1070-9 MECHANICAL BUTT SPLICES

When called for by the contract or when directed by the Engineer, use a mechanical butt reinforcing steel splice from an approved source. Use a standard metal filled sleeve, cement mortar filled sleeve, threaded steel couplings, forged steel sleeve or cold-forged sleeve. An exothermic process whereby molten filler metal, contained by a high strength steel sleeve of larger inside diameter than the bars, is introduced into the annular space between the bars and the sleeve and between the ends of the bars may be used. Provide a splice that is capable of transferring at least 125% of the yield strength of the bars from one bar to the other by the mechanical strength of the splice components.

For splices not on the approved list, before use and as a condition of approval, assemble three test splices in the presence of the Engineer for each size of bar which is proposed for use on the project. Forward the test splices to the Materials and Tests Unit in Raleigh, NC for testing and approval.

1070-10 REJECTION

Reinforcing material that does not meet the *Standard Specifications* is rejected. When required by the Engineer, replace reinforcing material that is bent, deformed, exhibits cracked material or welds, contaminated and when the maximum amount of coating damage exceeds the limits herein or degraded coating is observed and as determined by the Engineer.

SECTION 1072
STRUCTURAL STEEL

1072-1 GENERAL

Furnish and fabricate all structural steel and related incidental materials including sign supports and high mount lighting standards and use materials in accordance with this section.

(A) Department Steel Bridge Qualification Program

Fabricators furnishing structural steel bridge members for Department projects shall comply with this program. Qualifications shall be submitted prior to project letting.

(B) Fabricator Qualification

Use steel fabricators on the Department's Approved Structural Steel Fabricators List that have undergone and successfully completed the Department's audit process for the type work being performed as outlined below. The list is available from the Materials and Tests Unit or on the Department's website.

Employ fabricators that possess an AISC Bridge Component Quality Management Systems (QMS) Certified Component Manufacturer Certification (CPT) for the following:

(1) High mount lighting standards in excess of 80 feet in length

(2) Structural steel components of fender systems,

(3) Solar array platforms

(4) Retaining walls and noise walls

(5) Sign supports and sign structures

(6) Expansion joints (except modular joints)

Employ fabricators that possess an AISC certification category of Simple Bridge Requirement (SBR) for the following:

(1) Pot and expansion bearings

(2) Simple span rolled beams (unspliced rolled sections), including those requiring cover plates,

(3) Pedestrian bridge truss sections

(4) Modular expansion joints

Employ fabricators of rail structures, heat curved rolled beams, rolled beams for continuous spans and plate girders that are AISC certified bridge fabricator – Advanced Bridge Requirement (ABR). Employ fabricators of fracture critical bridge beams and girders that have a Fracture Critical Members Endorsement from AISC. Fabricators performing shop coating applications shall meet the minimum requirements outlined in Section 442.

When AISC certification is required, submit proof of registration and certification of the plant or shop under the AISC program to the State Materials Engineer before beginning fabrication and on an annual basis. The same requirements apply to fabricators subcontracting work from the fabricator directly employed by the Contractor.

(C) Office

Ensure that fabricators of main structural steel components of bridges provide an office area with an approximate floor space of 100 sf, a desk or drafting table, 2 chairs, telephone, facilities for proper heating and cooling, telephone, internet access and adequate lighting and located at the plant site for the exclusive use of the Engineer or their designee. Ensure fabricators of other structural steel items furnish reasonable work areas for the Engineer.

1072-2 SHAPES, PLATES, BARS AND SHEETS

Use shapes, plates, bars and sheets meeting AASHTO M 270 Grade 36 unless otherwise required by the contract. For painted beams or girders, use sheet material of 1/32 inch in thickness meeting ASTM A1008 or A1011, and sheet material of 1/16 inch through 5/32 inch thickness meeting ASTM A1011 for Grades 36, 40 or 45. For unpainted beams or girders, use sheet material less than 3/16 inch thickness meeting ASTM A606 for Type 4.

1072-3 BEARING PLATE ASSEMBLIES

Unless otherwise shown in the plans, galvanize steel bearing assemblies for both structural steel beams and girders and prestressed concrete girders. Galvanize anchor bolts, nuts and washers in accordance with AASHTO M 232. Cut pipe sleeves and collars from Schedule 40 PVC pipe meeting ASTM D1785.

Except for attachments of bearing plates to beams, fabricate and weld bearing plate assemblies before galvanizing the steel. Seal all joints of welded parts with weld material. After the fabrication of the bearing plate assembly is complete, galvanize the assembly in accordance with AASHTO M 111. For prestressed concrete girders, clean welds made for attaching bearing plates to beams or girders and give them two coats of organic zinc repair paint having a minimum total coating thickness of 3 dry mils. For steel beams and girders, clean and paint in accordance with Article 442-10.

Repair galvanized surfaces that are abraded or damaged at any time after the application of the zinc coating by thoroughly wire brushing the damaged areas and removing all loose and cracked coating, after which give the cleaned area two coats of organic zinc repair paint having a minimum total coating thickness of 3 dry mils.

Use zinc rich paint meeting Article 1080-9.

1072-4 ANCHOR BOLTS

Unless otherwise stated herein, use anchor bolts meeting ASTM A307 for Grade A.

Provide anchor bolts for bearing plate assemblies meeting ASTM A449.

Swedge anchor bolts for a distance equal to the embedment length minus 3 inches measured from the embedded end.

Hot-dip galvanize anchor bolts, nuts and washers in accordance with AASHTO M 232.

1072-5 HIGH STRENGTH BOLTS, NUTS AND WASHERS

(A) General

Furnish all high-strength bolts, nuts and washers, including direct tension indicators, in accordance with the appropriate AASHTO or ASTM materials specifications as amended and revised herein.

Furnish the Engineer a copy of the manufacturer's test report for each component. Ensure the report indicates the testing date, the city and state where the components were manufactured, the lot number of the material represented, the rotational capacity tests lot number and the source identification marking used by the manufacturer of each component. On test reports for direct tension indicators, include the tension load at which indicators are tested, gap clearance, nominal size and coating thickness.

Produce each permanent fastener component installed in a structure from domestically processed material containing the grade identification markings required by the applicable reference specification and the manufacturer's source identification marking. A copy of the source identification marking used by each manufacturer is on file with the Department's Materials and Tests Unit.

Obtaining permanent bolts, nuts and washers in any one structure from different manufacturers is allowed provided:

(1) All bolts are produced by only one manufacturer.

(2) All nuts are produced by only one manufacturer.

(3) All washers are produced by only one manufacturer.

Have all fasteners used in a structure furnished by the fabricator of the steel. When required, submit the fasteners for sampling and testing at least five weeks before delivery to the project site. The fabricator shall sample and test each diameter bolt, nut and washer assembly to be used on the project. In accordance with Table 1072-1, a minimum of three assemblies per Lot/Heat number shall be submitted by the fabricator to the Materials and Test Laboratory.

TABLE 1072-1
SAMPLING REQUIREMENTS FOR
HIGH STRENGTH BOLTS, NUTS AND WASHERS

Lot / Heat Number	Number of Samples
0-800	3 Assemblies
801-8000	6 Assemblies
> 8000	9 Assemblies

Ship only those fasteners to the project that are sampled, tested and approved. Protect the material from moisture during storage such that it does not contain any indication of rust at the time of installation. Ensure that each component contains a thin coat of lubricant at the time of installation.

When galvanized high strength bolts are required, use bolts, nuts and washers meeting Subarticle 1072-5(F).

When corrosion resistant structural steel is required by the plans, provide fasteners with atmospheric corrosion resistance and weathering characteristics comparable to that of the structural steel.

(B) Specifications

Ensure that all bolts meet ASTM F3125.

Ensure that all nuts meet ASTM A194 as applicable or ASTM A563. Completely coat each nut with a wax lubricant.

Ensure that all washers meet ASTM F436.

Ensure that all direct tension indicators meet ASTM F959.

(C) Manufacturing

(1) Bolts

Hardness for bolts shall be in accordance with ASTM F3125.

(2) Nuts

(a) Heat treat galvanized nuts to Grades 2H, DH or DH3.

(b) Use plain (ungalvanized) nuts of Grades 2, C, D or C3 meeting the hardness values in accordance with ASTM A194 or heat treat to Grades 2H, DH or DH3.

(c) Tap oversize galvanized nuts the minimum amount required by ASTM A563. Overtap the nut such that the nut assembles freely on the bolt in the coated condition and meets mechanical requirements of ASTM A563 and the rotational-capacity test herein.

(3) Mark all bolts, nuts and washers in accordance with the appropriate ASTM Specifications.

(4) Direct Tension Indicators

(a) For Type 3 high strength bolts, mechanically galvanize direct tension indicators to ASTM B695, Class 55, and then apply baked epoxy to a thickness of 1 mil minimum. Direct tension indicators need not be mechanically galvanized or epoxy coated if they are made from material conforming to ASTM F3125, Type 3 bolts.

(b) For plain Type 1 high strength bolts, provide direct tension indicators that are plain or mechanically galvanized to ASTM B695, Class 55.

