P-07-63

Oskarshamn site investigation

Boreholes KLX07A, KLX10, KLX05 and KLX12A

Extensometer measurement of the coefficient of thermal expansion of rock

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Keywords: Rock mechanics, Coefficient of thermal expansion, Temperature change, Density, Porosity, AP PS 400-06-141.

Abstract

The coefficient of thermal expansion and the wet density has been determined on 9 specimens from drill holes KLX05, KLX07A, KLX10 and KLX12A, Oskarshamn, Sweden. Four specimens were sampled from KLX05, two specimens from KLX07A, one specimen from KLX10 and two specimens from KLX12A. The investigated rock types are mapped as altered Ävrö granite (code 501044) and diorite-gabbro (code 501033). 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, except for specimen KLX10ST-90L-3 and the coefficient of thermal expansion for the investigated specimens range between 5.9 and 11.8×10^{-6} mm/mm °C, and the wet density between 2,660 and 2,960 kg/m^3.

Sammanfattning

Längdutvidgningskoefficienten och våtdensiteten har bestämts på 9 prover från borrhålen KLX05, KLX07A, KLX10 och KLX12A i Oskarshamn, Sverige. Fyra prover togs från KLX05, två prover togs från KLX07A, ett prov togs från KLX10 och två prov togs från KLX12A. De undersökta bergarterna är karterade som omvandlad Ävrö granit (kod 501044) och diorit-gabbro (kod 501033). Längdutvidgningskoefficienten bestämdes inom temperaturintervallet 20–80 °C. Resultaten indikerade att längdutvidgningen var nästan linjär, förutom provet KLX10ST-90L-3 och längdutvidgningskoefficienten för de undersökta proverna varierade mellan 5,9 och $11{,}8\times10^{-6}$ mm/mm °C och våtdensiteten mellan 2 660 och 2 960 kg/m^3.

Contents

1 Introduction

Specimens were sampled from the drill cores of boreholes KLX05, KLX07A, KLX10 and KLX12A at the Oskarshamn site investigation area, Sweden, see Figure 1-1, for determination of the Coefficient of thermal expansion and wet density.

The sampling was based on the bore core logging with the strategy to primarily investigate the properties of the dominant rock types. The samples, which were collected by Björn Ljunggren, Tyrens AB in November 21–22, 2006, were transported to SP (Technical Research institute of Sweden), department of Building and Mechanics, where they arrived in December, 2006. Testing commenced in December 2006 and was completed in February 2007.

The commission was carried out in compliance with the controlling documents presented in Table 1-1. Activity Plan and Method Descriptions are SKB's (The Swedish Nuclear Fuel and waste Management Company) internal controlling documents, whereas SP-QD 13.1 is an SP internal Quality document.

Figure 1-1. *Geological map and location of cored boreholes drilled up to Feburaury 2007.*

Table 1-1. Controlling documents for performance of the activity.

Activity Plan	**Number**	**Version**
Selektiv termisk laborationsprovning, Laxemar	AP PS 400-06-141	1.0
Method Description	**Number**	**Version**
Coefficient of thermal expansion of rock – using an extensometer	SKB MD 191.002	2.0
Determining density and porosity of intact rock	SKB MD 160.002	2.0
Quality Plan		
SP-QD 13.1		

2 Objective and scope

The purpose of determining the coefficient of thermal expansion and the wet density of intact rock cores is to use these parameters in the rock mechanics and thermal site descriptive model, which will be established for the candidate area selected for site investigations at Oskarshamn.

The testing comprised of 9 rock samples from boreholes KLX07A, KLX10, KLX05 and KLX12A.

3 Equipment

The following equipment has been used for the analyses:

- Extensometer (DEMEC inv no 102266) for measurement of the thermal expansion. 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 specimens

The specimens from boreholes KLX05, KLX07A, KLX10 and KLX12A were sampled at levels ranging between approximately 350–460 m borehole length. Table 4-1 shows the identification mark, sampling level and rock type of each specimen.

Table 4-1. Identification mark, sampling level and rock type of each specimen (rock-type classification according to Boremap).

