P-04-61

Oskarshamn site investigation

Drill hole KAV01

Extensometer measurement of the coefficient of thermal expansion of rock

Urban Åkesson
Swedish National Testing and Research Institute

March 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 five specimens from drill hole KAV01. The specimens were sampled on one level in the drill hole at a depth of approximately 500 m. The investigated rock type is mapped as Ävrö granite. The coefficient of thermal expansion has been determined between the temperature interval 20–80°C. The results indicated that the thermal expansion was almost linear except one specimen, and the coefficient of thermal expansion range between 3.8 and 6.5 x 10^{-6} mm/mm°C.

Contents

1 Introduction

This document reports the data collected by Simpevarp, which is one of the activities performed as part of the site investigation at Oskarshamn. The work was carried out in accordance with activity plan AP PS 400–03-091 (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 KAV01 in the Simpevarp area (Figure 1-1). It was sampled 11 November 2003 by Thomas Janson, Tyréns AB and Urban Åkesson, The Swedish National Testing and Research Institute (SP). Specimens were taken from one level in the rock core at a depth of approximately 500 m. The rock cores were transported by SP from Simpevarp and arrived to SP 12 November 2003. The testing was performed during March 2004.

Figure 1-1. *Map of Oskarshamn site.*

2 Objective and scope

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

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

3 Equipment

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 (see Appendix 2). The uncertainty of the extensometer is $\pm$ 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 $\pm$ 0.2 x 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 $\pm$ 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 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

From the Simpevarp area was specimens sampled on one level in drill hole KAV01. The drill hole starts at a depth of 100 m, and the sampled level was at approximately depth of 500 m. Six specimens, with a length of 250 mm and a diameter of 50 mm were sampled. The sampled rock type is Ävrö granite. Detailed geological description of the rock is given in SKB's BOREMAP. Table 4-1 show the rock type and identification marks of the specimens.

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

Rock type	Identification	Sampling depth, according to the marks on the drill-core boxes (Sec up)
Ävrö granite	KAV01-90L-7	504.69
Ävrö granite	KAV01-90L-8	505.24
Ävrö granite	KAV01-90L-9	505.50
Ävrö granite	KAV01-90L-10	505.76
Ävrö granite	KAV01-90L-11	508.38
Ävrö granite	KAV01-90L-12	508.67

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 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 3).
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 2). The coefficient of thermal expansion was determined between 20–80°C. Calibration of the instrument was done before the measurements on every new temperature (see Appendix 2).

5 Results

The main results of the site investigation of KAV01 could be found in the database SICADA FN96.

5.1 Description of the specimens and presentation of the results

The temperature of water for water saturation was 18.9°C and the density of the water was 998 kg/m^3. The coefficient of thermal expansion was determined between +20–80°C.

KAV01-90L-7 (504.69)

