x 10^{-6}	
Maximum value	14.4 x 10^{-6}	
Minimum value	5.2 x 10^{-6}	

Table 5-2. Summary of the results for the coefficient of thermal expansion and wet density of the tested specimens, level 2 (580 m).

Specimen	Coefficient of thermal expansion between 20 and 80 ˚C (mm/mm ˚C)	Wet density (Kg/m^3)
KFM04A-90L-7	6.2 x 10^{-6}	2659
KFM04A-90L-8	4.7 x 10^{-6}	2654
KFM04A-90L-9	7.3 x 10^{-6}	2660
KFM04A-90L-10	8.5 x 10^{-6}	2651
KFM04A-90L-11	4.9 x 10^{-6}	2656
KFM04A-90L-12	8.7 x 10^{-6}	2656
Median	6.7 x 10^{-6}	
Maximum value	8.7 x 10^{-6}	
Minimum value	4.7 x 10^{-6}	

Table 5-3. Summary of the results for the coefficient of thermal expansion and wet density of the tested specimens, level 3 (810 m).

Specimen	Coefficient of thermal expansion between 20 and 80 ˚C (mm/mm ˚C)	Wet density (Kg/m^3)
KFM04A-90L-13	8.9 x 10^{-6}	2652
KFM04A-90L-14	8.3 x 10^{-6}	2656
KFM04A-90L-15	3.9 x 10^{-6}	2659
KFM04A-90L-16	10.9 x 10^{-6}	2657
KFM04A-90L-17	8.1 x 10^{-6}	2659
KFM04A-90L-18	12.6 x 10^{-6}	2660
Median	8.6 x 10^{-6}	
Maximum value	12.6 x 10^{-6}	
Minimum value	3.9 x 10^{-6}	

5.3 Nonconformities

None.

5.4 Discussion

The variation between the specimens is approximately 10 x 10^{-6} mm/mm ˚C, that is more than 20 times the uncertainty of the measurement (0.4 x 10^{-6} mm/mm ˚C).

The diagrams of the thermal expansion indicate that the variation is not due to any lost of DEMEC studs, because the expansion increases with increasing temperature. It is therefore suggested that the variation is related to differences in the rock material or bending of the specimens.

Appendix 1

Beräkning av längdutvidgningskoefficient och provningsprotokoll för längdutvidgningskoefficient

Uppdragsnummer:	P400242
Borrhål:	KFM04A
Metod:	

Provkroppar som provas se nästa blad

Provberedning	**Datum**	**Sign**
Sågning:	2004-05-10	Lej
Foto:	2004-05-06	Jel
Vattenmättnad start datum:	2004-05-15	Lej
Vägning vattenmättat yttorrt tillstånd:	2004-08-09	Lej
Provning start:	2004-07-01	Lej
Vägning torrt tillstånd:		

Utrustning	**Inventarienummer**	**Kalibrerad datum**
Extensometer:	102266	2003-05-05
Våg	102291	2004-03-10
Torkskåp	102284	2003-05-21
Termometer	102080	2004-06-14

Övrigt	
Eventuella avvikelser under provning:	

	Datum	**Sign**
Proverna åter i kärnlådan:	2004-08-20	Lej

Provningsprotokoll längdutvidgningskoefficient									
Uppdrags nummer:		P400242							
Borrhål:	**KFM04A**								
									Median
Mättemperatur	**20**	**C**	20	C	20	C	20	C	20
							värde i grön kolumn använd vid beräkning		
Prov ID	Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		**Median**
KFM04A 90L-1	29	1/7 04	29	2/7 04	29	5/7 04	29		29,00
KFM04A 90L-2	119		119		118		115		118,50
KFM04A 90L-3	131		131		131		129		131,00
KFM04A 90L-4	-537		-537		-537		-538		-537,00
KFM04A 90L-5	-85		-85		-85		-85		-85,00
KFM04A 90L-6	318		318		317		315		317,50
KFM04A 90L-7	130		130		129		126		129,50
KFM04A 90L-8	109		109		109		109		109,00
KFM04A 90L-9	221		221		223		223		222,00
KFM04A 90L-10	54		54		53		53		53,50
KFM04A 90L-11	142		142		141		141		141,50
KFM04A 90L-12	-224		-224		-225		-227		-224,50
KFM04A 90L-13	-375		-375		-375		-376		-375,00
KFM04A 90L-14	1		1		1		1		1,00
KFM04A 90L-15					-47		-50		-48,50
KFM04A 90L-16	-77		-77		-80		-80		-78,50
KFM04A 90L-17	172		172		167		166		169,50
KFM04A 90L-18	75		75		74		74		74,50

