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Replacing EJ/T 998-1996

Construction requirements for prestressed concrete containments for pressure water reactor nuclear power plants

压水堆核电厂预应力混凝土安全壳建造规范

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Table of contents

Foreword

This standard was drafted in accordance with the rules given in GB/T 1.1-2009.

This standard replaces EJ/T 998-1996 “Construction requirements for prestressed concrete containments for pressure water reactor nuclear power plants”. As compared with EJ/T 998-1996, except for editorial changes, the main technical changes are as follows:

- MODIFY the normative references (see Chapter 2; Chapter 2 of 1996 version);
- MODIFY the requirements for cement and aggregate (see 5.2.1 and 5.2.2; 4.2.1 and 4.2.2 of 1996 version);
- ADD the requirements for admixtures (see 5.2.4); MODIFY the provisions on admixtures (see 5.2.5; 4.2.4 of 1996 version);
- DELETE the requirements for bell mouth and grouting connector (4.4.4 of 1996 version);
- MODIFY the requirements for prestressed tendons, anchorage, and steel strand conduit (see 5.4; 4.4 of 1996 version);
- MODIFY the material requirements for steel lining and the welding (see 5.5 and 5.6; 4.5 and 4.6 of 1996 version);
- MODIFY the technical requirements for concrete construction (see Chapter 6; Chapter 5 of 1996 version);
- MODIFY the fabrication, processing and installation of ordinary rebar (see Chapter 7; Chapter 6 of 1996 version);
- MODIFY some of the requirements for the processing and manufacture of prestressed systems (see Chapter 8; Chapter 7 of 1996 version);
- ADD the requirements for in-situ test before monitoring steel strand and prestressing work (see 8.8 and 8.9);
- MODIFY the welding requirements for steel linings (see 9.5; 8.5 of 1996 version).

This standard shall be under the jurisdiction of the Nuclear Industry Standardization Institute.

Construction requirements for prestressed concrete containments for pressure water reactor nuclear power plants

1 Scope

This standard specifies the processing, fabrication and installation requirements for the material, concrete construction and ordinary rebar, prestressing system, and steel linings of the prestressed concrete containment of pressure water reactor nuclear power plants. It excludes the construction of penetration pieces and gates.

This standard is applicable to the construction of prestressed concrete containment for pressure water reactor nuclear power plants.

2 Normative references

The following documents are essential to the application of this document. For the dated documents, only the versions with the dates indicated are applicable to this document; for the undated documents, only the latest version (including all the amendments) are applicable to this Standard.

GB 175 Common Portland cement

GB 1499.1 Steel for the reinforcement of concrete - Part 1: Hot rolled plain bars

GB 1499.2 Steel for the reinforcement of concrete - Part 2: Hot rolled ribbed bars

GB/T 5224 Steel strand for prestressed concrete

GB/T 8162 Seamless steel tubes for structural purposes

GB/T 14370 Anchorage, grip and coupler for prestressing tendons

GB/T 14684 Sand for construction

GB/T 14685 Pebble and crushed stone for construction

GB/T 17395 Dimensions, shapes, masses and tolerances of seamless steel tubes

GB/T 50081 Standard for test methods of mechanical properties on ordinary concrete

GB/T 50082 Standard for test methods of long-term performance and durability of ordinary concrete

GB 50164 Standard for quality control of concrete

GB 50204 Code for acceptance of construction quality of concrete structure

GB/T 50205 Code for acceptance of construction quality of steel structures

GB 50666 Code for construction of concrete structures

JGJ 18 Specification for welding and acceptance of reinforcing steel bars

JGJ 55 Specification for mix proportion design of ordinary concrete

JGJ 63 Standard of Water for Concrete

JGJ 85 Technical specification for application of anchorage, grip and coupler for prestressing tendons

JGJ 107 Technical specification for mechanical splicing of steel reinforcing bars