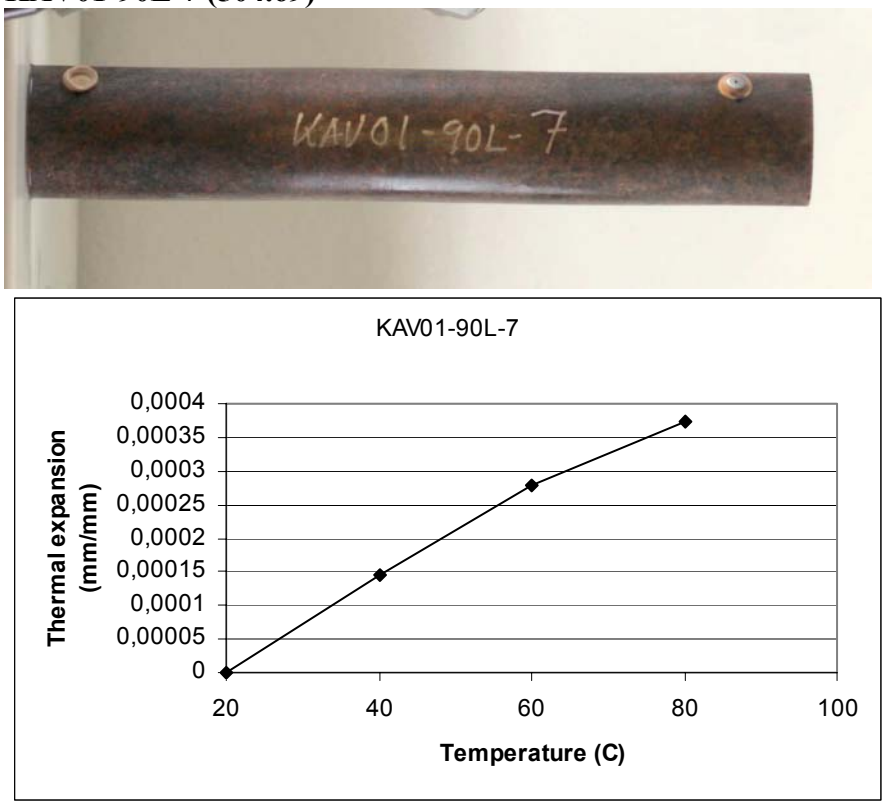
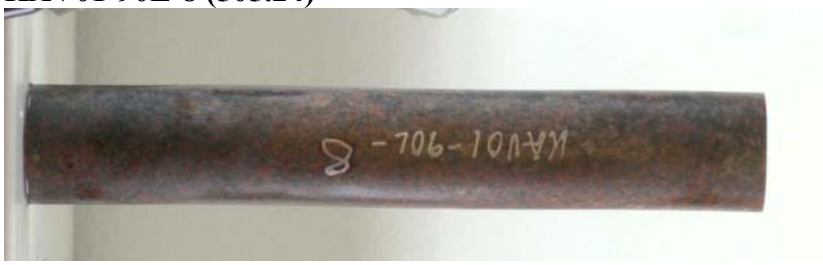


Figure 5-1. *Specimen KAV01-90L-7.*

The coefficient of thermal expansion for specimen KAV01-90L-7 was measured to be 6.2 x 10^{-6} mm/mm°C and the specimen had a wet density to 2660 kg/m^3.

KAV01-90L-8 (505.24)



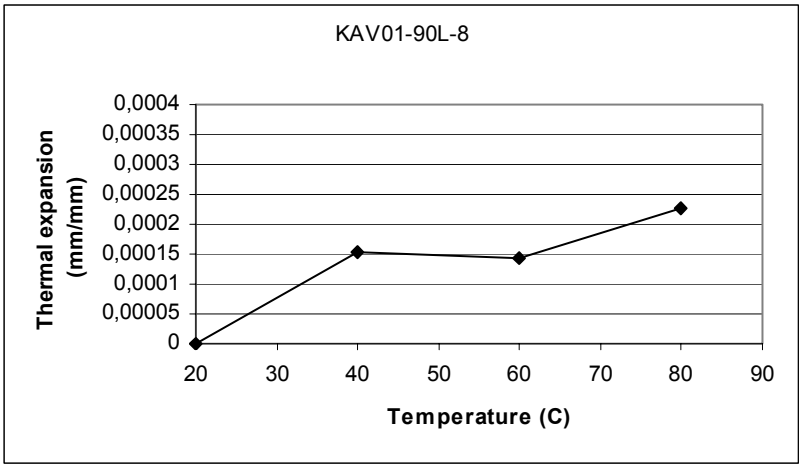


Figure 5-2. *Specimen KAV01-90L-8.*

The coefficient of thermal expansion for specimen KAV01-90L-8 was measured to be 3.8 x 10^{-6} mm/mm°C and the specimen had a wet density of 2670 kg/m^3. The measuring points (studs) fell of at the 2:nd measurement at 80°C. The result at 60°C is therefore questionable.

KAV01-90L-9 (505.50)

