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11 REINFORCEMENT

11.1 GENERAL

11.1.1 Scope

1 This Part includes tension, compression, and temperature reinforcing steel, including welded wire fabric, and epoxy coated reinforcing. The work includes furnishing, fabrication, and placement of reinforcement for cast-in-place concrete, including bars, welded wire fabric, ties, and supports.

2 Related Sections and Parts are as follows:

This Section

Part 16..... Miscellaneous

Part 17..... Structural Precast Concrete

11.1.2 References

ASTM A416/A416M ...Standard Specification for Steel Strand, Uncoated Seven-Wire for Prestressed Concrete

ASTM A615/A615M ...Standard Specification for Deformed and Plain Carbon-Steel Bars for Concrete Reinforcement

ASTM A706,Specification for Low-alloy Steel Deformed Bars for Concrete Reinforcement

ASTM A881/A881M ..Standard Specification for Steel Wire, Deformed, Stress-Relieved or Low-Relaxation for Prestressed Concrete Railroad Ties

ASTM A882/A882M- ..Standard Specification for Filled Epoxy-Coated Seven-Wire Prestressing Steel Strand

ASTM A955/A955M Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement

ASTM A1022/A1022M Standard Specification for Deformed and Plain Stainless Steel Wire and Welded Wire for Concrete Reinforcement

ASTM A1035/A1035M Deformed and Plain, Low-carbon, -Chromium, -Steel Bars for Concrete Reinforcement:

BS 4449Steel for the reinforcement of concrete. Weldable reinforcing steel. Bar, coil and decoiled product. Specification

BS 4482Steel wire for the reinforcement of concrete products. Specification

BS 4483Steel fabric for the reinforcement of concrete. Specification

BS 5896,High tensile steel wire and strand for the prestressing of concrete. Specification.

BS 8666,Scheduling, dimensioning, bending and cutting of steel reinforcement for concrete. Specification

EN 1011,Welding. Recommendation for welding of metallic materials

EN 1992-1-1 Eurocode 2: Design of concrete structures. General rules and rules for buildings

ISO 14654,Epoxy- coated steel for the reinforcement of concrete

ISO 14656,Epoxy powder and sealing material for the coating of steel for the reinforcement of concrete

ISO 3766Construction drawings -- Simplified representation of concrete reinforcement

ISO 9000,Quality management systems. Fundamentals and vocabulary

ISO 6935-1Steel for the reinforcement of concrete -Part 1: Plain bars
ISO 6935-2Steel for the reinforcement of concrete Part 2: Ribbed bars
ISO 6935-3Steel for the reinforcement of concrete Part 3: Welded fabric

11.1.3 Submittals

- 1 Product data including the manufacturer's specification and installation instructions for proprietary materials and reinforcement accessories shall be provided.
- 2 The Contractor shall submit the manufacturer's records of chemical and physical properties of each batch of billet steel bars and a certificate that the respective material furnished meets the requirements for the steel reinforcement specified. The manufacturer's records shall include certificates of mill as well as analysis, tensile and bend tests of the reinforcement.
- 3 Three copies of the steel test report shall be furnished with each consignment of steel reinforcement. The steel shall be tagged and cross-referenced with mill certificates.

11.1.4 Quality Assurance

- 1 The Contractor shall submit to the Engineer for source approval details of the proposed source of supply of the reinforcement. Details shall include chemical and physical tests for the past six months production and any independent test results for this period. Details of quality assurance procedures, including ISO 9000 certificate if held, shall also be given.
- 2 The Contractor shall furnish the Engineer with a certificate of compliance for each shipment of epoxy coated bars. The certificate of compliance shall state that representative samples of the epoxy coated bars have been tested and that the test results comply with the requirements herein specified. Test results shall be retained by the Contractor for seven years. A complete set of test results shall also be handed to the client at the completion of reinforcement works, and shall be made available to the Engineer upon request.

