The Project for
Capacity Development of Road and Bridge Technology
in the Republic of the Union of Myanmar (2016-2019)

QUALITY CONTROL MANUAL FOR STEEL BRIDGE

(1st Edition)

April 2019

Ministry of Construction, the Republic of the Union of Myanmar

Japan International Cooperation Agency

PREFACE

In the exercise of its primary mandate as the construction arm of the government, the Ministry of Construction endeavors to keep abreast with systematic quality control and the latest construction techniques, with the ultimate objective of being at par with the more advanced countries in ASEAN.

This quintessential goal cannot be achieved without having to adopt clear-cut, uniform, systematic and definitive procedures on Construction Supervision on Quality/Safety Control in the first place. It is a given prerequisite that Quality Infrastructure must be a direct result of good management and project implementation.

This manual, which was jointly prepared by the MOC Engineering Staff and the Experts assigned for the Project for Capacity Development of Road and Bridge Technology in the Republic of the Union of Myanmar (2016-2019) under the Japan International Cooperation Agency (JICA), serves an effective reference material to field engineers of road and bridge construction, instrumental in our pursuit of the aforementioned ambitious objective.

With this manual, the field engineers should become familiar with and knowledgeable of the overall process in Quality Control and Safety Control, thus making them more competent in constructing government projects that are in accordance with and in strict compliance to the specification/contract requirements of the project.

April 2019

U Han Zaw
Union Minister
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INTRODUCTION

BACKGROUND

The bridge construction technology has maintained in certain technological level since "Bridge Engineering Training Center (BETC) Project (1979-1985: JICA), however, new technology has not been transferred and bridge types that can be constructed in Myanmar are still limited. Besides, insufficient training for national engineers has hampered sustainable transfer of technology in bridge engineering. In this context, the Government of Myanmar requested "the Project for Capacity Development of Road and Bridge Technology" (hereinafter referred to as "the Project") to the Government of Japan. Through series of discussion, Ministry of Construction (MOC) and JICA concluded the Record of Discussion (R/D) in January 2016 to implement the Project focusing on capacity development on construction supervision of bridges and concrete structures.

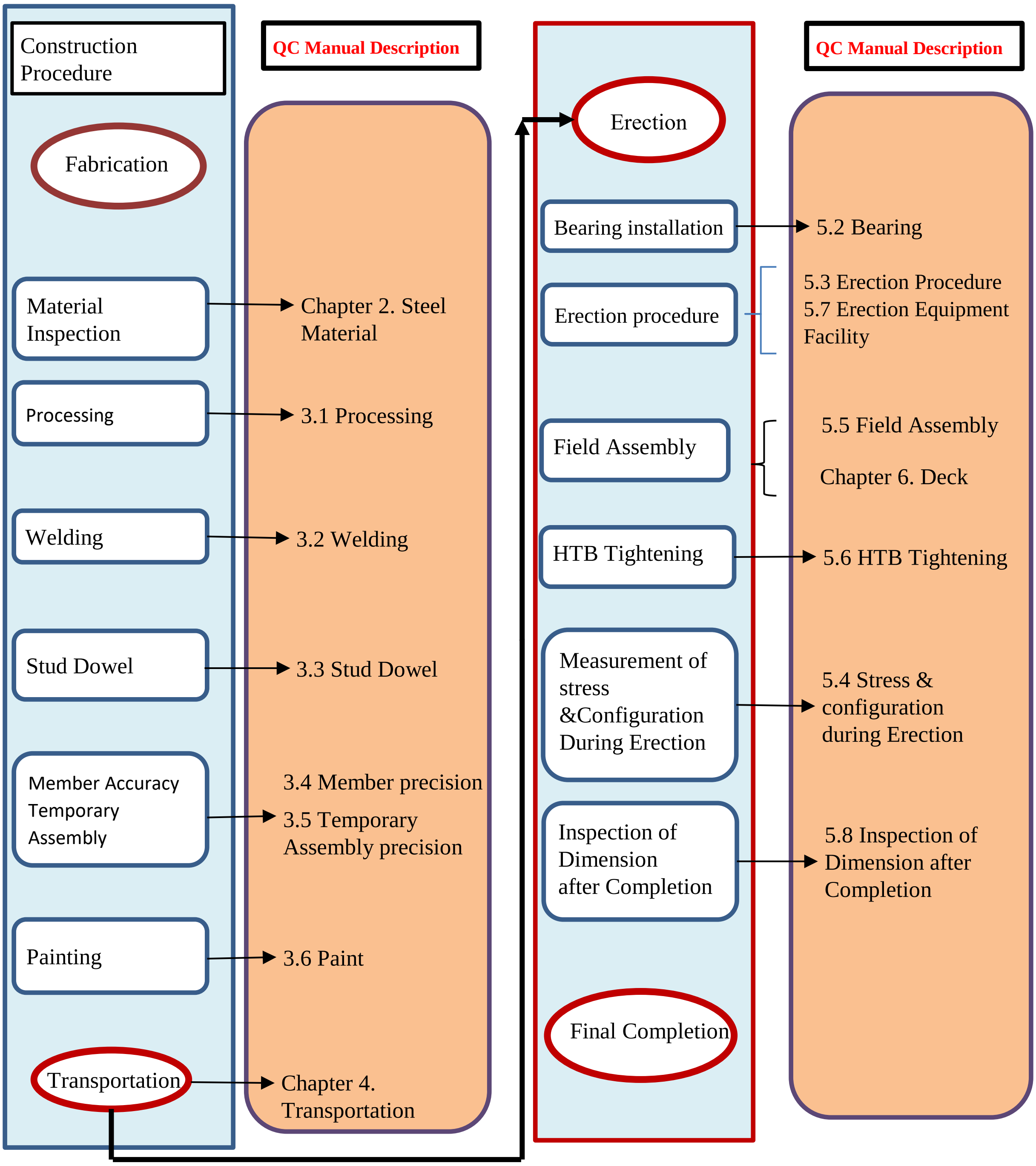
The Project was implemented for 3 years since 2016 in corroboration with MOC staff officer and JICA Experts aiming at improvement of quality as well as safety in construction of bridges and concrete structures. As the achievement of the Project, the Manuals on Quality and Safety Control for Bridge and Concrete Structure were developed in 2019 after several workshop and discussion.

REFERENCES

Following technical documents were referred as references.

1) Specification for Highway Bridges (2012, Japan Road Association, Japan)
2) Standard Specifications for Concrete Structures (2012, Japan Society of Civil Engineering)
3) Manual for Construction of Bridge Foundation (2015, Japan Road Association)
4) AASHTO LRFD Bridge Construction Specifications (3rd Edition, 2010)
5) The Guidance for the Management of Safety for Construction Works in Japanese ODA Projects (2014, JICA)
6) Manual for Construction Supervision of Concrete Works. (2016, NEXCO)
7) Manual for Construction Supervision of Road and Bridge Structures. (2016, NEXCO)
8) Construction Contract MDB Harmonized Edition (Version 3, 2010 Harmonized Red Book)

FLOWCHART OF QUALITY CONTROL FOR STEEL BRIDGE



QUALITY CONTROL MANUAL FOR STEEL BRIDGE

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ABBREVIATIONS

AASHTO	American Association of State Highway and Transportation Officials
AISC	American Institute of Steel Construction
ANSI	American National Standards Institute
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and and Materials
AWS	American Welding Society
Ceq	Carbon equivalent
DFT	Dry Film Thickness
DTI	Direct Tension Indicator
FCMs	Fracture Control Members
HAZ	Heat Affected Zone
HGC	In low hydrogen covered arc welding
HGL	Amount of diffusible hydrogen in deposited metal (HD) in low hydrogen covered arc welding, or in submerged arc welding and gas-shield arc metal welding
HPS	High Performance Steel
HRC	Rockwell Hardness
HTB	High Tension Bolt
ISO	International Organization for Standardization
JHBS	Japan Highway Bridge Standard
JIS	Japanese Industrial Standards
JRA	Japan Road Association
JSSI	Identification of Structural Steel
LRFD	Load and Resistance Factor Design
NC	Numerical Control
NDT	Non-Destructive Test
OPBT	Original Plate Blasting Treatment
PCM	Percentage of Crack sensitivity composition
QC	Quality Control
RH	Relative Humidity
Sa	Surface treatment by shot blasting
St	Surface treatment by power Tool
TMC	Thermo-Mechanical Control process steel
UNC	Unified coarse screw threads
µmRz	Max height of surface

CHAPTER 1. GENERAL

1.1 Scope of Application

This chapter shall be principally applied to the superstructures and the piers of bridge made of steel, designed in accordance with AASHTO LRFD or JHBS in Myanmar. Furthermore, it is also applied to structures using concrete in addition to steel such as steel girders having concrete decks.

When it is difficult to perform construction in accordance with the provisions of this volume, the safety in design must be verified separately.

If AASHTO Construction Specification is applied, the work shall comply with the following:

- The work shall consist of furnishing, fabricating, and erecting steel structures and structural steel portions of other structures in accordance with these Specifications and the contract documents.
- Unless otherwise specified, the structural steel fabricating plant shall be certified under the AISC Quality Certification Program, Category Ⅰ. The fabrication of fracture-critical members shall be Category III.
- Details of design which are permitted to be selected by the Contractor shall conform to the AASHTO LRFD Bridge Design Specifications, 2014.
- Painting shall conform to the provisions of Section 13," Painting" of LRFD Bridge Construction Specification 2010.
- Falsework used in the erection of structural steel shall conform to the provisions of Section 3, "Temporary Works" of LRFD Bridge Construction Specification 2010.
- Structural components designated in the contract documents as "fracture-critical" shall conform to the provisions of the AASHTO/ AWS Dl.5M/D 1.5 *Bridge Welding Code,* Section 12, "Fracture Control Plan (FCP) for No Redundant Members."
- Welding and weld qualification tests shall conform to the provisions of the current AASHTO/ AWS Dl .5M/D 1.5 *Bridge Welding Code.*

1.2 Construction in General

The construction of a steel bridge shall be performed in such a way that various conditions considered as premises in design are satisfied. The Contractor shall give the Engineer ample notice of the beginning of work at the mill or in the shop so that inspection may be provided. No material shall be manufactured or work done in the shop before the Engineer has been so notified.

1.3 Execution Plan

1.3.1 General

The execution plan is a generic term for the fabrication plan, welding procedure plan, erection plan, etc.

In construction, the execution plan shall be compiled in such a way that checks can be made to ensure that the construction is performed in satisfaction of various conditions considered as premises in design.

When checking whether a product secures the prescribed performance or not by a quality inspection in the final stage alone, there can be cases where although it is difficult to check the performance or although the performance is not secured, it is also difficult to cope with such situations. Therefore, it is generally necessary to conduct appropriate quality control in the middle of construction so that the prescribed performance can ultimately be achieved.

For these reasons, it is necessary to plan in advance the methods by which to ensure ultimate performance, to compile an execution plan for the purpose of recognizing the importance of ensuring quality in the middle of construction, and to show in these documents the methods of quality control during construction and its allowable values.

Moreover, the main points of quality control are stipulated in the respective clauses of this chapter. It is necessary to incorporate these provisions into the execution plan.

Additionally, the execution plan shall generally describe the instructions to show that the construction to ensure the performance required in design on the following items is carried out:

1) quality control plan, 2) material and part, 3) production (processing and the assembly of members), 4) welding, 5) assembly, 6) rust and corrosion prevention (shop painting, galvanizing, etc.), 7) transportation, 8) erection, 9) high-strength bolt, 10) floor deck work, and 11) field painting.

1.3.2 Working Drawings

The Contractor shall expressly understand that the Engineer's approval of the working drawings submitted by the Contractor covers the requirements for "strength and detail," and that the Engineer assumes no responsibility for errors in dimensions.

Working drawings must be approved by the Engineer prior to performance of the work involved and such approval shall not relieve the Contractor of any responsibility under the contract for the successful completion of the work.

(1) Shop Drawings

The Contractor shall submit copies of the detailed shop drawings to the Engineer for approval. Shop drawings shall be submitted sufficiently in advance of the start of the affected work to allow time for review by the Engineer and corrections by the Contractor, if any, without delaying the work.

Shop drawings for steel structures shall give full, detailed dimensions and sizes of component parts of the structure and details of all miscellaneous parts, such as pins, nuts, bolts, drains, etc.

Where specific orientation of plates is required, the direction of rolling of plates shall be shown.

Unless otherwise specified in the contract documents, shop drawings shall identify each piece that is to be made of steel which is to be other than AASHTO M 270M/M 270 (ASTM A709/A709M), Grade 36 (250 Mpa) steel.

(2) Erection Drawings

The Contractor shall submit drawings illustrating fully the proposed method of erection. The drawings shall show details of all falsework bents, bracing, guys, dead-men, lifting devices, and attachments to the bridge members: sequence of erection, location of cranes and barges, crane capacities, location of lifting points on the bridge members, and weights of the members. The drawings shall be completed in detail for all anticipated phases and conditions during erection. Calculations may be required to demonstrate that factored resistances are not exceeded and that member capacities and final geometry will be correct.

(3) Camber Diagram

A camber diagram shall be furnished to the Engineer by the Fabricator, showing the camber at each panel point in the cases of trusses or arch ribs, and at the location of field splices and fractions of span length (quarter points at minimum) in the cases of continuous beam and girders or rigid frames. The camber diagram shall show calculated cambers to be used in preassembly of the structure in accordance with Article, "3.5 Assembly Precision."

1.3.3 Inspection

(1) In construction, it shall be checked by such appropriate means that the construction satisfying the items required in design is performed.

(2) When conducting inspection by selecting inspection items from among the items 1) to 9) in consideration of the difficulty level of construction, types of material, etc. and confirming that the construction is carried out by the prescribed construction methods, Clause (1) may be deemed to be satisfied.

1) Material, 2) Bolt, arc Stud dowel, 3) Weld (welders, welding equipment, welding works, weld part), 4) Member and part (bearing, expansion joint, drainage appliance, etc.), 5) Member/ assembly precision, 6) Rust and corrosion prevention, 7) Erection (field joint, size at the time of erection, etc.), 8) Floor deck (form, reinforcement, finishing precision of floor deck), and 9) Completion.

For quality control, the following inspections are conducted in each stage of construction:

1) To inspect whether the products are processed with the prescribed performance or not.
2) To check whether the construction is being performed in accordance with the prescribed method or not.

The inspection referred to here is the one that the constructor of a steel bridge construction conducts in order to check quality, and is basically the one the constructor of a construction project carries out voluntarily.

When deciding which inspections to carry out about the inspection items shown in this chapter, it is advisable to choose either 1) or 2) above after considering the difficulty level of construction, types of material, etc. However, since it is not desirable to unnecessarily complicate the inspection, it is advisable to decide the frequency of inspection through careful consideration.

Additionally, there used to be an item of temporary assembly as part of the standard of inspection items. However, what is called temporary assembly is performed for the purpose of, among others, checking the assembly precision of the completed form of the bridge in the middle of production/construction as the need arises. For this reason, it is possible to skip it when the required precision can be ensured. Therefore, in this manual it has been changed to member/assembly precision as an inspection item.

(3) Material Inspection.

The Contractor shall furnish to the Engineer a copy of all mill orders and certified mill test reports. Mill test reports shall show the chemical analysis and physical test results for each heat of steel used in the work. With the approval of the Engineer, Certificates of Compliance shall be furnished in lieu of mill test reports for material that normally is not supplied with mill test reports and for items such as fills, minor gusset plates, and similar material when quantities are small and the material is taken from stock.

Certified mill test reports for steels with specified impact values shall include the results of Charpy V-Notch impact tests in addition to other test results. When fine grain practice is specified, the test report shall confirm the material that was so produced. Copies of mill orders shall be furnished at the time orders are placed with the Manufacturer. Certified mill test reports and Certificates of Compliance shall be furnished prior to the start of fabrication of material covered by these reports. The Certificate of Compliance shall be signed by the Manufacturer and shall certify that the material is in conformance with the specifications to which it has been manufactured.

Material to be used shall be made available to the Engineer so that each piece can be examined. The Engineer shall have free access at all times to any portion of the fabrication site where the material is stored or where work on the material is being performed.

CHAPTER 2. STEEL MATERIALS

2.1 Steel Materials of AASHTO

2.1.1 Structural Steel

(1) General

Steel shall be furnished according to the following specifications. The grade or grades of steel to be furnished shall be as specified in the contract documents.

All steel for use in main load-carrying member components subject to tensile stress shall conform to the applicable Charpy V-Notch impact test requirements of AASHTO M 270M/M 270 (ASTM A709/A709M).

Welded girders made of AASHTO M 270M/M 270 (ASTM A709/A709M), Grade HPS 70W (HPS 485W) shall be fabricated in accordance with the AASHTO/AWS Dl.5M/Dl.5 Bridge Welding Code and shall be supplemented by the AASHTO Guide Specifications for Highway Bridge Fabrication with HPS701V Steel.

(2) Carbon Steel

Unless otherwise specified in the contract documents, structural carbon steel for bolted or welded construction shall conform to: Structural Steel for Bridges, AASHTO M 270M/M 270 (ASTM A709/A709M), Grade36 (Grade 250).

(3) High-Strength, Low-Alloy Structural Steel

High-strength, low-alloy steel shall conform to Structural Steel for Bridges, AASHTO M 270M/M 270 (ASTM A709/A709M), Grades SO, SOS, SOW, or HPS SOW (Grades 345, 345S, 345W, or HPS 345W).

(4) High-Strength, Low-Alloy, Quenched, and Tempered Structural Steel Plate

High-strength, low-alloy, quenched, and tempered steel plate shall conform to Structural Steel for Bridges, AASHTO M 270M/M 270 (ASTM A709/A 709M), Grade HPS 70W (Grade HPS 485W).

(5) High-Yield-Strength, Quenched, and Tempered Alloy-Steel Plate

High-yield-strength, quenched, and tempered alloy- steel plate shall conform to:

Structural Steel for Bridges AASHTO M 270M/M 270 (ASTM A709/A709M), Grade HPS 100W (Grade HPS 690W).

Quenched-and-tempered alloy-steel structural shapes and seamless mechanical tubing meeting all of the mechanical and chemical requirements of AASHTO M 270M/M 270 (ASTM A709/A709M), Grade HPS 100W (Grade HPS 690W), except that the specified maximum tensile strength may be 140 ksi for structural shapes and l45 ksi for seamless mechanical tubing, shall be considered as AASHTO M 270M/M 270 (ASTM A709/A709M), Grade HPS 100W (Grade HPS 690W).

(6) Structural Tubing

Structural tubing shall be either cold-formed welded or seamless tubing conforming to ASTM A500, Grade B or Grade C, or ASTM A 847; or hot-formed welded or seamless tubing conforming to ASTM

A501 or ASTM A618.

2.1.2 High-Strength Fasteners

(1) Material

High-strength bolts for structural steel joints shall conform to either AASHTO M 164 (ASTM A325) or AASHTO M 253 (ASTM A490). When high-strength bolts are used with unpainted weathering grades of steel, the bolts shall be Type 3.

The supplier shall provide a lot of number appearing on the shipping package and a certification noting when and where all testing was done, including rotational capacity tests, and zinc thickness when galvanized bolts and nuts are used.

The maximum hardness for AASHTO M 164 (ASTM A325) bolts shall be 33 HRC.

Proof-load tests (ASTM F606, Method 1) shall be required for the bolts. Wedge tests of full-size bolts are required in accordance with Section 8.3 of AASHTO M 164 (ASTM A325). Galvanized bolts shall be wedge tested after galvanizing. Proof-load tests of AASHTO M 291 (ASTM A563) are required for the nuts. The proof- load tests for nuts to be used with galvanized bolts shall be performed after galvanizing, over tapping, and lubricating.

Except as noted below:

- Nuts for AASHTO M 164 (ASTM A325) bolts shall conform to AASHTO M 291 (ASTMA563), Grades DH, DH3, C, C3, and D (Property Class 8S, 8S3, 10S, or 10S3).
- Nuts for AASHTO M 253 (ASTM A490) bolts shall conform to the requirements of AASHTO M 291 (ASTM A563), Grades DH and DH3 (Property Class 10S or 10S3).

The exceptions are:

- Nuts to be galvanized (hot-dip or mechanically galvanized) shall be Grade DH (Property Class 10S).
- Nuts to be used with AASHTO M 164 (ASTM A325) Type 3 bolts shall be Grade C3 or DH3 (Property Class 8S3 or 10S3). Nuts to be used with AASHTO M 253 (ASTM A490), Type 3 bolts shall be Grade DH3 (Property Class 10S3).

All galvanized nuts shall be lubricated with a lubricant containing a visible dye. Black bolts must be oily to touch when delivered and installed.

Washers shall be hardened steel washers conforming to the requirements of AASHTO M 293 (ASTM F436) and Article 11.5.6.4.3, "Requirements for Washers."

(2) Identifying Marks

AASHTO M 164 (ASTM A325) for bolts and the specifications referenced therein for nuts require that bolts and nuts manufactured to the specification be identified by specific markings on the top of the bolt head and on one face of the nut. Head markings must identify the grade by the symbol "A325", the Manufacturer, and the type, if Type 3. Nut markings must identify the Property class, the Manufacturer, and, if Type 3, the type. Markings on direct tension indicators (DTI, ASTM F959) must identify the Manufacturer and Type "325" (Class "8.8"). Other washer markings must identify the Manufacturer, and, if Type 3, the type.

AASHTO M 253 (ASTM A490) for bolts and the specifications referenced therein for nuts require that bolts and nuts manufactured to the specifications be identified by specific markings on the top of the bolt head and on one face of the nut. Head markings must identify the grade by the symbol "A490", the Manufacturer, and the type, if Type 3. Nut markings must identify the property class, the Manufacturer and if Type 3, the type. Markings on direct tension indicators must identify the Manufacturer and Type "490" (Class "10.9"). Other washer markings must identify the Manufacturer, and, if Type 3, the type.

(3) Dimensions

Bolt and nut dimensions shall conform to the requirements for heavy hexagon structural bolts and heavy semi-finished hexagon nuts given in ANSI Standards B18.2.1 and B18.2.2 (Bl8.2.3.7M and Bl8.2.4.6M), respectively.

(4) Galvanized High-Strength Fasteners

AASHTO M 253 (ASTM A490) bolts shall not be galvanized.

When fasteners are galvanized, they shall be specified to be hot-dip galvanized in accordance with AASHTO M 232M/M 232 (ASTM Al53/Al53M), Class C or mechanically galvanized in accordance with AASHTO M 298 (ASTM B695), Class 50 (Class 345). Bolts to be galvanized shall be either AASHTO M 164 (ASTM A325) Type 1. Galvanized bolts shall be tension tested after galvanizing. Washers, nuts, and bolts of any assembly shall be galvanized by the same process. The nuts should be over tapped to the minimum amount required for the fastener assembly and shall be lubricated with a lubricant containing a visible dye so a visual check can be made for the lubricant at the time of field installation.

(5) Alternative Fasteners

Other fasteners or fastener assemblies, such as those conforming to the requirements of ASTM F1852, which meet the materials, manufacturing, and chemical composition requirements of AASHTO M 164 (ASTM A325) or AASHTO M 253 (ASTM A490) which meet the mechanical property requirements of the same specification in full-size tests, and which have body diameter and bearing areas under the head and nut, or their equivalent, not less than those provided by a bolt and nut of the same nominal dimensions prescribed in Article 2.1.2(3) may be used, subject to the approval of the Engineer. Such alternate fasteners may differ in other dimensions from those of the specified bolts and nuts.

Subject to the approval of the Engineer, high-strength steel lock-pin and collar fasteners may be used as an alternate for high-strength bolts as shown in the contract documents. The shank and head of high-strength steel lock− pin and collar fasteners shall meet the requirements of Article 2.1.2 (3). Each fastener shall provide a solid-shank body of sufficient diameter to provide tensile and shear strength equivalent to or greater than that of the bolt specified in the contract documents and shall have a cold-forged head on one end, of type and dimensions as approved by the Engineer; a shank length suitable for material thickness fastened; locking grooves; breakneck groove; and pull grooves (all annular grooves) on the opposite end. Each fastener shall provide a steel locking collar of proper size for shank diameter used which, by means of suitable installation tools, is cold-swaged into the locking grooves forming head for the grooved end of the fastener after the pull groove section has been removed. The steel locking collar shall be a standard product of an established Manufacturer of lock-pin and collar fasteners, as approved by the Engineer.

(6) Load-Indicator Devices

Load-indicating devices may be used in conjunction with bolts, nuts and washers specified in Article 2.1.2(1). Load-indicating devices shall conform to the requirements of ASTM Specification for Compressible-Washer Type Direct Tension Indicators for Use with Structural Fasteners, ASTM F959, except as provided in the following paragraph.

Subject to the approval of the Engineer, alternative design direct tension indicating devices may be used provided they satisfy the requirements of Article 11.5.6.4.6 of AASHTO Construction Specification or other requirements detailed in specifications provided by the Manufacturer and subject to the approval of the Engineer.

2.1.3 Steel Forgings and Steel Shafting

(1) Steel Forgings

Steel forgings shall conform to the Specifications for Steel Forgings Carbon and Alloy for General Use, AASHTO M 102M/M 102 (ASTM A668/A668M), Class C, D, F, or G.

(2) Cold-Finished Carbon Steel Shafting

Cold-finished carbon steel shafting shall conform to the specifications for Cold-Finished Carbon Steel Bars Standard Quality, AASHTO M 169 (ASTM A 108). Grades 10160 through 10300, inclusive, shall be furnished unless otherwise specified in the contract documents.

2.1.4 Steel Castings

(1) Mild Steel Castings

Steel castings for use in highway bridge components shall conform to Standard Specifications for Steel Castings for Highway Bridges, ASTM A781/A781M, Class 70 (Class 485), or Standard Specifications for Steel Castings, Carbon, for General Application, AASHTO M 103M/M 103 (ASTM A27/A27M), Class 70 or Grade 70-36 (Class 485 or Grade 485-250), unless otherwise specified.

(2) Chromium Alloy-Steel Castings

Chromium alloy-steel castings shall conform to the Specification for Corrosion-Resistant Iron-Chromium, Iron-Chromium-Nickel, and Nickel-Based Alloy Castings for General Application, AASHTO M 163M/M 163 (ASTM A743/A743M). Grade CA 15 (Grade CA 15M) shall be furnished unless otherwise specified.

2.1.5 Iron Castings

(1) Materials

- Gray Iron Castings-Gray iron castings shall conform to the Specification for Gray Iron Castings, AASHTO M 105 or ASTM A48/A48M, Class 30, unless otherwise specified in the contract documents.

- Ductile Iron Castings-Ductile iron castings shall conform to the Specifications for Ductile Iron Castings, ASTM A536, Grade 60-40-18 (Grade 414-276-18), unless otherwise specified in the contract documents. In addition to the specified test coupons, test specimens from parts integral with the castings, such as risers, shall be tested for castings with a weight (mass) more than 1.0 kip to determine that the required quality is obtained in the castings in the finished condition.
- Malleable Castings-Malleable castings shall conform to the Specification for Ferritic Malleable Iron Castings, ASTM A47/A47M. Grade 35018 (Grade 24118) shall be furnished unless otherwise specified in the contract documents.

(2) Work Quality and Finish

Iron castings shall be true to pattern in form and dimensions, free from pouring faults, sponginess, cracks, blow holes, and other defects in positions affecting their strength and value for the service intended.

Castings shall be boldly filleted at angles and the arises shall be sharp and perfect.

(3) Cleaning

All castings must be sandblasted or otherwise effectively cleaned of scale and sand so as to present a smooth, clean, and uniform surface.

2.1.6 Galvanizing

When galvanizing is specified in the contract documents, ferrous metal products, other than fasteners and hardware items, shall be galvanized in accordance with the Specifications for Zinc (Hot-Galvanized) Coatings on Products Fabricated from Rolled, Pressed, and Forged Steel Shape Plates, Bars, and Strip, AASHTO M111M/M 111(ASTM A123/A123M). Fasteners and hardware items shall be galvanized in accordance with the Specification for Zinc Coating (Hot-Dip) on Iron and Steel Hardware, AASHTO M 232M/M 232 (ASTM A 153/A153M), except as noted in Article 2.1.2 (4), "Galvanized High-Strength Fasteners."

2.2 Steel Materials of JHBS

(1) The steel materials shall have certain mechanical properties such as strength, elongation and toughness, chemical composition, limitations on harmful ingredients, geometrical dimensions such as thickness and warping, and quality.

(2) The steel materials given in Table 2-1 and Table 2-2 can be deemed to satisfy (1).

Table 2-1 Steel Materials (JIS)

Steel Type	Standard		Steel Material Symbol
1) Steels	JIS G 3101	Rolled steels for general structure	SS400
	JIS G 3106	Rolled steels for welded structure	SM400, SM490, SM490Y, SM520, SM570
	JIS G 3114	Hot-rolled atmospheric corrosion testing steels for welded structure	SMA400W, SMA490W, SMA570W
2) Steel pipes	JIS G 3444	Carbon steel tubes for general structural purpose	STK400, STK490
	JIS A 5525	Steel pipe piles	SKK400, SKK490
	JIS A 5530	Steel pipe sheet piles	SKY400, SKY490
3) Steel fasteners	JIS B 1186	Sets of a high strength hexagon bolt, hexagon nut and plain washers for friction grip joints	
	JIS B 1180	Hexagon head bolts and hexagon head screws	Strength divisions 4.6, 8.8, 10.9
	JIS B 1181	Hexagon nuts and hexagon thin nuts	Strength divisions 4, 8, 10
4) Welding materials	JIS Z 3211	Covered electrodes for mild steel	
	JIS Z 3212	Covered electrodes for high tensile strength steel	
	JIS Z 3214	Covered electrodes for atmospheric corrosion resisting steel	
	JIS Z 3312	MAG welding solid wires for mild steel and high strength steel	
	JIS Z 3313	Flux cored wires for gas shielded and self-shielded metal arc welding of mild steel, high strength steel and low temperature service steel	
	JIS Z 3315	Solid wires for CO2 gas shielded arc welding for atmospheric corrosion resisting steel	
	JIS Z 3320	Flux cored wires for CO2 gas shielded arc welding of atmospheric corrosion resisting steel	
	JIS Z 3351	Submerged arc welding solid wires for	

		carbon steel and low alloy steel	
	JIS Z 3352	Submerged Arc Welding Fluxes for Carbon Steel and Low Alloy Steel	
5) Castings	JIS G 3201	Carbon steel forgings for General Use	SF490A, SF540A
	JIS G 5101	Carbon steel castings	SC450
	JIS G 5102	Steel castings for welded structure	SCW4IO, SCW480
	JIS G 5111	High tensile strength carbon steel castings and low alloy steel castings for structural purposes	SCMnlA, SCMn2A
	JIS G 4051	Carbon Steels for Machine Structural Use	S35CN, S45CN
	JIS G 5501	Gray iron castings	FC250
	JIS G 5502	Spheroidal graphite iron castings	FCD400, FCD450
6) Wire rods and secondary wire products	JIS G 3502	Piano wire rods	SWRS
	JIS G 3506	High carbon steel wire rods	SWRH
	JIS G 3536	Uncoated stress-relieved steel wires and strands for pre-stressed concrete	SWPRl, SWPDl, SWPR2, SWPR7, SWPR19
	JIS G 3549	Wire ropes for structure	
7) Steel bars	JIS G 3112	Steel bars for Concrete Reinforcement	SR235, SD295A, SD295B, SD345
	JIS G 3109	Steel bars for pre-stressed concrete	SBPR785/1030, SBPR930/l080, SBPR930/l180
8) Others	JIS B 1198	Headed studs	Stud names 19 and 22

Table 2-2 Steel Materials (Other than JIS)

Steel Type	Standard	Steel material symbol
Steel fasteners	Sets of a tor-shear type high strength bolt, hexagon nut and plain washers for friction grip joints (Japan Road Association)	S10T
	High strength draft bolts, hexagon nuts and plain washers for bearing connection, conforming to the provisional standard (Japan Road Association)	B10T, B8T
Secondary wire products	Parallel wire strands (Standard of Japanese Society of Steel Construction)	
	Covered parallel wire strands (Standard of Japanese Society of Steel Construction)	

(1) This clause stipulates the fundamental requirements for the steel material used for bridges. The steel material shall have certain safety of the entire structure and the structural members of a bridge,

durability, or certain properties and quality required for the intended use of material such as weldability. Bridges are designed based on the assumption of the properties and quality of the materials used. Therefore, the steel materials shall have stable quality as well as the required properties.

(2) The properties and quality of steel material are determined during their production. In order to ensure such properties and quality, JIS and other standardized products are generally used. As for the steel materials that conform to JIS or Japan Road Association's standards, or that have been sufficiently proven through actual previous use, their properties are clearly defined and their quality is normally higher than a certain level. Thus, the material conforming to these standards are deemed to satisfy (1). That is, the materials given in Table 2-1 and Table 2-2 can be regarded as having the required properties and quality by ascertaining their mill sheets.

New steels have been proposed for rationalizing, manufacturing and erection processes, or for improving the economic efficiency or durability. In applying these new steel materials to a bridge, their properties having effects on the performance of the structure shall be qualified by experiments. Also, their quality shall be ascertained to be equal to JIS or other standards.

1) Steel for general structure

The "conventionally used rolled steels for general structure" and "rolled steel for welded structure" are chosen. As for the "hot rolled atmospheric corrosion resisting steels for general structural purposes", only the type W is chosen, which is usually used in bare state.

2) Steel pipes

The "carbon steel tubes for general structural purpose", "steel pipe piles" and "steel pipe sheet piles" are chosen, since they are now much used for steel pipe construction.

Table 2-3 Mechanical Properties of Steel Pipes

Mechanical Property / Material	Type Symbol	Tensile test				Bending test		Flattening test
		Yield point or proof stress (N/mm2)	Tensile strength (N/mm2)	Elongation(%)		Bending angle	Inner diameter r(D)denotes outer pipe diameter	Distance between parallel plates (D denotes outer pipe diameter.)
				Test piece No.11 Test piece No.12 Longitudinal direction	Test piece No.5 Lateral direction			
Carbon steel tubes for general structural purposes	STK 400	235 or over	400 or over	23 or over	18 or over	90°	6D	2/3D
	STK 490	315 or over	490 or over	23 or over	18 or over	90°	6D	7/8D
Steel pipe pile	SKK400	235 or over	400 or over	—	18 or over	—	—	2/3D
	SKK490	315 or over	490 or over	—	18 or over	—	—	7/8D
Steel pipe sheet pile	SKY400	235 or over	400 or over	—	18 or over	—	—	2/3D
	SKY490	315 or over	490 or over	—	18 or over	—	—	7/8D

3) Steel fasteners

As for the high strength bolts for friction grip joints, Classes 1 and 2 of JIS B 1186 shall generally be chosen.

Besides the ordinary high strength bolts stipulated in JIS, the "set of a high strength hexagon bolt, hexagon nut and plain washers for friction grip joints" conforming to the Japan Highway Bridge Standard may be used in the same manner as the ordinary bolts.

High strength drive bolts, hexagon nuts and plain washers for bearing connection are stipulated to conform the Japan Highway Bridge Standard "Provisional Standard for Bearing Connection High Strength Drive Bolts, Hexagonal Nuts and Plain Washers."

