

**Research Design and Standards Organization, Lucknow**  
**Report no BS-111 (Revision 6)**  
**Guidelines for use of High Strength Friction Grip (HSFG) bolting assemblies on**  
**bridges on Indian Railways**



Typical splice joint with HSFG bolting assembly

**May 2019**

### Foreword to BS-111 (Revision 6)

A committee was constituted by Railway Board for examining and reviewing the specifications of HSFG bolts, STR for HSFG bolts etc. One of the main recommendations of committee was to switch over to the manufacturing of HSFG bolts as per EN 14399 series code (HR system) and mandatory provisions of Direct Tension Indicator (DTI) washers without any exception. Accordingly the specifications for HSFG bolting assemblies with DTI washers have been finalized and uploaded on RDSO website. STR for vendor approval of HSFG bolting assemblies with DTI washers have also been finalized as per the recommendation of committee and uploaded on RDSO website.

At present provisions related to HSFG bolts are mainly based on IS codes. In cases where the IS codes are silent, EN codes have been referred. But present revision of this guideline has been done to update it in lines of revised specifications based on EN codes. Moreover STR for manufacturing of HSFG bolting assemblies has also been given in the annexure for understanding the process, tools and plants involved in the manufacturing of HSFG bolting assemblies with DTI washers.

All the users, designers as well as field engineers are once again requested to give further feedback on HSFG bolts to RDSO at e mail ID [directorbsrdso@gmail.com](mailto:directorbsrdso@gmail.com) so that the codal provisions can be improved and practical difficulties, if any, in implementing the guidelines are taken care of.

Executive Director (B&S) RDSO  
May 2019

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### Foreword to BS-111 (Revision 5)

HSFG bolts are being adopted on steel bridges widely since last two years and this document is being referred for guidance by the field as well as design engineers. An important feedback was received from field that the Quality Control of bolts is not covered properly in the earlier versions of the report even though the codal references had been given. **To address this issue, a new annexure V has been added to specify not only the tests required for quality control but also their frequency and their independent verification etc. It is hoped that this will help the field engineers in ensuring the quality of bolts.** Few other changes in this document include:

1. A & C slip no 10 of IRS B1 has been issued which incorporates the provisions regarding DTI washers and length of bolts, which were already included in this report vide Revision 4. Accordingly, the references have been changed to reflect the same.
2. IS:1367 Part 8 has revised version 2012 has been incorporated for torque to be given in the nuts.
3. The FAQs have been numbered Annexure III and Do's and Don't as Annexure IV.

RDSO extends hearty thanks for Mr Avadhesh and Mr Gautam Bose from M/S Panchsheel Fasteners, Mr Rupesh Patel from M/S Loyal Enterprises And Mr Sumit Kumar Udehra from M/S Udhera Mechanical Works who have given feedback on the report which has formed the basis of the changes in the document. The Inspection wing for steel girders at RDSO (B & S as well as M & C dtes) have also given their feedback on practicality of provisions, whose contribution is acknowledged here.

All the users, designers as well as field engineers are once again requested to give further feedback on HSFG bolts to RDSO at e mail ID [directorsteel2@gmail.com](mailto:directorsteel2@gmail.com) so that the codal provisions can be improved and practical difficulties, if any, in implementing the guidelines are taken care of.

Executive Director (B&S) RDSO  
April 2016

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### **Foreword to BS-111 (Revision 4)**

The knowledge in the field of HSFG bolts is expanding as the use of these is becoming progressively more prevalent. RDSO has already issued/ revised drawings for 25 T loading plate, composite and open web steel girders with HSFG bolts. Issues pointed out by the users, fabricators, manufacturers are being addressed on day-to-day basis by RDSO, but some issues have necessitated the revision of this document. Few minor changes are required in codal provisions for which draft correction slips have been sent to Railway Board. Important changes in this document include:

1. Codal specifications for DTI washers which were not given earlier. Now the relevant codes have been mentioned for better quality control. 0.25 mm feeler gauge which is required for some cases of DTI washer applications has now been incorporated.
2. Removal of ambiguity in provisions regarding projection of threads beyond the end of the bolt. The EN code and IS code provisions are differing in this respect. The ambiguity has been resolved.
3. The sequence of tightening has been better explained pictographically. The provisions for feeler gauges to be used with DTI washers has been changed as per provisions of EN 1090-2.
4. Some typographical errors have been rectified.

Hope the above changes and the newly added section– **Frequently Asked Questions** – to include some of the most commonly asked questions from field and design offices will help further clarify the matter. Ms Sheela Makwana, DyCE/ NW Rly, Dr Sanjeev Garg, DyCE/ N Rly and M/S Unbrako Fasteners deserve thanks for their feedback and correspondence.

All the users, designers as well as field engineers are once again requested to give further feedback on HSFG bolts to RDSO at e mail ID [directorsteel2@gmail.com](mailto:directorsteel2@gmail.com) so that the codal provisions can be improved and practical difficulties, if any, in implementing the guidelines are taken care of.

**Executive Director (B&S) RDSO**

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### **Foreword to BS-111 (Revision 3)**

HSFG bolts are evolving field for Indian Railways. Since the version 2 was issued, HSFG bolts have been included in Indian Railway Codes vide:

- 1) Correction Slip No. 19 to IRS Steel Bridge Code.
- 2) Correction Slip no. 6 to IRS B1-2001.
- 3) Correction Slip no. 27 to IR Bridge Manual.
- 4) Correction Slip no. 20 to IRS Steel Bridge Code.
- 5) Correction Slip no. 9 to IRS B1-200

The codal/manual provisions shall apply to HSFG bolts. This report may be referred to as explanatory handbook only and in case there is any contradiction, the codes/manuals will prevail.

This third revision of BS-111 has been necessitated to give guidance regarding torque to be applied for tightening of bolts. The correction slips already issued have been referenced as required. Special thanks to field engineers giving feedback, especially Girish Kumar Rao, AXEN/Con, Visakhapatnam, E. Co. Railway.

All the users, designers as well as field engineers are once again requested to give further feedback on HSFG bolts to RDSO at e mail ID [directorsteel2@gmail.com](mailto:directorsteel2@gmail.com) so that the codal provisions can be improved and practical difficulties, if any, in implementing the guidelines are taken care of.

**Executive Director (B&S) RDSO**

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### **Foreword to BS-111 (Revision 2)**

The guidelines (no BS-111) for use of High Strength Friction Grip Bolts (HSFG) on bridges on Indian Railways was issued in June-2012. The same was revised in July 2013 to incorporate the feedback received from the various railways. A matter regarding the thickness of aluminium metallising was raised by CBE, Northern Railway and this led to discovery of a few 'bugs' in the previous version, so the version 2 of the BS-111 is being issued

RDSO has already proposed correction slips to IRSB1, IRBM and Steel Bridge Code on the basis of this report. It may be noted that BS-111 was issued as a compilation of the codal provisions in the field of High Strength Friction Grip bolts. After the issue of the correction slips to the various codes/manuals, the provisions therein will govern. This document, however, will still remain useful in the form of commentary for the codal provisions.

All the users, designers as well as field engineers are requested to give further feedback on HSFG bolts to RDSO at e mail ID [directorsteel2@gmail.com](mailto:directorsteel2@gmail.com) so that the codal provisions can be improved and practical difficulties, if any, in implementing the guidelines are taken care of.