Provningsprotokoll längdutvidgningskoefficient

Uppdrags nummer:		**P400242**							
Borrhål:	**KFM04A**								
									Median
Mättemperatur	**39**	**C**	39,1	C	39,8	C		C	39,1
						värdet i grön kolumn används vid beräkning			
Prov ID	Skalvärde	/datum	Skalvärde	/datum	Skalvärde	/datum	Skalvärde	/datum	**Median**
KFM04A 90L-1	67	7/7 04	69	8/7 04	69	9/7 04			69
KFM04A 90L-2	149		149		149				149
KFM04A 90L-3	160		161		161				161
KFM04A 90L-4	-511		-511		-512				-511
KFM04A 90L-5	-37		-38		-35				-37
KFM04A 90L-6	349		349		349				349
KFM04A 90L-7	152		153		149				152
KFM04A 90L-8	139		139		139				139
KFM04A 90L-9	255		256		255				255
KFM04A 90L-10	83		81		78				81
KFM04A 90L-11	164		165		165				165
KFM04A 90L-12	-203		-201		-203				-203
KFM04A 90L-13	-343		-343		-338				-343
KFM04A 90L-14	44		43		45				44
KFM04A 90L-15	-22		-41		-42				-41
KFM04A 90L-16	-44		-44		-42				-44
KFM04A 90L-17	202		210		213				210
KFM04A 90L-18	113		114		114				114
0									#######

Provningsprotokoll längdutvidgningskoefficient									
Uppdrags nummer:		**P400242**							
Borrhål:	**KFM04A**								
									Median
Mättemperatur	**58,4**	**C**	58,5	C	59,3	C	58,6	C	58,55
						värdet i grön kolumn används vid beräkning			
Prov ID	Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		**Median**
KFM04A 90L-1	133	12/7 04	138	13/7 04	145	14/7 04	144	15/7 04	141
KFM04A 90L-2	184		186		186		185		185,5
KFM04A 90L-3	189		187		187		185		187
KFM04A 90L-4	-488		-489		-488		-490		-488,5
KFM04A 90L-5	-1		2		-7		-9		-4
KFM04A 90L-6	386		386		386		386		386
KFM04A 90L-7	180		183		183		170		181,5
KFM04A 90L-8	172		175		173		167		172,5
KFM04A 90L-9	295		298		298		298		298
KFM04A 90L-10	145		146		147		146		146
KFM04A 90L-11	176		178		174		174		175
KFM04A 90L-12	-143		-140		-136		-139		-139,5
KFM04A 90L-13	-290		-282		-280		-281		-281,5
KFM04A 90L-14	80		81		78		80		80
KFM04A 90L-15	-9		-9		-17		-13		-11
KFM04A 90L-16	-2		1		7		11		4
KFM04A 90L-17	258		258		260		261		259
KFM04A 90L-18	169		170		176		178		173
0									########

Provningsprotokoll längdutvidgningskoefficient

Uppdrags nummer:	**P400242**								
Borrhål:	**KFM04A**								
									Median
Mättemperatur	**77**	**C**	78	C	77	C	76	C	77
						värdet i grön kolumn används vid beräkning			
Prov ID	Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		**Median**
KFM04A 90L-1	170	19/7 04	250		264	21/7 04	221	22/7 04	235,5
KFM04A 90L-2	205		202		196		191		199
KFM04A 90L-3	216		211		188		197		204
KFM04A 90L-4	-454		-454		-428		-444		-449
KFM04A 90L-5	39		31		38		37		37,5
KFM04A 90L-6	436		448		437		425		436,5
KFM04A 90L-7	214		215		215		218		215
KFM04A 90L-8	179		177		175		177		177
KFM04A 90L-9	335		329		315		326		327,5
KFM04A 90L-10	182		178		157		173		175,5
KFM04A 90L-11	207		216		206		215		211
KFM04A 90L-12	-103		-101		-115		-94		-102
KFM04A 90L-13	-245		-250		-248		-251		-249
KFM04A 90L-14	121		121		119		119		120
KFM04A 90L-15	12		6		7		5		6,5
KFM04A 90L-16	77		67		77		77		77
KFM04A 90L-17	278		285		288		280		282,5
KFM04A 90L-18	252		259		257		245		254,5
0									########

