P-07-33

Forsmark site investigation

Boreholes KFM05A and KFM06A

Extensometer measurement of the coefficient of thermal expansion of rock

Urban Åkesson
SP, Technical Research Institute of Sweden

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Svensk Kärnbränslehantering AB
Swedish Nuclear Fuel
and Waste Management Co
Box 5864
SE-102 40 Stockholm Sweden
Tel 08-459 84 00
+46 8 459 84 00
Fax 08-661 57 19
+46 8 661 57 19

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Abstract

The coefficient of thermal expansion and the wet density have been determined on 6 specimens from the inclined boreholes KFM05A and KFM06A, Forsmark, Sweden. One specimen was sampled from KFM05A at a borehole length of approximately 697 m. Five specimens were sampled from two levels in the drill hole KFM06A at borehole lengths of approximately 590–660 m and 780–850 m. The investigated rock types are mapped as granite, metamorphic aplitic (101058) and granite, granodiorite, tonalite, metamorphic fine to medium grained (101051). 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 ranges between 6.9 and 8.0×10^{-6} mm/mm°C, and the wet density between 2,640 and 2,710 kg/m^3.

Sammanfattning

Längdutvidgningskoefficienten och våtdensiteten har bestämts på 6 prover från borrhålen KFM05A och KFM06A i Forsmark. Dessa prov är ansatta med en lutning av ca 60° från horisontalplanet. Ett prov togs från KFM05A vid en borrhålslängd på ca 697 m. Fem prover togs från två nivåer i borrhål KFM06A vid borrhålslängderna 590–660 m och 780–850 m. De undersökta bergarterna är karterade som granit, metamorf, aplitisk (101058) och granit, granodiorit, tonalit, metamorf, fin till medelkornig (101051). Längdutvidgningskoefficienten bestämdes inom temperaturintervallet 20–80 °C. Resultaten indikerade att längdutvidgningen var nästan linjär och längdutvidgningskoefficienten för de undersökta proverna varierade mellan 6,9 och 8,0×10–6 mm/mm°C och våtdensiteten mellan 2 640 och 2 710 kg/m^3.

Contents

1 Introduction

This document reports performance of and results from determination of the coefficient of thermal expansion and wet density. Specimens were sampled from the drill cores of the inclined boreholes KFM05A and KFM06A at the Forsmark site investigation area, Sweden, see Figure 1-1. The tests were carried out in the material and rock mechanics laboratories at the Department of Building Technology and Mechanics at the Swedish National Testing and Research Institute (SP).
The activity is part of the site investigation programme at Forsmark managed by SKB (Swedish Nuclear Fuel and Waste Management Co).

The sampling was based on the preliminary core logging with the strategy to primarily investigate the properties of the rock types of granite, metamorphic aplitic (101058) and granite, granodiorite, tonalite, metamorphic fine to medium grained (101051). The samples, which were collected by Björn Ljunggren, Tyréns AB on September 19, 2006, were transported to SP (Technical Research Institute of Sweden), department of Building and Mechanics, where they arrived on September 25, 2006. Testing commenced in November 2006 and was completed in January 2007.