JGJ 225 Metallic corrugated tubes for prestressed concrete

JGJ 256 Technical specification for application of headed bars

DL/T 5150 Test code for hydraulic concrete

NB/T 20002 Welding rules for mechanical components of PWR nuclear islands

NB/T 20003.2-2010 Non-destructive testing for mechanical components in nuclear island of nuclear power plants - Part 2: Ultrasonic testing

NB/T 20005.7-2010 Carbon steel and low alloy steel for pressurized water reactor nuclear power plants - Part 7: Classes 1, 2, 3 plates

NB/T 20009.1 Welding materials for pressurized water reactor nuclear power plant - Part 1: Carbon steel covered electrodes for classes 1, 2, 3 components

HAF 003 Nuclear power plant safety requirements for quality assurance

HAD 003.07 Quality assurance during construction of nuclear power plants

3 Terms and definitions

The following terms and definitions apply to this document.

3.1

Concrete material full performance test

It refers to the test used to check the physical and mechanical properties, thermal parameters, and other indicators of concrete.

3.2

Anchorage

It refers to, in the post-tensioned prestressed concrete structures, the permanent anchoring devices which are used to maintain the tension of the prestressing tendons AND transmit such tension to the structure.

3.3

Bearing plate

It refers to, in the post-tensioned prestressed concrete structures, the components used to withstand the prestressing forces from the anchors AND transmit such forces to the concrete, including common bearing plates and casted bearing plates.

3.4

Trumplate

It refers to the flared guide castings connected to the bearing plates and prestressed tubes.

3.5

Workability of concrete

It refers to the characteristics featured by concrete mixture to meet the requirements of construction operations AND to ensure concrete uniformity and density, which mainly includes mobility, cohesion and water retention.

5.2.2.4 The maximum nominal grain size of coarse aggregates shall not be greater than:

a) 1/5 of the smallest dimension between the formworks;

b) Shall not exceed 31.5 mm;

c) 3/4 of the minimum clear distance between the single rebar and prestressed tube.

Note: If it confirms through assessment that the concrete workability and vibratory methods can avoid the generation of honeycombs or voids when placing concrete, it cannot be subjected to the above limitations.

5.2.2.5 Aggregates shall be continuously graded AND meanwhile satisfy the pumping performance.

5.2.3 Water

5.2.3.1 The concrete mixing water, curing water and aggregate cleaning water shall be drinking water. When using non-drinking water, its indicators shall comply with the requirements of JGJ 63.

5.2.3.2 The content of soluble matter in mixing water shall not exceed 2000 mg/L; as for the mixing water including the free water at aggregate surface, its chlorides content shall not exceed 250 mg/L, AND sulfate content shall not exceed 250 mg/L.

5.2.4 Admixtures

5.2.4.1 It is strictly forbidden to use the admixture that causes harm to the human body OR pollutes the environment. The type and amount of the admixture as selected for the concrete shall be agreed by the design department AND comply with the requirements of relevant standards. It is not advisable to use air-entraining agent or air-entraining admixture in the prestressed concrete.

5.2.4.2 The admixtures used for reinforced concrete and prestressed concrete shall not contain chloride ions, except for the trace of chloride ions led in by the drinking water which is used to prepare liquid admixtures.

5.2.5 Mineral admixtures

5.2.5.1 In the concrete material of the containment structure, it is allowed to admix class I category F fly ash to improve the physical and mechanical properties of the concrete. The content of fly ash in concrete shall be

6.2.3 Stirring

6.2.3.1 The stirring capacity and the corresponding stirring time of all agitators shall be determined by the agitation uniformity test.

6.2.3.2 It shall record the amount of raw material used for each batching, AND keep it. The allowable deviation of the measurement of raw materials shall comply with the relevant provisions of GB 50666. It shall measure the moisture in aggregate, AND modify the batching water amount accordingly.