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479

Tempdifferens 19,1

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

Borrhål/nivå: KFM04A

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	Längdutvidgningskoeff mm/mm per grader C	Längdutv mm/mm
KFM04A 90L-1	29	69	40	0,0001588	0,03176	200,0	0,00000831	0,000159
KFM04A 90L-2	115	149	34	0,00013498	0,026996	200,0	0,00000707	0,000135
KFM04A 90L-3	129	161	32	0,00012704	0,025408	200,0	0,00000665	0,000127
KFM04A 90L-4	-538	-511	27	0,00010719	0,021438	200,0	0,00000561	0,000107
KFM04A 90L-5	-85	-37	48	0,00019056	0,038112	200,0	0,00000998	0,000191
KFM04A 90L-6	315	349	34	0,00013498	0,026996	200,0	0,00000707	0,000135
KFM04A 90L-7	126	152	26	0,00010322	0,020644	200,0	0,00000540	0,000103
KFM04A 90L-8	109	139	30	0,0001191	0,02382	200,0	0,00000624	0,000119
KFM04A 90L-9	223	255	32	0,00012704	0,025408	200,0	0,00000665	0,000127
KFM04A 90L-10	53	81	28	0,00011116	0,022232	200,0	0,00000582	0,000111
KFM04A 90L-11	141	165	24	0,00009528	0,019056	200,0	0,00000499	0,000095
KFM04A 90L-12	-227	-203	24	0,00009528	0,019056	200,0	0,00000499	0,000095
KFM04A 90L-13	-376	-343	33	0,00013101	0,026202	200,0	0,00000686	0,000131
KFM04A 90L-14	1	44	43	0,00017071	0,034142	200,0	0,00000894	0,000171
KFM04A 90L-15	-50	-41	9	0,00003573	0,007146	200,0	0,00000187	0,000036
KFM04A 90L-16	-80	-44	36	0,00014292	0,028584	200,0	0,00000748	0,000143
KFM04A 90L-17	166	210	44	0,00017468	0,034936	200,0	0,00000915	0,000175
KFM04A 90L-18	74	114	40	0,0001588	0,03176	200,0	0,00000831	0,000159

använder sista mätvärdet på 20 grader

använder median på 40 gradersmätn

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479

Tempdifferens 38,55

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

Borrhål/nivå: KFM04A

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	Längdutvidgningskoeff mm/mm per grader C	Längdutv mm/mm
KFM04A 90L-1	29	141	112	0,00044464	0,088928	200,0	0,00001153	0,000445
KFM04A 90L-2	115	185,5	70,5	0,000279885	0,055977	200,0	0,00000726	0,000280
KFM04A 90L-3	129	187	58	0,00023026	0,046052	200,0	0,00000597	0,000230
KFM04A 90L-4	-538	-488,5	49,5	0,000196515	0,039303	200,0	0,00000510	0,000197
KFM04A 90L-5	-85	-4	81	0,00032157	0,064314	200,0	0,00000834	0,000322
KFM04A 90L-6	315	386	71	0,00028187	0,056374	200,0	0,00000731	0,000282
KFM04A 90L-7	126	181,5	55,5	0,000220335	0,044067	200,0	0,00000572	0,000220
KFM04A 90L-8	109	172,5	63,5	0,000252095	0,050419	200,0	0,00000654	0,000252
KFM04A 90L-9	223	298	75	0,00029775	0,05955	200,0	0,00000772	0,000298
KFM04A 90L-10	53	146	93	0,00036921	0,073842	200,0	0,00000958	0,000369
KFM04A 90L-11	141	175	34	0,00013498	0,026996	200,0	0,00000350	0,000135
KFM04A 90L-12	-227	-139,5	87,5	0,000347375	0,069475	200,0	0,00000901	0,000347
KFM04A 90L-13	-376	-281,5	94,5	0,000375165	0,075033	200,0	0,00000973	0,000375
KFM04A 90L-14	1	80	79	0,00031363	0,062726	200,0	0,00000814	0,000314
KFM04A 90L-15	-50	-11	39	0,00015483	0,030966	200,0	0,00000402	0,000155
KFM04A 90L-16	-80	4	84	0,00033348	0,066696	200,0	0,00000865	0,000333
KFM04A 90L-17	166	259	93	0,00036921	0,073842	200,0	0,00000958	0,000369
KFM04A 90L-18	74	173	99	0,00039303	0,078606	200,0	0,00001020	0,000393

