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<b>Document title:</b> Specification for Higher-Strength Martensitic Stainless Steel for Bridge and Associated Structural Applications				

**RESEARCH DESIGNS AND STANDARD ORGANISATION  
MANAK NAGAR, LUCKNOW-226011**

**DOCUMENT NO.: BS-S-7.5.3.1-9**

**DOCUMENT TITLE: SPECIFICATION FOR HIGHER-STRENGTH MARTENSITIC STAINLESS STEEL FOR BRIDGE AND ASSOCIATED STRUCTURAL APPLICATIONS**

**AMENDMENT HISTORY:**

S. No.	Amendment Date	Version	Reasons for Amendments
1.	-	1.0	New specification

ADE/SB/B&S	DBS II	Printed
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**1.0 Scope:**

- 1.1** This document covers requirements of martensitic stainless steels for bridges & associated structural applications. The mechanical properties of these steels are customarily, but not necessarily, developed by a suitable heat treatment depending on the delivery condition of Martensitic grades of stainless steel i.e. annealed (ferritic) condition or the hardened and tempered (martensitic) condition.
- 1.2** Steel products under this specification shall be having minimum yield strength 350 MPa.
- 1.3** The thickness of sheet/plates is from 3 mm to 50 mm.
- 1.4** This specification is intended to help better understanding of the codal provisions. For actual use the relevant reference codes as given in para 2 below shall be referred to and followed. In case of any confusion, ambiguity, clarification or difference of opinion etc., the provisions given in the relevant reference codes as given in para 2 below shall prevail.

**2.0 Reference Codes & Specifications (Latest editions):**

Following codes has been referred while preparation of this specification:

- (I) ASTM A1010/A1010M-13 (Reapproved 2018) –Standard specification for higher Strength Martensitic Stainless Steel plate, sheet and strip
- (II) ASTM A709/A709M – Standard specification for structural steel for bridges
- (III) ASTM A480/A480M - Standard Specification for General Requirements for Flat-Rolled Stainless and Heat-Resisting Steel Plate, Sheet and Strip.
- (IV) ASTM A751- Test Methods, Practices, and Terminology for Chemical Analysis of Steel Products
- (V) ASTM A370- Test Methods and Definitions for Mechanical Testing of Steel Products
- (VI) ASTM A673/673M- Specification for Sampling Procedure for Impact Testing of Structural Steel
- (VII) ASTM A700 Guide for Packaging, Marking, and Loading Methods for Steel Products for Shipment
- (VIII) ASTM A6/A6M- Specification for General Requirements for Rolled Structural Steel Bars, Plates, Shapes, and Sheet Piling
- (IX) ASTM A240-Standard Specification for Chromium and Chromium-Nickel Stainless Steel Plate, Sheet, and Strip for Pressure Vessels and for General Applications
- (X) ASTM A193-Standard Specification for Alloy-Steel and Stainless Steel Bolting for High Temperature or High Pressure Service and Other Special Purpose Applications
- (XI) ASTM A194-Standard Specification for Carbon Steel, Alloy Steel, and Stainless Steel Nuts for Bolts for High Pressure or High Temperature Service, or Both
- (XII) AWS D1.6-2017 Changes: Welding Code – Stainless Steel
- (XIII) AASTHO LRFD Bridge Design Specifications
- (XIV) AASTHO LRFD Bridge Construction specification

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- (XV) ASTM A959: Standard Guide for Specifying Harmonized Standard Grade Compositions for Wrought Stainless Steels.

### 3.0 General Requirements:

The following requirements for orders for material furnished under this specification shall conform to the applicable requirements of the current edition of Specification ASTM A480/A480M:

#### 3.1 Terminology:

Relevant definition applicable for various products are given in A480/480M. For example, plate is defined as product 5.00 mm and over in thickness and over 250 mm in width. For details refer ASTM A480/480M.