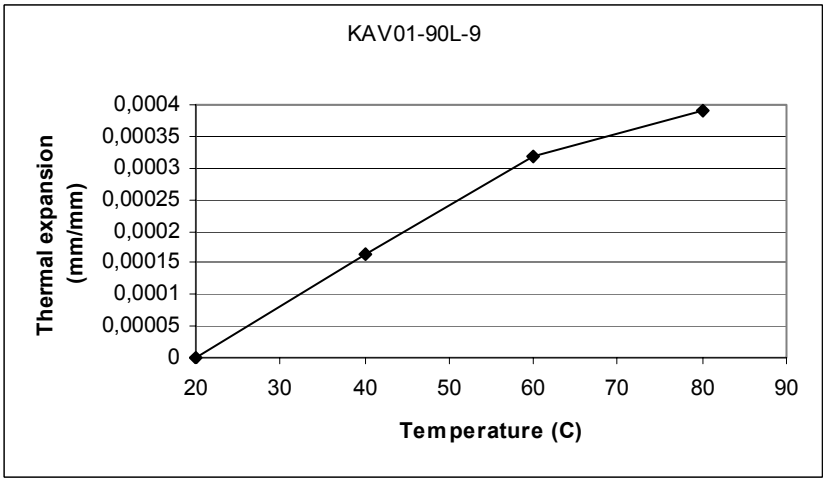


Figure 5-3. *Specimen KAV01-90L-9.*

The coefficient of thermal expansion for specimen KAV01-90L-9 was measured to be 6.5 x 10^{-6} mm/mm°C and the specimen had a wet density of 2660 kg/m^3.

KAV01-90L-10 (505.76)

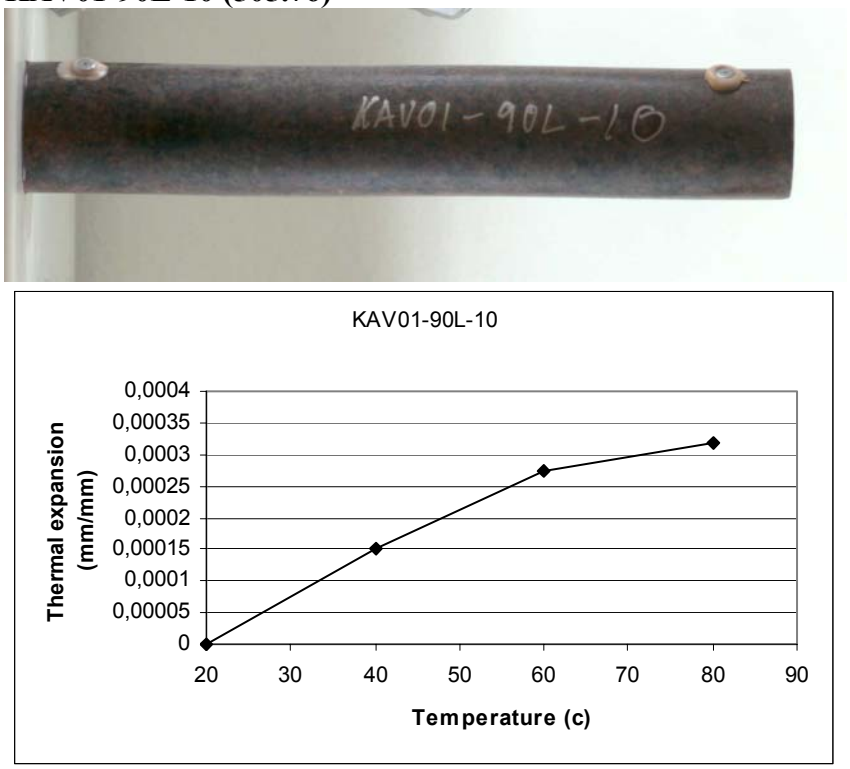


Figure 5-4. *Specimen KAV01-90L-10.*

The coefficient of thermal expansion for specimen KAV01-90L-10 was measured to be 5.3 x 10^{-6} mm/mm°C and the specimen had a wet density of 2660 kg/m^3.

KAV01-90L-11 (508.38)