6.2.4 Transportation

6.2.4.1 All equipment for transporting concrete mixtures shall be clean prior to use, AND shall not be in contact with aluminium during concrete transportation.

6.2.4.2 The transportation method of concrete from the agitator to the final location shall avoid the segregation or delamination of concrete.

6.2.4.3 During transportation, it shall ensure the uniformity and workability of concrete mixture, AND take measures to guarantee the continuous supply of concrete, in order to satisfy the site construction requirements.

6.2.4.4 After the concrete leaves from the agitator, it is prohibited to add admixtures or water any more.

6.3 Placing, vibrating and curing

6.3.1 Placing and vibrating

6.3.1.1 The concrete shall be placed as close to its placing position as possible, in order to avoid segregation due to handling or transport.

6.3.1.2 The concrete shall be placed in layers. The upper layer concrete shall be placed before the initial setting of the lower layer concrete. The initial setting time of the concrete shall be decided by experiment. When the interval between the layers of concrete exceeds the initial setting time, the level surface shall be treated as construction joints.

6.3.1.3 The concrete free fall height shall not be greater than 1.5 m; otherwise it shall use chute or tumbling barrel to guide it.

6.3.1.4 The concrete that has been partially hardened or contaminated shall not be placed into the structure; AND it shall not add water to re-mix the concrete OR use the concrete which is stirred again after initial setting. The duration from concrete unloading from the agitator to the completion of placing shall not exceed 60 min, OR otherwise determined through test.

6.4 Formwork and construction joints

6.4.1 Formwork

6.4.1.1 The formwork installation shall ensure that the shape, size and relative position of various components of the concrete structure are accurate. Formwork shall be sturdy and tight enough, in order to prevent leakage of slurry. The embedded parts fixed in the formwork, the instrument required for structural integrity test, and the reserved holes shall be free from leakage, AND installed firmly.

6.4.1.2 The design of formworks and supports shall take into account the following factors:

a) Concrete placing speed and method:

b) The density of concrete:

c) Construction loads, including vertical, horizontal and impact loads:

d) The special formwork erection requirements during construction.

6.4.1.3 When steel lining is used as a formwork, in order to keep the error of the penetration piece be within the allowable tolerance range as specified in the design, it shall reasonably install auxiliary support; in order to avoid the deformation of the steel lining exceeds the specified value, it shall reasonably control the concrete placing section height.

6.4.2 Construction joints

6.4.2.1 Construction joints shall be set in accordance with the position specified in the design. When the design does not clearly define the construction joint location, the configuration of construction joints shall comply with the relevant provisions of GB 50666.

6.4.2.2 In the construction joints, before continuing placing concrete, it shall conduct the following treatment:

a) Completely REMOVE the floating slurry, loose stone, and soft concrete layer from the hardened concrete junction surface;

b) ROUGHEN the Surface uniformly to expose the aggregate;

c) When bending rebar at the construction joints, AVOID the concrete surrounding the rebar from loosening or damage. AND it shall remove the oil stain, cement slurry or floating rust from the rebar;

7.2 Transportation and storage

7.2.1 In the transportation and storage of steel bar, it shall keep the label or mark, AND stack it neatly based on designation, specification, and batch number, in order to avoid rusting or pollution.

7.2.2 The storage yard shall be clean and neat; it shall not place the rebar directly on the floor to avoid moisture.

7.3 Forming

7.3.1 The rebar shall be shaped in accordance with the size and shape as required by the design.

7.3.2 The rebar processing shall be conducted at room temperature, during which it is not allowed to heat the rebar.

7.3.3 The rebar shall be bent in place once. Only the closed stirrups or tie bar of diameter not more than 12 mm are allowed to be formed during formwork erection; the deformed rebar of diameter more than 12 mm shall be bent mechanically, it is not allowed for vibration or impact, AND it shall be bent slowly to avoid temperature rise. The bending internal diameter of rebar shall comply with the provisions of GB 50666.