11.1.5 Delivery Storage and Handling

- 1 On delivery, bars in each lot shall be legibly tagged by the manufacturer. The tag shall show the manufacturer's test number and lot number and other applicable data that will identify the material with the certificate issued for that lot of steel. The fabricator shall furnish three copies of a certification which shows the batch number or numbers from which each size of bar in the shipment was fabricated.
- 2 Storage of reinforcement shall be on suitable structures a minimum of 450 mm above the ground surface to prevent damage and accumulation of dirt, rust and other deleterious matter. Storage facilities shall be such as to permit easy access for inspection and identification. Reinforcement bundles shall be clearly tagged with bar schedule and bar mark reference.
- 3 The reinforcement shall not be roughly handled, dropped from a height, or subjected to shock loading or mechanical damage. Steel reinforcing bars shall be kept clean and shall be free from pitting, loose rust, mill scale, oil, grease, earth, paint, or any other material which may impair the bond between the concrete and the reinforcement. The reinforcement shall be covered to ensure protection from wind blown dust, condensation and other deleterious materials.

11.2 REINFORCING MATERIALS

11.2.1 Reinforcing Bars

- 1 Reinforcement shall be from an acceptable source. All steel reinforcement bars shall comply with the requirements of:

- (i) ISO 6935 with minimum grade of B500 MPa or
 - (ii) BS 4449 with minimum grades of B500 MPa ; or..
 - (iii) ASTM A615 / A615M with minimum grade of 75 [520MPa]; or
 - (iv) Deformed and Plain, Low-carbon-Chromium-Steel Bars for Concrete Reinforcement: ASTM A1035/ A1035M
 - (v) ASTM A1022/A1022M Standard Specification for Deformed and Plain Stainless Steel Wire and Welded Wire for Concrete Reinforcement
 - (vi) ASTM A955/A955M Standard Specification for Deformed and Plain Stainless-Steel Bars for Concrete Reinforcement
 - (vii) Other types of reinforcement, as approved and requested by the designer.
- 2 As per project design, other steel grades of less than B500MPa may be used only for stirrups and secondary reinforcement of diameter of 10mm or less.
- 3 If the steel has excessive surface rust, dust or other deleterious material then the steel shall be sand blasted. Sand for blasting shall not contain materials deleterious to the durability of the reinforcement or concrete. Dune sand shall not be used for the sandblasting of reinforcement.
- 4 For extreme exposure class X5; protection measures such as epoxy coated bars; Low-carbon-chromium-steel bars; or Stainless Steel may be considered.

11.2.2 Welded Steel Wire Fabric

- 1 Steel fabric reinforcement shall comply with the requirements of QS ISO 6935-3 or BS 4483 and shall be delivered to Site in flat mats.
- 2 Welded intersections shall not be spaced more than:
- (a) 300 mm for plain round bars
 - (b) 400 mm apart for deformed high yield bars in direction of calculated stress except when used as stirrups.

11.2.3 Tie Wire

- 1 Tie wire shall conform to the requirements of BS 4482.
- 2 1.6 mm black annealed mild steel shall be used for tie wire.
- 3 No wires smaller than size D-4 shall be used.

11.2.4 Fiber Reinforcement:

- 1 Fibers are allowed for use as Temperature and Shrinkage reinforcement as per relevant ACI and EN codes.

11.3 INSPECTION, SAMPLING AND TESTING

- 1 Inspection of reinforcing steel and the installation thereof will be conducted by the Engineer.
- 2 The Contractor shall give 24 hour notice to the Engineer before closing forms or placing concrete.
- 3 The Engineer may instruct the Contractor to break out and remove completely all sections of the work already constructed under any of the following circumstances:
- (a) reinforcing steel sample under test fails to meet the specification requirements at any time

- (b) the Engineer considers that samples which were presented to him for test were not truly representative
- (c) a previously rejected reinforcing steel has been used in the Works.

11.3.2 Sampling

- 1 Representative samples of all reinforcing steel proposed for use in the Works must be submitted by the Contractor, before work is commenced, to the Engineer for his written approval.
- 2 Manufacturer's certificates stating clearly for each sample:
 - (a) place of manufacture
 - (b) expected date and size of deliveries to site
 - (c) all relevant details of composition, manufacture, strengths and other quality of the steel.
- 3 The Engineer reserves the right to sample and inspect reinforcement steel upon its arrival at the work site.
- 4 Frequency of sampling and the method of quality control shall be in accordance with steel bars manufactured standard QS ISO 6935 or BS 4449 .
- 5 Where epoxy coated steel is used, a sample of the coating material shall be supplied with each batch in an airtight container and identified by the batch number.
- 6 Allow 14 days for Engineer's review of samples.