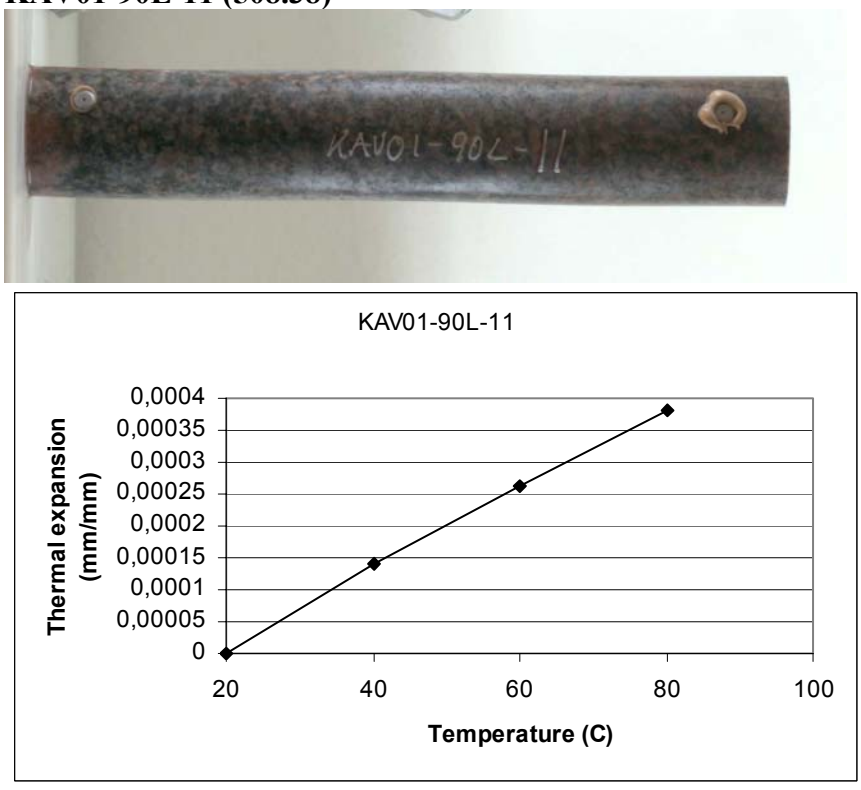
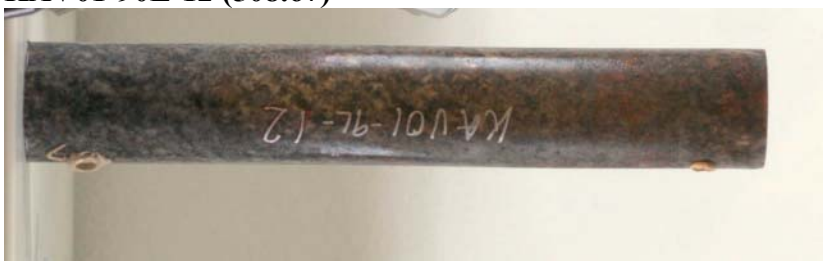


Figure 5-5. *Specimen KAV01-90L-11.*

The coefficient of thermal expansion for specimen KAV01-90L-11 was measured to be 6.4 x 10^{-6} mm/mm°C and the specimen had a wet density of 2690 kg/m^3.

KAV01-90L-12 (508.67)



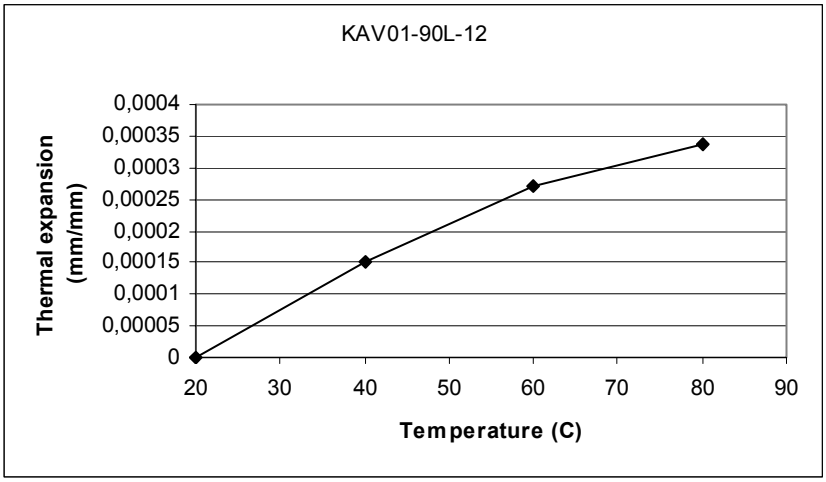


Figure 5-6. *Specimen KAV01-90L-12.*

The coefficient of thermal expansion for specimen KAV01-90L-12 was measured to be 5.6 x 10^{-6} mm/mm°C and the specimen had a wet density of 2690 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. Specimen KAV01-90L-8 is excluded when the median, maximum and minimum value are calculated.

