

CRD-C 125-63

METHOD OF TEST FOR COEFFICIENT OF LINEAR THERMAL EXPANSION OF COARSE AGGREGATE (STRAIN-GAGE METHOD)

Scope

1. This test method covers a procedure for determining the coefficient of linear thermal expansion of coarse aggregates using electrical resistance-wire strain gages.

Apparatus and Supplies

2. The apparatus used shall consist of:

- (1) A controlled-temperature cabinet capable of maintaining temperature settings between 30 and 150 F, and capable of rapidly changing the temperature of the specimens by 100 F,
- (2) an SR-4 strain indicator (Fig. 1),

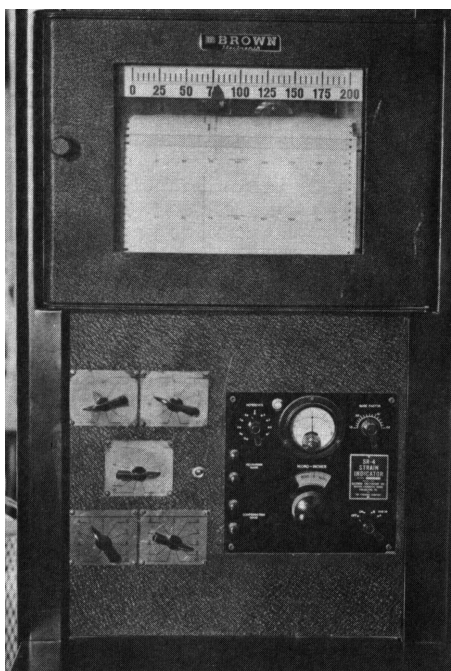


Fig. 1. Instrumentation for test for linear coefficient of thermal expansion of coarse aggregate

- (3) resistance-wire electrical strain gages (SR-4, Baldwin-Lima-Hamilton Corp., Waltham 54, Mass.) (Note 1),

Note 1.- Type A-1 gages attached by means of the cement provided for use therewith (Duco cement No. 5458) have been found generally satisfactory. Type A-5 or A-7 gages may be preferable for use with small specimens of fine-grained materials. Type AB-1 gages and bakelite cement may be used if desired.

- (4) suitable cement for attaching the gages to the specimens (Note 1),
- (5) a multiple-point recording potentiometer (see Fig. 1),
- (6) a standard specimen of known coefficient of thermal expansion, such as a quartz crystal, the coefficient of which parallel to the c-axis may be assumed to be $4.3 \text{ by } 10^{-6}/\text{F}$ (Note 2),

Note 2.- The subsequent paragraphs of this method are written for the use of a quartz crystal as the standard specimen since this material has been found satisfactory for this purpose. If another material is used as the standard specimen, its coefficient should be determined and used in the calculations.

- (7) a switchboard with silver-contact switches in circuit with the SR-4 indicator and individual lead wires to the panelboard (see Fig. 1),
- (8) a panelboard (Fig. 2) built for mounting specimens with gages attached through binding posts to the lead wires,
- (9) thermocouples for temperature measurements within cabinet at various points, and
- (10) a diamond cutoff wheel for sawing specimens.

Preparation of Specimens

3. (a) Test Specimens of Coarse Aggregate.- Specimens of coarse aggregate shall be selected (Note) of such size as to permit the preparation of surfaces for the mounting of SR-4 strain gages. The gages will be mounted in parallel pairs, one pair being located so as to measure strain in each of three mutually perpendicular directions in the specimen. Two

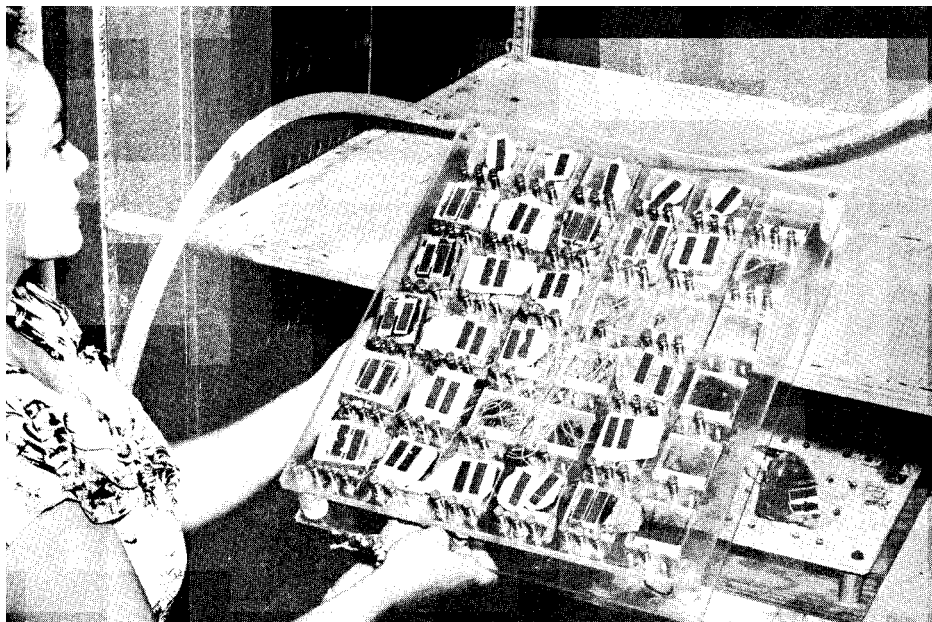


Fig. 2. Panelboard on which coarse aggregate samples to which strain gages have been attached are placed for test for thermal coefficient

