P-04-165

Forsmark site investigation

Drill hole KFM03A: Extensometer measurement of the coefficient of thermal expansion of rock

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June 2004

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Keywords: AP PF 400-04-20, Field note no Forsmark 215, 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 KFM03A. The specimens were sampled on four levels in the drill hole at a depth of approximately 260 m, 305 m, 525 m and 680 m. The investigated rock types are mapped as a tonalite and medium grained granite for level 1 (260 m) and level 2 (300 m) and medium grained granite for level 3 (530 m) and level 4 (680 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 5 and 11 x 10^{-6} mm/mm ˚C.

Contents

1 Introduction

This document reports the data collected within the activity “Undersökningar i Forsmarksområdet. KFM03A. 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 400-04-20 (SKB internal controlling document).

The principle of the measurements is to determine the coefficient of thermal expansion at different temperatures.

The cores are sampled from borehole KFM03A in the Forsmark area (Figure 1-1). They were sampled 29 October 2003 by Thomas Janson, Tyréns AB, and Urban Åkesson, The Swedish National Testing and Research Institute (SP). Specimens were taken from three levels at depths of approximately 300 m, 500 m and 700 m. The rock cores were transported by SP from Forsmark and arrived at SP 30 October 2003. The testing was performed during April and May 2004 (see Appendix 1).

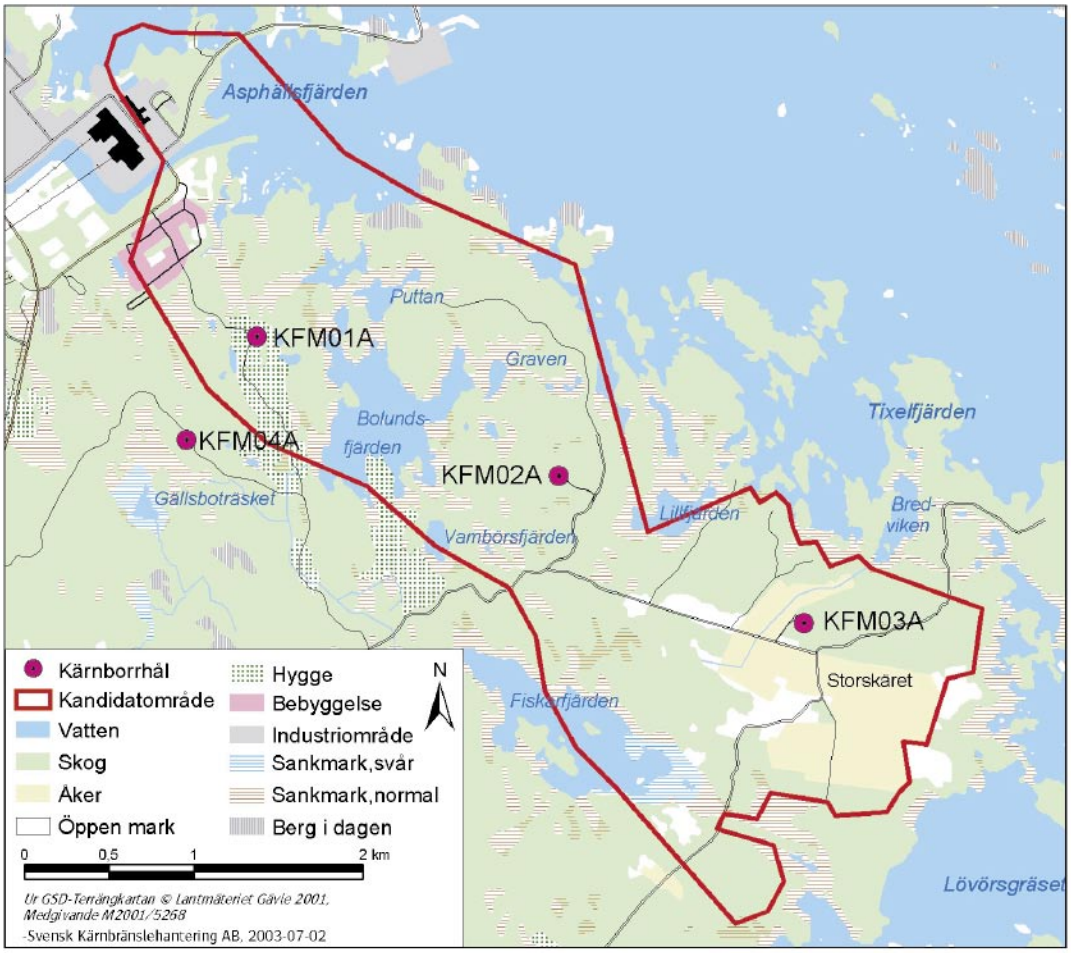


Figure 1-1. *Location of drill hole KFM03A at the Forsmark investigation area.*

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 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 2). 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 four levels in drill hole KFM03A. 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 260 m, 300 m, 530 m and 680 m. Eighteen specimens, with a length of 240 mm and a diameter of 50 mm, were sampled. The sampled rock types are a tonalite and a medium grained granite. Table 4-1 shows the rock type and identification marks of the specimens.

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

Identification	Sampling depth, according to the marks on the drill-core boxes (Sec low)	Rock type
KFM03A-90L-1	261.43	Tonalite and medium grained granite
KFM03A-90L-2	261.69	Tonalite and medium grained granite
KFM03A-90L-3	261.94	Tonalite and medium grained granite
KFM03A-90L-4	305.11	Tonalite and medium grained granite
KFM03A-90L-5	305.37	Tonalite and medium grained granite
KFM03A-90L-6	305.63	Tonalite and medium grained granite
KFM03A-90L-7	523.53	Medium grained granite
KFM03A-90L-8	523.79	Medium grained granite
KFM03A-90L-9	526.05	Medium grained granite
KFM03A-90L-10	526.64	Medium grained granite
KFM03A-90L-11	526.90	Medium grained granite
KFM03A-90L-12	527.16	Medium grained granite
KFM03A-90L-13	680.31	Medium grained granite
KFM03A-90L-14	680.57	Medium grained granite
KFM03A-90L-15	681.82	Medium grained granite
KFM03A-90L-16	684.15	Medium grained granite
KFM03A-90L-17	684.58	Medium grained granite
KFM03A-90L-18	684.84	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 3)
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 2). 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 KFM03A at Forsmark are stored in the database SICADA under field note no Forsmark 215.

5.1 Description of the specimens and presentation of the results

The temperature of water 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 KFM03A-90L-1 was measured to be 8.1 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2770 kg/m^3.

KFM03A-90L-1 (261.43)

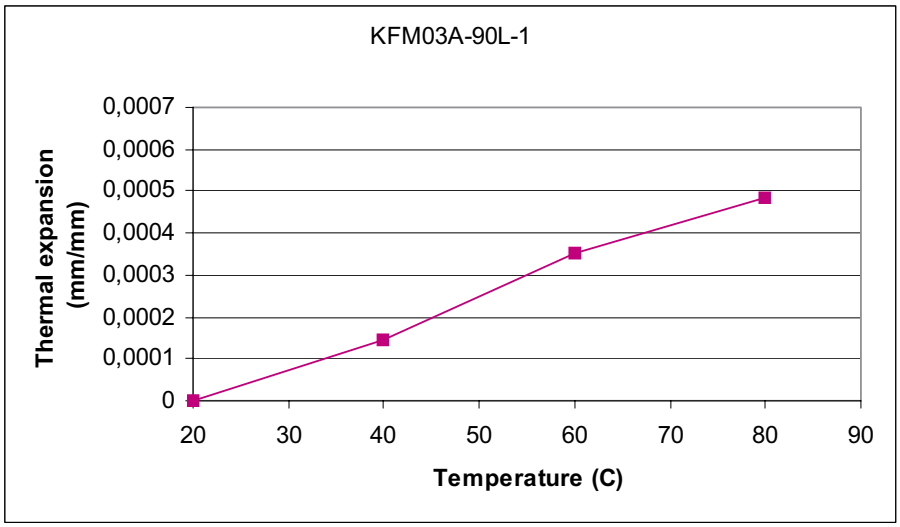


Figure 5-1. *Specimen KFM03A-90L-1.*

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 KFM03A-90L-2 was measured to be 8.2 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2770 kg/m^3.