The hexagonal bolts other than the high strength bolts used as finished bolts in a bridge bearing support are stipulated to conform the annex to JIS B 1180, and the three types of steel bolts in the strength divisions 4.6, 8.8 and 10.9 are chosen considering past records. Also, hexagonal bolts for combination use are chosen.

4) Welding materials

The welding materials are desirable to have sufficient mechanical strength, to be free from blowholes, cracks or other defects, to have deep penetration, and to offer good workability.

The covered electrodes for mild steels and for high tensile strength steels are stipulated in JIS Z 3211 and in JIS Z 3212, respectively. The welding electrode of tensile strength of 420 N/mm^2 and 570 N/mm^2 for hand welding is chosen here.

Even the same kind of standardized welding electrodes has various workability and mechanical properties. Therefore, workability inspections, cracking tests, and sampling tests concerning mechanical properties may be executed before use.

The moisture (including the crystal water) shall be completely removed from the coating material of the low hydrogen welding electrodes before use.

The submerged arc welding solid wires and fluxes for carbon steel are stipulated in JIS Z 3351 and JIS Z 3352, respectively. The quality divisions and testing methods are stipulated in JIS Z 3183 for deposited metals obtained by the combination of a wire and a flux.

The flux types are broadly classified into fused flux and bonded flux. For their proper application, 17.4.2 of the Volume on Steel Bridges, JHBS shall be referred.

The welding methods except for hand welding, gas shielded arc welding and submerged arc welding are seldom stipulated in the JIS standards. Their actual uses are also relatively few. Therefore, safety is desirable to be sufficiently investigated before employing them.

The welding materials for weather resistant steels are stipulated in JIS Z 3214, JIS Z 3315 and JIS Z 3320.

5) Castings

Castings are used for bearing supports, drainage apparatus, guard fences, steel connection keys, special expansion joints, and pins. The materials used for these accessories have been diversified as the trend of structures is recently enlarging and specializing. Castings with stable quality and large quantity are chosen. The mechanical properties of castings are summarized in Table 2-4

As for carbon steel forgings, SF490A and SF540A are chosen. As for carbon steel castings and steel castings for welded structure, SC450, and both SCW4IO and SCW480 are chosen respectively.

Low manganese steel castings contain Si and Mn and have higher toughness compared to SC450. Class 1 SCMnlA, equivalent to SS490 in mechanical properties, and Class 2 SCMn2A, equivalent to SM490, are chosen for these castings. When required strength is superior to SC450, low manganese steel castings shall generally be used.

For carbon steels for machine structural use, normalized S35CN and S45CN with a heat treatment are chosen. They have been conventionally used for machine parts and have been produced and used largely in quantity and stable in quality. They have been used for the anchor bolts of a steel pier and pins of a bearing support. The mechanical properties of these materials for the case with heat treatment are not stipulated in the JIS but are given for information only in a commentary appendix table in the JIS. When they are used as a strength member in an important part, their strength shall be ascertained by experiments. As for the gray cast iron castings and spheroidal graphite iron castings, FC250, and FCD400 or FCD450 are chosen.

Table 2-4 Mechanical Properties of Castings

Material \ Mechanical property	Type symbol	Tensile test (Test piece No. 14A or test opiece No 4): Yield point or proof stress (N/mm2)	Tensile test: Tensile strength (N/mm2)	Tensile test: Elongation: Elongation (%)	Tensile test: Elongation: Reduction of area (%)	Impact test (Test piece No.4): Temperature test (℃)	Impact test: Charpy absorbed energy (J)	Hardness HB[3]	Carbon equivalent (%)
Carbon steel forgings	SF490A	245 or over	490-590	22 or over	40 or over	-	-	134 or over	-
	SF540A	275 or over	540-640	20 or over	35 or Over	-	-	152 or over	-
Carbon steel casting	SC450	225 or over	450	19 or over	30 or over	-	-	-	-
Castings for welded structure	SCW410	235 or over	410	21 or over	-	0	0	-	0.4 or less
	SCW480	275 or over	480	20 or over	-	0	0	-	0.45 or less
High-tensile carbon steel and low alloy steel castings (low manganese steel castings)	SCMn1A	275 or over	540	17 or over	35 or over	-	-	143 or over	-
	SCMn 2A	345 or over	590	16 or over	35 or over	-	-	163 or over	-
Carbon steels for machine structure[1]	S35CN	305 or over	510	23 or over	-	-	-	149-207	-
	S45CN	345 0r over	570	20 or over	-	-	-	167-241	-
Grey iron castings[2]	FC250	-	250	-	-	-	-	241 or over	-
Spheroidal graphite iron castings	FCD400	250 or over	400	15 or over	-	-	-	130-180[5]	-
	FCD450	280 or over	450	10 0r over	-	-	-	140-210[5]	-

2.3 Defects before Fabrication

(1) As for the steel used for a steel superstructure and pier structure, it shall be confirmed before the start of construction that the steel complies with the steel standard described in the design drawings, etc., or, when a special performance is required, that it satisfies such requirement.

(2) In storing steel, a consideration shall be taken so that the characteristics and qualities that the steel originally possesses will be maintained and secured. Moreover, when an event considered to have affected its characteristics and qualities arises during the storage period and it is found that the steel does not satisfy the required performance as a result of an assessment of the effect, the steel shall undergo repair or remedy by an appropriate, non-damaging method.

(3) The permissible variation of the thickness of the steel plate on the negative side shall be within 5 percent of the nominal plate thickness with the application of the permissible variation of thickness of the Table 4 of the JIS G 3193, "Dimensions, Mass and Permissible Variations of Hot-Rolled Steel Plates, Sheets and Strips" and according to Remark 1.

(4) There must be no harmful flaw on the surface of the steel plate.

(5) The surface smoothness of the steel plate shall be such that it poses no hindrance to cutting plan, marking, joint work, etc.

(1) The steel used for a steel superstructure and pier structure is generally brought into check with the items described in the steel inspection certificate (mill sheet) issued by a steel manufacturer. Moreover, it is verified that it complies with the required performance of the steel standard described in the design drawings, etc., and also with the required performance added as the need arises for design and production/erection. Additionally, these required performances of steel are generally according to the stipulated values described in Section 3.1 Steel Materials" of "Part I: Common" and "Section 1.6: Steel Grade Selection" of "Part II: Steel Bridges, JHBS".

Additionally, it is necessary to confirm before the start of construction that there are no harmful flaws on the surface of the steel plate. On the other hand, in using commercial steel it is necessary to check its size, shape and surface in advance as well as the values described in the steel inspection certificate (mill sheet) and to confirm that it satisfies the required performance.

When many types of steel are used for the same bridge, identification by color display or sign display is generally performed so that confusion will not arise in the process of producing members. Standard examples of identification by color display are shown in Table 2-5.

(2) In storing steel, sufficient consideration shall be taken so that the characteristics and qualities that the steel originally possesses, such as mechanical properties, will not be damaged by the marked generation of rust, etc., as well as the lack of surface smoothness and generation of surface flaws that may take place during the storage period, or that may bring about hindrance to work, or fail to satisfy the required performance as members.

When an event considered to have affected the characteristics and qualities of the steel arises during the storage period and, as a result of an inspection by an appropriate method, it is found that it does not satisfy the required performance, the steel may be used after undergoing repair or remedy by an appropriate method. However, the method shall not be harmful to the steel, and the size, shape, mechanical properties, etc., shall satisfy the required performance after the repair or remedy is conducted.

For example, a repair in the case of a harmful flaw on the surface shall be carried out carefully by sufficiently considering the effect of the repair on the base material and welded joint in order to ensure the sound functioning of the base material and welded joint. Examples of the method to repair a flaw are shown in Table 2-6. Additionally, for the detail of the repair method, it is advisable to refer to Appearance (3), Section 6 of the JIS G 3193 "Dimensions, Mass and Permissible Variations of Hot-Rolled Steel Plates, Sheets and Strips."

In the weld repair of steel plate, the preheating temperature shall be determined through sufficient consideration according to Section 3.2.4 (2) iv) of this Manual so that no crack may take place in the welding heat affected zone; and following Section 3.2.5. (2) iv) of this Manual, "Repair of Defective Portion," a careful treatment shall be conducted so that no flaws may arise at the beginning and ending portions of the welding heat affected zone. Moreover, reinforcement of weld shall be removed by an appropriate manner such as using a grinder and shall be finished neatly at the same height as the surface of the steel plate.

The flaw on the surface of high-strength steel that is SM570-class steel or more shall generally be removed by means of a grinder, and it is desirable not to use cladding repair by welding. However, when conducting a cladding repair by welding due to necessity, it is necessary to decide whether the repair is right or wrong after judging in advance from the location, size, depth, etc., of the repair in the member whether the repair would be harmful or not to the member.

Once the cladding repair by welding is performed, it is necessary to check by a nondestructive test whether there are any harmful surface flaws and internal flaws after finishing it smoothly with a grinder.

Table 2-5 Standard for Identification by Color Display

(a) Steel stipulated in JIS

Steel type	Identification color		Remark
	Color type	Standard color	
SS400	White	N9.5	
SM400A, SM400B, SM400C	Green	5G5.5/6	A, B, or C is to be entered in letters.
SM490A, SM490B, SM490C	Yellow	2.5Y8/12	A, B, C or TMC is to be entered in letters.
SM490YA, SM490YB	Orange color	2.5YR6/13	A, B or TMC is to be entered in letters.
SM520C	Pink	2.5R6.5/8	C or TMC is to be entered in letters.
SM570Q, SM570N	Red	5R4/13	Q, N or TMC is to be entered in letters.
SMA400AW, SMA400BW, SMA400CW	Green	5G5.5/6	AW, BW, or CW is to be entered in letters.
SMA490AW, SMA490BW, SMA490CW	Yellow	2.5Y8/12	AW, BW, CW or TMC is to be entered in letters.
SMA570WQ, SMA570WN	Red	5R4/13	WQ, WN or TMC is to be entered in letters.

(b) Steel of which the yield point or strength does not change

According to the plate thickness stipulated in Section 1.6 commentary of Vol. 2, JHBS.

Steel type	Identification color		Remarks
	Color type	Standard color	
SM400C-H	Green	5G5.5/6	C-H is to be entered in letters.
SMA400CW-H	Green	5G5.5/6	CW-H is to be entered in letters.
SM490C-H	Yellow	2.5Y8/12	C-H is to be entered in letters.
SMA490CW-H	Yellow	2.5Y8/12	CW-H, or TMC is to be entered in letters.
SM520C-H	Pink	2.5R6.5/8	C-H or TMC is to be entered in letters.
SM570-H	Red	5R4/13	-H or TMC is to be entered in letters.
SMA570W-H	Red	5R4/13	W-H is to be entered in letters.

Note 1) This table is based on Japanese Society of Steel Construction Standard: "Marks for Identification of Structural Steel (JSS I 02)."

2) The color type of identification color is based on JIS Z 8102 (Color Name), while the standard color is based on JIS Z 8721 (Method of the Display of Colors by Three Attributes).

3) TMC: Thermo mechanical control process steel

4) For the steel that is ensured of the characteristics in the direction of the plate thickness, the signs corresponding to the requirements such as "-Z25" shall be entered in letters.

Table 2-6 Methods of Repairing Flaws

	Type of flaw	Repair method
1	Flaw on the surface of steel and the one whose area is clear, like pitting and scratching	Grinder finishing shall generally be used. In the case of a deep flaw in the local area, cladding repair by welding may be performed, followed by grinder finishing.
2	Flaw on the surface of steel and the one whose area is unclear, like spalling and cracking	Repair shall generally be performed through means of removal using a grinder. In the case of a flaw deeper than the lower limit of the tolerance for the plate thickness, a decision for or against repair shall be made after considering the effect of cladding repair if performed on that member from the steel type, the depth after the removal of the flaw and the area. Grinder finishing shall be applied after cladding repair by welding.
3	Layered crack on the end face of steel	If there remains a crack of approximately one-fourth or less of the plate thickness from the end face of the steel even after all kinds of things have been performed, cladding repair by welding may be carried out after removing the crack from the end face. Grinder finishing shall be applied after cladding repair by welding.

(3) JIS G 3193 "Dimensions, Mass and Permissible Variations of Hot-Rolled Steel Plates, Sheets and Strips (Table 4, Permissible Variation of Thickness)" shall be applied to the permissible variation of the thickness of the steel plate, and the permissible variation on the negative side shall be within 5 percent of the nominal plate thickness in accordance with Remark 1. The total range of permissible variation in this regard shall be equal to the total range of permissible variation of said table.

(4) A check that there is no harmful flaw on the surface of the steel plate shall be performed through means of visual inspection. The repair of a surface flaw shall be carried out in accordance with JIS G 3193.

(5) The surface smoothness of the steel plate shall be such as to pose no hindrance to cutting plan, marking, joint, etc. For this reason, it is desirable to use the steel plate whose upper limit target for surface smoothness is approximately 2/3 of JIS standard (JIS G 3193) (Table 2-7).

Table 2-7 Upper Limit Target for Surface Smoothness of Steel Plate

(mm)

Width (mm) / Thickness (mm)	Less than 2,000	2,000 and above less than 3,000	3,000 and above
6.00 and above less than 10.0	9	14	15
10.0 and above less than 25.0	8	11	12
25.0 and above less than 40.0	6	9	10
40.0 and above less than 63.0	6	8	8
63.0 and above less than 100	5	7	7

CHAPTER 3. FABRICATION

3.1 Working (Processing)

(1) In working on steel, the characteristics such as mechanical properties required in design shall be ensured. Moreover, the hole of a high-strength bolt shall be made with such a quality that it will ensure the joint strength stipulated in design.

(2) When verified in accordance with 1) to 8), Clause (1) may be deemed to be satisfied.

1) Cutting Plan (Plank Layout)

In the cutting plan of a main member, the direction of the main stress and that of rolling shall generally be identical. However, when the mechanical properties of the standard required in design are also satisfied in the direction perpendicular to the rolling, this provision shall not be applicable.

2) Marking

In performing marking, flaws by chisel or punch shall not generally be given to the location that remains after completion.

3) Dissection/Cutting/Groove face

i) The dissection of a main member shall generally be performed by automatic gas cutting. However, when the qualities of next item ii) are ensured, the automatic cutting such as the plasma-arc cutting method and the laser cutting method may be used.

ii) The qualities of cutting/grinding and the groove face shall be superior to those shown in Table 3-1.

Table 3-1 Quality of Dissection/Cutting Surface

Type of member	Main member	Secondary member
Max. surface roughness	50μmRy or less	100μmRy or less
Notch depth	There shall be no notch	1 mm or less
Slag	Although slag clumps are dotted around and attached, they can be easily exfoliated without leaving any marks.	
Upper edge melt	The one that is slightly rounded but in a smooth state	

Note:

1) The maximum surface roughness shall be the maximum height of the surface roughness stipulated in JIS B 0601.

2) The notch depth is referred to as the depth from the upper edge of the notch to the valley.

3) In case of cutting, it shall be 50 μmRy or less.

i) The filler, tie-plate, shaped steel, gusset plate with its plate thickness of 10 mm or less, stiffener, etc., may be cut by shear. However, when there are extreme shoulder losses, burrs or irregularities, etc., on the line of the cutting plane, a smooth finish shall be achieved by performing edge planning or grinder finishing until these are removed. The quality of the finished surface in this regard shall be superior to the qualities shown in Table 3-1.

ii) The chamfer shall be applied to the corner of the cross-section that will become a free edge after assembly in a main member that will be coated.

4) Hole Making

i) Bolt-hole diameter

The diameter of a bolt hole shall be as shown in Table 3-2.

Table 3-2 Diameter of Bolt Hole

Nominal designation of bolt	Diameter of bolt hole (mm)	
	Friction/tension connection	Bearing connection
M20	22.5	21.5
M22	24.5	23.5
M24	26.5	25.5

ii) Permissible variation of the diameter of bolt hole

The permissible variation of the diameter of bolt hole shall be as shown in Table 3-3. In this regard, in the case of the friction grip connection, up to + 1.0 mm shall be able to be allowed for 20 percent of one bolt group.

Table 3-3 Permissible Variation of the Diameter of Bolt Hole

Nominal designation of bolt	Permissible variation of diameter of bolt hole (mm)	
	Friction/tension connection	Bearing connection
M20	+0.5	±0.3
M22	+0.5	±0.3
M24	+0.5	±0.3

iii) Drilling of bolt hole

In making a hole into the prescribed diameter, it shall be performed by a drill or through the combined use of a drill and reamer. However, the hole making of a material piece of a secondary member with the plate thickness of 16 mm or less may be conducted by punching.

In making a hole with a prescribed diameter in a main member before assembly, the template shall generally be used. However, when using an NC drill, this provision shall not be applicable.

The burr generated around the hole by the hole making shall be chipped off.

5) Cold-Forming

When a cold bending work is performed on a main member, the characteristics and qualities of the steel shall be ensured in accordance with the provisions of Section 1.6 of Vol. 2, JHBS.

6) Hot-Forming

The hot-forming shall not be applied generally to the quenched and tempered steel (Q) and thermo-mechanical control process steel (TMC).

7) Strain removal

i) The deformation of a member generated by welding shall be remedied by press or the gas flame heating method, etc.

ii) The surface temperature of the steel when remedied by the gas flame heating method and cooling methods shall be in accordance with Table 3-4.

Table 3-4 Surface Temperature of Steel during Linear Heating by Gas-Flame Heating Method and Cooling Method

Steel type		Surface temperature of steel	Cooling method
Quenched and tempered steel (Q)		750℃ or less	Air-cooling (or water-cooling at 600℃ or less after air-cooling)
Thermo-mechanical control process steel (TMC)	$Ceq > 0.38$	900℃ or less	Air-cooling (or water-cooling at 500℃ or less after air-cooling)
	$Ceq \leq 0.38$	900℃ or less	Water-cooling or air-cooling immediately after heating
Other steel		900℃ or less	Avoiding water cooling from the red heat state

$$\mathrm{Ceq} = \mathrm{C} + \frac{Mn}{6} + \frac{Si}{24} + \frac{Ni}{40} + \frac{Cr}{5} + \frac{Mo}{4} + \frac{V}{14} + \left(\frac{Cu}{13}\right) (\%)$$

In this regard, the item in ( ) shall be included in the case of Cu≥ 0.5 percent.

8) Precision of bolt hole in checking the size precision by combining the actual members and checking the connection among the members, etc. (temporary assembly) before the completion of erection.

i) Distortion of bolt hole

When combining material pieces that will undergo the bearing connection, the hole distortion shall be a maximum of 0.5 mm.

ii) Penetration rate and stop rate of bolt hole

In a bolt hole, the penetration rate of a penetration gauge and the stop rate of a stop gauge shall satisfy the values shown in Table 3-5.

Table 3-5 Penetration Rate and Stop Rate of Bolt Hole

	Nominal designation of screw	Diameter of penetration gauge (mm)	Penetration rate (%)	Diameter of stop gauge (mm)	Stop rate (%)
Friction/tension connection	M20	21.0	100	23.0	80 or more
	M22	23.0	100	25.0	80 or more
	M24	25.0	100	27.0	80 or more
Bearing connection	M20	20.7	100	21.8	100
	M22	22.7	100	23.8	100
	M24	24.7	100	25.8	100

1) Plank layout

The difference in mechanical properties between the direction of rolling and the direction perpendicular to rolling is generally not so great in terms of tensile strength and yield point, but the elongation and reduction in the direction perpendicular to rolling is smaller than that in the direction of rolling by 10 percent to 15 percent and by 5 percent to 15 percent, respectively. Moreover, there are cases where the Charpy absorption energy in the direction perpendicular to rolling is shown to be approximately half of that exhibited in the direction of rolling. Because there are also cases where the transition temperature, as considered in usage in a cold region showing a difference of 10℃ or more, the direction of the main stress and that of rolling in the plank layout of a primary member are stipulated to be generally made identical. However, this provision shall not apply to a member that is not welded, such as a connection plate. Moreover, it is stipulated that the direction of the main stress may be made identical to the direction perpendicular to rolling if the prescribed mechanical properties are satisfied in the direction perpendicular to rolling.

2) Scratching

In the portion where the tensile stress is great or in the portion on which the load acts repeatedly, the yield strength may decrease due to a minor flaw. For such reason the provision of this item is stipulated.

When inscribing an assembly mark for erection directly on a member, it is advisable to avoid hitting with a chisel as much as possible and to employ a method that will not damage the quality of the base material. When inscription with a chisel cannot be avoided, one must prevent leaving behind chisel or punch flaws until after completion. Moreover, the location where the stress concentration or tensile force is great must be avoided.

However, this provision shall not apply when using the low-stress engraved mark for the identification control that has small stress concentration.

3) Dissection/Cutting

Among the methods used to dissect the steel plate are the gas cutting method and shear method. Although the shear method may be employed when the plate thickness is minor, it is stipulated that the automatic gas cutting method shall generally be used to cut a primary member with a view to ensuring the quality of the cross section.

When the shear method is employed, problems such as the decrease, etc., of the adhesion degree and loading capacity of a material piece arise if there are extreme shoulder losses, burrs, etc. Therefore, it must be finished.

The untreated corner of the cross section of a steel member is at a sharp angle, so when the coating is performed the coated film will become thin irrespective of the coating method. For this reason, it is stipulated that the chamfer shall be applied to the corner of the free edge of a primary member in order to prolong the life of the coating. It is advisable to stipulate approximately 1 mm for the size of the chamfer.

Additionally, when using a coating system that can maintain the rust-proof and corrosion-proof effects for a long time, it is desirable to perform the curved surface finish.

Moreover, when using a method of rust-proofing and corrosion-proofing other than by coating, the cut edge must be treated in accordance with a manner suitable to the method as the need arises.

As for cutting, the quality of a cutting surface is stipulated to be 50 μ mRy or less for the maximum surface roughness, according to Table 3-1. Although up to 100 μ mRy is recognized for a secondary member in Table 3-1, the limit of roughness is stipulated to be only 50 μ mRy for the maximum surface roughness, given the fact that it is difficult for the current work method to finish the cutting surface with its maximum surface roughness of 50 μ mRy or more, as well as for the purpose of avoiding confusion.

4) Hole Making

The hole diameter for the friction connection is stipulated to be the nominal diameter + 2.5 mm after considering the permissible variation 0.5 mm, as the cross-sectional deduction in design is the nominal diameter + 3 mm. However, in the following cases that are considered unavoidable from the standpoint of implementing construction, an enlarged hole of up to the nominal diameter + 4.5 mm may be made.

In this respect, the safety of the joint must be verified anew with the cross-sectional deduction in design set to be the diameter of the enlarged hole + 0.5 mm.

i) When it is difficult to perform the reaming with the members combined together:

- The longitudinal rib joint of a box-section member

- The longitudinal rib joint of a steel deck bridge

ii) When the stress condition for a member differs between the time of temporary assembly and the time of erection depending on the erection method:

- The longitudinal rib joint attaching the main girder and steel deck of a steel deck bridge

When an enlarged hole is applied in the case where the weld and the high-tension bolt's friction connection are mixed at the connection part, careful consideration must be given in reference to Section 17.6, "Combined work of the weld and the high-tension bolt friction connection in a member that mainly receives a bending moment."

Concerning the bearing connection, because the precision of a hole strongly affects the difficulty level of the placement work, provisions regarding its precision are stipulated as the allowable limit in working.

In making a hole in a bridge member, there is a method of making a hole into a prescribed diameter from the beginning. There is also a method of performing the reaming into a prescribed diameter after a temporary hole is made in the beginning and the actual members are assembled into the state of combination before erection. In either case, a drill shall generally be used.

When making a hole into a prescribed diameter before erection, its precision is important. For this reason, it is stipulated that a template must generally be used for a primary member. Moreover, although it is efficient to make the hole by punching, it damages the material around the hole.

Therefore, it is stipulated that punching is allowed only for the hole making on a secondary member having a plate thickness of 16 mm or less. When it is used for a material piece with its plate thickness of more than 16 mm, the joint performance must be checked by conducting a construction test.

In either case, the burr generated around the hole must be chipped off by a grinder, etc., since it obstructs the adhesion of the material piece and may become one of the causes in the generation of a crack at the neck of the bolt.

5) Cold-working

When cold-working is performed, the toughness of the steel may decrease or a crack in the steel may occur. Therefore, when it is necessary to perform cold-working on a primary member, suitable steel must be selected according to the provisions of Section 1.6 of Vol. 2, JHBS. Moreover, it must be ensured that the characteristics of the steel (such as its mechanical properties) will not be damaged, by taking such measures as not providing a large deformation locally.

Moreover, when the bending work is performed, the following aspects must be taken satisfied:

i) The press blade and cradle shall be cleaned sufficiently before working so that the working will not provide the material with a flaw that will become a notch. The minimum chamfer of 0.1 t shall generally be carried out for the edge of bent portion.

ii) Punching shall not be done before working to the outside of the steel plate that will undergo the bending work. Moreover, the provisions of this item shall not be applied to the preset distortion that is needed in production.

6) Hot-working

When the steel such as the quenched-and-tempered steel (Q) that has undergone quench hardening and metal tempering is heated more than the metal tempering temperature (650° C) for hot-working, the characteristics obtained from the heat treatment will be lost. Therefore, working in this manner must be avoided.

The changes in mechanical properties that occur when quenched-and-tempered steel is heated to various temperatures and then left to air-cool are shown in Figure 3-1.

This indicates that its mechanical properties decrease by heating it beyond the temperature at which the metal is tempered.

Similarly, hot-working must be avoided for thermal mechanical control process steel (TMC).

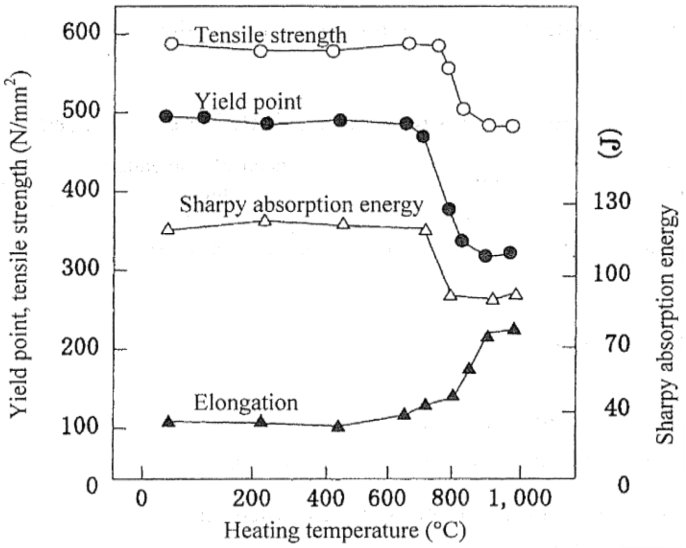


Figure 3-1 Changes of Mechanical Properties by Heating Quenched-and-Tempered Steel

7) Strain Removal

Concerning the strain removal, provisions are stipulated for the case where the strain is corrected by the gas flame. The conditions for the thermal mechanical control process steel (TMC) are stipulated on the basis of the study carried out by the Japan Welding Engineering Society.

8) Precision of bolt hole in temporary assembly

In the bearing connection, the hole precision strongly affects the difficulty level of the placement work, and consequently a strict value is stipulated in regard to the hole distortion. In the friction connection, no particular problem arises from the hole distortion in terms of the performance of the joint and therefore the bolt insertion can be checked by the penetration gauge, so this part was deleted in the revision of 1990. Regarding the penetration gauge, its diameter is stipulated to be the nominal diameter of the bolt + 1 mm so that the screw thread will not be damaged during bolt insertion. As described in the commentary of item 4) about the bolt hole in the friction connection, when using an enlarged hole of up to the nominal diameter of the bolt + 4.5 mm due to the unavoidable reasons in construction, the values in Table 3-6 Penetration Rate and Stop Rate When Enlarged Hole is used shall be used for the penetration rate of the penetration gauge and the stop rate of the stop gauge.

Additionally, since the temporary assembly shape is reconstructed on the erection site it is preferable to place a pilot hole for erection to the main girder or main structure depending on the erection method such as the one that does not use a vent.

Table 3-6 Penetration Rate and Stop Rate When Enlarged Hole is used

Diameter of penetration gauge (mm)	Penetration rate (%)	Diameter of stop gauge (mm)	Stop rate (%)
d_0 +1.0	100	d_1 +0.5	80 or more

d_0 : Nominal bolt diameter (mm) d_1 : Enlarged bolt diameter (mm)

3.2 Welding

3.2.1 Welding in general

The welding works shall be performed appropriately after considering sufficiently the items shown below in order to ensure the weld quality required for each joint. 1) Type and characteristic of the steel 2) Type and characteristic of welding consumable 3) Welder's qualification 4) Shape and precision of a joint 5) Welding condition and facility 6) Conditions of welding work and points to consider 7) Inspection procedure of weld zone 8) Treatment of nonconforming product

The welded joint includes a butt joint, T joint, corner joint, lap joint, etc., and the size and shape of a weld required in terms of the strength, stiffness and rigidity are shown in a design drawing, etc., by a welding symbol. However, the performance of a welded joint is generally not determined only by the instruction of the welding symbol but instead varies widely depending on metallurgical properties relating to work, the existence of a flaw, etc. Moreover, the weld joint cannot necessarily be checked on all the lines, and generally it is impossible to verify 100 percent after work that the required quality of welding is ensured. For these reasons, it is very important that the engineers have the experience and knowledge sufficient to formulate an appropriate work instruction that at least includes the contents stipulated in the clause. It is equally important that the work be performed correctly in accordance with the work instruction in order to ensure the appropriate quality of the joint portion.

While this article stipulates the items that shall at least be checked in order to ensure the quality of welding, the quality of welding may to some extent is influenced by the operator' s ability and awareness. Therefore, to ensure the quality of welding it is necessary to bring home to those involved the contents of an instruction prescribed in advance, and also to establish an appropriate work control system and a method that sufficiently consider the importance of the joint and the difficulty level, etc., of the work so that the work may be conducted in accordance with the instruction. Moreover, it is necessary to determine in advance the method by which it will be demonstrated that the work has been performed correctly according to the prescribed welding performance procedure.

3.2.2 Welding Consumables

(1) The welding consumables to be used shall possess the constituents and mechanical properties required for a joint in accordance with the steel type to which the welding consumables are applied.

(2) Clause (1) may be deemed to be satisfied, when welding is conducted in accordance with the items 1) to 3).

1) The division of usage for welding consumables shall generally be as stipulated in Table 3-7.

Table 3-7 Division of Welding Consumables

	Division of Usage
Welding steels of the same strength	Welding consumables possessing mechanical properties equal to or greater than the specification values of the base material
Welding steels of different strengths	Welding consumables possessing mechanical properties equal to or greater than the specification values of a base material on the low side with respect to strength
Welding steels of the same toughness	Welding consumables possessing toughness equal to or greater than the required values of the base material
Welding steels of different toughness	Welding consumables possessing toughness equal to or greater than the required values of a base material on the low side with respect to toughness
Welding weathering steel and common steel	Welding consumables possessing mechanical properties and toughness equal to or greater than the base material
Welding weathering steel and weathering steel	Welding consumables possessing mechanical properties, toughness and weatherproof performance equal to or greater than the base material

2) When falling under the following items, low hydrogen type welding consumables shall be used:

i) When a weathering steel is welded

ii) When a steel of SM490 or more is welded

3) Drying of welding consumables

i) Welding consumables shall be used after it is confirmed that is has been properly stored.

ii) The drying of a covered electrode and flux for submerged arc welding shall generally be as stipulated in the Table 3-8 and Table 3-9.

Table 3-8 Drying of Electrode

Electrode type	Dry condition of electrode	Drying temperature	Drying time
Covered electrode for soft steel	When 12 hours or more have passed since drying (breaking a seal) or when it is possible that the electrode has absorbed moisture	100 to 150 C	1 hour or more
Low-hydrogen type of covered electrode	When 4 hours or more have passed since drying (breaking a seal) or when it is possible that the electrode has absorbed moisture	300 to 400 C	1 hour or more

Table 3-9 Drying of Flux

Flux type	Drying temperature	Drying time
Fused flux	150 to 200C	1 hour or more
Bonded flux	200 to 250C	1 hour or more

(2) 1) & 2) The division of usage for welding materials is stipulated here, and when a covered electrode is used for weathering steel and high-tensile steel, it is stipulated that only a low hydrogen type electrode shall be used, in consideration of crack resistance.

3) The standards of the drying condition and allowable unattended time of a covered electrode and a flux for submerged arc welding are shown here.

While an electrode for mild steel is used where there is no possibility of cracking, the issue of drying must not be neglected because the excessive absorption of moisture can give rise to an unexpected defect. Because a low hydrogen type electrode is characterized by minor hydrogen generation and good crack resistance, any manner of handling that would undermine such characteristics must be avoided. The drying temperature and time prescribed in regard to the low hydrogen electrode are the conditions necessary to sufficiently eliminate the absorbed moisture, and the relationship among the unattended time, absorbed moisture and diffusible hydrogen amount (HGC) is as shown in Figure 3-2 and Figure 3-3.

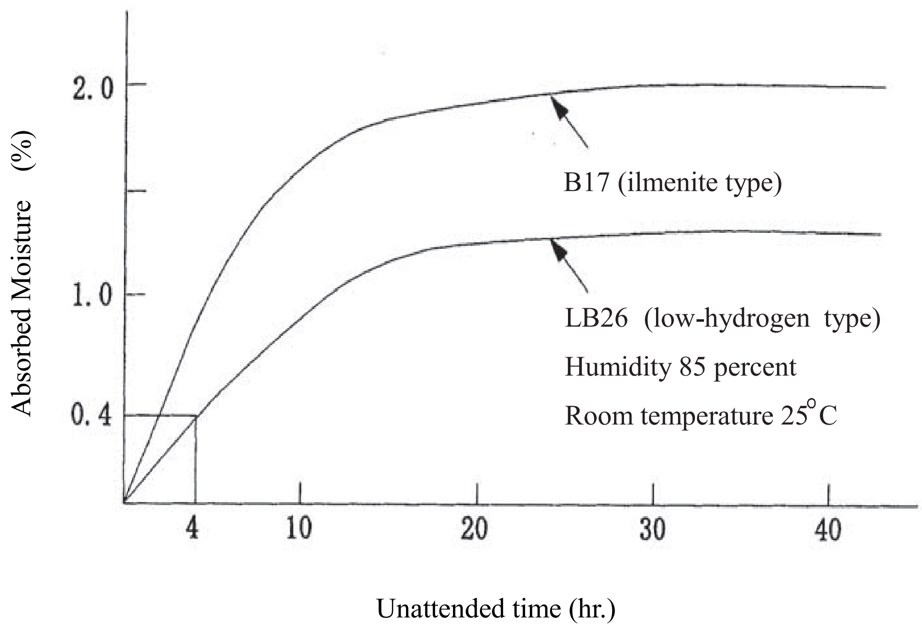


Figure 3-2 Relationship between Unattended Time and Absorbed Moisture of Covered Electrode

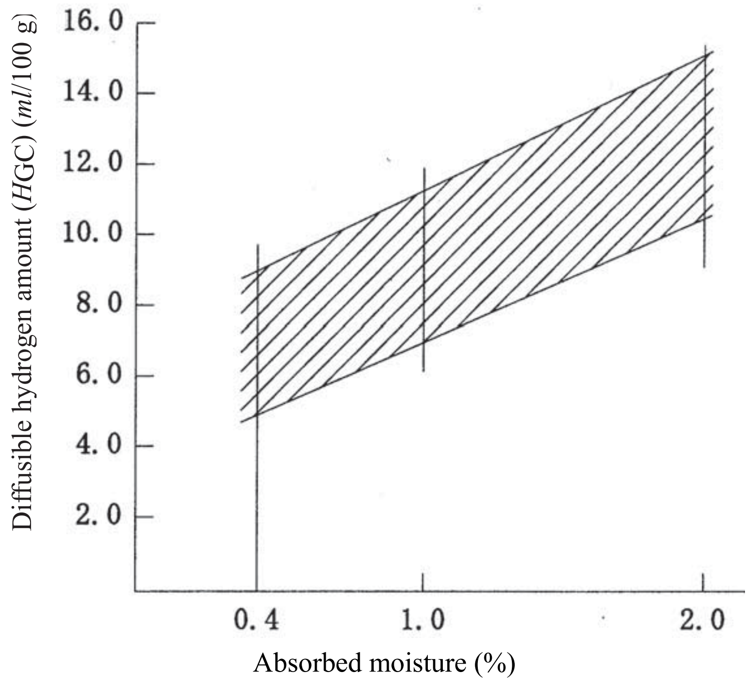


Figure 3-3 Relationship between Absorbed Moisture and Diffusible Hydrogen Amount of Covered Electrode

More specifically, the absorbed moisture of a low hydrogen type electrode after being left unattended for four hours at a room temperature of 25 ºC and humidity of 85 percent is approximately 0.4 percent, and the respective diffusible hydrogen amounts in the absorbed moisture (*H*GC by the gas chromatographic method in JIS Z 3118, "Method for Measurement of Amount of Hydrogen Evolved from Steel Welds") are largely 5 to 9 ml/100 g. These figures satisfy all the diffusible hydrogen amounts (see Table 3-10) prescribed in JIS Z 3212, "Covered Electrodes for High-Tensile-Strength Steel." On the other hand, the results of measuring the diffusible hydrogen amount of D5016 series electrodes are as shown in Figure 3-4. Based on the above, four hours have been considered appropriate as the allowable unattended time.