(c) For galvanized Type 1 high strength bolts, mechanically galvanize direct tension indicators to ASTM B695, Class 55.

(D) Testing

(1) Bolts

(a) Proof load tests in accordance with ASTM F606, Method 1, are required at the minimum frequency as specified in ASTM F3125.

(b) Wedge tests on full size bolts in accordance with ASTM F606. If bolts are galvanized, perform the tests after galvanizing. Test at a minimum frequency as specified in ASTM F3125.

(c) If galvanized bolts are supplied, measure the thickness of the zinc coating. Take measurements on the wrench flats or top of bolt head.

(2) Nuts

(a) Proof load tests in accordance with ASTM F606, Paragraph 4.2, are required at the minimum frequency of as specified in ASTM A563 and ASTM A194. If nuts are galvanized, perform the tests after galvanizing, overtapping and lubricating.

(b) If galvanized nuts are supplied, measure the thickness of the zinc coating. Take measurements on the wrench flats.

(3) Washers

(a) If galvanized washers are supplied, perform hardness testing after galvanizing.

(b) Remove the coating before taking hardness measurements.

(c) If galvanized washers are supplied, measure the thickness of the zinc coating.

(d) Test direct tension indicators in accordance with ASTM F959.

(4) Assemblies

Rotational-capacity tests are required to be performed by an AASHTO accredited laboratory. Ensure the manufacturer or distributor perform such tests on all black or galvanized (after galvanizing) bolt, nut and washer assemblies before shipping. Washers are required as part of the test.

The following applies:

(a) Except as modified herein, perform the rotational-capacity test in accordance with ASTM F3125.

(b) Test each combination of bolt production lot, nut lot and washer lot as an assembly. Where washers are not required by the installation procedures, do not include in the lot identification.

(c) Assign a rotational-capacity lot number to each combination of lots tested.

(d) The minimum frequency of testing is two assemblies per rotational-capacity lot.

(e) Assemble the bolt, nut and washer assembly in a Skidmore-Wilhelm Tension Indicating Device (Calibrator) or an acceptable equivalent device (This requirement supersedes the current ASTM F3125 requirement to perform the test in a steel joint). For short bolts that are too short for assembly in the Skidmore-Wilhelm, see Subarticle 1072-5(D)(4)(i).

(f) The minimum rotation, from a snug tight condition (10% of the specified proof load), is: 240° (2/3 turn) for bolt lengths less than 4 diameters; 360° (1 turn) for bolt lengths greater than 4 diameters and less than 8 diameters; 480° (1 1/3 turn) for bolt lengths greater than 8 diameters.

(g) These values differ from ASTM F3125.

(h) Achieve tension at the above rotation equal to or greater than 1.15 times the required installation tension. The installation tension and the tension for the turn test are shown in Table 1072-2.

TABLE 1072-2
BOLT TENSION REQUIREMENTS

Diameter, inch	**1/2"**	**5/8"**	**3/4"**	**7/8"**	**1"**	**1 1/8"**	**1 1/4"**	**1 3/8"**	**1 1/2"**
Req. Installation Tension, kips	12	19	28	39	51	64	81	97	118
Turn Test Tension, kips	14	22	32	45	59	74	94	112	136

(i) After the required installation tension listed in Table 1072-2 is exceeded, one reading of tension and torque is taken and recorded. The torque value shall conform to the following equation:

$$\textbf{Torque} \leq 0.25(P \times D)$$

Where:

Torque	=	measured torque in foot-lbs.
P	=	measured bolt tension in lbs.
D	=	bolt diameter in feet

For bolts that are too short to test in a Skidmore-Wilhelm Calibrator, test in a steel joint. The tension requirement of Subarticle 1072-5(D)(4)(h) is computed using a value of **P** equal to the turn test tension shown in the Table 1072-2.

(5) Reporting

(a) Record the results of all tests, including zinc coating thickness, required herein and in the appropriate specifications.

(b) Report the location where tests are performed and date of tests on the appropriate document.

(6) Witnessing

Witness of the test by an inspection agency is not required; however, ensure the manufacturer or distributor performing the tests certifies that the recorded results are accurate.

(7) Documentation

(a) Mill Test Report(s)

(i) Furnish Mill Test Report(s) for all mill steel used in the manufacture of the bolts, nuts or washers.

(ii) Indicate in the Mill Test Report the place where the material was melted and manufactured, the lot number of the material represented and the source identification used by the manufacturer.

(b) Manufacturer Certified Test Report(s)

(i) Have the manufacturer of the bolts, nuts and washers furnish Manufacturer Certified Test Report(s) for the item furnished.

(ii) Include in each Manufacturer Certified Test Report the relevant information required in accordance with Subarticle 1072-5(D)(5).

(iii) Have the manufacturer or distributor performing the rotational-capacity test include on the Manufacturer Certified Test Report:

A) The lot number of each of the items tested.

B) The rotational-capacity lot number as required in Subarticle 1072-5(D)(4)(c).

C) The results of the tests required in Subarticle 1072-5(D)(4).

D) The pertinent information required in Subarticle 1072-5(D)(5)(b).

E) A statement that the Manufacturer Certified Test Report for the items are in conformance to the *Standard Specifications* and the appropriate AASHTO specifications.

F) The location where the bolt assembly components were manufactured.

(c) Distributor Certified Test Report(s)

(i) Ensure that the Distributor Certified Test Report(s) includes Manufacturer Certified Test Reports above for the various bolt assembly components.

(ii) Ensure the rotational-capacity test is performed by a distributor or a manufacturer and reported on the Distributor Certified Test Report.

(iii) Include in the Distributor Certified Test Report the results of the tests required in Subarticle 1072-5(D)(4).

(iv) Include in the Distributor Certified Test Report the pertinent information required in Subarticle 1072-5(D)(5)

(v) Include in the Distributor Certified Test Report the rotational-capacity lot number as required in Subarticle 1072-5(D)(4)(c).

(vi) Ensure that the Distributor Certified Test Report certifies that the Manufacturer Certified Test Reports are in conformance to this *Standard Specifications* and the appropriate ASTM specifications.

(E) Shipping

(1) Ship bolts, nuts and washers, where required, from each rotational-capacity lot in the same container. If there is only one production lot number for each size of nut and washer, shipping of the nuts and washers in separate containers is allowed. Permanently mark each container on the side with the rotational-capacity lot number such that identification is possible at any stage before installation.

(2) Provide the appropriate MTR and MCTR or DCTR to the contractor or owner as required by the contract.

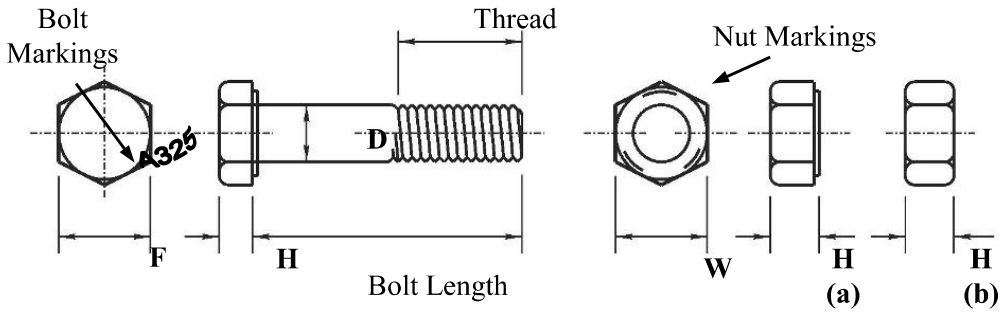

Figure 1072-1. Bolt and nut description. Bolt and nut marking varies. Refer to Subarticle 1072-5(B). **F** is the width across the flats of the bolt. **H** is the height of the bolt or nut. Nuts may be washer facing as in **(a)** or double chamfered as in **(b)**. **D** is the bolt diameter and nominal bolt size. **W** is the width across the flats of the nut.