KFM03A-90L-2 (261.69)

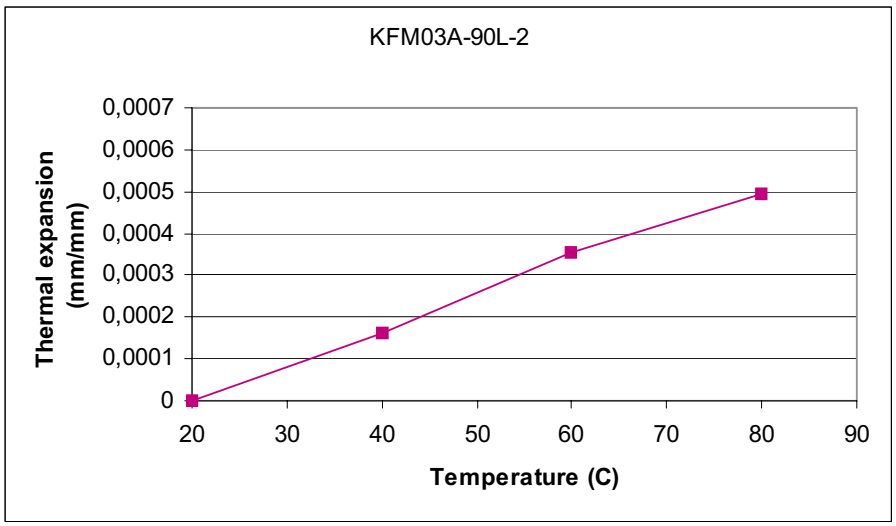


Figure 5-2. *Specimen KFM03A-90L-2.*

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 KFM03A-90L-3 was measured to be 5.3 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2770 kg/m^3.

KFM03A-90L-3 (261.94)

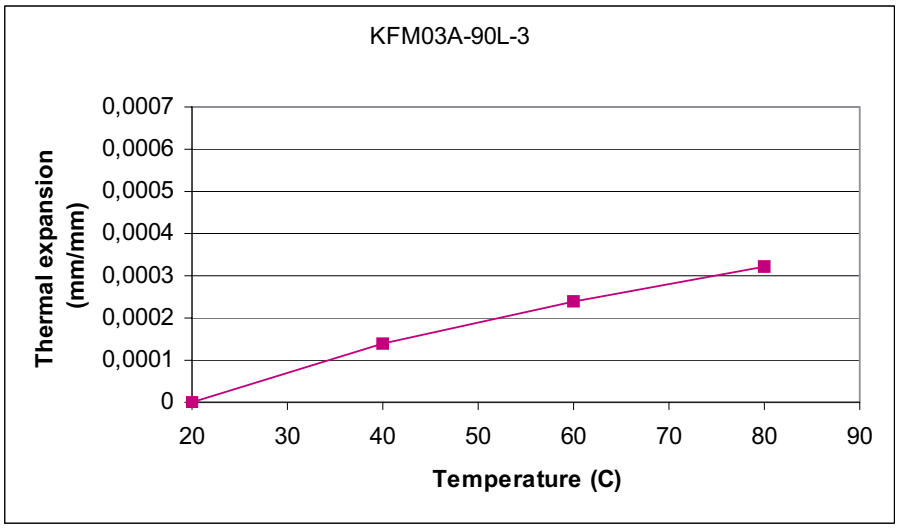


Figure 5-3. *Specimen KFM03A-90L-3.*

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 KFM03A-90L-4 was measured to be 10.0 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2790 kg/m^3.

KFM03A-90L-4 (305.11)

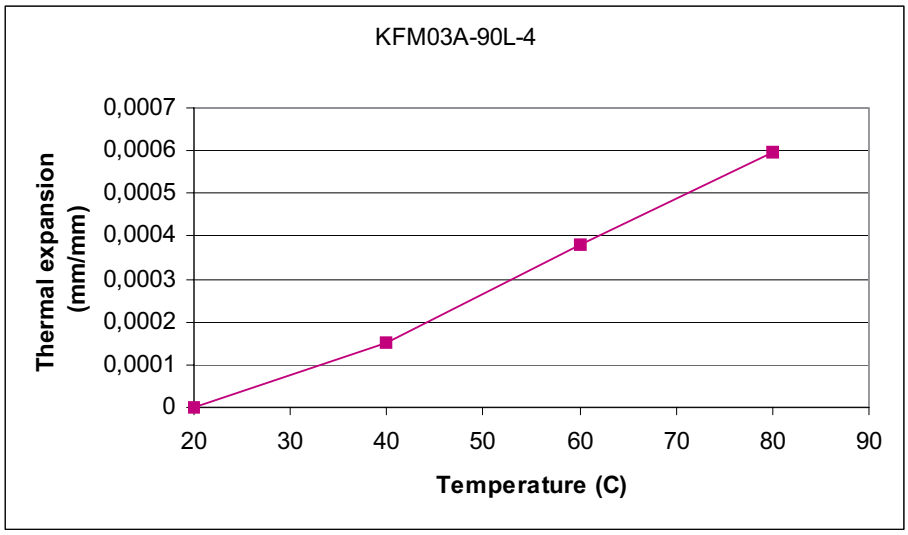


Figure 5-4. *Specimen KFM03A-90L-4.*

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 KFM03A-90L-5 was measured to be 7.5 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2800 kg/m^3.

KFM03A-90L-5 (305.37)

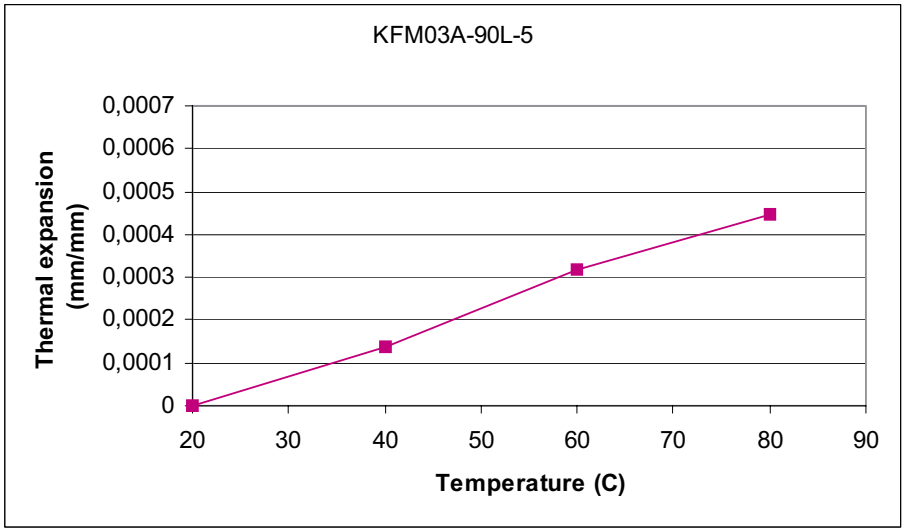


Figure 5-5. *Specimen KFM03A-90L-5.*

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 KFM03A-90L-6 was measured to be 6.5 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2810 kg/m^3.

KFM03A-90L-6 (305.63)

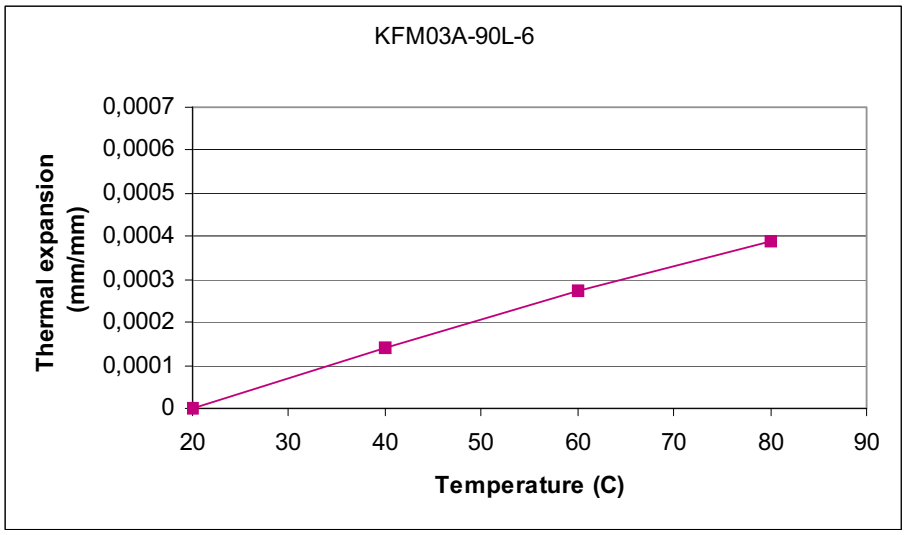
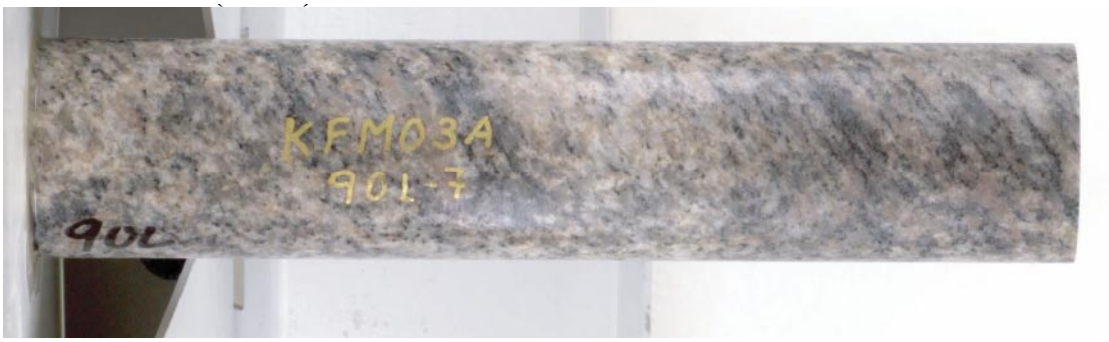


Figure 5-6. *Specimen KFM03A-90L-6.*

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 KFM03A-90L-7 was measured to be 8.3 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2650 kg/m^3.