#### 3.2 Ordering Information:

It is the responsibility of the purchaser to specify all requirements that are necessary for material ordered under this specification. Such requirements may include, but are not limited to, the following:

Quantity (weight and number of pieces), Name of material (stainless steel), Condition (hot-rolled, annealed, heat treated), Finish, Temper, Dimensions (thickness, width, length), Type or UNS designation, Specification designation and date of issue, Additions to specification or special requirements, Marking requirements, Preparation for delivery etc.

#### 3.3 Process:

The steel shall be manufactured/produced by one of the following processes: electric-arc, electric-induction, or other suitable processes. The above-mentioned processes should be suitably governed by relevant codes/ standards/specifications and product produced by such process fulfils the provisions of this specifications.

#### 3.4 Heat Analysis:

Methods and practices relating to chemical analysis shall be in accordance with Test Methods, Practices, and Terminology mentioned in ASTM A751.

An analysis of each heat shall be made by the steel producer to determine the percentages of the elements specified in this specification. This analysis shall be made from a test sample taken during the pouring of the melt, or from the in-process product later in the manufacturing flow. The heat analysis shall conform to the chemical requirements for each of the specified elements for the grade ordered, as listed in relevant para of this specification. For details clause 6 of ASTM A480/A480M should be referred.

#### 3.5 Product Analysis:

The purchaser is permitted to perform a product analysis to verify the identity of the finished material representing each heat or lot. Such analysis shall be made by any of the commonly accepted methods that will positively identify the material. The chemical composition determined from product analysis shall conform to the limits of the material specification within

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the tolerances of Table A1.1 of ASTM A480/A480M, unless otherwise specified in the applicable material specification or the purchase order. The allowable variation of a particular element in a single sample for product analysis is permitted to be either above or below the specified range. However, percentages must exhibit the same tendencies in all samples; that is, the several determinations of any individual element in a heat shall not vary both above and below the specified range.

### **3.6 Workmanship and Finish:**

The material shall be of uniform quality consistent with good manufacturing and inspection practices. The steel shall have no imperfections of a nature or degree, for the type and quality ordered, that will adversely affect the stamping, forming, machining, or fabrication of finished parts.

For sheet and strip, restricted only to material ordered to have a No. 1 finish in accordance with clause 11.1.1 and 12.1.1 of ASTM A480/A480M respectively, and for plate restricted to material ordered to hot-rolled, annealed or heat treated, blast cleaned or pickled in accordance with clause 13.1.2 of ASTM A480/A480M, it is permitted to grind to remove surface imperfections, provided such grinding does not reduce the thickness or width at any point beyond the permissible variations in dimensions. An iron free abrasive wheel shall be used for such grinding and shall be operated at a speed ample to ensure that defective areas are cleanly cut out. For more details related to workmanship and finish, clause 10, 11, 12 and 13 of ASTM A480/A480M shall be referred.

### **3.7 Test Specimens**

#### **3.7.1 Tension Test:**

Tension test specimens shall be taken from finished material and shall be selected in either or both longitudinal and transverse direction. The tension test specimen shall conform to the appropriate sections of Test Methods and Definitions of ASTM A370, unless otherwise specified in the applicable material specification or agreed upon by the seller and the purchaser.

The testing speed between the yield strength and the fracture of the specimen, shall be conducted at a constant strain rate between 3.18 mm and 12.70 mm inclusive, per 25.40 mm of gauge length per minute, or at a crosshead speed that will give a strain rate within this range. For the purposes of this specification, the rate of strain shall be determined by a strain-rate pacer, indicator, or controller, or by dividing the unit elongation by the elapsed time from yield strength to fracture.

### **3.8 Number of Tests:**

Unless otherwise specified by agreement between the seller and the purchaser to perform a greater number of tests, the following number of tests are to be performed:

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In the case of plate, sheet, and strip produced in coil form, one or more tension tests shall be made on specimens taken from each coil. If the material is temper rolled, tensile properties must be determined on both coil ends.

In the case of plate, sheet, or strip produced in cut lengths, one tension test and two tension tests if the material is temper rolled (one tension test for single piece lots).