Table 3-10 Surface Diffusible Hydrogen Amount of Low Hydrogen Type Electrode

Type	Diffusible hydrogen amount by gas chromatographic method (*ml*/100 g)
D5016 D5026	15 or less
D5316 D5326	12 or less
D5816 D5826	10 or less

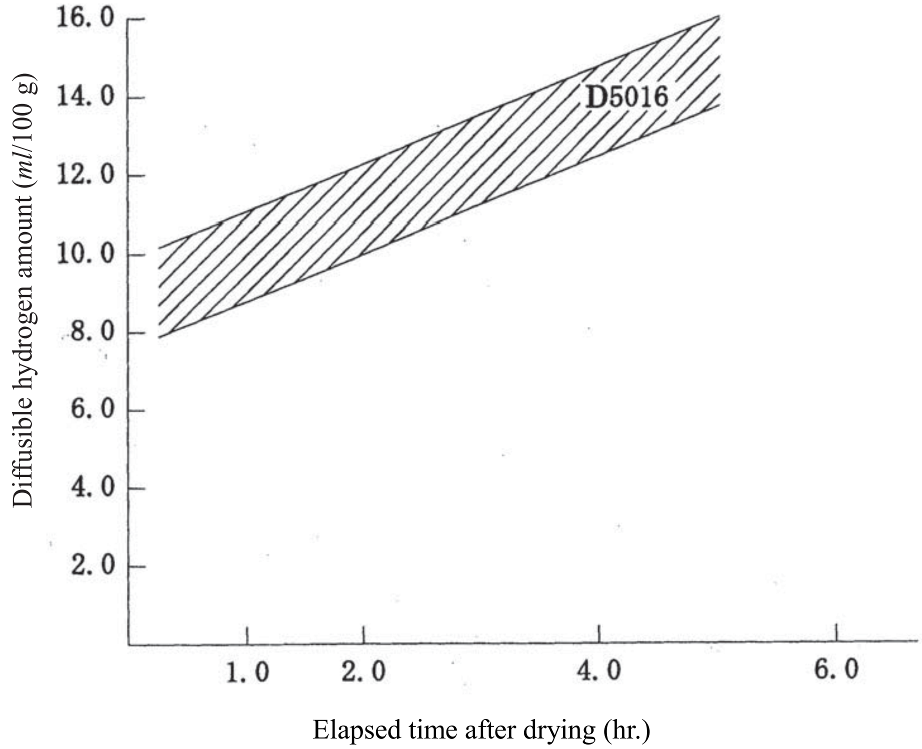


Figure 3-4 Relationship between Elapsed Time after Drying and Diffusible Hydrogen Amount in Low Hydrogen Type Electrode

Although the fused type of flux widely used as flux for submerged arc welding does not actually absorb moisture, there are cases where moisture will attach to the surface of a particle under high temperature and humidity. Therefore, it is advisable that the flux undergo drying. On the other hand, because the particle of bonded flux absorbs moisture, the drying temperature for it is stipulated to be high. When a flux-cored wire is used as a CO_2 gas shielded semi-automatic welding wire, sufficient care shall be taken in regard to moisture absorption.

Moreover, when CO_2 gas contains moisture, it may become a cause for defects such as a blow hole, etc., in the weld zone. Therefore, the three types that contain small amounts of moisture as prescribed in JIS K 1106, “Liquefied Carbon Dioxide (Liquefied Carbonic Acid Gas),” shall be used.

3.2.3 Assembly tolerance of material pieces

(1) The assembly tolerance of material pieces shall be such as that the stress transfer to the joint portion is carried out smoothly and the joint performance is satisfied.

(2) Clause (1) may be deemed to be satisfied when the assembly tolerance is in accordance with Clause (3).

(3) The assembly tolerance of material pieces shall generally be as the values below. However, when the allowable values of error are confirmed by a welding procedure test, they may be followed.

i) Groove weld

a) Error in route distance: stipulated values 1.0 mm or less

b) Eccentricity of material piece in direction of plate thickness:

$t \leq 50$ 10 percent or less of thickness of thinner plate

$50 < t$ 5 mm or less

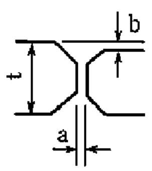
t: Thickness of thinner plate

c) Adhesion degree in the case of using backing strip: 0.5 mm or less

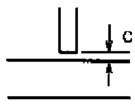
d) Groove angle: Stipulated values 10°

ii) Fillet weld

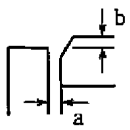
Adhesion degree of material piece: 1.0 mm or less



a: Route distance, ±1mm or less
b: Eccentricity of material piece in plate thickness direction, 1/10 of thinner plate or less and less than 3 mm.



c: Adhesion degree, 1mm or less.



a: Route distance, ±1mm or less
b: Eccentricity in plate thickness direction, 1/10 of thinner plate or less and less than 3 mm.

d: Adhesion degree with backing strip, 0.5mm or less.

Figure 3-5 Assembly Tolerance of Material Piece

In assembling members, poor precision in combining material pieces would not only reduce the precision of the completed members and eventually the precision of the whole bridge, but would also tend to result in a local welding defect. Therefore, the assembly tolerance of material pieces shall be such that the stress transfer at the joint portion is carried out smoothly and the joint performance is satisfied.

The standard values shown in this clause indicate that the values given in the instruction of welding performance procedures ensure good welding. Accordingly, there are cases where the route distance of a groove weld and the groove precision are varied, depending on the builder. However, because the allowable eccentricity of a material piece in the direction of the plate thickness is stipulated on the assumption that there can be a joint such as a steel deck site joint and a butt joint of pipes for which it is difficult to maintain precision, it is desirable to perform work with the lower limit of the allowable range set as a guide in the case of common factory work.

The adhesion degree of material pieces in the fillet welding can be secured with relative ease in a common linear portion, but defects tend to arise in the case where bending work or a butt joint is involved in the material. Therefore, an allowable value is stipulated so that sufficient control may be attained in such cases. However, when the member is a fitted type of joint such as a cruciform joint that penetrates the slit of the other member, and when it cannot comply with this adhesion degree due to the necessity of work, it is advisable to make an arrangement as follows:

When $1 < \delta \leqq 3$, increase the leg of fillet weld by δ

When $3 < \delta$, groove weld

Where

δ : Space between materials (mm)

Additionally, in assembling members it shall be ensured that a welding operator can perform the assembly welding with a natural posture by making effective use of a support device. Moreover, one should avoid as much as possible the situation in which a dissimilar material such as a supporting member and a strongback is temporarily installed to the base material. When the base material is damaged by a temporary installment performed out of necessity, a repair shall be carried out according to Table 3-16.

3.2.4 Welding Procedure

(1) The welding procedure shall be carried out in such a way that the prescribed weld quality can be ensured.

(2) Clause (1) may be deemed to be satisfied when the welding is carried out in accordance with items i) to vi).

i) Qualification of Welder

a) The welder engaged in the assembly welding and regular welding shall possess the qualifications described below:
The welder shall have passed the tests by "National Skill Standard Authority of The Republic of the Union of Myanmar" or the equivalent tests approved by The Engineer for each welding method.

b) The welder engaged in shop welding must be someone who has been engaged in the welding work for six months or more and has been engaged in the welding work in the factory for two or more months continuously prior to the construction.

c) The welder engaged in site welding must be someone who has been engaged in the welding work for six months or more and possesses experience in the welding procedure being adopted or shall have received sufficient training.

ii) Welding Procedure Test

A welding procedure test shall be conducted under any of the items below:

a) When the heat input per pass exceeds 7,000 J/mm in SM570, SMA570W, SM520 and SMA490W;

b) When the heat input per pass exceeds 10,000 J/mm in SM490 and SM490Y;

c) When conducting welding other than the shield metal arc welding method (manual welding only), gas-shield arc welding method (CO2 gas or mixed gas of Ar and CO2) and submerged arc welding method;

d) When there is no record in regard to the fabrication of steel bridges;

e) When the supply of materials is received from those with no usage records;

f) When there are no work records of the welding procedure being adopted. Additionally, for a factory where welding procedure tests have been conducted in the past under the same or stricter conditions, and when such factory possesses the appropriate work experience, judging from the test reports of those times, it shall be permissible to skip the welding procedure test.

The welding procedure test shall generally be conducted by selecting appropriate items from among the test items stipulated in Table 3-11, and the following provisions shall generally be applied to the selection of test steels, welding conditions, etc.

Table 3-11 Welding Procedure Test

Test type	Test item	Welding procedure	Shape of test piece	Number of test piece	Test procedure	Criterion
Groove welding test	Tensile test	See Figure 3-5	JIS Z 3121 No.1	2	JIS Z 2241	The tensile strength is equal to or greater than the standard value of the base material.
	Guided bend test (Root bend for less than 19 mm) (Side bend for 19 mm or more)		JIS Z 3122	2	JIS Z 3122	Cracking shall not generally be generated.
	Impact test		JIS Z 2202 No.4	Three for each site	JIS Z 2242	Equal to or greater than the standard of the base material at welded metal and in the portion affected by welding heat (average of three for each)
			(The location for collection of the test piece is as shown in Figure 3-6)			
	Macroscopic test		—	1	JIS G 0553 correspondingly	No defect
	Non-destructive test		—	Test piece Joint Overall length	JIS Z*) 3104	Category 2 or more (on tensile side) *) Category 3 or more (on compressive side)
Fillet welding test	Macroscopic test	See Figure 3-7	See Figure 3-7	1	JIS G 0553 correspondingly	No defect

a) The steel plate under the worst condition among those under similar conditions shall be used for a test plate.

b) The welding shall be conducted under the same conditions as the actual work, and the most disadvantageous welding position among the actual welding positions shall be adopted.

c) The groove welding test on dissimilar steels shall be performed in the same combination as that of the actual work. For joints of the same steel with different plate thicknesses, the test may be conducted on the one with a thinner plate thickness.

d) The retest shall use twice as many test pieces as the first test.

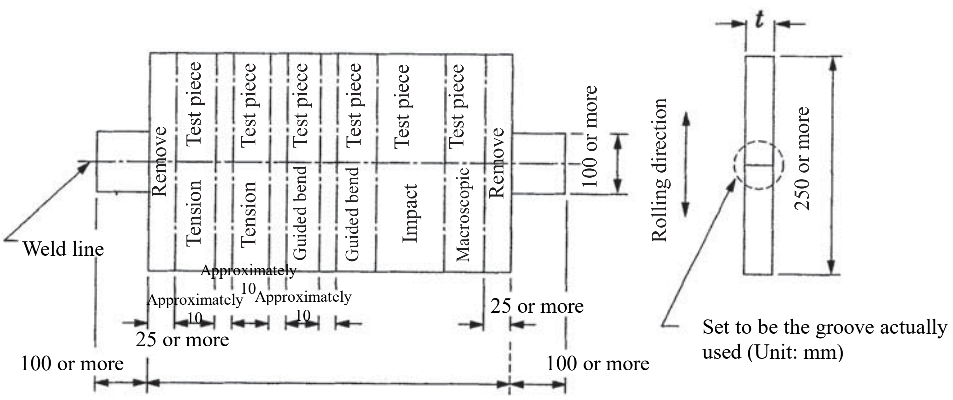
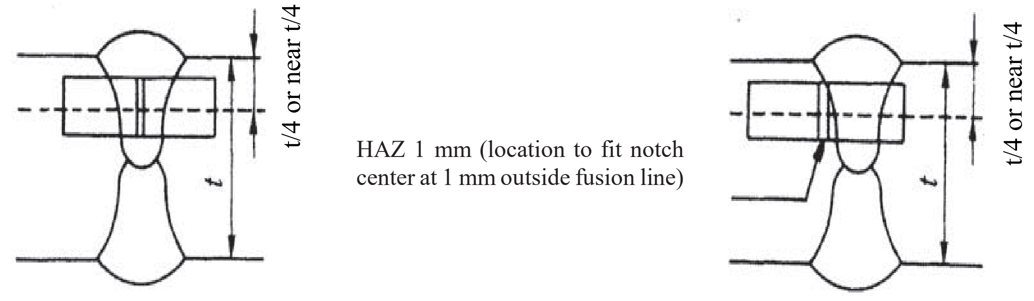


Figure 3-6 Groove Welding Test Method



(a) Welded metal portion (b) Heat affected portion

Figure 3-7 Impact Test Piece (Location to Collect Groove Welding Test Piece)

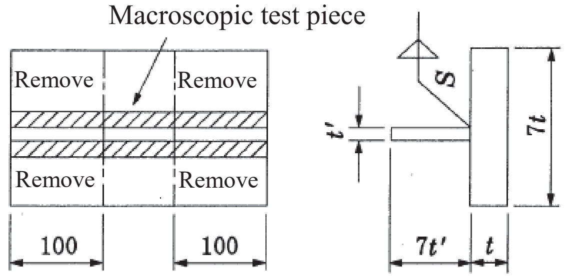


Figure 3-8 Fillet Welding Test (Macroscopic Test) Welding Method and Shape of Test Piece

iii) Assembly welding

i) The assembly welding shall be worked with the same control as regular welding.

ii) The leg of fillet weld of an assembly welding shall be 4 mm or more, and its length shall be 80 mm or more. However, when the thickness of the thicker plate is 12 mm or less, or when the weld cracking sensitivity composition PCM obtained after calculating by the following formula is 0.22 percent or less, it can be stipulated as 50 mm or more.

$$PcM = C + \frac{Mn}{20} + \frac{Si}{30} + \frac{Ni}{60} + \frac{Cr}{20} + \frac{Mo}{15} + \frac{V}{10} + \frac{Cu}{20} + 5B\ (\%)$$

iii) In the assembly welding, slag shall be removed by the end of assembly, and it must be confirmed that no cracking has occurred on the surface of the weld zone. When a crack is found, an appropriate measure must be taken after its cause is investigated.

iv) Preheating

Depending on the steel type and welding procedure, the 100 mm on both sides of a weld line and the range of 100 mm ahead of the arc of the base material shall generally be preheated in accordance with Table 3-12.

Table 3-12 Preheating Temperature Standard

Steel Type	Welding Procedure	Preheating Temperature (°C)			
		Plate Thickness Division (mm)			
		25 or less	Over 25 and 40 or less	Over 40 and 50 or less	Over 50 and 100 or less
SM400	Covered arc welding by electrode other than low hydrogen type	No preheating	50	–	–
	Covered arc welding by low hydrogen type electrode	No preheating	No preheating	50	50
	Submerged arc welding Gas shield arc welding	No preheating	No preheating	No preheating	No preheating
SMA400W	Covered arc welding by low-hydrogen type electrode	No preheating	No preheating	50	50
	Submerged arc welding Gas shield arc welding	No preheating	No preheating	No preheating	No preheating
SM490 SM490Y	Covered arc welding by low hydrogen type electrode	No preheating	50	80	80
	Submerged arc welding Gas shield arc welding	No preheating	No preheating	50	50
SM520 SM570	Covered arc welding by low hydrogen type electrode	No preheating	80	80	100
	Submerged arc welding Gas shield arc welding	No preheating	50	50	80
SMA490W SMA570W	Covered arc welding by low hydrogen type electrode	No preheating	80	80	100
	Submerged arc welding Gas shield arc welding	No preheating	50	50	80

Under conditions of "no preheating," when the air temperature (room temperature in the case of indoor) is 5°C or less, heating to approximately 20°C is performed.

v) Heat Gain Restriction

a) The heat gain per pass shall generally be controlled at 7,000 J/mm or less for SM570, SMA570W, SM520 and SMA490W, and 10,000 J/mm or less for SM490 and SM490Y.

b) When the heat gain of item a) is exceeded, it is necessary to conduct a welding procedure test and confirm that the prescribed quality is obtained at the weld zone.

vi) Note for Welding Works

Cleaning and drying the member at the weld zone

a) There shall be no harmful mill scale, rust, paint, oil, etc., on the part where welding is to be conducted.

b) Before the welding is conducted, the part near the welding line must be sufficiently dried.

Weld tab

a) In the work of the groove welding and fillet welding, etc., of the flange and web plate of the main girder, the weld tab that possesses the same groove as a member shall generally be installed so that the start point and end point of the weld may not interfere with the member to be welded.

b) The weld tab shall be removed by the gas cutting method after welding, and shall be finished with a grinder.

Work of partial penetration groove welding

When working on continuous weld lines by two welding methods in the work of the partial penetration groove welding, the end of previous bead shall be chipped and performed next welding after confirming that there is no defect. However, this provision shall not be applicable when a crater treatment is conducted in the manual welding or semi-automatic welding.

Work of fillet welding and partial penetration groove welding

a) The fillet welding that ends at the corner portion of a material piece must be performed in a continuous manner by rotating the corner portion.

b) When using the submerged arc welding method or other welding method, it is advisable not to cut the arc in the middle of a joint.

Installment and removal of suspender bracket and temporary member, etc.

a) The welding used to install a suspender bracket, temporary member, etc., to be used for transportation, erection, etc., shall generally be performed within a factory, and its condition must be equal to or greater than the condition for shop welding. When installation is conducted on site out of necessity, it must be done carefully under sufficient control.

b) The removal of a suspender bracket, temporary member, etc. must be conducted carefully so that no harmful flaws will remain in base material. Additionally, appropriate work needs to be performed corresponding to the member, etc. For example, the treatment of a removal mark must be carried out in consideration of the effect on pavement.

i) Qualification of Welder

Because the quality of welding is greatly dependent on the skills of the welder, it is a common practice that qualified operators who have passed the prescribed tests are assigned to the welding structure. The welder shall have passed the tests by “National Skill Standard Authority of The Republic of the Union of Myanmar” or the equivalent tests approved by The Engineer for each welding method.

ii) Welding Procedure Test

Because the purpose of the welding procedure test is to determine the weld ability of the steels to be used and the applicability of welding procedures, it is stipulated that the steels and welding procedures currently with a small number of usage records and those that require special care in working are targeted.

Moreover, when the welding procedure test of the test that targets the above condition has been conducted with the same material, the same level of carbon equivalent, the weld-cracking sensitivity composition and special ingredient, as well as the same welding procedure and the same welding technique, and when there are work experiences, it is stipulated that the welding work test can be skipped in deference to the submittal and consideration of documents.

a) Because the weld cracking sensitivity composition of the steels currently used for steel bridges is generally controlled to be low even when the plate is thick, the procedure test in terms of the quality of material and plate thickness is stipulated to be skipped. However, the portion near a weld bead in heat-treated steel tends to lose the effect of quenched and tempered by the heat cycle, which therefore leads to softening and embrittlement.

Therefore, when

$$\frac{\text{Current (amp)} \times \text{Voltage (volts)} \times 60}{\text{Heat gain Q (J/mm)}} = \text{Welding speed (mm/ min)}$$

is large, both the extent and range of alteration become large and the joint performance decreases. A number of experiments have confirmed that no decrease in joint performance is found at the heat gain of approximately 7,000 J/mm or less in SM570, SMA570W, SM520 and SMA490W and the submerged arc welding method used in the construction of a common steel bridge can be appropriately applied to the welding work with this heat gain or less. For these reasons 7,000 J/mm is stipulated to be the upper limit of a common welding work. When the heat gain exceeds 7,000 J/mm in the groove welding of a thick plate due to the usage of a particularly high current, the usage of the tandem method, etc., it is stipulated that its applicability be investigated by means of a welding procedure test.

b) When the heat input exceeds 10,000 J/mm in SM490 and SM490Y, the joint performance may decrease. Therefore, a welding procedure test is stipulated to be performed for checking.

c) It is stipulated that the manual welding by a covered electrode, submerged arc welding method and gas shield arc welding method (CO2 gas or mixed gas of Ar and CO2) are given a common treatment and other welding methods are made the objects of the work test. Concerning welding methods for steel structures, MIG welding, self-shield arc welding, electroslag welding, electro-gas arc welding, gravity welding, etc., are used. Although these welding methods are superior to manual welding in terms of efficiency, they have yet to become so common place in terms of the training of welders and the control of aptitude conditions to such an extent that they can be adopted without limitation. Thus, particular problems may arise, depending on the joint applied. Therefore, these are stipulated to be checked by a welding procedure test.

d) When there is no past record of steel bridge fabrication, a welding procedure test (in actual-size test pieces if necessary) shall be conducted in order to confirm that there is no problem concerning the quality of the weld zone or in the form of completed work.

e) When materials are supplied from a source that has no record of past usage, a welding procedure test is stipulated to be performed until an accumulation of reliable test data is obtained.

f) The on-site welding is generally under disadvantageous conditions compared to shop welding in terms of weather condition, welding position, groove precision, etc. Moreover, in the on-site welding such as the one- sided welding of a steel deck, the horizontal welding of a pier or the reinforcement of an existing bridge, the work on joint itself is often extremely different from common shop welding as well. For these reasons, in the past a welding procedure test incorporating on-site conditions would generally be performed for on-site welding. However, since work records have increased it is stipulated that a welding procedure test need not necessarily be conducted when quality is ensured. However, when adopting a work method that has no record of past usage, a check must be conducted by a welding procedure test.

Table 3-11 shows two types of tests: the groove welding test, and fillet welding test. However, it is not necessary to consider that each of these tests will always be performed in the welding procedure test. For example, while nearly all tests are to be conducted when the plate thickness exceeds the standard values as the characteristics of the steel are the issue, only the groove welding test is required when the welding falls under only item a) or item b).

Moreover, the test contents shown here include elements strongly colored by technical qualifications (for example, the radiographic testing and stud welding test). However, it is possible to check the quality-control system of the builder by these tests, so they are stipulated to be included once the meaning of the welding procedure test is broadly interpreted.

Even if a crack is generated in the guided bend test of a groove welding test, it is considered as permissible, provided there is confirmation that the cause of the generation is a blowhole or a slag inclusion and when the length of the crack is up to approximately 3 mm.

Additionally, 3 mm is stipulated as the permissible limit of the length of the crack in "JIS Z 3801 Standard Qualification Procedure for Manual Welding Technique 3.2," "Ministry of International Trade and Industry Technical Standards on the Welding of Electric Structures," "AWS 5, 12, 1, 2 Root-, Face- and Side-Bend Tests," "ASME QW-1 Acceptance Criteria-Bend Tests," etc.

The provisions of item c have been obtained once the consistency between the welding procedure test and the execution work has been considered. The steel and welding consumables that will be actually used are stipulated to be adopted for a welding procedure test of dissimilar steels.

The decision to pass or fail in this instance shall be made based on the standard values of the steel on the low-strength side.

The impact test on the groove weld zone used to be conducted only about the deposited metal. However, to conduct a more definitive test, the impact test on the weld heat-affected zone is added so that the toughness values of the base material can be satisfied. Moreover, although the maximum hardness test used to be conducted in order to determine the necessity of preheating, the maximum hardness test has been deleted from among the items of the welding procedure test since the previous time because preheating has been prescribed in the weld cracking sensitivity composition.

iii) Assembly Welding

Although there are cases where all the assembly welding is re-melted through regular welding, part or most of it remains within the regular welding. Therefore, this item is stipulated so that the quality of the assembly welding may be made equal to that of regular welding. Moreover, although the term "tack welding" was formerly used, it has been changed to "assembly welding" because consideration for the prevention of weld cracking in this welding process is as important as in the regular welding. Consequently, the expression “tack” is not necessarily appropriate. Because the assembly welding is performed at the assembly stage, its welding control tends to be neglected. To avoid this, it is important first of all to engage the qualified welders. AWS stipulates to also conduct technical qualifications for the welders who are engaged in assembly welding. However, our country does not possess a qualification system for assembly welding alone, so it is necessary to engage in assembly welders who possess skills equivalent to those of the operators who perform regular welding.

The length of assembly welding (80 mm or more) is based on a research result that while cracking tends to be generated from the root and along the bond when a fillet welding of a short bead is applied to a T joint of steel of 490 N/mm^2, cracks cease to be generated when the bead length becomes 80 mm or more. However, recent research has revealed that no cracking is generated even if the length of assembly welding is 50 mm, provided that the thickness of the thicker plate is 12 mm or less or that the carbon equivalent (Ceq) of the steel is 0.36 percent or less. Moreover, there is largely the correlation between Ceq and PCM in the steel of 570 N/mm^2 class for a bridge, and the PCM equivalent to Ceq 0.36 is 0.22 percent. It is therefore stipulated that the length of assembly welding can be 50 mm or more when PCM is 0.22 percent or less.

While the above-mentioned root crack does not appear on the surface of the bead in many cases, other types of assembly welding cracks often appear on the surface of the bead due to the small cross section. When a crack is detected by a surface inspection at the end of assembly, measures can be taken at that stage. Accordingly, it is stipulated that the slag of a bead in assembly welding is removed at the end of assembly and an inspection is performed on the surface of the bead.

iv) Preheating

Recent research has revealed that it is better to use the weld cracking sensitivity composition as an index of preheating rather than the carbon equivalent that has conventionally been used. Moreover, in addition to the increase in plate thickness in the previous revision, the plate thickness applied to weathering steel has been increased to 100 mm in this revision. Correspondingly, it has become necessary to more accurately select the preheating condition in welding for the purpose of preventing the delayed cracking by hydrogen, so it is stipulated that the provisions of preheating are reviewed on the basis of PCM.

Based on the usage records of steels for bridges in Japan, Table 3-13 has been obtained after reordering is made in accordance with PCM. On the other hand, the preheating temperature for crack prevention in accordance with the PCM values of the steel in the common joint of a bridge, the plate thickness and welding procedure are shown in Table 3-14.

Table 3-13 Condition of P_{CM} in Application of Preheating Temperature Standard (%)

Steel type / Steel plate thickness (mm)	SM400	SMA400W	SM490 SM490Y	SM520 SM570	SAM490W SMA570W
25 or less	0.24 or less	0.24 or less	0.26 or less	0.26 or less	0.26 or less
Over 25 and 50 or less	0.24 or less	0.24 or less	0.26 or less	0.27 or less	0.27 or less
Over 50 and 100 or less	0.24 or less	0.24 or less	0.27 or less	0.29 or less	0.29 or less

It has been known that while the restriction of a joint by welding increases as the plate thickness increases, that the increase peaks out when the plate thickness exceeds 40 mm to 50 mm and that cracking can be prevented without increasing the preheating temperature above certain degrees. Because the usage records of steels with plate thickness of 50 mm or more have been increasing, it is stipulated that the restriction becomes constant at the plate thickness of 50 mm or more and that the preheating temperature is the same for the plate thickness of 40 mm to 100 mm of steels with the same PCM. Additionally, the preheating temperature division has been simplified with the distance of 20 to 30° C into "no preheating", "50° C", "80° C" and "100° C", hereby aiming at the streamlining of the preheating control.

The preheating temperature standards in Table 3-12 in the clause has been obtained by ordering the preheating temperatures in reference to the traditional experience, other standards, etc., on the basis of the amount of diffusible hydrogen of the deposited metal and the joint condition of a bridge where the restriction of a joint is standard from the relationship among PCM , plate thickness and preheating temperature of Table 3-14, based on the assumption of the PCM condition of the steels of Table 3-13.

Moreover, the preheating temperature of shield arc welding other than the low- hydrogen type is stipulated to be as stated previously, due to the reason that it cannot be ordered using PCM.

Because preheating is a means to perform a sound welding that does not generate cracks, it is not sufficient simply to always preheat to the temperature shown in these tables. It is necessary to take care of the work condition such as conducting the preheating of even higher temperature to prevent the generation of cracks depending on the PCM of the steel, the condition of joint restriction, etc.

Moreover, the preheating temperature can be decreased by reducing the PCM values of the steel. The preheating temperature in this instance shall be according to Table 3-14. When using an electrode of extremely low hydrogen under a well-controlled condition, the preheating temperature can be lowered to the same as the gas-shield arc metal welding method. Additionally, when crack prevention is guaranteed by the data from experiments such as the welding crack test that simulates the actual structure, the preheating temperature can be lowered below those shown in Table 3-12.

Table 3-14 Standard of P_{CM} Value and Preheating Temperature

P_{CM}	Welding method	Preheating temperature (°C)		
		Plate thickness division (mm)		
		$t < 25$	$25 < t < 40$	$40 < t < 100$
0.21	SMAW	No preheating	No preheating	No preheating
	GMAW, SAW	No preheating	No preheating	No preheating
0.22	SMAW	No preheating	No preheating	No preheating
	GMAW, SAW	No preheating	No preheating	No preheating
0.23	SMAW	No preheating	No preheating	50
	GMAW, SAW	No preheating	No preheating	No preheating
0.24	SMAW	No preheating	No preheating	50
	GMAW, SAW	No preheating	No preheating	No preheating
0.25	SMAW	No preheating	50	50
	GMAW, SAW	No preheating	No preheating	50
0.26	SMAW	No preheating	50	80
	GMAW, SAW	No preheating	No preheating	50

0.27	SMAW	50	80	80
	GMAW, SAW	No preheating	50	50
0.28	SMAW	50	80	100
	GMAW, SAW	50	50	80
0.29	SMAW	80	100	100
	GMAW, SAW	50	80	80

Note) SMAW: Covered arc welding by low hydrogen type electrode
GMAW: Gas-shield arc metal welding
SAW: Submerged arc welding

Note 1: In "no preheating," when air temperature (room temperature in the case of indoor) is 5° C or less, warm up (heating to approximately 20°C) shall be performed in order to remove any condensation.

Note 2: Preheating temperature calculation formula

$$Tp\ (°C) = 1{,}440P_W - 392$$

Where,

$$Pw = PcM + \frac{HGL}{60} + \frac{K}{400{,}000}$$

Note 3: The preheating temperature in the table is calculated on the basis of the following assumptions:

a) Amount of diffusible hydrogen in deposited metal (HD)

In low hydrogen covered arc welding HGL = 2 ml/100 g

In submerged arc welding and gas-shield arc metal welding HGL =1ml/100 g

b) Restriction of welded joint (K)

Two hundred times the plate thickness (t) is assumed for the average restriction of the welded joint of a bridge.

K = 200 t N/mm·mm

Plate thickness t shall be 50 mm in the case of 50 mm or more.

v) Heat Gain Restriction

When the welding heat gain is increased in the welding work, the speed of the temperature decrease becomes slower once the temperature reaches the peak by welding heat, and therefore the toughness and strength of the deposited metal and weld heat-affected zone (HAZ) are reduced. Consequently, it is necessary to ensure that the heat input is restricted in accordance with the steel and welding procedure so that the mechanical properties required for a joint can be ensured.

The welding with excessive heat input is generally rare in the welding work of a steel bridge. However, there may be cases where toughness degradation in the weld heat-affected zone (i.e., the HAZ) of the steel becomes a problem with the adoption of the weld that generates excessive heat input in submerged arc welding, electro-gas arc welding, etc., for the purpose of improving the efficiency of welding work. Accordingly, to ensure the toughness of the zone affected by weld heat-affected zone (HAZ), the heat gain in submerged arc welding shall generally be controlled to 7,000 J/mm or less for SM570, SMA570W, SM520 and SMA490W, and generally to 10,000 J/mm or less for SM490 and SM490Y. When performing a welding that exceeds these heat gains, it is necessary to conduct a performance check through means of a welding procedure test.

Additionally, when conducting large-heat-gain welding such as above, it is preferable to use appropriate materials according to the heat gain, since steels whose toughness in the weld heat-affected zone (HAZ) is good even in large-heat-gain welding have also been developed. On the other hand, with regard to weld consumables it is necessary to select appropriate consumables that will ensure the performance of the deposited metal.

vi) Notes for Welding Work

a) Cleaning and drying member before welding

The mill scale, rust, paint, oil, etc., near the weld line can cause blowholes or cracks. However, the generation status of defects varies considerably, depending on the amount of the foreign material and the welding procedure. For example, the common primer coating is nearly harmless in the context of flat manual welding, but it is particularly harmful in the case of fillet welding performed at a high speed, such as vertical downward welding. The state where moisture is attached to the weld line is stipulated to be prohibited, because such a state obviously affects the welding in a negative manner.

b) Weld tab

The start point and end point of a welded bead must use the weld tab since they tend to generate defects, while the fillet welding at the end of a main girder is also stipulated to use the end tab. This is because the fillet welding of the main girder flange and web is presently performed by the submerged arc welding method, so it is not desirable for a large crater particular to the automatic welding to remain in the end portion where shear stress is great.

However, the welding procedure without the steel weld tab (such as the flux tab) has recently been developed. Such a method may be used when it is recognized that the procedure can prevent the generation of defects at the end of a weld zone in the same manner as the steel weld tab.

c) Work of partial penetration groove welding

The crater generally arises at the end of a welded bead and the so-called crater crack tends to be generated in this portion. This tendency is particularly strong in cases where the groove angle is relatively small, such as in partial penetration groove welding. Accordingly, it is desirable in the automatic welding method to perform the work on the weld line continuously without cutting the bead on the way. When cutting the bead or changing the welding procedure on the way based on necessity due to the change of the shape of the member or the change of the groove, etc., it is stipulated that the end of the previous bead be chipped away before the next welding is performed.