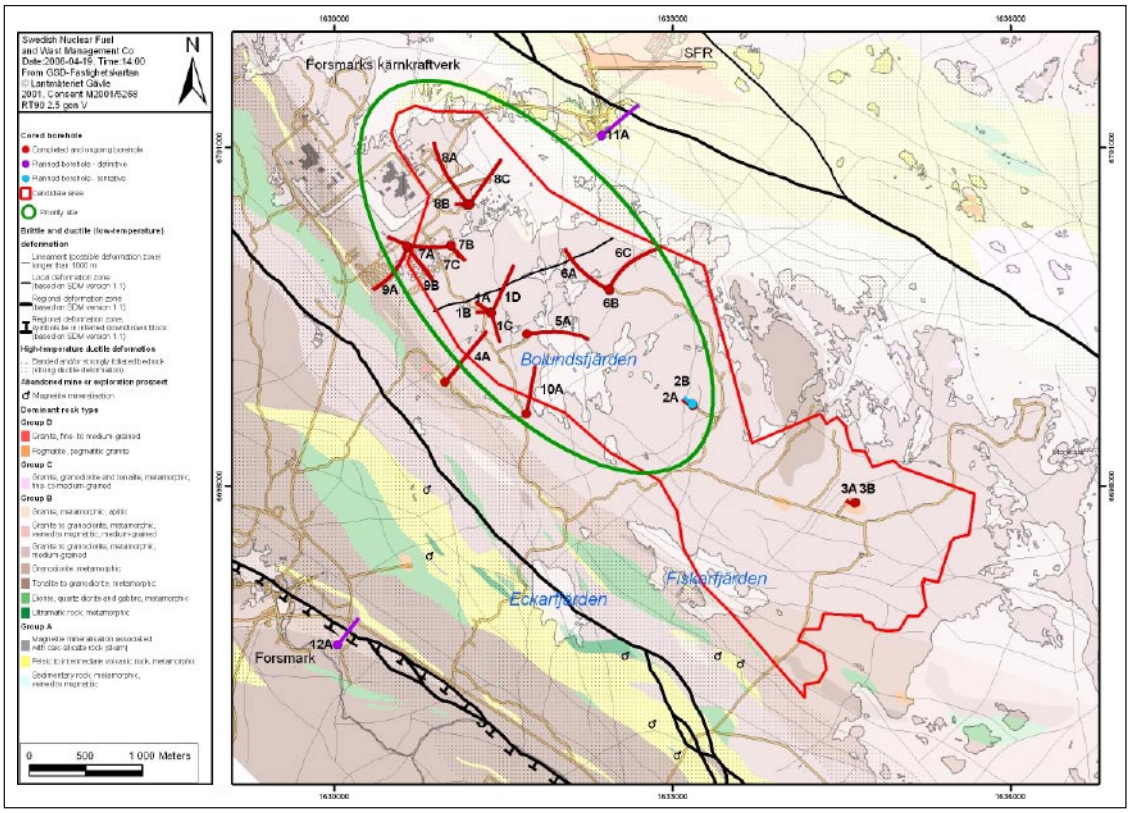


Figure 1-1. *Geological map and location of all telescopic boreholes drilled up to April 2006 within and close to the Forsmark candidate area. The projection of each borehole on the horizontal plane at top of casing is also shown in the figure. Boreholes KFM05A and KFM06A are inclined c. 60°C from the horizon.*

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.

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

Activity Plan	**Number**	**Version**
Kompletterande termiska laboratorie-undersökningar	AP PF 400-06-087	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 Forsmark.

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 calibration of 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 KFM05A and KFM06A were sampled at levels ranging between approximately 590 and 850 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/ occurence
KFM05A 90L-1	696.62	(101051)
KFM06A 90L-2	590.42	(101051)
KFM06A 90L-3	595.83	(101051)
KFM06A 90L-4	651.47	(101058)
KFM06A 90L-5	779.75	(101058)
KFM06A 90L-6	842.03	(101058)

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 were performed with 24 h intervals in order to ensure that the expansion was completed for each temperature level. The coefficient of thermal expansion was determined between 20–80°C.

4.3 Nonconformities

During the measurements of the thermal expansion it was noticed that the unit on the extensometer was changed from millimetre to inch. Therefore all specimens were measured a second time. Otherwise, the Activity Plan was followed without any deviations.

5 Results

The results of the coefficient of thermal expansion and wet density determinations of core samples from KFM05A and KFM06A 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

Figure 5-1 shows a picture of the specimen KFM05A-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 KFM05A-90L-1 was measured to be 7.6×10^{-6} mm/mm°C and the specimen had a wet density of 2,710 kg/m^3.

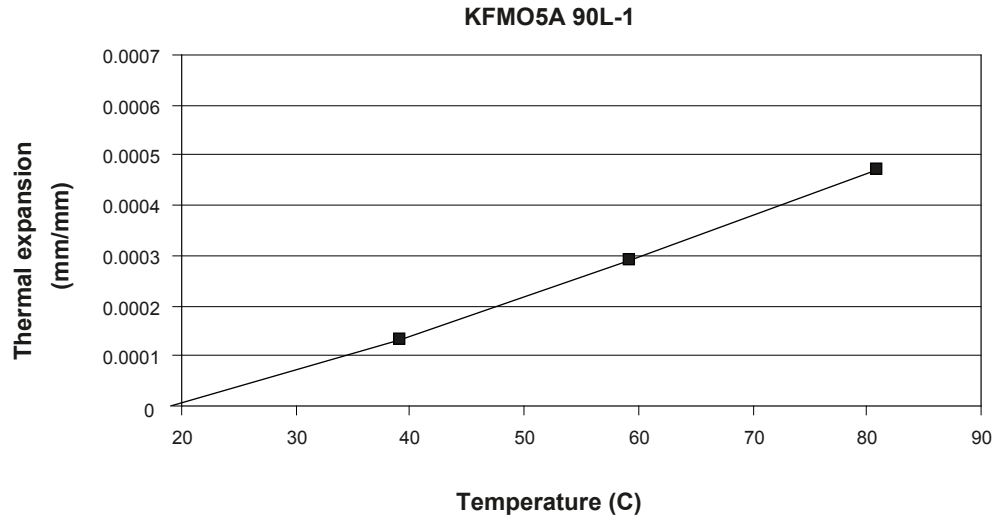


Figure 5-1. *Diagram showing the thermal expansion of specimen KFM05A-90L-1 between 20 and 80°C, median values plotted.*

Figure 5-2 shows a picture of the specimen KFM06A-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 KFM06A-90L-2 was measured to be 7.7×10^{-6} mm/mm°C and the specimen had a wet density of 2,710 kg/m^3.

