CHAPTER 2: MATERIALS

2.1 GENERAL

Materials to be used shall be of confirmed quality.

[COMMENT]:
CFRM are new materials with limited field experience, and for some types little data on quality are available. It is therefore necessary to confirm the quality of the materials. In order to enhance the effectiveness in service of CFRM, it is particularly important to ensure that the concrete and any reinforcing or prestressing bars, anchoring devices, couplers, covering, protective materials, sheaths, grout etc. are of confirmed quality.

2.2 CONCRETE

(1) Concrete shall have a design strength of not less than the values given in **table 2.2.1**.

Table 2.2.1 Minimum design strength of concrete

CFRM application	Minimum design strength
As substitute for reinforcing bars	21 N/mm^2
As prestressing materials	30 N/mm^2

(2) Concrete quality shall be in accordance with chapter 2 of JSCE Standard Specification (Construction).

(3) Quality of cement, water, fine aggregate, coarse aggregate, and admixtures used in concrete shall be in accordance with chapter 3 of JSCE Standard Specification (Construction).

[COMMENT]:
When using CFRM as prestressing materials, greater compressive strength of concrete is required, as with conventional prestressed concrete structures.

In structures where steel is not used and where there is no danger of corrosion of CFRM anchorages and couplers, the limitations on chloride contents in concrete given in JSCE Standard Specification (Construction) need not be applied. An excess of alkali ions such as Na^+ and K^+, however, will tend to accelerate alkali-aggregate reaction, and appropriate methods should be taken to prevent alkali-aggregate reaction, for instance by eliminating reactive aggregate.

2.3 CONTINUOUS FIBER REINFORCING MATERIALS

(1) CFRM used in construction shall normally be materials meeting the requirements given in JSCE-E 131 "Quality Standards for Continuous Fiber Reinforcing Materials".

(2) Where CFRM do not meet the requirements of JSCE-E 131 "Quality Standards for Continuous Fiber Reinforcing Materials" are to be used, tests must first be carried out to establish the design strength, design value of modulus of elasticity, design ultimate strain and method of use.

(3) Where CFRM are to be subjected to heat treatment or other form of processing for anchoring, jointing, processing, assembly or placement, tests shall be performed to determine the level of quality loss due to the treatment, and an appropriate deign tensile strength and other design values shall be determined separately.

[COMMENTS]:

(2) Tests shall be conducted according to JSCE-E 531 "Test Method for Tensile Properties of Continuous Fiber Reinforcing Materials", and guaranteed values such as the tensile strength, modulus of elasticity and ultimate strain shall be determined based on the test results. Bonding strength shall be tested according to JSCE-E 539 "Test Method for Bond Strength of Continuous Fiber Reinforcing Materials by Pull-Out Testing". Flexural tensile failure strength, creep failure strength, relaxation, fatigue strength, coefficient of thermal expansion, alkali resistance, and shear strength shall be determined using test methods meeting JSCE standards. Values determined using well-established alternative test methods, however, may also be used provided a reliable guaranteed value allowing for the effect of anchorage is obtained.

(3) See section **3.3** below for details of treatment and handling for heat treatment or other forms of processing.

2.4 REINFORCING BARS

(1) Where CFRM are to be used in conjunction with reinforcing bars, the bars shall be selected to conform to the intended purpose of the CFRM.
(2) Where CFRM are to be used to enhance the corrosion resistance of a structure, epoxy-coated reinforcing bars used in conjunction with the CFRM shall conform to JSCE-E 102 "Quality Standards for Epoxy-Coated Reinforcing Steel Bars".
(3) Where ordinary reinforcing bars without corrosion-proofing are to be used, section 3.7.1 of JSCE Standard Specification (Construction) shall be adhered to.

[COMMENTS]:

(1) CFRM are used mainly for their corrosion-resistant and non-magnetic properties, therefore reinforcing bars used in conjunction with CFRM must be selected in accordance with the intended purpose. It should be noted in this connection that non-magnetic reinforcing bars have also been developed in recent years.