7.3.4 The rebar shall be straightened by mechanical equipment without extension functions; AND it is not preferable to straighten the rebar through cold drawing. The straightening of rebar shall not damage the transverse rib of the ribbed rebar. The straightened rebar shall be straight AND free from local bending.

7.3.5 Unless otherwise specified in the design drawings or with the permission of the relevant designer, the bending and straightening of the rebar shall be conducted before the rebar is embedded in the concrete.

7.3.6 The bending or straightening of the rebar which is partially embedded into the hardened concrete shall comply with the following requirements:

a) The bending of the rebar shall be as slow as possible, and gradually form the arc. The bending diameter of the rebar shall not be smaller than 8 times the diameter of the rebar, AND the distance from the starting point of bending to the hardened concrete surface shall not be less than 8 times of rebar diameter.

b) The rebar of diameter less than or equal to 16 mm is allowed to be cold bent once, AND the subsequent straightening and bending shall be pre-heated; the rebar of diameter more than 16 mm shall be pre-heated before

having a diameter 5 mm larger than the conduit diameter shall be able to screw onto this conduit;

c) 100% sealing inspection, AND the conduit having defects at joint shall not be used.

8.3.3 Installation of conduit

8.3.3.1 The construction plan of the prestressing system shall specify the detailed conduit installation procedure, which shall contain such information as conduit installation position and tolerance, connection type, support method, and temporary anti-corrosion measures and so on.

8.3.3.2 Conduit connection. Depending on the different connection pieces, the connection is as follows:

a) The connection between the grouting connector and the thin wall steel tube as well as the connection between the steel tubes may adopt bell-and-spigot connection or welding connection;

b) The connection between corrugated tubes shall adopt the sleeve screwing connection;

c) The connection between steel tube and corrugated tube shall be such that the corrugated tube is directly inserted into the trumplate of the steel tube.

8.3.3.3 Connection of exhaust tube and drain tube to corrugated tube or steel tube. USE a short steel tube the both ends of which are processed into trumplate, to connect the corrugated tube or steel tube in accordance with the methods aforementioned, with the middle part of the short steel tube welded or threaded a grouting conduit.

8.3.3.4 To ensure the tightness of the conduit connection, it shall take the following measures:

a) As for the conduit which needs to be inserted into the trumplate or corrugated connection sleeve, its insert end shall be coated with one coating of epoxy resin to bond with the trumplate, AND the excessive resin shall be smoothened to form an annular seal;

b) At the connection point, INSTALL heat shrink sleeve and COVER the joint.

8.3.3.5 Conduits shall be put in place in accordance with the sizes specified in the construction drawing, AND adjusted in accordance with allowable deviations after placing concrete.

c) It shall, based on the minimum spacing between conduits as specified in the construction drawing, FIND out all inter-connection conditions;

d) The reliability of the fixation and support of the conduit;

e) Whether there are holes or serious defects; if finding holes, they shall be repaired or replaced;

f) USE gauge to check the conduit section; when the conduit section is oval or has impact mark which cannot be corrected, it shall be replaced;

g) The correctness of the connection practices;

h) The position of the vent;

i) Whether the conduit mouth has been capped or plugged.

8.3.3.11 Before, during and after placing concrete, it shall use the pass ball to go through the conduit, in order to check whether all the conduit cross sections reach to the minimum diameter requirements and the conduit smooth degree.

8.4 Processing and fabrication of steel tendon

8.4.1 The construction plan of the prestressing system shall specify the detailed steel tendon fabrication procedure, which shall contain the work checklist and information, including steel strand coil number, the steel tendon length, location and number, the steel strand corrosion grade, the temporary anti-corrosion measures for steel tendon, cutting methods and procedures, and the cutting tolerances, etc.

8.4.2 The cutting of steel strand shall be through cutting machine or grinding wheel saw; it shall not use electric arc cutting.