No crater arises in manual welding when the end portion is treated carefully, nor is a large crater generated in semi-automatic welding if a power source equipped with a crater filler function is used and the end portion is treated by the crater- filler current. Therefore, in such cases it is not necessary to chip away the end portion.

d) Work of fillet welding and partial penetration groove welding

This provision is stipulated for the same reason as mentioned in item iii). When working on a long joint by the semi-automatic welding method, continuous welding cannot be performed if the equipment layout or mobility is poor, so it is desirable to make a sufficient arrangement for them in advance.

e) Installment and removal of suspending bracket and temporary member, etc.

It is stipulated here that the welding used to install the suspending bracket and temporary member, etc., be performed within a factory in consideration of the fact that it constitutes welding to a primary member. On the other hand, when on-site welding is conducted out of necessity of the work, such as in the case of (among hanging rings) the floor deck type framed hanging ring installed to the top surface of the upper flange during the casting of the floor deck, it is necessary for the welding to satisfy the welding condition equivalent to that of shop welding.

When removing the suspender, temporary member, etc., consideration must be made not only in regard to the effects of flaws, etc., on the base material, but also in regard to the effects of the degree of finish, prong height of the removal mark, etc., on the work and quality of coating, bridge deck pavement, etc. Accordingly, "Bridge Deck Pavement Standard (Plan), Honshu-Shikoku Bridge Authority, April 1983" can be used as reference in the degree of finish on the pavement, etc.

3.2.5 Surface Flaw Inspection

(1) Upon the completion of welding, an inspection must be conducted on the bead form and appearance using the naked eye or other appropriate nondestructive inspection method in order to confirm that the welding quality required of a joint is satisfied.

(2) Clause (1) may be deemed to be satisfied when the inspections are conducted in accordance with items i) to iv).

i) Weld crack inspection

There must be no cracking whatsoever in the weld bead or its vicinity. While the crack inspection shall generally be conducted with the naked eye, it is advisable to use the magnetic particle method or liquid penetrant method if any flaw is suspected.

ii) Inspection of weld bead appearance and form

a) Pit on surface of weld bead

There must be no pitting on the surface of a bead in a T-joint and corner joint constituting the butt joint and cross section of a primary member. Up to three pits per joint or per meter of the joint's length shall be allowed for the fillet welding and partial penetration groove welding in others. However, when the size of the pit is 1 mm or less, three pits shall be regarded as one pit in calculation.

b) Unevenness on the surface of weld bead

The unevenness on the surface of a bead shall be shown by the difference of elevation within 25 mm of the length of the bead, and there must be no unevenness exceeding 3 mm.

c) Undercut

The depth of an undercut must be less than 0.5 mm.

d) Overlap

There must be no overlap.

e) Size of fillet welding

The size and throat thickness of a fillet welding must not under-run the size and throat thickness of a designated fillet. However, in the portion excluding 50 mm of both ends of a weld line within the range of up to 10 percent of the weld length, an error margin of -1.0 mm shall be allowed for both the size and throat thickness.

iii) Reinforcement and finish of groove weld

In the groove weld having no particular specification regarding finish in design, a reinforcement within the range shown in Table 3-15 need not undergo finishing. When the reinforcement height exceeds the values shown in Table 3-15, the bead form, particularly its toe portion, must be finished smoothly.

Table 3-15 Groove Weld Reinforcement (mm)

Bead width (***B***)	Weld reinforcement height (***h***)
$B < 15$	$h \leqq 3$
$15 \leqq B < 25$	$h \leqq 4$
$25 \leqq B$	$h \leqq (4/25) \cdot B$

iv) Repair of Defective Portion

The repair of a defective portion must be carried out carefully in consideration of the effect of the repair on the base material.

The methods to repair defects are shown in Table 3-16. In this regard, the length of the bead of a repair weld shall be 40 mm or more, and sufficient care for preheating, etc., shall be used in the repair work.

Table 3-16 Method for Defect Repair

	Defect type	Repair Method
1	Arc strike	The portion on the surface of base material where a dent has been generated shall be grinder finished after over laying. The one with a tiny mark shall undergo only the grinder finish.
2	Defect in assembly weld	The defective portion shall be removed with the arc air gouging, etc., and if necessary, an assembly welding shall be conducted again.
3	Weld crack	The cracking portion shall be completely removed, and a re-welding shall be performed after the cause of the problem is identified.
4	Pit on surface of weld bead	That portion shall be removed with the arc air gouging, and re-welding shall be performed.
5	Overlap	It shall be trimmed with a grinder and formed fairly.
6	Unevenness on surface of weld bead	It shall be finished with a grinder.
7	Undercut	It shall be just finished with a grinder, depending on the degree, or it shall be finished with a grinder after welding.

i) Weld crack inspection

Needless to say, no cracking can be allowed in a weld structure, but it is quite difficult to detect all cracks perfectly that may be present. Therefore, this provision is stipulated for the purpose of allowing no cracks that can be detected from the surface. However, this does not mean nothing else needs to be done when the surface detectable cracks can be prevented, so the conditions of execution must have absolute compliance in order to prevent the generation of cracks. More specifically, concerning the weld crack, it is the prime challenge to prevent its generation. Therefore, the maximum preventive efforts must be made in compliance with the provisions of the specifications.

On the other hand, the radiographic testing and ultrasonic testing methods are used to detect internal flaws. However, it is difficult to differentiate between the un-welded metal zone and a weld defect at the root zone in the portion of the fillet weld portion of a T-joint or the partial penetration weld of a corner joint, so these test procedures have not been included as inspection methods of cracks.

ii) Inspection of weld bead appearance and form

Because the judgment of defects or otherwise concerning the appearance and form of a weld bead varies among individuals, it is stipulated that the appropriate allowable amounts of these are provided in this item, thereby establishing the inspection criteria with which an objective judgment can be made. While the reinforcement of a groove weld is referred to in item iii), other factors that determine the quality of the appearance and form of a bead are the pitting on the surface, unevenness of the surface, undercut, overlap, the size of a fillet weld, etc. The provisions are stipulated here on the basis of the "Quantitative Inspection and Control Criteria of the Appearance of Vessel's Body" (edited by the Welding Work Committee, Shipbuilding Section, Japan Welding Engineering Society)4) and by adding various circumstances of bridges to it.

a) Pits on the surface of a weld bead are the vent holes of the gas generated from foreign materials and moisture. Of these, small and sporadic ones do not affect the strength, but large ones and those occurring in clusters can cause stress concentration and are not desirable in appearance. Therefore, it is stipulated that these not be allowed in the primary joints but that some will be allowed in the secondary joints.
b) Unevenness on the surface of a weld bead appears mainly at the joint of the bead. Because it becomes quite large when the crater treatment and the start point treatment are poor, its acceptance criteria are stipulated to be 3 mm from the perspective of letting such treatment be carried out carefully and in consideration of good appearance.
c) Because undercuts are the main cause of the stress concentration and lead to the promotion of corrosion, its acceptance criteria are stipulated to be 0.5 mm or less based on past records, etc. Additionally, in the case of the fillet welded joints such as ribs and stiffeners, the undercut in the toe zone (on the lower-leg side of the fillet weld) connecting with the main body structure is particularly important from the standpoint of stress concentration, so the lower-leg side must be inspected without fail. Moreover, there are cases where the requirements for the undercut allowed in satisfying the prescribed fatigue strength grades are stricter than the provision of this item; therefore, separate consideration is needed in such case. For matters pertaining to fatigue, "Guideline of Fatigue Design for Steel Road Bridges" (Japan Road Association) can be used as reference.
d) Overlaps are stipulated not to be recognized at all in consideration of the fact that no overlaps occur with recent welding materials unless under exceptionally poor conditions.
e) Recognizing negative tolerance for the size and throat thickness of a fillet welding, it is stipulated that -1.0 mm is allowed for up to 10 percent of the length in the middle part of the weld line. This is a result of considering, among others, the fact that the strength of the welded metal in a fillet weld is considerably higher than that of the base material in general. Additionally, it is due to the judgment that if the target values are stipulated with the lower limit of the variation of the work as the prescribed size, the average size will become unnecessarily large, causing disadvantages in deformation.

iii) Reinforcement and finish of groove weld

Because it is considered that the stress concentration by weld reinforcement is related to the form of the toe zone of a bead but is not directly related to the height of the center part of the weld reinforcement, a provision is stipulated as in Table 3-15 with the bead width adopted as the acceptance criteria.

Concerning the weld reinforcement that exceeds this provision, the excess part must be removed as a matter of course. However, in that instance, even if the height is reduced by trimming the center part only, the effect of the form of the toe zone will not be decreased, so it is necessary to ensure that the toe zone is made particularly smooth.

The stress concentration by the presence of the weld reinforcement is important for a welded structure, and there are cases where it is demanded from the standpoint of appearance that the weld reinforcement should undergo finishing. Therefore, the locations where the weld reinforcement finish is needed should be instructed in design drawings. During execution, it is necessary to perform the work by carefully checking for the existence of this finish mark.

iv) Repair of defective portion

Because the purpose of the repair is to ensure the sound functioning of the base material and welded joint portion, the repair method must be determined in careful consideration of the effect on the entire member, and the repair must be conducted carefully in order to prevent unnecessary welding or heating. Particularly, harmful defects tend to be generated in the start point and end point of a repair welded portion. Therefore, care should be taken.

3.2.6 Internal flaw inspection

(1) The inspection for the internal flaw of a full penetration butt welding joint must be conducted by an appropriate nondestructive inspection after the welding is completed, and it must be checked that the required weld quality is satisfied.

(2) When the inspection for the internal flaw of a full penetration butt welding joint is conducted in accordance with the method shown below, Clause (1) may be deemed to be satisfied.

1) Inspection method

The nondestructive inspection is performed through radiographic testing and ultrasonic testing.

2) Sampling inspection rate, acceptance criteria and judgment of acceptance

i) Sampling inspection rate

For a primary member, a sampling inspection of picking one joint per group shown in Table 3-17 shall be performed. However, of the full penetration butt welding joints that undergo site welding, for the welded portion of the beam and column of a steel bridge pier, the flange and web plate of a main girder and the steel deck plate, the inspection shall be conducted in accordance with Table 3-18. Additionally, when the allowable stress in other member is set to be the same value as the joint of the same type that undergoes shop welding, an inspection shall be carried out by a nondestructive inspection for the entire length of the joint.

Table 3-17 Nondestructive Inspection Rate of Full Penetration Butt Welding Joint of Primary Member

<table>
<tr><th colspan="3">Member</th><th>Maximum number of joints per group in grouping 1 inspection lot</th><th>Number of photo shoots in radiographic testing</th><th>Number of joints to be inspected in ultrasonic testing</th></tr>
<tr><td colspan="3">Tensile member</td><td>1</td><td>One shoot (including end part)</td><td>1</td></tr>
<tr><td colspan="3">Compressive member</td><td>5</td><td>One shoot</td><td>1</td></tr>
<tr><td rowspan="4">Bending member</td><td colspan="2">Tensile flange</td><td>1</td><td>One shoot</td><td>1</td></tr>
<tr><td colspan="2">Compressive flange</td><td>5</td><td>One shoot</td><td>1</td></tr>
<tr><td rowspan="2">Web plate</td><td>Joint in direction perpendicular to stress</td><td>1</td><td>One shoot (on the tension side)</td><td>1</td></tr>
<tr><td>Joint in parallel direction to stress</td><td>1</td><td>One shoot (including end part)</td><td>1</td></tr>
<tr><td colspan="3">Steel floor deck</td><td>1</td><td>One shoot (including end part)</td><td>1</td></tr>
</table>

Table 3-18 Nondestructive Inspection Rate of Full Penetration Butt Welding Joint That Undergoes Site Welding

<table>
<tr><th rowspan="2">Member</th><th>Radiographic testing</th><th>Ultrasonic testing</th></tr>
<tr><th>Location to shoot</th><th>Inspection length</th></tr>
<tr><td>Beam and column of steel bridge pier</td><td colspan="2" rowspan="2">Entire length of joint in general</td></tr>
<tr><td>Flange of main girder (excluding steel floor deck) and plate</td></tr>
<tr><td>Orthotropic steel deck</td><td>50cm continuously at the start point and end point of joint (two shoots), one location per meter in middle part (one shoot) and one location at wire joint portion (one shoot) in general.</td><td>Entire length of joint in general</td></tr>
</table>

ii) Acceptance Criteria

Based on current study for fatigue strength, allowable defect sizes are t/6 mm for thickness of larger than 18mm and 3mm for thickness of less than 18mm for full penetration transverse butt weld bead or cross shape weld bead, and t/3 mm for longitudinal full penetration bead respectively in terms of fatigue strength category D in JHBS. As for partial penetration groove welding of high strength steel plate, it is 3mm in width and 8mm in height from Honshu Shikoku Bridge Standard.

3.3 Stud Dowel

3.3.1 Scope of Application

This volume is applied to the welding quality control of the arc stud dowel.

3.3.2 Material and Shape Dimensions

The chemical composition, mechanical properties, shape and dimensions of the studs prescribed in JIS B 1198 are as follows:

Table 3-19 Chemical Composition

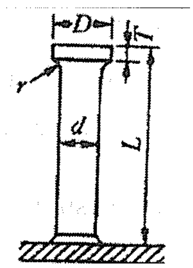
Material	Chemical element (%)					
	C	Si	Mn	P	S	Al
Silicon killed steel	0.20 or less	0.15 to 0.35	0.30 to 0.90	0.040 or less	0.040 or less	-
Aluminum killed steel	0.20 or less	0.10 or less	0.30 to 0.90	0.040 or less	0.040 or less	0.02 or more

Table 3-20 Mechanical Properties

Yield point or 0.2% proof stress (N/mm^2)	Tensile strength (N/mm^2)	Elongation (%)
235 or more	400 to 550	20 or more

If the design is performed based on AASHTO LRFD, AASHTO Construction Specification shall be applied.

Table 3-21 Shape, Dimensions and their Tolerance

Nominal designation	Shaft diameter *d*		Head diameter *D*		Head thickness *T* Minimum	Roundness *r* under neck	Standard shape and dimensional symbol
	Basic dimension	Tolerance	Basic dimension	Tolerance			
19	19.0	±0.4	32.0	±0.4	10	Two or more	
22	22.0		35.0				

3.3.3 Welding Procedure Test

Welding conditions such as current, voltage, arc time, preheating, etc. of the stud dowel welding and auxiliary materials etc. shall be determined from the results of the welding procedure test.

The Procedure Test shall be conducted in the following cases, the test items and test methods shall be in accordance with Table 3-22.

- A Bridge Construction Unit has no experience of the stud dowel welding.

- When any of the serial number of the stud dowel, the welding machine, or the welder has changed
- One per 5,000

Table 3-22 Welding Procedure Test

Test type	Test item	Welding procedure	Shape of test piece	No. of test piece	Test procedure	Criterion
Stud welding test	Tensile test	JIS B 1198	JIS B 1198	3	JIS Z 2241	235 N/mm^2 or more at yield point, 400 to 550 N/mm^2 for tensile strength and 20% or more for elongation. However, it must not break during the welding process.
	Bend test	JIS Z 3145	JIS Z 3145	3	JIS Z 3145	No cracking shall occur in the welded part.

3.3.4 Check of Quality after Stud Welding

The quality of the stud bolt after welding shall be checked by appearance and bending test in the following procedure. (Figure 3-9)

(1) Flow of Quality Check

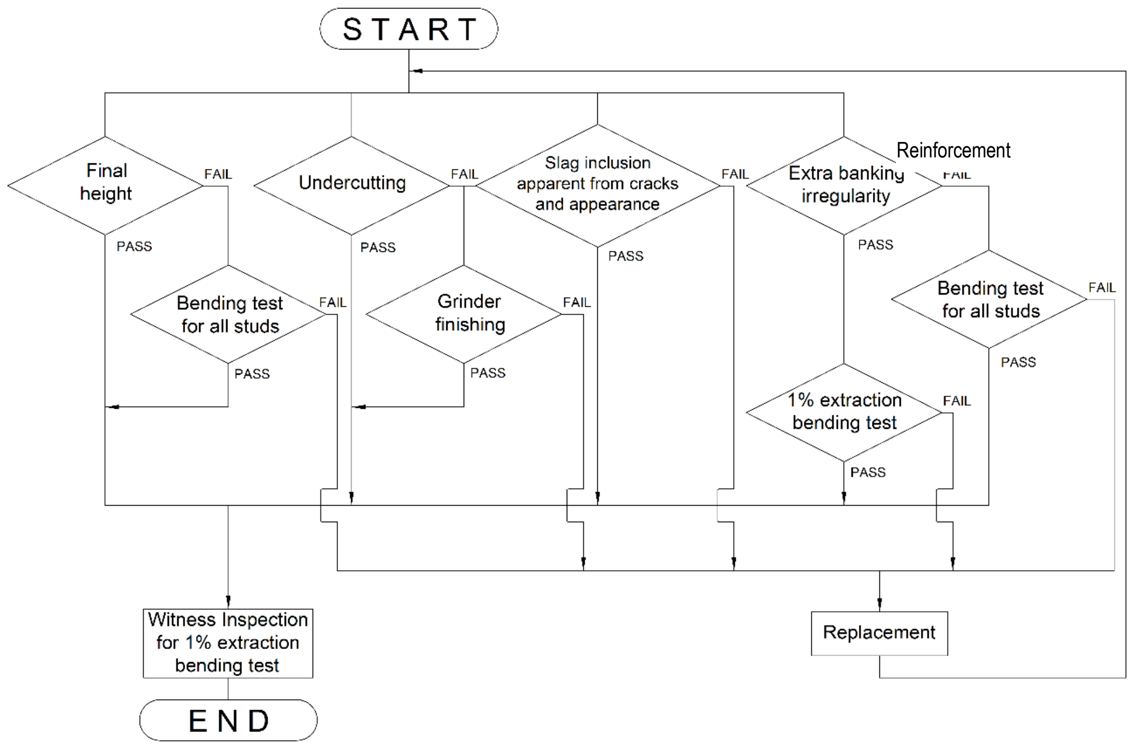


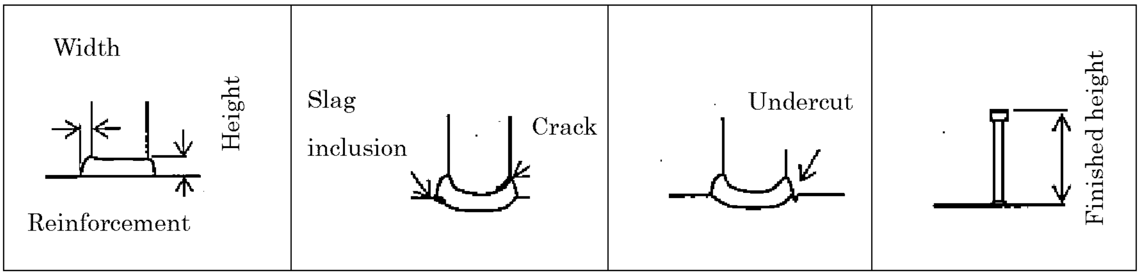
Figure 3-9 Flowchart for Quality Check of Stud Bolt

(2) Visual inspection of arc stud

The visual inspection of arc studs shall be performed for all pieces, and must satisfy Table 3-23.

Table 3-23 Arc Stud Visual Inspection Criteria

Defect	Criteria
Irregularity of weld reinforcement form	The weld reinforcement must surround the whole circumference. In this regard, the one with the height of 1 mm or more and the width of 0.5mm or more is regarded as weld reinforcement.
Crack and slag inclusion	There must be none of them.
Undercut	There must be no sharp notch-like undercut or an undercut with a depth exceeding 0.5mm. However, the one whose grinder finish amount falls within 0.5mm shall pass after finishing.
Finished height of stud dowel	Design value ±2mm must not be exceeded.



(3) Hammer impact inspection

All the stud dowels that have failed a visual inspection shall undergo a bend inspection by hammer impact. The stud dowel that is not surrounded by a weld reinforcement shall be bent up to 15 degrees in the direction opposite its own direction. Moreover, 1 percent of the stud dowels that have passed a visual inspection shall undergo a sampling bend inspection.

1) As a result of the hammer impact inspection, those that have generated no defects such as cracks, etc., shall pass. Those that have generated no defects after being bent 15 degrees must remain bent without being restored to the original form.
2) When fail is the result of the sampling bend inspection, twice the number of the pieces shall undergo a further inspection, and with all pieces having passed it shall be considered a pass.

3.3.5 Report

Prior to welding of the stud dowel, the welding procedure shall be submitted to the supervisor.

The management records must be made every day. In the management record, the following items shall be described.

(1) Name of the bridge, name of the contractor, welder, working date

(2) Type of welding equipment, model number

(3) Working Procedure Report

Working date, welder name, welding conditions, working number, the treated region, quality check results. However, the item of the quality check result shall be as follows:

- The judgment by appearance and the type, number, rejection rate of defects that failed in bending test
- Measures for stud dowels that fail

3.3.6 Commentary

(1) Submission of Execution Plan

The working procedure planning is intended to describe the following matters.

i) Material	: Standard certificate (mill sheet)
ii) Shape dimensions	: Weighing standard type quality control report by sampling inspection method
iii) Processing	: Processing method of each part
iv) Welding equipment	: Power supply, welding equipment, measuring instrument
v) Welder list	: Welder name, acquisition qualification, construction history
vi) Welding condition	: Setting current, voltage and arc time
vii) Work environment	: Welding location and weather condition

(2) Welder qualifications

The qualification of the welder engaged in the welding operation of the stud dowel is according to "Welding procedure" of "JHBS Steel bridges, 2012" 18.4.4.

(3) Auxiliary material of stud dowel

Welding aid materials such as ferrules and cartridges are basically based on not changing their specifications during the same construction. In case of unavoidable change, approval from the supervisor shall be obtained by the results of the arc stud weld test.

(4) Weather conditions

When the temperature is 0 ° C or less, welding is generally performed after preheating the steel material to about 50 ° C with a gas burner or the like.

When doing outdoor work, work is performed by shielding the wind by an appropriate method.

In rainy weather, do not do outdoor work. Also, in working right after the rain, pay attention to drying.

(5) Cleaning up

When performing welding, the tip end portion of the stud shall be prevented from foreign matters such as rust, grease, moisture, and the like from adhering to the welding.

The surface of the steel plate to be welded removes scales, rust, primers, etc. by grinding and removes harmful foreign matter such as water and oil.

(6) Drying of welding auxiliary material

A welding auxiliary material such as a ferrule and a cartridge shall be used in dry. Auxiliary materials that have been moisture-proofed shall not be used when it elapsed for more than 4 hours since opening.

(7) Welding position

The welding of the arc stud dowel should be done downward as a standard.

(8) Securing welding conditions

Welding conditions determined by welding procedure test shall be completely satisfied during welding operation.

(9) Variation range of welding conditions

For stud dowel welding, the allowable error range of current and arc time is based on within ± 5% of the target value.

(10) Magnetic blow prevention

At the time of welding, measures shall be taken such as placing iron pieces or the like so as not to cause offset or undercut of reinforcement by magnetic blowing.

(11) Test welding

Test welding shall be conducted before welding is started and welding conditions shall be confirmed.

If work is interrupted during lunch breaks or the like, test welding is newly conducted and welding conditions are confirmed by a method such as bending test.

(12) Field welding

Welding stud dowels at the site shall be avoided because scaffolding, power supply, welding environment etc. are difficult to be maintained.

(13) Re-welding

When re-welding is carried out, finish the base material smoothly. It is checked whether defects remain in the steel plate.

It is desirable to perform the re-welding at the adjacent position. Weld repair with electrode shall not be carried out.

3.3.7 Referential provisions of AASHTO related to shear connector (stud dowel)

(1) Materials

Stud shear connectors shall conform to the requirements of Cold-Finished Carbon Steel Bars and Shafting, AASHTO M 169 (ASTM Al08), cold-drawn bars, Grades 1015, 1018, or 1020, either semi- or fully− killed. If flux retaining caps are used, the steel for the caps shall be of a low-carbon grade suitable for welding and shall comply with Cold-Rolled Carbon Steel Strip, ASTM A 109/A109M.

Tensile properties, as determined by tests of bar stock after drawing or of finished studs, shall conform to the requirements in Table 3-24 in which the yield strength is as determined by a 0.2-percent offset method.

Table 3-24 Tensile Properties of Stud Shear Connectors

Tensile Strength	60 ksi
Yield Strength	50 ksi
Elongation	20% in 2.0 in.
Reduction of Area	50%

(2) Test Method

Tensile properties shall be determined in accordance with the applicable sections of AASHTO T 244 (ASTM A370), Mechanical Testing of Steel Products. Tensile tests of finished studs shall be made on studs welded to test plates using a test fixture similar to that shown in Figure 7.2 of the current AASHTO/AWS Dl.5M/Dl.5 *Bridge Welding Code*. If fracture occurs outside of the middle half of the gage length, the test shall be repeated.

(3) Finish

Finished studs shall be of uniform quality and condition, free from injurious laps, fins, seams, cracks, twists, bends, or other injurious defects. Finish shall be as produced by cold-drawing, cold-rolling, or machining.

(4) Certification

The Manufacturer shall certify that the studs as delivered are in accordance with the material requirements of this section. Certified copies of in-plant quality-control test reports shall be furnished to the Engineer upon request.

(5) Check samples

The Engineer may select, at the Contractor's expense, studs of each type and size used under the contract documents as necessary for checking the requirements of this Section.

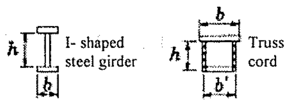
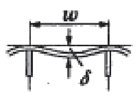
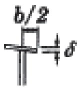
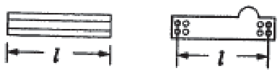
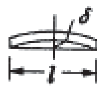
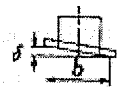
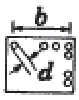
Note: For details on working, see 7. Stud Welding of Bridge Welding Code of AASHTO.

3.4 Member Precision

(1) The precision of the size of the members constituting a steel bridge must be at the level satisfying the prescribed precision that is the premise of the design.

(2) Clause (1) may be deemed to be satisfied, when the precision of a member is as stipulated in Table 3-25.

Table 3-25 Precision of Member

No.	Item			Allowable variation (mm)	Remark	Measurement method
1	Flange width b (m) Web plate height h (m) Web plate distance b' (m)			$\pm 2 \cdots\cdots b \leqq 0.5$ $\pm 3 \cdots\cdots 0.5 < b \leqq 1.0$ $\pm 4 \cdots\cdots 1.0 < b \leqq 2.0$ $\pm(3+b/2) \cdots\cdots 2.0 < b$	The b in the left column represents b, h and b'.	
2	Plate deviation from flatness (mm)	Web plate of member such as a bridge girder, truss, etc.		h/250	h: Web plate height (mm)	
		Flange of box girder, truss, etc., and deck plate of steel floor system		w/150	w: Distance of web plate or rib (mm)	
3	Flange squareness (mm)			b/200	b: Flange width (mm)	
4	Member length l (m)	Steel girder		±3・・・・l≦10 ±4・・・・・l＞10		
		Truss, arch, etc.		±2・・・・・・ l≦10 ±3・・・・・・・ l＞10		
		Expansion joint		0 to 30		
5	Bend of compression member (mm)			l /1,000	l: Member length (mm)	
6	Steel pier	Perpendicular degree between stud and base plate (mm)		b/500	b: Member width (mm)	
7		Base plate	Hole position	2	b: Distance between hole centers (mm)	
			Hole width	0 to 5	d: Hole diameter (mm)	

Concerning the member precision, the allowable values corresponding to the provisions on design from the chapters 2 to 16 of JHBS 2002 are shown and the measurement methods are clearly described.

It is preferable to refer to Table 3-26 for the measurement points and quantities.

Table 3-26 Measurement Point or Quantity of Member

No.	Item			Steel girder	Truss, arch, etc.
1	Flange width *b* (m) Web plate height *h* (m) Web plate distance b' (m)			Main girder, main structure	Near each support and each middle span
				Floor system, etc.	Near the center of one member picked up per five members for each structure
2	Plate deviation from flatness (mm)	Web plate of member such as a bridge girder, truss, etc.		Main girder	Near each support and each middle span
		Flange of box girder, truss, etc., and deck plate of steel floor system			
3	Flange squareness (mm)				
4	Member length *l* (m)	Steel girder		Total number of primary members in general that are not for temporary assembly	
		Truss, arch, etc.			
		Expansion joint		Products in general	
5	Bend of compression member(mm)			—	Total number of primary members
6	Steel pier	Perpendicular degree between stud and base plate (mm)		—	Each stud, base plate
7		Base plate	Hole position	–	Total number
			Hole width	–	Total number

The plate deviation from flatness shows the allowable value of distortion from welding, and together with the bend precision of a compression member corresponds to the fact that the allowable stress of a compression member is obtained by taking the effect of the initial deflection into consideration. However, because the allowable value stipulated here shows the limit of distortion, it is recommended that values smaller than those shown here be targeted during construction. Moreover, the flatness deviation is the limit of the allowable value of a deck plate for pavement and also the limit of the unevenness due to welding of a stiffener in a web plate, etc.

The allowable value on the negative side of the member length of an expansion joint has been abolished in order to ensure the effective width of a road.

3.5 Assembly Precision

(1) The assembly precision of the members constituting a steel bridge must be at the level satisfying the performance required in design after the completion of erection.

(2) Clause (1) may be deemed to be satisfied when erected in accordance with Clause (3).

(3) After the completion of erection, the assembly precision of the combined members satisfies the allowable values of Table 3-27.

Table 3-27 Assembly Precision after Completion of Erection

Item	Allowable value (mm)
Span length	(20 + *L*/5)
Warp	(25 + *L*/2)
Alignment	(10 + 2*L*/5)

Note: In the formula of allowable value, L is the span length (m) of the main girder and the main structure, respectively.

The size precision required in the construction of a bridge is for the bridge to be of the shape conforming to the design in its competed system. However, it is difficult to stipulate these in a concrete manner in accordance with the required performance of a bridge. Consequently, the items shown in Table 3-27 are stipulated from existing records, the actual situation of construction, etc., in consideration of securing the basic sizes of the steel bridge and of the effect on the post-process such as floor deck work and paving work.

Concerning other items that are not stipulated here, it may be considered that the necessary precision can be secured under the normal circumstances by ensuring the member precision stipulated in Section 3.4 and by conducting the appropriate quality control and site management until the completion of the erection. This is shown as an example in which the sufficient precision of the distance between girders can essentially be achieved by managing the installment precision of the bearing and the length of the crossbeam. Therefore, no particular provisions about these items are stipulated in the clause. Moreover, the span length can be stipulated by the amount of displacement of a bearing. In this case the displacement amount at each bearing may be stipulated to be within (10 + L/10).

Besides the items of Table 3-27, for the purpose of preventing excessive torsion in a completed form it must be checked that the supports are at the prescribed heights. Furthermore, the allowable values (albeit empirical) concerning the pier after the completion of erection as shown in Table 3-28 may be adopted for reference.

Table 3-28 Assembly Precision of Pier after the Completion of Erection

Item	Allowable value
Standard height	20 (mm)
Distance between gate piers	20 (mm)
Tilt of column	1/500

The check of size precision (temporary assembly) performed in the middle of manufacturing and erection with the members combined is performed in order to confirm beforehand that the prescribed assembly precision will be obtained after the completion of erection. There can be cases where the assembly precision after the completion of erection can be secured without conducting a temporary assembly by maintaining the member precision or the precision of the installment of a bearing in a bridge, etc., through means of a simple structure and easy precision management.

Contrastingly, there can also be cases where it is preferable to perform a temporary assembly for the purpose of avoiding adjustments in a bridge form with a complicated structure or after the completion of erection. Therefore, it is necessary to study the necessity of the temporary assembly as well as its method and range in consideration of the structural form, skew angle, curvature and erection method of a bridge.

Moreover, in performing a temporary assembly, a quality-control procedure for the measuring item, measurement method, allowable value, etc. must be stipulated appropriately in advance at the design stage, and Table 3-29 may be used in this regard for reference. Additionally, Table 3-30 may be used for the criteria of the measurement method and frequency of the measuring item at the time of assembly.

Concerning the temporary assembly, there are the method of actually assembling members and the method of checking the state of assembly by a numerical simulation using the results of member measurement. In the latter case, in applying a system whose sufficient reliability has been confirmed by showing consistency with the data from measurement of the actual shape, it is possible to perform the same degree of confirmation in terms of quality as the method of actually assembling members.

Moreover, in the method of actually combining members it is generally conducted with a support so that each member may be regarded as being in the state of non-stress. In such a case, bolts and drift pins must be used and solidly tightened up in the portion of on-site connection of the primary part out of respective combined members. Additionally, when a mismatch between the base material and connection plate arises, the necessary repair must be performed.

When the site joint is re-created on the erection site in the same manner as in the temporary assembly, the prescribed shape can be obtained. However, there may be cases where all members are not put into the same stress state as in the temporary assembly, depending on the erection method. For example, when erecting a curved girder to be erected without support and a skew bridge with a steep skew angle, there may be cases where the distortion of a main girder and the difference of mutual deflection between the main girders arise, resulting in a discrepancy in connection between the crossbeam and the sway bracing on the one hand and a main girder on the other. In such cases, an appropriate method of temporary assembly must be selected in consideration of design and the method of erection.

The warping in Table 3-29 shows the values when individual members are combined in the state of non-stress. Therefore, when stress is acting upon the members when conducting a temporary assembly by actually combining the members, strain is generated in the members however accurately the shape is formed, and it is impossible to assemble them accurately in erection. For example, because the steel girder that is a composite girder has relatively small stiffness, the warping can be adjusted over a wide range by changing the intensity of the reaction force at the support in a temporary assembly. However, one must avoid subjecting the members to deformation at the time of temporary assembly, since it would create an obstacle to assembly at the time of erection.

Additionally, when the warping of a bridge girder or a steel floor-deck girder is measured, the measurement is affected by the difference in temperature between the upper and lower flanges arising from solar radiation. Care should be taken in this regard.

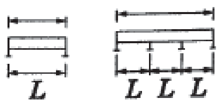
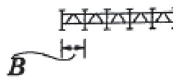
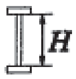
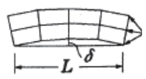
The allowable value of a clearance in the site joint portion is the one having been conventionally stipulated on the basis of the actual work situation. Particularly when there is a problem of water infiltration from a clearance, a water-proofing treatment such as the filling of a water-proofing agent shall be administered.

Moreover, when a concave member, etc., is involved, there are cases where a clearance is made in a site joint portion in order to facilitate the assembly of members on site. The value of a clearance in a site joint portion shown in Table 3-29 indicates the allowable variation for the values described in design drawings in consideration of these factors.

Because the expansion joint is directly subjected to the wheel load, the impact increases when a bump is generated, giving rise to the failure of the expansion joint itself, the portion to connect with the girder, floor deck, etc. Therefore, care should be taken.

Additionally, for the location at which to measure the various types of precision shown in Table 3-29, Table 3-30 can be used as a standard.