Specimen	Coefficient of thermal expansion between 20 and 80°C (mm/mm°C)	Wet density (kg/m^3)
KAV01-90L-7	6.2 x 10^{-6}	2660
KAV01-90L-8	–	2670
KAV01-90L-9	6.5 x 10^{-6}	2660
KAV01-90L-10	5.3 x 10^{-6}	2660
KAV01-90L-11	6.4 x 10^{-6}	2690
KAV01-90L-12	5.6 x 10^{-6}	2690
Median	6.2 x 10^{-6}	
Maximun value	6.5 x 10^{-6}	
Minimun value	5.3 x 10^{-6}	

5.3 Discussion

During the first measurements of the thermal expansion at 80°C, one measuring point was lost on specimen KAV01-90L-8, and therefore was only one measurement performed instead of three measurements as suggested by the method.

The variation between the samples is approximately 1.2 mm/mm°C which is approximately 6 times the uncertainty of the measurement (0,2 x 10^{-6} mm/mm°C).

References

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

Checklist – measurements

Kvalitetsdokument **Blankett** **BMm-QR 51**
Version 1,0
Utfärdat 2003-12-19
Författare Lotta Carlsson
Godkännare Matz Sandström
Sida 1(1)

Bygg och Mekanik
Checklista längdutvidgning

Fyll i datum och signatur i rutorna. ***appendix 1 thermal expansion***
Sida 1 av 1

Instrument (inventarienr): 102266

Prov id	Provberedning	Limning mätdubbar	Vattenmättning	Vattenmättnads densitet	Provning
KAVO1-7	04-02-10 Lej	04-02-19 Lej	04-02-Lej	04-03-23 Lej	04-02-10 till 04-03-23 Lej
-8	04-02-10 Lej	04-02-19 Lej	04-02-Lej	04-03-23 Lej	04-02-10 till 04-03-23 Lej
-9	04-02-10 Lej	04-02-19 Lej	04-02-Lej	04-03-23 Lej	04-02-10 till 04-03-23 Lej
-10	04-02-10 Lej	04-02-19 Lej	04-02-Lej	04-03-23 Lej	04-02-10 till 04-03-23 Lej
-11	04-02-10 Lej	04-02-19 Lej	04-02-Lej	04-03-23 Lej	04-02-10 till 04-03-23 Lej
-12	04-02-10 Lej	04-02-19 Lej	04-02-Lej	04-03-23 Lej	04-02-10 till 04-03-23 Lej

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Determination of the linear coefficient of thermal expansion

Appendix 2

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479

Vattenmättad temperaturintervall 20-80 C

Borrhål/nivå: KAV01 500 m nivå

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**	**Differens skaldelar**	**strain**	**Delta l**	**l**	**Längdutvidgningskoeff**	**Längdutv**
	20 C	2004-03-08 40C		(mm/mm)			mm/mm per grader C	mm/mm
KAV01-90L-7	40	70	30	0,0001191	0,02382	200,0	0,00000596	0,000119
KAV01-90L-8	20	54	34	0,00013498	0,026996	200,0	0,00000675	0,000135
KAV01-90L-9	25	61	36	0,00014292	0,028584	200,0	0,00000715	0,000143
KAV01-90L-10	30	62	32	0,00012704	0,025408	200,0	0,00000635	0,000127
KAV01-90L-11	12	45	33	0,00013101	0,026202	200,0	0,00000655	0,000131
KAV01-90L-12	25	58	33	0,00013101	0,026202	200,0	0,00000655	0,000131
		2004-03-09 40C						
KAV01-90L-7	40	75	35	0,00013895	0,02779	200,0	0,00000695	0,000139
KAV01-90L-8	20	60	40	0,0001588	0,03176	200,0	0,00000794	0,000159
KAV01-90L-9	25	65	40	0,0001588	0,03176	200,0	0,00000794	0,000159
KAV01-90L-10	30	68	38	0,00015086	0,030172	200,0	0,00000754	0,000151
KAV01-90L-11	12	48	36	0,00014292	0,028584	200,0	0,00000715	0,000143
KAV01-90L-12	25	63	38	0,00015086	0,030172	200,0	0,00000754	0,000151
		2004-03-10 40C						
KAV01-90L-7	40	78	38	0,00015086	0,030172	200,0	0,00000754	0,000151
KAV01-90L-8	20	60	40	0,0001588	0,03176	200,0	0,00000794	0,000159
KAV01-90L-9	25	67	42	0,00016674	0,033348	200,0	0,00000834	0,000167
KAV01-90L-10	30	69	39	0,00015483	0,030966	200,0	0,00000774	0,000155
KAV01-90L-11	12	47	35	0,00013895	0,02779	200,0	0,00000695	0,000139
KAV01-90L-12	25	64	39	0,00015483	0,030966	200,0	0,00000774	0,000155
		2004-03-11 40C						
KAV01-90L-7	40	78	38	0,00015086	0,030172	200,0	0,00000754	0,000151
KAV01-90L-8	20	58	38	0,00015086	0,030172	200,0	0,00000754	0,000151
KAV01-90L-9	25	67	42	0,00016674	0,033348	200,0	0,00000834	0,000167
KAV01-90L-10	30	68	38	0,00015086	0,030172	200,0	0,00000754	0,000151
KAV01-90L-11	12	48	36	0,00014292	0,028584	200,0	0,00000715	0,000143
KAV01-90L-12	25	63	38	0,00015086	0,030172	200,0	0,00000754	0,000151