### **3.9 Test Methods:**

The properties enumerated in applicable specifications shall be determined in accordance with the following ASTM standards:

**3.9.1 Tension Tests:** Test Methods and Definitions ASTM A370.

**3.9.2 Charpy Impact Testing:** Test Methods and Definitions A370. Charpy V-notch impact tests shall be conducted in accordance with Specification A673/A673M. The frequency of testing, the test temperature to be used, and the absorbed energy requirements shall be as per clause 10 of ASTM A709/A709M. Impact energy (Average) as per ASTM A709/A709(M), Table 12 is minimum 34 J (At 21°C and 4°C).

**3.9.3 Ultrasonic Examination:** The material shall be ultrasonically examined in accordance with the requirements specified on the order. Ultrasonic examination to be done as per ASTM A578- Level B for plate thickness 12 mm. to 40 mm. For plate thickness more than 40 mm. refer ASTM A435.

### **3.10 Retests and Retreatment:**

Retests are permitted in accordance with the provisions of Test Methods and Definitions ASTM A370.

If any test specimen shows defective machining or develops flaws, it is permitted to discard the flawed specimen and substitute another specimen. If the percentage of elongation of any tension specimen is less than that specified and any part of the fracture is more than 19.1 mm from the centre of the gauge length of the 50.8 mm specimen or is outside the middle half of the gauge length of an 203.2 mm specimen, as indicated by scribe marks placed on the specimen before testing, a retest shall be allowed.

If the results of any test lot are not in conformance with the requirements of the applicable material specification, the producer is permitted the option of retreating such lots. The material shall be accepted if the results of retests on retreated material are within the specified requirements.

If any specimens selected to represent any heat fail to meet any of the test requirements as specified in the applicable material specification, it is permitted to reheat treat the material represented and resubmit it for testing.

If the product analysis fails to conform to the specified limits, analysis shall be made on a new sample. The results of this retest shall be within the specified requirements.

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**3.11 Dimensions and Permissible Variations:**

Sheet, strip, and plate shall conform to the permitted variations in thickness, width, length and flatness, and other properties when specified, as listed in Annex A2 and Annex A3 for A480 and A480M respectively, for the ordered product form, or as agreed upon by seller and user and specified in the purchase order.

**3.12 Packaging, Marking, and Loading:**

**3.12.1 Marking:**

Unless otherwise specified in the applicable material specification or the purchase order, marking shall be conducted as follows:

- (i) Sheet, strip, and plate shall be marked on one face, in the location indicated below with the specification designation number, type of steel (type or UNS designation), material identification number, and the name or mark of the manufacturer. For sheet, strip, and plate whose length and width dimensions are both less than 600 mm., each piece shall be marked with the type of steel and material identification number. The specification and designation number, and name or mark of the manufacturer shall be marked on the piece(s) or attached to the item or bundle. The characters shall be of such size as to be clearly legible. The marking shall be sufficiently stable to withstand normal handling. Unless otherwise specified by the purchaser, the marking, at the producers option, is permitted to be done with (a) marking fluid, (b) low-stress blunt-nosed continuous or low-stress blunt-nosed-interrupted-dot die stamp, (c) a vibratory tool with a minimum tip radius of 0.1 mm, or (d) electrochemical etching.
- (ii) Flat sheet, strip in cut lengths, and plate shall be marked in two places near the ends or shall be continuously line marked along one edge. For flat sheet, strip in cut lengths, and plate whose length and width dimensions are both less than 1200 mm., it is permitted to mark such pieces in only one place.
- (iii) Sheet, strip, and plate in coil form shall be marked near the outside end of the coil. The inside of the coil shall also be marked or shall have a tag or label attached and marked with the information of (i) above.
- (iv) Material less than 6.4 mm in thickness shall not be marked with die stamps.
- (v) The manufacturer’s test identification number shall be legibly stamped on each test specimen, if to be shipped to the customer.