**Executive Director (B&S) RDSO**

## Foreword to BS-111(Revision1)

The guidelines for use of High Strength Friction Grip Bolts (HSFG) on bridges on Indian Railways was issued in June-2012. This is a new field for Indian Railways and lots of issues have been raised by the users, designers and field engineers. There has been need to modify certain provisions to ensure smooth field working and so a need for revision in the original guidelines issued has arisen.

The following major changes have been made in the revised guidelines:-

1. In para 7.II. the nominal diameter of hole has been changed from 2mm to 1.5mm more than bolt diameter for bolts having diameter less than 25mm and 2mm more than the bolt diameter for larger diameter bolts. This para has been added so that hole diameter is same as used for rivets.
2. Para 8, sub-para VII has been modified to cover different cases of provision of washers in field including DTI washers as old provisions were creating some confusion.
3. In para 10.I.c). a sub-clause vi is added describing Personnel for Tightening. This para has been added for better quality control.
4. In para 10.II.b).iv, the 0.1mm feeler gauge has been specified to be used for checking and term refusal has been defined.
5. In para 12.II.(c), the para regarding use of HSFG bolts for repair/rehabilitation work has been reworded to make it more clear.
6. In para 12.III, the para on painting has been replaced by a para specifying Painting during initial installation and Painting in service. This is as per feedback received.
7. Table 2 and Annexure D of IS:4000 have been provided at the end of report for ready reference of engineers.
8. In addition, minor changes have been made in wordings etc. in paras 8.II.a), para 9, para 10.I.c).iii, para 10.III.iii and para 10.VI for making these clearer.

RDSO is proposing correction slips to IRSB1, IRBM and Steel Bridge Code on the basis of these revisions. All the users, designers as well as field engineers are requested to give further feedback on HSFG bolts to RDSO at e mail ID [directorsteel2@gmail.com](mailto:directorsteel2@gmail.com) so that the codal provisions can be improved and practical difficulties, if any, in implementing the guidelines are taken care of.

**Executive Director (B&S) RDSO**

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## Foreword

Steel is an important material for construction of bridges. The connections in shop are now being made by submerged arc welding. But for field connections, rivets have been traditionally used. The riveted connections have served us well for over 150 years. But the rivets pose some difficulties:

1. In difficult and inaccessible areas, making rivets is difficult and often quality of rivets in such locations is very poor.
2. For large grips, longer rivets are required. The shanks of these rivets are difficult to be heated uniformly and while transporting the hot rivets, the same get differentially cooled and the rivets are not able to completely fill up the annular space all round.
3. With changing times, Indian Railways and the only major organization in India still using structural rivets and the availability of skilled labour required for riveting is diminishing.

RDSO has been seized of these issues and has been looking for replacement of the rivets with some other type of connections and High Strength Friction Grip (HSFG) bolts have been found suitable for the same. These can be used in road bridges as their use has been permitted by IRC codes. For railway bridges, the relevant codes are required to be changed (clauses pertaining to design of HSFG bolts for railway loading need to be introduced) before the HSFG bolts can be used for the same.

While preparing these guidelines IS codes, Eurocodes, American codes and literature on the subject have been referred. The drawings issued by zonal railways incorporating HSFG bolts for ROBs were also studied. RDSO has tried to make the guidelines comprehensive and cover the design, installation and maintenance aspects in the same. The concerns of engineers about theft and sabotage have also been addressed in the guidelines. The draft guidelines were published on internet for comments at RDSO website as well IRICEN website and lots of comments have been received. RDSO is thankful to Shri Gautam Bose from Panchsheel fasteners, Shri A Ghoshal from M/S STUP Consultants, Shri Naresh Lalwani, SPB2, IRICEN, Shri Y S Hooda, Director ( B & S) RDSO, Shri Murthy Raju, DyCE/C/D S W Rly and Shri Radhakrishan, SSE(B), S Rly, for their very useful comments. The comments from Shri Lalwani and Shri Ghoshal were in detail and RDSO is thankful to them for devoting so much time for studying the draft guidelines closely.

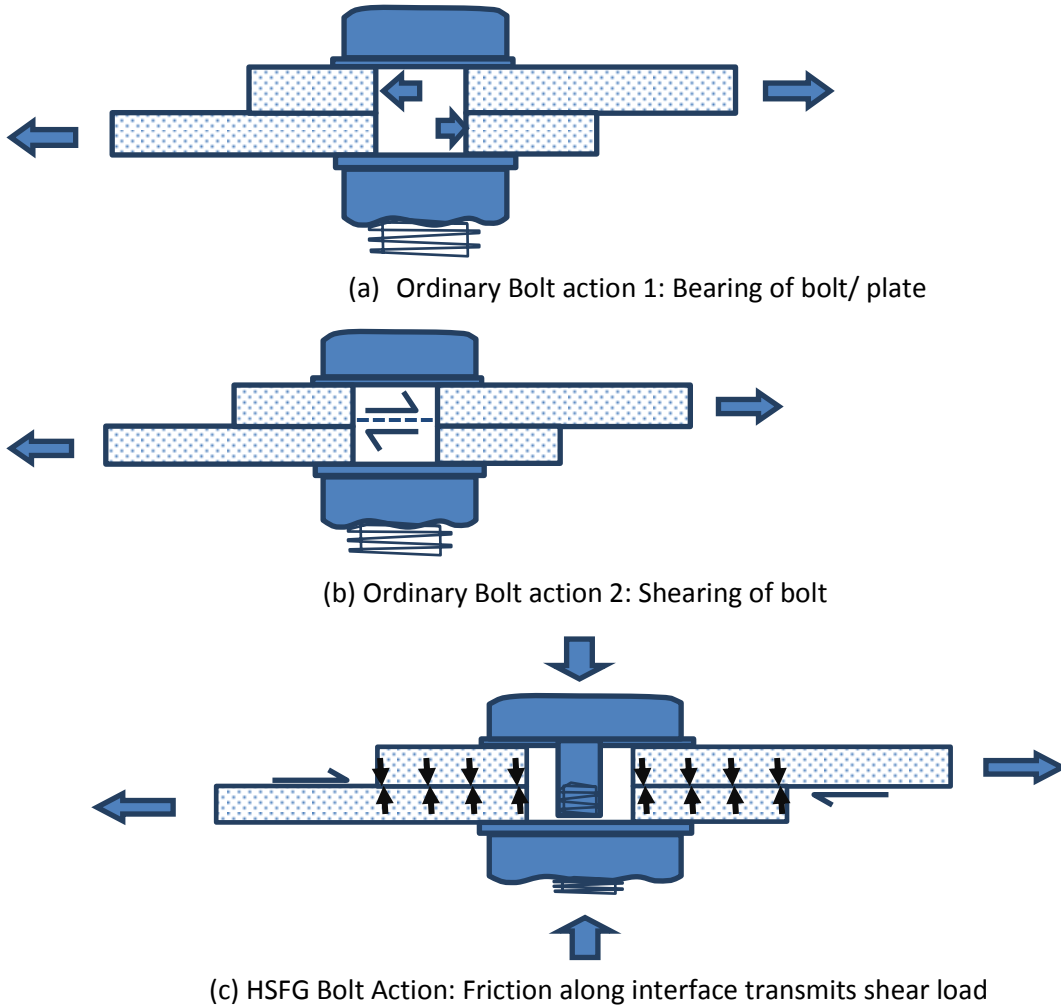
The comments received have been incorporated in the guidelines. All the users, designers as well as field engineers are requested to give the feedback on HSFG bolts to RDSO at e mail id [directorsteel2@gmail.com](mailto:directorsteel2@gmail.com) so that the codal provisions can be improved and practical difficulties, if any, in implementing the guidelines are taken care of.

