P-05-95

Oskarshamn site investigation

Drill hole KLX03A

Extensometer measurement of the coefficient of thermal expansion of rock

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June 2005

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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 10 specimens from drill hole KLX03A. The specimens were sampled from two levels in the drill hole at depths of approximately 520 and 710 m. There are two dominating rock types in the drill hole. Between 100 and 620 the dominating rock type is mapped as Ävrö granite, and from 620 to 1,000 m the dominating rock type is mapped as Quartz monzodiorite. 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 5.6 and 8.3×10^{-6} mm/mm °C, and the wet density between 2,773 and 2,821 kg/m^3.

Sammanfattning

Längdutvidgningskoefficienten och våtdensiteten har bestämts på 10 prover från borrhål KLX03A. Proverna kommer från två olika nivåer i borrhålet, på ett ungefärligt djup av 520 och 710 m. Två bergarter dominerar i borrhålet. Mellan 100 och 620 m dominerar bergarten Ävrögranit, och från 620 till 1 000 m dominerar bergarten kvartsmonzodiorit. Längdutvidg ningskoefficienten bestämdes inom temperaturintervallet 20–80 °C. Resultaten indikerade att längdutvidgningen var nästan linjär och längdutvidgningskoefficienten för de undersökta proverna varierade mellan 5,6 och $8{,}3\times10^{-6}$ mm/mm °C och våtdensiteten mellan 2 773 och 2 821 kg/m^3.

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 400-04-106 (SKB internal controlling document).

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

The cores were sampled from borehole KLX03A in the Laxemar area (Figure 1-1). They were sampled 23 November 2004 by Thomas Janson and Björn Ljunggren Tyréns AB. The specimens were taken from two levels at depths of approximately 520 and 710 m. The rock cores were transported by SKB and arrived to SP in December 2004. The testing was performed in January 2005.