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479

Vattenmättad temperaturintervall 20-80 C
Borrhål/nivå:

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	Differens skaldelar	strain	Delta l	l	Längdutvidgningskoeff	Längdutv
	20 C	2004-03-16 60C		(mm/mm)			mm/mm per grader C	mm/mm
KAV01-90L-7	40	100	60	0,0002382	0,04764	200,0	0,00000596	0,000238
KAV01-90L-8	20	53	33	0,00013101	0,026202	200,0	0,00000328	0,000131
KAV01-90L-9	25	94	69	0,00027393	0,054786	200,0	0,00000685	0,000274
KAV01-90L-10	30	105	75	0,00029775	0,05955	200,0	0,00000744	0,000298
KAV01-90L-11	12	76	64	0,00025408	0,050816	200,0	0,00000635	0,000254
KAV01-90L-12	25	90	65	0,00025805	0,05161	200,0	0,00000645	0,000258
		2004-03-17 60C						
KAV01-90L-7	40	110	70	0,0002779	0,05558	200,0	0,00000695	0,000278
KAV01-90L-8	20	56	36	0,00014292	0,028584	200,0	0,00000357	0,000143
KAV01-90L-9	25	105	80	0,0003176	0,06352	200,0	0,00000794	0,000318
KAV01-90L-10	30	99	69	0,00027393	0,054786	200,0	0,00000685	0,000274
KAV01-90L-11	12	78	66	0,00026202	0,052404	200,0	0,00000655	0,000262
KAV01-90L-12	25	93	68	0,00026996	0,053992	200,0	0,00000675	0,000270
		2004-03-18 60C						
KAV01-90L-7	40	110	70	0,0002779	0,05558	200,0	0,00000695	0,000278
KAV01-90L-8	20	56	36	0,00014292	0,028584	200,0	0,00000357	0,000143
KAV01-90L-9	25	106	81	0,00032157	0,064314	200,0	0,00000804	0,000322
KAV01-90L-10	30	97	67	0,00026599	0,053198	200,0	0,00000665	0,000266
KAV01-90L-11	12	79	67	0,00026599	0,053198	200,0	0,00000665	0,000266
KAV01-90L-12	25	94	69	0,00027393	0,054786	200,0	0,00000685	0,000274

Längdutvidgningskoefficient

Provningsmetod: NT BUILD 479

Vattenmättad temperaturintervall 20-80 C
Borrhål/nivå:

