TEST METHOD FOR COEFFICIENT OF THERMAL EXPANSION OF CONTINUOUS FIBER REINFORCING MATERIALS BY THERMO-MECHANICAL ANALYSIS (JSCE-E 536-1995)

1. SCOPE

This specifications specifies mainly the test method for measuring the coefficient of thermal expansion of CFRM used in place of steel reinforcement or prestressing tendon in concrete by thermomechanical analysis.

2. DEFINITIONS

The following terms are defined for general use in this Specifications, in addition to the terms used in the "Recommendation for Design and Construction for Concrete Structures using Continuous Fiber Reinforcing Materials" and the "Quality Specifications for Continuous Fiber Reinforcing Materials":

(1) Thermomechanical analysis (TMA): Method for measuring deformation of a material as a function of either temperature or time, by varying the temperature of the material according to a calibrated program, under a non-vibrating load

(2) TMA curve: In the context of TMA, a graph with temperature or time represented on the horizontal axis, and deformation on the vertical axis

(3) Coefficient of thermal expansion: the average coefficient of linear thermal expansion between given temperatures. The average of the given temperatures is taken as the representative temperature.

3. TEST PIECES

3.1 Pre-test curing of test pieces

Prior to testing, test pieces shall normally be kept for a minimum of 24 hours at a temperature of 20±2°C and relative humidity of 65±5%, under Specifications Temperature Conditions Class II and Specifications Humidity Conditions Class II, in accordance with JIS K 7100. The test pieces shall then normally be kept for 48 hours at the maximum test temperature, in order to eliminate strain resulting from bending, and for dehumidification and deaeration.

3.2 Dimensions of test piece

The specifications test piece cut from the CFRM shall be 20mm in length, with a round or square cross-section of diameter or breadth of not more than 5mm.

3.3 Number of test pieces

The number of test pieces shall be not less than three.

4. TESTING DEVICE

4.1 Testing device

The TMA apparatus used for testing shall be capable of measuring in compression mode, of maintaining a constant atmosphere around the test piece, and of raising the temperature of the test piece at a constant rate.

4.2 Calibration of testing device

(1) Sensitivity calibration of the displacement gauge shall be carried out periodically using either an external micrometer as defined in JIS B 7502, or a micrometer attached to the testing machine.
(2) Calibration of the temperature gauge shall be carried out using a pure substance of known melting point.

4.3 Installation of testing device

The TMA apparatus must be installed in a location not subject to vibration during testing.

5. TEST METHOD

5.1 Mounting of test piece

The test piece, gauge rod and test platform shall be cleaned, and the test piece placed upright and if possible bonded to the platform.

5.2 The gauge rod shall be placed in the center of the test piece, with no pressure applied.

5.3 The atmosphere around the test piece shall consist of dry air (water content not more than 0.1% w/w) or nitrogen (water content not more than 0.001% w/w, oxygen content not more than 0.001% w/w), maintained at a flow rate in the range of 50~100 ml/min.

5.4 The load shall be applied gently to the tip of the gauge rod at room temperature, and in general the temperature shall first be lowered to 0°C then raised to 60°C, and the full process of displacement of the test piece shall be recorded.

5.5 The rate of temperature increase shall not be more than 5°C per minute.

5.6 The compressive stress acting on the test piece shall be around 4 mN/ mm^2.

6. CALCULATION AND EXPRESSION OF TEST RESULTS

6.1 The coefficient of thermal expansion of the test piece within the measured temperature range (T_1~T_2) shall be calculated according to Eq. (1).

$$a_{sp} = (\Delta L_{spm} - \Delta L_{refm}) / \{L_0 \times (T_2 - T_1)\} + a_{set} \qquad (1)$$

where

a_{sp} = coefficient of thermal expansion (/°C)

ΔL_{spm} = difference in length of test piece between temperatures T_1 and T_2 (mm)

ΔL_{refm} = difference in length of specifications test piece for length calibration between temperatures T_1 and T_2 (mm)

$L_{0=}$ length of test piece at room temperature (mm)

T_2 = maximum temperature for calculation of coefficient of thermal expansion (normally 60°C)

T_1 = minimum temperature for calculation of coefficient of thermal expansion (normally 0°C)

a_{set} = coefficient of thermal expansion calculated for specifications test piece for length calibration between temperatures T_1 and T_2 (/°C)

For apparatus in which the test piece and specifications test piece for length calibration are measured simultaneously, ΔL_{refm} shall be = 0 in the above equation.

6.2 Rounding off of numerical values

Each of the coefficients of thermal expansion shall be calculated to six decimal places (10^{-7}), and the average value rounded off to five decimal places (10^{-6}). If the average value is less than 1, it shall be expressed accurate to six decimal places (10^{-7}).

7. TEST REPORT

The test report shall include the following items:

(1) Name of CFRM

(2) Type of fiber and fiber binding material, volume ratio of fiber

(3) Numbers or identification marks of test pieces

(4) Designation, nominal diameter, nominal cross sectional area

(5) Date of test

(6) Dimensions of test pieces

(7) Pre-test curing method

(8) Type of testing machine

(9) Type of ambient atmosphere during test, and flow rate

(10) Name of substance used for temperature calibration, and measurements taken

(11) Type of specifications test piece for length calibration

(12) Temperature range for which the coefficient of thermal expansion was measured, and representative temperature

(13) TMA curve for each test piece

(14) Coefficient of thermal expansion for each test piece, and average coefficient of thermal expansion