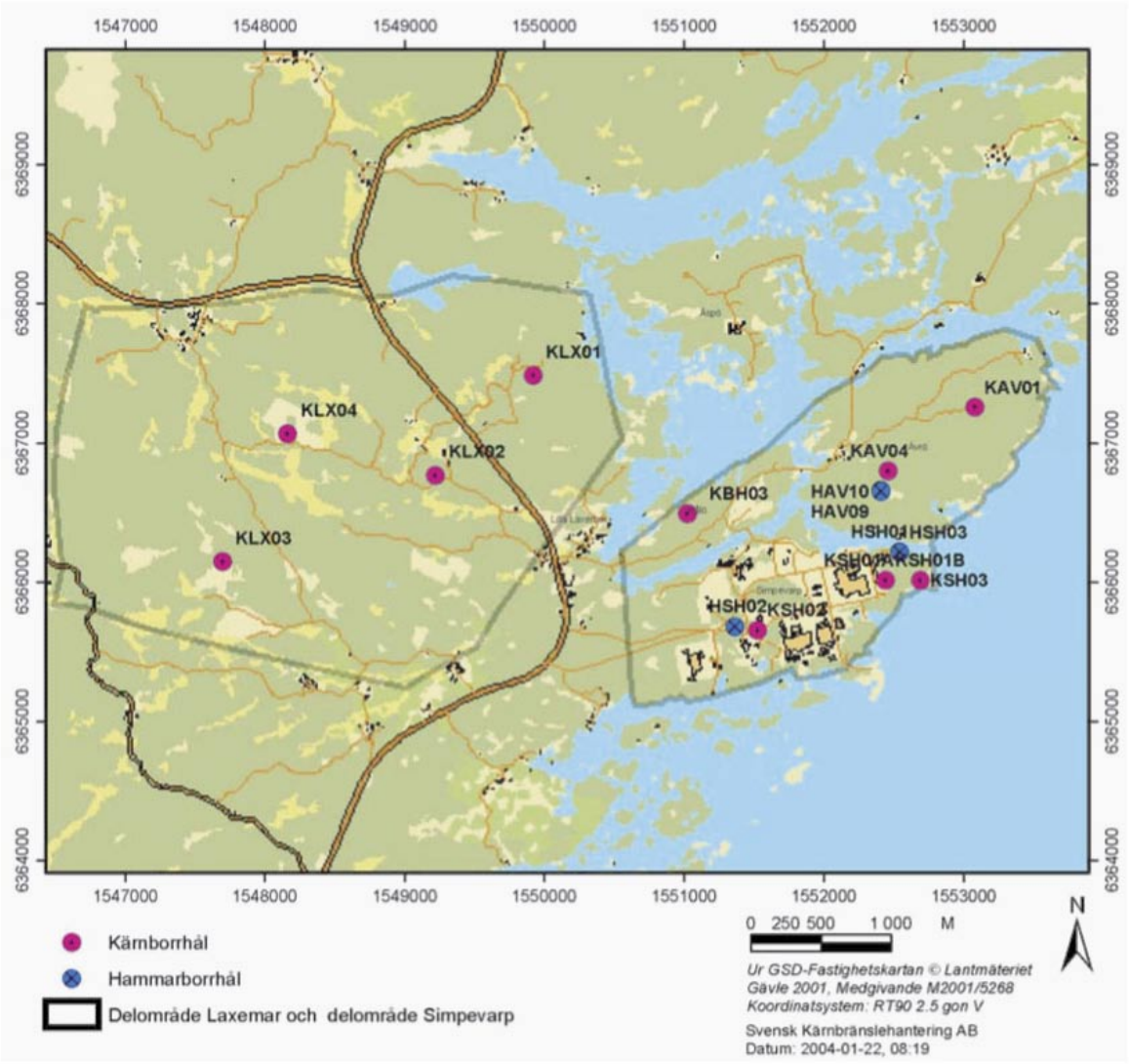


Figure 1-1. *Location of borehole KLX03A at the Oskarshamn site investigation area.*

2 Objective and scope

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

These parameters will be included in the site descriptive rock mechanics model for the Oskarshamn 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 measurement of the thermal expansion. Calibration of the instrument was done for each temperature interval. The uncertainty of the extensometer is ± 3.97×10^{-6} mm/mm (strain), which equals an uncertainty of a single measurement of the coefficient of thermal expansion of ± 0.2×10^{-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 two levels, approximately at 520 and 710 m, in drill hole KLX03A. The sampled rock type at the 520 m level is mapped as Ävrö granite, and at 710 m the rock type is Quartz monzodiorite. Ten specimens, with a length of 240 mm and a diameter of 50 mm were sampled. 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).

Rock type	Identification	Sampling depth, according to bore map (Adj Sec low)
Ävrö granite	KLX03A-90L-1	517.500
Ävrö granite	KLX03A-90L-2	518.408
Ävrö granite	KLX03A-90L-3	518.660
Ävrö granite	KLX03A-90L-4	519.072
Ävrö granite	KLX03A-90L-6	519.422
Quartz monzodiorite	KLX03A-90L-7	711.101
Quartz monzodiorite	KLX03A-90L-9	711.875
Quartz monzodiorite	KLX03A-90L-10	712.370
Quartz monzodiorite	KLX03A-90L-11	712.882
Quartz monzodiorite	KLX03A-90L-12	713.373

4.2 Testing

The execution procedure followed the prescription in SKB MD 191.002 and SKB MD 160.002 (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	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.
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. The coefficient of thermal expansion was determined between 20–80°C.

5 Results

The main results of the site investigation of KLX03A could be found in the SICADA database.

5.1 Description of the specimens and presentation of the results

The temperature of the water used for water saturation was 18.1°C and the density of the water was 999 kg/m^3. The coefficient of thermal expansion was determined between +20–80°C.

KLX03A-90L-1 (517.500 m)