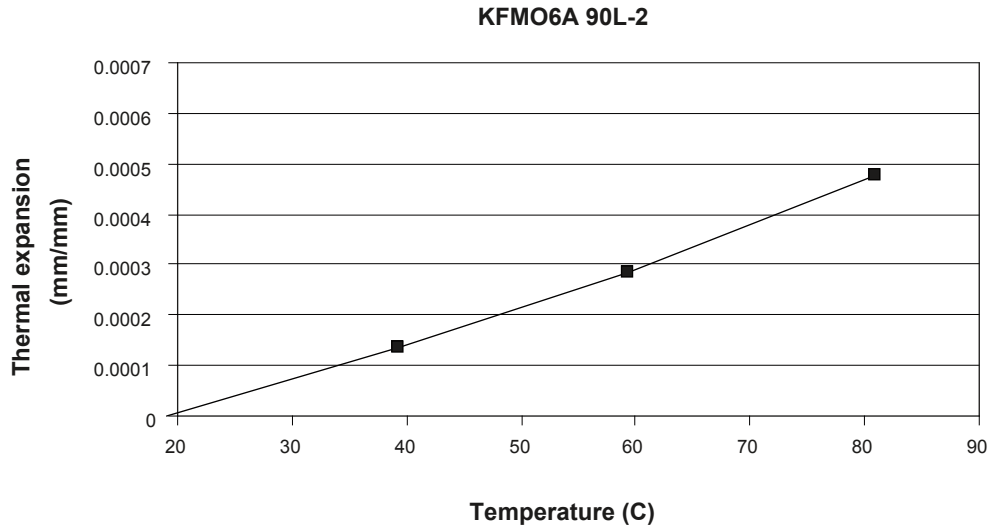


Figure 5-2. *Diagram showing the thermal expansion of specimen KFM06A-90L-2 between 20 and 80°C, median values plotted.*

Figure 5-3 shows a picture of the specimen KFM06A-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 KFM06A-90L-3 was measured to be 7.3×10^{-6} mm/mm°C and the specimen had a wet density of 2,690 kg/m^3.

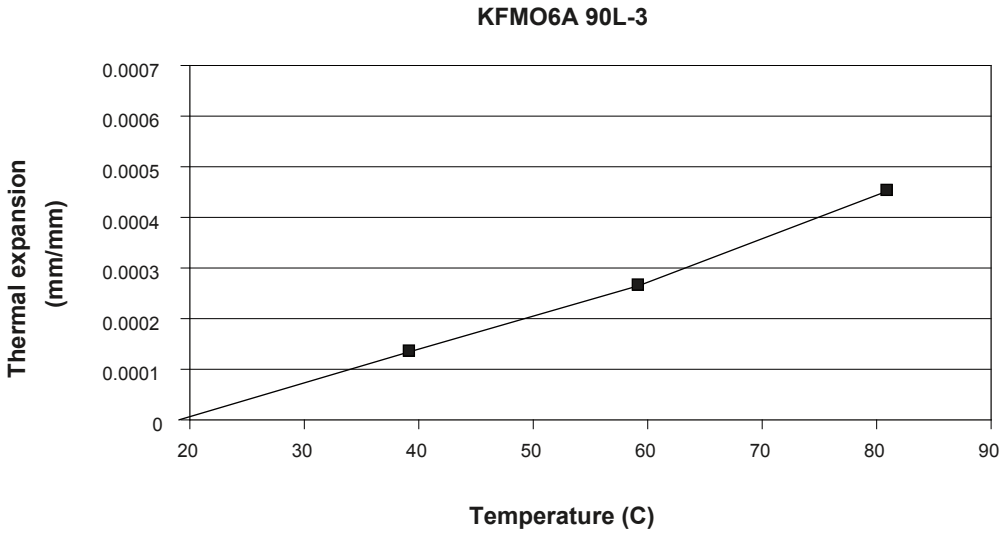


Figure 5-3. *Diagram showing the thermal expansion of specimen KFM06A-90L-3 between 20 and 80°C, median values plotted.*

Figure 5-4 shows a picture of the specimen KFM06A-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 KFM06A-90L-4 was measured to be 7.5×10^{-6} mm/mm°C and the specimen had a wet density of 2,650 kg/m^3.

