TEST METHOD FOR LONG-TERM RELAXATION OF CONTINUOUS FIBER REINFORCING MATERIALS (JSCE-E 534-1995)

1. SCOPE

This specifications specifies mainly the test method for evaluating the relaxation ratio for long-term relaxation under a given constant temperature and strain, for CFRM used in place of steel reinforcement or prestressing tendon in concrete.

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) Relaxation: Refers to stress relaxation: the time-dependent decrease in load in a CFRM held at a given constant temperature with a prescribed initial load applied and held at a given constant strain.

(2) Relaxation rate: Percentage reduction of loading relative to the initial load after a given period of time when an initial load is applied and the strain fixed. In particular, the relaxation value after 1 million hours (approximately 114 years) is referred to as the million year relaxation rate.

(3) Tensile capacity: The average of the tensile failure loads determined based on tests conducted in according with the "Test Method for Tensile Testing of Continuous Fiber Reinforcing Materials". The test temperature shall normally be within the range 20±2°C, except in special circumstances.

3. TEST PIECES

3.1 Preparation, handling and dimensions of test pieces

Test pieces shall be prepared and handled in accordance with the "Test Method for Tensile Properties of Continuous Fiber Reinforcing Materials".

3.2 Number of test pieces

The number of test pieces for each test condition shall not be less than three. If the test piece is found clearly to have failed at the anchoring section, or to have slipped out of the anchoring section, an additional test shall be performed on a separate test piece taken from the same lot.

4. TESTING MACHINE AND DEVICES

4.1 Testing machine

The testing machine must be capable of applying a sustained load while maintaining a constant length. The machine must be capable of loading at a rate of 200±50 N/mm^2 per minute.

4.2 Anchorage
The anchorage must be in accordance with the "Test Method for Tensile Properties of Continuous Fiber Reinforcing Materials".

4.3 Accuracy of initial load
The accuracy of the initial load applied to the test piece shall be as follows:

Test machines with loading capacity of equal to or less than 1 kN: ±1.0% of set load

Test machines with loading capacity of more than 1 kN: ±2.0% of set load

4.4 Accuracy of load measurements
The accuracy of readings or automatic recording of loads applied to the test piece shall be within 0.1% of the initial load.

4.5 Strain fluctuations
The test machine shall control strain fluctuations no greater than $\pm 25 \times 10^{-6}$ in the test piece throughout the test period, once the strain in the test piece has been fixed. If the CFRM slips from the anchoring section, the distance of slippage shall be compensated so as not to affect the test results.

4.6 Extensometer and strain gauge
If an extensometer or strain gauge is to be fitted to the test piece, the extensometer or strain gauge shall be in accordance with the "Test Method for Tensile Properties of Continuous Fiber Reinforcing Materials".

4.7 Hour meter
The hour meter for measuring the passage of time must be accurate to within 1% of the elapsed time.

5. TEST TEMPERATURE

The test temperature shall normally be within the range 20±2°C, except in special circumstances. Where the test results are heavily dependent on temperature, additional tests shall be performed at 0°C and at 60°C. In either case, temperature fluctuation over the test period shall be not more than ±2°C.

6. TEST METHOD

6.1 Mounting of test piece and gauge length
Mounting of test pieces and gauge length shall be in accordance with the "Test Method for Tensile Properties of Continuous Fiber Reinforcing Materials".

6.2 Prestretching
If a strain gauge is to be set to the test piece, the test piece shall first be stretched taut by applying a load of 10~40% of the prescribed initial load, thereafter the strain gauge shall be attached and correctly calibrated.

6.3 Initial load

The initial load shall be either 70% of the guaranteed tensile capacity, or 80% of the million hour creep failure capacity, whichever is the smaller.

6.4 Application of initial load

(1) The initial load must be applied without subjecting the test piece to any shock or vibration.
(2) The specifications rate of loading the test piece shall be between 200±50 N/ mm^2 per minute.
(3) The strain on the test piece shall be fixed after the initial load has been applied to the test piece, and maintained for 120±2 seconds. This time shall be deemed to be the test start time.

6.5 Measurement of load reduction

Load reduction shall generally be measured over a period of at least 1000 hours. Load reduction shall be recorded automatically by a recorder attached to the testing machine. If no recorder is attached to the testing machine, load reduction shall be measured and recorded after the following times have elapsed:

1, 3, 6, 9, 15, 30, 45 minutes; 1, 1.5, 2, 4, 10, 24, 48, 72, 96, 120 hours; and in general every 24 hours subsequently, at a minimum of one measurement every 120 hours.

7. CALCULATION AND EXPRESSION OF TEST RESULTS

7.1 Relaxation value

The relaxation value shall be calculated by dividing the load measured in the relaxation test by the initial load.

7.2 Relaxation curve

The relaxation curve shall be plotted on a semi-logarithmic graph where the relaxation value (%) is represented on an arithmetic scale on the vertical axis, and test time in hours is represented on an logarithmic scale on the horizontal axis. An approximation line for Eq. (1) shall be derived from the graph data using the least-square method.

$$Y = a - b \log T$$

where

Y = relaxation rate (%)
a,b = empirical constants
T = time (h)

7.4 Million hour relaxation rate

The relaxation rate after 1 million hours (approximately 114 years) shall be evaluated from the approximation line; this value represents the million hour relaxation rate. Where the service life of the structure in which the CFRM is to be used is determined in advance, the relaxation rate for the number of years of service life ("service life relaxation rate") shall also be determined.

8. 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, test temperature and temperature fluctuations
(6) Type of test machine
(7) Initial load and loading rate of initial load
(8) Guaranteed tensile capacity, and ratio of initial load to guaranteed tensile capacity
(9) Relaxation curve for each test piece
(10) Average relaxation rates at 10, 120 and 1000 hours
(11) Formula for derivation of an approximation line
(12) Million hour relaxation rate
(13) Relaxation rate corresponding to design service life allowed for in design ("service life relaxation rate"), where applicable