Identification	Sampling level (m borehole length, Adj seclow)	Rock type
KLX07AST-90L-1	443.49	Ävrö granite (501044)
KLX07AST-90L-2	553.63	Ävrö granite (501044)
KLX10ST-90L-3	459.75	Ävrö granite (501044)
KLX05ST-90L-4	356,95	Diorite-gabbro (501033)
KLX05ST-90L-5	360,49	Diorite-gabbro (501033)
KLX05ST-90L-6	346,35	Diorite-gabbro (501033)
KLX05ST-90L-7	350,52	Diorite-gabbro (501033)
KLX12AST-90L-9	460.91	Diorite-gabbro (501033)
KLX12AST-90L-10	461.70	Diorite-gabbro (501033)

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 and TIF 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.

4.3 Nonconformities

The Activity Plan was followed without any deviations.

In the measurements of specimen KLX10ST-90L-3 there is a dip in the curve at 60°C, resulting in a nonlinear expansion. There are no signs of lost of demec studs or bending of the specimen. Since expansion continuous at 80°C, the probable reason for the nonconformity is the reading at 40°C.

5 Results

The results of the coefficient of thermal expansion and wet density determinations of core samples from KLX05, KLX07A, KLX10 and KLX12A are stored in SKB´s database SICADA, where they are traceable by the Activity Plan number.

The temperature of the water used for the water saturation was 22.5°C and the density of the water was 997 kg/m^3. The coefficient of thermal expansion was determined between +20–80°C.

5.1 Description of the specimens and presentation of the results

KLX07AST-90L-1

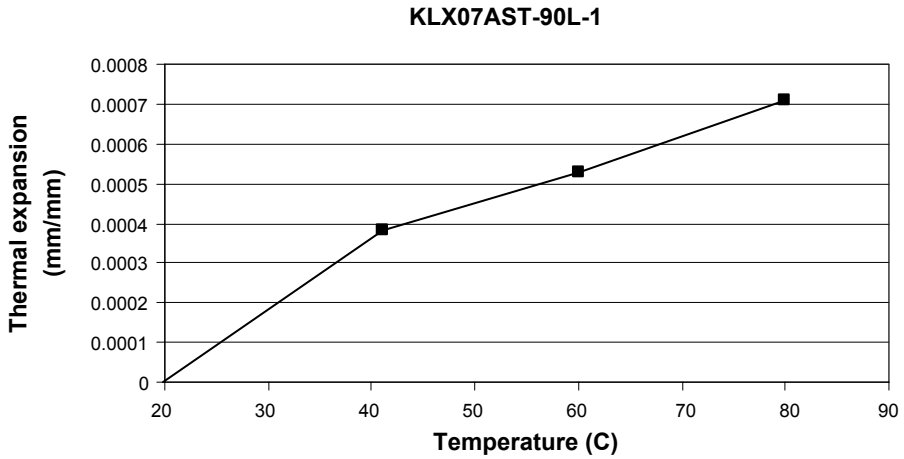
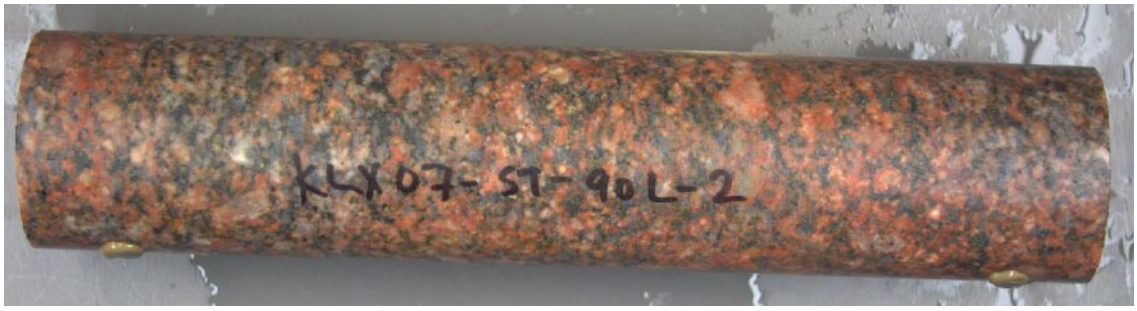


Figure 5-1. *Diagram showing the thermal expansion of specimen KLX07AST-90L-1 between 20 and 80°C, median values plotted.*

Figure 5-1 shows a picture of the specimen KLX07AST-90L-1 and a diagram for the thermal expansion in the interval 20, 40, 60 and 80°C. The coefficient of thermal expansion for specimen KLX07AST-90L-1 was measured to be 11.8×10^{-6} mm/mm°C and the specimen had a wet density of 2,680 kg/m^3.