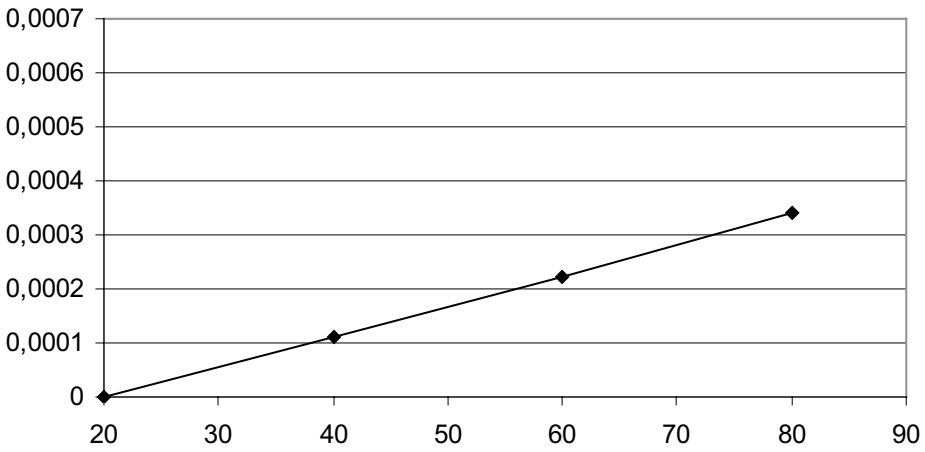
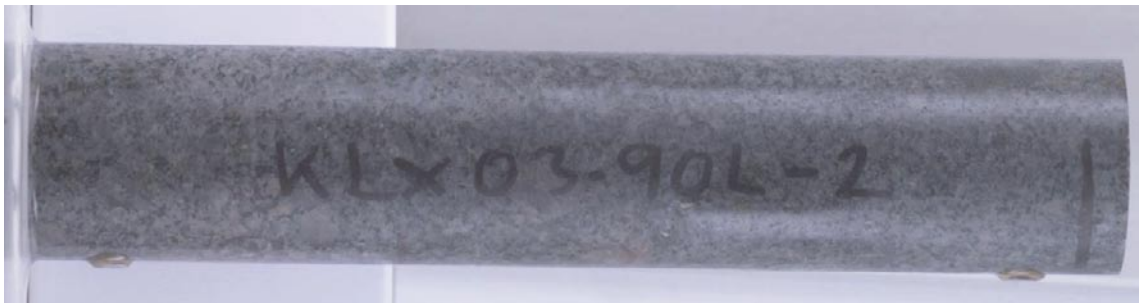


Figure. 5-1. *Diagram showing the thermal expansion of specimen KLX03-90L-1 between 20 and 80°C, median values plotted.*

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 KLX03A-90L-1 was measured to be 5.6×10^{-6} mm/mm °C and the specimen had a wet density to 2,779 kg/m^3.

KLX03A-90L-2 (518.408 m)



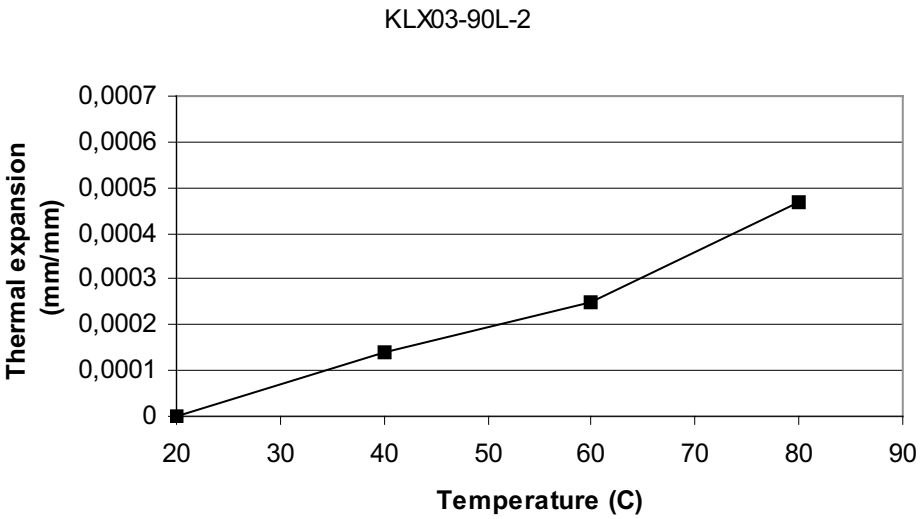


Figure 5-2. *Diagram showing the thermal expansion of specimen KLX03-90L-2 between 20 and 80°C, median values plotted.*

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 KLX03-90L-2 was measured to be 7.7×10^{-6} mm/mm °C and the specimen had a wet density of 2,773 kg/m^3.