TABLE 1072-3
HIGH STRENGTH BOLTS
BOLT AND NUT DIMENSIONS

Nominal Bolt Size, inch	Heavy Hexagon Structural Bolt Dimensions, inch			Semi-Finished Heavy Hexagon Nut Dimensions, inch	
	Width Across Flats	Height	Thread Length	Width Across Flats	Height
(D)	*(F)*	*(H)*	*(Thread)*	*(W)*	*(H)*
1/2	7/8	5/16	1	7/8	31/64
5/8	1 1/16	25/64	1 1/4	1 1/16	39/64
3/4	1 1/4	15/32	1 3/8	1 1/4	47/64
7/8	1 7/16	35/64	1 1/2	1 7/16	55/64
1	1 5/8	39/64	1 3/4	1 5/8	63/64
1 1/8	1 13/16	11/16	2	1 13/16	1 7/64
1 1/4	2	25/32	2	2	1 7/32
1 3/8	2 3/16	27/32	2 1/4	2 3/16	1 11/32
1 1/2	2 3/8	15/16	2 1/4	2 3/8	1 15/32

TABLE 1072-4
HIGH STRENGTH BOLTS WASHER DIMENSIONS

Bolt Size D, inch	Circular Washers Dimensions, inch				Square or Rectangular Beveled Washers Dimensions for American Standard Beams and Channels, inch		
	Nominal Outside Diameter	Nominal Diameter of Hole	Thickness Min.	Thickness Max.	Minimum Side Dimension	Mean Thickness	Slope of Taper in Thickness
1/2	1 1/16	17/32	.097	.177	1 3/4	5/16	1:6
5/8	1 5/16	11/16	.122	.177	1 3/4	5/16	1:6
3/4	1 15/32	13/16	.122	.177	1 3/4	5/16	1:6
7/8	1 3/4	15/16	.136	.177	1 3/4	5/16	1:6
1	2	1 1/8	.136	.177	1 3/4	5/16	1:6
1 1/8	2 1/4	1 1/4	.136	.177	2 1/4	5/16	1:6
1 1/4	2 1/2	1 3/8	.136	.177	2 1/4	5/16	1:6
1 3/8	2 3/4	1 1/2	.136	.177	2 1/4	5/16	1:6
1 1/2	3	1 5/8	.136	.177	2 1/4	5/16	1:6
1 3/4	3 3/8	1 7/8	.178[A]	.28[A]	-	-	-
2	3-3/4	2-1/8	.178[A]	.28[A]	-	-	-
Over 2 to 4 Incl.	2**D**-1/2	**D**+1/8	.24[B]	.34[B]	-	-	-

A. 3/16 inch nominal
B. 1/4 inch nominal

(F) Galvanized High Strength Bolts, Nuts and Washers

Use galvanized high strength bolts, nuts and washers meeting all other requirements of this subarticle except as follows:

(1) Use Type 1 bolts.

(2) Quench and temper washers.

(3) Mechanically galvanize in accordance with ASTM B695, Class 55.

(4) Ship galvanized bolts and nuts in the same container.

(5) Use organic zinc repair paint for touch-up of galvanized surfaces meeting Article 1080-9.

(6) Include in manufacturer's test reports results of the zinc coating thickness measurements.

(7) Have each galvanized nut coated with a wax lubricant with a color contrast to that of the zinc coating.

1072-6 WELDED STUD SHEAR CONNECTORS

Use Type B shear studs in accordance with the Bridge Welding Code as defined in Article 1072-18.

Use and install welded stud shear connectors meeting Article 1072-18. Ensure that shear studs and the areas of beams, girders or other structural steel to which the studs are welded are free of rust, rust pits, oil, grease, moisture, paint, galvanizing, loose mill scale or other deleterious matter which adversely affects the welding operation. Apply shear studs on steel with tightly adhering mill scale as determined by the Engineer provided acceptable results are achieved and the installed studs meet the Bridge Welding Code. Unless otherwise directed by the Contract plans, studs shall be welded with automatically timed stud welding equipment connected to a suitable source connected to an electrode negative (DCEN) power. Welding

voltage, current, time, and gun settings for lift and plunge should be set at optimum settings based on past practice, recommendations of stud and equipment manufacturer, or both.

1072-7 INSPECTION

(A) General

Give the Materials and Tests Unit 72 hours' notice for in-state producers and 192 hours' notice for producers out-of-state before beginning work in the shop. The "hours' notice" is defined as working hours' Monday thru Friday, 8 AM to 5 PM. Do not manufacture or fabricate any material, other than stock items, before the Materials and Tests Unit is notified and the final shop drawings are reviewed, accepted and returned to the fabricator. The fabricator shall have a stamped approved set of drawings assigned to the NCDOT assigned inspection staff and delivered to him upon his/her arrival on site. Shop drawings shall include all current revisions.

The shop inspection performed by the Department or inspection agency hired by the Department is intended as QA to assure to the Department that the fabricator is following all quality control requirements and is providing a product conforming to the Contract requirements. The inspection is not expected to replace the fabricator's quality control. The inspection and acceptance of the work performed by the Department or its representative does not relieve the fabricator of providing materials and finished products as specified.

The Department may reject defective or non-conforming materials at any time. Replace rejected materials promptly at no additional cost to the Department.

The contractor/fabricator shall be responsible for and shall be required to perform all quality control inspections and nondestructive testing in accordance with the Bridge Welding Code as defined in Article 1072-18 and as required by the contract. Perform all quality control inspection and nondestructive testing in the presence of the Department's inspector unless otherwise approved by the Department's inspector. Obtain approval for all quality control inspectors from the Department's inspector and ensure their qualification in accordance with the Bridge Welding Code and these specifications. Maintain all QC reports as required by the Bridge Welding Code, including, but not limited to, visual and nondestructive testing reports and all phases of coating application inspection. Provide copies of all QC reports, including all radiographic films, to the Department inspector upon request. These copies become the property of the Department and shall bear certification (written testimony) signature of the quality control inspector. No separate payment is made for this inspection and testing. The entire cost of this work is included in the unit contract price for the structural steel items involved.

Furnish facilities for the inspection of material and work in the mill and shop, and allow the inspectors unescorted, free access to the necessary parts of the mill or shop. Do not ship any member or component of the structural steel from the shop to the job site before approval by the Department's inspector. Such approval is stamped on the member or appropriate container by the fabricator's quality control and the Department's inspector only after piece mark, quantity, and contract specifications compliance have been verified.

Furnish the Engineer with as many copies of mill orders and shipping statements as directed. The acceptance of any material or finished member by the Department's inspector is not a bar to their subsequent rejection, if found defective. Replace rejected material and correct rejected work promptly and satisfactorily.

(B) Shop and Mill Inspection

Shop inspection is performed on all structural steel used on any project. Mill inspection of structural steel is performed when so noted in the plans or in the Specifications. Furnish complete certified mill test reports for all structural steel used except a Type 6 (Supplier Certification) material certification in accordance with Article 106-3 as to the grade of steel used is acceptable for small amounts of structural steel items which are furnished from the supplier's stock and which are difficult to identify on any mill test report.

Show in the supplier's certification the items fabricated from stock material and the pounds of steel required for each item. A supplier's certification represents only anchor bolts, pipe sleeves, masonry plates, sole plates, diaphragm tees, connector plates and web stiffener plates. Represent all other items required for a structure by certified mill test reports as specified above.

Indicate in the complete certified mill test reports the pounds of steel and the item or items they represent and show heat number of steel, mechanical tests, chemical analyses, Department's project number, station number, the ASTM or AASHTO specification to which the material conforms and a signed statement certifying where the steel was melted and manufactured.

Forward to the Materials and Tests Unit a letter which states by contract number, project number, structure number and station number the items and pounds of steel that are represented by a supplier's certification and those represented by the certified mill test reports identifying the beam and/or plate material for each main member.

The Department reserves the right to select any item for test. Bear any expense of obtaining the sample. The tests are performed at the Department's expense.

(C) Sampling Structural Steel

Furnish samples of structural steel at the beginning of fabrication when random sampling is required.

Furnish one 2 1/2 inch x 26 inch sample for each grade of steel used on a project per 1,000,000 lbs. No more than 2 are required per project.

Take all samples at the location and in the manner directed by an authorized representative of the Engineer. Furnish the necessary personnel and equipment for obtaining samples and be responsible for providing a smooth finish to the areas from which the samples are taken. Fabricator shall be responsible for obtaining representative samples in the presence of the Department's inspector and submitting to the Materials and Test Laboratory.

(D) Charpy V-Notch Tests

Furnish all structural steel for girders, beams and diaphragm components connecting horizontally curved members meeting the longitudinal Charpy V-Notch Tests specified in the supplementary requirements in AASHTO M 270 for Zone 1. Unless otherwise noted in the plans, mark and test the materials as non-fracture critical. Sample and test in accordance with AASHTO T 243 and use the (H) frequency of heat testing. Use the grade or grades of structural steel required in the plans. Obtain and submit certified mill test reports to the Materials and Tests Unit to show the results of each test required by the *Standard Specifications*.

1072-8 WORKING DRAWINGS

Working drawings shall include Contract number, project number, structure number and station number. Submit prints of checked structural steel shop drawings and changes thereto, including shipping diagrams for review, comments, acceptance and distribution as follows:

(A) Submit two sets for review, comments and acceptance on all steel structures. After review, comments and acceptance, submit 7 sets for distribution.

(B) Submit five sets for review, comments and acceptance for all bridges carrying railroad traffic, and after acceptance, submit 9 sets for distribution.

(C) Furnish any additional sets requested by the Engineer or for his use, review, comments, acceptance and/or distribution.

Shop drawings are not checked by the Engineer except to ascertain general compliance with the design and the *Standard Specifications*. Thoroughly check all shop drawings in all respects. Review, comments and acceptance of shop drawings by the Engineer is not considered as relieving the Contractor of his responsibility for the accuracy of his drawings, or for the fit of all shop and field connections and anchors.

The maximum size of prints for shop drawings is 22 inches x 36 inches, including borders which are at least 1 inch at the left edge of the sheet. Provide shop drawings on any medium provided they are legible and are reproducible. Upon completion of the project, furnish to the Engineer one complete set of reproducible shop drawings that represent the as-built condition of the structural steel including all approved changes if any. Supply drawings that are 22 inches x 36 inches. These drawings will become the property of the Department.

