CHAPTER 4: QUALITY CONTROL AND INSPECTION

4.1 GENERAL

The necessary quality control and inspections of concrete materials, CFRM, steel used in conjunction with CFRM, other materials, equipment, working procedures and completed structures shall be carried out to ensure the safe and economic construction of continuous fiber reinforced concrete structures of the required quality.

[COMMENT]:
Quality control when using CFRM is equally as important as when conventional materials are used (c.f. the comment of section 13.1 of JSCE Standard Specification (Construction).

4.2 TESTS

4.2.1 General

Quality control shall be carried out by testing of materials, equipment and machinery according to the prescribed methods, in order to ascertain their performance. Testing of CFRM shall generally be carried out according to this Recommendation.

[COMMENT]:
General provisions for quality control methods are given in the comments of section 13.1 and 13.2 of JSCE Standard Specification (Construction), but as JIS standards for testing of CFRM are not available, this Recommendation has been adopted as standard.

4.2.2 Tests for Concrete

The performance of concrete before and after work, and if necessary also during work, shall be tested according to the prescribed methods.

[COMMENT]:
Tests for quality control of concrete are given in section 13.5 and 27.10.1 of JSCE Standard Specification (Construction), and these specifications are followed here.

As noted in the comments of section **2.2** above, in structures where CFRM are not used in conjunction with steel and where there is no possibility of corrosion of anchorages and couplers, the requirements for chloride contents in concrete given in JSCE Standard Specification (Construction) need not be applied. Contents of chloride ions in concrete must still be tested and kept within strict limits in order to prevent deterioration of the concrete itself due to alkali-aggregate reaction etc.

4.2.3 Tests for CFRM tendons

(1) Quality tests shall be conducted on CFRM tendons prior to use, in order to ensure the required performance. Quality testing shall cover the following items:

(a) Tensile strength (or maximum tensile load); tensile modulus of elasticity (or tensile rigidity), and ultimate strain;
(b) Fatigue strength;
(c) Relaxation rate;
(d) Bond strength;
(e) Coefficient of thermal expansion;
(f) Other

The above tests may be dispensed with for materials of proven quality and performance.

(2) Quality of tensioning systems using CFRM tendons shall generally be tested for the whole system including anchorages and couplers, with quality testing carried out before use to ascertain performance. Quality testing shall cover the following items:

(a) Tensile strength (or tensile load); tensile Young's modulus (or tensile rigidity);
(b) Fatigue strength;
(c) Relaxation rate

The above tests may be dispensed with for materials of proven quality and performance.

[COMMENTS]:

The handling of CFRM is generally very different from that of steel in terms of mechanical properties, durability and handling method, and quality controls must be implemented allowing for these differences.

(1) These tests are required to control the performance of CFRM tendons themselves; bond strength testing may be omitted for CFRM tendons to be used unbonded. "Other" tests refers to accelerated deterioration testing in high temperatures, alkaline or acid conditions, creep failure testing etc. Such tests shall be performed if necessary to ascertain quality.

Quality control through these tests is extremely important, but it normally requires special, precision testing equipment, extensive expertise in measurement and / or long periods of time. Adoption of manufacturers' guaranteed values has therefore been allowed where performance has been checked by suitable testing prior to shipment, and where the suitability of transportation methods has been confirmed. If there is a possibility of mishandling during shipment or of significant damage due to long periods of storage, however, the materials must not be used without first being tested, even in the absence of any visible damage. This shall also apply to materials during work; materials suspected of having suffered damage shall immediately be replaced and tested.

Possible factors affecting CFRM before and during work are given below.

-Factors affecting CFRM before start of work: Bending beyond prescribed limits, subjection to shocks, dragging etc. during transportation; temperature, humidity, dampness or direct sunlight (ultraviolet rays) during storage; welding sparks, chemicals etc.

-Factors affecting CFRM during work: Bending or impact force beyond allowed limits during placement; over-tight binding, welding sparks, chemicals, excessively high temperatures during curing

etc.

(2) The mechanical properties of CFRM tendons are significantly affected by the anchorages and couplers, and there is a tendency for systems as a whole to give lower performance than either single or multiple tendons alone. When using CFRM tendons, therefore, tests must be carried out on factors likely to be affected when anchorages and couplers are used in a complete system, in order to ascertain performance.

These tests may be dispensed with for CFRM tendons of proven quality used in conjunction with anchorages and couplers of guaranteed quality and known performance, which are specified in the Documentation section of this Recommendation as being designed expressly for use with CFRM tendons in question.

4.2.4 Tests for anchorages and couplers

Anchorages and couplers for use with CFRM tendons shall be tested for quality before use. Such tests may be dispensed with for materials of proven quality.