8.4.3 The cutting of steel strand shall be based on design requirements, AND consider the allowance as required by tension, which can be determined by the construction unit itself.

8.4.4 The steel strand cutting can be through the method of cutting after making a single wire penetration, OR otherwise through woven penetration method. When using the woven penetration method, after cutting, it shall be straightened one by one AND tied into a bundle. When the bundled steel strand is coiled for the convenience of transportation, it shall not use the mechanical clips which may be harmful to the steel tendon; AND the coil inner diameter shall be specified in the established procedure.

precision pressure gauge at site as required as follows: every 2 weeks, after 75 times of tensioning, OR when the pressure gauge has abnormal reading.

8.6.4 The components of the tensioning equipment shall be accurately positioned and supported on the axis of the matched steel tendon. Before tensioning, accurately and tightly CONNECT different components and as well as components and anchorages. Before any effective load is transited to the steel tendon, it shall conduct positioning calibration against all anchorages, temporary connection pieces, and jacks.

8.6.5 Steel tendon may be symmetrically tensioned in batches and phases; BUT the tensioning sequence shall comply with the provisions of design.

8.6.6 When tensioning the steel tendon, the concrete strength of the containment shall comply with the design requirements.

8.6.7 Before formal tensioning the steel tendon, it shall conduct equal-tensioning pre-stressing against each steel strand.

8.6.8 The tensioning of steel tendon shall adopt stress control; AND the tensioning control stress shall comply with design requirements.

8.6.9 In order to calibrate the prestressing value, in the tensioning process, it shall measure the actual elongation value of the steel tendon. The actual elongation value of the steel tendon shall be measured from the time when the steel tendon stress reaches to about 10% of the ultimate strength, until the tensioning force reaches to the design control stress. The calculated value of the elongation due to the application of the initial force before starting the measurement shall be added to the elongation value. The calculated elongation value and the actual elongation value shall comply with the requirements below:

- It shall specify in advance the calculated elongation of each steel tendon. If the difference between the calculated elongation value and the actual elongation value of the single tendon is more than -5% or +8%, it shall suspend tensioning, find out reasons, AND take measures for adjustment, before continuing tensioning.

- The actual elongation value measurement method may be determined by the construction unit. When it is required to mark on the steel strand, the marking shall be light and indelible.

8.6.10 The tensioning of steel tendon is to be divided into both ends tensioning and one end tensioning in accordance with design requirements. The tensioning control stress shall be divided into several levels; during both ends tensioning, it is preferable to increase same load at the both ends of the steel tendon, AND until finishing all the measurement of both ends of the steel tendon

8.8.1 Each containment shall, based on the design requirements, select the monitoring tendon to monitor the prestressing change of the containment within the monitoring service life.

8.8.2 One of both ends of the monitoring tendon is installed with the tendon force sensor.

8.8.3 The holes for monitoring tendon shall be filled with special purpose anti-corrosion grease or paraffin.

8.8.4 The anti-corrosion grease or paraffin shall have the following characteristics:

a) The grease or paraffin in the hole shall be dense and seamless, not flow at room temperature and be with good moisture absorption, anti-aging, AND no corrosion to the tendon;

b) The grease, when heated to 80 °C ~ 100 °C, AND the paraffin, when heated to 110 °C ~ 160 °C, shall be at flowing state;

c) When using the high pressure oil pump for grouting, it shall pay attention to the control of the heating control device, pressure transmission systems, sealing and valve.

8.8.5 All grouting work shall be completed within 30 min.

8.9 Site test before prestressing work

8.9.1 Friction test

8.9.1.1 The friction test shall be conducted on the first reactor containment before the first steel tendon of the same type is tensioned, AND the test shall be conducted in accordance with the design requirements.

8.9.1.2 The friction test shall be conducted using the same strand as used in construction, AND tensioned by the jacking equipment as actually used for construction.