Executive Director ( B & S) RDSO  
June 2012

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### Basics about HSFG Bolts

- 1. Introduction:** Rivets have been used historically for making field connections in steel girders subject to railway and highway loadings. Rivets, however, require skilled workers and elaborate equipment/arrangements. With passage of time, the availability of such labour and equipment for small quantum of work is becoming difficult and Indian Railways (IR) is looking for alternatives to rivets. Also, rivets are difficult to make when the grip length increases as the uniform heating of longer rivets and also ensuring that rivets do not cool down before the same is driven becomes problematic in field. One option for substitute for rivets, namely High Strength Friction Grip (HSFG) bolting assembly is covered in these guidelines. In HSFG bolting assembly, high strength structural bolt has been tightened such as to induce predefined tension in the bolt shank. Due to the tension in the bolt, the interface between the plies (steel members in a joint) cannot move relative to each other because of the frictional resistance. The bolts act differently than normal bolts or rivets as explained below:



**Fig. 1- Comparison of mechanism of ordinary bolting assembly vis-à-vis HSFG bolting assembly**

2. **Scope:** These guidelines cover the use of HSFG bolts in friction type joints for bridges covered by IRS Steel Bridge Code, from sizes M12 to M36. **These guidelines are intended to help better understanding of the codal provisions. For actual design/ use, the source codes shall be referred to and followed.** These guidelines cover the use of HSFG bolting assembly in Road Over Bridges as well as Railway Bridges. At the moment, IRC codes allow use of HSFG bolting assembly and with issue of correction slips to codes for incorporating provisions related to HSFG bolting assembly, HSFG bolting assembly can be used as an alternative to the rivets in all types of railway bridges. Due to different actions, HSFG bolting assembly cannot be used in conjunction with rivets/ welds in same joint without considering the structural action.
3. **Reference Codes:** This guideline has been revised for using the EN 14399 series codes (High strength structural bolting assemblies for preloading) in manufacture of HSFG bolting assemblies. In earlier version, design and manufacture was done using IRS and IS codes and where these codes were silent, EN codes were referred. However, in this revision of guidelines, the design is to be done on basis of provisions of IRS Steel Bridge Code (IRS SBC provisions of design of HSFG bolting assemblies are basically based on IS 4000:1992 code) while manufacturing of HSFG bolting assemblies to be switched over to EN 14399 series code (HR system). Following are the reference codes:
  - I. EN 14399 Series (High strength structural bolting assemblies for preloading):
    - (a) EN 14399-1:2015- General requirements
    - (b) EN 14399-2:2015- Suitability for preloading
    - (c) EN 14399-3:2015- System HR- Hexagonal bolt and nut assemblies
    - (d) EN 14399-5:2015- Plain washers
    - (e) EN 14399-6:2015- Plain chamfered washers
    - (f) EN 14399-9:2009- Direct Tension Indicator for bolt and nut assembly
  - II. EN-1090-2: 2008, Execution of Steel Structures and Aluminium Structures part 2 – Technical Requirements for Steel Structures.
  - III. IS 4000: 1992 – High Strength Bolts in Steel structures – Code of Practice.
4. **HSFG bolting assemblies:** Preloaded HSFG bolting assemblies are very sensitive to differences in manufacture and lubrication. Therefore it is important that the complete HSFG bolting assembly including Direct Tension Indicator (DTI) washer, shall be supplied by single manufacturer who shall be responsible for the function of the assembly. For the same reason it is important that hot dip galvanizing or other surface coatings of the assembly shall be under the control of single manufacturer.

DTI washers are to be sold as part of a complete assembly only that comprises bolts and nuts and that otherwise complies with EN 14399-3. The systems of bolt/nut/washer assemblies are described in Table 1. Use of DTI washer shall be mandatory in HSFG bolting assemblies.

Beside the mechanical properties of the components, the functionality of the assembly requires that the specified preload can be achieved when the average gap remaining after tightening (compressed protrusions in DTI washers) is less than the specified values in Table 3, if the assembly is tightened with a suitable procedure. The test method given in EN 14399-2 and EN 14399-9 has been developed to demonstrate the suitability of the components for preloading.

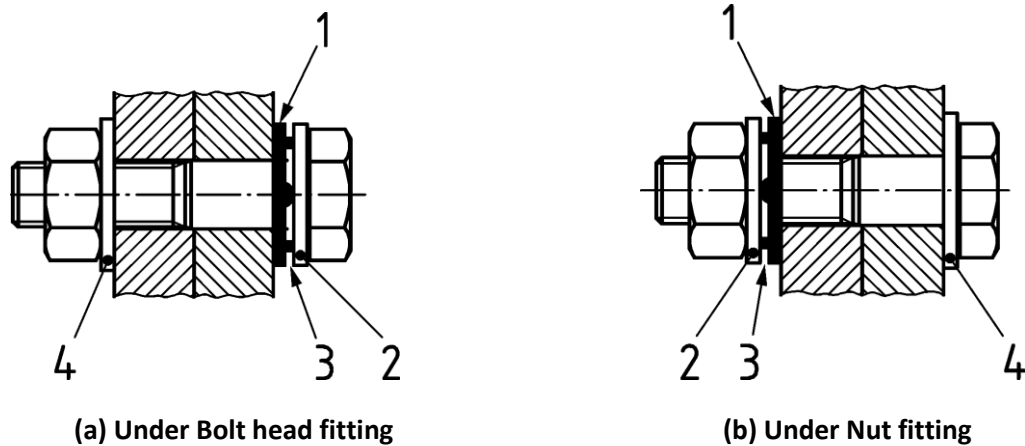


**Table 1 — Composition of high-strength structural bolting assembly and its component marking**

Type of bolting assembly		System HR	
General requirements		EN 14399-1	
Suitability for preloading		EN 14399-2 and, if any, additional testing specified in the product standard	
Bolt & Nut		EN 14399-3	
Marking	Bolt	HR8.8	HR10.9
	Nut	HR8 or HR10	HR10
Washers		EN 14399-5 <sup>a</sup> or EN 14399-6	
Marking		H or HR <sup>b</sup>	
Direct tension indicator and nut face washer or bolt face washer		EN 14399-9	
Marking	Direct Tension Indicator	H8	H10
	Nut Face Washer	HN	
	Bolt Face Washer	HB	
<sup>a</sup> EN 14399-5 can only be used under the nut. <sup>b</sup> At the choice of the manufacturer.			

- I. **Type of HSGF bolting assemblies with DTI:** Bolting assemblies according to this code consist of bolts and nuts which shall meet all the requirements of EN 14399-3 (HR System). The functional characteristics of the bolting assemblies shall be achieved when tested together with direct tension indicators. The assembly may include washers according to EN 14399-6 or EN 14399-5 (under the nut only) and/or nut face or bolt face washers in accordance with Clause 4 of EN 14399-9.  
Composition of high-strength structural bolting assembly (HR System) and its component marking has been given in Table 1. The assembly configurations which can be used with direct tension indicators shall be according to Fig. 2 and Fig. 3 below.
- II. **Functional characteristics of the bolt/nut/washer(s)/DTI assembly:** The functional characteristics of the bolting assembly (comprising of a bolt, a nut, a direct tension indicator and applicable washers, as required) shall be achieved when tested in accordance with the following. The principle of the test is to tighten the bolting assembly and to measure during tightening the following parameters: (a) Relative rotation between the nut and the bolt (b) Bolt force. This test procedure is based on the requirements according to EN 14399-2 and incorporates requirements applicable to assemblies which include direct tension indicators.
- III. **Suitability test for preloading with direct tension indicator in an assembly:** Direct tension indicators conforming to EN 14399-9 are suitable according to EN 14399-2 provided they are used in an assembly comprised of matched components in accordance with Table 1 and with EN 14399-3 (System HR) that have been tested in accordance with EN 14399-2 to determine the relative rotation between the bolt and nut. Type tests shall be carried out

separately for the direct tension indicator under the bolt head and under the nut. The type test shall be used to demonstrate that  $\Delta\theta_2$  measured with assemblies incorporating a direct tension indicator exceeds the appropriate  $\Delta\theta_2, \text{min}$ , by at least 10 %.