KFM03A-90L-7 (523.53)



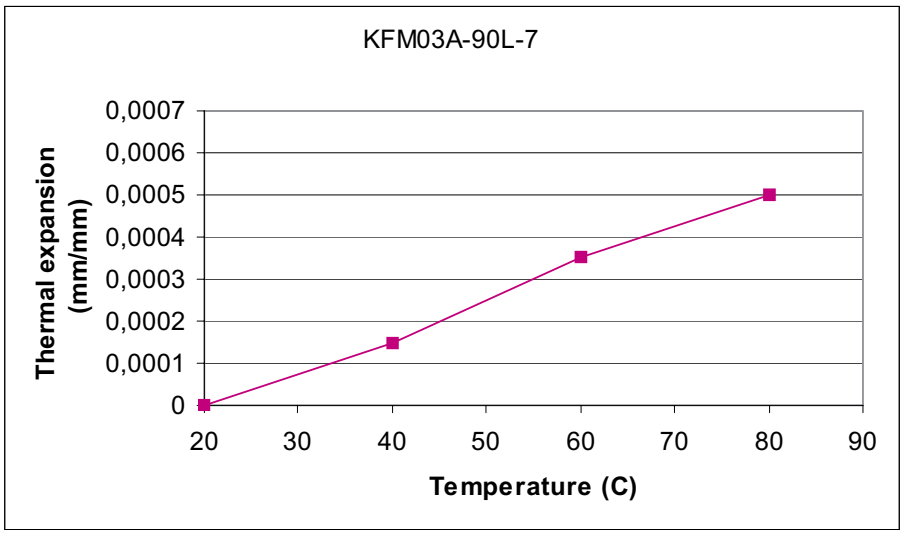


Figure 5-7. *Specimen KFM03A-90L-7.*

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 KFM03A-90L-8 was measured to be 11.4 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2650 kg/m^3.

KFM03A-90L-8 (523.79)

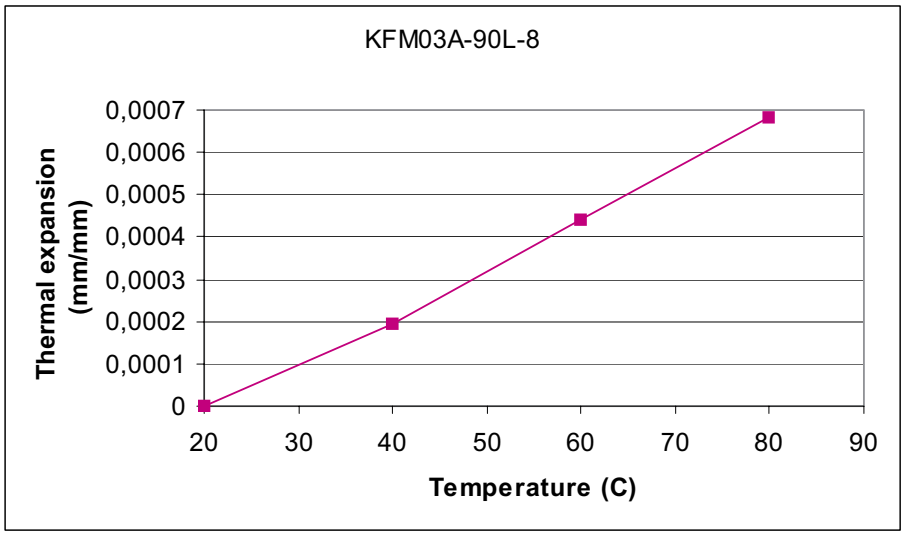


Figure 5-8. *Specimen KFM03A-90L-8.*

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 KFM03A-90L-9 was measured to be 2.1 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2660 kg/m^3. The result for thermal expansion at 80 degrees is uncertain. After the first measurement at 80 degrees the studs fell off.

KFM03A-90L-9 (526.05)

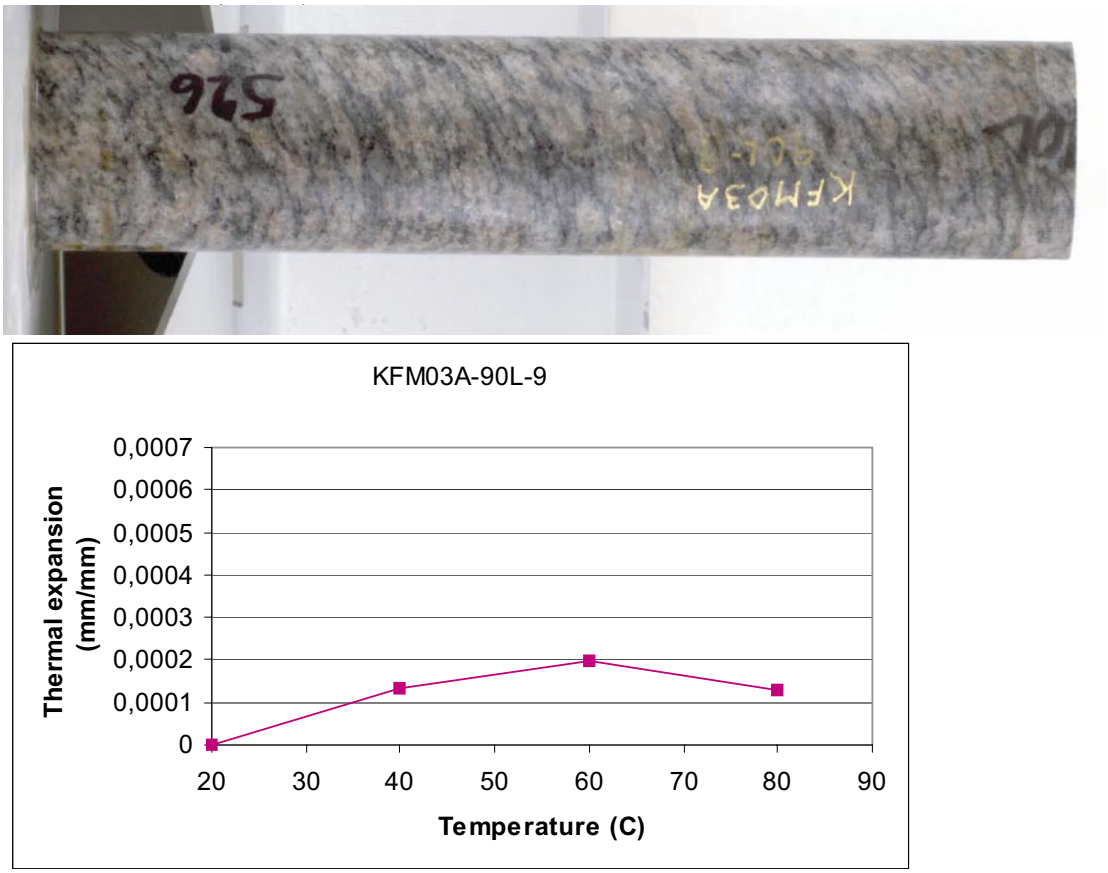


Figure 5-9. *Specimen KFM03A-90L-9.*

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 KFM03A-90L-10 was measured to be 8.6 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2660 kg/m^3.

KFM03A-90L-10 (526.64)

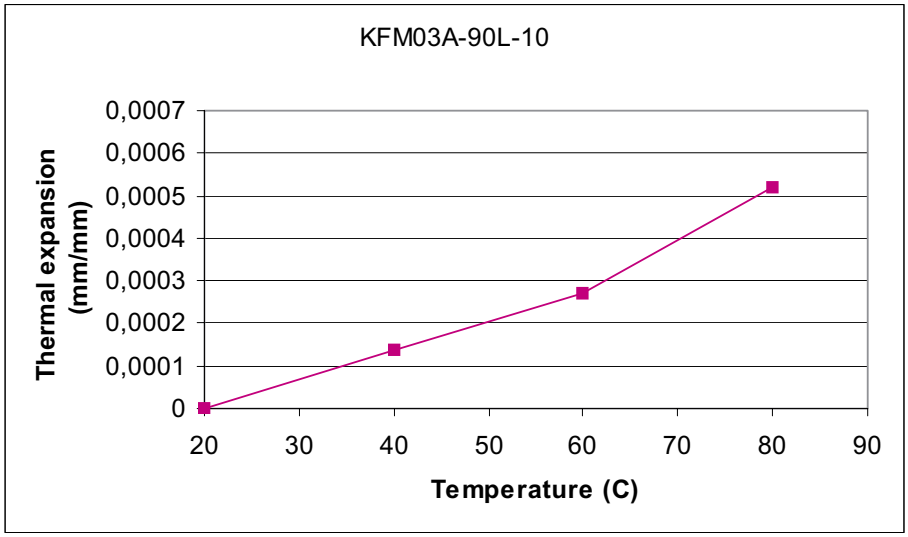


Figure 5-10. *Specimen KFM03A-90L-10.*

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 KFM03A-90L-11 was measured to be 10.1 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2660 kg/m^3.