(2) The material properties of CFRM tend to lead to their being used in harsh, saline environments etc., thus epoxy-coated reinforcing bars are prescribed as standard for use in conjunction with CFRM, in order to ensure corrosion protection. Galvanized reinforcing bars could also be considered, but owing to the lack of experience with this in combination with CFRM, epoxy-coated reinforcing bars have been preferred here.

(3) Where ordinary unprotected reinforcing bars are used, the prescription given in section 3.7.1 of

JSCE Standard Specification (Construction) of conformity with JIS G 3112 "Steel Bars for Concrete Reinforcement" must be adhered to.

Stainless and corrosion-proof reinforcing bars have been developed in recent years. Where these or non-magnetic reinforcing bars re to be used, they must first be confirmed to have performance equivalent to the JIS standard quoted above.

2.5 PRESTRESSING STEEL

Where prestressing steel is to be used, section 3.7.2 of JSCE Standard Specification (Construction) shall be adhered to.

[COMMENT]:
Where ordinary prestressing steel without corrosion-proofing is to be used, the requirements of section 3.7.2 of JSCE Standard Specification (Construction) are to be applied as-is; this means prestressing steel must generally conform to JIS G 3109 "Steel Bars for Prestressed Concrete", JIS G 3137 "Small Size Deformed Steel Bars for Prestressed Concrete", and JIS G 3536 "Uncoated Stress-relieved Steel Wires and Strands for Prestressed Concrete".

Corrosion-proofed or stainless prestressing steels have been developed in recent years. Where these steels are to be used, they must first be confirmed to have performance equivalent to the JIS standards quoted above, and, additionally, the effectiveness of their corrosion-proofing must be adequately assessed.

2.6 ANCHORAGES AND COUPLERS

(1) Anchorages and couplers shall be of a structure and strength such that they do not fail below the guaranteed capacity or undergo significant deformation.

(2) Materials used in anchorages and couplers shall be of confirmed quality.

(3) Anchorages and couplers shall be tested for performance according to JCSE-E 537 " Test Method for Performance of Anchorages and Couplers in Prestressed Concrete using Continuous Fiber Reinforcing Materials".

[COMMENTS]:
(1) Anchorages or couplers shall be of a structure and strength corresponding to or superior to the anchoring or coupling system using CFRM, allowing for safety during prestressing work, the need to prevent excessive set in anchorage etc. The guaranteed capacity of the anchorages or couplers, and the guaranteed capacity of the tendons, are treated separately here. The reason for this is that the tensile strength of CFRM is evaluated allowing for the effects of the anchorages, while in many cases the anchoring device does not allow the CFRM to exert its full tensile strength, and in multi-cables especially, the fall-off is significant. "Anchoring or coupling system using CFRM" here refer respectively to systems configured with CFRM and anchorages, and CFRM and couplers.

(2) "Materials used in anchorages and couplers" refers to synthetic resins, anchoring expansion agents,

grout, anchor bars etc. As these are the most important materials in anchoring and coupling of prestressed concrete structures, they must be of proven, reliable quality and outstanding durability.

(3) Performance testing of anchorages and couplers may be carried out according to JSCE-E 537. This test, however, is intended for new types or types for which adequate test data is not available; testing may be omitted for types of proven quality and reliability. for which test data is given in the Documentation section of this Recommendation.

2.7 SHEATHS

(1) Sheaths shall be of a type not easily deformed during handling or concrete placement, and capable of withstanding intrusion of cement paste at laps and joints.

(2) Sheaths should be preferably have low friction with tendons, and should not cause damage to tendons during tensioning.

(3) The effects of the sheaths on the structure must be fully known.

[COMMENTS]:

(1) Bonding between CFRM and prestressed concrete grout, or between sheaths and concrete, may or may not be factored into the design, therefore the sheath material and geometry must give the performance intended in the design. Plastic sheaths may be used, in addition to conventional steel sheaths. Plastic sheaths must be sufficiently rigid to prevent any hindrance of placement etc. Severe deformation of sheaths or leakage of cement paste may hinder or prevent prestressing work, therefore the use of non-rigid or damaged sheaths must be avoided.