8.9.1.3 Test equipment. It mainly includes jacks, pumps, pressure gauges, and elongation measuring instrument, etc.

8.9.1.4 Test sequence and requirements:

a) INSTALL the jacks at both ends of the steel tendon;

b) PRE-STRESS the steel tendon under test;

linings

9.1 General requirements

9.1.1 The construction unit shall, before construction, compile the steel lining construction plan. Steel lining construction plan shall include material acceptance, material processing, welding procedure assessment requirements, welding operations, assembly and installation, as well as weld and geometric dimension testing, etc.

9.1.2 Welder qualification shall comply with the requirements of HAF 603.

9.1.3 Welders participating in lining welding shall have a stamp, AND after welding, stamp nearby each weld AND make quality records.

9.2 Material acceptance and identification

9.2.1 The steel materials, fittings, and welding consumables for the fabrication of steel lining shall be checked whilst entering into factory or site, to prove compliance with the design and current standards, before being accepted.

9.2.2 Lining material shall be provided with identification markings until the lining is assembled. When the material is divided into several segments, before dividing, it shall correctly move the original marking to each segment, in order to ensure tracing and identification in the fabrication and installation process. It is allowed for the embedded piece and other accessory materials to be bundled and labelled. Materials used to make small items shall be managed to ensure that they are identifiable at all times.

9.2.3 Accepted welding consumables shall be strictly managed during the fabrication and installation of the lining, in order to ensure that the material is identifiable before it is consumed. It shall take measures to prevent the electrodes and flux from becoming damp during storage.

9.3 Cutting and forming

9.3.1 The setting out and cutting of lining materials shall, based on the technical requirements, consider the processing allowance of cutting, edge planning, and welding shrinkage, etc. Cutting may be through mechanical method, such as machining, cutting, and grinding, OR through oxygen cutting or electric arc cutting method; when using oxygen cutting method, all the slag, debris or other harmful substances generated by cutting operation shall be removed mechanically before further processing, fabrication or use.

of the completed weld, it shall take special measures to integrate it with the completed weld.

9.4.3 The allowable deviation of welding connection, assembly and positioning shall comply with the relevant provisions of GB 50205.

9.4.4 The welding deformation of the welding parts shall corrected by static jacking method; AND it is not allowed to use hammering.

9.4.5 When installing each piece of lining, it shall, in accordance with the horizontal and vertical positional axis as specified in the construction drawing, install it in place.

9.4.6 During lining installation, it shall consider the requirements for placing concrete and wind resistance; AND it shall provide sufficient support and tie, in order to avoid deformation which exceeds the specified tolerance.

9.5 Welding

9.5.1 The welding of steel linings and their accessories shall comply with the requirements of level 1 weld in NB/T 20002, AND shall comply with the design requirements.

9.5.2 The welding of the lining plate anchoring studs shall be subjected to connection performance test, with one anchoring stud welding connection taken from 100 for such test. The anchoring stud under test may be welded onto the plate which is connected with the lining AND adjacent to the anchoring stud under observation, the plate thickness and type shall be same as those of the lining, its edge size shall not be less than 4 times of the anchoring stud diameter, AND the temporarily connected plate shall be fully fixed during the test period. The test shall be conducted by hammering the anchoring stud to an angle of 15°, if there is no failure, it can be considered as qualified. If the anchoring stud is damaged, it shall take another 2 from the existed 100 anchoring studs for test; if there is still one damaged, this batch of anchoring stud shall be subjected to bending test or be rejected.

9.5.3 The weld shall be inspected as follows:

a) The butt weld shall be subjected to 100% visual inspection, liquid penetration testing or magnetic particle testing. The vacuum box testing and volume inspection shall comply with the design requirements;

b) The fillet weld (excluding the connection weld between the stiffening rib and the lining plate) shall be subjected to 100% visual inspection, liquid penetration testing or magnetic particle testing. The vacuum box testing and volume inspection shall comply with the design requirements.

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