KLX03A-90L-3 (518.660 m)

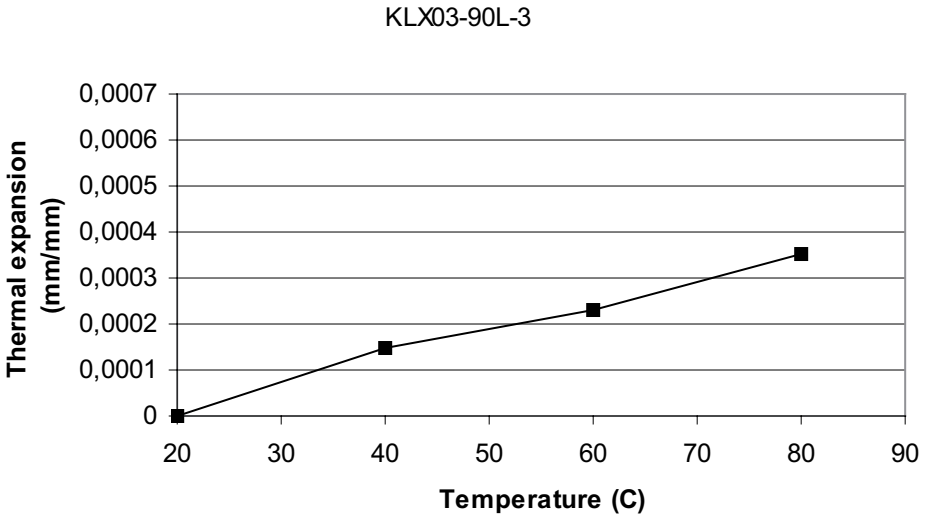


Figure 5-3. *Diagram showing the thermal expansion of specimen KLX03A-90L-3 between 20 and 80°C, median values plotted.*

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 KLX03A-90L-3 was measured to be 5.8×10^{-6} mm/mm °C and the specimen had a wet density of 2,804 kg/m^3.

KLX03A-90L-4 (519.072 m)

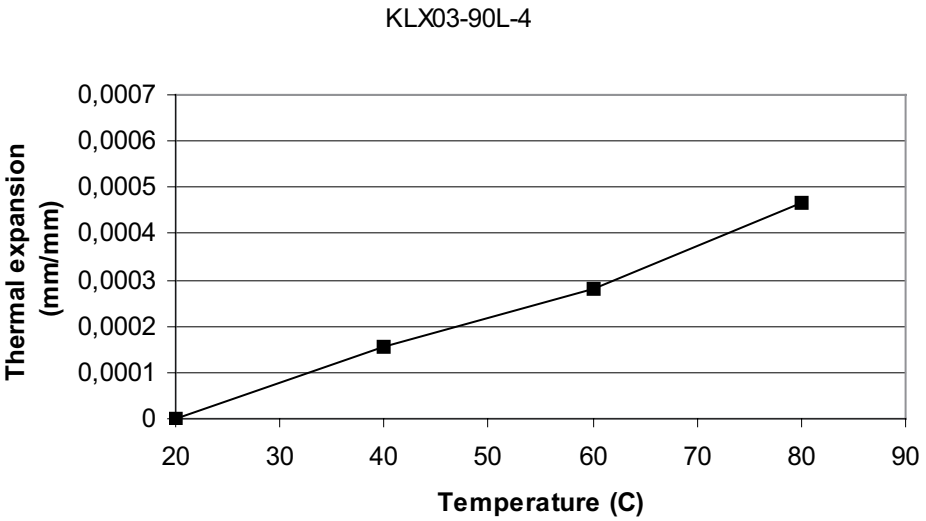


Figure 5-4. *Diagram showing the thermal expansion of specimen KLX03A-90L-4 between 20 and 80°C, median values plotted.*

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 KLX03A-90L-4 was measured to be 7.7×10^{-6} mm/mm °C and the specimen had a wet density of 2,779 kg/m^3.

KLX03A-90L-6 (519.672 m)