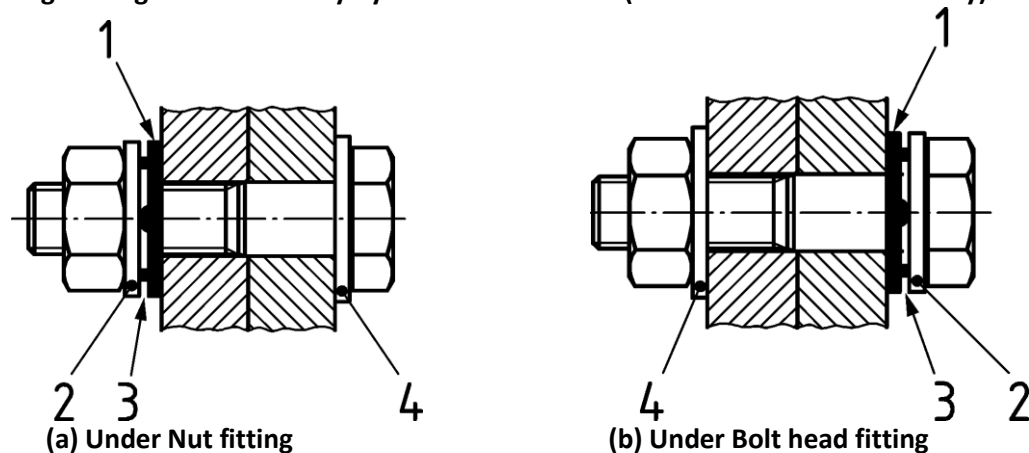


Key

1. Direct Tension Indicator
2. Bolt face washer (not required for property class 8.8)
3. Gap
4. washer according to EN 14399-5 or -6

1. Direct Tension Indicator
2. Nut face washer
3. Gap
4. washer according to EN 14399-6 (not required for property class 8.8)

**Fig.2: Tightening of the assembly by rotation of the nut (Normal method of assembly)**



Key

1. Direct Tension Indicator
2. Nut face washer
3. Gap
4. washer according to EN 14399-6

1. Direct Tension Indicator
2. Bolt face washer
3. Gap
4. washer according to EN 14399-5 or -6 (not required for property class 8.8)

**Fig.3: Tightening of the assembly by rotation of the bolt head (Alternative method of assembly)**

- IV. Suitability test for establishing bolt force:** The test shall be carried out in a calibrated load cell with the requirements generally as specified in EN 14399-2. If shims are required to adjust the length between bolt head and nut, these shall be used as specified in EN 14399-2. The assembly shall be assembled in accordance with Fig 2(a) horizontally; the bolt force ( $F_{bi}$ ) shall be determined in accordance with Table 2 and not be less than the minimum bolt force specified in Table 4 of EN 14399-9.
- 5. Bolts:** For the purpose of HSFG connections, only high strength structural bolts confirming to the requirements for assemblies of high-strength structural bolts and nuts of system HR suitable for preloaded joints with large width across flats as specified in EN 14399-3 together with EN 14399-1 and 14399-2 can be used. Specification for bolts and reference standards for material, general requirements, thread, mechanical properties, tolerances, finish-coatings, surface integrity, acceptability etc. has been given in Table 3 of EN 14399-3. EN 14399-3 gives two property classes: 8.8 or 10.9 for the same. The bolts shall have the following characteristics:
- I. Property class:** A property class has two parts separated by a decimal in the form x.y. The first part, x, indicates 1/100 of the nominal tensile strength in Newton per sq mm and y indicates ten times the ratio of the lower yield stress and nominal tensile strength.<sup>1</sup> For example, property class 8.8 means that the bolt will have nominal Ultimate Tensile strength of 800 N/mm<sup>2</sup>, and lower yield stress of 80% of 800 N/mm<sup>2</sup>, i.e. 640 N/mm<sup>2</sup>.
  - II. Identification/Marking:** High strength structural bolts manufactured according to EN 14399-3 shall be marked with: (a) Property class marking with the letters HR e.g. 8.8HR or 10.9HR (b) Identification mark of the manufacturer of bolting assembly. It is permissible for the marking to be either embossed or indented on top surface of the head.<sup>2</sup> For having better traceability, heat mark of the raw material shall be embossed on the bolt head, nut and washers. Apart from heat mark, length of bolt may also be embossed on bolt head. This will be in addition to name of manufacture and property class of bolt material.
  - III. Diameter:** Table 2 of EN14399-3 gives the dimensions of the bolt.
  - IV. Length:** The bolt length shall be chosen such that after tightening the following requirements are met for bolt end protrusion beyond the nut face and the thread length: (a) The length of protrusion shall be at least the length of one thread pitch measured from outer face of the nut to the end of the bolt. (b) For preloaded bolts according to EN 14399-3, at least four full threads (in addition to the thread run out) shall remain clear between the bearing surface of the nut and the unthreaded part of the shank.<sup>3</sup>
  - V. Surface Finish & Coatings:** Wherever property class 8.8 bolts are used these should be hot dip galvanized as per ISO: 10684 (latest version) to provide salt spray resistance suitable as per site condition depending upon severity of environment. Property class 10.9 bolts should not be hot dip galvanized since this may cause hydrogen embrittlement. So these bolts should be coated with Zinc flakes as per ISO: 10683 (latest version), to provide salt spray resistance suitable as per site condition depending upon severity of environment. However,

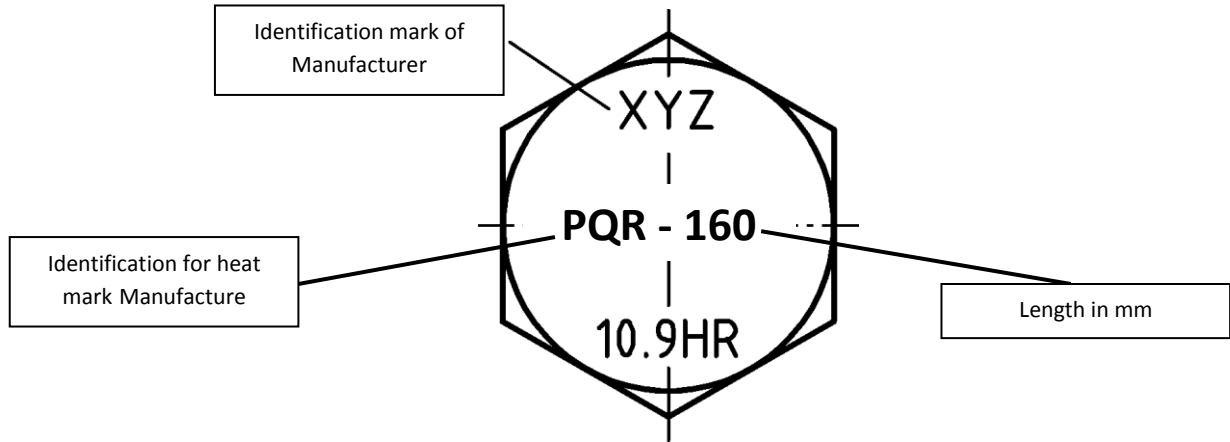
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<sup>1</sup> Table 3.1 of EN 1993-1-8.