Changes on shop drawings after acceptance or distribution are subject to the approval of the Engineer. Furnish a record of such changes.

Make substitution of sections different from those on the structure plans only when approved in writing.

1072-9 HANDLING AND STORING MATERIALS

Load, transport, unload and store structural material so the metal is kept clean and free from damage. Repair any coating damage per Section 442. Do not use chains, cables or hooks without softeners that could result in damage or scarring of the material. Repair all materials which are scarred or damaged and inspect at the fabricators expense as deemed necessary by the Engineer.

Use lifting equipment and rigging equipment with adequate capacity to handle the material at all times. Do not bend, twist, damage or excessively stress any materials. Do not perform hammering which injures or distorts the members. In the event that damage or overstressing does occur, prepare and submit an inspection and testing verification plan to the Engineer for approval. Operate and maintain all lifting equipment in a safe manner and in accordance with the manufacturer's directions.

When lifting main structural steel members, use spreader bars. Do not use one point pick-ups on members over 50 feet in length. Use two point pick-ups so the amount of overhang and the distance between hooks does not exceed the distances as noted in Table 1072-5.

TABLE 1072-5
SPREADER BAR PICKUP REQUIREMENTS

Property	Beam Size			
	30" or Less	33" WF	36" WF	Plate Girders
Maximum Distance Between Hooks	74 lf	80 lf	85 lf	100 lf
Maximum Overhang	25 lf	28 lf	30 lf	35 lf

Store structural material, either plain or fabricated, above the ground upon platforms, skids or other supports. Keep free from blast media, dirt, grease, vegetation and other foreign matter, and protect from corrosion.

Keep material clean and properly drained. Transport and store girders and beams with the web in the vertical plane and the top flange up. Request permission in writing and await approval to invert haunched girders and beams for transport for safety reasons. Use extreme

care in turn-over operations to prevent excessive bending stresses in the edge of flanges. Support long members on blocking placed near enough together to prevent damage from deflection.

Do not use any beam, girder, diaphragm, cross frame or other material, in any stage of fabrication that will be permanently incorporated into the finished structure as a workbench, lifting device or dunnage for any purpose for which it was not specifically intended.

1072-10 STRAIGHTNESS, CAMBER AND DIMENSIONAL TOLERANCES

(A) General

Ensure that rolled material, before being laid out or fabricated, is straight. If straightening is necessary, use methods that do not damage the metal. Kinks or sharp bends are cause for rejection of the material.

Ensure that heat straightened parts are substantially free from external forces, except those resulting from mechanical means used in conjunction with the application of heat.

Heat curving and heat cambering shall be completely free from any external forces. Any heating operation to address straightening, cambering, or curving shall be monitored by the Fabricator's QC department. Personnel performing heating operations shall have adequate training (documented), shall possess proper temperature indicating devices and shall have received instructions for appropriate use.

After heating, allow the metal to cool, without artificial cooling, down to 600°F. Below 600°F, only dry compressed air is permitted to artificially cool steels having minimum yield strength greater than 36,000 psi as indicated by a Type 1 (Certified Mill Test Report) material certification in accordance with Article 106-3.

(B) Straightening

Straighten distorted members and bent material by mechanical means or, if approved, by the carefully planned and supervised application of a limited amount of localized heat. Do not allow the temperature of the heated area to exceed 1,150°F as controlled by temperature indicating crayons or other approved methods.

Following the straightening of a bend or buckle, verify the surface is free of evidence of fracture as indicated by visual inspection or, if directed, by appropriate nondestructive testing.

Shop straighten the bottom flanges of steel beams or girders at bearings as necessary to provide uniform contact between the flanges and the bearings. If bearings are to be field installed, the Fabricator shall demonstrate appropriate bearing contact surfaces as defined by the AWS Bridge Welding Code prior to shipping.

(C) Camber

Show the required camber on the drawings.

Make adequate provision in the fabrication of structural members to compensate for change of camber due to welding of the shear connectors and other fabrication work.

Fabricate camber into the members on built-up plate girders and trusses. Where camber is required on rolled sections, induce it by heat cambering, except that for rolled sections within the depth, length and camber ordinate range shown in Table 1072-6, induce camber by cold cambering or "gagging" at the mill or in the shop provided approval procedures for cold cambering are employed.

Where reverse curvature is required in a single rolled shape, induce it by heat cambering.

Show camber diagrams showing the required offset at each tenth point of the span and at any web splice or field splice location and blocking diagrams on the shop drawings. Show additional points if desired by the fabricator. Ensure that the beams, girders or

other members with field splices meet all of the blocking ordinates without inducing stress into the members.

Following cambering or camber correction, correct evidence of fracture indicated by visual inspection or, if directed, by appropriate nondestructive testing.

Show camber and blocking diagrams on the shop drawings. Shop assemble continuous beams meeting all the blocking ordinates without inducing stress into the members.

TABLE 1072-6
ACCEPTABLE COLD CAMBER FOR ROLLED SECTIONS

Beam Length, feet	Section Designation and Nominal Depth	
	W-Shapes 14" to 21" Inclusive S-Shapes 12" and Over	W-Shapes 24" and Over
Over 30 through 42	3/4" to 2 1/2" inclusive	1" to 2" inclusive
Over 42 through 52	1" to 3" inclusive	1" to 3" inclusive
Over 52 through 65	2" to 4" inclusive	2" to 4" inclusive
Over 65 through 85	2 1/2" to 5" inclusive	3" to 5" inclusive
Over 85 through 100	As directed by the Engineer	3" to 6" inclusive

(D) Heat Cambering of Rolled Beams and Welded Plate Girders

(1) General

Where heat cambering is used, only V-type heating is permitted. Perform V-type heating by the carefully planned and supervised application of a limited amount of localized heat.

When minor corrections in camber are required, use small localized heats limited to the flange material. Perform major corrections in camber by V-type heating to prevent web distortion.

Begin heating at the apex of the heating pattern and progress slowly towards the base of the pattern as each area is brought up to temperature as stated in Subarticle 1072-10(D)(5). Do not progress the heating torches toward the base of the heating pattern until the apex of the pattern is brought up to the specified temperature. Do not return the heating torch toward the apex of the heating triangle after heating has progressed towards the base. Continue heating to successive areas until the base of the triangular heating pattern is brought up to the required temperature across the full width of the flange.

(2) Heat Cambering of Rolled Beams

Heat cambering of rolled beams is allowed to provide the required vertical curvature. Space triangular heating patterns throughout the length of the member to provide the required curvature. Locate the apex of the heating triangle at a point not less than 75% of the depth of the member measured from the flange that is concave after cambering. Limit the total included angle of the heating pattern to 20°.

Weld all detail material such as connection plates, bearing stiffeners and gusset plates attached to the member to the rolled beam after the beam is cambered as required.

(3) Heat Cambering of Welded Plate Girders

Heat cambering of welded plate girders is only permitted when approved in writing as a necessary repair procedure for plate girders rejected for camber deviation.

When it is necessary to correct camber deviation in welded plate girders, heating is permitted in V-type heating patterns centered on intermediate stiffeners and connection plates. Where necessary, add stiffeners for this purpose if approved.

Locate the apex of the heating pattern not less than 3/4 of the depth of the member from the flange that is shortened after cooling. The maximum included angle of the heating pattern is 10°. The maximum width of the base of the heating pattern is 10 inches. Where shallow members or thin webs prescribe heating patterns with a width substantially less than 10 inches at the junction of the web to flange, extend the heating pattern in the flange at that location beyond the limits of the heating pattern in the web by no more than 1 inch provided the total width of pattern in the flange does not exceed the 10 inch limit stated above.

(4) Support of Members for Heat Cambering

Heat camber members with the web vertical and supports spaced to take the maximum advantage of dead load in the member before applying heat. Ensure all supports are approved by the Department's inspector before beginning work.

Do not place any combination of support system or external load on the member that causes a compressive stress in the flange to exceed 20,000 psi before heating for AASHTO M 270 Grades 36, 50 and 50W steels.

(5) Heating Process and Equipment

Confine heating to the patterns described herein and conduct to bring the steel within the planned pattern to a temperature between 1,100°F and 1,150°F as rapidly as possible without overheating the steel.

Any heating procedure which causes a portion of the steel to exceed a temperature greater than 1,150°F is destructive heating and is automatically cause for rejection of the steel. Steel rejected for destructive heating is investigated for re-acceptance, repair or replacement if allowed by the Engineer. Bear the cost of such tests and any necessary repair or replacement.

(6) Heat Measurement

Specified temperatures are checked using portable digital pyrometers or temperature indicating crayon. When using a temperature indicating crayon, the following procedure shall be employed; mark on the surface of metal or sheet with the required crayon. Once the surface reaches the rated temperature of the crayon, the mark will melt and show liquid smear appearance. At this point, the heating operation shall cease to prevent overheating. Exceeding the specified temperature is strictly prohibited.

(E) Heat Curving Girders

(1) Type of Heating

With approval, use continuous or V-type heating methods to curve girders. For the continuous method, simultaneously heat a strip along the edge of the top and bottom flanges that is of sufficient width and temperature to obtain the required curvature. For V-type heating, heat the top and bottom flanges simultaneously in truncated triangular or wedge-shaped areas. Position the areas with their base along the flange edge and spaced at regular intervals along each flange. Set the spacing and temperatures to approximate the required curvature by a series of short chords. Heat along the top and bottom flanges at approximately the same rate.