KFM03A-90L-11 (526.90)

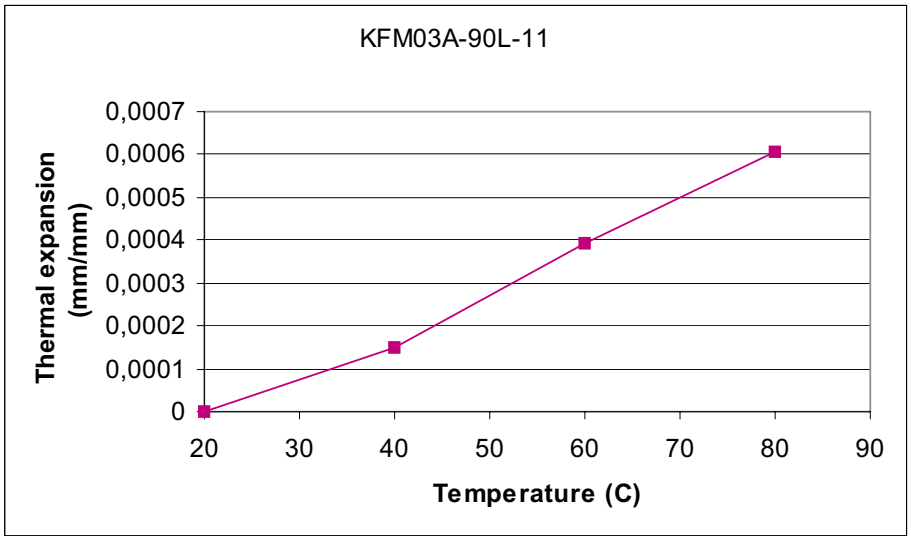


Figure 5-11. *Specimen KFM03A-90L-11.*

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 KFM03A-90L-12 was measured to be 6.7x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2660 kg/m^3. The result at 80 degrees is probably uncertain. It may depend on the glue or on bending of the specimen.

KFM03A-90L-12 (527.16)

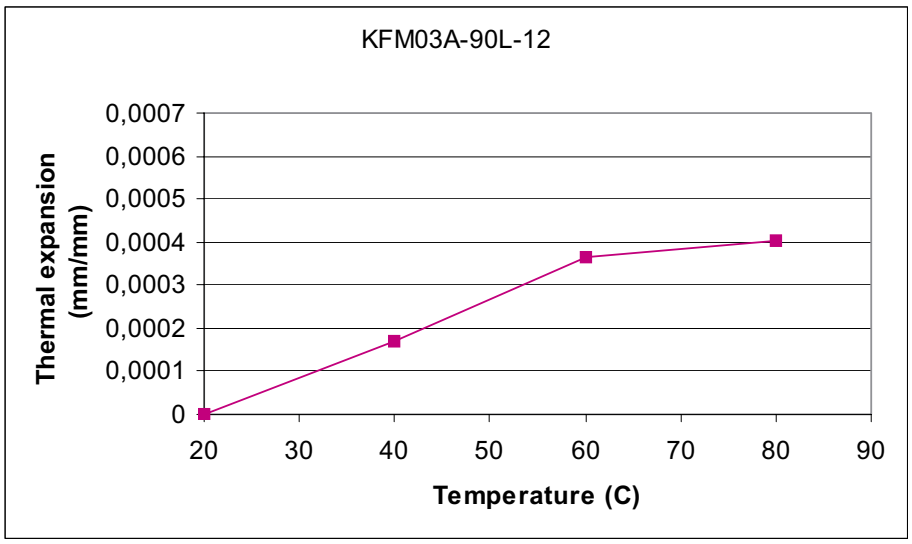


Figure 5-12. *Specimen KFM03A-90L-12.*

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 KFM03A-90L-13 was measured to be 8.1 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2660 kg/m^3.

KFM03A-90L-13 (680.31)

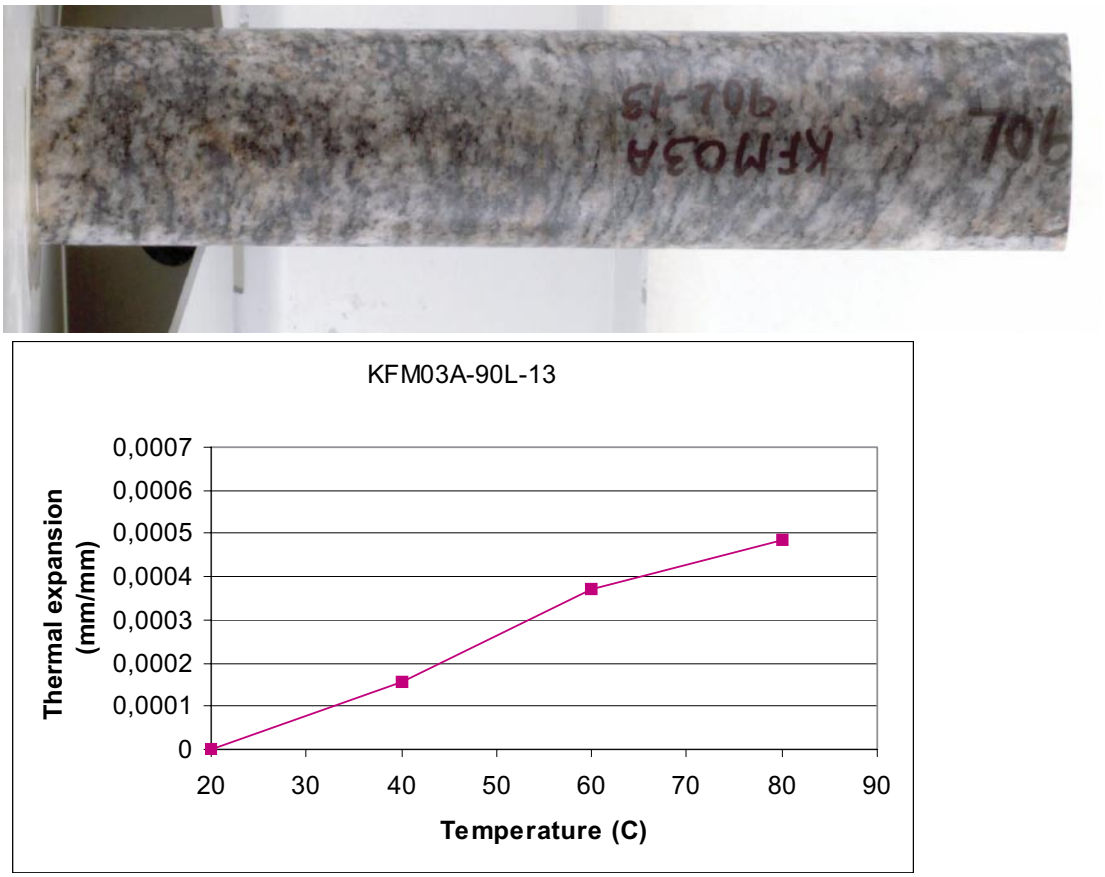


Figure 5-13. *Specimen KFM03A-90L-13.*

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 KFM03A-90L-14 was measured to be 4.5 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2650 kg/m^3. The result at 80 degrees is probably uncertain. It may depend on the glue or on bending of the specimen.