<sup>2</sup> Clause 3.3 of EN 14399-3.

<sup>3</sup> Clause 8.2.2 of EN 1090-2:2008

depending on the site conditions, locations of the bolts in the structure and corrosion proneness, use of Zinc flake spray coating as per ISO 10683 (latest version) can be adopted even for property class 8.8 bolts as well.

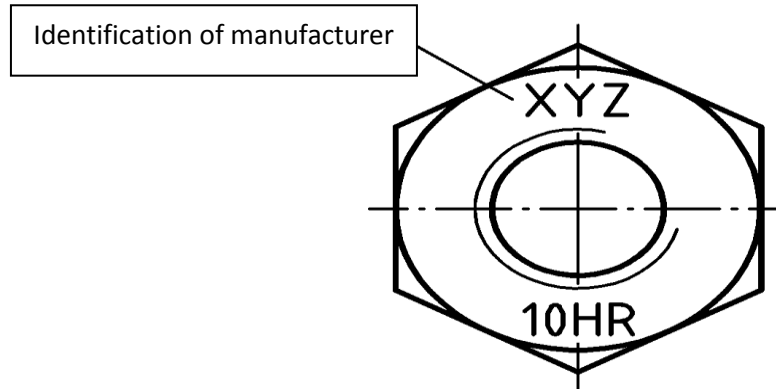


**Fig. 4: Typical Marking on bolt-heads**

6. **Nut:** For the purpose of HSFSG connections, only high strength structural nuts confirming to the requirements for assemblies of high-strength structural bolts and nuts of system HR suitable for preloaded joints with large width across flats as specified in EN 14399-3 together with EN 14399-1 and 14399-2 can be used. Specification for nuts and reference standards for material, general requirements, thread, mechanical properties, tolerances, finish-coatings, surface integrity, acceptability etc. has been given in Table 5 of EN 14399-3. Nuts shall run freely on their partnering bolt, which is easily checked during hand assembly. Any nut and bolt assembly where nut does not run freely shall be discarded. If a power tool is used, either of the following two checks may be used: (a) For each new batch of nuts or bolts their compatibility may be checked by hand assembly before installation (b) For mounted bolt assemblies but prior to tightening, sample nuts may be checked for free running by hand after initial loosening. The nuts shall have the following characteristics:
  - I. **Property Class:**<sup>4</sup>Nuts are designated by property class designation, which is equal to 1/100 of the minimum tensile strength in Newton per square mm of the bolt. For HSFSG bolting assemblies, the property classes to be used are 8 and 10 as specified in EN 14399-3. Property class 8 nut to be used with bolts of property class 8.8 only whereas property class 10 nuts can be used with bolts of property class 8.8 and 10.9 both. Dimensions of the nuts should be as per the table 4 of EN 14399-3.
  - II. **Identification of Nut:** High strength structural nuts manufactured according to EN 14399-3 shall be marked with: (a) Property class marking with the letters HR e.g. 8HR or 10HR (b) Identification mark of the manufacturer of bolting assembly. The marking shall be indented

<sup>4</sup> Table-5 of EN 14399-3.

on either bearing face of chamfered nuts and shall be either indented or embossed on the non-bearing face of washer faced nuts.



**Fig. 5: Typical markings on nuts**

- III. Surface finish and coatings of Nut:** HSFG nuts of property class 8 should be hot dip galvanized as per ISO 10684 (latest version) to provide salt spray resistance suitable as per site condition depending upon severity of environment. Property class 10 nuts should not be hot dip galvanized since this may cause hydrogen embrittlement. So these nuts should be coated with Zinc flakes as per ISO: 10683, to provide salt spray resistance suitable as per site condition depending upon severity of environment. However, depending on the site conditions, locations of the nuts in the structure and corrosion proneness, use of Zinc flake spray coating can be adopted even for property class 8 nuts as well.

In nuts the thread type depends on the type of coating adopted for nuts. In case of hot dip galvanization of nuts, the thread in nuts should be as per tolerance class 6AZ as per ISO 261, ISO 965-5 and in other type of coatings the threads should be as per tolerance class 6H as per ISO 261, ISO 965-2, ISO 965-5.

- IV. Position of nut in bolt:** HSFG bolt cannot be easily opened out except by use of torque wrench. Still, as an additional precaution, it may be ensured that the nut is not easily accessible for opening out by anti-social elements, the same shall be provided preferably as follows:

- a) **In girder web:** Towards outside of the girder.
- b) **In flanges:** Towards bottom (Except when in composite construction).
- c) **In composite construction:** Towards inside of concrete.
- d) **In bracing:** Towards the rolled section side so that the space for rotation of the nut is not readily available.
- e) Where **Tapered washer** is used, the nut shall preferably be on the other side.

- 7. Holes for HSFG Bolts:** Normal holes in the steel members being connected by the rivets shall be used for HSFG bolts also, subject to the following:

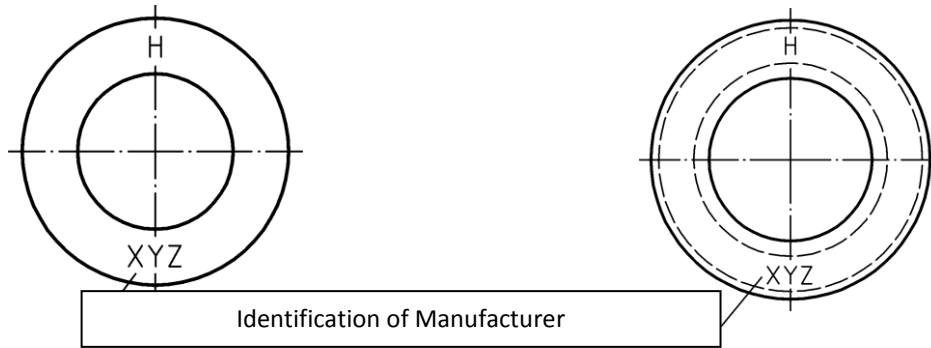
- I. Making of holes:** The holes shall be made by drilling only.