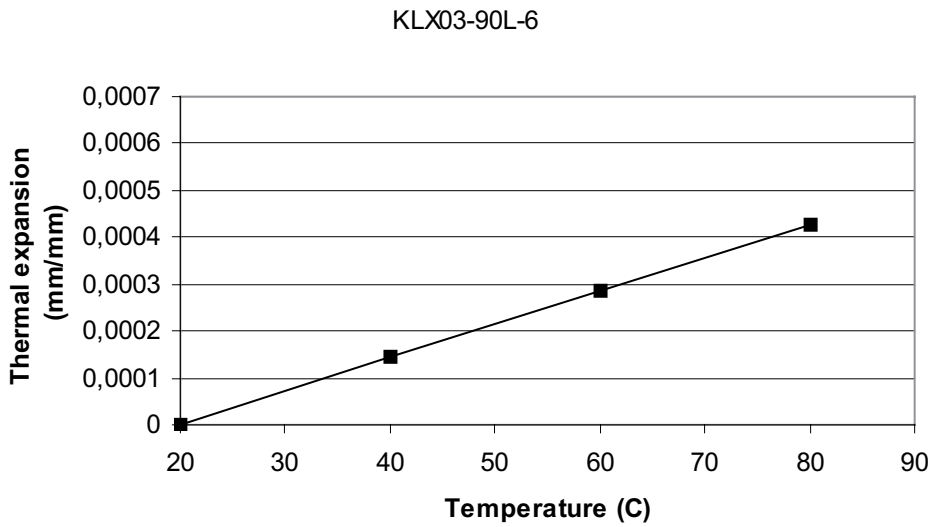


Figure 5-5. *Diagram showing the thermal expansion of specimen KLX03A-90L-6 between 20 and 80°C, median values plotted.*

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 KLX03A-90L-6 was measured to be 7.0×10^{-6} mm/mm °C and the specimen had a wet density of 2,791 kg/m^3.

KLX03A-90L-7 (711.101 m)

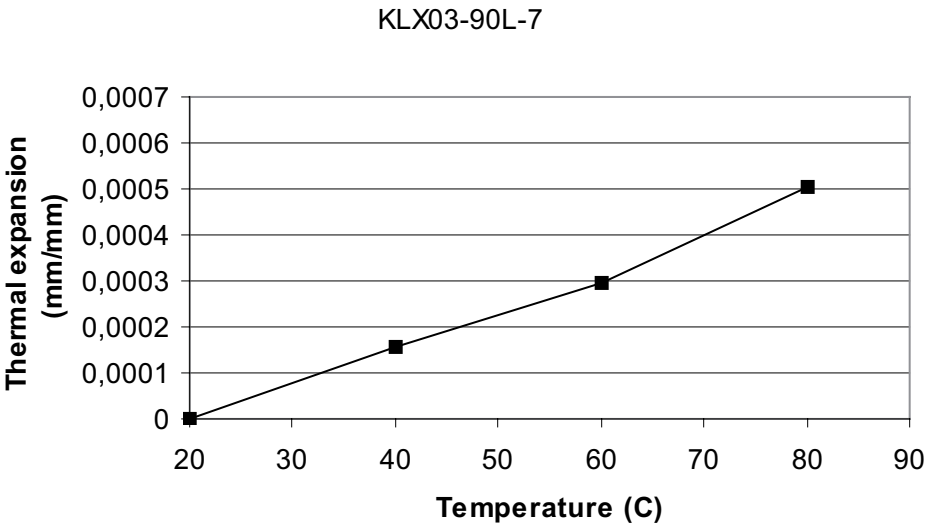


Figure 5-6. *Diagram showing the thermal expansion of specimen KLX03A-90L-7 between 20 and 80°C, median values plotted.*

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 KLX03A-90L-7 was measured to be 8.3×10^{-6} mm/mm °C and the specimen had a wet density of 2,793 kg/m^3.

KLX03A-90L-9 (711.352 m)