Table 3-29 Precision of Temporary Assembly

Item	Permissible variation (mm)	Remark	Measurement method
Overall length, span length L (m)	$\pm$ $(10+L/10)$		Overall Length Overall Length 
Distance between centers of main girder, main structure B (m)	± 4 $B \leqq 2$ $\pm$ $(3+B/2)$ $B>2$		
Assembled height of main structure H (m)	± 5 $H \leqq 5$ $\pm$ $(2.5+H/2)$ $B>5$		
Bridge edge of main girder, main structure (mm)	$5+L/5$ $L \leqq 100$ 25 $L>100$	L: Traverse line length (m)	 Main girder

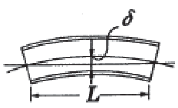
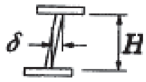
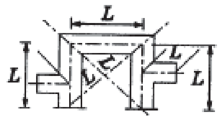
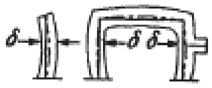
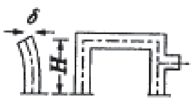
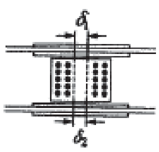
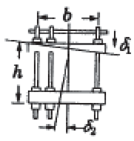
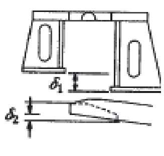
Warping of main girder, main structure (mm)		-5 to +5 $L \leqq 20$ -5 to +10 $20 < L \leqq 40$ -5 to +15 $40 < L \leqq 80$ -5 to +25 $80 < L \leqq 200$	L: Span length of main girder, main structure (m)	
Crosspoint difference at bridge edge of main girder, main structure (mm)		10		 Main girder
Verticality of main girder, main structure (mm)		3+H/1,000	H: Height of main girder, main structure (mm)	
Steel pier	Distance between centers, diagonal length of column L (m)	± 5 $L \leqq 10$ ± 10 $10 < L \leqq 20$ $\pm 10 + \left(\frac{L-20}{10}\right)$ $20 < L$		
Steel pier	Camber of beam and bend of column (mm)	L/1,000	L: Traverse line length (m)	Side view Front view 
Steel pier	Verticality of column (mm)	10 $H \leqq 10$ H $H > 10$	H: Height (m)	Side view Front view 
Clearance in site joint portion (mm)		5	δ: δ1 or δ2 of the right figure, whichever is larger (mm)	
Anchor frame	Levelness of upper δ1 (mm)	b/500	b: Bolt distance (mm)	
Anchor frame	Verticality δ2 (mm)	h/500	h: Height (mm)	
Anchor frame	Height h (mm)	5		
Expansion joint	Difference in height from expansion joint to be combined δ1 (mm)	Designed value ±4		 Actual measurement value
Expansion joint	Discrepancy between fingers δ2 (mm)	2		

Table 3-30 Location or Number to Measure Temporary Assembly Precision

Item		Steel girder	Truss, arch, etc.
Overall length, span length	L(m)	Total number of main girders, main structures	
Distance between centers of main girder, main structure	B(m)	Near each support and each middle span	
Assembled height of main structure	H(m)	–	Both end portion and central portion

Alignment of main girder, main structure		δ(mm)	One support and one middle span concerning outermost main girder or main structure	
Warping of main girder		δ(mm)	Distance of 10 to 12 m for each main girder	Each panel point of each main structure
Cross point difference at bridge edge of main girder		δ(mm)	Either end of main girder (main structure)	
Verticality of main girder		δ(mm)	Both end portion of each main girder	Near support and middle span
Steel pier	Distance between centers, diagonal length of column	L(m)	–	Both end portion and cantilever beam portion
	Camber of beam and bend of column	δ(mm)	–	Each panel point of each main structure
	Verticality of column	δ(mm)	–	Each column and cantilever beam portion
Clearance in site joint portion		δ(mm)	Half of total number of joints of main girder, main structure	
Anchor frame	Levelness of upper surface	δ(mm)	–	Total number on axle core
	Verticality	δ(mm)	–	
	Height	h(mm)	–	
Expansion joint	Difference in height from expansion joint to be combined	δ1(mm)	Near both end portions and central portion	
	Discrepancy between fingers	δ2(mm)		

3.6 Painting

3.6.1 General

(1) Scope of Application

i) This Manual is applied for the painting work for new steel bridge construction in the Republic of the Union of Myanmar.

ii) Special members such as cables and accessories are dealt with other specification.

iii) Concrete, timber, drainage facilities, inspection car, lighting pole and submarine structures are out of scope of this Manual.

Hot dip zinc galvanization is desirable for inspection ways, bearings and bolts for secondary members. On the other hand, combined member of zinc galvanized and aluminum or stainless shall not be used because of contact corrosion of different kinds metal.

(2) Painting Management and execution method.

Contractors shall submit the painting work plan including painting work method and internal inspection method and get approval of the Engineer.

The Manual is established to commit QC to QC management system of contractor on entire painting work of steel bridge. Painting work shall be done even in different environments of both at factory and field in accordance with compatible QC system.

(3) Painting manager

Contractor shall establish a paint work manager who is well versed in painting work.

Painting manager shall summarize to proceed paint classification, paint adjustment, painting equipment and instrument adjustment, working environment adjustment and quality guarantee of coated film internal inspection in smooth and safe, and manage with managing sheet.

i) Paint classification

Classification due to members, paint classification of splicing members, classification of inside and outside of box section.

ii) Adjustment of paint material

Material to be used shall satisfy the paint standards, amount of paint shall be enough to provide the necessary film thickness, paint quality shall satisfy that the specified period did not pass and satisfy the condition of pot life etc. to keep the required performance.

iii) Adjustment of painting instruments

Select the appropriate paint tools in accordance with paint characteristics and paint method and adjust sufficiently.

iv) Adjustment of painting work environment

It may happen that even though paint, tools and skills are sufficient, good painting film cannot be obtained when working in bad environment.

To comprehend the limitation of temperature and humidity depending on paint, and limitation of working condition of objects to be painted is needed. Particularly, rainfall, snow fall and dew formation after painting work needs sufficient treatment. And also, to decide in comprehensive manner and to proceed the work in consideration for environment, tentative base, and working scaffold are necessary. Environmental contamination during painting should be paid attention.

v) Quality Assurance of paint film and internal inspection

Inspect and confirm the surface treatment, painting interval, film thickness and inspection of paint color. Record the decision, inspection and result.

Wide range of knowledge is necessary including safety countermeasure during painting work, paint component and dust due to blasting.

vi) Safety Control

Wide range of knowledge is necessary including safety countermeasure during painting work, paint component and dust due to blasting.

vii) Others

Contact and cooperation are needed with person in charge of overall responsible Manager.

(4) Inspection

There are two inspections. One is internal inspection and other is witnessed inspection by supervisor. Internal inspection is conducted by the Contractor voluntarily in accordance with progress of his work and results are treated in accordance with this Manual.

Followings are items of internal inspection

1) Acceptance inspection of paint material
2) Storing inspection
3) Surface treatment inspection
4) Environment inspection
5) Stirring inspection of paint
6) Paint inspection of maturity and pot life
7) Film Inspection (thickness and defects)
8) Repaired film inspection
9) Repainting inspection

Supervisor's inspection are as follows.

1) Painting Plan・・・・・・・・・・・Confirmation and Approval.
2) Dry film thickness・・・・・・・・Witness Inspection or Document Inspection
3) Repair Painting・・・・・・・・・Witness Inspection or Document Inspection
4) Repainting・・・・・・・・・・・Witness Inspection or Document Inspection

(5) Reporting

Report based on this manual shall be done by documents after inspection.

1) Photo record shall be attached in line with work progress.
2) Contractor shall preserve inspection record for 3 years after completion.

(6) Defect

The items of intended paint film defect are as follows.

1) Significant color change or degradation
2) Crack
3) Swelling
4) Corrosion
5) Peeling

(7) Query and Others

Contractor shall confer with Supervisor with written documents when query arises on this Manual.

Contractor shall confer previously with Supervisor for preparation of Work Plan and actual Paint Work if Queries arise.

3.6.2 New Bridge Painting

(1) Painting Specification

i) General

5 painting specifications are proposed depending on bridge site environment and condition of client order with respect to member portions.

Spec. I is applied for Category 1 Bridge. Spec. II is applied for Category 2 Bridge. Spec. III is applied for Category 3 Bridge. Spec. IV is applied for Category 4 Bridge and Spec. V is applied for Category 5 Bridge.

Painting specification for galvanized member, cables, difficult part to paint are specified in contract document respectively.

Table 3-31 Applied Specification

	Use Application
Category 1	Current specification executed in general condition
Category 2	Contact surface is coated to protect contamination due to rust in addition to Spec. 1
Category 3	Top coat is changed to fluorine from Spec 2. This is applied for the bridge's durability is required such as cross over railway, or weather resistant in consideration for Aesthetic view.
Category 4	Under very severe condition such as coastal area with moderate salinity.
Category 5	Under very severe condition such as coastal area with high salinity.

Table 3-32-a Spec. I (Refer to ISO 12944-5-2007)

Spec. I (ISO-12944-5: C4-High, A4.15)

	Surface Treatment	Primer Binder	Primer DFT (μm)	Surface Treatment	1st Layer Binder	1st Layer DFT (μm)	Interval	2nd Layer Binder	2nd Layer DFT (μm)	Interval	3rd Layer Binder	3rd Layer DFT (μm)	Total DFT (μm)
	Steel Mill			Fabrication Shop									
External General Part	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	60	1.5h-1M	Epoxy Resin Paint	120	1.5h-1M	Polyurethane	60	240
	Steel Mill			Fabrication Shop									
Internal General Part	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	75	1.5h-1M	Epoxy Resin Paint	90				165
	Steel Mill			Fabrication Shop									
Contact Surface of Bolt Joint	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)									0
	Steel Mill			Site									
External of Un-contact Surface of Bolt Joint	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	60	1.5h-1M	Epoxy Resin Paint	120	1.5h-1M	Polyurethane	60	240
	Steel Mill			Site									
Internal of Un-contact Surface of Bolt Joint	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	75	1.5h-1M	Epoxy Resin Paint	90				165
	Steel Mill			Fabrication Shop									
To be paved surface of steel deck	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	50							50
	Steel Mill			Site									
External of Welded Joint	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	60	1.5h-1M	Epoxy Resin Paint	120	1.5h-1M	Polyurethane	60	240
	Steel Mill			Site									
Internal of Welded Joint	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	75	1.5h-1M	Epoxy Resin Paint	90				165

Table 3.32b Spec. II

Spec. II (ISO-12944 C4-High, XXXX)

	Surface Treatment	Primer Binder	Primer DFT (μm)	Surface Treatment	1st Layer Binder	1st Layer DFT (μm)	Interval	2nd Layer Binder	2nd Layer DFT (μm)	Interval	3rd Layer Binder	3rd Layer DFT (μm)	Total DFT
	Steel Mill			Fabrication Shop									
External General Part	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	60	1.5h-1M	Epoxy Resin Paint	120	1.5h-1M	Polyurethane	60	240
	Steel Mill			Fabrication Shop									
Internal General Part	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	75	1.5h-1M	Epoxy Resin Paint	90				165
	Steel Mill			Fabrication Shop									
Contact Surface of Bolt Joint	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO Sa 2.5	*In-Organic or organic Zinc Rich Paint	75							75
	Steel Mill			Site									
External of Un-contact Surface of Bolt Joint	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	60	1.5h-1M	Epoxy Resin Paint	120	1.5h-1M	Polyurethane	60	240
	Steel Mill			Site									
Internal of Un-contact Surface of Bolt Joint	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	75	1.5h-1M	Epoxy Resin Paint	90				165
	Steel Mill			Fabrication Shop									
To be paved surface of steel deck	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	50							50
	Steel Mill			Site									
External of Welded Joint	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	60	1.5h-1M	Epoxy Resin Paint	120	1.5h-1M	Polyurethane	60	240
	Steel Mill			Site									
Internal of Welded Joint	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	75	1.5h-1M	Epoxy Resin Paint	90				165

*1) If Organic Zinc Rich Paint is used, it should be proved the friction factor of contact surface is over 0.4

Table 3.32c Spec. III

Spec III (ISO-12944 C4-High, XXXX)

	Primer			1st Layer				2nd Layer			3rd Layer			3rd Layer		Total
	Surface Treatment	Binder	DFT (μm)	Surface Treatment	Binder	DFT (μm)	Interval	Binder	DFT (μm)	Interval	Binder	DFT (μm)	Interval	Binder	DFT (μm)	DFT (μm)
External General Part	Steel Mill			Fabrication Shop												
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	60	1.5h-1M	Epoxy Resin Paint	140	1.5h-1M	Fluorine Undercoat	30	2h - 10d	Fluorine Resin Paint	30	260
Internal General Part	Steel Mill			Fabrication Shop												
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	75	1.5h-1M	Epoxy Resin Paint	90							165
Contact Surface of Bolt Joint	Steel Mill			Fabrication Shop												
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO Sa 2.5	*In-Organic or Organic Zinc	75										75
External of Un-contact Surface of Bolt Joint	Steel Mill			Site												
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	60	1.5h-1M	Epoxy Resin Paint	120	1.5h-1M	Fluorine Undercoat	30	2h - 10d	Fluorine Resin Paint	30	240
Internal of Un-contact Surface of Bolt Joint	Steel Mill			Site												
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	75	1.5h-1M	Epoxy Resin Paint	90							165
To be paved surface of steel deck	Steel Mill			Fabrication Shop												
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	50										
External of Welded Joint	Steel Mill			Site												
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	60	1.5h-1M	Epoxy Resin Paint	120	1.5h-1M	Fluorine Undercoat	30	2h - 10d	Fluorine Resin Paint	30	240
Internal of Welded Joint	Steel Mill			Site												
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint	75	1.5h-1M	Epoxy Resin Paint	90							165

*1) If Organic Zinc Rich Paint is used, it should be proved the friction factor of contact surface is over 0.4

Table 3.32d Spec. IV （Refer to C5 of Japanese Standard Handbook of Corrosion Protection 2014）

Spec IV（Paint Manual for Steel Bridge（Japan Road Association,2015)

	Primer			1st Layer				2nd Layer			3rd Layer			4th Layer			5th Layer		Total
	Surface Treatment	Binder	DFT (μm)	Surface Treatment	Binder	DFT (μm)	Interval	Binder	DFT (μm)	Interval	Binder	DFT (μm)	Interval	Binder	DFT (μm)	Interval	Binder	DFT (μm)	DFT (μm)
External General Part	Steel Mill			Fabrication Shop															
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO Sa 2.5	Inorganic Zinc Rich Paint	75	4h-6M	Epoxy Resin Paint(Mist Coat)	(15)	1.5h-1M	Epoxy Resin Paint	120	1.5h-1M	Fluorine Undercoat	30	2h - 10d	Fluorine Resin Paint	25	250
Internal General Part	Steel Mill			Fabrication Shop															
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Modified Epoxy Resin Paint	120	1.5h-1M	Modified Epoxy Resin Paint	120										240
Contact Surface of Bolt Joint	Steel Mill			Fabrication Shop															
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO Sa 2.5	Inorganic Zinc Rich Paint	75													75
External of Un-contact Surface of Bolt Joint (Plate Surface)	Steel Mill			Fabrication Shop			Site												
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO Sa 2.5	Inorganic Zinc Rich Paint	75	4h-6M	Modified Epoxy Resin Paint(Mist Coat)	(15)	1.5h-1M	Ultra thick Epoxy Resin Paint or Epoxy Resin	300	16h - 10d 1.5h x 3 - 10day	Fluorine Undercoat	30	2h - 10d	Fluorine Resin Paint	30	435
External of Un-contact Surface of Bolt Joint (Bolt Head and Nut)	Steel Mill			Fabrication Shop			site												
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3	Organic Zinc Rich Paint (x 1～2)	75	4h-6M	Ultra thick Epoxy Resin Paint or Epoxy Resin Paint (x2～3)	300	16h - 10d 1.5h x 3 - 10day	Fluorine Undercoat	30	2h - 10d	Fluorine Resin Paint	30				435
Internal of Un-contact Surface of Bolt Joint (Plate Surface, Bolt Head and Nut)	Steel Mill			Fabrication Shop			Site												
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO Sa 2.5	Inorganic Zinc Rich Paint	75	4h-6M	Modified Epoxy Resin Paint (Mist Coat)	(15)	1.5h-1M	Ultra thick Epoxy Resin Paint or Epoxy Resin Paint (x2～3)	300							375
To be paved surface of steel deck	Steel Mill			Fabrication Shop															
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint (x 1～2)	50													50
External of Welded Joint	Steel Mill			Fabrication Shop			site												
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint (x 1～2)	75	4h-6M	Modified Epoxy Resin Paint	60	1.5h-1M	Modified Epoxy Resin Paint	60	1.5h-1M	Fluorine Undercoat	30	2h - 10d	Fluorine Resin Paint	30	255
Internal of Welded Joint	Steel Mill			Fabrication Shop			site												
	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint (x 1～2)	75	4h-6M	Ultra thick Epoxy Resin Paint or Epoxy Resin Paint (x2～3)	300										375

All interval periods are minimum.

Table 3.32e Spec. V （Refer to revised ISO 12944-5-2018 C-5 Very High）

Spec V (ISO 12944-5-2018 C-5 very high

=L1	Surface Treatment	Primer		Surface Treatment	1st Layer		Interval	2nd Layer		Interval	3rd Layer		Interval	4th Layer		Interval	5th Layer		Total DFT (μm)
		Binder	DFT (μm)		Binder	DFT (μm)		Binder	DFT (μm)		Binder	DFT (μm)		Binder	DFT (μm)		Binder	DFT (μm)	
	Steel Mill			Fabrication Shop															
External General Part	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO Sa 2.5	Inorganic Zinc Rich Paint	75	4h-6M	Epoxy Resin Paint (Mist Coat)	(15)	1.5h-1M	Epoxy Resin Paint	100×2	1.5h-1M	Fluorine Undercoat	30	2h - 10d	Fluorine Resin Paint	30	335
	Steel Mill			Fabrication Shop															
Internal General Part	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Modified Epoxy Resin Paint	120	1.5h-1M	Modified Epoxy Resin Paint	120										240
	Steel Mill			Fabrication Shop															
Contact Surface of Bolt Joint	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO Sa 2.5	Inorganic Zinc Rich Paint	75													75
	Steel Mill			Fabrication Shop			Site												
External of Un-contact Surface of Bolt Joint (Plate Surface)	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO Sa 2.5	Inorganic Zinc Rich Paint	75	4h-6M	Modified Epoxy Resin Paint (Mist Coat)	(15)	1.5h-1M	Ultra thick Epoxy Resin Paint or Epoxy Resin Paint (x2～3)	300	16h - 10d 1.5h x 3 - 10day	Fluorine Undercoat	30	2h - 10d	Fluorine Resin Paint	30	435
	Steel Mill			Site															
External of Un-contact Surface of Bolt Joint (Bolt Head and Nut)	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3	Organic Zinc Rich Paint (x 1～2)	75	4h-6M	Ultra thick Epoxy Resin Paint or Epoxy Resin Paint (x2～3)	300	16h - 10d 1.5h x 3 - 10day	Fluorine Undercoat	30	2h - 10d	Fluorine Resin Paint	30				435
	Steel Mill			Fabrication Shop			Site												
Internal of Un-contact Surface of Bolt Joint (Plate Surface, Bolt Head and Nut)	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO Sa 2.5	Inorganic Zinc Rich Paint	75	4h-6M	Modified Epoxy Resin Paint (Mist Coat)	(15)	1.5h-1M	Ultra thick Epoxy Resin Paint or Epoxy Resin Paint (x2～3)	300							375
	Steel Mill			Fabrication Shop			Site												
To be paved surface of steel deck	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint (x 1～2)	50													50
	Steel Mill			Fabrication Shop			Site												
External of Welded Joint	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint (x 1～2)	75	4h-6M	Modified Epoxy Resin Paint	60	1.5h-1M	Modified Epoxy Resin Paint	60	1.5h-1M	Fluorine Undercoat	30	2h - 10d	Fluorine Resin Paint	30	255
	Steel Mill			Fabrication Shop			Site												
Internal of Welded Joint	ISO Sa 2.5	Inorganic Zinc Rich Primer or Epoxy Primer	(15)	ISO St 3 (Power Tool)	Organic Zinc Rich Paint (x 1～2)	75	4h-6M	Ultra thick Epoxy Resin Paint or Epoxy Resin Paint (x2～3)	300										375

All interval periods are minimum.

ii) Common

Common items covering all painting systems are as follows.

i) Mill Plate Blasting means painting system conducted by mill maker. Epoxy primer or inorganic zinc rich primer is painted after roll and removal of mill scale automatically. Steel plate is damaged on the process of cutting and welding and then corrosion arise. After removing these corrosions by blasting or power tool such as disc sander or power brush, 1st layer painting work shall be started.

ii) Grades of rust removal on surface treatment

Primary surface treatment : better than ISO Sa2.5

Secondary surface treatment : Blasting better than ISO Sa2.5

Power tool better than ISO St3

iii) When white rust arises on thick inorganic zinc rich paint, white rust shall be removed as much as possible.

iv) Epoxy resin or modified epoxy resin paint diluted to approximately 50% shall be used for mist coat.

v) Dry film thickness is shown with standard value. They are dry film thickness painted by spray in factory and brushing at the site. Mist coat is not added to total film thickness.

vi) Painting interval is the time restriction under condition of temperature 20℃, humidity 75%. Painting interval should be adjusted when the condition is quite different from standard condition. Hereafter, h means hour, d means day, m means month.

vii) When piling up the coat of paint, different color shall be used.

(2) Paint

i) Paint to be used and Standards

Paint to be used for new construction bridge shall conform to Table 3-33 and exert the necessary performance. The paint that are used at the same part shall be the products produced in same paint maker from lower layer to top layer.

Table 3-33 Paint to be used

No	Standard No	Paint Name
	ISO 12944-5 or JIS K 5552: 2010	In-organic zinc rich primer
	ISO 12944-5 or JIS K 5551: 2008	Epoxy primer
	ISO 12944-5	Organic zinc rich paint
	ISO 12944-5	Epoxy resin paint
	ISO 12944-5	Epoxy resin paint (Mist Coat)
	ISO 12944-5	Polyurethane
	ISO 12944-5	In-organic zinc rich paint
	ISO 12944-5	Fluorine Undercoat*1)
	ISO 12944-5	Fluorine Resin Paint*2)
	ISO 12944-5	Modified Epoxy Resin Paint
	ISO 12944-5	Modified Epoxy Resin Paint (Mist Coat)
	ISO 12944-5	Ultra- thick Epoxy Resin Paint

Standard No. is in accordance with XXX.

*1) The Fluorine Undercoat is made by epoxy polyol or Fluorine as a main material and should not hinder top coat painting.

*2) The Fluorine Resin Paint should contain 15% Fluorine.

ii) Inspection of Quality of Paint Material

a) Standard Certificate (Pass certificate inside company); With regard to paint material to be used, Standard Certificate shall be compatible with relevant Standard. Standard certificate shall be inspected with respect to kinds of paint and production lots.

b) Confirm the display on the container of standard number and its name.

c) As for amount of paint, it shall be confirmed that required design amount has been conveyed.

d) Sample Inspection of paint; When the quality of paint to be used is doubted and sampling inspection is judged necessary, random sampling test shall be done by picking up from paint material to be used at the official organization based on this paint standard. If the result is failed, additional tests shall be done two times by sampling two times specimens from same lot as failed specimen, and both two results reveal to pass, they are acceptable. If even one of them fail, the lot shall be rejected and not be used.

1) Quality inspection is carried out in paint maker in principle.
2) Example of assurance of quality standard of paint is shown as Table 3-34.
3) Sampling inspection method is stipulated in contract documents

Table 3-34 Quality Certificate of Paint

	Paint Name	**Company Name**
Product Name		Paint Component
Lot Number		
Amount of Delivery		
Standard and Test Result		
Test Items	**Paint Standard**	**Test Result**
Grain		
Workability		
Drying Time		
Remarks	Specific gravity in case of	
	showing in l:	

iii) Color

a) Color of intermediate and lower layer are adjusted and selected to get the prescribed color on top layer in specified documents.
b) Uneven color shall not be allowed.
c) Colors on intermediate and lower layer shall be hidden by top layer. Color number of top layer shall be shown based on the Standard of color swatch (this will be stipulated in Myanmar)

iv) Storage and Management of Paint

a) Storage and management shall comply with Fire Defense Law, Industrial Safety and Health Law, and Organic Solvent Intoxication Prevention Law etc. and relevant law.
b) Paint shall be stored not to convert, and paint of which effective period is displayed shall not be used for expired period.
c) The paint of which can opened shall be used within same day.
d) As inflammable substance and harmful materials are included in paint, paint material shall be paid caution for safety control during storage, and not stored in high temperature and exposed open air where materials are concerned to convert.
e) Multi liquid mixture paint is apt to convert in long term storage. It is a problem to determine the effective duration uniformly because the period to convert is significantly different

depending on the stored state, temperature during storage. Therefore, storage place should be taken consideration as a standard of effective period which paint maker designates. It should be confirmed that paint material does not convert before use.

(3) Surface Treatment

i) Primary Surface treatment

a) Primary surface treatment means to blast and get suitable state on the original steel surface prior to processing at mill maker. (Hereinafter referred to as OPBT (original plate blasting treatment.)

b) OPBT is executed to all steel materials, however, product blasting can be adopted to form steel with approval of supervisor (The Engineer).

c) Grade of corrosion removal after blasting treatment shall comply with ISO Sa2 1/2.

d) Surface roughness is less than 80μ Rz based on the 10 points average roughness display method in JIS B 0601 or equivalent.

e) Blast treatment surface shall be cleaned and no harmful substance adhere.

f) Blasting method shall be dry method.

g) After blasting, epoxy primer or in-organic zinc rich primer shall be painted. Interval limit between blasting and painting is within 4 hours.

h) Movement of member after primer painting shall be after the paint film dry.

i) Paint manager shall make the controlling sheets. Inspector shall confirm the controlling sheets when attend the inspection.

Table 3-35 shows the comparison of original steel plate blasting and product blasting.

Table 3-35 Comparison of Blasting

Items	Original plate blasting	product blasting
efficiency	Highly efficient due to automatic blasting machine	Not efficient due to manual machine
Safety	Good in safety and health because of mechanization	Special consideration is needed in safety and health.
Pollution	The work is done inside mill maker. Pollution problems are less.	This is done inside fabrication factory and counter measure for particles and noise must be facilitated.
Relation with welding and cutting	Primer paint affects to gas cutting, welding and strain removable.	No
Others	No	Flaw and other extra ordinaries during processing can be found

Surface roughness shall be tested by test blasting with measurement and determine the treatment conditions, quality and shape of blasting material.

ii) Secondary Surface Treatment

a) Secondary surface treatment is the work to make steel surface suitable for painting by blasting or power tool treatment after processing and assembly.

b) Product blasting is composed of full surface blasting and partial blasting. Classification of surface treatment and finishing state are shown in Table 3-36.

Table 3-36 Classification of Surface Treatment and Finishing State

Category	Grade of derusting	Surface roughness
product blasting treatment	ISO Sa2 1/2	70μRz or less
power tool treatment	ISO St3	

(Note)1. De-rusting grade comply with ISO

2. Surface roughness comply with JIS B 0601 10-point average roughness display method.

c) Secondary surface treatment is classified into that for new painting and repair painting

Table 3-37 Classification of Applied Treatment and Application Status

Treatment Classification		Applied State
Surface treatment prior to new painting	Full Surface Blasting	Full surface Blasting after block assembly
	Partial Surface Blasting	Partial blasting for corroded part after block assembly
	Power Tool	Power tool treatment to corroded part after block assembly.
Surface treatment prior to repair painting	Partial Blasting	Damaged part reaching to steel plate expand to wide area
	Power Tool	Damaged part reaching to steel plate expand to narrow area

a) Round cut with half diameter 2mm shall be attached at the corner of cut face at outer painting.

b) Product blasting shall be done indoors and within humidity of 80 %.

c) Time from secondary surface treatment to lower layer shall be within 4 hours.

d) Manager shall take a control sheet so as to be done according to working manual.

(4) Painting Work

i) Preparation of Work

Work preparation shall be done in accordance with following procedure.

a) Paint Instrument

Instrument shall be selected in consideration for shape, paint material and workability of object to be painted.

b) Working scaffold

Scaffold shall be safe and appropriate and installed in line with regulation. Foreman of scaffold work and safety manager shall be assigned, and caution shall be paid for safety countermeasure.

c) Preparation of object to be painted prior to painting

Members to be painted shall be placed on pedestals and kept on appropriate height to paint underside.

Surface to be painted shall be sufficiently cleaned of sand, dusts, oil and other harmful substances.

The part not to be painted (paint free part) shall be protected sufficiently for paint material not to adhere.

Surface not to be painted shall be as follows in principle.

Table 3-38 Paint Free Part

Sort	Intended Part
Paint free part	Finished surface such as bearing, pins, roller etc.
	Faying surface of bolt connection of general bridge
Long term exposed epoxy primer or inorganic zinc rich primer is allowed	Contact surface of concrete and steel plate

If sea salt particle adhere, surface shall be sufficiently cleaned by water prior to painting.

d) Preparation of Paint material

- Paint material shall be stirred sufficiently and uniformly after opening the can.
- Mixed paint shall be stirred sufficiently with main material and hardening agent by agitator and used after prescribed matured time and shall not be used after pot life (valid time) passed.
- When air spray is used, it shall be percolated with appropriate roughness sieve.

e) Mixture of dilution agent

Paint to be used shall be adjusted into appropriate viscosity depending on painting method and temperature.

When dilution agent is used, it shall be quantified accurately and added at least quantity. In this regard, dilution agent shall not be used for solvent free paint.

ii) Painting Scaffold

a) Painting scaffold shall comply with Labor Safety and Health Rule, bearing sufficiently loads of labor, instruments and paint etc. and shall be uninterrupted structure for work and facilitated with safety countermeasures for falling protection.

b) Field painting scaffoldings shall be facilitated with protection measures to avoid negative effects such as dispersion of paint etc.

c) Erection and removal work of scaffoldings shall comply with Labor Safety and Health Rule and be carried out under control of responsible foreman of scaffolding assemble.

d) When inspection car is used for painting, approval of the Engineer is needed.

iii) Selection of Painting Method

a) Painting work in factory shall be air spray and previous painting shall be brush.

b) Field painting shall be brush in principle. However, air spray can be used with approval of the Engineer, if sufficient protection counter measure is executed.

iv) Execution of Painting Work

a) Narrow and half sealed parts shall be painted prior to assembly.

b) Paint work shall be prohibited when temperature and humidity are under condition of Table 3-40.

c) Paint work shall not be permitted in states of Table 3-41. However, provided the counter measures shown in Table 3-41 are implemented.

d) As inorganic zinc rich paint is apt to deposit, it shall be stirred continuously during painting work.

e) Blending management shall be done in consideration for characteristics of each paint.

f) Primer shall be painted within 4 hours after surface treatment.

g) Overpainting Interval shall be sufficiently kept and done after confirming the state that the lower layer is available for overpainting.

h) In case of brush painting, uniform paint film shall be attained without significant unevenness of brush trace.

i) Wet film gauge shall be used for controlling film thickness during painting to get prescribed dry film thickness.

j) Paint film defects of each layer shall be repaired prior to next procedure.

Table 3-39 Check Sheet for Execution Condition

ST 01

Trade Name ofPaint					Made on Year/Month/Day		
Paint Sort							
	(Viscosity shall be measured by Iwata cup or Rion Viscosity Guage)						
Paint component	main medium						
	main pigment						
	main solvent	included amount (Wt%)					
Color phase							
Standard film thickness(μ m)/time	wet μ m				Dry μm		
Theoretical adhered quality(g/m2)					used spray (g/m2)		*
Specific gravity	Rare paint				Volatilised part Wt%		
Non volatilised part Wt%					Mixing ratio		
Viscosity of original liquid (20℃)							
Film Thickness limit at wet condition	Flow				Crack		
*No need to describe							
		0℃	5℃	10℃	20℃	30℃	
Drying time	Finger touch						
	half hardening						
	Perfect hardening						
Paint Interval	min						
	max						
Pot life							
Dilution Rate(Wt%)	Air Spray						
	Brush						
Maturity time							
Paint condition	Spray film condition	Viscosity		Appropriate:		Limit:	
		Distance to surface		mm	Nozzle tip number		
		Paint instrument			Mesh size of percolation		
		Primary pressure			Secondary pressure (Paint)		
	Environmental Condition	Relative humidity		% RH	Temperature		℃
		Surface temperature to be painted		Min, Max	Wind Speed		m/sec
Safety	Flashing Point (℃)						
	Risk Rate						
	Explosion Limit	Lower limit: % (Volume)			Upper limit: % (Volume)		
Parking Mode							
Dangerous, Poisonous and harmful substance display							

v) Paint Interval

Paint Interval shall be kept as shown in Spec. I – Spec. V. When the temperature and humidity are under condition of Table 3-40, painting work shall be stopped.

Table 3-40 Prohibited Condition of Temperature, humidity

Kinds of paint	Air temperature (℃)	Relative humidity （%）
Inorganic Zinc Rich Paint	lower than 5	lower than 50
Epoxy (Resin) Zinc Rich Paint	lower than 5	higher than 85
Epoxy Resin Paint for lower coat	lower than 5	higher than 85
Polyurethane Resin Paint for Top Coat	lower than 0	higher than 85
Inorganic Zinc Rich Primer	lower than 0	higher than 50
Epoxy resin primer	lower than 5	higher than 85
Organic Zinc Rich Paint for Upper surface of Steel Deck	lower than 5	higher than 85
Modified Epoxy Resin Paint for interior part	lower than 5	higher than 85
Ultra-thick Epoxy Resin Paint	lower than 5	higher than 85
Organic zinc rich paint	lower than 5	higher than 85
Epoxy Resin Paint for middle coat	lower than 5	higher than 85
Fluorine Resin Paint for top coat	lower than 5	higher than 85
Modified Epoxy Resin paint for lower coat of exterior surface	lower than 5	higher than 85
Epoxy Resin Primer	lower than 5	higher than 85
Fluorine under coat	lower than 5	higher than 85

vi) Restricted State of objects to be painted during Painting

Paint works shall not be allowed in the state of forbidden states shown in Table 3-41. However, it is permitted if measures in Table 3-41 are treated.

Table 3-41 Restricted State of Objects to be Painted

	Forbidden State	Measures	Reason
1	Surface to be painted is wet due to dew formation etc., and predicted that the state continues	Remove the liquid by air blow or sweeping with waste cloth.	It causes incomplete adherence of paint and corrosion
2	Temperature on the surface to be painted is lower than restriction or higher than 50˚ C	Wait until appropriate temperature or adjust the temperature in house.	It causes hardening and crack of paint and hampers to dry. Bubble and holes arise under hot weather.
3	Mud, sand, dirt, grease and other foreign material etc. are adhered on the surface to be painted.	Remove with power tool and waste cloth. However, grease etc. on Zinc Rich Paint shall be removed with blasting and Paint Zinc Rich Paint again	It causes incomplete adherence swelling and corrosion.
4	In outdoor painting works, rainfall snow and similar phenomena occur and predicted to affect paint film	Stop Painting or convey into house and just the temperature and humid	Hardening, incomplete adherence and change of properties occur
5	When predicted foreign materials are mixed in.	Stop painting and cure with appropriate cover	It causes incomplete adherence, swelling and corrosion
6	Prescribed surface treatment is not done	Do it as prescribed	Same as above

7	Using Paint material expires its pot life	Dispose of over pot file material	It causes bad performance of paint
8	Aberrance is found in Paint material due to default of appropriate dilution, mixing and stirring	Readjust. If readjustment cannot be done, it shall be disposed	Same as above

vii) Control of paint film thickness

1) Painting worker shall understand the relation between wet film thickness and dry film thickness of each paint prior to work, and confirm the conditions to attain targeted dry thickness with test painting. Wet film gauge shall be used during painting to control film thickness.