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	Differens skaldelar	strain	Delta l	l	Längdutvidgningskoeff	Längdutv
	20 C	2004-03-20 80C		(mm/mm)			mm/mm per grader C	mm/mm
KAV01-90L-7	40	136	96	0,00038112	0,076224	200,0	0,00000635	0,000381
KAV01-90L-8	20	77	57	0,00022629	0,045258	200,0	0,00000377	0,000226
KAV01-90L-9	25	123	98	0,00038906	0,077812	200,0	0,00000648	0,000389
KAV01-90L-10	30	108	78	0,00030966	0,061932	200,0	0,00000516	0,000310
KAV01-90L-11	12	106	94	0,00037318	0,074636	200,0	0,00000622	0,000373
KAV01-90L-12	25	109	84	0,00033348	0,066696	200,0	0,00000556	0,000333
		2004-03-22 80C						
KAV01-90L-7	40	132	92	0,00036524	0,073048	200,0	0,00000609	0,000365
KAV01-90L-8				0	0	200,0	0,00000000	0,000000
KAV01-90L-9	25	123	98	0,00038906	0,077812	200,0	0,00000648	0,000389
KAV01-90L-10	30	110	80	0,0003176	0,06352	200,0	0,00000529	0,000318
KAV01-90L-11	12	109	97	0,00038509	0,077018	200,0	0,00000642	0,000385
KAV01-90L-12	25	111	86	0,00034142	0,068284	200,0	0,00000569	0,000341
		2004-03-23 80C						
KAV01-90L-7	40	134	94	0,00037318	0,074636	200,0	0,00000622	0,000373
KAV01-90L-8				0	0	200,0	0,00000000	0,000000
KAV01-90L-9	25	122	97	0,00038509	0,077018	200,0	0,00000642	0,000385
KAV01-90L-10	30	111	81	0,00032157	0,064314	200,0	0,00000536	0,000322
KAV01-90L-11	12	108	96	0,00038112	0,076224	200,0	0,00000635	0,000381
KAV01-90L-12	25	110	85	0,00033745	0,06749	200,0	0,00000562	0,000337

Prov id	längdutv mm/mm												
	40	40	40	40	**median40C**	60	60	60	**median60C**	80	80	80	**median 80C**
KAV01-90L-7	0,000119	0,000139	0,000151	0,000151	**0,00014491**	0,000238	0,000278	0,000278	**0,0002779**	0,000381	0,000365	0,000373	**0,000373**
KAV01-90L-8	0,000135	0,000159	0,000159	0,000151	**0,00015483**	0,000131	0,000143	0,000143	**0,00014292**	0,000226	0	0	**0,000226**
KAV01-90L-9	0,000143	0,000159	0,000167	0,000167	**0,00016277**	0,000274	0,000318	0,000322	**0,0003176**	0,000389	0,000389	0,000385	**0,000389**
KAV01-90L-10	0,000127	0,000151	0,000155	0,000151	**0,00015086**	0,000298	0,000274	0,000266	**0,00027393**	0,00031	0,000318	0,000322	**0,000318**
KAV01-90L-11	0,000131	0,000143	0,000139	0,000143	**0,00014094**	0,000254	0,000262	0,000266	**0,00026202**	0,000373	0,000385	0,000381	**0,000381**
KAV01-90L-12	0,000131	0,000151	0,000155	0,000151	**0,00015086**	0,000258	0,00027	0,000274	**0,00026996**	0,000333	0,000341	0,000337	**0,000337**

Prov id				
	20	40	60	80
KAV01-90L-7	0	0,000145	0,000278	0,000373
KAV01-90L-8	0	0,000155	0,000143	0,000226
KAV01-90L-9	0	0,000163	0,000318	0,000389
KAV01-90L-10	0	0,000151	0,000274	0,000318
KAV01-90L-11	0	0,000141	0,000262	0,000381
KAV01-90L-12	0	0,000151	0,00027	0,000337

Determination of wet density

Vattenmättnadsdensitet

Uppdrags nr: P303920
Metod: EN 13755, ISRM (1973), avsnitt 3 samt SKB MD 160.002 version 1.0
Provad av: Lej
Datum: 2004-03-23

	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	KAVO1 90L-7	534,34	854,91		321,08	856,28	266,68	0,000	2,663
2	8	536,47	857,48		321,52	858,85	267,12	0,000	2,667
3	9	535,56	856,73		321,68	858,10	266,75	0,000	2,663
4	10	534,58	856,48		322,42	857,85	266,07	0,000	2,656
5	11	546,02	868,66		323,16	870,05	269,24	0,000	2,688
6	12	546,37	869,48		323,63	870,87	269,10	0,000	2,687
7					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
8					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
9					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
10					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
11					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
12					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
13					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
14					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
15					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
16					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
17					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
18					0,00	0,00	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
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	538,890	860,623	#DIVISION/0!	92,071	246,286	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!
	std avvikelse	5,710	6,601	#DIVISION/0!	149,173	399,043	#DIVISION/0!	#DIVISION/0!	#DIVISION/0!

Vattnets temperatur (‘	18,9
Vattnets desitet (ºC):	0,9984

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