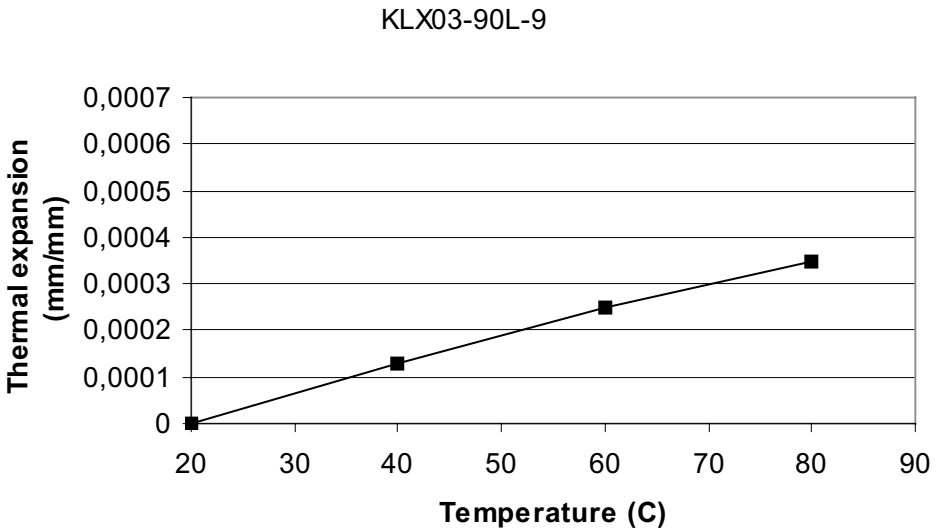


Figure 5-7. *Diagram showing the thermal expansion of specimen KLX03A-90L-9 between 20 and 80°C, median values plotted.*

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 KLX03A-90L-9 was measured to be 5.8×10^{-6} mm/mm °C, and the specimen had a wet density of 2,799 kg/m^3.

KLX03A-90L-10 (712.370 m)

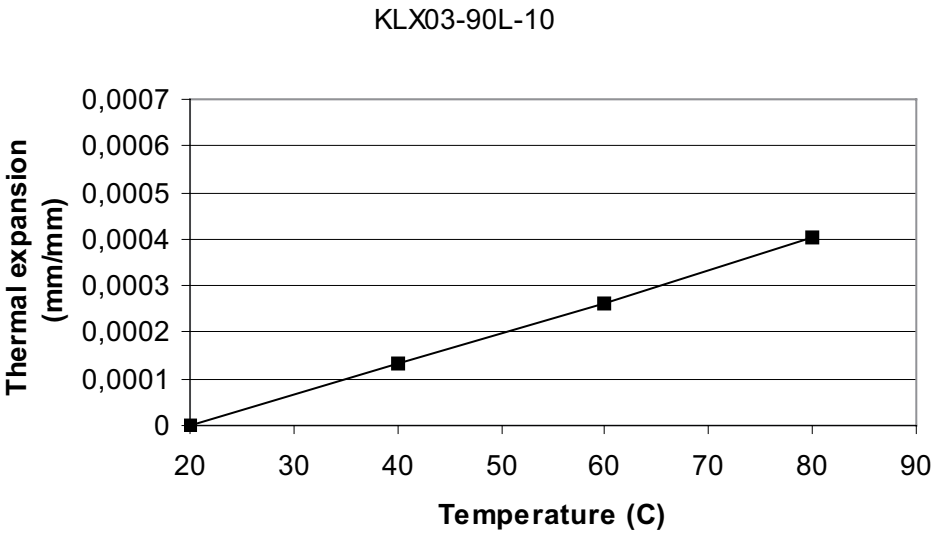


Figure 5-8. *Diagram showing the thermal expansion of specimen KLX03-90L-10 between 20 and 80°C, median values plotted.*

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 KLX03A-90L-10 was measured to be 6.7×10^{-6} mm/mm °C and the specimen had a wet density of 2,787 kg/m^3.

KLX03A-90L-11 (712.882 m)

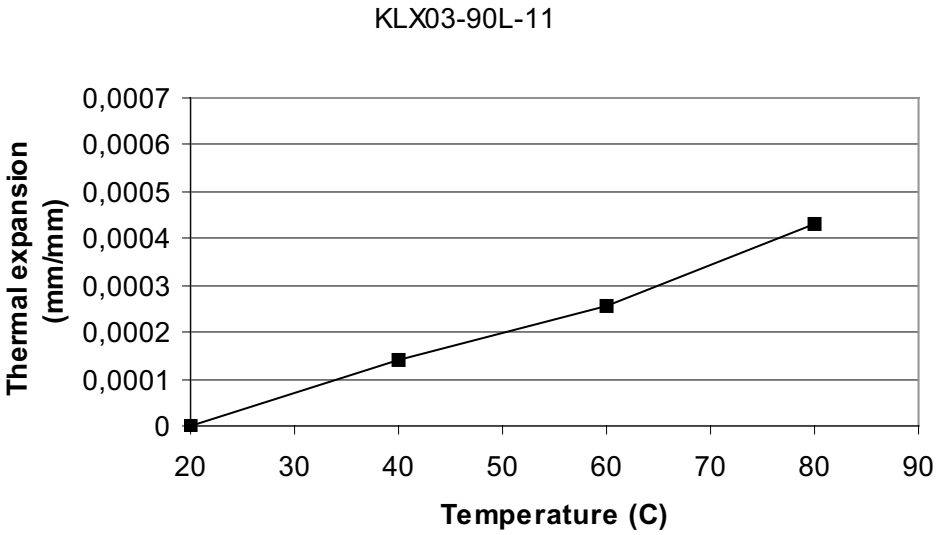


Figure 5-9. *Diagram showing the thermal expansion of specimen KLX03A-90L-11 between 20 and 80°C, median values plotted.*