KLX07ST-90L-2



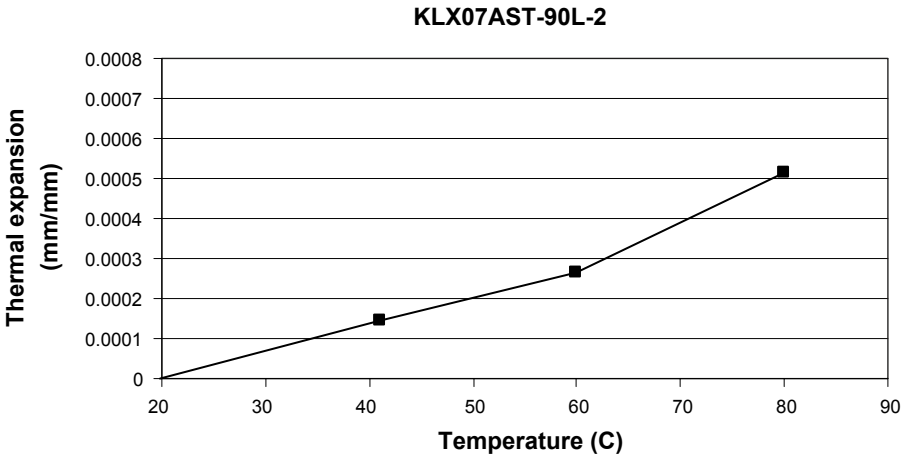


Figure 5-2. *Diagram showing the thermal expansion of specimen KLX07ST-90L-2 between 20 and 80°C, median values plotted.*

Figure 5-2 shows a picture of the specimen KLX07AST-90L-2 and a diagram for the thermal expansion in the interval 20, 40, 60 and 80°C. The coefficient of thermal expansion for specimen KLX07AST-90L-2 was measured to be 8.6×10^{-6} mm/mm°C and the specimen had a wet density of 2,680 kg/m^3.

KLX10ST-90L-3

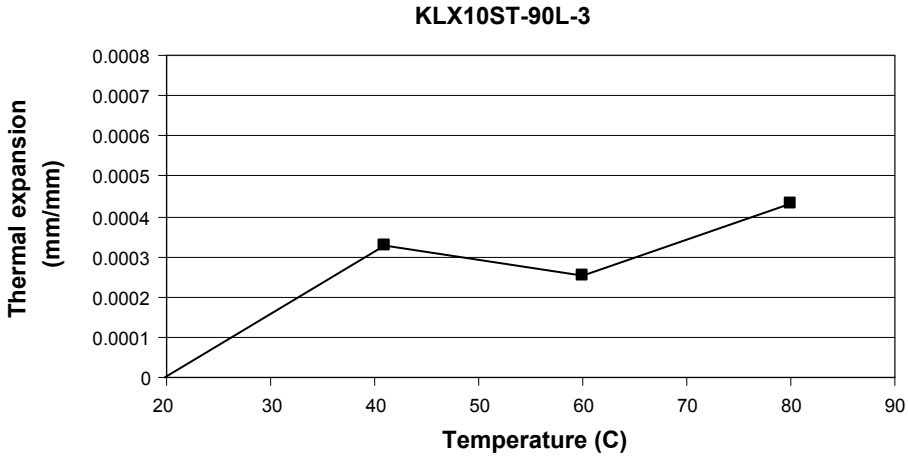


Figure 5-3. *Diagram showing the thermal expansion of specimen KLX10ST-90L-3 between 20 and 80°C, median values plotted.*

Figure 5-3 shows a picture of the specimen KLX10ST-90L-3 and a diagram for the thermal expansion in the interval 20, 40, 60 and 80°C. The coefficient of thermal expansion for specimen KLX10ST-90L-3 was measured to be 7.2×10^{-6} mm/mm°C and the specimen had a wet density of 2,660 kg/m^3.