**3.12.2 Packaging and Loading:**

Unless otherwise specified in the applicable material specification or the purchase order, packaging and loading shall be in accordance with the procedures recommended by Practices ASTM A700.

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### **3.13 Inspection:**

Inspection of the material by the purchaser's representative at the producing plant shall be made as agreed upon between the purchaser and the seller as part of the purchase order.

Unless otherwise specified in the contract or purchase order: (1) the seller is responsible for the performance of all the inspection and test requirements in this specification, (2) the seller is permitted to use own or other suitable facilities for the performance of the inspection and testing, and (3) the purchaser shall have the right to perform any of the inspection and tests set forth in this specification. The manufacturer shall afford the purchaser's inspector all reasonable facilities necessary to satisfy the inspector that the material is being furnished in accordance with the specification. Inspection by the purchaser shall not interfere unnecessarily with the manufacturer.

### **3.14 Rejection and Rehearing:**

Unless otherwise specified, any rejection based on tests made in accordance with this specification shall be reported to the seller within 60 working days from the receipt of the material by the purchaser.

Material that shows injurious imperfections as described in para 3.6 above, subsequent to its acceptance at the purchaser's works will be rejected and the seller shall be notified.

Samples tested in accordance with this specification that represent rejected material shall be retained for three weeks from the date of the notification to the seller of the rejection. In case of dissatisfaction with the results of the test, the seller is permitted to make claim for a rehearing within that time.

### **3.15 Material Test Report and Certification:**

A report of the results of all tests required by the product specification shall be supplied to the purchaser. This material test report shall reference the product specification designation and year date indicating that the material was manufactured, sampled, tested, and inspected in accordance with requirements of the product specification and has been found to meet those requirements. For details please refer clause 8 of ASTM A480/480M.

## **4.0 Chemical Composition, Mechanical Properties and other Requirements:**

### **4.1 Materials and manufacture:**

The steel shall be killed. It shall be developed by a suitable heat treatment depending on the delivery condition of Martensitic grades of stainless steel i.e. annealed (ferritic) condition or the hardened and tempered (martensitic) condition. The material shall be supplied in hot rolled, annealed or heat treated, shot blasted and pickled condition and shall be to the specific rationalized sizes required. Weld repair of the base metal by the material manufacturer or supplier is not permitted.

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#### 4.2 Chemical Composition:

The steel shall conform to the requirements as to chemical composition specified in Table 1, and shall conform to applicable requirements specified in the current edition of Specification ASTM A1010/A1010M.

<b>Table-1: Chemical Composition Requirements</b>	
<b>Element</b>	<b>Percentage (%)*</b>
<b>UNS Designation</b>	<b>S41003</b>
Carbon (C)	0.030
Manganese (Mn)	1.5
Silicon (Si)	1.00
Sulphur (S)	0.010
Phosphorus (P)	0.040
Nickel (Ni)	1.50
Molybdenum (Mo)	0.10-0.75
Chromium (Cr)	10.5 – 12.5
Nitrogen (N)	0.030
Other Elements	-----

\*Maximum, unless range or minimum is indicated.

#### 4.3 Heat Treatment:

**4.3.1** Heat treatment for Martensitic grade delivered in hardened and tempered (martensitic) condition shall be performed by the manufacturer and shall consist of heating the steel to a temperature in the range of 870 to 925°C, cooling in air or quenching in water, and tempering between 650 to 760°C for a time to be determined by the manufacturer. The heat-treating temperatures shall be reported on the test certificates. Suitable microstructure examination test to establish the heat treated quenched and tempered microstructure in martensitic steel may be done if required.

**4.3.2** Heat treatment for Martensitic grades delivered in the annealed (ferritic) condition shall be performed by the manufacturer and shall consist of annealing. Factors such as temperature and soaking time etc. should be suitably decided by manufacturer such that produced product satisfies all the relevant requirements mentioned in this specification. The heat-treating temperatures and other important parameters of process shall be reported on the test certificates. Suitable microstructure examination test to establish the heat treated microstructure of Martensitic grades delivered in the annealed (ferritic) condition steel may be done if required.

