Designation: D 5335 – 08

# Standard Test Method for Linear Coefficient of Thermal Expansion of Rock Using Bonded Electric Resistance Strain Gauges[1]

This standard is issued under the fixed designation D 5335; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

## 1. Scope*

1.1 This test method covers the laboratory determination of the linear (one-dimensional) coefficient of thermal expansion of rock using bonded electric resistance strain gauges.

1.2 This test method is applicable for unconfined pressure conditions over the temperature range from 20 to 260°C (68 to 500°F).

NOTE 1—Unconfined tests performed at elevated temperatures may alter the mineralogy or grain structure of the test specimen. This alteration may change the physical and thermal properties of the test specimen.

NOTE 2—The strain gauges are mounted with epoxy. Most commercially available high temperature epoxies require elevated temperature curing. The elevated temperature required for this curing may alter the physical and thermal properties of the test specimen. Epoxy should be selected based upon the maximum expected test temperature. Room temperature curing epoxy should be used whenever possible.

1.3 The test specimens may be either saturated or dry. If saturated specimens are used, then the test temperature shall be at least 10°C (18°F) less than the boiling point of the saturating fluid in order to minimize the effects of evaporation of the fluid.

NOTE 3—When testing a saturated specimen, the moisture content of the specimen may change unless special precautions are taken to encapsulate the test specimen. Refer to 7.4.

1.4 For satisfactory results in conformance with this test method, the principles governing the size, construction, and use of the apparatus described in this test method should be followed. If the results are to be reported as having been obtained by this test method, then all pertinent requirements prescribed in this test method shall be met.

1.5 It is not practicable in a test method of this type to aim to establish details of construction and procedure to cover all contingencies that might offer difficulties to a person without technical knowledge concerning the theory of heat flow, temperature measurement, and general testing practices. Standardization of this test method does not reduce the need for such technical knowledge. It is recognized also that it would be unwise, because of the standardization of this test method, to resist in any way the further development of improved or new methods or procedures by research workers.

1.6 The values stated in SI units are to be regarded as the standard. The values given in parentheses are mathematical conversions to inch-pound units that are provided for information only and are not considered standard.

1.7 All observed and calculated values shall conform to the guidelines for significant digits and rounding established in Practice D 6026.

1.7.1 The method used to specifiy how data are collected, calculated, or recorded in this standard is not directly related to the accuracy to which the data can be applied in design or other uses, or both. How one applies the results obtained using this standard is beyond its scope.

1.8 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory requirements prior to use.*

## 2. Referenced Documents

2.1 *ASTM Standards:* [2]

D 653 Terminology Relating to Soil, Rock, and Contained Fluids

D 2113 Practice for Rock Core Drilling and Sampling of Rock for Site Investigation

D 2216 Test Methods for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass

D 3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction

D 6026 Practice for Using Significant Digits in Geotechnical Data

E 83 Practice for Verification and Classification of Extensometer Systems

E 122 Practice for Calculating Sample Size to Estimate, With Specified Precision, the Average for a Characteristic of a Lot or Process

[1] This test method is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.12 on Rock Mechanics.

Current edition approved July 1, 2008. Published July 2008. Originally approved in 1992. Last previous edition approved in 2004 as D 5335 – 04.

[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

***A Summary of Changes section appears at the end of this standard.**

E 228 Test Method for Linear Thermal Expansion of Solid Materials With a Push-Rod Dilatometer
E 289 Test Method for Linear Thermal Expansion of Rigid Solids with Interferometry

## 3. Terminology

3.1 See Terminology D 653 for general definitions.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *linear coefficient of thermal expansion*—the change in length of a unit length for a temperature change of 1°. The mathematical expression is:

$$\bar{\alpha} = [(L_2 - L_1)/L_0] \times [(1/(T_2 - T_1)] \quad (1)$$

In terms of thermal strains:

$$\bar{\alpha} = (\varepsilon_{T2} - \varepsilon_{T1})/(T_2 - T_1) = \Delta\varepsilon_T/\Delta T \quad (2)$$

where $\varepsilon_{T1}$ and $\varepsilon_{T2}$ are the thermal strains of the specimen as a result of a temperature change from $T_0$ to $T_1$ and from $T_0$ to $T_2$ respectively, $\bar{\alpha}$ is obtained by dividing the change in thermal strain ($\Delta\varepsilon_T$) by the change in temperature ($\Delta T$). The units of $\bar{\alpha}$ are millimetres/millimetre per degree Celsius (inches/inch per degree Fahrenheit).