KLX05ST-90L-4

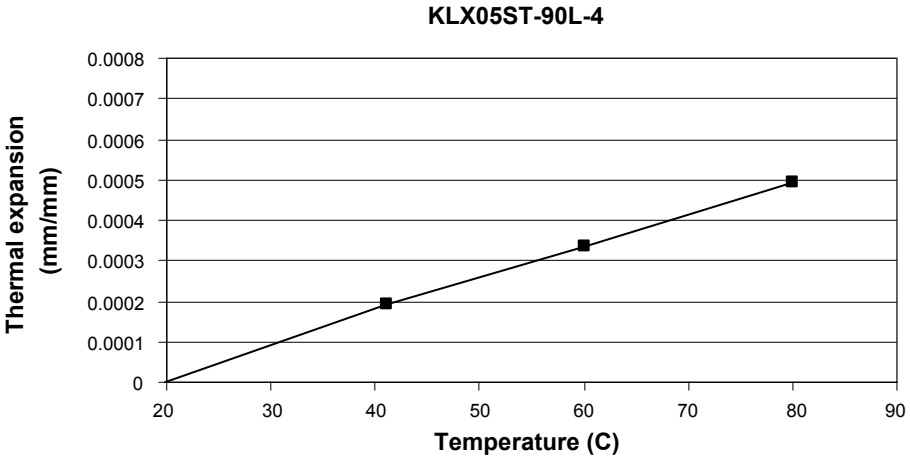


Figure 5-4. *Diagram showing the thermal expansion of specimen KLX05ST-90L-4 between 20 and 80°C, median values plotted.*

Figure 5-4 shows a picture of the specimen KLX05ST-90L-4 and a diagram for the thermal expansion in the interval 20, 40, 60 and 80°C. The coefficient of thermal expansion for specimen KLX05ST-90L-4 was measured to be 8.2×10^{-6} mm/mm°C and the specimen had a wet density of 2,950 kg/m^3.

KLX05ST-90L-5

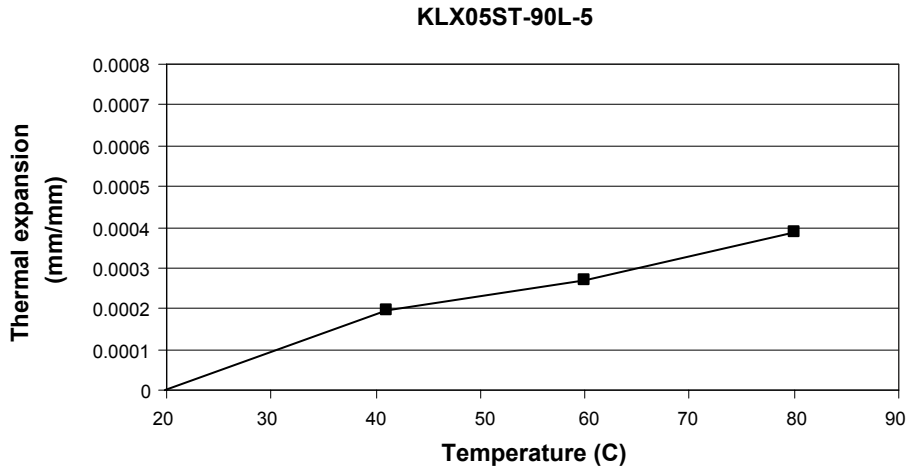


Figure 5-5. *Diagram showing the thermal expansion of specimen KLX05ST-90L-5 between 20 and 80°C, median values plotted.*

Figure 5-5 shows a picture of the specimen KLX05ST-90L-5 and a diagram for the thermal expansion in the interval 20, 40, 60 and 80°C. The coefficient of thermal expansion for specimen KLX05ST-90L-5 was measured to be 6.5×10^{-6} mm/mm°C and the specimen had a wet density of 2,950 kg/m^3.

KLX05ST-90L-6

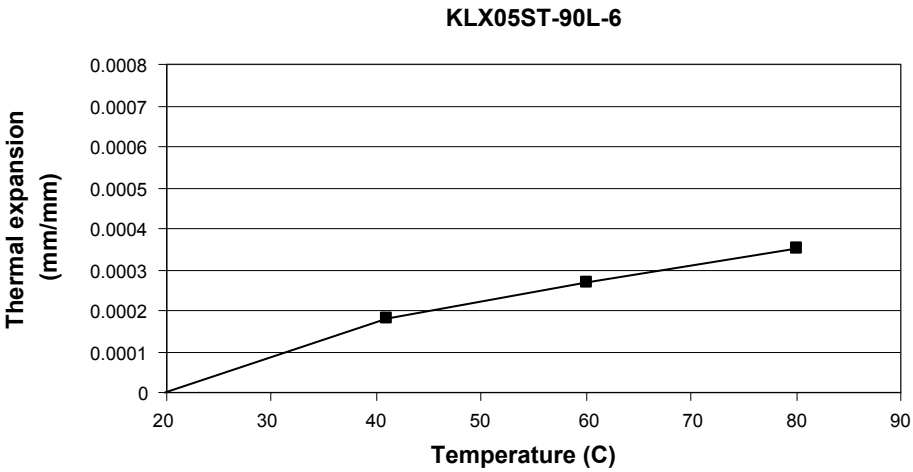


Figure 5-6. *Diagram showing the thermal expansion of specimen KLX05ST-90L-6 between 20 and 80°C, median values plotted.*