KFM03A-90L-14 (680.57)

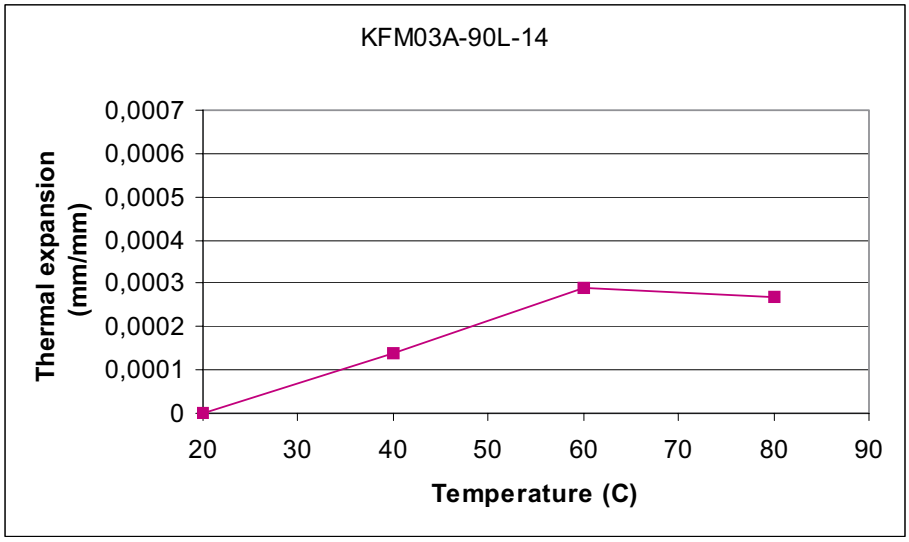


Figure 5-14. *Specimen KFM03A-90L-14.*

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 KFM03A-90L-15 was measured to be 10.8 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2660 kg/m^3.

KFM03A-90L-15 (681.82)

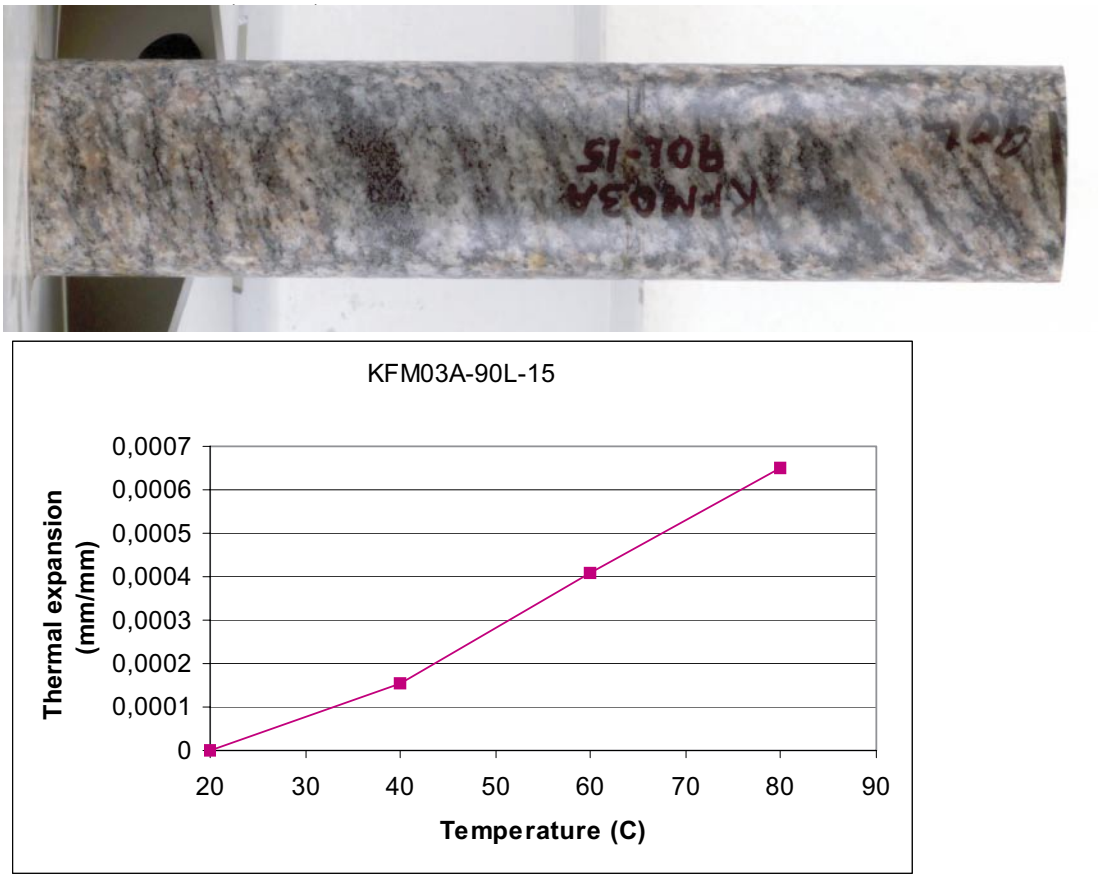
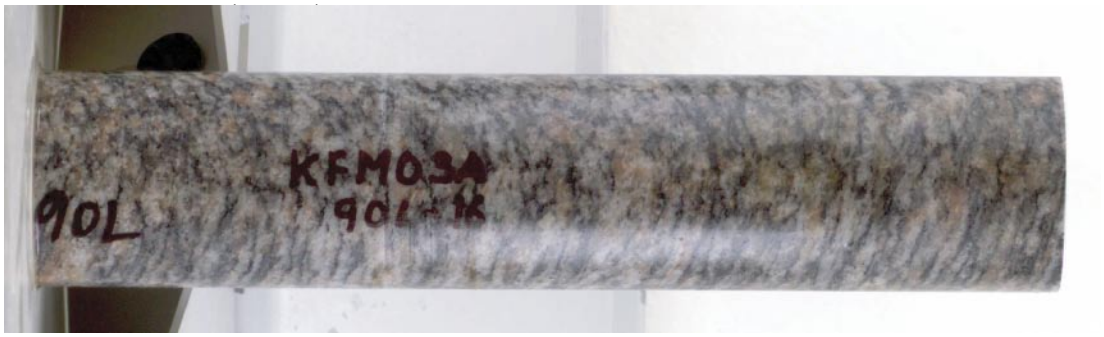


Figure 5-15. *Specimen KFM03A-90L-15.*

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 KFM03A-90L-16 was measured to be 7.7 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2660 kg/m^3.

KFM03A-90L-16 (684.15)



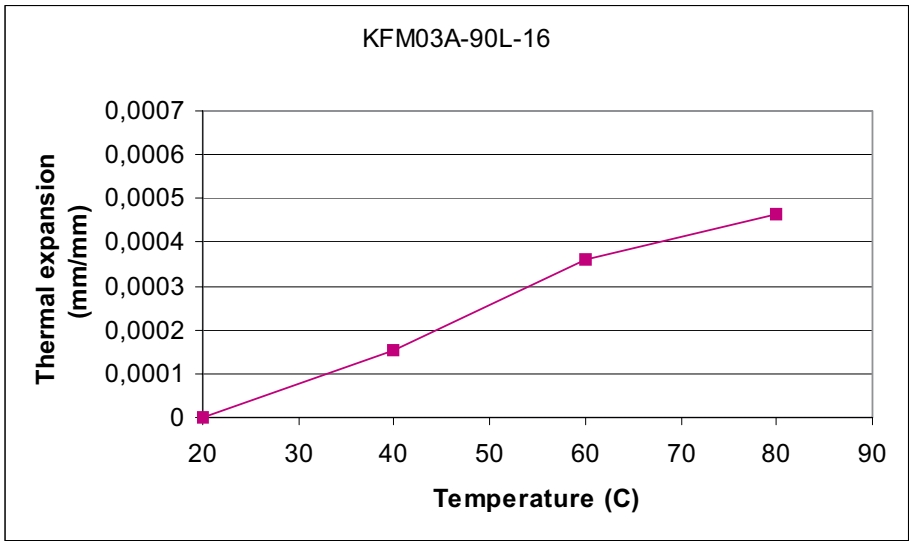


Figure 5-16. *Specimen KFM03A-90L-16.*

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 KFM03A-90L-17 was measured to be 9.3 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2650 kg/m^3.