3.2.2 *thermal strain*—the change in length of a unit length of a sample due to a change in temperature. The mathematical expression is:

$$\varepsilon_T = \frac{L_2 - L_1}{L_0} \quad (3)$$

where $L_1$ and $L_2$ are the specimen lengths at temperatures $T_1$ and $T_2$, respectively, and $L_0$ is the specimen length at the reference temperature $T_0$.

## 4. Summary of Test Method

4.1 The application of heat to rock causes it to expand. This change in dimension of the rock when divided by the length of rock is the strain developed in the rock. A wire or foil grid suitably bonded to the rock will be strained precisely the same amount as the rock. This straining, or stretching, of the grid results in a change in the electrical resistance of the grid. Measurement of the change in the electrical resistance of the grid is thus a measure of the change in dimension of the rock.

4.2 The application of heat to the grid may cause a change in the electrical resistance of the grid. To eliminate errors due to gauge heating, a second grid is attached to a reference specimen and the output of the gauge attached to the reference specimen is subtracted from the output of the gauge attached to the test specimen.

## 5. Significance and Use

5.1 Information concerning the thermal expansion characteristics of rocks is important in the design of any underground excavation where the temperature of the surrounding rock may be altered. Thermal strain causes thermal stress that ultimately affects the stability of underground excavations. Examples of applications where rock thermal strain is important include: nuclear waste repositories, underground power stations, compressed air energy storage facilities, and geothermal energy facilities.

5.2 The linear coefficient of thermal expansion, α, of rock is known to vary as the temperature changes. Rock thermal strain is normally not a linear function of temperature. This test method provides a procedure for continuously monitoring thermal strain as a function of temperature. Therefore, information on how a changes with temperature is obtained.

5.3 Other methods of measuring the expansion coefficient of rock by averaging the thermal strain of a large specimen over a temperature range of many degrees may result in failure to determine the variation in α of that rock for one or more of the following reasons:

5.3.1 Alpha is not always linear with temperature,

5.3.2 Some rocks are anisotropic having directional characteristics which can vary by more than a factor of two.

5.3.3 Alpha may have a negative value in one direction and, at the same time, a positive value in the others.

5.4 Strain gauges, both wire and foil types, have been successfully employed to measure the thermal expansion coefficients of rock. These coefficients are frequently very small, being on the order of millionths of a millimetre per millimetre for each degree Celsius (millionths of an inch per inch for each degree Fahrenheit). The thermal strain of rocks is about one tenth that of plastics and one half or one quarter that of many metals. Therefore, measurement methods for rocks require greater precision than methods that are routinely used on plastics and metals.

NOTE 4—Notwithstanding the statements on precision and bias contained in this test method; the precision of this test method is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D 3740 are generally considered capable of competent and objective testing. Users of this test method are cautioned that compliance with Practice D 3740 does not in itself assure reliable testing. Reliable testing depends on many factors; Practice D 3740 provides a means of evaluating some of those factors.

## 6. Apparatus

6.1 *Bonded Strain Gauges*, corresponding to ASTM Class A resistance strain gauge extensometer (see Practice E 83). The gauge length shall be at least ten times the largest grain in the rock. Care shall be exercised to have the same length and type of connecting wires on all specimens.

6.2 *Strain-Measuring System*, having sensitivity of at least 5 μm/m (5 μin./in.) with an accuracy of at least ±0.1 % of the reading and a linearity of at least ±0.1 % of the interval.

6.3 *Reference Specimen*, having minimum dimensions at least twice the length of the strain gauge. The reference specimen shall have a maximum linear coefficient of thermal expansion of $0.5 \times 10^{-6}$ cm/cm°C ($0.9 \times 10^{-6}$ in./in.°F).

NOTE 5—Suitable reference materials include titanium silicate, Zerodur, and ultra-low expansion glass, all having expansion coefficients of less than $0.5 \times 10^{6}$/°C ($0.9 \times 10^{6}$/°F) over the temperature range from 0 to 200°C (32 to 400°F)

6.4 *Temperature Measurement System*—The system chosen to monitor and record temperature depends primarily on the test apparatus and the maximum test temperature. Special limits of error thermocouples or platinum resistance thermometers (RTDs) are recommended. The temperature sensor (transducer) shall be accurate to better than 0.2°C (0.5°F) with a resolution of better than 0.05°C (0.1°F).