använder sista mätvärdet på 20 grader

använder median på 60 gradersmätn

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479 Tempdifferens 57

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

Borrhål/nivå: KFM04A

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	Längdutvidgningskoeff mm/mm per grader C	Längdutv mm/mm
KFM04A 90L-1	29	235,5	206,5	0,000819805	0,163961	200,0	0,00001438	0,000820
KFM04A 90L-2	115	199	84	0,00033348	0,066696	200,0	0,00000585	0,000333
KFM04A 90L-3	129	204	75	0,00029775	0,05955	200,0	0,00000522	0,000298
KFM04A 90L-4	-538	-449	89	0,00035333	0,070666	200,0	0,00000620	0,000353
KFM04A 90L-5	-85	37,5	122,5	0,000486325	0,097265	200,0	0,00000853	0,000486
KFM04A 90L-6	315	436,5	121,5	0,000482355	0,096471	200,0	0,00000846	0,000482
KFM04A 90L-7	126	215	89	0,00035333	0,070666	200,0	0,00000620	0,000353
KFM04A 90L-8	109	177	68	0,00026996	0,053992	200,0	0,00000474	0,000270
KFM04A 90L-9	223	327,5	104,5	0,000414865	0,082973	200,0	0,00000728	0,000415
KFM04A 90L-10	53	175,5	122,5	0,000486325	0,097265	200,0	0,00000853	0,000486
KFM04A 90L-11	141	211	70	0,0002779	0,05558	200,0	0,00000488	0,000278
KFM04A 90L-12	-227	-102	125	0,00049625	0,09925	200,0	0,00000871	0,000496
KFM04A 90L-13	-376	-249	127	0,00050419	0,100838	200,0	0,00000885	0,000504
KFM04A 90L-14	1	120	119	0,00047243	0,094486	200,0	0,00000829	0,000472
KFM04A 90L-15	-50	6,5	56,5	0,000224305	0,044861	200,0	0,00000394	0,000224
KFM04A 90L-16	-80	77	157	0,00062329	0,124658	200,0	0,00001093	0,000623
KFM04A 90L-17	166	282,5	116,5	0,000462505	0,092501	200,0	0,00000811	0,000463
KFM04A 90L-18	74	254,5	180,5	0,000716585	0,143317	200,0	0,00001257	0,000717

använder sista mätvärdet på 20 grader

använder median på 60 gradersmätn

Längdutvidgningskoeff	**Borrhål:**	**KFM04A**		
Temperatur/ mm/mm per grader C	**20**	**39,1**	**58,55**	**77**
KFM04A 90L-1	0	8,31414E-06	1,15E-05	1,44E-05
KFM04A 90L-2	0	7,06702E-06	7,26E-06	5,85E-06
KFM04A 90L-3	0	6,65131E-06	5,97E-06	5,22E-06
KFM04A 90L-4	0	5,61204E-06	5,1E-06	6,2E-06
KFM04A 90L-5	0	9,97696E-06	8,34E-06	8,53E-06
KFM04A 90L-6	0	7,06702E-06	7,31E-06	8,46E-06
KFM04A 90L-7	0	5,40419E-06	5,72E-06	6,2E-06
KFM04A 90L-8	0	6,2356E-06	6,54E-06	4,74E-06
KFM04A 90L-9	0	6,65131E-06	7,72E-06	7,28E-06
KFM04A 90L-10	0	5,8199E-06	9,58E-06	8,53E-06
KFM04A 90L-11	0	4,98848E-06	3,5E-06	4,88E-06
KFM04A 90L-12	0	4,98848E-06	9,01E-06	8,71E-06
KFM04A 90L-13	0	6,85916E-06	9,73E-06	8,85E-06
KFM04A 90L-14	0	8,9377E-06	8,14E-06	8,29E-06
KFM04A 90L-15	0	1,87068E-06	4,02E-06	3,94E-06
KFM04A 90L-16	0	7,48272E-06	8,65E-06	1,09E-05
KFM04A 90L-17	0	9,14555E-06	9,58E-06	8,11E-06
KFM04A 90L-18	0	8,31414E-06	1,02E-05	1,26E-05