(3) The bonding characteristics of the intended sheaths with concrete and grout, and the effects on the structure of cracking, differences in coefficients of thermal expansion etc. must be fully known in advance.

Details of handling of sheaths are given in section **3.3.4** below.

2.8 TENDON COATING MATERIALS AND TENDON PROTECTION MATERIALS

(1) Materials used for tendon coating shall not cause damage to CFRM tendons or to the concrete, and shall not cause bonding between CFRM tendons and the concrete during prestressing.

(2) Tendon protection materials shall protect CFRM tendons fully from damage due to external factors.

[COMMENT]:

Tendon coating materials are used to prevent bonding between CFRM tendons and concrete, whereas tendon protection materials are used to protect CFRM tendons from physicochemical deterioration due to external factors, hence the distinction drawn here between the two types of material. Both types should of course fulfill their intended purpose, and the materials used must be of guaranteed durability and quality.

2.9 GROUT FOR PRESTRESSED CONCRETE

(1) Grout for prestressed concrete shall be of sufficient quality to protect the tendons and to form a monolithic structure by bonding with the member concrete and the tendons.

(2) The quality and materials of cement grout for prestressed concrete shall satisfy the following conditions.
(a) Consistency: The consistency shall be set at a level appropriate for the construction, taking into account the length and shape of the sheaths and ducts, construction season and weather conditions, type of tendon and the proportion of the sectional area of the prestressing steel to that of the duct.
(b) Bleeding rate: The bleeding rate shall be not more than 3%, and preferably not more than 1%.
(c) Expansion rate: The expansion rate shall be not more than 10%. The expansion rate after grouting shall exceed the bleeding rate until maximum bleeding is reached. The standard time from the completion of agitation to the completion of grouting should be around 30 minutes.
(d) Strength: Compressive strength at 28 days shall be not less than 20 N/mm^2.
(e) Water-cement ratio: The water-cement ratio of the grout shall be not more than 45%.
(f) Cement: Cement used for grouting shall comply with JIS R 5210.
(g) Water: Water used for grouting shall not contain harmful levels of substances adversely affecting the grout or the prestressing tendons.
(h) Admixtures: The advisability of using admixtures, and the quality and method of use of the admixtures, shall be studied in advance.

(3) Grout for prestressed concrete other than that specified in (2) above shall first be checked for quality and the method of use adequately studied.

[COMMENTS]:

(1) The purpose of grouting is to protect the tendons and to create a monolithic structure through bonding of member concrete and tendons. The grout must therefore fill ducts completely, and surround the tendons. The grout must therefore maintain good fluidity and workability up to the completion of grouting, with minimum bleeding, proper expansion after grouting, and adequate strength.

Grouting should ideally be carried out from below, causing the grout to flow gradually upwards. Where tendons are placed with multiple bend-ups and bend-downs, grout will shift from higher levels to lower levels, therefore the use of high quality grout with little or no bleeding is advised. Further, if the gap between sheaths and tendons is too narrow, it will not be properly grouted, therefore the use of large-diameter sheaths and high quality grout is advised.

(2) High-quality grouts are now available with superplasticizers in place of conventional plasticizers, giving little or no bleeding, and maintaining initial levels of fluidity for long periods while at the same time giving high viscosity.

The water-cement ratio should be kept as low as possible given the fluidity requirements. A high water-cement ratio will cause loss of strength and bonding, and incomplete grouting of ducts due to bleeding and shrinkage. Conversely, a low water-cement ratio will result in high viscosity and poor workability. The standard water-cement ratio is therefore given as 45%. The use of recently developed superplasticizers allows the water-cement ratio to be reduced while giving a grout with high fluidity and workability.

(3) The use of cement-based grout may be inadvisable in certain circumstances owing to adverse effects on durability of CFRM tendons. In such cases, tests should be carried to check that the grout meets the required quality standards.