2) Confirmation shall be done whether dry film state is managed to comply with following standard value.

   i) The measured average film thickness shall be more than 90% of total thickness of standard.

   ii) Minimum measured film thickness shall be more than 70% of total thickness of standard.

   iii) Standard deviation of measured film thickness distribution shall be less than 20% of standard thickness. However, in case average is more than standard value, it can exceed 20%.

3) Measuring instrument shall be 2-point adjustable electromagnetic film thickness gauge. Standard steel plate to adjust shall be approximate material with measured material in principle, and thickness 6mm, size larger than 100 ×100mm, and surface roughness less than 5μRz. In addition, standard steel plate shall have approximate thickness and shall be non-magnetic.

4) Measuring lot and measuring number are as follows.

   i) Lot area

   Measuring lot is prepared with paint system, paint method, member to be painted. Area of lot shall be approximately 500m^2.

   ii) Measuring number

   Measuring number per lot is more than 25 points. Each point shall be measured 5 times and average of them shall be the measured value of the point.

5) Measuring time of dry thickness shall be at the completion of factory painting and final field painting shall be carried out with confirmation of dry state on surface.

In this regard, in case the 1st coat is inorganic zinc rich paint, measurement shall be done after completion of 1st coat.

6) If more than one of 3 conditions of average, minimum and standard deviation do not satisfy standard value of 2), additional painting shall be done.

Example of film thickness recording sheet is shown as Commentary Table 3-42.

Table 3-42 Measurement Record Sheet for Film Thickness

ST 02

Name of construction						
Objective members				Paint system		
Measured time						
Measured Y/M/D				Measured by		
	Measured value					
Measured position	1	2	3	4	5	Ave. X
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
15						
15						
17						
18						
19						
20						
21						
22						
23						
24						
25						
Average	$X=\frac{1}{N}\sum_{i=1}^{n} xi$					
Standard deviation	$\sqrt{\frac{1}{N-1}\sum_{i=1}^{n}(x-xi)^2}$					
Managing Target	Average					
	Min					
	Standard deviation					

viii) Working Procedure

Draw up a working procedure so as to attain required film.

ix) Paint Worker

Painting worker shall have sufficient experience of painting steel bridge and also sufficient comprehension about using paint.

Paint worker shall participate in training workshop to upgrade his technical ability.

x) Painting at the welded part

a) Painting at the welded part shall be done after the hydrogen discharge time shown on Table 3-43.

Table 3-43 Hydrogen Discharge Time

Kind of electrode	Natural discharge		Heating discharge (Heating on bead surface)
	Non-oil paint system	oil paint system	
Low hydrogen (including automatic weld)	longer than 70hr	longer than 20hr	15min at 300℃
Aluminite	longer than 70hr	longer than 100hr	30min at 300℃

b) In the vicinity of welded part, painting work shall be done after neutralization treatment with phosphating solution (5-10% Volume %) to prevent from alkali swelling and then remove the neutralized saline matter. However, neutralization is not necessary in following case.

a) Red rust arises along entire bead.

b) Product blasting is done.

c) Welding method is submerged arc welding or gas shield arc welding.

c) In case that sputter and slug during welding and melting cut exist, painting work shall be stopped.

xi) Quality Control during painting work

Quality control during painting work is implemented with regard to Table 3-44.

Table 3-44 QC Items

1.	Working environmental condition
2.	State of paint to be used
3.	State of surface to be painted and out view of paint film
4.	Painting Interval
5.	Film Thickness

i) QC Items in Table 3-44 are the least necessary items for paint performance to be exerted sufficiently. Therefore, other items also required to be considered to form prescribed film.

ii) As paint material has each characteristic. It is necessary to control painting work relevant to control items.

iii) Example of QC control sheet are shown on Table 3-45.

Table 3-45 Example of Quality Control Sheet

ST 03

Construction No.	Construction Name	Structure Category	Member Name	Member No.	Paint Classification	Paint Area		Paint Manager	Paint charged person	Responsible person of work
					Exterior, Interior, Connection, Others( )	(m2)				

Paint system								Work day, time		Meteorological Phenomena			Paint Method	Blend	Used quantity			Wet thickness		
Process	Paint Standard Name			Paint Name			Standard thickness	M/D	time	Weather	Temperature(℃)	Humidity (%)	A: Airlesss B: Brussh	dilution (%) / Viscosity (CP)	kg	kg/m2	Lot No.	Measured	Article(blend, others)	
Layer No.							g/m2	·					A･B	%				μ m / μ		
2							g/m2	·					A･B	%				μm / μ m		
3							g/m2	·					A･B	%				μ m / μ m		
4							g/m2	·					A･B	%				μ m / μ m		
5							g/m2	·					A･B	%				μ m / μ m		
6							g/m2	·					A･B	%				μ m / μ m		
7							g/m2	·					A･B	%				μ m / μ m		

Process	Inspection date (Y/M/D)	State of paint film													Repair paint				Note
		transparency	lack of thickness	crack	flaw	eye hole	bubble	Shrinkage	chalking	unevenness	dust	swelling			Otheres	Execution date	Repaire Item	Surface Treatment	Repair result
Layer 1																			
2																			
3																			
4																			
5																			
6																			
7																			

3.6.3 Repair Painting

(1) Scope of Application

This chapter is applied to repair the paint film where factory painting and site painting are completed.

(2) Repair Paint Specification

Table 3-46 Repair Paint Specification

Paint System	Surface treatment	1st Layer	t(μ)	Interval	2nd layer	t(μ)	Interval	3rd layer	t(μ)	Interval	4th layer	t(μ)	Dry thickness	Paint location	Base paint	Damage level	Factory or Site
a1	Partial blast or Power tool	Epoxy Zinc Rich Paint	60	1-10 days	Epoxy Resin Paint	120	1-10 days	Polyurethane	60				240	External part	A1、A2	I，II	F,S
a2	Partial blast or Power tool	Epoxy Resin Primer	30	1-10 days	Epoxy Resin Paint	300	1-10 days	Fluorine Resin paint	30	1-10 days	Fluorine Resin paint	25	385	External part	A3	I，II	F,S
b1	Partial blast or Power tool	Epoxy Resin Primer	30	1-10 days	Epoxy Resin Paint	300							330	Internal part	B2	I，II	F,S
b2	Partial blast or Power tool	Epoxy Resin Primer	30	1-10 days	Solvent-free modified Epoxy Resin	300							330	Internal part	B2	I，II	F,S
b2	Partial blast or Power tool	Tar Epoxy Resin	75	1-10 days	Tar Epoxy Resin	90							165	Internal part	B1	I，II	F,S
b3	Partial blast or Power tool	Solvent-free modified Epoxy Resin	75	1-10 days	Solvent-free modified Epoxy Resin	90							165	Internal part	B2	I，II	F,S
c1	Paper or Power tool	Epoxy Resin Paint	30	1-10 days	Fluorine Resin paint	25							55	External part of general member and splice	A3	III	F,S
c2	Paper or Power tool	Epoxy Resin Paint	30	1-10 days	Polyurethane	25							55	External part	A1、A2	III	F,S
d1	Partial blast	Inorganic zinc rich paint	50	1-10 days									50	Upper surface of Steel deck	D1	I，II	F,S
d2	Partial blast or Power tool	Epoxy Zinc Rich Paint	30	2d-1M	Epoxy Zinc Rich Paint	30							60	Welded part of upper surface of steel deck	D2	I，II	S
d3	Partial blast or Power tool	Epoxy Resin Primer	30	1d-10d	Epoxy Resin Paint	150	1d-10d	Polyurethane	60				240	Welded part of lower part of steel deck	D3	I，II	S
d4	Partial blast or Power tool	Epoxy Resin Primer	30	1d-10d	Epoxy Resin Paint	165	1d-10d	Polyurethane	60				255	Welded part of lower part of steel deck	D4	I，II	S
j1	Partial blast	Inorganic Zinc Rich Paint	75										75	Faying surface	J3	I，II	F,S
j2	Power tool	Epoxy zinc rich paint	60										60	Faying surface	J2	I，II	F,S

(3) Damage Level

Damage level is categorized into 3 stages

Level I: Large area of steel surface is exposed.

Level II: Small area of steel surface is exposed, or primer and inorganic zinc rich paint are exposed.

Level III: Only intermediate coat and top coat are damaged.

i) Level I is such that gas cut part of lifting piece, paint film is damaged by burning during temporary assembly and large area (larger than $0.2m^2$) of steel surface is exposed or remaining no paint due to skids.

ii) Level II is such as the small flaw (approximately $50cm^2$) caused by wire during carrying or lifting, and paint film is taken off by impact.

iii) Level III is such as the flaw due to same causes as ii), and the flaw do not reach to lower coat.

(4) Repainting

Repainting shall comply with following methods.

1) As for flow and shear drop, they shall be treated with knife or scraper and remove them and then paint one layer.
2) For unevenness and transparency, upper coat shall be painted.
3) Dispersion, bleeding, shrinkage, cockle, whitening and pin hole are dealt with power tool and intermediate and upper coat shall be painted.
4) As for swelling, flaking, cracking, damaged film shall be removed and paint from the removed layer.
5) If the flaking is caused by incompleteness of surface treatment, surface treatment shall be done again. And in case, film thickness is short, upper coat shall be painted.

(5) Display Items

Items relevant to painting shall be displayed near the abutment after completion of field painting.

Bridge Name

Erection Date/Month/Year

Painting Date/Month/Year

Paint System

Paint maker

Contractor

In factory

In field

CHAPTER 4. TRANSPORTATION

A transportation Plan shall be prepared for complex or large structures. The type of girder supports required and their locations shall be identified. The types, size, and locations of tie-downs shall be shown. A sufficient number of tie-downs shall be specified to provide adequate redundancy. Girder stresses due to self-weight while being shipped shall be computed with a dynamic load allowance of 100 percent. A 100 percent dynamic load allowance is provided to account for dropping the girders on rigid supports. The computed girder stresses shall satisfy the provisions of Article 6.10.3.2 or 6.11.3.2 of the AASHTO LRFD Bridge Design Specifications, as applicable fatigue stresses shall not exceed the constant amplitude fatigue threshold for the appropriate categories in Table 6.6.1.2.5-3 of the AASHTO LRFD Bridge Design Specifications. Wherever practical, girder sections should be shipped in the same orientation as in the completed structure.

Girders shall be supported in such a manner that their cross-section shape is maintained and through-thickness stresses are minimized. Supports should be such to ensure that dynamic lateral bending stresses are controlled. Temporary stiffening trusses or beams, if required to meet the requirements of this section, shall be specified in the Transportation Plan.

Moreover, after marine transportation, there may be the adhesion of excessive salt content, which may affect the quality of painting in the field, etc. Therefore, it is necessary to consider measures such as performing curing in advance and water washing after transportation.

Each member shall be painted or marked with an erection mark for identification and an erection diagram showing these marks shall be furnished to the Engineer. The weight (mass) of the individual members shall be shown on the statements. Members having a weight (mass) of more than 3.0 tons shall have the weight (mass) marked thereon. Structural members shall be loaded on trucks or cars in such a manner that they may be transported and unloaded at their destination without being damaged.

Bolts, nuts, and washers (where required) from each rotational-capacity lot shall be shipped in the same container. If there is only one production lot number for each size of nut and washer, the nuts and washers may be shipped in separate containers. Pins; small parts; and packages of bolts, washers, and nuts shall be shipped in boxes, crates, kegs, or barrels but the gross weight (mass) of any package shall not exceed 300lb. A list and description of the contained materials shall be plainly marked on the outside of each shipping container.

CHAPTER 5. ERECTION

5.1 Handling and Storing Material

The prescribed quality of the members that have been received on the site shall generally be maintained until the completion of erection.

The members to be stored at the work site shall be placed above the ground and it shall be kept clean and properly drained.

The long member, such as long chord and diagonal members shall be sufficiently supported so they will receive no damage due to stack placement.

The members under assembly shall be handled carefully to avoid to be damaged.

This section stipulates the quality maintenance of the members on the erection site. Because the temporary storage site in the field cannot necessarily secure flat ground, special attention shall generally be paid to prevent a fall.

5.2 Bearing

(1) The bearing shall be accurately installed in the prescribed place.
(2) A Special care shall be taken to embed anchor bolts and to fix bearings to the substructure.

(1) When installing a bearing, confirm the error based on the results of substructure survey and the tentative superstructure shop assembly measurement. Rubber bearings should be exactly installed at the prescribed position taking into account the vertical stiffness obtained by product inspection.
Bearings should be installed taking into account the following points.

1) Error between the steel tape measure or geodimeter at site and those used for tentative shop assembly
2) Span change due to the temperature difference between tentative shop assembly and the actual erection
3) Span change due to the deflection caused by dead loads
4) Method to absorb the girder expansion or contraction due to camber or temperature variation of the superstructure

As to when fixing the bearing, there are roughly two methods to fix bearings regrading timing. Bearings are fixed before the erection of the superstructure by another method. For steel bearings, the general method is to fix the lower bearings to the substructure first and then to adjust the girder expansion or contraction due to temperature variations, drying shrinkage or camber by moving the upper bearing to an appropriate biased position. On the other hand, for rubber bearings which consist of an upper and lower bearings as one-unit, biased installation used for steel bearings will incur complicated work. Therefore, rubber bearings are allowed to be installed with the designed amount of movement assumed at the design stage. However, for an especially large designed amount of movement, the design of the rubber bearing may become irrational. In this case, it is recommended to assume the temperature of installation and to secure an appropriate amount of movement by adjusting the displacement and installing the bearing at the prescribed position. For concrete creep and expansion or contraction due to drying shrinkage, it is necessary to appropriately consider the concrete age and its effect.

(2) Because there are cases where adequate work execution becomes difficult for the lower face bearings and for the fixing of anchor bolts, no shrinking mortar should be used as a general rule. Even if no shrinking mortar is used, unexpected damage may occur if the work is inappropriate. Careful control of works is indispensable for filling mortar.

5.3 Erection Procedure

5.3.1 General

Erection shall be performed in accordance with the Contractor’ s construction plan which meets the premises of design as approved by the Engineer. When the method differing from the erection method or erection sequence considered at design time, the stress and deformation during erection shall be confirmed and its safety shall be checked.

The erection of a steel bridge shall generally be performed by the erection work that was assumed at the time of design. Depending on the various erection methods, the same structure will have different dead load stresses arising from the steel dead load. The good examples are erection by the bent method, erection by the cantilever erection method and erection by the launching method. Therefore, in making an erection plan, considering the design calculation sheet of the main body and understanding on what assumptions the dead load stress arising from the steel dead load has been calculated, one shall carry out the erection work in such a way that no erection stress that is not considered in the design is left once the erection is complete.

Given the use of an erection method differing from the one assumed in design, a large difference will arise in the deformation of the bridge body when the dead load stress on the steel dead load varies significantly, and this may lead to a situation in which the closure of the last member cannot be performed. When such a method needs to be adopted out of necessity, the stress of the bridge body during erection and at the time of completion shall be verified in advance, safety shall be confirmed, and the closure of the member shall be performed by concomitantly using the method, etc., of moving up and down the bearing, among others.

Additionally, when pavement is placed on the orthotropic steel deck, the effects arising due to the fact that the members become hot and the fact that the temperature of the members differs extremely, etc. may sometimes be generated. In such cases as well, if necessary, the safety in the effect on each part of the bridge shall generally be confirmed in advance.

5.3.2 Erection Drawings

Erection drawings shall be prepared by the Contractor in accordance with provision of 1.3.

5.3.3 Reaming of the bolt holes

Reaming of bolt holes during erection shall be permitted only with the approval of the Engineer.

5.4 Stress and Configuration During Erection

(1) Erection Stress

Any erection stresses induced in the structure as a result of using a method of erection which differs from the contract documents shall be accounted for by the Contractor. The calculations shall indicate any change in stresses or change in behavior for the temporary and final structures.

(2) Maintaining Alignment and Camber

During erection, the Contractor shall be responsible for supporting segments of the structure in a manner that will produce the proper alignment and camber in the completed structure. Cross frames and diagonal bracing shall be installed as necessary during the erection process to provide stability and assure correct geometry. Temporary bracing, if necessary, at any stage of erection, shall be provided by the Contractor.

(3) Stress Adjustment

When consideration is made in design for performing the stress adjustment during erection, it shall generally be checked through appropriate means that the introduced stress satisfies the design.

However, when it can be confirmed that the work method (such as the work sequence) is implemented in accordance with the conditions introduced at the time of design, the measurement of displacement and strain of the adjustment results can be skipped after the introduction of the stress.

Stress adjustment may be performed when a composite girder for dead load, continuous composite girder, etc., are made to be pre-stressed composite girders, when the axial force of an arch is adjusted, when the bending moment is introduced to a closured portion after the closure is made in the middle span in the erection of a continuous girder, or when the bending moment of a hinged portion is released after a cantilever girder is erected as a continuous girder, etc.

There are various ways to introduce stress. The methods by which to know the introduced stress are the methods of measuring the force to be added to the pre-stressed member or to measure the elongation of the pre-stressed member, the method of measuring the flexural deformation of a girder and the method of measuring the strain of a member. For the measurement of strain, there is a method by a contact gauge, a method using a wire strain gauge. It is advisable to check that the design conditions are satisfied through the concomitant use of these methods.

When the total amount of introduction is given at one time, overstress may arise locally. Therefore, sufficient attention shall be paid, particularly in regard to buckling. It is necessary to introduce stress in several batches, to consider the amount of introduction in the middle of the work, and to carry out the operation by ensuring that the stress adjustment is advanced without fail. When there are doubtful points in the stress status, it is recommended to investigate the stress status in advance through experiments using models.

Because the girder may be subjected to large deformation during the stress adjustment operation, the margin of each portion that has been designed in consideration of only deformation by the ordinary load may sometimes be insufficient. Therefore, careful consideration shall generally be made for the rotational margin and movable amount of a bearing in particular. Attention shall also be paid to the margin, etc., between the girder end and the parapet wall.

When the stress adjustment is performed by moving the girder supports up and down, etc., attention shall be paid to the movement of the girder. It is a matter of course to consider the safety degree of supports, and attention shall be paid particularly to the structure of the support where uplifting force arises.

5.5 Field Assembly

(1) The connection of the members shall generally be performed in accordance with the provisions of Sections 3.4, 3.5, 5.4, 5.5.
(2) Prior to the work of site welding and the tightening of high strength bolts, the respective members shall generally be properly combined.
(3) The assembly of the members shall generally be performed accurately in accordance with the assembly marks and prescribed assembly sequence.

This section stipulates the assembly of the members and the work on the connection zone. The work of site welding joint and the tightening of high strength bolts joint are stipulated to follow the respective related provisions, and accordingly this section describes the assembly between the members in general.

Prior to the work of the connection zone, the temporary fixing of the members is performed in the following manner: The total of temporary tightening bolts and drift pins to be used for the assembly of the members shall generally be approximately one-third of them or more and furthermore, one third of them shall be drift pins. However, when a large erection stress is active, the amount of temporary bolts and drift pins that would sufficiently bear the erection stress shall be used.

Moreover, the statement that the total of temporary tightening bolts and drift pins shall generally be one-third the number of the bolts indicates a tentative guide, and the amount shall vary in quantity in accordance with the work method. More specifically, when the bent cannot be installed by any means due to the site circumstances, the number shall generally be increased. However, in the cable erection method, etc., it may be advantageous to perform work by taking the measure of reducing the number and increasing the freedom between the members, so care shall generally be taken. Additionally, it is stipulated that at least one-third or more of the temporary tightening bolts and drift pins shall be drift pins for the purpose of using the drift pins to determine the location and using the bolts for surface adhesion.

5.6 HTB Tightening

5.6.1 High Strength Bolt working in general

In the tightening work of the high strength bolt, the following items must be considered sufficiently and the work must be executed appropriately in order to ensure the qualities required of a joint.

(1) Joint type and characteristics
(2) Type of high strength bolt and its qualities
(3) Method of tightening, control of tightening axial force and inspection method
(4) Method of treatment of joint surface
(5) Assembly accuracy of material piece to be tightened

The methods of connecting high strength bolt joints include friction grip connection, bearing connection and tensile connection, and there are different mechanisms for the transfer of stress. Accordingly, based on a sufficient understanding of the features of the tightening work, an execution plan to ensure the qualities required of a joint must be compiled for the tightening work, and then must be carried out in strict accordance with the plan.

The friction grip connection tightens together the members constituting a Joint using high strength bolts, taking advantage of the high axial force, and transfers force with the friction force generated on the contact surface between the material pieces. Therefore, it is necessary in the work to ensure the tightening axial force, slip coefficient of the contact surface and contact density between the tightened material pieces.

The bearing connection transfers force by means of the bearing force between the holes of members constituting a joint and the bolt axes through the shear resistance of the bolts. When using the hammering type of high strength bolt that generates no relative displacement in the joint portion, the drilling accuracy and the generation of hole-mismatch in the joint portion must be checked prior to performing the tightening work in order to prevent any problems from taking place in the tightening work.

Additionally, the tightening axial force is generally given with a view to improving the joint performance, and in this instance an execution management similar to that of the friction grip connection is required.

The high strength bolt tensile connection employs the style of transferring the force in the direction of the bolt axis by generating the contact stress on the joint surface. Given this type of connection, it is necessary to ensure the tightening axial force of the bolt as well as to secure the flatness on the contact surface of the joint and the contact density after the tightening. Moreover, since it is sometimes necessary even in the tensile connection to resist the shear force with the friction force on the connection surface, an execution management equivalent to that of the friction grip connection is required in this instance.

The tightening methods include the torque control method, angle control method, torque gradient control method, etc. depending on the method to control the tightening axial force. Because there are cases where particular bolts and tightening equipment are used, depending on the particular method, the tightening work and its quality control must be performed after sufficiently grasping the types of the bolts and characteristics of the equipment to be used.

Additionally, the assembly accuracy of members concerning the inconsistency among members at the joint portion, the degree of the lap gap between material pieces, hole mismatch, etc., must be checked before implementing the tightening work, and appropriate treatments must be conducted so that no problems will arise in the performance of the Joint after the tightening and in the implementation of the tightening work.

5.6.2 Bolts, Nuts, and Washers

(1) The bolts, nuts and washers used for a high strength bolted joint shall satisfy the required mechanical properties or other characteristics, as well as the quality, in accordance with the methods of fastening and connection to be used.

(2) For the bolts, nuts and washers used for a high strength bolted joint, Clause (1) may be deemed to be satisfied when they satisfy the provisions of Clause (3).

(3) Friction grip connection

1) Except for the tor-shear type, the nuts, bolts and washers used for a friction grip connection shall generally be the nominal sizes M20, M22 and M24 of Type 1(F8T) and Type 2 (F10T), as stipulated in JIS B 1186. In this case the torque coefficient as a set shall conform to Table 5-1.

Table 5-1 Torque Coefficient as a set

Mean of torque coefficient of one manufacturing lot at shipment	0.110 to 0.160
Coefficient of variation of torque coefficient on one manufacturing lot at shipment	5% or less
Temperature induced variation of torque coefficient of one manufacturing lot at shipment	For a temperature change of 20℃, up to 5% of mean of torque coefficient at shipment

.

2) The torcher type bolts, nuts and washers used for a friction grip connection shall conform to set of Torshear –Type High strength bolt, Hexagonal Nut and Plain Washer (Japan Road Association) (S10T).

3) The high strength bolts B 1186 and offer good hexagonal nuts and washers for friction grip connection, when fastened by the yield- point method, shall generally be nominal sizes M20, M22 and M24 of Type 2 (F10T) stipulated in JIS B 1186 and shall offer good delayed fracture resistance.

4) Bearing connection Bolt, Hexagon

The bolts, nuts and washers used for a bearing connection shall conform to “Provisional Standards for Set of High-Strength Drive Bolt, Hexagon Nut and Plain Washer for Bearing Connection (Japan Road Association)”.

5) Tension connection

For the bolts used for a tension connection, the F10T shown in 1) of Clause (3) or the S10T shown in 2), or a steel rod of a material equivalent to these shall generally be used. For the nuts and washers, a set of nuts and washers for the F10 T shall generally be used.

5.6.3 Quality Control and Storage of High Strength Bolt

(1) Concerning the bolts, nuts, washers and their sets, tests and inspections to ensure their characteristics and quality must be conducted at the time of factory shipment and verification of conformance to the specifications must be conducted at the time of factory shipment and verification that they are bolt sets whose characteristics and quality are guaranteed.

(2) Attention must be paid to the packaging and site storage of the bolt sets so that their quality at the time of factory shipment may be maintained until the execution of the work on site.

(1) The high strength bolt must conform to the specifications prescribed in design. In executing the work, it must be verified that the mechanical properties and shape and size of the bolts, nuts, washer and their sets, torque coefficient value, tightening axial force values, etc., conform to the prescribed specifications as the time of factory shipment. Moreover, it must be verified that the delivered bolts are those guaranteed of their quality by checking them off with the attached inspection report at the time of delivery to the site.

(2) When the bolts require special performance and specifications in terms of their mechanical characteristics, chemical components, manufacturing methods, etc., those qualities must be verified through tests and inspections, and it must be confirmed that the results are stated in the inspection report. Concerning the storage of bolt sets, they must be stored as they were packed in the factory, if circumstances allow, and with care that they will not be exposed to moisture such as rain and night dew. Additionally, it must be ensured that the quality at the time of factory shipment is maintained until the execution of the work on site. Because quality tends to diminish after unpacking due to moisture such as rain and night dew, the occurrence of rust, adhesion of dust, sand, etc., to the screw portion, and damage in the screw portion due to rough handling, the package must preferably be unpacked immediately before the execution of work. It is therefore necessary to conduct the systematic delivery of the bolts to the work location and to ensure that unnecessary unpacking is not performed. Additionally, to maintain the quality at the time of factory shipment until the execution of the work, it is desirable to be aware of the above points and make an arrangement to limit, as much as possible, the period from the factory shipment to the execution of the work on site.

5.6.4 Connection Surface Treatment

(1) An appropriate treatment must be applied to the contact surface of the material piece that is connected by the friction grip connection so that the required slip coefficient may be obtained.

(2) When the following treatments are applied, it may be considered that the slip coefficient of 0.4 or more is obtained:

1) When the contact surface is not painted, the mill scale shall be removed from the contact surface, turning it into a rough surface. In tightening a material piece, the loose rust, oil, mud, etc., shall be removed from the contact surface through sufficient cleaning.

2) When the contact surface is painted, the high build type inorganic zinc-rich paint shall be used in accordance with the conditions shown in Table 5-2.

3) When a treatment other than as specified in item 1) or item 2) is applied to the contact surface, careful consideration shall be made so that the slip coefficient of 0.4 or more may be obtained.

Table 5-2 Condition in Application of High Build Type Inorganic Zinc-Rich Paint

Item	Condition
Minimum dry film thickness per side of contact surface	30μm or more
Total dry film thickness of contact surface	90-200μm
Zinc content in dry film	80% or more
Grain diameter of zinc powder (50% of average grain diameter)	Approx. 10μm or more

(3) The slip strength of as friction grip joint is calculated by assuming the slip coefficient of the contact surface, so an appropriate treatment must be applied to the contact surface so that the slip coefficient assumed in design may be ensured in the work.

(4) Moreover, when the tightening axial force is applied to the bolt in order to improve the joint performance in the bearing connection and accordingly the transfer of force by the friction force is hoped for, or when the shear force is transferred by the friction force of the contact surface in the tensile connection, a treatment similar to the one in the friction grip connection must be applied to the contact surface.

(5) It has been conventionally known that a sufficient slip coefficient of 0.4 or more can be secured in a joint whose contact surface is turned into a rough surface through the removal of mill scale. However, even if such a treatment is applied during shop fabrication it is difficult to maintain this status until the connection is performed on site, and the loose rust, oil, mud, etc., are often attached to the connection surface. In such a case it is important to remove them by sufficiently cleaning the connection surface immediately before the connection is carried out on site.

However, because the weights of the splice plates increase as bridges grow in size, the operation to remove the loose rusts etc., on site is becoming difficult and the paint in the connection portion tends to become a weakness after completion in terms of resistance to rust and corrosion. Thus, the application of a surface treatment such as a paint to the connection surface has been considered. Concerning the paint specification used to secure the slip coefficient of 0.4 or more, it has been revealed that the slip coefficient of 0.4 or more can be secured if the paint is performed according to the conditions shown in the text of item (2)2), so the conditions in applying the high build type inorganic zinc-rich paint are stipulated. Different kinds of high build type inorganic zinc-rich paints must not be applied to each of the contact surface, nor must other paints be used concomitantly. The high build type inorganic zinc-rich paint shall be directly applied following surface treatment.

When the high build type inorganic zinc-rich paint is applied only to the friction grip connection surface but other types of paints are used for other portions, it is necessary to pay attention to the treatment on the boundary zone and to give due consideration in advance so that no adverse effect may be exerted on either paint. Additionally, control of the film thickness shall be performed sufficiently.

When a rust and corrosion prevention other than as specified in the texts of items (2)1) and 2) is applied to the contact surface, it may not be possible to secure the slip coefficient of 0.4 or more depending on the type and thickness of the paint film, and the creep of the paint film may cause a decrease in the bolt axial force. Therefore, such a treatment must be used after careful consideration (including the question of its necessity) is made.

Moreover, it is advisable to apply a blast treatment to the connection surface that has been applied with a galvanizing treatment as part of a hot dip galvanized bridge, and to secure a slip coefficient of 0.4 or more cannot be obtained depending on the type of the blast material, it is advisable to refer to Bibliography 10) etc.

5.6.5 Bolt Tightening

(1) In tightening bolts, the operation must be performed so as to obtain the design bolt axial force.

(2) Tightening bolts must be performed in such a way that contact density between the respective material pieces is ensured and sufficient stress is transferred.

(3) When the provisions of items i) to v) are applied, the Clauses (1) and (2) may be deemed to be satisfied.

i) Bolt tightening

a) The introduction of the bolt axial force is generally performed by rotating the nut. When the head rotation is conducted out of necessity, the change of the torque coefficient shall be checked.

b) When the tightening of bolts is performed through the torque control method, the tightening torque shall be adjusted in such a way that the axial force of bolt tightening is introduced uniformly to each bolt.

c) When the torque shear type high strength bolts are used, a special tightener shall be employed for the final tightening.

d) When the tightening of bolts is performed by the angle control method, the tightening with the torque wrench or with the assembly spanner using all one's might shall be carried out, to the extent that the lap gap of the contact surface disappears. The rotational angles shown below shall be given.

However, the angle control method shall be applied to F8T and B8T only.

❖ When the length of bolt is 5 times it's diameter or less: 1/3 turn (120 degrees) ± 30 degrees

❖ When the length of bolt exceeds 5 times its diameter: the target rotational angle shall be determined by the preliminary test that is consistent with the work condition.

e) When the tightening of bolts is performed through the torque gradient control method, the high strength bolts stipulated in item 6.3.2 (3)3) of Part 2, Steel Bridge, JHBS, shall be used and the final tightening shall be conducted by means of the special tightener.

f) The tightening of the hammering type of high strength bolt is performed by hammering bolts until the nuts reach the screw portion of the bolts and then pulling in the bolts by rotating the nuts.

ii) Calibration of Machinery and Device

The calibration of bolt tighteners and measuring instruments shall be conducted at appropriate periods, and their precision shall be checked.

iii) Tightening bolt axial force

a) The bolt to be used for the friction grip connection, bearing connection and tensile connection shall be tightened in such a way that the design bolt axial force shown in Table 5-3 can be obtained.

Table 5-3 Design Bolt Axial Force (KN)

Set	Nominal designation of thread	Design bolt axial force
F8T B8T	M20	133
	M22	165
	M24	192
F10T S10T B10T	M20	165
	M22	205
	M24	238

b) The tightening bolt axial force in the case of tightening by means of the torque control method shall generally be 10 percent greater than the design bolt axial force.

c) Concerning the tightening bolt axial force of the torque shear type high strength bolt at normal temperature (10℃-30℃), the average value of testing five sampling sets randomly selected from one production lot must fall within the range of the bolt axial force shown in Table 5-4.

Table 5-4 Average Value of Tightening Bolt Axial Force at Normal Temp. (10-30℃)

Set	Nominal designation of thread	Average value of tightening bolt axial force of the set of one production lot (KN)
S10T	M20	172～202
	M22	212～249
	M24	247～290

d) Concerning the tightening bolt axial force in the case of tightening by the torque gradient control method, the average value of testing five sampling sets randomly selected from one production lot for the tightened to be used must fall within the range of the bolt axial force shown in Table 5-5.

Table 5-5 Average Value of Tightening Bolt Axial Force by Torque Gradient Control Method

Set	Nominal designation of thread	Average value of tightening bolt axial force of the set of one production lot (KN)
F10T	M20	0.196 σy ～ 0.221 σy
	M22	0.242 σy ～ 0.273 σy
	M24	0.282 σy ～ 0.318 σy

σ y: Proof stress of bolt test piece (N/mm^2) (base on JIS test Piece No.4)

iv) Tightening Order

Tightening bolts shall be performed by starting from the bolt at the center of the splice plate and making for the bolts at the end portion, and the second tightening shall be conducted

(Figure 5-1).

Additionally, marking shall generally be applied to bolts, nuts and washers so that failed tightening and dragged rotation can be readily identified after the preliminary tightening.

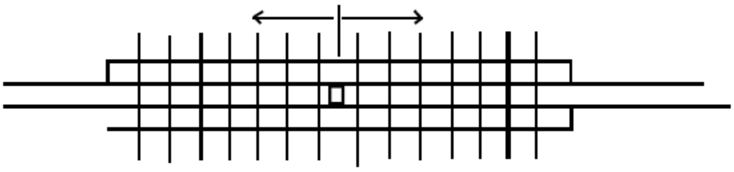


Figure 5-1 Tightening Order

v) Contact face Gap of Joint

The member and splice plate or the mutually connected material pieces shall be attached to each other by means of tightening, leaving no room for the contact face.

i) Bolt Tightening

The method of tightening bolts in a friction grip joint is generally categorized into the torque control method, angle control method and torque gradient control method, depending on the manner used to control the tightening bolt axial force.

Considering the torque control method, because the torque coefficient value is stipulated in the case where tightening is performed by rotating the nut, the bolt tightening shall generally be conducted by rotating the nut. When rotating the bolt head out of necessity due to the work procedure, it is necessary to check the value again. On the other hand, when the surface- treated washer is used to decrease the torque coefficient value, care must be taken to use it on the side being rotated.

When using the torque control method, the tightening torque must be selected before the work in order to achieve the bolt axial force that matches the work standard mentioned in item iii).

When using the torque shear type high strength bolt, a special tightener shall be adopted.