of these directions will lie in the major structural plane of the rock, if such plane can be located. For convenience it is recommended that slabs of dimensions approximately 2 by 1-1/2 by 1/2 in. be cut parallel to three mutually perpendicular planes,

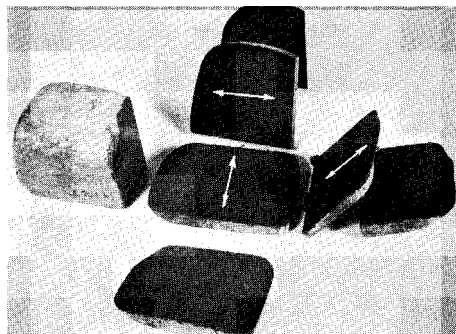


Fig. 3. Slabs parallel to three mutually perpendicular, planes cut from a sample, showing directions parallel to which gages are to be mounted

one of which is the principal structural plane of the rock (Fig. 3). The surfaces to which gages are to be attached will be prepared by sawing and grinding or by grinding and will be smoothed to remove visible ridges and hollows, but will not be polished. The surfaces shall be dry and free of oil when the gages are attached. The SR-4 strain gages will be attached in accordance with the instructions provided by the manufacturer, using only sufficient cement to coat completely the gage and specimen surfaces to be joined. After attachment the gage shall be covered with cardboard and gently loaded with a weight of at least 1 lb and cured for approximately 24 hr at room temperature.

Note.- Ordinarily, rock types making up less than 5 percent of the coarse aggregate will not be tested.

(b) Standard Quartz Specimen.- Two gages taken from the same lot number from which the gages attached to the test specimens of coarse

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aggregate were taken, shall be attached to the standard specimen of quartz parallel to the c-axis. The procedure for attaching these gages shall be in accordance with the applicable portions of Par. 3(a).

Installation and Test Procedure

4. (a) Thermocouples.- Thermocouple elements will be placed at points within the controlled-temperature cabinet in the upper, middle, and lower sections; and others will be attached at the center

and on the surface of a 2-in. cube of typical rock.

(b) Specimens.- After the curing period the specimens will be mounted on the panelboard, and the gage leads will be connected through the lead wires to individual switch points, in accordance with the schematic wiring diagram given in Fig. 4. One of the two gages mounted on the quartz crystal will be connected to an individual switch point in the same manner as are the test gages. This gage will be called the "standard gage" in the remainder of the procedure. The