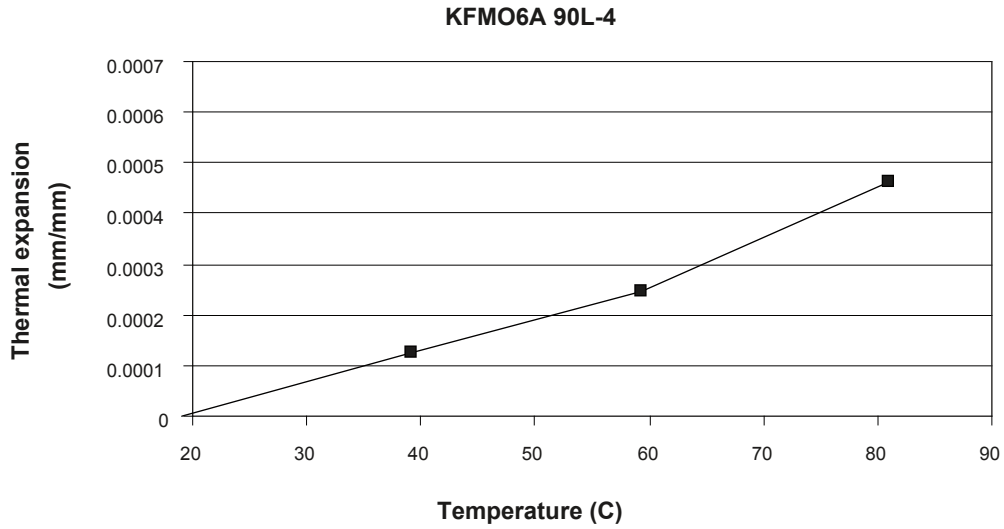
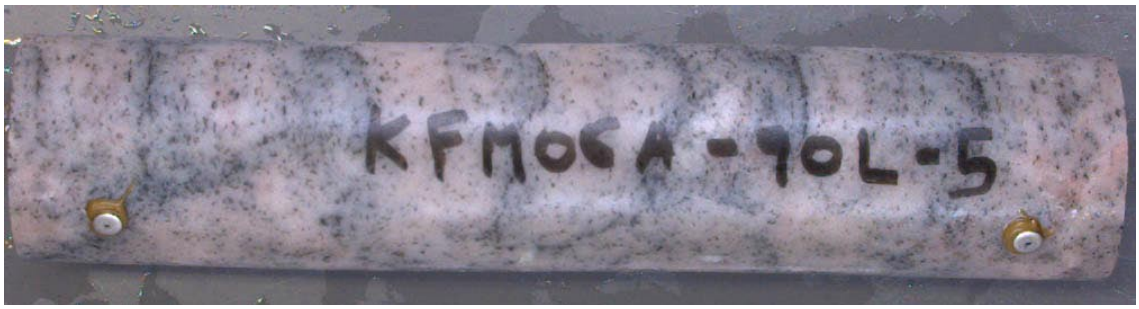


Figure 5-4. *Diagram showing the thermal expansion of specimen KFM06A-90L-4 between 20 and 80°C, median values plotted.*

Figure 5-5 shows a picture of the specimen KFM06A-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 KFM06A-90L-5 was measured to be 6.9×10^{-6} mm/mm°C and the specimen had a wet density of 2,640 kg/m^3.