For V-type heating, terminate the apex of the truncated triangular area applied to the inside flange surface just before the juncture of the web and flange. To avoid web distortion, make certain that heat is not applied directly to the web when heating the inside flange surfaces (the surfaces that intersect the web). Extend the apex of the truncated triangular heating pattern applied to the outside flange surface to the juncture of the flange and web. Use an included angle of approximately 15° to 30° in the truncated triangular pattern, but do not allow the base of the triangle to

exceed 10 inches. Vary the patterns prescribed above only with the Engineer's approval.

For both types of heating, heat the flange edges that will be on the inside of the horizontal curve after cooling. Concurrently heat both inside and outside flange surfaces for flange thicknesses of 1.25 inches and greater. Adhere to the temperature requirements presented below.

(2) Temperature

Conduct the heat curving operation so the temperature of the steel never exceeds 1,150°F as measured by temperature indicating crayons or other suitable means. Do not artificially cool the girder until it naturally cools to 600°F. Below 600°F, use dry compressed air to artificially cool the girder.

(3) Position for Heating

Heat-curving the girder with the web in either a vertical or horizontal position is permitted. When curved in the vertical position, brace or support the girder so the tendency of the girder to deflect laterally during the heat-curving process does not cause the girder to overturn.

When curved in the horizontal position, support the girder near its ends and at intermediate points, if required, to obtain a uniform curvature. Do not allow the bending stress in the flanges to exceed 27,000 psi. To prevent a sudden sag due to plastic flange buckling when the girder is positioned horizontally for heating, place intermediate safety catch blocks at the midlength of the girder within 2 inches of the flanges at all times during the heating process.

(4) Sequence of Operations

Conduct the heat-curving operation either before or after completing all the required welding of transverse intermediate stiffeners to the web. However, unless provisions are made for shrinkage, position and attach connection plates and bearing stiffeners after heat-curving. In any event, weld the stiffeners, connection plates, and bearing stiffeners to the girder flanges after the member is curved. If longitudinal stiffeners are required, heat-curve or oxygen-cut these stiffeners separately before welding to the curved girder.

(5) Camber and Curvature

Camber the girders before heat-curving. Cut the web to the prescribed camber allowing for shrinkage due to cutting welding and heat-curving. If approved, a carefully supervised application of heat is permitted to correct moderate deviations from the specified camber.

Horizontal curvature and vertical camber is measured for final acceptance after all welding and heating operations are complete and the flanges have cooled to a uniform temperature. Horizontal curvature is checked with the web in the vertical position by measuring offsets from a string line or wire attached to both flanges or by using other suitable means. Camber is checked with the web in the horizontal position. Camber the girder so it meets the horizontal and vertical curvature ordinates without inducing stress into the girders by mechanical force.

Compensate for loss of camber in the heat-curved girders as residual stresses dissipate during service life of the structure. Compute this anticipated loss of camber in accordance with the *AASHTO LRFD Bridge Design Specifications*.

(6) Procedure Specification and Shop Drawings

Submit structural steel shop drawings, including a detailed written procedure specification for heat curving the girders, supplemented by calculations and sketches, for review, comments and acceptance. On the shop drawings, indicate the type, location and spacing of heat sectors, if used, supports and catch blocking for each field section of girders. Include suitable blocking diagrams for measuring horizontal curvature similar to those usually prepared for camber and vertical curvature.

(F) Camber Measurement

At the time of acceptance at the shop and after erection, ensure that all stringers and girders for bridges meet the required camber values within the tolerances specified in Subarticle 1072-10(G). Follow the procedure for measuring camber as outlined below:

(1) Assemble the member at the shop as specified in Article 1072-19 and measure with the member lying on its side.

(2) Camber repairs are only allowed when approved by the Engineer. Camber deviation is judged irreparable if corrective measures in the shop produce web buckling in excess of the specified tolerance, in which case the member is rejected.

(3) The final camber measurement is made by the Engineer in the field after erection. At the time of this measurement, ensure that the members have all of the specified camber less the dead load deflection of the steel as specified in Subarticle 1072-10(G).

(G) Dimensional Tolerances

Ensure that dimensions of all material covered by Section 1072 conform to ASTM A6 when received at the fabrication shop. Fabricate member dimensions conforming to this subarticle whether designated to be straight, cambered or curved and regardless of whether curvature is heat-induced (when so permitted). Dimensional tolerances not listed in this subarticle shall be as specified by the Bridge Welding Code as defined in Article 1072-18 and applied to rolled shapes where applicable as well as to welded members.

Place welded butt joints no further than 1/2 inch from the point detailed. Intermediate stiffeners varying ± 1/2 inch from the point detailed are allowed. Connector plates for field connections varying ± 1/8 inch from the point detailed are allowed. Ensure that the actual centerline of bearing lies within the thickness of the bearing stiffener.

Members with end milled for bearing and members with faced end connection angles deviating from the detailed length by -0, +1/32 inch are acceptable. All other members varying from detailed length by ± 1/8 inch are acceptable.

Align to within ± 1/8 inch from the location shown on the approved shop drawings all steel requiring shop assembly for reaming, drilling from the solid or weld joint preparation.

Deviation from specified camber of fabricated members as verified during shop assembly and before shipment from the fabrication shop is limited to:

-0;

$\frac{+3/32" \times \text{No. of ft from nearest bearing}}{10}$, up to 3/4" maximum.

Deviation from specified camber of erected steel bridge superstructures measured when the steel work is complete and the superstructure is subject to steel dead load stresses only is limited to:

-0;

$$+\frac{1/8\text{" x No. of ft from nearest bearing,}}{10} \text{ up to 1" maximum.}$$

If the plans do not require shop induced camber, provide an actual member that is straight or one of the following:

(1) If natural camber "turned up" is required, the maximum plus camber is the algebraic sum of the allowable deviation, dead load deflection, vertical curve ordinate and superelevation ordinate;

(2) If natural camber 'turned down" is required, the maximum negative camber is equal to the algebraic sum of the dead load deflection, vertical curve ordinate and superelevation ordinate.

Do not exceed 1/8 inch per 10 foot length for the actual deviation from curvature shown in the plans.

1072-11 OXYGEN CUTTING

Oxygen cutting of structural steel is allowed, provided a smooth surface free from cracks and notches is secured and an accurate profile is secured by the use of a mechanical guide. Hand cut only where approved and grind smooth leaving no burnt edges.

In all oxygen cutting, adjust and manipulate the cutting agent to avoid cutting beyond (inside) the prescribed lines. Provide oxygen cut surfaces meeting the ANSI surface roughness rating value of 1,000 except ensure that oxygen cut surfaces of members not subject to calculated stress meet the surface roughness value of 2,000 (AWS C4.1-G Surface Roughness Gauge). Round corners of oxygen cut surfaces of members carrying calculated stress to a 1/16 inch radius, or an equivalent flat surface at a suitable angle, by grinding after oxygen cutting.

Fillet re-entrant cuts to a radius of not less than 1 inch.

Remove surface roughness exceeding the above values and occasional notches and gouges not more than 3/16 inch deep on otherwise satisfactory oxygen cut surfaces by chipping or grinding. Such removal shall be faired to the material edge with a slope not steeper than one in ten and with machine and grinding marks parallel to the surfaces.

Repair occasional gouges of oxygen cut edges more than 3/16 inch deep, but not more than 7/16 inch deep, by welding with low hydrogen electrodes not exceeding 5/32 inch in diameter and with a minimum preheat of 250°F. Grind the completed weld smooth and flush with the adjacent surface. Radiographically test any gouge repaired by welding.

1072-12 EDGE PLANING

Plane sheared edges of plates more than 5/8 inch in thickness that carry calculated stress to a depth of 1/4 inch. Pre-drill re-entrant cuts before cutting. Round all edges of plates and shapes parallel to calculated stress and all free edges of plates and shapes intended for coating or galvanizing to 1/16 inch radius or provide an equivalent flat surface at a suitable angle. Flame cut edges found to have a Rockwell Hardness Value of C 30 or greater will be considered unacceptable. A portable Rockwell Hardness Tester shall be employed by the Quality Control Inspector to determine conformance with these requirements. Unacceptably hard surfaces shall be removed by grinding, machining, or approved heat treating procedures. Grind edges of all other plates and shapes to remove burrs, slag or shear lip. The ends of all steel piles, intended for coating or galvanizing, are not required to be radiused, but remove all burrs, slag and shear lip.

1072-13 FACING OR BEARING SURFACES

Provide a surface finish of bearing and base plates and other bearing surfaces that come in contact with each other or with concrete that meet Table 1072-7 following ANSI surface roughness requirements as defined in ASME B46.1.