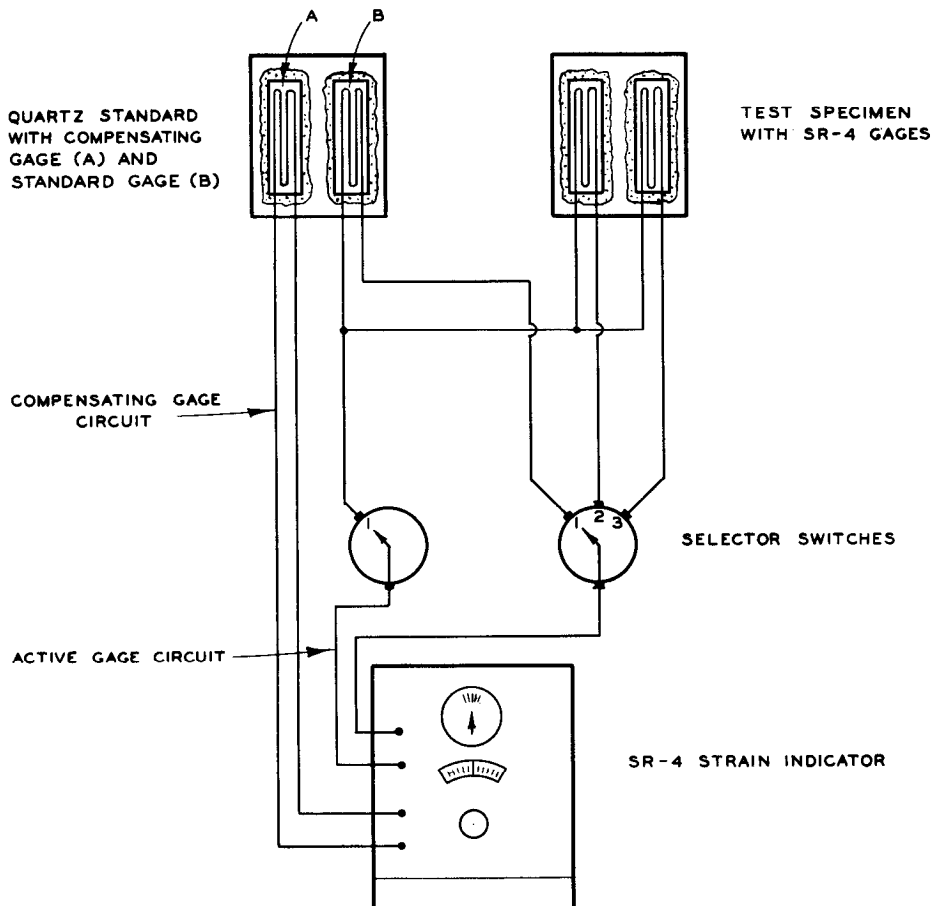


Fig. 4. Schematic wiring diagram for determination of coefficients of linear thermal expansion by use of resistance wire (SR-4) strain gages

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other gage on the quartz crystal will be connected to the SR-4 strain indicator terminals marked "Compensating Gage."

(c) Test Procedure.- The cabinet temperature will be set for 135 F and the interior allowed to come to equilibrium as indicated by overlapping of all temperature records on the potentiometer. As soon as possible after equilibrium has been achieved, each gage will be read on the SR-4 indicator by successively switching gages into the circuit. Readings of the standard gage will also be taken. The temperature setting will then be changed to 35 F and as soon as possible after equilibrium is attained, readings will again be taken. This procedure will be repeated for at least ten cycles between 135 F and 35 F. Due to "shaking down" of the cement the readings in the first cycle will be discarded. Readings at one temperature shall be taken within 1-1/2 hr after completion of readings at the previous temperature. The specimens shall be returned to and held at room temperature during periods when successive readings cannot be taken within the 1-1/2-hr interval.

Calculations

5. The SR-4 indicator shows strain in microinches per inch. The difference between successive readings of a test gage, divided by the temperature difference, has been found not to give an accurate value for coefficient of thermal expansion even when the compensating gage is attached to a specimen of negligible coefficient of thermal expansion. The inaccuracies are believed to result from the influence of extraneous factors such as change in resistance of leads with varying room temperatures, differences in contact pressure of switch points and binding posts, and variation in humidity (Note). The procedure adopted for correcting for these inaccuracies is the use of the standard specimen and gages described above, and the following formula.

Note.- A slippage ("creep") of gages cemented to surfaces can occur during the test and cause errors in

these factors should be considered. erratic results that suggest that creep is taking place. than Duo-cemented gages. If there are indications of bafelite-cemented gages are less susceptible to creep to become a significant factor. It is understood that hr for equilibrium to be reached, it could cause creep time for temperature change is much greater than 1-1/2 surface to which the gages are cemented or increased of the cement film varies, variations in texture of applying the gages, by which the thickness and continuity period. It is possible that variations in texture of equilibrium and readings are taken within a 1-1/2-hr effects of creep on the test results are negligible when Duo cement used as described herein has been that the gage readings. Experience with type A-1 gages and

The calculation is made as follows:

$$c = \frac{4.3\Delta t - \Delta y + \Delta x}{\Delta t}$$

where:

- c = linear coefficient of thermal expansion x 10⁶/deg F,
- 4.3 = linear coefficient of thermal expansion of quartz parallel to c-axis x 10⁶/deg F,
- Δt = temperature difference between successive readings, deg F,
- Δy = difference between successive readings of standard gage, microinches/in., and
- Δx = difference between successive readings of test gage, microinches/in.

Example:

Item	Reading No. 1	Reading No. 2	Difference
Temperature	135	35	-100(Δt)
Standard gage reading	3.1475	3.1435	- 40 (Δy)
Test gage reading	2.0965	2.1060	+ 95 (Δx)

$$c = \frac{4.3 (-100) - (-40) + (+95)}{-100}$$

$$= \frac{-430 + 40 + 95}{-100}$$

$$= \frac{-295}{-100} = 2.95 \times 10^6/\text{deg F.}$$

These calculations (Note) are repeated for each gage and for successive readings. The coefficients so determined for each gage are averaged, and an average for each pair of gages

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in parallel orientation is obtained, giving the coefficient of linear thermal expansion for the specimen in the direction of the gages. An average of the three coefficients for each sample tested is calculated for use as the overall coefficient of thermal expansion of the sample. Averages should be reported to one decimal place only.

Note.- In the above calculations, careful attention must be given to the sign of the calculated differences in order to obtain correct values.

Report

6. When an average value for the coefficient of thermal expansion of a coarse aggregate consisting of several or many types of rock is desired, the average value to be reported shall be a weighted average based on a relative percentage of each rock type in the sample determined and calculated in accordance with the applicable provisions CRD-C 127.