

## Chapter 1    General

### 1.1 Scope of Application

(1) The Draft recommendations in this document (hereafter called the “recommendations”) provide the basic principles of design and construction of a structure using the ultra high strength fiber reinforced concrete (hereafter called “UFC”) in order that the guidelines will meet the performance requirements for safety, serviceability, durability, and fatigue resistance.

(2) The UFC is a type of cementitious composites reinforced by fiber with characteristic values in excess of 150 N/mm<sup>2</sup> in compressive strength, 5 N/mm<sup>2</sup> in tensile strength, and 4 N/mm<sup>2</sup> in first cracking strength.

The matrix of the UFC is as follows: it should be composed of aggregates, whose maximum particle sizes are less than 2.5 mm, cement, and pozzolans and the water-cement ratio is less than 0.24. It contains reinforcing fibers of more than 2% by volume, whose tensile strength exceeds  $2 \times 10^3$  N/mm<sup>2</sup>, ranging 10 to 20 mm in length and 0.1 to 0.25 mm in diameter.

If materials outside the conditions above are used, it should be verified that the physical properties of the materials are either equivalent or exceed the values stated in this guide in respect to strength, durability, and efficiency in construction as required for the UFC.

(3) The UFC requires heat curing as the standard method of curing.

[Comments]

(1) The recommendations provide general requirements for the design and construction of structures made with UFC with high-performance in strength, toughness, and durability.

(2) The hardened state of the UFC is evaluated by characteristic values described in Section 3.2.

A concrete with less than 150 N/mm<sup>2</sup> in the compressive strength and 5 N/mm<sup>2</sup> in the tensile strength is outside the scope of the recommendations, as it requires reinforcing steel and makes the construction non-economical. The recommendations are applied to the matrix (except the portion of fiber reinforcement) consisting of aggregates, cement, and pozzolans. Special care is necessary to arrange particle size distribution of the materials in order to achieve a high dense as filler and provide the excellent self-compacting ability at the time of casting and molding. The particle size of the pozzolans shall be less than 1 μm. Silica fumes and other pozzolanic materials

may be used. A higher density can be achieved by adding quartz particles, whose size is intermediate between cement and pozzolans, to the matrix. The silica flour, a type of quartz particles ranging from  $2\ \mu\text{m}$  to  $20\ \mu\text{m}$ , may be used for the purpose of increasing the dense. Adequate tensile strength may not be achieved if the size of the aggregates exceeds 2.5 mm, as it makes it difficult to attain the desired compression strength, and fibers are not uniformly dispersed within the concrete. In addition, if the W/C ratio exceeds 0.24, the desired compression strength and tensile strength will not be achieved. It may also lower the durability.

The standard application of the fiber reinforcement is the use of fibers 10 to 20 mm in length and 0.1 to 0.25 mm in diameter, with a tensile strength of  $2 \times 10^3\ \text{N}/\text{mm}^2$  or more and 2% volume fraction. Other than these conditions, the target effect of reinforcement may not be achieved since the fibers will not be homogeneously dispersed in the concrete.

The recommendations stipulate that, in case of the use of materials outside the conditions above, it should be verified that the physical properties of the materials are either equivalent or exceed the values stated in this document in respect to strength, durability, and efficiency in construction as required for UFC.

(3) Heat curing is applied to achieve a high-density in the hardened concrete. There are steam curing and other methods for this purpose. The effects of heat curing on UFC are as follows.

- It accelerates the development of strength.
- It decreases the effect of shrinkage and creep after completion of the curing.
- It increases durability by achieving higher dense of the concrete.

Considering the above, it was determined that the use of heat curing is the standard curing operation for UFC. The details of the heat cure are described in Section 12.8.

Anything not documented in the recommendations shall be addressed in accordance with the Standard Specifications for Concrete Structures prepared by the Japan Society of Civil Engineers in 2002 (hereafter called "Standard Specifications" ) and related documents.

## 1.2 Definition of Terms

The terminologies in the recommendations are as follows.

**UFC:** The concrete that satisfies the conditions described in 1.1 (2).

**Reinforcing fiber:** The fiber that satisfies the conditions described in 1.1 (2), which is added to the concrete matrix for reinforcement.

**First Cracking Strength:** A stress level with which the first crack occurs on UFC when subjected to tensile stress. It is a stress where the assumption of linear elasticity is no longer applicable in the stress-strain curve, a point at which the shape of the curve becomes nonlinear.

**Tensile Strength:** The maximum tensile strength of UFC.

**Premix Method:** A method to produce UFC using the matrix grain blended in advance by a special mixer, using the materials individually examined and procured.

**Non-premix Method:** A method to produce UFC using the materials individually examined, procured, stored, and then measured immediately before mixing.

**Standard Mixed Ingredients:** The matrix grain confirmed of its conformity to the recommendations with respect to strength, durability and efficiency of construction required for the UFC. The pre-mix method shall be employed for production

**Heat Curing:** A curing method applied after hardening of the UFC, for the purpose of improving strength and durability.

### 1.3 Notations

The symbols used in the recommendations are as follows.

$f_{cr}$ : The first cracking strength of UFC.

$f_t$ : The tensile strength of UFC.

$f_v$ : The averaged tensile strength perpendicular to the diagonal crack of UFC.

$L_{eq}$ : Equivalent specific length.

$V_f$ : The shear strength provided by reinforcing fibers.

$V_{rpc}$ : The shear strength of a beam or a column that has no shear reinforcement, excluding the strength that is provided by fiber reinforcement.

$w_{1k}$ : In the tension softening curve, a range of CMOD (crack mouth opening displacement) for which the concrete can still maintain a certain level of tensile stress after the first crack has occurred.

$w_{2k}$ : In the tension softening curve, the point of CMOD where tensile stress becomes zero.

$\beta_i$ : An angle of a diagonal crack.

All other symbols shall comply with the notations of the Standard Specifications.