TABLE 1072-7
SURFACE ROUGHNESS REQUIREMENTS

Item	ANSI Surface Roughness
Steel slabs	ASME 2,000
Heavy plates in contact in shoes to be welded	ASME 1,000
Milled ends of compression members, milled or ground ends of stiffeners and fillers	ASME 500
Bridge rollers and rockers	ASME 250
Pins and pin holes	ASME 125
Sliding bearings	ASME 125

1072-14 ABUTTING JOINTS

Face and bring to an even bearing abutting joints in compression members, girder flanges and tension members where so indicated on the drawings. Where joints are not faced, do not exceed an opening of 1/4 inch.

1072-15 BENT PLATES

Provide cold-bent, load carrying rolled-steel plates conforming to the following:

(A) Take from the stock plates so the bendline is at right angles to the direction of rolling.

(B) Use a radius of bends such that no cracking of the plate occurs. Use minimum bend radii, measured to the concave face of the metal, as shown in Table 1072-8.

If a shorter radius is essential, bend the plates hot at a temperature not greater than 1,200°F and air cool slowly down to a temperature of 600°F. Below 600°F, use only dry compressed air to artificially cool steels having a minimum yield strength greater than 36,000 psi. Use hot bent plates conforming to Subarticle 1072-15(A) above.

(C) Before bending, round the corners of the plates to a radius of 1/16 inch throughout the portion of the plate at which bending occurs.

TABLE 1072-8
MINIMUM BEND RADII

Plate Thickness (t)	Minimum Bend Radii, Ratio of Thickness
Up to 1/2"	2**t**
Over 1/2" to 1"	2 1/2**t**
Over 1" to 1 1/2"	3**t**
Over 1 1/2" to 2 1/2"	3 1/2**t**
Over 2 1/2" to 4"	4**t**

Hot bend low alloy steel in thicknesses over 1/2 inch for small radii, if required.

1072-16 HOLES FOR BOLTS AND OTHER FASTENERS

(A) General

Punch or drill all holes and remove any burrs. Punching material forming parts of a member composed of not more than 5 thickness of metal 1/16 inch larger than the nominal diameter of the fastener is allowed whenever the thickness of the material is not greater than 3/4 inch for structural steel, 5/8 inch for high-strength steel or 1/2 inch for quenched and tempered alloy steel, unless subpunching and reaming is required by Subarticle 1072-16(D).

When there are more than five thicknesses or when any of the main material is thicker than 3/4 inch for structural steel, 5/8 inch for high-strength steel or 1/2 inch for quenched and tempered alloy steel, either subdrill and ream or drill all holes full size.

When required by Subarticle 1072-16(D), subpunch or subdrill all holes (subdrill if thickness limitation governs) 1/4 inch smaller and, after assembling, ream 1/16 inch larger or drill full size to 1/16 inch larger than the nominal diameter of the fastener.

(B) Punched Holes

Do not use a diameter of the die exceeding the diameter of the punch by more than 1/16 inch. If any holes require enlargement to admit the fasteners, ream such holes. Clean cut holes without torn or ragged edges. Poor matching of holes is cause for rejection. Grind all burrs smooth.

(C) Reamed or Drilled Holes

Make reamed or drilled holes cylindrical and perpendicular to the member complying with the size requirements of Subarticle 1072-16(A). Where practicable, direct reamers by mechanical means. Grind all burrs smooth. Poor matching of holes is cause for rejection. Ream and drill with twist drills. If required, take assembled parts apart for removal of burrs caused by drilling. Assemble connecting parts requiring reamed or drilled holes, securely hold while reaming or drilling and match mark before disassembling.

(D) Subpunching and Reaming of Field Connections

Subpunch or subdrill, if required according to Subarticle 1072-16(A), holes in all field connections and field splices of main members of trusses, arches, continuous beam spans, bents, towers (each face), plate girders, and rigid frames. Subsequently ream while assembled as required by Article 1072-19. Subpunch and ream to a steel template or ream while assembled all holes for floor beam and stringer field end connections. Ream or drill full size field connection holes through a steel template after the template is located with utmost care as to position and angle and firmly bolted in place. Use templates for reaming matching members, or the opposite faces of a single member that are exact duplicates. Accurately locate templates used for connections on like parts of members such that the parts or members are duplicates and require no match-marking.

(E) Accuracy of Punched and Subdrilled Holes

Accurately punch or subdrill all holes punched full size, subpunched or subdrilled such that after assembling, and before any reaming is done, a cylindrical pin 1/8 inch smaller in diameter than the nominal size of the hole enters perpendicular to the face of the member, without drifting, in at least 75% of the contiguous holes in the same plane. If the requirement is not fulfilled, the badly punched pieces are rejected. If any hole does not pass a pin 3/16 inch smaller in diameter than the nominal size of the hole, this is cause for rejection.

(F) Accuracy of Reamed and Drilled Holes

When holes are reamed or drilled, ensure that 85% of the holes in any contiguous group, after reaming or drilling, show no offset greater than 1/32 inch between adjacent thicknesses of metal.

Use all steel templates with hardened steel bushings in holes accurately dimensioned from the centerlines of the connection as inscribed on the template. Use the centerlines in locating accurately by the template from the milled or scribed ends of the members.

(G) Alternate Methods

As an option, make the fastener holes by procedures other than those described in Subarticles 1072-16(A) through 1072-16(F) provided that the requirements for quality

and for dimensional accuracy are met. Plasma cutting of holes for high strength fasteners is prohibited. Wherever an alternate method is employed, demonstrate the ability of each alternate method to produce holes and connections consistently meeting all requirements for quality and dimensional accuracy for the type of joint fabricated. When such ability of an alternate method is previously demonstrated on similar work for the Department, continue its use by certifying, on each subsequent project, that the procedure and equipment are the same as the method previously qualified, and that the equipment involved is in good repair and adjustment. Failure of joints to meet the quality and accuracy requirements is cause for rejection. In the case of repeated failures revise and/or requalify the method or discontinue its use.

At the time of qualification of an alternate method, submit for approval a written procedure specification describing the procedures and equipment and giving upper and lower value limits and tolerances for all pertinent variables. Accurately reflect the actual procedures, equipment and values used in the qualification tests. In addition to the certification on each subsequent project, the Engineer may request copies of the approved procedure specification.

(H) Oversize, Short-Slotted, and Long-Slotted Holes

Where shown in the plans or permitted in writing, use oversize, short-slotted and long-slotted holes with high strength bolts 5/8 inch and larger in diameter. Do not allow the distance between edges of adjacent holes or edges of holes and edges of members to be less than permitted under the AASHTO specification. Oversize, short-slotted and long-slotted holes are defined as follows:

(1) Oversize holes are 3/16 inch larger than bolts 7/8 inch and less in diameter, 1/4 inch larger than bolts 1 inch in diameter, and 5/16 inch larger than bolts 1 1/8 inches and greater in diameter. When oversized holes are permitted, they are allowed in any or all plies of friction type connections. Install hardened washers over exposed oversize holes.

(2) Short-slotted holes are 1/16 inch wider than the bolt diameter and have a length that does not exceed the oversize diameter requirements of Subarticle 1072-16(H)(1) by more than 1/16 inch. When short-slotted holes are permitted, they are allowed in any or all plies of friction-type or bearing-type connection. Locate holes without regard to direction of loading in friction-type connections, but orient normal to the direction of the load in bearing-type connections. Install hardened washers over exposed short-slotted holes.

(3) Long-slotted holes are 1/16 inch wider than the bolt diameter and have a length more than allowed in Sub-paragraph 2 but not more than 2 1/2 times the bolt diameter. Structural plate washers or a continuous bar not less than 5/16 inch in thickness are required to cover long slots that are the outer plies of joints. Ensure that these washers have a size sufficient to completely cover the slot after installation. When long-slotted holes are permitted, they are allowed in only one of the connected parts of either a friction-type or bearing-type connection at an individual faying surface.

When used in slip critical connections, locate holes without regard to direction of loading if one-third more bolts are provided than needed to satisfy the allowable unit stresses except as herein restricted.

When used in bearing-type connections, orient the long diameter of the slot normal to the direction of loading. No increase in the number of bolts over those necessary for the allowable unit stress is required.

(I) Misfits

When misfits occur for any reason, enlargement of the holes by reaming is limited to 1/16 inch over the nominal size hole called for unless otherwise permitted in writing.

(J) Erection Bolt Holes

At field welded connections where erection bolts are used, provide holes 3/16 inch larger than the nominal erection bolt diameter.

1072-17 INSTALLING BOLTS

Install high strength bolts in accordance with Article 440-8.

1072-18 WELDING

(A) Definition

The Bridge Welding Code referred to herein is the edition of the ANSI/AWS/AASHTO Bridge Welding Code D 1.5 and any applicable interim that is current on the date of advertisement for the project, and as modified by the *Standard Specifications*.

(B) General

Commercially blast clean all steel used in girders, beams and connecting members to SSPC-SP 6 before welding. With the exception of rolled beams, the Contractor at their option may submit to the Department for review, an alternate cleaning method for main member material exposed to welding.