- II. **Nominal Diameter of Hole:** The actual diameter of hole shall be 1.5 mm more than the bolt diameter<sup>5</sup> for less than 25mm dia. bolts and 2 mm more than nominal dia. of HSFG bolts for larger diameters i.e. for 20 mm dia HSFG bolt, the hole shall be 21.5 mm in diameter.
  - III. **Oversize Holes:** In case the bolts are to be provided in existing structure, the maximum size of hole shall not exceed 1.25 d or d + 4 mm whichever is less i.e. for 16 mm dia bolt, the maximum diameter of hole shall not exceed 20 mm and for 24 mm dia bolt, the maximum diameter shall not exceed 28 mm.<sup>6</sup>
- 8. Plain and Plain Chamfered Washer:** Washers used under heads of preloaded bolts shall be chamfered according to EN 14399-6 and positioned with the chamfer towards the bolt head. Washers according to the EN 14399-5 shall only be used under nuts. Washers according to EN 14399-5 and EN 14399-6 are not intended to be used in direct contact with oversized or slotted holes. Specification and reference standards for plain washers and plain chamfered washers regarding material, general requirements, mechanical properties, tolerances, finish-coatings, workmanship, acceptability etc. has been given in Table 3 of EN 14399-5 and EN 14399-6 respectively. Dimensions of plain and plain chamfered washers have been given in table 2 of EN 14399-5 and EN 14399-6 respectively. Plain Washers (or if necessary hardened taper washers) shall be used for HSFG bolting assemblies as follows: (a) For 8.8 bolts a washer shall be used under the bolt head or the nut, whichever is to be rotated (b) For 10.9 bolts washers shall be used under both the bolts and the nut.
- Plate washers shall be used for connections with long slotted and oversized holes. One additional plate washers or up to three washers with a maximum combined thickness of 12 mm may be used in order to adjust the grip length of bolt assemblies. They shall be placed on the side that is not turned. Dimensions and steel grades of plate washers shall be specified. They shall not be thinner than 4 mm.
- Taper washers shall be used if the surface of the constituent product is at an angle to a plane perpendicular to the bolt axis of more than: (a) 1/20 (3°) for bolts with  $d \leq 20$  mm (b) 1/30 (2°) for bolts with  $d > 20$  mm. Dimensions and steel grades for taper washers shall be specified. The washers have the following characteristics:
- I. **Identification:** Hardened and tempered plain washers shall be marked with at least manufacturer's identification mark and letter H. Alternatively; these may also be marked with HR in place of H when supplied as component of bolting assembly of system HR. Marking shall be indented on one of the bearing surfaces. The marking of washers with enlarged outer diameter shall be HD.
- Similarly for hardened and tempered chamfered washers shall be marked with at least manufacturer's identification mark and letter H. Alternatively; these may also be marked with HR in place of H when supplied as component of bolting assembly of system HR. Marking shall be indented on non chamfered side.

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<sup>5</sup> Clause 6.1 of IS 4000 provides for 2mm extra for friction type joints. However, the same has been kept as 1.5mm till 25mm for uniformity with holes made for rivets.

<sup>6</sup>As per para 7.12.5 of IRS Steel Bridge Code.



**Fig. 6: Typical markings/shapes on plain and plain chamfered washers**

**II. Surface Finish and coatings:** Washers as per EN 14399-5 and EN 14399-6 can be hot dip galvanized as per ISO 10684 (latest version) to provide salt spray resistance suitable as per site condition depending upon severity of environment, however attention is drawn to the need to consider the risk of hydrogen embrittlement when selecting an appropriate surface treatment process (e.g. cleaning and coating) as per relevant coating standard. So these washers can also be coated with Zinc flakes as per ISO: 10683, to provide salt spray resistance suitable as per site condition depending upon severity of environment to avoid risk of hydrogen embrittlement.

**9. Direct Tension Indicators (DTI) washers:** Compressible washer-type Direct Tension Indicators (DTI) as per EN 14399-9 (known formerly as load indicating washers) used in conjunction with bolt and nut face washers are a load indicating device which are placed under the bolt head or under the nut. The direct tension indicators have protrusions on one face which compress under load and thus may be used to indicate the magnitude of the preload in the assembly.

Salient features of DTI as per EN 14399-9 are as below:

- I. Dimensions of DTI:** Before installation, the dimensions and tolerances of compressible washer-type direct tension indicators shall be as given in Table 2 of EN 14399-9. The size and number of protrusions on the direct tension indicator shall be sufficient to meet the performance requirements of clause 3.3 of EN 14399-9 and their number shall be not less than four. The protrusions on a direct tension indicator shall be spaced at equal angular intervals. The shape of the protrusions is at the discretion of the manufacturer.
- II. Specifications and reference standards for DTI:** Specifications and reference standards regarding material, general requirements, heat treatment, maximum hardness, surface finish, associated bolts and nuts, associated washers, acceptability etc. have been given in Table 3 of EN 14399-9.
- III. Performance test of DTI:** The direct tension indicators shall be tested on a calibrated load-measuring device as per description given in clause 3.4 of EN 14399-9 for the test procedure. The load requirement of Table 4 of EN 14399-9 shall be met when the direct tension indicators are compressed to the average gaps given in Table 9 of EN 14399-9. Samples of direct tension indicators shall be tested by the manufacturer after the final production process including the surface finish, if any. The minimum number of direct

tension indicators tested per manufacturing lot shall be eight and all samples shall pass the test.

- IV. Marking of DTI:** Direct tension indicators shall be marked with the identification mark of the manufacturer of the assembly and H8 or H10 as appropriate. The marking shall be indented into the direct tension indicator face from which the protrusions project. It is recommended to stamp lot numbers on the face of the direct tension indicator.



**Fig. 7: Two faces of Compressible washer type Direct Tension Indicator**

- V. Nut face washers and Bolt face washers:** Dimensions and tolerances of Nut face washers and Bolt face washers shall be as given in Table 6 and 7 of EN 14399-9 respectively. Specification and reference standards for Nut face washers and Bolt face washers regarding material, general requirements, heat treatment, hardness alternatives, tolerances, surface finish, associated bolts and nuts, associated washers, acceptability etc. have been given in Table 8 of EN 14399-9. Nut face washers shall be marked with the identification mark of the manufacturer of the bolting assembly and the letters HN. The marking shall be indented into one face. Bolt face washers shall be marked with the identification mark of the manufacturer of the bolting assembly and the letters HB. The marking shall be indented into one face.
- VI. Surface finish and coatings:** For corrosion protection of DTI, Nut face washers and Bolt face washers; hot dip galvanization should not be done because in case of hot dip galvanization it is difficult to accurately control the thickness of coating as well as risk of hydrogen embrittlement. Moreover excessive coating of DTI washers may lead to erroneous tensioning of HSFG bolt assembly. Hence in DTI, Nut face washer and Bolt face washer surface finish should be sherardized according to EN 13811 or zinc flake coating as per ISO 10683 should be done.
- VIII. Functional characteristics of DTI in bolting assembly:** A specified feeler gauge as per Table 9 of EN 14399-9 which is reproduced below shall be used to determine that the required bolt preload has been achieved by the assembly after it has been tightened. Tests have shown the need for a smaller gap when the direct tension indicator is used under the rotated component. Direct tension indicators fitted as specified will result in the same loads being attained when the bolts are tightened to the specified gaps. The average specified indicator gap shall be determined using the following measurement procedure;