[COMMENT]:
The geometry, performance, service conditions etc. of anchorages and couplers vary significantly for different types, and also depending on the type of CFRM tendons they are used with. Such anchorages and couplers must therefore be tested following an appropriate method capable of reproducing the service conditions and expected tensile forces. Tests must confirm that the strength and structure of the materials are such that failure or significant deformation do not occur below the guaranteed tensile load, and that the required anchoring or coupling effect is achieved with the proposed CFRM tendons. Standard test methods for anchorages and couplers are given in JSCE-E 537 "Test Method for Performance of Anchorages and Couplers in Prestressed Concrete using Continuous Fiber Reinforcing Materials", and these test methods may be followed here. Depending on the type of anchorages and couplers, it is also important to check that set loss due to tendon slippage is within allowable limits; furthermore, given that continuous fiber reinforced concrete structures are often located in extreme environments, any steel anchorages and couplers must also be confirmed to be sufficiently durable for the environment.

Such tests may be dispensed with for materials of proven quality which are given in the Documentation section of this Recommendation.

4.2.5 Tests for other materials used in continuous fiber prestressed concrete

Materials used in anchorages and couplers, sheaths, tendon coating and protection materials, grout etc. shall be quality tested before use to ascertain their performance. Such tests may be dispensed with for materials of proven quality.

[COMMENT]:
The materials listed here must be tested according to appropriate methods to ensure they have no adverse physicochemical effect on CFRM tendons, and that they give the required performance.

For sheaths, in addition to testing according to section 27.10.4 of JSCE Standard Specification (Construction), the frictional force arising between sheaths and tendons must also be tested by methods capable of adequately reproducing service conditions, as the surface configurations of CFRM tendons are very varied. Where plastic or other non-conventional, non-steel sheaths are to used, bonding characteristics with concrete and grout, thermal characteristics, durability etc. must also be ascertained by testing prior to use, in order to ensure the required performance is achieved in the structure.

Monitoring by tests for grout is covered in section 27.10.6 of JSCE Standard Specification (Construction), and this specification is followed here. Where non-cement grouts are used, further testing of bonding characteristics, thermal characteristics, and durability will also be required, in addition to the tests given in this Standard Specification.

4.2.6 Tests for CFRM reinforcement

(1) Quality tests shall be conducted on CFRM reinforcement prior to use, in order to ensure the required performance. Quality tests shall cover the following items:

(a) Tensile strength (or maximum tensile load); tensile modulus of elasticity (or tensile rigidity), and ultimate strain;
(b) Fatigue strength;
(c) Bond strength;
(d) Coefficient of thermal expansion;
(e) Other

The above tests may be dispensed with for materials of proven quality and performance.

[COMMENT]:

Tests of CFRM reinforcement is broadly similar to that for CFRM tendons, covered in section 4.2.3 above, with the exception of relaxation test, omitted here as necessary only for tendons. .

4.2.7 Testing for other materials for use with continuous fiber reinforced concrete

Steel reinforcement etc. for use with CFRM in concrete shall be tested at the required times following the prescribed methods to confirm performance.

[COMMENT]:

Tests for monitoring of reinforcing bars, their joints, prestressing steels, their anchorages and couplers, prestressing steel sheaths, spliced materials, friction-reducing agents etc. used in conjunction with CFRM are covered in chapters 13 and 27 of JSCE Standard Specification (Construction) and this specification is followed here.

Testing of epoxy-coated reinforcing bars used in conjunction with CFRM shall follow chapter 2 of JSCE "Recommendations for Design and Construction of Reinforced Concrete Structures using Epoxy-Coated Reinforcing Steel Bars", .

4.3 INSPECTION OF STRUCTURES

Inspection of structures shall be conducted after the completion of concrete structures.

[COMMENT]:
Continuous fiber reinforced concrete structures are frequently located in harsh environments, and in such cases, more detailed inspection in preparation for future maintenance should be carried out, as outlined in the comments of section 13.9.1 of JSCE Standard Specification (Construction). When the loading test is necessary to confirm the safety of structures, the method should be followed in section 13.9.1 of JSCE Standard Specification (Construction).

4.4 CONSTRUCTION RECORDS

The construction program, working conditions, curing methods, meteorological conditions, air temperature, quality controls and inspections, structural inspections etc. shall be recorded during the construction as the circumstances demand. Construction records shall be retained in the long term.

[COMMENT]:
CFRM are generally more resistant to chloride ion corrosion than conventional steel, giving continuous fiber reinforced structures superior durability. In the longer term, however, CFRM may undergo complex forms of deterioration in various environments, either independently or through compound interaction with concrete. As stated in the comments of section 14.1 of JSCE Standard Specification (Construction), the keeping and preservation of construction records provides essential information for future maintenance of continuous fiber reinforced concrete structures.