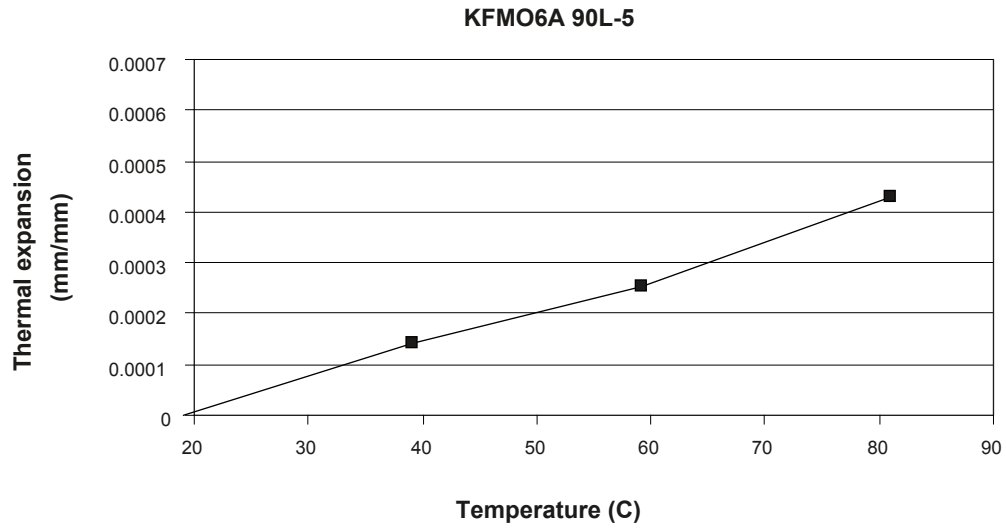
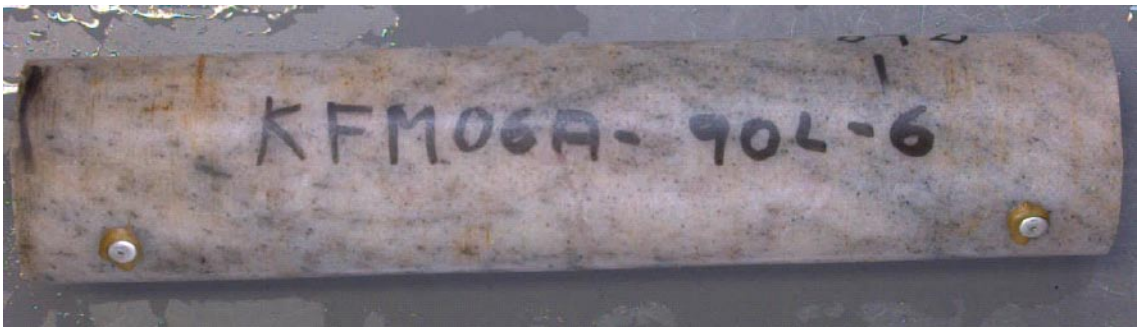


Figure 5-5. *Diagram showing the thermal expansion of specimen KFM06A-90L-5 between 20 and 80°C, median values plotted.*

Figure 5-6 shows a picture of the specimen KFM06A-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 KFM06A-90L-6 was measured to be 8.0×10^{-6} mm/mm°C and the specimen had a wet density of 2,650 kg/m^3.



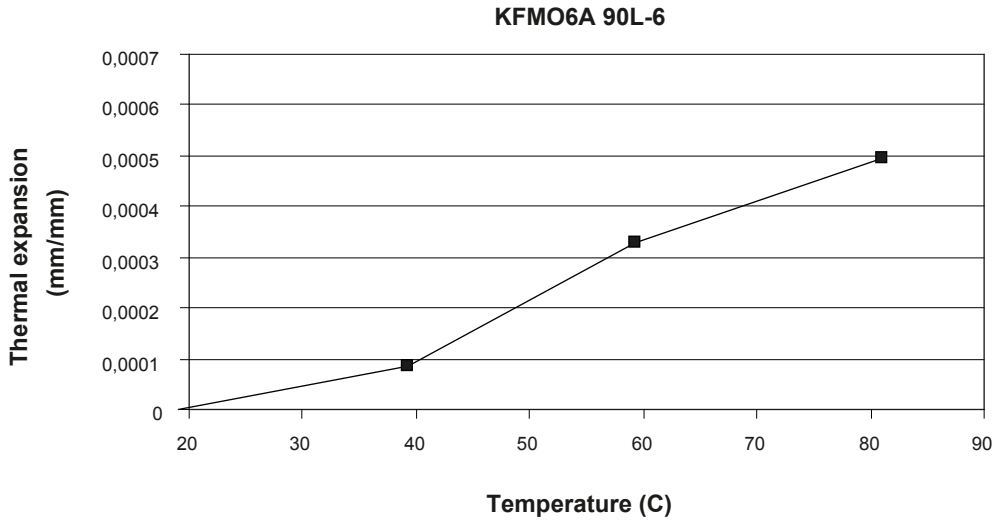


Figure 5-6. *Diagram showing the thermal expansion of specimen KFM06A-90L-6 between 20 and 80°C, median values plotted.*

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 KFM05A and KFM06A.

Specimen	Coefficient of thermal expansion between 20 and 80°C (mm/mm°C)	Wet density (kg/m^3)
KFM05A-90L-1	7.6×10^{-6}	2,710
KFM06A-90L-2	7.7×10^{-6}	2,710
KFM06A-90L-3	7.3×10^{-6}	2,690
KFM06A-90L-4	7.5×10^{-6}	2,650
KFM06A-90L-5	6.9×10^{-6}	2,640
KFM06A-90L-6	8.0×10^{-6}	2,650