The angle control method controls the bolt axial force arising from the tightening by the elongation of the bolt, and the elongation of the bolt appears as the amount of nut rotation. The amount of nut rotation stipulated in item d) has been determined in order to secure the standard bolt axial force and with an allowance for the bolt's elongation after fracture. When this rotational amount is given, the bolt axial force reaches the degree exceeding the yield point. However, based on the existing experience and the results of a number of experiments it is determined that such tightening is safe with the 8T bolt, and therefore it is stipulated that the angle control method can be used.

Moreover, since the under-head length of the bolt commonly used is five times its diameter or less, the rotational angle in the case of five times or less is stipulated. When using the bolt longer than this, it is stipulated that the rotational amount is checked by means of a preliminary test. Although the 10T bolt shows deformation characteristics similar to those of the 8T bolt in the results of experiments, the angle control method is stipulated as being applied only to the 8T due to the lack of data on delayed fracture.

Moreover, the bolt axial force at the start point of measuring the amount of rotation is important as well. Therefore, the amount of rotation shall be measured on the basis of the state of tightening with the assembly spanner with all one’s might or by tightening with the impact wrench to the extent of giving the first impact so that the lap gap between the material pieces will disappear.

The torque gradient control method is a tightening method where the management is performed by the tightener capturing the property that the relationship between the introduced axial force at the time of tightening the high strength bolt and the nut rotational amount becomes nonlinear near the proof stress, whereby the prescribed axial force is introduced. Although the site management of this method is easy and there is minimal variation in the introduced axial force, its introduced axial force is high compared to the torque control method. Therefore, the property of resistance to delayed fracture is enhanced by stipulating the chemical components, mechanical properties, etc., of the bolt to be used more strictly then JIS B 1186, as shown in Section 6.3.2. This tightening method has a number of past records in the Honshu-Shikoku Bridges, etc.

When using the hammering type high strength bolts in the bearing connection, the hole diameter and mismatch of the holes must be checked prior to tightening in order to prevent problems from taking place in the workability of the hammering-in (difficulty level of hammering-in). Additionally, care must be taken so that no harmful flaws will be generated in the vicinity of the holes at the time the bolts are hammered in.

ii) Calibration of Machinery and Device

The calibration of the device mentioned here refers to periodic calibration, not daily on-site calibration.

The axial force meters consist of the type used to measure the axial force by the change of oil pressure and the load-cell type using a strain gauge. These meters must always be in such a state that they can be used at the prescribed level of precision. Accordingly, it is necessary to check their precision prior to the site work by performing a calibration once immediately before delivery to the site and then periodically after that. Because the precision of the axial force meter is less affected by the handling than the torque wrench, etc., its periodic calibration can generally be performed once in a three-month period.

Moreover, the stiffness of the portion of the axial force meter tightened by the bolts is not necessarily the same as the stiffness of the actual member. For this reason, there are cases where there is some difference in the introduced bolt axial force between the tightening of the axial force meter and the tightening of the actual member under the same output torque. It is therefore desirable to use the axial force meter that possesses a degree of stiffness as close as possible to that of the actual member.

While there are several types of torque wrenches such as the one that reads the torque with the scale of a dial gauge, the one that reads the scale by the deflection of the torque wrench, and the ratchet type, each type tends to give rise to irregularities if handled roughly. Accordingly, it is advisable to conduct the calibration of a torque wrench once at the time of delivery to the site and then generally once a month after the delivery, or to determine the time of the periodic calibration separately depending on the frequency of usage.

The tightener has the electric motor type and hydraulic type. Since either has a good ability to sustain tightening precision, their calibration may be performed once before delivery to the site and the periodic calibration may be performed once before delivery to the site and the periodic calibration after the delivery can generally be conducted once every three months. Since the tightener whether electric motor type or hydraulic model is used in combination of the gun and control device or a hydraulic pressure adjustment device, the periodic calibration shall be performed on the combination. Moreover, in the case of the torque control method, the precision of the output torque shall be calibrated in several stages of the range of torque values.

In addition to the above-mentioned tighteners, there is the electrical torque-controlled impact wrench. However, because it presents difficulty in terms of fine adjustment and cannot easily sustain tightening precision, it is advisable not to use it for final tightening.

However, since the preliminary tightening does not require such a high tightening precision a torque-controlled impact wrench with good operation efficiency may be used.

The socket portion of the tightener of torque shear type high strength bolts consists of two sockets that hold a nut and a pintail, respectively. It is a system in which the outer socket holds the nut and applies the tightening torque, while the inner socket holds the pintail and transfers the reaction force of the tightening torque. The sockets rotate in opposite directions relative to each other, and they continue to rotate until the tightening torque reaches the fracture torque of the fracture groove to severance.

Because in this way the tightening torque is controlled by cutting the pintail, the special tightener offers no function to control the torque. It only provides the torque, so there is no need to calibrate it, and consequently only the maintenance and inspection procedures need to be performed.

iii) Tightening Bolt Axial Force

The design bolt axial force of Table 5-3 is the bolt axial force in design that is necessary to satisfy the prescribed allowable force, as mentioned in the commentary of Section 3.2.3(2) of Part 2, Steel Bridge, JHBS.

In tightening the bolt, the tightening is performed in order to obtain the above-mentioned design bolt axial force. However, taking into consideration further the effects of the variation of the torque coefficient, creep and relaxation, variation of slip coefficient, etc., the bolt axial force at the time of the work is generally stipulated to be 10 percent greater than the design bolt axial force.

On the other hand, in the angle control method, the tightening bolt axial force is secured if the nut rotational amount stipulated in i) is provided.

In the case of the torque shear high strength bolt, as stated in above- mentioned devices in tightening the bolt, in this instance one must pay attention to the fact that the torque coefficient obtained on site is fundamentally different from the torque coefficient of the product in a factory stipulated in Section 6.3.2 of Part2, Steel Bridge, JHBS.

When using the torque shear type high strength bolt, the tightener possesses no function to control the torque as was mentioned in the commentary of item ii), the tightening axial force varies depending on the performance of the bolt. Therefore, it must be checked that the average value of the tightening bolt axial force at the time of factory shipment falls within a certain range and that the performance is maintained from the time of factory shipment to the time of work at the site. For this reason, it is necessary to check the performance of the bolts using Table 5-4 before the bolts are tightened.

Additionally, in the on-site test of the tightening axial force, it is sometimes difficult to administer the test to the bolts with every kind of under-head length due to the functional constraints on the inspection equipment to be used for the test. In this instance the performance of the bolts to be used may be guaranteed by selecting the bolts with the under-head lengths that can be tested from among the bolts with the same nominal diameter and delivered during the same period to the site from the same manufacturer as that of the bolts to be used that have been kept under the same storage environment. This is done by conducting the tightening test on these bolts and thus by verifying that the performance at the time of factory shipment has been maintained since delivery to the site.

Because the torque coefficient value of the bolt changes according to temperature, the tightening bolt axial force changes as well. When the test is conducted outside the range of the normal temperature (0℃-10℃, 30℃-60℃), the range of the bolt axial force shown in Table 5-6 shall be applied.

Table 5-6 Average Value of Tightening Bolt Axial Force Outside Range of Normal Temperature (0℃-10℃, 30℃-60℃)

Set	Nominal designation of thread	Average value of tightening bolt axial force of the set of one production lot (KN)
S10T	M	167~211
	M	207~261
	M	241~304

When tightening is performed through means of the torque gradient control method as well, it is necessary to check before the work is done, in accordance with the text that the average value of the control action axial force of the tightener falls with a certain range. Moreover, when it is difficult to perform the tightening axial force test on site, such as in the case of the torque shear high strength bolt, a test similar to that of the torque shear high strength bolt, a test similar to that of the torque high strength bolt shall be conducted.

iv) Order of Tightening

When the bolt axial force within a joint is uneven, the slip strength may decrease. For that reason, this item stipulates the provision to tighten the group of bolts as evenly as possible. When the bolts are tightened from the outer end of the joint. the splice plate tends to be raised. Leading to poor contact density, so the bolts shall be tightened from the center outward.

Generally, when the tightening is performed up to the required axial force at one time, the bolts tightened earlier tend to become loose, so it is stipulated that the tightening is generally to be conducted in twice. It is advisable for the preliminary tightening to achieve approximately 60 percent of the tightening bolt axial force.

On the other hand, when the tightening is performed in the beginning to the extent that the lap gap is eliminated in the case of the angle control method, the tightening force becomes large enough to render unnecessary the secondary tightening as mentioned above.

v) Contact Gap of Joint

This item stipulates the treatment used to sufficiently transfer the stress due to the friction of respective material pieces constituting a member in the state in which the tightening is completed. The generation of a contact gap in the vicinity of a bolt hole prevents the transfer of stress, so care must be taken not to generate such a contact gap in tightening bolts. When the contact gap is generated only in the edge portion away from the bolt hole, it cannot necessarily be said that there is a problem in terms of stress transfer. However, even in such a case it is necessary to consider the resistance to rust and corrosion.

The contact gap between material pieces occurs in such cases where there is a difference in plate thickness or where there is inconsistency among members. The difference in plate thickness mentioned here is what arises from the plate thickness tolerance, so for the treatment to the case where members with different nominal plate thicknesses are spliced, the design must consider measures such as eliminating the difference in plate thickness with the installation of a filler. Concerning the plate thickness tolerance, the tolerance increases as the thickness of the steel increases, and there is existence of a lap contact must be checked at the time of the preliminary tightening of a joint, and in the case where the contact gap is expected to remain after the final tightening, appropriate treatments such as installing a filler plate and attaching a taper to the material to be tightened must be applied.

Concerning the inconsistency, it is difficult to remedy the inconsistency on site. Therefore, it is important to pay attention to fabrication methods, etc., at the time of shop fabrication so that no inconsistency may arise, and when a temporary assembly is performed, it is important to check that there is no inconsistency, and to conduct appropriate repair when a lap gap accompanying the inconsistency is found. Additionally, when a splice plate is tightened in the state of inconsistency, carful measures must be taken since there are cases where harmful deformation occurs to the splice plate.

5.6.6 Inspection after Completion of Tightening

(1) The bolt shall undergo inspection after tightening to confirm that the prescribed tightening has been performed.

(2) In the case of rejection in inspection, an appropriate treatment shall generally be applied in order to secure the prescribed quality.

(3) When the provisions of items i) and ii) are applied, Clauses (1) and (2) may be deemed to be satisfied.

- i) The tightening inspection shall be performed immediately after the bolt tightening.
- ii) The inspection of the tightening axial force and the treatment in the case of rejection shall be performed as follows:
  - a) In the case of the torque control method, the tightening inspection shall be performed using a toque wrench on 10 percent of each group of bolts as the standard number of bolts. For acceptance criteria in this instance, when the tightening torque value is within ± 10 percent of the torque value stipulated at the time of calibration, it shall pass the test. Concerning the rejected group of bolts, double the number of bolts shall be picked up for re-inspection, and in the case of rejection in the re-inspection the entire number of bolts shall be inspected. Those bolts whose tightening torque is below the prescribed tightening torque shall be further tightened to the prescribed torque, and those bolts whose tightening torque is more than 10 percent above the prescribed tightening torque shall be replaced with new bolt sets for retightening.
  - b) In the case of the torque shear type high strength bolt, the check of the pin tail severance and the appearance inspection by marking shall be conducted. When a skipped tightening is identified, tightening shall be performed, and when a simultaneous rotation is recognized it shall be replaced with a new bolt set for retightening.
  - c) In the case of the angle control method, the appearance inspection by marking shall be conducted for the whole number, and it shall be confirmed that the tightening rotational angle is within the range stipulated in Section 5.6.5. Those lacking in the rotational angle shall be further tightened to the prescribed rotational angle. Those with an excessive angle shall be replaced with a new bolt set for retightening.

5.7 Erection Equipment Facility

5.7.1 Erection Stability

Girders shall be stabilized with false work, temporary bracing, holding cranes, or a combination of these until a sufficient number of adjacent girders are erected with diaphragms or cross-frames that connect to provide the necessary local and global stabilities, making the structure self-supporting.

5.7.2 Crane Information

The Erection Plans and Procedures shall show the location of each crane to be used for each primary member to select the crane type, crane pick radius, crane support methods (crane mats, barges, work trestles, etc.), and the means of attachment to the girders being lifted or supported.

The Erection submittal shall include capacity charts or tables that address and demonstrate the adequacy of each crane configuration, boom length, counterweight configuration, outrigger configuration, and pick weight required to do the proposed work. The Erection Plans and Procedures shall also indicate any potential above or below ground obstructions or restrictions to crane operations (such as existing structures, utilities, etc.)

In the event that the submitted cranes are not available at the time of construction, the Contractor can propose alternate cranes, subject to review and approval by the Owner. The submittal package for alternate cranes shall include capacity charts or tables that address and demonstrate the adequacy of each crane configuration, boom length, counterweight configuration, outrigger configuration, and pick weight required to do the propose work; however, resubmittal of the full Erection Plans and Procedures and the Erection Engineering Calculations package is not required.

Any plans associated with crane supports (such as crane mats, barges, work trestles, etc.) shall also be included. When applicable, manufacturers' certifications documents or catalog cuts for pre-engineered devices or equipment may be used to meet this requirement; these items shall be included with the Erection Plans and Procedures and shall be subject to review and approval by the Owner. Calculations for crane supports (crane mats, barges, work trestles, etc.) do not need to be included in the Erection Plans and Procedures and Calculations submittal, unless otherwise specifically required on the plans or in special provisions, but the Owner reserves the right to request their submittal for review and approval at any time.

5.8 Inspection of Dimensions after Completion

(1) The assembly precision of the members constituting a steel bridge must be at the level satisfying the performance required in design after the completion of erection.

(2) Clause (1) may be deemed to be satisfied when erected in accordance with Clause (3).

(3) After the completion of erection, the assembly precision of the combined members satisfies the allowable values of Table 5-7.

Table 5-7 Assembly Precision after the Completion of Erection

Item	Allowable value (mm)
Span length	± (20 + L/5)
Warp	± (25 + L/2)
Alignment	± (10 + 2L/5)

Note: In the formula of allowable value, L is the span length (m) of the main girder and the main structure, respectively.

Table 5-8 Assembly precision of pier after the completion of erection

Item	Allowable value
Standard height	± 20 (mm)
Distance between gate piers	± 20 (mm)
Tilt of column	1/500

The check of size precision (temporary assembly) performed in the middle of manufacturing and erection with the members combined is performed in order to confirm beforehand that the prescribed assembly precision will be obtained after the completion of erection.

CHAPTER 6. DECK

6.1 General

Dimensional tolerance limits for orthotropic-deck bridge members shall be applied to each completed but unloaded member and shall be as specified in paragraph 3.5 of the AASHTO/AWS D1.5M/D1.5 Bridge Welding Code, except as follows:

(The term element as used herein refers to individual panels, stiffeners, flanges, or other pieces)

-The deviation from detailed flatness, straightness, or curvature at any point shall be the perpendicular distance from that point to a template edge which has the detailed straightness or curvature and which is in contact with the element at two other points.

-The template edge may have any length not exceeding the greatest dimension of the element being examined and, for any panel, not exceeding 1.5 times the least dimension of the panel; it may be placed anywhere within the boundaries of the element.

-The deviation shall be measured between adjacent points of contact of the template edge with the element; the distance between these adjacent points of contact shall be used in the formulas to establish the tolerance limits for the segment being measured whenever this distance is less than the applicable dimension of the element specified for the formula.

(The term panel as used in this Article means a clear area of steel plate surface bounded by stiffeners, webs, flanges, or plate edges and not further subdivided by any such elements. The provisions of this Article apply to all panels in the bridge; for plates stiffened on one side only such as orthotropic-deck plates or flanges of box girders, this includes the total clear width on the side without stiffeners as well as the panels between stiffeners on the side with stiffeners.)

6.2 Flatness of Panels

The maximum deviation, δ, from detailed flatness or curvature of a panel shall not exceed the greater of 0.1875 inches or:

$$\delta \leqq \frac{D}{144\sqrt{T}}$$

Where:

D = the least dimension along the boundary of the panel, in.

T = the minimum thickness of the plate comprising the panel, in.

6.3 Straightness of Longitudinal Stiffeners Subject to Calculated Compressive Stress, Including Orthotropic-Deck Ribs

The maximum deviation, δ, from detailed straightness or curvature in any direction perpendicular to its length of a longitudinal web stiffener or other stiffener subject to calculated compressive stress shall not exceed:

$$\delta \leqq \frac{L}{480}$$

Where:

L = the length of the stiffener or rib between cross members, webs, or flanges, in.

6.4 Straightness of Transverse Web Stiffeners and Other Stiffeners Not Subject to Calculated Compressive Stress

The maximum deviation, δ, from detailed straightness or curvature in any direction perpendicular to its length of a transverse web stiffener or other stiffener not subject to calculated compressive stress shall not exceed:

$$\delta \leqq \frac{L}{240}$$

Where:

L = the length of the stiffener between cross members, webs, or flanges, in.

6.5 Welded Joint of Closed Section Rib

(1) The work of a full penetration butt welded joint that uses the backing strip of a closed section rib shall generally be performed in such a way that the joint prevents a crack in the gap portion between the backing strip and the base material of the closed section rib, and so it possesses the prescribed fatigue strength against the generation of a fatigue crack from the root.

(2) The backing strip shall be tightly adhered to the closed section rib, and the assembly welding shall be administered only to the groove portion before the welding of the first layer is conducted.

(3) The material that can ensure the prescribed welding quality shall be used for the backing strip.

(4) The work shall be performed in such a manner that a sufficient penetration amount is secured.

(5) The joint of a closed section rib shall generally be a high strength bolt joint, but when the site welded joint is adopted out of necessity, the joint shall be in accordance with full penetration butt welding. There are two methods to obtain a backing strip: the method of using a flat bar that has been processed into the form of a closed section rib, and the method of concomitantly using a diaphragm. However, judging from the results of fatigue tests it is desirable to use the flat bar. Moreover, in using a flat bar, when a cold bending work portion of the closed section rib is not sufficiently attached, a weld crack may arise. It is difficult to conduct a non-destructive inspection in the vicinity of the weld root portion of a full penetration butt weld that uses a backing strip when a closed structure such as the closed section rib is involved, so it is necessary to control the work condition in order to secure the required quality. Accordingly, the following quality about the precision inside a groove is stipulated. When the welding work has been performed unfailingly, the quality within a weld may be deemed to be secured.

Root distance: 4 mm – 8mm

Irregularity: 1 mm or less

Gap with backing strip: 1 mm or less

(6) Based on the results of fatigue tests of the site welding of the closed section rib, the main cracks that arise in the butt welding using a backing strip have been identified as follows:

・Cracks generated on the surface of a bead from the root of the common portion of a butt weld;

・Cracks generated on the surface of a bead from the root in the vicinity of a deck plate;

・Cracks generated from the toe of a fillet weld performed to install a backing strip.

Moreover, when the adhesion of the cold-bending work portion of a closed section rib is poor, a crack that occurred at the time of welding may be the origin of the fatigue crack. In performing a butt welding that uses a backing strip for a closed section rib, there have been results from the existing investigations showing that the method of welding the first layer after an assembly welding is performed inside the groove as is shown in the working instruction of Figure 6-1 is preferable from the standpoint of improving the fatigue strength and preventing the occurrence of cracks during welding.

(7) Because a steel plate with a thin plate thickness is used for a backing strip in many cases, it is difficult to acquire a rolled steel for welded structure (SM steel). When materials other than the rolled steel for welded structure are used, it shall generally be checked in advance that these materials have no problem in regard to weldability.

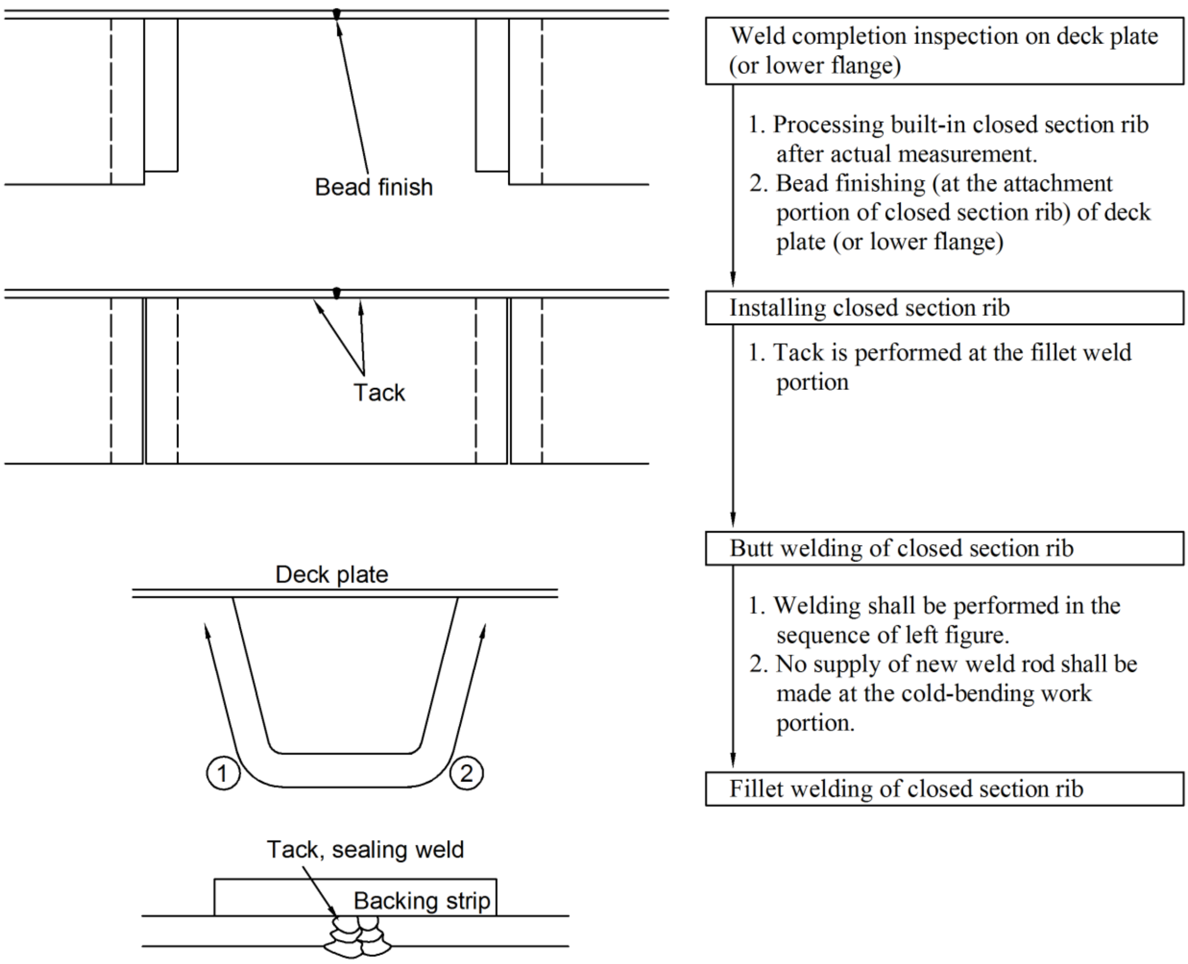


Figure 6-1 Example of Working Instruction on Site Welding of Closed Section Rib

6.6 Welding deck plate in lengthwise direction

(1) In the welding between a closed section rib or corner plate and a deck plate, it shall generally be confirmed that the prescribed throat and penetration is secured.

(2) The welding work test shall be performed, and after it is confirmed that the prescribed throat and penetration amount have been secured, the welding shall be conducted under the welding condition confirmed there. Moreover, the groove shall generally be taken when necessary for the purpose of securing the penetration amount.

(3) As a method to check the welding between a closed section rib and a deck plate or between a corner plate and a deck plate by a non-destructive inspection, the method by the ultrasonic testing can be considered. However, when the angle beam testing is conducted from the side of the closed section rib or the side of the deck, the flaw detection work requires a huge amount of labor. It is therefore difficult to secure the precision of flaw detection needed to ensure that the required amount of penetration has been obtained. Accordingly, the penetration amount of a weld section shall generally be confirmed by conducting a work test in advance under the same condition as the actual work. The prescribed penetration is stipulated to be secured by performing the actual welding under that condition. In this regard the penetration amount is defined by the depth of penetration in the direction of the plate thickness of a closed section rib, as is shown in Figure 6-2.

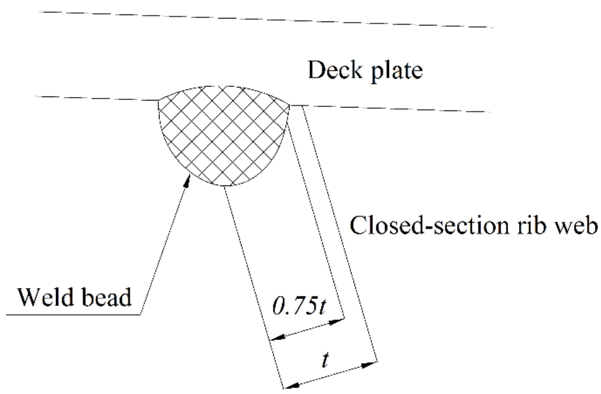


Figure 6-2 Amount of Penetration in the Welding of Longitudinal Rib and Deck Plate

6.7 Inspection of deck plate welding

A scallop is usually installed to the cross rib and longitudinal rib that cross the weld line of a deck plate. In an ultrasonic testing, the boxing and fillet weld of the scallop portion make it difficult to detect flaws using reflection echo from the back side of the deck plate so attention shall be paid to the reflection from the back side of a deck plate and the zone of flaw detection with respect to the welded portion.

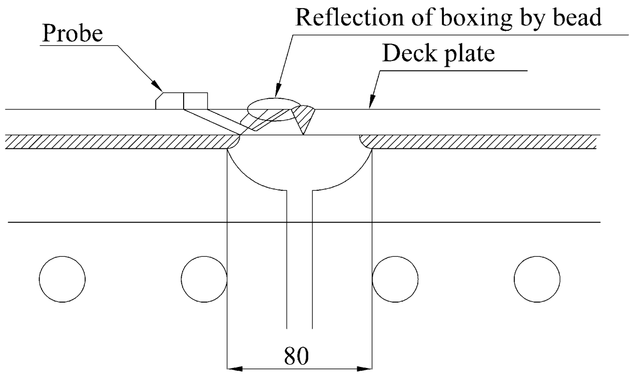


Figure 6-3 Inspection of Deck Plate Welded Portion by Ultrasonic Flaw Detection

Additionally, when the deck plate is thick, the work in the conventional one pass by the submerged arc welding becomes difficult. Therefore, the work of multi-layered buildup welding where the CO2 gas-shield welding is used for the first layer and the submerged arc welding is used on the next, etc., can be expected. In this case, it is desirable to determine the sampling rate in the quality inspection of the welded portion in consideration of the past record such as the occurrence frequency of flaws by multi-layered buildup welding.

6.8 Corner welding

(1) In the crossover portion of the longitudinal rib and cross rib or crossbeam, the welding work shall generally be performed in such a way that the prescribed fatigue strength at the site where the weld lines of three directions from the welding of the closed section rib and deck plate in the longitudinal direction, the welding of the deck plate and cross rib or crossbeam and the welding of the closed section rib and cross rib or crossbeam intersect with one another can be secured.

(2) In the location where the weld lines of three directions from the welding of the longitudinal rib and deck plate in the longitudinal direction, the welding of the longitudinal rib web and cross-rib web and the welding of cross-rib web and deck plate intersect with one another, the cross-rib web shall be corner cut and the welding work shall be performed in such a way that excessive space does not remain.

(3) The start-and-end point of welding shall not be located in the corner portion. When scallops are installed on the side of the deck plate, there is the possibility of generating the fatigue crack in any of the welded portions of the three directions. This fatigue crack can be restrained by not installing the scallops, but when the welding in the corner cut portion is not sufficiently performed, the fatigue crack can be considered to occur with an internal void as its source. Accordingly, care shall be taken of welding so that an excessive void that can cause a fatigue crack does not remain.

Moreover, the start-and-end portion of the welding tends to generate weld defects, and when such a start- and-end point is put on the location where the weld lines of three directions intersect with one another, a fatigue crack may be generated. For this reason, the start-and end point shall be put by avoiding the crossover portion. The standard detail of the crossover portion and welds that take the fatigue strength into consideration are shown in Figure 6-4.

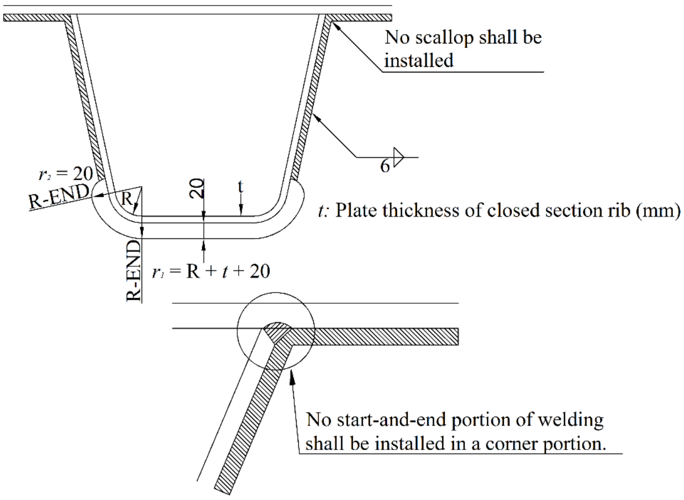


Figure 6-4 Detail of Crossover Portion and Weld

Appendices

Appendix 1 : Standard Items of QC & Inspection Records

Chapter		Items	Check Sheet Title	Inspection		
				Contractor Voluntary	Submit to Supervisor	Supervisor Attendance
1	General					
	1.1	Scope of Application				
	1.2	Construction in General				
	1.3	Execution Plan	Fabrication Plan	○	○	A
			Welding procedure	○	○	A
			Erection Plan	○	○	A
			Working Drawing	○	○	A
			Shop Drawing	○	○	A
			Erection Drawing	○	○	A
			Camber Diagram	○	○	A
2	Steel					
	2.1		Mill Sheets	○	○	B
	2.2		Storing status	○	–	C
3	Fabrication					
	3.1	Working (Processing)	Reference Tape/Plank layout	○	○	A
			Dissection/Cutting	○	–	C
			Bolt Hole	○	–	C
			Strain removal	○	–	C
			Penetration and stop rate of bolt hole	○	–	C
			Cold bent radius	○	–	C
	3.2	Weld	Welding plan, Material	○	–	B
			Management of electrode and flux	○	–	C
			Welder Welding procedure test and results	○	○	A
			Welding control sheet(Pre-heating, Heat gain restriction,	○	–	B
			Flaw inspection, repair	○	–	B
			Non-Destructive Testing	○	○	B
			Attachment and removal of Suspension jig	○	○	B
			Repair of welding flaw	○	○	B
	3.3	Stud Bolt	Material, Dimensions	○	—	C
			visual inspection	○	—	B
	3.4	Bolt Tightening		○	○	B
	3.5	Member Precision	Dimension	○	○	A
	3.6	Assembly Precision	Dimension including temporary assembly precision	○	○	A

3	3.7	Painting	Painting work plan	○	—	A
			Paint Material inspection	○	—	C
			Storing inspection	○	—	C
			Surface treatment inspection	○	—	C
			Environmental inspection	○	—	C
			Stirring inspection	○	—	C
			Maturity and pot life inspection	○	—	C
			Paint film inspection	○	-	B
			Used volume inspection	○	—	C
			Repair paint inspection	○	—	C
			Repaint inspection	○	—	C
			Scaffolding	○	—	C
			Painting work sheet	○	—	C
4	Transportation			○	○	C
5	Erection					
	5.1	Handling & Storing Material		○	○	C
	5.2	Installation of Bearing		○	○	A
	5.3	Erection Procedure		○	○	A
	5.4	Stress & Configuration during Erection	Stress and configuration observation during construction	○	○	A
	5.5	Field Assembly		○	○	A
	5.6	HTB Tightening	Material , Tightening control sheets, Contact surface control, Assembly accuracy	○	○	A
	5.7	Erection Equipment , Facility		○	—	C
	5.8	Inspection of dimensions after completion		○	○	A
6	Deck					
	N	Precast Deck		○	○	A
	6.1	Orthotropic Deck		○	○	A
7	Completion Inspection					
	Ap-1	Loading Test		○	○	A
	Ap-2	Shape Inspection		○	○	A
	AP-	Submission Documents		○	○	A
	○	Necessary				
	—	Not Necessary				
	A	Attend in principle				
	B	Inspect during other inspection				
	C	No need to attend				

Followings are reference when fabrication is complied with AASHTO.

Chapter number is in accordance with AASHTO Construction Specification.

11.4 Fabrication

11.4.1 Identification of Steels during Fabrication

The Contractor's system of assembly-marking individual pieces, and the issuance of cutting instructions to the shop shall be such as to maintain identity of the original piece.

The Contractor may furnish material that can be identified by heat number and mill test report from stock. During fabrication, up to the point of assembling members, each piece of steel, other than Grade 36 (Grade 250) steel, shall show clearly and legibly its specification.

Any piece of steel, other than Grade 36 (Grade 250) steel, which will be subject to fabricating operations such as blast cleaning, galvanizing, heating for forming, or painting which might obliterate marking prior to assembling into members, shall be marked for grade by steel die stamping or by a substantial tag firmly attached. Steel die stamps shall be low stress-type.

Upon request by the Engineer, the Contractor shall furnish an affidavit clarifying that throughout the fabrication operation the identification of steel has been maintained in accordance with this specification.

11.4.2 Storage of Materials

Structural material, either plain or fabricated, shall be stored above the ground on platforms, skids, or other supports. It shall be kept free from dirt, grease, and other foreign matter, and shall be protected as far as practicable from corrosion. Storage of high-strength fasteners shall conform to Article 11.5.6.4, "Installation."

11.4.3 Plates

11.4.3.1 Direction of Rolling

Unless otherwise specified in the contract documents, steel plates for main members and splice plates for flanges and main tension members, not secondary members, shall be cut and fabricated so that the primary direction of rolling is parallel to the direction of the main tensile and/or compressive stresses.

11.4.3.2 Plate-Cut Edges

11.4.3.2.1 Edge Planning

Sheared edges of plate more than 0.625 in. in thickness and carrying calculated stress shall be planed, milled, ground, or thermal-cut to a depth of 0.25 in.

11.4.3.2.2 Oxygen Cutting

Oxygen cutting of structural steel shall conform to the requirements of the current AASHTO/ AWS DI 1.5M/D 1.5 *Bridge Welding Code*.

11.4.3.2.3 Visual Inspection and Repair of Plate- Cut Edges

Visual inspection and repair of plate-cut edges shall be in accordance with the current AASHTO/ AWS D1.5M/D l .5 *Bridge Welding Code*.

11.4.3.3 Bent Plates

11.4.3.3.1 General

Cold-bending of fracture-critical steels and fracture− critical members is prohibited. Perform cold-bending of other steels or members, in accordance with the AASHTO/AWS D 1.5M/D 1.5 *Bridge Welding Code* and Table 11.4.3.3-1 and in a manner such that no cracking occurs.

Unless otherwise approved, the minimum bend radii for cold-forming (at room temperature), measured to the concave face of the plate are given in Table 11.4.3.3-1. If a smaller radius is required, heat may need to be applied as a part of the bending procedure. Provide the heating procedure for review by the Engineer. For grades not included in Table 11.4.3.3-1, follow minimum bend radii recommendations of the plate producer.

