CHAPTER 1: GENERAL

1.1 SCOPE

(1) This Design Recommendation gives general requirements for design of concrete structures using continuous fiber reinforcing materials. Subjects not covered in this Recommendation shall comply with the JSCE "Standard Specification for Design and Construction of Concrete Structures (Design)" (hereinafter referred as the "JSCE Standard Specification (Design)").

(2) Continuous fiber reinforcing materials shall in principle conform to JSCE-E 131 "Quality Specifications for Continuous Fiber Reinforcing Materials".

[COMMENT]:
(1) "Concrete structures using continuous fiber reinforcing materials" include structures where continuous fiber reinforcing materials is used together with steel reinforcement or prestressing steel. Chapter and section numbers given in this Design Recommendation refer to the JSCE Standard Specification (Design), 1996 edition.

1.2 DEFINITIONS

The following terms are defined for general use in this Design Recommendation:

Reinforcing materials: Materials used to reinforce concrete. These include steel and continuous fiber reinforcing materials.

Continuous fiber: General term for continuous fibers used to reinforce concrete. These include carbon fibers, Aramid fibers and glass fibers.

Fiber binding materials: Adhesive used to consolidate continuous fibers. These are mostly plastics such as epoxy resin or vinylester resin.

Continuous fiber reinforcing materials (CFRM): General term for unidirectional reinforcement formed from continuous fibers impregnated with a fiber binding material, then hardened and molded, in the form of bundled or woven continuous fibers, used for reinforcing the concrete.

Capacity of CFRM: Maximum load that a continuous fiber reinforcing material can sustain.

Strength of CFRM: Value obtained by dividing the capacity of continuous fiber reinforcing material by the nominal cross-sectional area.

Characteristic value of capacity of CFRM: Value for the capacity of continuous fiber reinforcing material below which the percentage of test results obtained using a given test method is guaranteed not to exceed a given figure, allowing for variations in test results.

Specified value of capacity of CFRM: (as distinct from the characteristic value of capacity of CFRM:) Capacity value for continuous fiber reinforcing material determined in accordance with structural specifications other than this Recommendation, or other regulations.

Guaranteed capacity of CFRM: Guaranteed capacity in accordance with JSCE-E 131 "Quality Specifications for Continuous Fiber Reinforcing Materials"

Design capacity of CFRM: Value obtained by dividing the characteristic value of capacity of continuous fiber reinforcing material by the material coefficient.

Characteristic value of ultimate strain of CFRM: Strain corresponding to the characteristic value of tensile capacity of continuous fiber reinforcing material.

Design ultimate strain of CFRM: Value obtained by dividing the characteristic value of ultimate strain of continuous fiber reinforcing material by the material coefficient.

Tensile rigidity of CFRM: Slope of the tensile force-strain curve for continuous fiber reinforcing material, when this curve is assumed to be linear.

Young's modulus of CFRM: Value obtained by dividing the tensile rigidity of continuous fiber reinforcing material by the nominal cross-sectional area.

Nominal cross-sectional area of CFRM: Value obtained by dividing the volume of continuous fiber reinforcing material by the length.

Bent portion of CFRM: Portion of continuous fiber reinforcing material set in a curved shape by hardening with a fiber binding material while the continuous fibers are bent.

Curved placement of CFRM: Placement of straight continuous fiber reinforcing material in a curved layout.

Creep failure: Failure due to progressive loss of tensile capacity over time, when continuous fiber reinforcing material is subjected to a continuous static tensile load.

Creep failure capacity: Capacity at the time of creep failure.

Flexural compressive failure: Form of failure in members subjected to flexure, whereby the compressed section of concrete fails before the main continuous fiber reinforcing material breaks.

Fiber rupture flexural failure: Form of failure in members subjected to flexure, whereby the main continuous fiber reinforcing material breaks before the failure of the compressed section of concrete.

Fiber rupture shear failure: Form of shear failure in members subject to shear forces, due to breaking of continuous fiber reinforcing material used as shear reinforcement.

[COMMENTS]:
Definitions of shear reinforcement, lateral ties, hoop reinforcement, spiral reinforcement, and tendons follow the JSCE Standard Specification (Design), where "steel reinforcement or prestressing steel" shall be read simply as "reinforcing materials".

Since the nominal cross-sectional area of CFRM is obtained by dividing the volume of the CFRM by the length, and volume generally includes sectional area which does not contribute to the strength of the reinforcement, the strength and Young's modulus of CFRM obtained by division by the nominal cross-sectional area are not identical with the value for the continuous fiber itself.

1.3 NOTATION

Notation used in this Design Recommendation with reference to structural design is as follows:

A_f : Cross-sectional area of CFRM placed in tensile zone
A_{fc} : Cross-sectional area of CFRM necessary based on calculation
c_f : Center-to-center distance of CFRM
E_0 : Standard Young's modulus (200 kN/mm^2 = Young's modulus of steel)
E_f : Young's modulus of CFRM used in verification of service limit state
E_{fp} : Young's modulus of CFRM used as tendons
E_{fu} : Young's modulus of CFRM used in verification of ultimate limit state
E_w : Young's modulus of shear reinforcement or transverse torsional reinforcement
F_{fu} : Tensile capacity of CFRM
f_{fb} : Strength of bent portion of CFRM
f_{fc} : Creep failure strength of CFRM
f_{fpu} : Tensile strength of CFRM used as tendons
f_{fu} : Tensile strength of CFRM
f_w : Strength of shear reinforcement or transverse torsion reinforcement
g_{mf} : Material coefficient of CFRM
e_{fspd} : Design value of strain at ultimate limit state for spiral reinforcement
e_{fu} : Ultimate strain of CFRM
e_{fwd} : Design value of strain at ultimate limit state for shear reinforcement
s_{fe} : Increase in reinforcement stress due to design load, used in verification of crack width
s_{fp} : Increase in reinforcement stress due to permanent load
s_{fpe} : Increase in tendon stress due to design load, used in verification of crack width
s_{fpp} : Increase in tendon stress due to permanent load

[COMMENT]:
Subscript *f* refers to CFRM.