Figure 5-6 shows a picture of the specimen KLX05ST-90L-6 and a diagram for the thermal expansion in the interval 20, 40, 60 and 80°C. The coefficient of thermal expansion for specimen KLX05ST-90L-6 was measured to be 5.9×10^{-6} mm/mm°C and the specimen had a wet density of 2,920 kg/m^3.

KLX05ST-90L-7

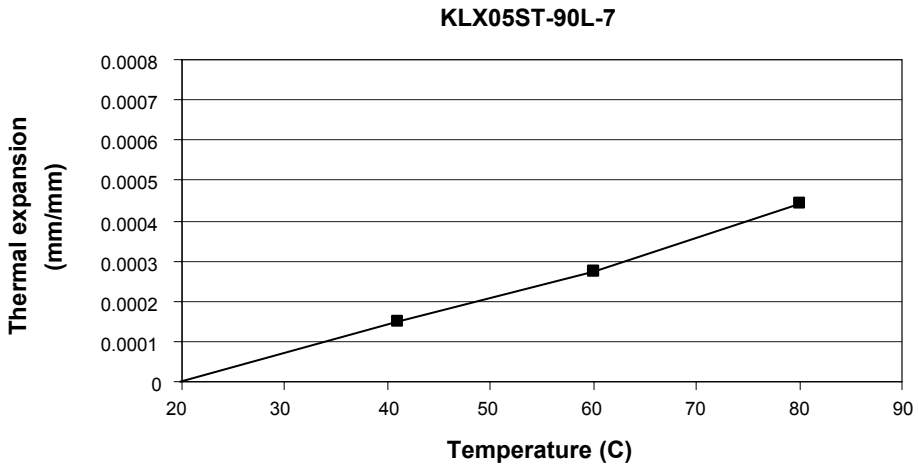


Figure 5-7. *Diagram showing the thermal expansion of specimen KLX05ST-90L-7 between 20 and 80°C, median values plotted.*

Figure 5-7 shows a picture of the specimen KLX05ST-90L-7 and a diagram for the thermal expansion in the interval 20, 40, 60 and 80°C. The coefficient of thermal expansion for specimen KLX05ST-90L-7 was measured to be 7.3×10^{-6} mm/mm°C and the specimen had a wet density of 2,910 kg/m^3.

KLX12AST-90L-9

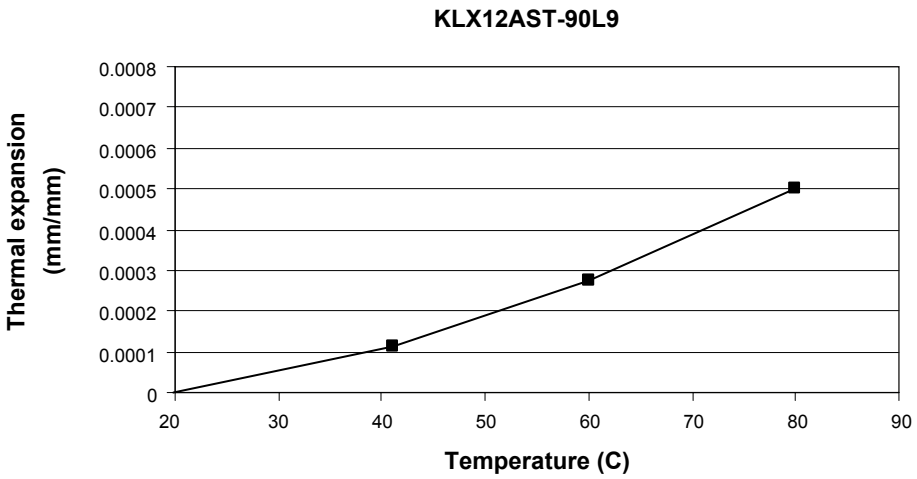
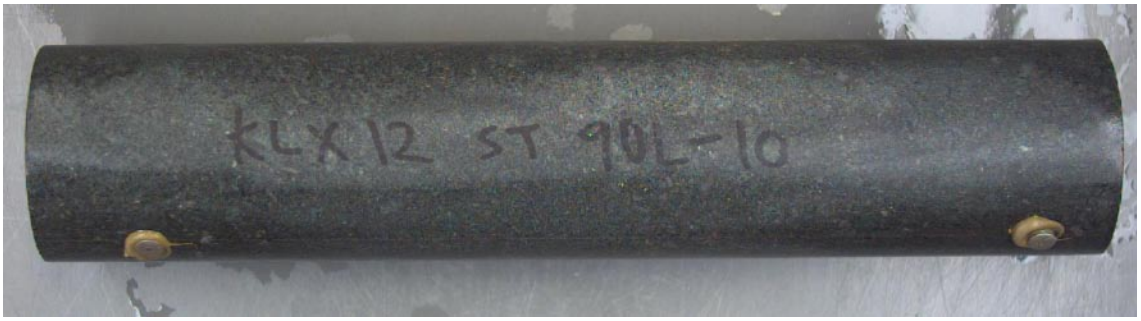