KFM03A-90L-17 (684.58)

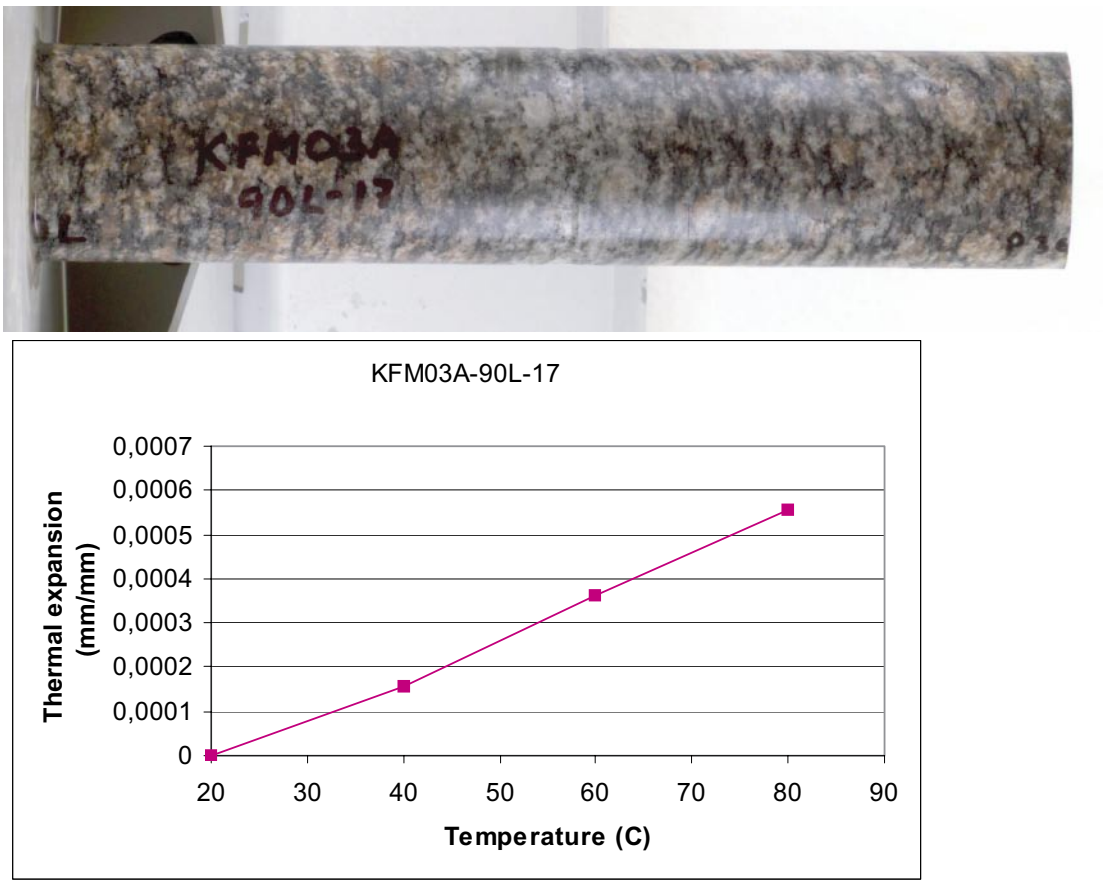


Figure 5-17. *Specimen KFM03A-90L-17.*

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 KFM03A-90L-18 was measured to be 8.2 x 10^{-6} mm/mm ˚C and the specimen had a wet density of 2650 kg/m^3.

KFM03A-90L-18 (684.84)

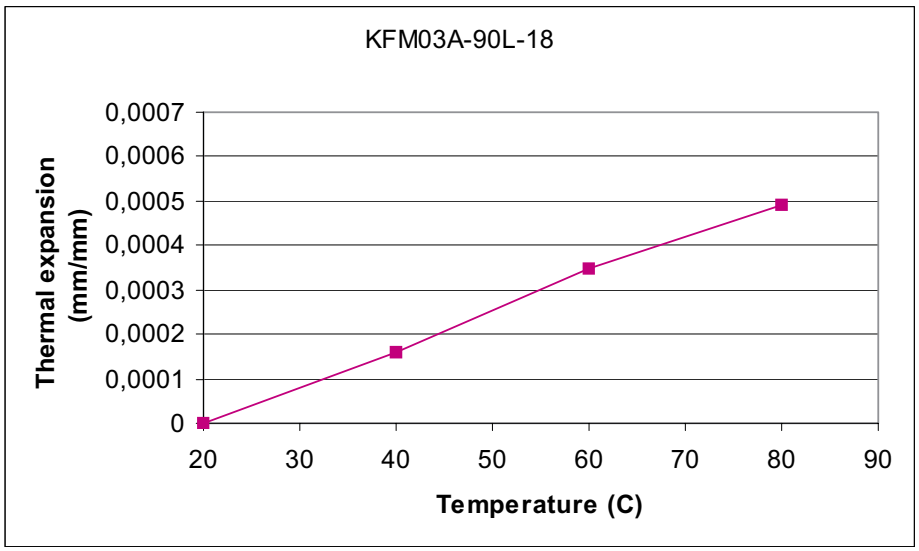


Figure 5-18. *Specimen KFM03A-90L-18.*

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 (261 m).

Specimen	Coefficient of thermal expansion between 20 and 80 ˚C (mm/mm ˚C)	Wet density (Kg/m^3)
KFM03A-90L-1	8.1 x 10^{-6}	2770
KFM03A-90L-2	8.2 x 10^{-6}	2770
KFM03A-90L-3	5.3 x 10^{-6}	2770
Median	8.1 x 10^{-6}	
Maximum value	8.2 x 10^{-6}	
Minimum value	5.3 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 (305 m).

Specimen	Coefficient of thermal expansion between 20 and 80 ˚C (mm/mm ˚C)	Wet density (Kg/m^3)
KFM03A-90L-4	10.0 x 10^{-6}	2790
KFM03A-90L-5	7.5 x 10^{-6}	2800
KFM03A-90L-6	6.5 x 10^{-6}	2810
Median	7.5 x 10^{-6}	
Maximum value	10.0 x 10^{-6}	
Minimum value	6.5 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 (524-527 m).

Specimen	Coefficient of thermal expansion between 20 and 80 ˚C (mm/mm ˚C)	Wet density (Kg/m^3)
KFM03A-90L-7	8.3 x 10^{-6}	2650
KFM03A-90L-8	11.4 x 10^{-6}	2650
KFM03A-90L-9	-	2660
KFM03A-90L-10	8.6 x 10^{-6}	2660
KFM03A-90L-11	10.1 x 10^{-6}	2660
KFM03A-90L-12	-	2660
Median	9.4 x 10^{-6}	
Maximum value	11.4 x 10^{-6}	
Minimum value	8.3 x 10^{-6}	

Table 5-4. Summary of the results for the coefficient of thermal expansion and wet density of the tested specimens, level 4 (680-685 m).

Specimen	Coefficient of thermal expansion between 20 and 80 ˚C (mm/mm ˚C)	Wet density (Kg/m^3)
KFM03A-90L-13	8.1 x 10^{-6}	2660
KFM03A-90L-14	-	2650
KFM03A-90L-15	10.8 x 10^{-6}	2660
KFM03A-90L-16	7.7 x 10^{-6}	2660
KFM03A-90L-17	9.3 x 10^{-6}	2650
KFM03A-90L-18	8.2 x 10^{-6}	2650
Median	8.2 x 10^{-6}	
Maximum value	10.8 x 10^{-6}	
Minimum value	7.7 x 10^{-6}	

5.3 Nonconformities

On one specimen, KFM03A-90L-9, the studs fell off after the first measurement at 80 degrees.

Specimens KFM03A-90L-12 and KFM03A-90L-14 are thus associated with an uncertainty. The result at 80 degrees on these specimens is probably uncertain. It may depend on the glue or on bending of the specimens.

5.4 Discussion

The variation between the samples is approximately 9 x 10^{-6} mm/mm ˚C that is more than 10 times the uncertainty of the measurement (0.4 x 10^{-6} mm/mm ˚C).

Protokoll Checklista längdutvidgning

Kvalitetsdokument **Blankett** **BMm-QR 51**
Bygg och Mekanik
Checklista längdutvidgning

Version 1,0
Utfärdat 2003-12-19
Författare Lotta Carlsson
Godkännare Matz Sandström
Sida 1(1)

Fyll i datum och signatur i rutorna.

Appendix 1
Thermal expansion
KFM03A

Instrument (inventarienr): 102266

Prov id	Foto	Provberedning & limning mätdubbar	Vattenmättning startad	Vattenmättnadsdensitet	Provning startad	Retur i lådor
KFMO3A-1	04-04-28	04-04-30	04-05-05	05-05-12	04-05-12	
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
13						
14						
15						

16
17

Appendix 2

Beräkning av längdutvidgningskoefficient och Provningsprotokoll för längdutvidgningskoefficient

Provningsprotokoll längdutvidgningskoefficient									
Uppdrags nummer:	########								
Borrhål:	*****								
Mättemperatur	**20 grader C**								
Prov ID	Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		**Median**
KFM03A-90L-1	14	04-05-12	13	04-05-13	13	04-05-14	14	04-05-17	13,50
KFM03A-90L-2	15		15		15		14		15,00
KFM03A-90L-3	-5		-6		-5		-6		-5,50
KFM03A-90L-4	30		29		29		29		29,00
KFM03A-90L-5	11		9		10		10		10,00
KFM03A-90L-6	4		4		4		4		4,00
KFM03A-90L-7	41		41		41		41		41,00
KFM03A-90L-8	12		13		14		15		13,50
KFM03A-90L-9	22		20		21		22		21,50
KFM03A-90L-10	10		7		6		2		6,50
KFM03A-90L-11	17		17		17		18		17,00
KFM03A-90L-12	-593		-593		-593		-593		-593,00
KFM03A-90L-13	37		38		37		39		37,50
KFM03A-90L-14	15		15		14		14		14,50
KFM03A-90L-15	13		11		12		13		12,50
KFM03A-90L-16	-9		-9		-7		-7		-8,00
KFM03A-90L-17	-97		-98		-97		-94		-97,00
KFM03A-90L-18	22		20		21		22		21,50
									########
									########
									########
									########