Weld all steel in the shop or in the field for bridges, whether permanent or temporary, and perform all other work related to welding including, but not limited to, testing and inspection of welds, preparation of material, oxygen cutting, electrodes, shielding and shear studs, meeting the Bridge Welding Code. Weld other steel items not covered under the Bridge Welding Code in accordance with the applicable AWS Welding Code. Some examples may include but not limited to; Structural Welding Code-Steel (AWS D1.1), Structural Welding Code- Aluminum (AWS D1.2), Structural Welding Code-Sheet Steel (AWS D1.3), Structural Welding Code- Reinforcing Steel (AWS D1.4) and Structural Welding Code-Stainless Steel (AWS D1.6).

Weld only where shown in the plans or where called for in the *Standard Specifications* unless requesting and receiving written approval from the Department for additional welding.

Show all permanent and all temporary welds on the shop drawings. For groove welds, indicate on the shop drawings the particular detail and process to be employed in production of the work. For prequalified joints, use of the Bridge Welding Code letter classification designation of the joint (B-L2b-S etc.) along with the appropriate symbol satisfies this requirement. Tack welds that become part of a permanent weld are not required on the shop drawings.

Provide fillet welds, including seal welds, at least the minimum size allowed by the Bridge Welding Code for the thickness of material welded or the size called for in the plans, whichever is larger. For exposed, bare, unpainted applications of steel, the basic requirements for weld filler metal with atmospheric corrosion resistance and coloring characteristics similar to that of the base metal are mandatory. The variations from these basic requirements listed in the Bridge Welding Code for single pass welds are not permitted.

All welds designated as Fracture Critical (FC) and subject to tension shall be so designated on the shop drawings. Unless otherwise directed by the Engineer, any flange to web (FC) complete joint penetration (CJP) groove weld subjected to calculated tensile stress normal to the weld axis, shall be so designated on the design and shop drawings.

(C) Qualification of Personnel

Ensure that each welder, welding operator and tacker is qualified in accordance with the Bridge Welding Code or other applicable AWS Welding Code as determined by the Engineer. For field applications, employ welders that are qualified by the Department. Welders shall be requalified by the Department every 5 years. Contact the Materials and Tests Unit to schedule qualification tests.

Permanent in-shop welders employed by a fabricator who passed the appropriate welding tests and whose weldments are radiographically tested with regularly acceptable results are exempt from additional testing when approved by the Engineer. Welder qualification testing shall be administered and witnessed by a current AWS Certified Welding Inspector (CWI). Ensure all welder qualification testing is witnessed by an independent testing agency approved by the Department. As evidence of such qualification, furnish a satisfactory certificate, or a copy thereof, issued by a fabricator or Department approved testing agency as applicable. Submit certification for each welder, welding operator or tacker, and for each project, stating the name and identification number of the welder, welding operator or tacker; the name and title of the person who conducted the examination; the kind of specimens; the position of welds; the AWS electrode classification used; the results of the tests; the date of the examination and witness thereof. Such certifications are required for all persons performing shop or field welds of any kind on the work, whether permanent or temporary. Ensure each welder provides a picture ID upon request or other form of positive identification as required by the Engineer.

(D) Qualification of Welds and Procedures

For shop employed welded construction, submit to the Department all welding procedures, prequalified or qualified by test 30 days in advance before performing any welding. All welding shall comply with the applicable AWS designed code of construction.

For field weld applications, submit prequalified Welding Procedure Specifications (WPS) for each joint configuration for approval at least 30 days before performing any welding. In lieu of the aforementioned,, use the WPS provided and preapproved by the Department. Field welding operations are limited to using SMAW welding process. These preapproved WPS are available from the Materials and Tests Unit. Use non-prequalified welding procedures that have been submitted and approved by the Engineer. At no cost to the Department, demonstrate their adequacy in accordance with the applicable AWS Welding Code.

On all welding, include in the welding procedure continuous visual inspection by welders, welding operator, tackers, welding supervisors and all personnel involved in preparation of the material for welding.

Approval by the Engineer of the procedure specifications does not relieve the Contractor of his responsibility to develop a welding procedure that produces weldments meeting the required quality and dimensions.

If non-prequalified joints procedures are previously found acceptable to the Engineer on another project, furnish the inspector with a copy of the joint details and procedure specification approved at the time of qualification. Such documentation is required from each fabricator employing a non-prequalified joint or procedure on the work. Failure to produce such documentation results in the fabricator being required to requalify the joint or procedure or to use prequalified joints, procedures, and procedure specifications.

On weldments where geometric shape prevents compliance with requirements to weld a particular position, alternate procedures are considered for approval. Previously qualified alternate procedures are considered for approval without further procedure qualification tests. No separate payment is made for developing, demonstrating and

documenting for future use such alternate procedures, as such work is incidental to the work of welding.

(E) Requirements for Testing and Inspection

Require the fabricator to make provisions for convenient access to the work for inspection and cooperate with the inspector during the required inspection and testing.

Visual welding inspection shall be performed by an inspector qualified in accordance with AWS QC-1. Inspect welds in the presence of the Department's inspector unless otherwise approved by the Department's inspector, using visual inspection and the nondestructive tests herein prescribed in addition to the test requirements of the Bridge Welding Code and the contract. Employ quality control inspectors and NDT technicians qualified in accordance with the Bridge Welding Code and preapproved by the Engineer before the start of any fabrication. Supply the appropriate certifications as required by the Bridge Welding Code to the Department's inspector for all inspectors. Individuals assigned to production welding activities or processes and their supervisors are not acceptable for performing quality control testing. Ensure a qualified quality control welding inspector (CWI) is present any time welding is in progress. No separate payment is made for inspection and testing.

Retest welds requiring repairs or replacement in the presence of the Department's inspector after the repairs or replacements are made. Approval of the Engineer is required for any repair exceeding three attempts to correct.

If the Engineer finds that acceptable repair to defective work is not feasible; the entire piece is rejected.

Payment at the contract prices for the various items in the contract which include the work of welding is full compensation for all costs resulting from the required nondestructive testing of welds and from the required inspection of welds.

(F) Nondestructive Test Required

Personnel performing Nondestructive Testing (NDT) other than visual examination shall be certified in conformance with the latest edition of the American Society for Nondestructive Testing's (ASNT) recommended practice number (SNT-TC-1A). The Employer's program shall meet all established guidelines of SNT-TC-1A for the qualification of NDT personnel. In addition, all personnel performing NDT for final weld acceptance shall be subject to the Department's practical proficiency test.

The extent of nondestructive testing required for main members is as prescribed in the Bridge Welding Code and by the contract except that all flange splices shall be radiographed for their full length. The term "main members" in this regard means girders, diaphragms for curved girders, beams, floor beams, stringers, truss members, high strength bolts, columns, bearing stiffeners, bearing shoes, high mount lighting standards and components of main member carrying stress, including the end connections for such members. Nondestructive testing of other complete welds or weld passes is required when so noted in the plans or deemed necessary by the Engineer. For bridge applications involving tubular structures that may be subject to the AWS D1.1 welding code, the extent of NDT shall be as specified above for main members. Tests other than those prescribed are also required when deemed necessary by the Engineer. Perform all radiographic testing in accordance with procedures established by the Engineer. Copies of these procedures are available from the State Materials Engineer.

High mount lighting standards shall be examined in accordance with Section 1401-2. Other nondestructive test methods are sometimes deemed necessary by the Engineer to determine the quality of the welds. No separate payment is made for inspection and testing.

Any NDT not identified above shall be examined as directed by the Engineer.

The entire cost of this work is included in the unit contract price for the structural steel items involved.

(G) Welded Structural Shapes

Produce butt welds of flanges and webs, and fillet welds of web to flanges of plate girders and haunched beams using the submerged arc process. Produce other structural shapes built up from plates and bars using the submerged arc process unless another process is qualified for these joints in accordance with the Bridge Welding Code and is subject to the approval of the Engineer.

After all shop welded splices in the flanges and webs for the full length of the field section are made, tested and approved, fit the flange plates tight and square against the web to leave no gap and to not bow the web. Brace one side of each flange against the web with gussets or struts and tack weld securely to the web at the stiffener locations. Upon removal of the welds, grind any nicks or gouges, preheat, weld and test or incorporate into the stiffener fillet weld.

Connect the flanges to the web by starting the fillet weld at one end of the girder and proceeding to the other ends.

As an option, make adjacent welds simultaneously.

The sequence for making the flange to web fillet welds is subject only to the provisions for control of shrinkage and distortion and to the position requirements of the Bridge Welding Code.

After flange to web welds are complete, shift bracing gussets or struts if necessary, then remove all temporary gussets or struts. Remove tack welds by grinding flush with parent metal.

Straighten any transverse warpage of the flanges if necessary by heating along the centerline of the outside face.

Fit tight, square and tack weld stiffeners securely to the web. With the girder in the flat position (web horizontal), weld the stiffeners to the web. Do not weld or tack weld stiffeners to the flanges except where noted in the plans. Stiffeners are not to be used to correct tilt of flange due to distortion associated to welding.

After all parts are welded into place, trim the girder to detail length with adjustments for slope and end rotation exceeding 1/4 inch nett.

1072-19 SHOP ASSEMBLING

(A) General

Assemble the field connections of main members of continuous beam spans, plate girders and rigid frames in the shop with milled ends of compressing members in full bearing, and then ream their sub-size holes to specified size while the connections are assembled. Assembly shall be either Full Girder Assembly or Progressive Girder Assembly unless Full Girder Assembly or Special Complete Structure Assembly is required by the contract.