Längdutvidgning				
Temperatur / mm/m	**20**	**39,1**	**58,55**	**77**
KFM04A 90L-1	0	0,0001588	0,000445	0,00082
KFM04A 90L-2	0	0,00013498	0,00028	0,000333
KFM04A 90L-3	0	0,00012704	0,00023	0,000298
KFM04A 90L-4	0	0,00010719	0,000197	0,000353
KFM04A 90L-5	0	0,00019056	0,000322	0,000486
KFM04A 90L-6	0	0,00013498	0,000282	0,000482
KFM04A 90L-7	0	0,00010322	0,00022	0,000353
KFM04A 90L-8	0	0,0001191	0,000252	0,00027
KFM04A 90L-9	0	0,00012704	0,000298	0,000415
KFM04A 90L-10	0	0,00011116	0,000369	0,000486
KFM04A 90L-11	0	0,00009528	0,000135	0,000278
KFM04A 90L-12	0	0,00009528	0,000347	0,000496
KFM04A 90L-13	0	0,00013101	0,000375	0,000504
KFM04A 90L-14	0	0,00017071	0,000314	0,000472
KFM04A 90L-15	0	0,00003573	0,000155	0,000224
KFM04A 90L-16	0	0,00014292	0,000333	0,000623
KFM04A 90L-17	0	0,00017468	0,000369	0,000463
KFM04A 90L-18	0	0,0001588	0,000393	0,000717

Beräkning densitet

Vattenmättnadsdensitet

KFMO4A

Uppdrags nr: P400242
Metod: EN 13755, ISRM (1973), avsnitt 3 samt SKB MD 160.002 version 1.0
Provad av: Lej
Datum: 2004-08-05

	Provmärkning:	Vikt i vatten, Msub (g)	Yttor vikt, Msat (g)	Yttorr vikt, Ms (g)	Bulk volume, V (cm3)	Pore volume, Vv (cm3)	Porosity, n (%)	Dry density, ρd (g/cm3)	Wet density (g/cm3)
1	KFMO4A-1	818,58	1309,92		492,42	1312,81	266,60	0,000	2,660
2	2	827,46	1311,58		485,19	1314,47	270,92	0,000	2,703
3	3	816,44	1300,8		485,43	1303,67	268,56	0,000	2,680
4	4	824,29	1308,78		485,56	1311,67	270,14	0,000	2,695
5	5	823,78	1309,09		486,38	1311,98	269,74	0,000	2,691
6	6	825,12	1311,25		487,20	1314,14	269,73	0,000	2,691
7	7	809,25	1295,41		487,23	1298,27	266,46	0,000	2,659
8	8	801,90	1285,08		484,25	1287,91	265,96	0,000	2,654
9	9	810,64	1297,13		487,56	1299,99	266,63	0,000	2,660
10	10	805,28	1291,33		487,12	1294,18	265,68	0,000	2,651
11	11	806,90	1292,38		486,55	1295,23	266,21	0,000	2,656
12	12	806,97	1292,5		486,60	1295,35	266,20	0,000	2,656
13	13	805,01	1290,65		486,71	1293,50	265,76	0,000	2,652
14	14	806,86	1292,49		486,70	1295,34	266,15	0,000	2,656
15	15	808,91	1294,85		487,01	1297,70	266,46	0,000	2,659
16	16	808,69	1294,9		487,28	1297,76	266,33	0,000	2,657
17	17	810,26	1296,83		487,64	1299,69	266,52	0,000	2,659
18	18	807,98	1292,94		486,03	1295,79	266,61	0,000	2,660
19					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
20					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
21					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!

Vattnets temperatur ('	21,8
Vattnets desitet (ºC):	0,9978

Våg, inv.nr:	102291
Termometer, inv.nr:	102080