Provningsprotokoll längdutvidgningskoefficient									
Uppdrags nummer:	**########**								
Borrhål:	**#####**								
Mättemperatur	**40 grader C**								
Prov ID	Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		**Median**
KFM03A-90L-1	47	04-05-18	51	04-05-19	51	04-05-20	51	04-05-21	51
KFM03A-90L-2	53		54		56		55		54,5
KFM03A-90L-3	29		31		30		29		29,5
KFM03A-90L-4	66		70		68		67		67,5
KFM03A-90L-5	45		46		45		44		45
KFM03A-90L-6	40		40		39		37		39,5
KFM03A-90L-7	77		78		79		78		78
KFM03A-90L-8	60		64		64		63		63,5
KFM03A-90L-9	56		57		56		55		56
KFM03A-90L-10	37		38		37		37		37
KFM03A-90L-11	54		56		55		56		55,5
KFM03A-90L-12	-554		-548		-550		-551		-550,5
KFM03A-90L-13	76		79		78		79		78,5
KFM03A-90L-14	45		50		49		48		48,5
KFM03A-90L-15	51		51		53		54		52
KFM03A-90L-16	32		30		32		33		32
KFM03A-90L-17	-55		-54		-54		-55		-54,5
KFM03A-90L-18	62		63		63		62		62,5
0									########
0									########
0									########
0									########

Provningsprotokoll längdutvidgningskoefficient

Uppdrags nummer:		**########**							
Borrhål:	**#####**								
Mättemperatur	**60 grader C**								
Prov ID	Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		**Median**
KFM03A-90L-1	103	04-05-24	104	04-05-26	101	04-05-27	103	04-05-28	103
KFM03A-90L-2	104		103		105		103		103,5
KFM03A-90L-3	55		57		54		54		54,5
KFM03A-90L-4	123		127		125		125		125
KFM03A-90L-5	91		92		88		90		90,5
KFM03A-90L-6	76		75		70		68		72,5
KFM03A-90L-7	132		132		127		127		129,5
KFM03A-90L-8	128		127		123		124		125,5
KFM03A-90L-9	92		72		72		69		72
KFM03A-90L-10	71		74		69		70		70,5
KFM03A-90L-11	110		117		117		118		117
KFM03A-90L-12	-495		-526		-502		-500		-501
KFM03A-90L-13	132		133		131		133		132,5
KFM03A-90L-14	88		87		87		86		87
KFM03A-90L-15	112		115		117		116		115,5
KFM03A-90L-16	83		85		84		83		83,5
KFM03A-90L-17	0		-3		-3		-4		-3
KFM03A-90L-18	114		110		109		108		109,5
0									########
0									########
0									########
0									########

Provningsprotokoll längdutvidgningskoefficient									
Uppdrags nummer:	**########**								
Borrhål:	**#####**								
Mättemperatur	**80 grader C**								
Prov ID	Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		Skalvärde/datum		**Median**
KFM03A-90L-1	140	04-06-02	134	04-06-03	137	04-06-04	136	04-06-08	136,5
KFM03A-90L-2	134		127		142		143		138
KFM03A-90L-3	77		76		73		72		74,5
KFM03A-90L-4	179		179		181		180		179,5
KFM03A-90L-5	118		125		123		123		123
KFM03A-90L-6	100		102		101		102		101,5
KFM03A-90L-7	166		168		167		164		166,5
KFM03A-90L-8	182		185		190		193		187,5
KFM03A-90L-9	54								54
KFM03A-90L-10	124		134		133		132		132,5
KFM03A-90L-11	172		172		170		167		171
KFM03A-90L-12	-479		-494		-488		-500		-491
KFM03A-90L-13	156		159		164		165		161,5
KFM03A-90L-14	85		88		79		77		82
KFM03A-90L-15	175		177		176		177		176,5
KFM03A-90L-16	109		105		111		111		110
KFM03A-90L-17	47		47		45		45		46
KFM03A-90L-18	143		146		146		146		146
0									########
0									########
0									########
0									########

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479

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

Borrhål/nivå: #REFERENS!

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
KFM03A-90L-1	14	51	37	0,00014689	0,029378	200,0	0,00000734	0,000147
KFM03A-90L-2	14	54,5	40,5	0,00016079	0,032157	200,0	0,00000804	0,000161
KFM03A-90L-3	-6	29,5	35,5	0,00014094	0,028187	200,0	0,00000705	0,000141
KFM03A-90L-4	29	67,5	38,5	0,00015285	0,030569	200,0	0,00000764	0,000153
KFM03A-90L-5	10	45	35	0,00013895	0,02779	200,0	0,00000695	0,000139
KFM03A-90L-6	4	39,5	35,5	0,00014094	0,028187	200,0	0,00000705	0,000141
KFM03A-90L-7	41	78	37	0,00014689	0,029378	200,0	0,00000734	0,000147
KFM03A-90L-8	15	63,5	48,5	0,00019255	0,038509	200,0	0,00000963	0,000193
KFM03A-90L-9	22	56	34	0,00013498	0,026996	200,0	0,00000675	0,000135
KFM03A-90L-10	2	37	35	0,00013895	0,02779	200,0	0,00000695	0,000139
KFM03A-90L-11	18	55,5	37,5	0,00014888	0,029775	200,0	0,00000744	0,000149
KFM03A-90L-12	-593	-550,5	42,5	0,00016873	0,033745	200,0	0,00000844	0,000169
KFM03A-90L-13	39	78,5	39,5	0,00015682	0,031363	200,0	0,00000784	0,000157
KFM03A-90L-14	14	48,5	34,5	0,00013697	0,027393	200,0	0,00000685	0,000137
KFM03A-90L-15	13	52	39	0,00015483	0,030966	200,0	0,00000774	0,000155
KFM03A-90L-16	-7	32	39	0,00015483	0,030966	200,0	0,00000774	0,000155
KFM03A-90L-17	-94	-54,5	39,5	0,00015682	0,031363	200,0	0,00000784	0,000157
KFM03A-90L-18	22	62,5	40,5	0,00016079	0,032157	200,0	0,00000804	0,000161
0	0	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	200,0	#OGILTIGT!	#OGILTIGT!
0	0	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	200,0	#OGILTIGT!	#OGILTIGT!
0	0	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	200,0	#OGILTIGT!	#OGILTIGT!
0	0	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	200,0	#OGILTIGT!	#OGILTIGT!

använder sista mätvärdet på 20 grader

använder median på 40 gradersmätn

Tempdifferens 20 grader

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479

Borrhål/nivå: #REFERENS!

1 skaldel motsvarar 3,97 mikrostrain = 3,97x10-6 strain
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
KFM03A-90L-1	14	103	89	0,00035333	0,070666	200,0	0,00000883	0,000353
KFM03A-90L-2	14	103,5	89,5	0,00035532	0,071063	200,0	0,00000888	0,000355
KFM03A-90L-3	-6	54,5	60,5	0,00024019	0,048037	200,0	0,00000600	0,000240
KFM03A-90L-4	29	125	96	0,00038112	0,076224	200,0	0,00000953	0,000381
KFM03A-90L-5	10	90,5	80,5	0,00031959	0,063917	200,0	0,00000799	0,000320
KFM03A-90L-6	4	72,5	68,5	0,00027195	0,054389	200,0	0,00000680	0,000272
KFM03A-90L-7	41	129,5	88,5	0,00035135	0,070269	200,0	0,00000878	0,000351
KFM03A-90L-8	15	125,5	110,5	0,00043869	0,087737	200,0	0,00001097	0,000439
KFM03A-90L-9	22	72	50	0,0001985	0,0397	200,0	0,00000496	0,000199
KFM03A-90L-10	2	70,5	68,5	0,00027195	0,054389	200,0	0,00000680	0,000272
KFM03A-90L-11	18	117	99	0,00039303	0,078606	200,0	0,00000983	0,000393
KFM03A-90L-12	-593	-501	92	0,00036524	0,073048	200,0	0,00000913	0,000365
KFM03A-90L-13	39	132,5	93,5	0,0003712	0,074239	200,0	0,00000928	0,000371
KFM03A-90L-14	14	87	73	0,00028981	0,057962	200,0	0,00000725	0,000290
KFM03A-90L-15	13	115,5	102,5	0,00040693	0,081385	200,0	0,00001017	0,000407
KFM03A-90L-16	-7	83,5	90,5	0,00035929	0,071857	200,0	0,00000898	0,000359
KFM03A-90L-17	-94	-3	91	0,00036127	0,072254	200,0	0,00000903	0,000361
KFM03A-90L-18	22	109,5	87,5	0,00034738	0,069475	200,0	0,00000868	0,000347
0	0	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	200,0	#OGILTIGT!	#OGILTIGT!
0	0	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	200,0	#OGILTIGT!	#OGILTIGT!
0	0	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	200,0	#OGILTIGT!	#OGILTIGT!
0	0	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	200,0	#OGILTIGT!	#OGILTIGT!

använder sista mätvärdet på 20 grader
använder median på 60 gradersmätn

Tempdifferens 40 grader

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479

Borrhål/nivå: #REFERENS!