11.3.3 Testing

- 1 Tests shall be carried out when directed by the Engineer.
- 2 Tests shall be carried out in accordance with QS ISO 6935 or BS 4449.
- 3 The following information shall be provided with each delivery of reinforcement:
 - (a) elastic limit
 - (b) ultimate strength
 - (c) stress/strain curve
 - (d) cross-sectional area
 - (e) deformation/bond characteristics of deformed bars.
- 4 The Contractor shall allow for dimensions and weight measurements, tensile, bend and/ or rebend tests at own cost, for each size of bar to be used in the concrete construction.
- 5 Test results for each bar size shall be submitted to the Engineer three weeks before concrete work commences on Site.
- 6 Full testing shall be required if the source of supply of reinforcement changes, in which case the cost of such extra testing will be borne by the Contractor.
- 7 When any test results do not conform to the relevant standard the reinforcement steel shall be removed from the Site and all costs resulting therefrom shall be borne by the Contractor.

11.4 CUTTING AND BENDING OF REINFORCEMENT

- 1 Cutting and bending of reinforcement shall be in accordance with ISO 3766 or BS 8666 and shall be done without the application of heat. Bends shall have a substantially constant curvature. For epoxy coated steel the provisions of Clause 11.6.1 of this Part shall apply
- 2 Steel bars manufactured according to the approved ASTM standards shall be bent according to the same standard.

- 3 Reinforcement shall not be straightened or rebent without the approval of the Engineer. If permission is given to bend projecting reinforcement care shall be taken not to damage the concrete and to ensure that the radius is not less than the minimum specified in ISO 3766 or BS 8666.

11.5 FIXING OF REINFORCEMENT

11.5.1 General

- 1 All reinforcement shall be securely and accurately fixed in positions shown on the Drawings to ensure that the reinforcement steel framework as a whole shall retain its shape. The framework shall be supported to retain its correct position in the forms during the process of placing and consolidating the concrete.
- 2 The ends of all tying wires shall be turned into the main body of the concrete and not allowed to project towards the surface.
- 3 No part of the reinforcement shall be used to support access ways, working platform or for the conducting of an electric current.
- 4 The Contractor's specific attention is drawn to the following general requirements:
- (a) lapped joints shall be as indicated on the Drawings and/or in accordance with the requirements of EN 1992-1-1 or BS 8666
 - (b) hooks shall be semicircular with a straight length of at least:
 - (i) four bar diameters for mild steel
 - (ii) six bar diameters for high yield steel.

11.5.2 Welding

- 1 Welding shall not be used unless authorised by the Engineer and recommended by the reinforcement manufacturer.
- 2 Where welding is approved it shall be executed under controlled conditions in a factory or workshop.
- 3 Welding shall not take place on site without the approval of the Engineer and unless suitable safeguards and techniques are employed and the types of steel employed have the required welding properties.
- 4 Welding if approved, may be used for:
- (a) fixing crossing or lapping reinforcement in position
 - (b) fixing bars to other steel members
 - (c) structural welds involving transfer of loads between reinforcement or between bars and other steel members.
- 5 The length of run deposited in a single pass shall not exceed five times the bar diameter. If a longer welded length is required, the weld shall be divided into sections with the space between runs made not less than five times the bar diameter.
- 6 Butt welds shall be formed by flash butt welding or metal-arc welding. Other methods may be approved, subject to their satisfactory performance in trial joints.
- 7 Metal-arc welding or electrical resistance welding may be used for fixing suitable steels or for lapped joints.

- 8 Flash butt welding shall be executed with the correct combination of flashing, heating, upsetting and annealing, using only machines which automatically control this cycle of operations.
- 9 Metal-arc welding shall comply with EN 1011 and the recommendations of the reinforcement manufacturer.
- 10 Welded joints shall not be made at bends in the reinforcement. Joints in parallel bars of principle reinforcement shall be staggered, unless otherwise approved. The distance between staggered joints shall be not less than the end anchorage length joints.
- 11 Weldable reinforcement where shown on the Drawings shall conform to ASTM A706, BS 4449.

11.5.3 Mechanical Splices

- 1 Mechanical splices shall comply with EN 1992-1-1 or BS 8666, and shall be used as and where indicated on the Drawings.
- 2 Details of mechanical splices shall be submitted to the Engineer for approval.

11.5.4 Bundling and Splicing of Bundled Bars

- 1 Bundling and splicing of bundled bars shall be in accordance with EN 1992-1-1 or BS 8666.
- 2 Splicing, except where indicated on the Drawings or approved shop drawings, will not be permitted without the approval of the Engineer.