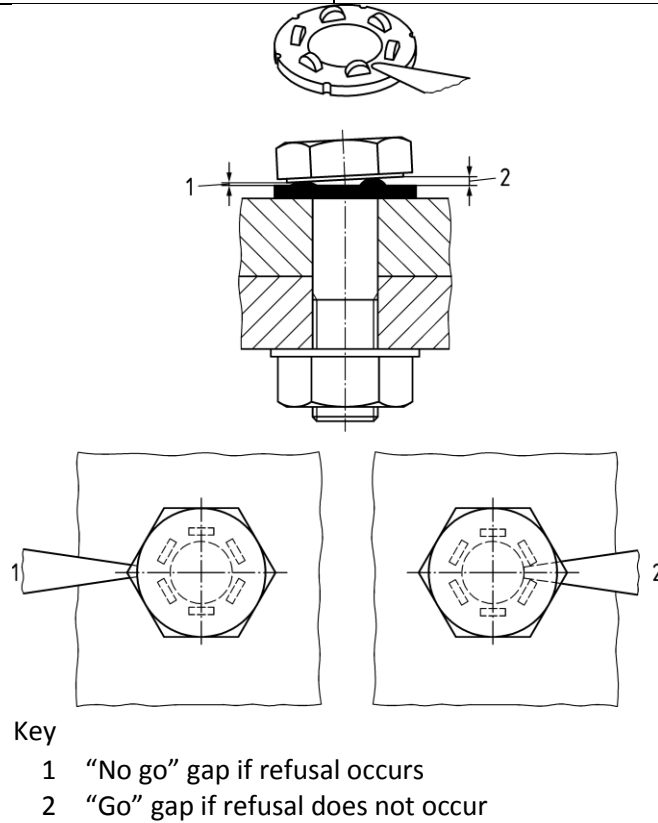
the feeler gauge shall be used as a “no go” inspection tool. The feeler gauge shall be pointed at the centre of the bolt as per Figure 9 of EN 14399-9 and shall refuse to enter the number of refusal spaces specified in Table 10 of EN 14399-9.

**Table 2: Thickness of the feeler gauge**

Direct tension indicator positions	Designation H8 and H10 Thickness of feeler gauge (mm)
Under bolt head, when nut is rotated (Figure 7a)	0.40
Under nut, when bolt is rotated (Figure 8a)	
Under nut, when nut is rotated (Figure 7b)	0.25
Under bolt head, when bolt is rotated (Figure 8b)	

**Table 3: Feeler gauge requirements**

Number of indicator protrusions	Minimum number of feeler gauge refusals
4	3
5	3
6	4
7	4
8	5
9	5



**Fig.8: Checking the indicator gap (example with six protrusions)**

**10. Surface preparation for steel interface before providing HSFG bolts:** The steel interface between the plies which form a joint having HSFG bolts shall have special surface preparation so that sufficient slip factor as assumed by designer in design is available. The surface preparation shall be assumed by designer in design, based on slip factor specified in Table XIII of the IRS Steel Bridge Code. The following surface preparation shall be done:

- I. **New construction:** The interface between the plies which are connected together by the HSFG bolts shall be “**Aluminium metallised without any over coating**”. The aluminium metallising shall be as per para 39.2.1 of IRS B1.<sup>7</sup>
- II. **Existing structures:** The interface of plies which are to be included in the HSFG bolts shall be cleaned by wire brushing/ flame cleaning equivalent to the surface specified in IRBM para 217, 1 (b), (i) to (iv).<sup>8</sup>The surfaces shall be cleaned to remove all loose rust and paint layers (Only isolated patches of coatings/ rust can remain). If, however, in existing structures, rivets are to be replaced by bolts but no surface preparation is possible, the slip factor shall be suitably reduced.

**11. Installation of HSFG bolting assemblies:** Installation/tightening of preloaded bolting assemblies to be carried out in accordance with clause 8.3, clause 8.5 of EN 1090-2 and clause 5.2 of EN 14399-9. The salient provisions of these are given below:

- I. **General:** Unless otherwise specified the nominal minimum preloading force ( $F_{pC}$ ) shall be taken as given in Table 19 of EN 1090-2. This level of preload shall be used for all slip resistant preloaded connections. Any of the four tightening method (i.e. Torque method, Combined method, HRC tightening method and DTI method) has been recommended in EN 1090-2 for use as given in Table 20 of EN 1090-2. However this document recommends using only the DTI method due to its simplicity in application in field. Details related to installation of bolting assemblies as per DTI method is elaborated below as per relevant provisions of EN 1090-2 and EN 14399-9.

The as delivered calibration is valid for tightening by rotation of the nut. If tightening is done by rotation of the bolt head, calibration shall be done according to annex H of EN 1090-2 or by supplementary testing from the fastener manufacturer otherwise in accordance with EN 14399-2. However in case of DTI method the same has been taken care by specifying different thickness of feeler gauges in different position of DTI with respect to tightening by nut or bolt head. So in case of DTI method no need for calibration if tightening is done by rotation of bolt head.

Burrs, loose materials and excessive thickness of paint that would prevent solid seating of the connecting parts shall be removed before assembly.

Before commencement of preloading, the connected components shall be fitted together and bolts in a bolt group shall be tightened in accordance with clause 8.3 of EN 1090-2 but the residual gap shall be limited to 2 mm with the necessary corrective action on steel

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<sup>7</sup>IRS B1 specifies that metallising be done in two layers. The same will constitute only one coat, which shall not be painted over.

<sup>8</sup> As per para 28.10.3 (ii) of IRS B1.

components. The connected components shall be drawn together such that they achieve firm contact. Shims may be used to adjust the fit. For constituent products with  $t \geq 4$  mm for plates and sheeting and  $t \geq 8$  mm for sections, unless full contact bearing specified, residual gaps of up to 2 mm may be left at the edges on condition that contact bearing is achieved at the central part of connection. Each bolt assembly brought at least to a “Snug-Tight condition”, with special care being given to avoid over-tightening. The tightening process shall be carried out from bolt to bolt of the group, starting from the most rigid part of the connection and moving progressively towards the least rigid part. To achieve a uniform “Snug-Tight condition”, more than one cycle of tightening may be necessary. The most rigid part of a cover plate connection of an I section is commonly in the middle of connection bolt group. The most rigid parts of end plate connections of I sections are usually besides the flanges. The term “Snug-Tight condition” can generally be taken as that achievable by the effort of one man using a normal sized spanner without an extension arm, and can be set as the point at which a percussion wrench starts hammering.

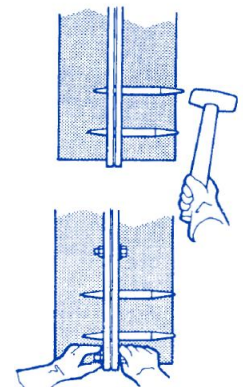
Tightening shall be carried out progressively from the most rigid part of the joint to the least rigid part. To achieve uniform preloading, more than one cycle of tightening may be necessary.

If a bolt assembly has been tightened to the minimum preload and later un-tightened, it shall be removed and whole assembly shall be discarded. Bolt assemblies used for achieving initial fit up should not generally need to be tightened to the minimum preload or un-tightened, and would therefore still be usable in location in the final bolting up process.

The potential loss of preloading force from its initial value due to several factors e.g. relaxation, creep of surface coatings is considered in tightening methods. In case of thick surface coatings, it shall be specified if measures shall be taken to offset possible subsequent loss of preloading force.