1 skaldel motsvarar 3,97 mikrostrain = 3,97x10-6 strain
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
KFM03A-90L-1	14	136,5	122,5	0,00048633	0,097265	200,0	0,00000811	0,000486
KFM03A-90L-2	14	138	124	0,00049228	0,098456	200,0	0,00000820	0,000492
KFM03A-90L-3	-6	74,5	80,5	0,00031959	0,063917	200,0	0,00000533	0,000320
KFM03A-90L-4	29	179,5	150,5	0,00059749	0,119497	200,0	0,00000996	0,000597
KFM03A-90L-5	10	123	113	0,00044861	0,089722	200,0	0,00000748	0,000449
KFM03A-90L-6	4	101,5	97,5	0,00038708	0,077415	200,0	0,00000645	0,000387
KFM03A-90L-7	41	166,5	125,5	0,00049824	0,099647	200,0	0,00000830	0,000498
KFM03A-90L-8	15	187,5	172,5	0,00068483	0,136965	200,0	0,00001141	0,000685
KFM03A-90L-9	22	54	32	0,00012704	0,025408	200,0	0,00000212	0,000127
KFM03A-90L-10	2	132,5	130,5	0,00051809	0,103617	200,0	0,00000863	0,000518
KFM03A-90L-11	18	171	153	0,00060741	0,121482	200,0	0,00001012	0,000607
KFM03A-90L-12	-593	-491	102	0,00040494	0,080988	200,0	0,00000675	0,000405
KFM03A-90L-13	39	161,5	122,5	0,00048633	0,097265	200,0	0,00000811	0,000486
KFM03A-90L-14	14	82	68	0,00026996	0,053992	200,0	0,00000450	0,000270
KFM03A-90L-15	13	176,5	163,5	0,0006491	0,129819	200,0	0,00001082	0,000649
KFM03A-90L-16	-7	110	117	0,00046449	0,092898	200,0	0,00000774	0,000464
KFM03A-90L-17	-94	46	140	0,0005558	0,11116	200,0	0,00000926	0,000556
KFM03A-90L-18	22	146	124	0,00049228	0,098456	200,0	0,00000820	0,000492
0	0	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	200,0	#OGILTIGT!	#OGILTIGT!
0	0	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	200,0	#OGILTIGT!	#OGILTIGT!
0	0	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	200,0	#OGILTIGT!	#OGILTIGT!
0	0	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	#OGILTIGT!	200,0	#OGILTIGT!	#OGILTIGT!

använder sista mätvärdet på 20 grader
använder median på 60 gradersmätn
tempdifferens 60 grader

Längdutvidgningskoeff	**Borrhål:**	**#REFERENS!**		
mm/mm per grader C	20	40	60	80
KFM03A-90L-1	0	7,3445E-06	8,83E-06	8,10542E-06
KFM03A-90L-2	0	8,03925E-06	8,88E-06	8,20467E-06
KFM03A-90L-3	0	7,04675E-06	6E-06	5,32642E-06
KFM03A-90L-4	0	7,64225E-06	9,53E-06	9,95808E-06
KFM03A-90L-5	0	6,9475E-06	7,99E-06	7,47683E-06
KFM03A-90L-6	0	7,04675E-06	6,8E-06	6,45125E-06
KFM03A-90L-7	0	7,3445E-06	8,78E-06	8,30392E-06
KFM03A-90L-8	0	9,62725E-06	1,1E-05	1,14138E-05
KFM03A-90L-9	0	0,000006749	4,96E-06	
KFM03A-90L-10	0	6,9475E-06	6,8E-06	8,63475E-06
KFM03A-90L-11	0	7,44375E-06	9,83E-06	1,01235E-05
KFM03A-90L-12	0	8,43625E-06	9,13E-06	
KFM03A-90L-13	0	7,84075E-06	9,28E-06	8,10542E-06
KFM03A-90L-14	0	6,84825E-06	7,25E-06	
KFM03A-90L-15	0	7,7415E-06	1,02E-05	1,08183E-05
KFM03A-90L-16	0	7,7415E-06	8,98E-06	7,7415E-06
KFM03A-90L-17	0	7,84075E-06	9,03E-06	9,26333E-06
KFM03A-90L-18	0	8,03925E-06	8,68E-06	8,20467E-06

level 1	max	8,20467E-06
	min	5,32642E-06
	median	8,10542E-06
level 2	max	9,95808E-06
	min	6,45125E-06
	median	7,47683E-06
level 3	max	1,14138E-05
	min	8,30392E-06
	median	9,37913E-06
level 4	max	1,08183E-05
	min	7,7415E-06
	median	8,20467E-06

Längdutvidgning				
mm/mm	20	40	60	80
KFM03A-90L-1	0	0,00014689	0,000353	0,0004863
KFM03A-90L-2	0	0,000160785	0,000355	0,0004923
KFM03A-90L-3	0	0,000140935	0,00024	0,0003196
KFM03A-90L-4	0	0,000152845	0,000381	0,0005975
KFM03A-90L-5	0	0,00013895	0,00032	0,0004486
KFM03A-90L-6	0	0,000140935	0,000272	0,0003871
KFM03A-90L-7	0	0,00014689	0,000351	0,0004982
KFM03A-90L-8	0	0,000192545	0,000439	0,0006848
KFM03A-90L-9	0	0,00013498	0,000199	0,0001270
KFM03A-90L-10	0	0,00013895	0,000272	0,0005181
KFM03A-90L-11	0	0,000148875	0,000393	0,0006074
KFM03A-90L-12	0	0,000168725	0,000365	0,0004049
KFM03A-90L-13	0	0,000156815	0,000371	0,0004863
KFM03A-90L-14	0	0,000136965	0,00029	0,0002700
KFM03A-90L-15	0	0,00015483	0,000407	0,0006491
KFM03A-90L-16	0	0,00015483	0,000359	0,0004645
KFM03A-90L-17	0	0,000156815	0,000361	0,0005558
KFM03A-90L-18	0	0,000160785	0,000347	0,0004923

Appendix 3

Beräkning densitet

Vattenmättnadsdensitet

Uppdrags nr: P302791
Metod: EN 13755, ISRM (1973), avsnitt 3 samt SKB MD 160.002 version 1.0
Provad av: Lej
Datum: 2004-05-12

	Provmärkning:	Vikt i vatten, Msub (g)	Yttor vikt, Msat (g)	Torr vikt, Ms (g)	Bulk volume, V (cm3)	Pore volume, Vv (cm3)	Porosity, n (%)	Dry density, ρd (g/cm3)	Wet density (g/cm3)
1	KFMO3A-1	859,29	1344,52		486,10	1346,94	277,09	0,000	2,766
2	2	858,70	1343,59		485,76	1346,01	277,09	0,000	2,766
3	3	859,33	1344,32		485,86	1346,74	277,19	0,000	2,767
4	4	874,37	1360,87		487,38	1363,32	279,73	0,000	2,792
5	5	879,89	1366,38		487,37	1368,84	280,86	0,000	2,804
6	6	884,76	1371,02		487,14	1373,49	281,95	0,000	2,814
7	7	800,45	1284,54		484,96	1286,86	265,35	0,000	2,649
8	8	801,90	1286,26		485,23	1288,58	265,56	0,000	2,651
9	9	806,99	1293,09		486,98	1295,42	266,01	0,000	2,655
10	10	806,92	1292,17		486,13	1294,50	266,29	0,000	2,658
11	11	804,12	1287,97		484,72	1290,29	266,19	0,000	2,657
12	R12	806,98	1292,39		486,29	1294,72	266,25	0,000	2,658
13	13	806,09	1291,51		486,30	1293,84	266,06	0,000	2,656
14	14	805,98	1291,95		486,85	1294,28	265,85	0,000	2,654
15	15	804,25	1287,61		484,23	1289,93	266,39	0,000	2,659
16	16	808,80	1295,12		487,20	1297,46	266,31	0,000	2,658
17	17	805,53	1291,15		486,50	1293,48	265,88	0,000	2,654
18	R18	803,93	1288,87		485,81	1291,19	265,78	0,000	2,653
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!
	Medel	826,571	1311,852	#DIVISION/0!	416,705	1126,472	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
	std avvikelse	31,855	32,294	#DIVISION/0!	174,322	472,180	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!

Vattnets temperatur ('	19,9
Vattnets desitet (ºC):	0,9982

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