11.5.5 Examination

- 1 The Contractor shall notify the Engineer at least 24 hours before commencing the fixing of reinforcement in order to facilitate the inspection of formwork.
- 2 The Contractor shall ensure that areas to receive reinforcement are cleaned before fixing.

11.5.6 Electrolytic Action

- 1 Reinforcement shall not be fixed or placed in contact with non-ferrous metals.

11.5.7 Cover

- 1 Correct concrete cover to reinforcement shall be maintained with the aid of approved spacer pieces.
- 2 The cover shall not be less than given in Section 5 Part 6.
- 3 Spacers, chairs and other supports shall be provided as necessary to maintain the reinforcement in its correct position.
- 4 In a member where the nominal cover is dimensioned to the links, spacers between the links and formwork shall be the same dimension as the nominal cover.
- 5 Spacer bars shall be of the same diameter as longitudinal bars, but not less than 25 mm in diameter, and shall be fixed between two layers at 1.5 m centres except where bundled bars are detailed.
- 6 Spacers, chairs and other supports shall be made of concrete, plastic or other material to the approval of the Engineer. Where supports are made of concrete they shall have at least the same cube strength as the concrete in the host member.

11.5.8 Reinforcement

- 1 Placing of all reinforcement steel bars will be checked by the Engineer and in no case is concrete to be placed around any reinforcement steel that has not been approved by the Engineer. Insertion of bars into or the removal of bars from concrete already placed will not be permitted.
- 2 Reinforcement steel temporarily left projecting from the concrete at the joints shall not be bent without the prior approval of the Engineer.

11.5.9 Forms and Linings

- 1 Damage to forms and linings shall be avoided.

11.5.10 Tanking

- 1 Reinforcement shall not be fixed until completion of placing tanking (membrane) protection.

11.5.11 Adjustment and Cleaning

- 1 Check position of reinforcement before and during placing concrete:
 - (a) pay particular attention to the position of top reinforcement in cantilever sections
 - (b) ensure that reinforcement is clean and free from corrosive pitting, loose rust, loose mill scale, oil and other substances which may adversely affect reinforcement, concrete, or the bond between the two.
- 2 Protect projecting reinforcement from the weather where rust staining of exposed concrete surfaces may occur.
- 3 At the time of concreting, all reinforcement steel shall have been thoroughly cleaned and freed from all mud, oil or any other coatings that might destroy or reduce the bond:
 - (a) clean all set or partially set concrete which may have been deposited thereon during the placing of a previous lift of concrete
 - (b) all uncoated rust bars shall be again sand blasted and pressure washed.
- 4 Immediately before concrete placing the reinforcing steel shall be washed thoroughly with high pressure potable water jets to remove any deposited salts.

11.6 PROTECTIVE COATINGS TO REINFORCEMENT

- 1 All the forgoing clauses of this part apply equally to epoxy coated reinforcing bars.

11.6.2 Epoxy Coated Reinforcing Bars

- 1 Reinforcing steel which are to be coated shall be free of slivers, scabs, excessive pitting, rust, grease, oil and other surface defects detrimental to proper coating.
- 2 The surface shall be prepared in accordance with ISO 14654.
- 3 Coating shall be applied to the cleaned surface as soon as possible after cleaning and before any visible oxidation to the surface occurs.
- 4 Reinforcing steel shall not have surface defects that would be detrimental to coating.
- 5 Coating material shall be epoxy resin powders as specified in ISO 14654 and ISO 14656 for coating of reinforcing bars and as follows:
 - (a) epoxy resin powders which do not meet the above requirements must be tested by an approved independent testing laboratory and accepted by the Engineer before use