Furnish a camber diagram to the Engineer showing the camber at each panel point of each continuous beam line, plate girder or rigid frame. When the shop assembly is Full Girder Assembly or Special Complete Structure Assembly, ensure the camber diagram shows the camber measured in assembly. When any of the other methods of shop assembly is used, show the calculated camber in the camber design.

Clean surfaces of metal in contact before assembling. Assemble the parts of a member, pin well and firmly draw together with bolts before reaming. Take assembled pieces apart, if necessary, for removal of burrs and shavings produced by the reaming operation. Ensure that the member is free from twists, bends and other deformation.

Drift during assembling only to bring the parts into position, and not sufficient to enlarge the holes or distort the metal. If any holes are enlarged to admit the fasteners, ream them.

Match-mark those connecting parts assembled in the shop for the purpose of reaming holes in field connections and provide a diagram showing marks furnished by the Engineer.

(B) Full Girder Assembly

Full Girder Assembly consists of assembling all members of each continuous beam line, plate girder or rigid frame at one time.

(C) Progressive Girder Assembly

Progressive Girder Assembly consists of assembling initially for each continuous beam line or plate girder at least two contiguous shop sections or all members in at least two contiguous shop panels but not less than the number of panels associated with three contiguous section lengths (i.e., length between field splices) and not less than 150 feet in the case of structures longer than 150 feet. Add at least one shop section at the advancing end of the assembly before removing any member from the rearward end, so the assembled portion of the structure is never less than the specified above.

(D) Special Complete Structure Assembly

Special Complete Structure Assembly consists of assembling the entire structure, including the floor system.

Ensure each assembly, including camber, alignment, accuracy of holes and fit of milled joints, is approved by the Engineer before reaming.

1072-20 PAINTING AND OTHER PROTECTIVE COATINGS

Shop paint in accordance with Section 442.

Repair galvanized surfaces that are abraded or damaged in accordance with Article 1076-7.

1072-21 MARKING AND SHIPPING

Paint or mark each member with an erection mark for identification and furnish an erection diagram with erection marks shown thereon. Notification of shipping shall be provided to the Department in writing as soon as practical but in no case less than 24 hours for in-state producers and 72 hours for out of state producers. Hours are as defined in Subarticle 1072-7(A).

Prior to loading, the Fabricator's quality control (QC) shall make certain (QC stamped approved) that all material meets the Contract specifications and has been presented to the Department for final inspection.

Furnish to the Engineer as many copies of material orders, shipping statements and erection diagrams as the Engineer directs. Show the weights of the individual members on the statement. Mark the weights on members weighing more than 3 tons. Load structural members on trucks or cars in such a manner that they are transported, unloaded and stored at their destination without being excessively stressed, deformed or otherwise damaged.

Load and ship steel beams and girders in accordance with the Figures 1072-2 and 1072-3 and Table 1072-9 for all types of transportation. When the contractor wishes to place members on trucks not in accordance with these limits, to ship by rail, to attach shipping restraints to the members, to ship horizontally curved steel members, or to invert members, he shall submit a shipping plan before shipping. Refer to Article 1072-9.

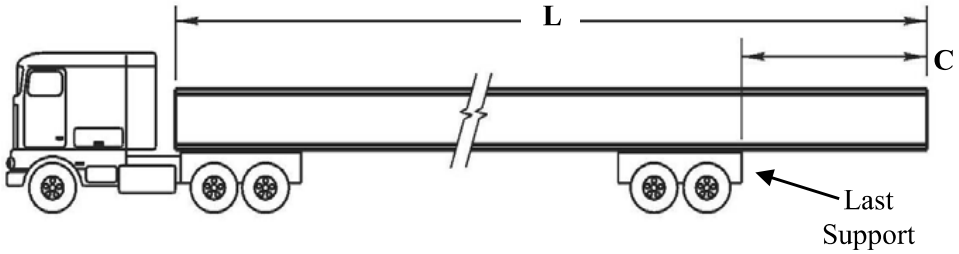

Figure 1072-2. Truck loading diagram for when the length past the last support, **C**, is 15 ft or less.

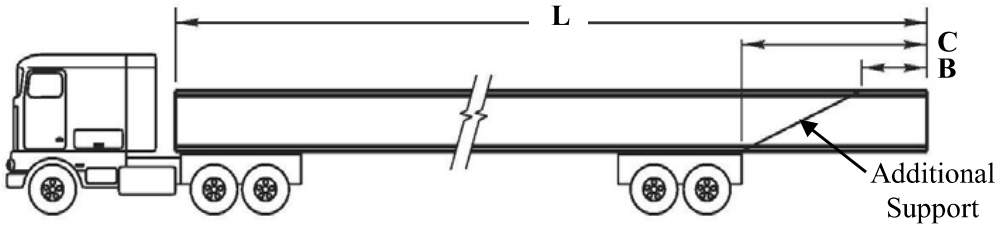

Figure 1072-3. Truck loading diagram for when the length past the last support, **C**, is between 15 feet and 30 feet.

For truck loading with the length of the last support between 15 feet and 30 feet in Figure 1072-3, use the following formulas to calculate truck loading limits or use the values given in Table 1072-9:

$$\mathbf{B} = 0.4C$$

$$\mathbf{C} = 0.2L \text{ to } 0.3L \text{, up to 30 ft}$$

Where **B** is the length of the member past a required additional restraint, **C** is the length of the member extending past the last support and **L** is the length of the member.

TABLE 1072-9
LIMITS FOR PLACEMENT OF STEEL BEAMS AND GIRDERS DURING SHIPMENT

Length of Member, feet	Minimum Length Past Last Support, feet	Maximum Length Past Last Support, feet	Maximum Length Past Additional Restraint, feet
(L)	*(C)*	*(C)*	*(B)*
75	15	22.5	9
80	16	24	9.6
85	17	25.5	10.2
90	18	27	10.8
95	19	28.5	11.4
100	20	30	12
105	21	30	12
110	22	30	12
115	23	30	12
120	24	30	12
125	25	30	12
130	26	30	12
135	27	30	12

Restrain overhanging ends of beams or girders both vertically and horizontally to prevent excess movement. Chains are permitted to secure beams and girders during shipping only when adequate measures are taken to prevent damage to the material by the use of approved protective material. If necessary, use adequate bracing to prevent bending of the top flange.

Pack bolts of one length and diameter and loose nuts or washers of each size separately. Ship pins, small parts and packages of bolts, washers and nuts in boxes, crates, kegs or barrels, but do not allow the gross weight of any package to exceed 300 lbs. Plainly mark a list and description of the contained material on the outside of each shipping container.

Steel die stamped fabricator's identity, station number, girder number and span number of main members into an unpainted area (if available) near the end of the member. Die stamp members with painted ends outside the painted area but as close to the end as possible.

Ship anchor bolts, washers and other anchorage or grillage materials, in time to be incorporated into the masonry portion of the structure.

SECTION 1074
MISCELLANEOUS METALS AND HARDWARE

1074-1 WELDING

Any facility performing welding operations shall be approved by NCDOT Materials and Tests Unit. Weld other steel items not covered under the Bridge Welding Code in accordance with the applicable AWS Welding Code. Some examples may include but not limited to; Structural Welding Code-Steel (AWS D1.1), Structural Welding Code- Aluminum (AWS D1.2), Structural Welding Code-Sheet Steel (AWS D1.3), Structural Welding Code-Reinforcing Steel (AWS D1.4) and Structural Welding Code-Stainless Steel (AWS D1.6). Certify all welders performing any welding on any metals in accordance with the applicable AWS welding code in the position and process required as approved by the Engineer.

1074-2 EXPANSION ANCHORS

Unless otherwise shown in the plans, provide expansion anchors consisting of two or more units with a minimum of two hard metal conical ring wedges and two expandable lead sleeves of an equally effective design that is approved by the Engineer. Use anchors providing a minimum safe holding power of 3,000 lbs. for 3/4 inch bolts and 2,000 lbs. for 5/8 inch bolts, based upon 1/4 of the actual holding power of the anchor in 3,000 psi concrete. Furnish satisfactory evidence, based upon actual tests performed by a commercial testing laboratory, which indicate that the anchors develop the minimum required safe holding power.

When it is proposed to use anchors that are previously accepted as meeting the above requirements, the anchors are accepted on the basis of a certified statement indicating the prior acceptance of the furnished anchors.

1074-3 PLAIN STEEL BARS WITH THREADED ENDS

Provide plain steel bars with threaded ends meeting ASTM A307, Grade A.

1074-4 HARDWARE FOR TIMBER STRUCTURES

Use machine bolts, drift-bolts and dowels that are either wrought iron or medium steel. Use washers that are cast iron ogee, malleable iron castings or cut from medium steel or wrought iron plate.

Use machine bolts with square heads and nuts. Use nails that are cut or round wire of standard form. Use spikes that are cut, wire spikes or boat spikes.

Use black or galvanized nails, spikes, bolts, dowels, washers and lag screws for untreated timber.