Figure 5-8. *Diagram showing the thermal expansion of specimen KLX12AST-90L-9 between 20 and 80°C, median values plotted.*

Figure 5-8 shows a picture of the specimen KLX12AST-90L-9 and a diagram for the thermal expansion in the interval 20, 40, 60 and 80°C. The coefficient of thermal expansion for specimen KLX12AST-90L-9 was measured to be 8.3×10^{-6} mm/mm°C and the specimen had a wet density of 2,960 kg/m^3.

KLX12AST-90L-10



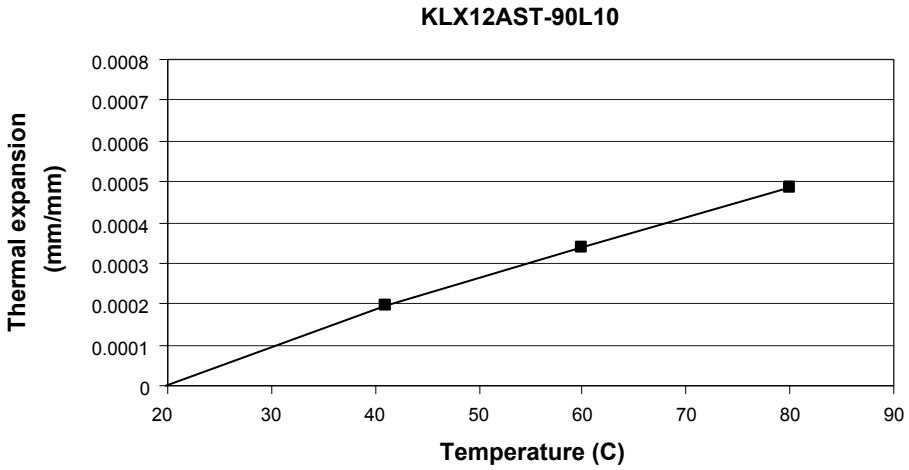


Figure 5-9. *Diagram showing the thermal expansion of specimen KLX12AST-90L-10 between 20 and 80°C, median values plotted.*

Figure 5-9 shows a picture of the specimen KLX12AST-90L-10 and a diagram for the thermal expansion in the interval 20, 40, 60 and 80°C. The coefficient of thermal expansion for specimen KLX12AST-90L-10 was measured to be 8.1×10^{-6} mm/mm°C and the specimen had a wet density of 2,950 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 from KLX05, KLX07,KLX10 and KLX12A.

Specimen	Coefficient of thermal expansion between 20 and 80°C (mm/mm°C)	Wet density (kg/m^3)
KLX07AST-90L-1	11.8×10^{-6}	2,680
KLX07AST-90L-2	8.6×10^{-6}	2,680
KLX10ST-90L-3	7.2×10^{-6}	2,660
KLX05ST-90L-4	8.2×10^{-6}	2,950
KLX05ST-90L-5	6.5×10^{-6}	2,950
KLX05ST-90L-6	5.9×10^{-6}	2,920
KLX05ST-90L-7	7.3×10^{-6}	2,910
KLX12AST-90L-9	8.3×10^{-6}	2,960
KLX12AST-90L-10	8.1×10^{-6}	2,950

References

/1/ NT BUILD 479. Natural Building stones: Coefficient of thermal expansion.