- (b) only fusion bonded epoxy-coated reinforcing steel will be accepted
 - (c) no other means of epoxy coating will be approved.
- 6 Patching material shall be:
- (a) furnished by the epoxy coating manufacturer
 - (b) compatible with the coating
 - (c) inert in concrete
 - (d) suitable for repairs to the coated reinforcing bars to be made by the coating applicator and the Contractor at the project site.
- 7 Fabrication shall be performed before coating except as hereinafter specified for bent bars and straight bars less than 7.6 m long.
- 8 Bent reinforcing steel bars shall be coated after bending, unless the fabricator can show that satisfactory results can be obtained by coating before bending.
- 9 Any visible cracks in the coating on the outside of the bend or damage to coating resulting in debonding of the coating after bending shall be rejected.
- 10 Bars less than 7.6 m long may be sheared or sawn to length after coating, provided:
- (a) end damage to coating does not extend more than 12 mm back
 - (b) cut end is patched before any visible oxidation appears.
- 11 Flame cutting will not be permitted.
- 12 Epoxy coating shall be checked visually after cure for continuity of coating and shall be free from holes, contamination, cracks and damaged areas.
- 13 There shall not be more than two holidays (pinholes not visually discernible) in any 300 mm of the epoxy coated bar.
- 14 A holiday detector shall be used in accordance with the manufacturer's instruction to check the epoxy coating for holidays. A 67.5 V detector such as the Tinker and Rasor Model M-1 or its approved equivalent shall be used.
- 15 Patching of holidays is not required if there are less than three holidays per 300 mm length. Bars having three or more holidays per 300 mm shall be cleaned and recoated or replaced as directed by the Engineer.
- 16 Epoxy coating film shall be cured and/or post cured to a fully cured condition. A representative proportion of each production lot shall be checked by the epoxy coating applicator, using the method most effective for measuring cure to ensure that the entire production lot of epoxy coating is supplied in the fully cured condition.
- 17 Contractor shall repair all coating damaged by fixtures used to handle or support the bars in the coating process as follows:
- (a) patching shall be done as soon as possible and before visible oxidation occurs
 - (b) excessive patching from other causes will not be permitted
 - (c) satisfactory correction shall consist of proper adjustment of process, and rerunning the bars through the plant.
- 18 The Engineer reserves the right for access to the epoxy coating applicator's plant to witness epoxy coating processes for project work and to obtain specimens from test bars for any testing desired.

- 19 All chairs, tie wires and other devices used in connecting, supporting, securing or fastening epoxy coated reinforcement steel shall be made of or coated with a dielectric material.
- 20 Before the reinforcement is lowered into place and before placement of the concrete, the coated bars shall be inspected by the Engineer for damage to the epoxy coating.
- 21 Sheared ends of bars and other areas requiring limited repair due to scars and minor defects shall be repaired, using the specified patching or repair materials.

11.6.3 Handling of Epoxy Coated Reinforcement

- 1 Reinforcement steel bars shall be handled and stored in a manner to prevent damage to bars or, where used, the epoxy coating.
- 2 Bars, or where used epoxy coating, damaged in handling or other operations shall be satisfactorily repaired at no additional cost to the Employer.
- 3 Where epoxy coated bars are used all handling systems shall have plastic mandrel and padded contact areas wherever possible.
- 4 Where epoxy coated bars are used all bundling bands shall be padded.
- 5 All bundles shall be lifted with a strongback, multiple supports or a platform bridge so as to prevent bar to bar abrasion from sags in the bar bundle.
- 6 Bars or bundles shall not be dropped or dragged.
- 7 During vibration care shall be taken to ensure that the epoxy-coated reinforcement is not damaged by the pokers.

11.6.4 Testing of Epoxy Coated Reinforcement

- 1 Adhesion and flexibility of the epoxy coating shall be evaluated on test bars coated with each production lot.
- 2 At least 1 % of the length or 6 m, whichever is less, of each size of bar to be coated shall be furnished as test bars.
- 3 Test bars may be in one length or multiple lengths as required to have one test bar of each size with each production lot.
- 4 The production epoxy coated test bars shall be evaluated by bending 120 ° (after rebound) around a mandrel of a diameter corresponding to size of bar indicated in Table 11.1.

Table 11.1
Mandrel Diameter for Bar Diameter for
Evaluation Test of Epoxy Coated Test Bars

Bar Diameter (mm)	Diameter of Mandrel (mm)
10	79
12	95
13	103
14	111
16	127
18	143
20	159
22	175
24	191
25	198

Bar Diameter (mm)	Diameter of Mandrel (mm)
26	206
28	222
30	238
32	254
34	270
36	286

- 5 Bend shall be made at a uniform rate and may take up to one minute to complete.
- 6 Bend test shall be conducted at a room temperature of between 20 °C and 30 °C after the specimen has been exposed to room temperature for a sufficient time to ensure that it has reached thermal equilibrium.
- 7 No cracking of the epoxy coating shall be visible to the naked eye on the outside radius of the bent bar.

END OF PART