If possible, orient bend lines perpendicular to the direction of final rolling of the plate. If the bend line is parallel to the direction of final rolling, multiply the suggested minimum radii in Table 11.4.3.3-1 by 1.5.

Table 11.4.3.3-1 Minimum Cold-Bending Radii

	Thickness, in. (t)			
AASHTO M 270M/M 270 (ASTM A709/A709M) Grades: ksi	Up to 0.75	Over 0.75 to 1.0, incl.	Over 1.0 to 2.0, incl.	Over 2.0
36	1.5t	1.5t	1.5t	2.0t
50, 50S, 50W, or HPS 50W	1.5t	1.5t	2.0t	2.5t
HPS 70W	1.5t	1.5t	2.5t	3.0t
HPS 100W	1.75t	2.25t	4.5t	5.5t

11.4.3.3.2 Hot-Bending

If a radius shorter than the minimum specified for cold-bending is essential, the plates shall be bent hot at a temperature not greater than 1200° F, except for AASHTO M 270M/M 270 (ASTM A709/A709M), Grades HPS 70W and HPS 100W (Grades HPS 485W and HPS 690W) for which plates shall be bent hot at a temperature not greater than 1l00° F.

11.4.4 Fit of Stiffeners

End bearing stiffeners for girders and stiffeners intended as supports for concentrated loads shall have full bearing (either milled, ground, or on weldable steel in compression areas of flanges, welded as specified in the contract documents) on the flanges to which they transmit load or from which they receive load. Intermediate stiffeners not intended to support concentrated loads, unless specified in the contract documents otherwise, shall have a tight fit against the compression flange.

11.4.5 Abutting Joints

Abutting ends in compression members of trusses and columns shall be milled or saw-cut to give a square joint and uniform bearing. At other joints, not required to be faced, the opening shall not exceed 0.375 in.

11.4.6 Facing of Bearing Surfaces

The surface finish of bearing, base plates, and other bearing surfaces that are to come in contact with each other or with concrete shall meet the ANSI surface roughness requirements as defined in ANSI B46.l, Surface Roughness, Waviness, and Lay, Part I:

Table 11.4.6-1 Facing of Bearing Surface

Steel slabs	ANSI 2000 μin. (50 μm) (RMS)
Heavy plates in contact in shoes to be welded	ANSI 1000 μ m (25 μ m) RMS
Milled ends of compression members, milled or ground ends of stiffeners and fillers	ANSI 500 μ m. (12.5 μ m) RMS
Bridge rollers and rockers	ANSI 250 μin. (6.3 μm) (RMS)
Pins and pin holes	ANSI 125 μin. (3.2 μm) (RMS)
Sliding bearings	ANSI 125 μin. (3.2 μm) (RMS)

11.4.7 Straightening Material

The straightening of plates, angles, other shapes, and built-up members, when permitted by the Engineer, shall be done by methods that will not produce fracture or other injury to the metal. Distorted members shall be straightened by mechanical means or, if approved by the Engineer, by carefully planned procedures and supervised application of a limited amount of localized heat, except that heat-straightening of AASHTO M 270M/M 270 (ASTM A709/A709M) Grades HPS 70W and HPS 100W.

(Grades HPS 485W and HPS 690W) steel members shall be done only under rigidly controlled procedures, each application subject to the approval of the Engineer. In no case shall the maximum temperature exceed values in Table1 11.4.7-1.

Table 11.4.7-1 Maximum Straightening Temperature

AASHTO M270M/M 270 (ASTM A709/A709M) Grades	Temperature
HPS 70W	1100°F
HPS 100W	1100°F

In all other steels, the temperature of the heated area shall not exceed 1200° F as controlled by temperature indicating crayons, liquids, or bimetal thermometers. Heating in excess of the limits shown shall be cause for rejection, unless the Engineer allows testing to verify material integrity.

Parts to be heat-straightened shall be substantially free of stress and from external forces, except stresses resulting from mechanical means used in conjunction with the application of heat.

Evidence of fracture following straightening of a bend or buckle will be cause for rejection of the damaged piece.

11.4.8 Bolt Holes

11.4.8.1 Holes for High-Strength Bolts and Unfinished Bolts

(1) General

All holes for bolts shall be either punched or drilled, except as noted herein. The width of each standard hole shall be the nominal diameter of the bolt plus 0.0625 in. The standard hole diameter for metric bolts M24 and smaller shall be the nominal diameter of the bolt plus 2 mm. For metric bolts M27 and larger, the standard hole diameter shall be the nominal diameter of the bolt plus 3 mm.

Except as noted in the articles below, material forming parts of a member composed of not more than five thicknesses of metal may be punched full-size.

When more than five thicknesses of material are joined or, as required by Article 11.4.8(5), material shall be sub-drilled or sub-punched and then reamed full-size, or drilled full-size while in assembly.

When required, all holes shall be either sub-punched or sub-drilled 0.1875 in. smaller and, after assembling, reamed or drilled to full size.

Holes in cross frames, lateral bracing components, and the corresponding holes in connection plates between girders and cross frames or lateral components may be punched full size. Holes in longitudinal main load-carrying members, transverse floor beams, and any components designated as fracture critical (FCMs) shall not be punched full-size.

When shown in the contract documents, enlarged or slotted holes are allowed with high-strength bolts.

With the owner's approval, round or slotted holes for non-main members in thin plate may be thermally cut by plasma, laser, or oxygen-acetylene methods subject to the requirements herein.

(2) Punched Holes

If any holes must be enlarged to admit the bolts, such holes shall be reamed. Holes must be clean-cut without torn or ragged edges. The slightly conical hole that naturally results from punching operations shall be considered acceptable.

(3) Reamed or Drilled Holes

Reamed or drilled holes shall be cylindrical, perpendicular to the member, and shall comply with the requirements of Article 11.4.8.1(1) as to size. Where practical, reamers shall be directed by mechanical means. Burrs on the outside surfaces shall be removed. Reaming and drilling shall be done with twist drills, twist reamers, or rotabroach cutters. Connecting parts requiring reamed or drilled holes shall be assembled and securely held while being reamed or drilled and shall be match-marked before disassembling.

(4) Accuracy of Holes

Holes not more than 0.03125 in. larger in diameter than the true decimal equivalent of the nominal diameter that may result from a drill or reamer of the nominal diameter shall be considered acceptable. The width of slotted holes which are produced by thermal cutting or a combination of drilling or punching and thermal cutting should be not more than 0.03125 in. greater than the nominal width. The thermally-cut surface shall be ground smooth to obtain a maximum surface roughness of ANSI 1000 μin.

11.4.8.2 Accuracy of Hole Group

(1) Accuracy before Reaming

All holes punched full-size, sub-punched, or sub-drilled shall be so accurately punched that after assembling (before any reaming is done) a cylindrical pin 0.125 in. smaller in diameter than the nominal size of the punched hole may be entered perpendicular to the face of the member, without drifting, in at least 75 percent of the contiguous holes in the same plane. If the requirement is not fulfilled, the badly punched pieces shall be rejected. If any hole will not pass a pin 0.1875 in. smaller in diameter than the nominal size of the punched hole, this shall be a cause for rejection.

(2) Accuracy after Reaming

When holes are reamed or drilled, 85 percent of the holes in any contiguous group shall, after reaming or drilling, show no offset greater than 0.03125 in. between adjacent thicknesses of metal.

All steel templates shall have hardened steel bushings in holes accurately dimensioned from the centerlines of the connection as inscribed on the template. The centerlines shall be used in locating accurately the template from the milled or scribed ends of the members.

(3) Numerically-Controlled Drilled Field Connections

In lieu of sub-sized holes and reaming while assembled, or drilling holes full-size while assembled, the Contractor shall have the option to drill or punch bolt holes full-size in unassembled pieces and/or connections including templates for use with matching sub-sized and reamed holes, by means of suitable numerically-controlled (N/C) drilling or punching equipment. Full-size punched holes shall meet the requirements of Article 11.4.8.1.

If N/C drilling or punching equipment is used, the Contractor shall be required to demonstrate the accuracy of this drilling or punching procedure in accordance with the provisions of "Check Assembly − Numerically-Controlled Drilling," by means of check assemblies.

Holes drilled or punched by N/C equipment shall be drilled or punched to appropriate size either through individual pieces or drilled through any combination of pieces held tightly together.

(4) Holes for Ribbed Bolts, Turned Bolts, or Other Approved Bearing-Type Bolts

All holes for ribbed bolts, turned bolts, or other approved bearing-type bolts shall be sub-punched or sub-drilled 0.1875 in. smaller than the nominal diameter of the bolt and reamed when assembled, or drilled to a steel template or, after assembling, drilled from the solid at the option of the Fabricator. In any case, the finished holes shall provide a driving fit as specified in the contract documents.

(5) Preparation of Field Connections

Holes in all field connections and field splices of main member of trusses, arches, continuous-beam spans, bents, towers (each face), plate girders, and rigid frames shall be sub-punched or sub-drilled and subsequently reamed while assembled or drilled full-size through a steel template while assembled. Holes in cross frames, lateral bracing components, and the corresponding holes in connection plates between girders and cross frames or lateral components may be punched full size. Holes in longitudinal main load-carrying members, transverse floor beams, and any components designated as fracture critical (FCMs) shall not be punched full-size. Holes for field splices of rolled beam stringers continuous over floor beams or cross frames may be drilled full-size unassembled to a steel template. All holes for floor beams or cross frames may be drilled full-size unassembled to a steel template, except that all holes for floor beam and stringer field end connections shall be sub-punched and reamed while assembled or drilled full-size to a steel template. Reaming or drilling full-size of field-connection holes through a steel template shall be done after the template has been located with utmost care as to position and angle and firmly bolted in place. Templates used for reaming matching members or the opposite faces of a single member shall be exact duplicates. Templates used for connections on like parts or members shall be so accurately located that the parts or members are duplicates and require no match-marking.

For any connection, in lieu of sub-punching and reaming or sub-drilling and reaming, the fabricator may, at the Fabricator's option, drill holes full-size with all thicknesses or material assembled in proper position.

11.4.9 Pins and Rollers

(1) General

Pins and rollers shall be accurately turned to the dimensions shown on the drawings and shall be straight, smooth, and free from flaws. Pins and rollers more than 9.0 in. in diameter shall be forged and annealed. Pins and rollers 9.0 in. or less in diameter may be either forged and annealed or cold-finished carbon-steel shafting.

In pins larger than 9.0 in. in diameter, a hole not less than 2.0 in. in diameter shall be bored full-length along the axis after the forging has been allowed to cool to a temperature below the critical range, under suitable conditions to prevent injury by too rapid cooling, and before being annealed.

(2) Boring Pin Holes

Pin holes shall be bored true to the specified diameter, smooth and straight, at right angles with the axis of the member and parallel with each other unless otherwise required. The final surface shall be produced by a finishing cut.

The diameter of the pin hole shall not exceed that of the pin by more than 0.02 in. for pins 5.0 in. or less in diameter, or by 0.03125 in. for larger pins.

The distance outside to outside of end holes in tension members and inside to inside of end holes in compression members shall not vary from that specified more than 0.03125 in. Boring of pin holes in built-up members shall be done after the member has been assembled.

(3) Threads for Bolts and Pins

Threads for all bolts and pins for structural steel construction shall conform to the United Standard Series UNC ANSI B 1.1, Class 2A for external threads and Class 2B for internal threads, except that pin ends having a diameter of 1.375 in. or more shall be threaded six threads to the inch (metric screw threads-M Profile ANSI BI.13M with a tolerance Class 6G for external threads and 6H for internal threads).

11.4.10 Eyebars

Pin holes may be flame-cut at least 2.0 in. smaller in diameter than the finished pin diameter. All eyebars that are to be placed side by side in the structure shall be securely fastened together in the order that they will be placed on the pin and bored at both ends while so clamped. Eyebars shall be packed and match-marked for shipment and erection. All identifying marks shall be stamped with steel stencils on the edge of one head of each member after fabrication is completed so as to be visible when the bars are nested in place on the structure. Steel die stamps shall be low stress-type. No welding is allowed on eyebars or to secure adjacent eyebars.

The eyebars shall be straight and free from twists and the pin holes shall be accurately located on the centerline of the bar. The inclination of any bar to the plane of the truss shall not exceed a slope of 0.5 percent. The edges of eyebars that lie between the transverse centerline of their pin holes shall be cut simultaneously with two mechanically operated torches abreast of each other, guided by a substantial template, in such a manner as to prevent distortion of the plates.

11.4.11 Annealing and Stress Relieving

Structural members which are indicated in the contract documents to be annealed or normalized shall have finished machining, boring, and straightening done subsequent to heat treatment. Normalizing and annealing (full annealing) shall be as specified in ASTM A941. The temperatures shall be maintained uniformly throughout the furnace during the heating and cooling so that the temperature at no two points on the member will differ by more than 100° F at any one time.

Members of AASHTO M 270M/M 270 (ASTM A709/A 709M) Grades HPS 70W and HPS 100W (Grades HPS 485W and HPS 690W) steels shall not be annealed or normalized and shall be stress relieved only with the approval of the Engineer after consultation with the material producers.

A record of each furnace charge shall identify the pieces in the charge and show the temperatures and schedule actually used. Proper instruments, including recording pyrometers, shall be provided for determining at any time the temperatures of members in the furnace. The records of the treatment operation shall be available to and meet the approval of the Engineer. The holding temperature for stress relieving shall be in accordance with Section 4.4 of the current AASHTO/ AWS D1.5M/D1.5 *Bridge Welding Code*.

Members, such as bridge shoes, pedestals, or other parts that are built up by welding sections of plate together shall be stress relieved in accordance with the procedure of Section 4.4 of the current AASHTO/ AWS D 1.5M/D 1.5 *Bridge Welding Code*, when required by the contract documents.

11.4.12 Curved Girders

11.4.12.1 General

Flanges of curved, welded girders may be cut to the radii specified in the contract documents or curved by applying heat as specified in the succeeding articles providing the radii is not less than allowed by Article 10.15.2, "Minimum Radius of Curvature," of the AASHTO *Standard Specifications for Highway Bridges*, 17th Edition, Design Specifications.

11.4.12.2 Heat-Curving Rolled Beams and Welded Girders

(1) Materials

Structural steels conforming to AASHTO M 270M/M 270 (ASTM A709/A709M), Grade 36, 50, 50S, 50W, HPS 50W, HPS 70W, or HPS 100W (Grade 250, 345, 345S, 345W, HPS 345W, HPS 485W, or HPS 690W) may be heat-curved.

(2) Type of Heating

Beams and girders may be curved by either continuous or V-type heating as approved by the Engineer. For the continuous method, a strip or intermittent strips along the edge of the top and bottom flange shall be heated approximately simultaneously depending on flange widths and thicknesses; the strip shall be of sufficient width and temperature to obtain the required curvature. For the V-type heating, the top and bottom flanges shall be heated in truncated triangular or wedge-shaped areas having their base along the flange edge and spaced at regular intervals along each flange; the spacing and temperature shall be as required to obtain the required curvature and heating shall progress along the top and bottom flange at approximately the same rate.

For the V-type heating, the apex of the truncated triangular area applied to the inside flange surface shall terminate just before the juncture of the web and the flange is reached. To avoid unnecessary web distortion, special care shall be taken when heating the inside flange surfaces (the surfaces that intersect the web) so that heat is not applied directly to the web. When the radius of curvature is 1000 ft or more, the apex of the truncated triangular heating pattern applied to the outside flange surface shall extend to the juncture of the flange and web. When the radius of curvature is less than 1000 ft, the apex of the truncated triangular heating pattern applied to the outside flange surface shall extend past the web for a distance equal to one-eighth of the flange width or 3.0 in., whichever is less. The truncated triangular pattern shall have an included angle of approximately 15 to 30 degrees but the base of the triangle shall not exceed 10.0 in. Variations in the patterns prescribed above may be made with the approval of the Engineer.

For both types of heating, the flange edges to be heated are those that will be on the inside of the horizontal curve after cooling. Heating both inside and outside flange surfaces is only mandatory when the flange thickness is 1.25 in. or greater, in which case, the two surfaces shall be heated concurrently. The maximum temperature shall be prescribed as follows.

(3) Temperature

The heat-curving operation shall be conducted in such a manner that the temperature of the steel does not exceed 1200° F for Grades 36, 50, 50S, 50W, and HPS 50W (Grades 250, 345, 345S, 345W, and HPS 345W); and 1100° F for Grades HPS 70W and HPS 100W (Grades HPS 485W and HPS 690W) as measured by temperature-indicating crayons or other suitable means. The girder shall not be artificially cooled until after naturally cooling to 600° F. The method of artificial cooling shall be subject to the approval of the Engineer.

(4) Position for Heating

The girder may be heat-curved with the web in either a vertical or a horizontal position. When curved in the vertical position, the girder shall be braced or supported in such a manner that the tendency of the girder to deflect laterally during the heat-curving process will not cause the girder to overturn.

When curved in the horizontal position, the girder shall be supported near its ends and at intermediate points, if required, to obtain a uniform curvature; the bending stress in the flanges due to the dead load of the girder and externally applied loads shall not exceed the usual allowable design stress. When the girder is positioned horizontally for heating, intermediate safety catch blocks shall be maintained at the mid-length of the girder within 2.0 in. of the flanges at all times during the heating process to guard against a sudden sag due to plastic flange buckling.

(5) Sequence of Operations

The girder shall be heat-curved in the fabrication shop before it is painted. The heat-curving operation may be conducted either before or after all the required welding of transverse intermediate stiffeners is completed. However, unless provisions are made for girder shrinkage, connection plates and bearing stiffeners shall be located and attached after heat-curving. If longitudinal stiffeners are required, they shall be heat-curved or oxygen-cut separately and then welded to the curved girder. When cover plates are to be attached to rolled beams, they may be attached before heat-curving if the total thickness of one flange and cover plate is less than 2.5 in. and the radius of curvature is greater than l 000 ft. For other rolled beams with cover plates, the beams shall be heat-curved before the cover plates are attached; cover plates shall be either heat-curved or oxygen-cut separately and then welded to the curved beam.

(6) Camber

Girders shall be cambered before heat-curving. Camber for rolled beams may be obtained by heat−cambering methods approved by the Engineer. For plate girders, the web shall be cut to the prescribed camber with suitable allowance for shrinkage due to cutting, welding, and heat-curving. However, subject to the approval of the Engineer, moderate deviations from specified camber may be corrected by a carefully supervised application of heat.

(7) Measurement of Curvature and Camber

Horizontal curvature and vertical camber shall be measured for final acceptance after all welding and heating operations are completed and the flanges have cooled to a uniform temperature. Horizontal curvature shall be checked with the girder in the vertical position.

Appendix 3 : Loading Test

1. **Purpose of the Test**

   The purpose of the test is to verify the theoretical strength or rigidity of the proposed structure and also to verify if the load distribution in the structure is as predicted in the analysis. At the same time, the test will reveal any unusual structural behavior which is not accounted for in the analysis. Loading test is carried out after completion and before service.

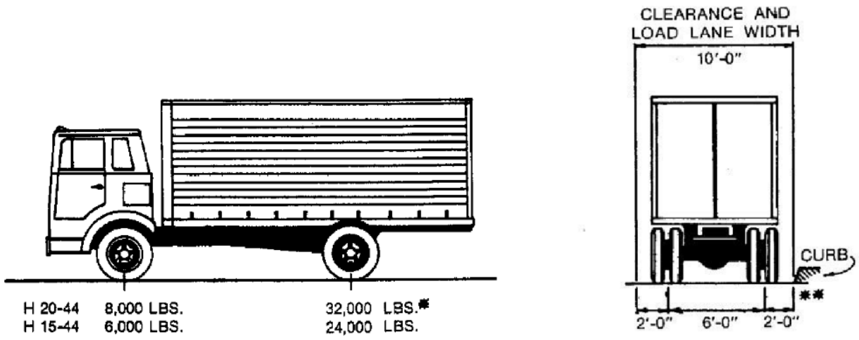
2. **Design Live Loads**

   Static live load

   There are some design live loads in Myanmar. Those are,

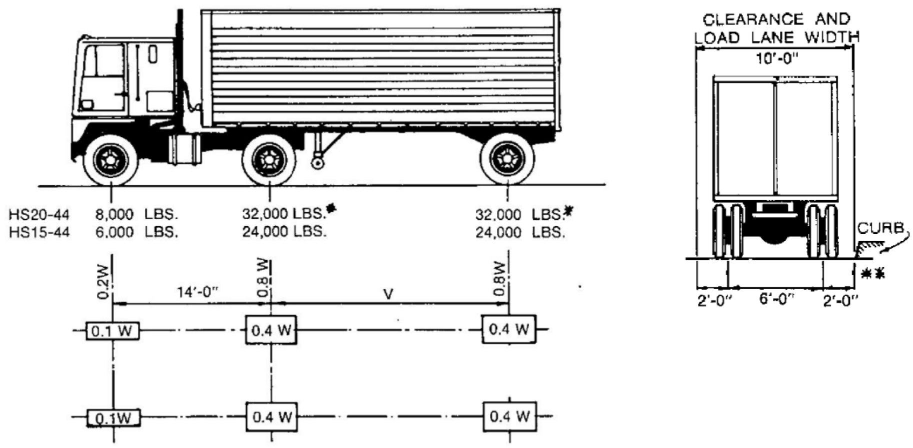
   (1) Truck Loading

   1)-1 H truck



(a)-1 H Truck

   1)-2 HS 20 or HL 93 Truck

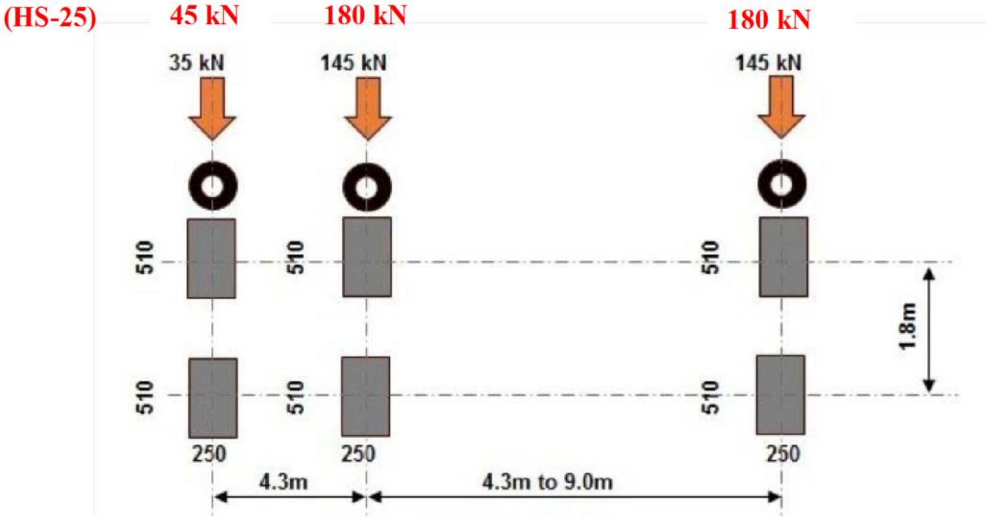


W = COMBINED WEIGHT ON THE FIRST TWO AXLES WHICH IS THE SAME AS FOR THE CORRESPONDING H TRUCK.
V = VARIABLE SPACING — 14 FEET TO 30 FEET INCLUSIVE. SPACING TO BE USED IS THAT WHICH PRODUCES MAXIMUM STRESSES.

(a)-2 HS Truck

1)-3 HS-25 Truck

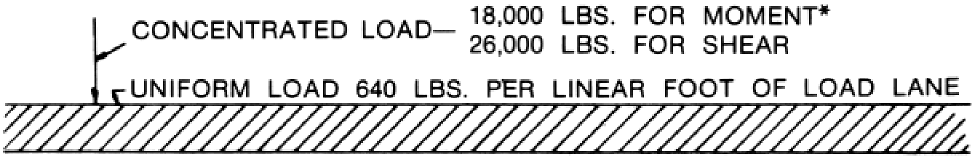
Hs-25 Loading = 1.25×HS-20



(2) Tandem Loading

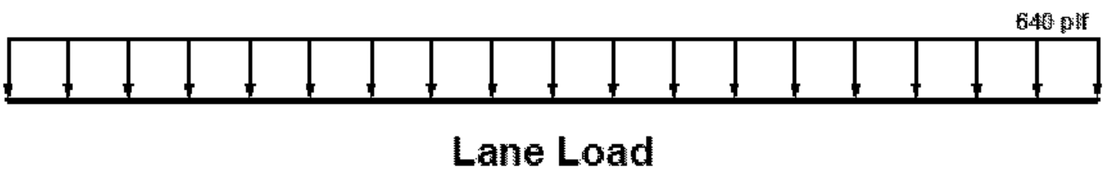
(3) Lane Loading

3)-1 HS20-44



H20-44 LOADING
HS20-44 LOADING

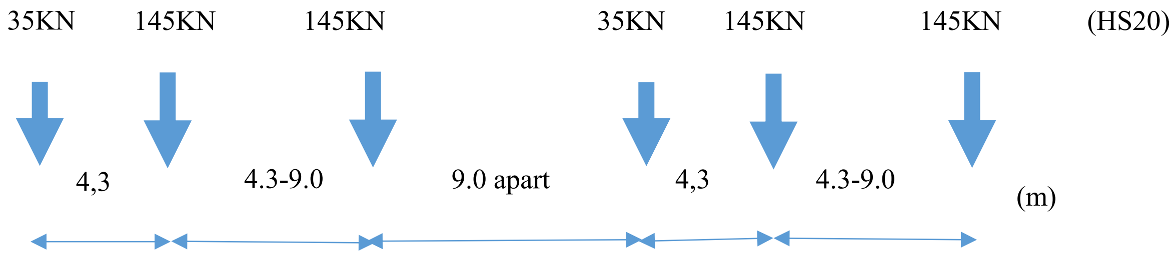
3)-2 HL93



(4) Truck load loading

4)-1 HS 20-44 and HS25-44

a. Truck Train Axle Distance



4)-2 HL93

As for truck load, 1 Vehicle /lane.

(5) Combination of Live Load

Loading Case	(a) HS20-44	(b) HS25-44	(c) HL93
(1)	Truck Train Load	Truck Train Load	Single Track Load +Lane Load
(2)	Single Tandem Load	-	Single Tandem Load + Lane Load
(3)	Lane Load	-	-
(4) Impact (Not applied to lane load)	50/(L+125) = 0.3	50/(L+125) = 0.3	0.33

Comparison of Load Intensity for Bridge 2-lane, 40m span.

(a) HS20-44

(1) Truck train Load 325*2*2*1.3 = 1690KN

(2) Single Tandem Load 24kips*2*4.4KN/kips*n*1.3 = 274KN*n

(3) Lane Load （18Klb*4.4KN/kips*2=158KN) + (9.3KN*2*40=744KN) = 902KN

(b) HS25-44

(1) Truck Train Load (45+2*180) *2*2*1.3 = 2106KN

(c) HL93

(1) Single Truck Load +Lane Load (325*2*1.33=865KN) + (9.3KN*2*40=744KN)=1609KN

(2) Single Tandem Load +Lane Load (25kips*2*4.4KN/kips*1.33=293KN) + (9.3KN*2*40=744KN) =1037KN

3. Measurement Items

Measurement items are as follows:

1) Static Measurement
   a. Vertical deflection
   b. Stresses as necessary
   c. Expansion and contraction due to temperature change
2) Vibration Test
   a. Fundamental natural periods and modes

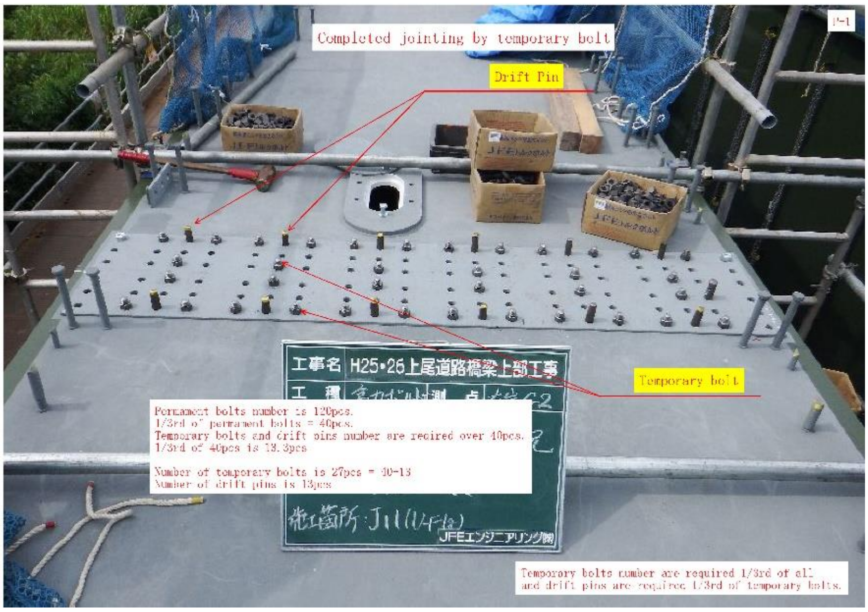
4. Measurement method

1) Static measurement
   a. Live load for static measurement is the design load without impact in principle. In case, no design truck is available at the loading test site, equivalent truck loading can be applied.
   b. Contraction and expansion amount are measured with use of temperature change of night time and day time.
2) Vibration Test

   Vibration test is applied for long span bridges.

Appendix 4 : Work Procedure for Bolt

1. Temporary fixing

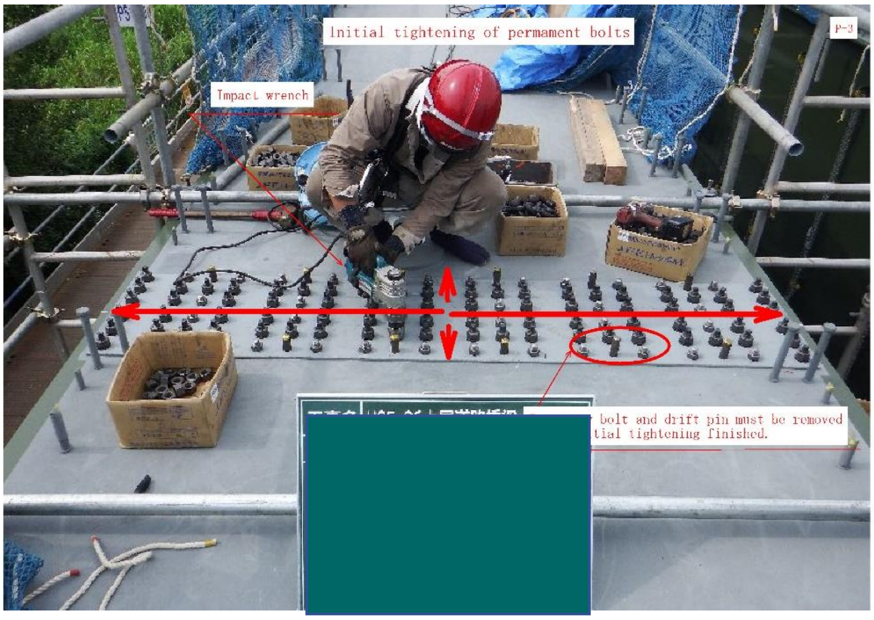


- Drift pins are firstly driven. If pilot holes are determined in factory, drift pins are driven first into the pilot holes.
- Service bolts are installed into inner holes to outer holes

2. Inserting actual bolts

- Permanent bolts are inserted into the empty holes.

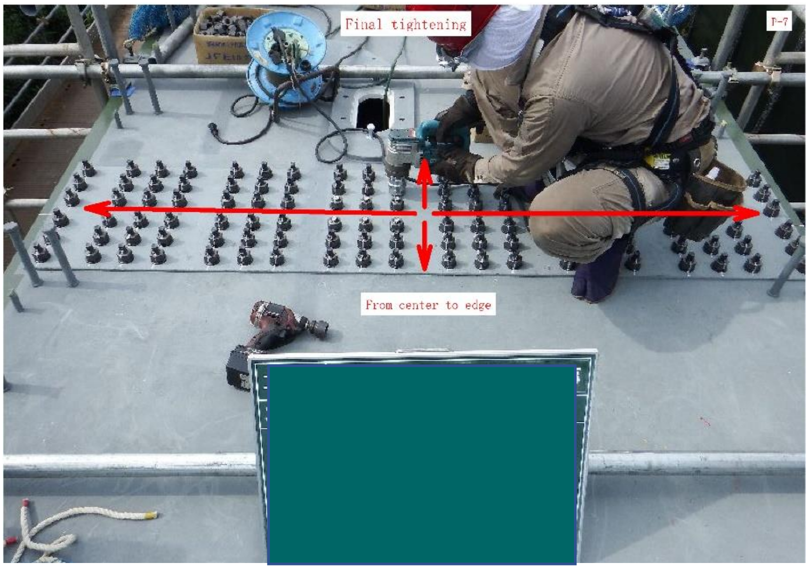
3. Initial tightening



- Initial tightening is done from inward to outward until 60% of target axial force by impact wrench.
- Temporary bolts and drift pins must be removed after initial tightening finish.
- Temporary bolts shall be removed first and drift pin shall be second.

4. Marking

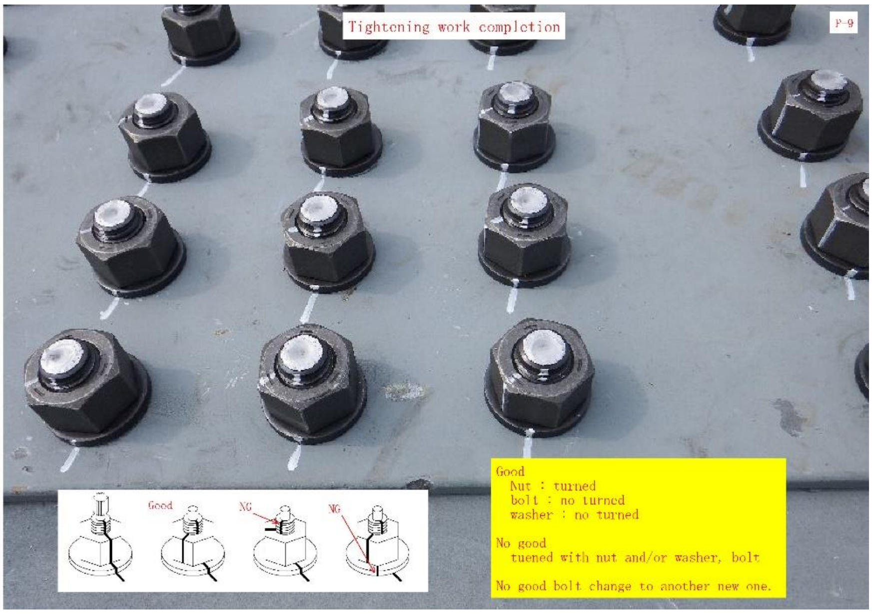
5. Secondary tightening



- Secondary tightening is done from inward to outward till 100% target axial force or pin tail cut by bolt tightener.

6. Inspection after tightening

- Torque control method
  - Induced torque is measured by torque wrench.
  - Confirmation of marking.
- Torshear bolt method



- Confirmation of marking.
- Confirmation of marking and pin tail cut.