#### 4.4 Mechanical Properties:

The material shall conform to the mechanical properties specified in Table 2. For details table 2 of ASTM A1010/A1010M may be referred.

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<b>Table 2: Mechanical Test Requirement</b>				
<b>Grade name</b>	<b>Plate Thickness (mm)</b>	<b>Yield Strength min (MPa)</b>	<b>Tensile Strength min (MPa)</b>	<b>% Elongation in 50 mm min</b>
IRS 350 CR	Up to 50	350	485	18

#### **4.5 Weldability and relevant specification to welding:**

**4.5.1** The plates, sheets and sections are suitable for metal arc welding. Welding process and other specifications related to welding being done during fabrication of structure, such as welding consumables like filler wires, electrodes and flux etc.; establishment of WPSS; WPQR; weld execution; weld inspection and other associated features should be done in accordance with relevant provisions of AWS D1.5 and AWS D1.6.

**4.5.2** For SAW Welding, it is recommended to use ER308L, ER309L, ER316L, and their higher silicon content counterparts, however ER309L has by far been the most widely used filler wire for welding of the plate girders fabricated with this steel. Suitable flux should be used with filler wires. For FCAW, ER 309L and for GMAW – ER 309L/ER 309LMo with Gas mixture Ar-98% are recommended. However, any other suitable welding consumable permissible by AWS D1.6 may also be used.

**4.5.3** Any welding consumables other than the mentioned above can also be used subject to the condition that these meets the design requirement (ultimate as well as serviceability requirements of structure including fatigue) and do not have any adverse effect on the corrosion resistance of the stainless steel provided as per this specification.

**4.5.4** AWS D1.6/D1.6M-2017: Structural Welding Code – Stainless Steel can be referred for:

- (a)** Welding recommendations for the fabrication, assembly, and erection of welded structures and weldments subject to design stress in which at least one of the materials being joined is stainless steel.
- (b)** It is for use with base metals with a minimum thickness of 1.5 mm, in conjunction with any complementary code or specification for the design or construction of stainless steel structures and weldments.
- (c)** In addition to background information and terms relevant to those involved with stainless steel fabrication, the AWS D1.6-2017 code includes a clause that covers guidance on the design of welded connections.
- (d)** Other clauses in the standard focus on exempting a Welding Procedure Specification (WPS) from qualification by testing, qualifying WPSs and welding personnel, the fabrication, assembly, and erection of welded

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stainless-steel structures, inspection and acceptance criteria, and stud welding.

#### 4.6 Fasteners:

Following grade of nuts, bolts and washers are recommended for fabrication purpose. Any grade of fasteners other than the mentioned below can also be used subject to the condition that these grades meets the design requirement (ultimate as well as serviceability requirements of structure including fatigue) and do not have any adverse effect on the corrosion resistance of the stainless steel provided as per this specification:

Item	Code	Grade
Bolt	ASTM A193	GR B8 Class 2
Nut	ASTM A194	GR 8
Washer	-	Type 303

#### 5.0 Responsibility and Authority:

The following table indicate responsibility related to this document:

Activity	Responsible	Approver	Supporting	Consulted	Informed
Creation, maintenance of this document	DBS-II	ED/B&S	ADE/SB-II and Staff of ADE/SB-II	-	Through intranet/ soft copy.
Compliance of Directive contained in this document	ADE/SB-II	DBS-II	Directorate staff	-	-
Requirement of Deviation from Directive	DBS-II	ED/B&S	ADE/SB-II	-	Through intranet/soft copy

#### 6.0 ABBREVIATION:

ED/B&S = Executive Director/B&S/Steel

DBS-II = Director/Joint Director(B&S)/SB-II

ADE/SB-II = Assistant Design Engineer/SB-II

SSE = Senior Section Engineer/Section Engineer/ Junior Engineer

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