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 KLX03A-90L-11 was measured to be 7.1×10^{-6} mm/mm °C and the specimen had a wet density of 2,805 kg/m^3.

KLX03A-90L-12 (713.373 m)

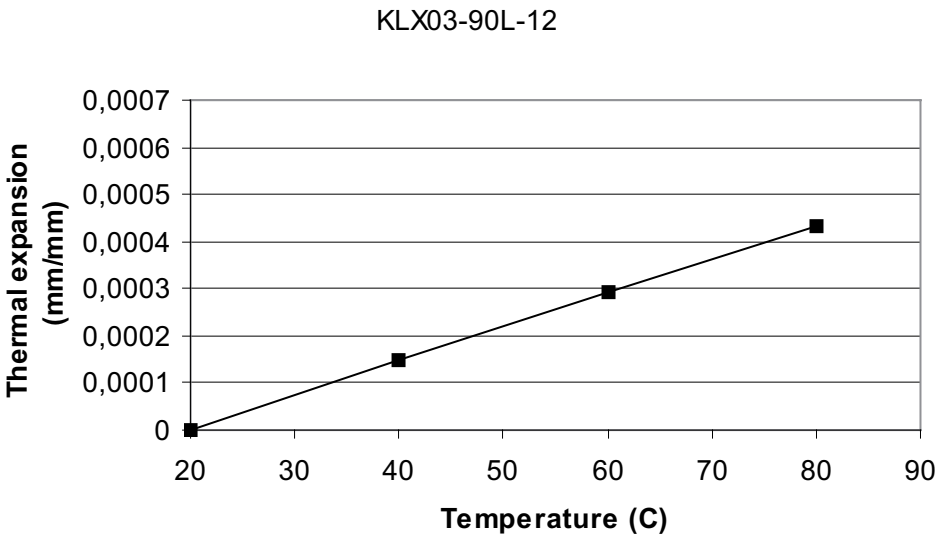


Figure 5-10. *Diagram showing the thermal expansion of specimen KLX03A-90L-12 between 20 and 80°C, median values plotted.*

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 KLX03A-90L-12 was measured to be 7.1×10^{-6} mm/mm °C and the specimen had a wet density of 2,821 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 (517.500–519.672 m).

Specimen	Coefficient of thermal expansion between 20 and 80°C (mm/mm °C)	Wet density (kg/m³)
KLX03A-90L-1	5.6×10^{-6}	2,779
KLX03A-90L-2	7.7×10^{-6}	2,773
KLX03A-90L-3	5.8×10^{-6}	2,804
KLX03A-90L-4	7.7×10^{-6}	2,779
KLX03A-90L-6	7.0×10^{-6}	2,791
Median	7.0×10^{-6}	
Maximum value	7.7×10^{-6}	
Minimum value	5.6×10^{-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 (711.101–713.373 m).

Specimen	Coefficient of thermal expansion between 20 and 80°C (mm/mm °C)	Wet density (kg/m³)
KLX03A-90L-7	8.3×10^{-6}	2,793
KLX03A-90L-9	5.8×10^{-6}	2,799
KLX03A-90L-10	6.7×10^{-6}	2,787
KLX03A-90L-11	7.1×10^{-6}	2,805
KLX03A-90L-12	7.1×10^{-6}	2,821
Median	7.1×10^{-6}	
Maximum value	8.3×10^{-6}	
Minimum value	5.8×10^{-6}	

5.3 Discussion

The variation between the specimens is approximately 3.0×10^{-6} mm/mm °C, which is approximately 15 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, therefore it is suggested that the variation of the results are related to the difference of geological properties. The specimens KLX03A-90L-5 and KLX03A-90L-8 failed during the sample preparation and were therefore substituted with KLX03A-90L-6 and KLX03A-90L-12.

References

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