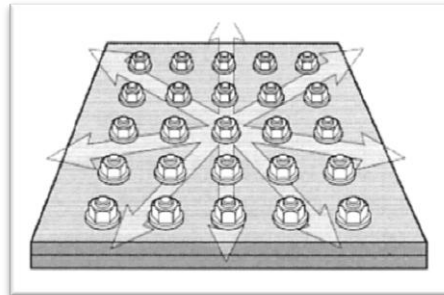
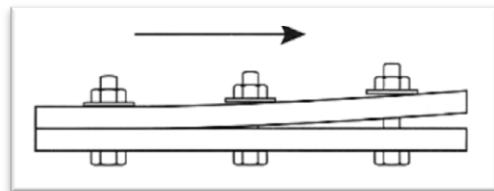
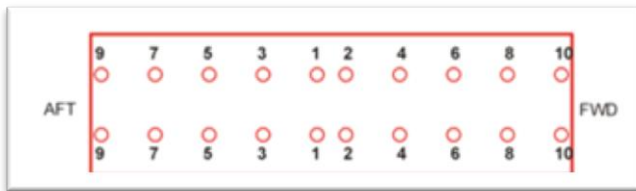
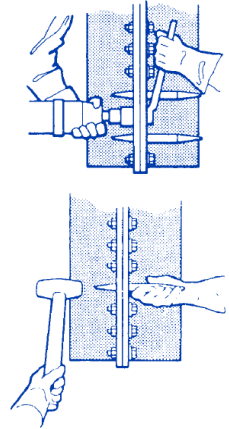
**II. Sequence of tightening:** The following steps shall be followed for tightening of bolts:

1. The holes shall be brought in alignment by using drifts etc such that the bolt threads are not damaged during insertion of bolts. Drifting shall not distort the metal or enlarge the holes.<sup>9</sup>
2. The members being joined shall be held in position by insertion of few HSFG bolts (tightened to first stage only). These bolts shall not be tightened to second stage till all the bolts in a joint are inserted and tightened to first stage.
3. After the alignment/ geometry of members is verified to be correct as per drawings, balance bolts shall be inserted and tightened upto first stage of tightening. The drifts inserted as above shall also be replaced by HSFG bolts one by one.



<sup>9</sup> Clause 7.1.4 of IS 4000.

4. The final tightening shall not proceed until the gap between the plates has been closed such that the residual gap, if any, is less than 2 mm at edges.<sup>10</sup> There shall, however, be no gap in the central portion. In case the central portion is not in close contact or gap at edges is more than 2 mm, straightening of members may be done after opening out the bolts inserted and the entire procedure i) to iii) above shall be repeated.
5. During tightening of bolts also, the steel members can continue to deform and hence the tightening of subsequent bolts can lead to loosening of already tightened bolts. In order to minimize the loosening of already tight bolts, tightening in the two stages shall be done starting from the stiffest part to the free edges.<sup>11</sup> Stiffest parts of joint are generally towards the center of the joint. Bolt tightening sequence for typical flange/web splices, based on above principles, is shown below:



- III. **Personnel For Tightening:** The tightening of HSFG bolts is a technical procedure. Only trained personnel who understand the procedure shall carry out the installation of HSFG bolts. Before any person is deployed for installation, his knowledge of the procedure for tightening shall be checked and if found satisfactory, a competency certificate shall be issued by an engineer not below the rank of ADEN or equivalent. The competency certificate once issued shall be valid for six months. Any person deployed for installation of HSFG bolts must possess a valid competency certificate.
- IV. **Procedure for Installation of HSFG Bolts Using Direct Tension Indicator:** This is the preferred method of installation of HSFG bolting assemblies. In this document only this method of installation has been recommended to use due to its simplicity of application in field.

<sup>10</sup> Clause 8.5.1 and 8.3 of EN 1090-2

<sup>11</sup> Clause 7.1.5 of IS 4000

- i. **Calibration of Direct Tension Indicator:** The direct tension indicators shall be tested on a calibrated load-measuring device as per description given in clause 3.4 of EN 14399-9 for the test procedure. The load requirement of Table 4 of EN 14399-9 shall be met when the direct tension indicators are compressed to the average gaps given in Table 9 of EN 14399-9. Samples of direct tension indicators shall be tested by the manufacturer after the final production process including the surface finish, if any. The minimum number of direct tension indicators tested per manufacturing lot shall be eight and all samples shall pass the test. Only the lot of DTIs which satisfy the calibration shall be brought to site for work.
- ii. **Procedure:**<sup>12</sup>The tightening is done in two stages so that the bolts already tightened do not get loose when the subsequent bolts are tightened.
- a. **First Stage of Tightening:** As a first stage, all bolts in the joint shall be tightened to 'snug tight' condition. Snug tight condition means the nut is tightened using an ordinary wrench by an average worker, applying maximum force on the wrench. This stage is required to bring the plies in close contact.
  - b. **Checks after First stage tightening:** After first stage of tightening, the joint shall be checked to see if the plies are in close contact and the clearances are not exceeded.
  - c. **Second Stage of Tightening:** During the second stage of tightening, torque wrench is used to tighten the bolts until the indentations on the DTI indicate full tightening.
  - d. **Checks after Second stage tightening:**<sup>13</sup> 0.40 mm/0.25 mm thick feeler gauge shall be used to check 100% of the bolts for proper tightening. If the DTI is provided on the part (nut/bolt head) not being rotated, then 0.40 mm thick feeler gauge shall be used. Else if the DTI is being provided under the part (nut/bolt head) being rotated, 0.25 mm feeler gauge shall be used. If this gauge cannot be inserted in the space between indicator positions on a DTI, it is called a 'refusal'. The feeler gauge shall be used to determine if the bolt has been sufficiently tightened, as follows:

Number of indicator positions in DTI washer	Minimum number of feeler gauge refusals
4	3
5	3
6	4
7	4
8	5
9	5

The procedure for checking the proper tightening of bolt using DTI is shown in the Fig. 8 above.

<sup>12</sup>Based on clause 8.5.6 of EN 1090-2.

<sup>13</sup>Clause 28.10.6 (d) of IRS B1 and Clause 5.2 of EN 14399-9.

**12. Economics of HSFG bolts:** The HSFG bolts are direct replacements of rivets and with proper design, the number HSFG bolts in a joint/ splice shall be less than or equal to the number of rivets. At current prices, the cost of rivets and HSFG bolts are comparable to each other. Cost of HSFG bolts is likely to go down as the volume of work grows and multiple manufacturers are available. HSFG bolts bring other benefits to the railway, namely:

- a. **Reduced time** of assembly/ erection.
- b. **Reduced** requirement of **scaffolds**.
- c. **Less skilled manpower** requirement.
- d. **Less rejections** and easier supervision.
- e. Providing quality HSFG bolts is **feasible** as compared to other alternatives: welds in field are non feasible, whereas rivets are getting difficult to execute day by day.

**13. Maintenance of HSFG bolting assembly:**

- a. **Anti-theft and Anti-sabotage measures:** Where it is apprehended that theft/sabotage might take place, the tack welding shall not be resorted to as anti theft measure as it may have adverse impact on metallurgical properties of HSFG bolting assembly due to careless or improper tack welding and will adversely affect the functioning of bolting assemblies. Hence, tack welding in HSFG bolts shall not be resorted to as anti theft measure for whatsoever reason. Instead, suitable bonding agent (like Loctite, Kent, Devcon or any other functionally similar product) to seize or lock the bolt in position may be applied to the threads projecting beyond the nut. Any bonding agent must increase the torque required for opening of bolt by minimum 200 Nm (RDSO report no. C-226 may be referred to). The name of suggested bonding agent is for guidance only and these products should be tested experimentally to ascertain its torque increasing capacity as mentioned above in different site and environment conditions before any actual use. It has been observed that HSFG bolts up to 20 mm diameter can be opened with very much difficulty, especially in the bracing/ cross frames near the supports or in accessible girder locations. But Larger bolt diameters (M22 and above) require considerable force to open and cannot be opened by stealth. Use of larger bolt diameter (M22 and above) will help in achieving the considerable safety against anti theft. It may be noted that hammering of bolts to damage its threads is likely to affect the entire bolt assembly and is not recommended.
- b. **Inspection:** During inspection, the bolts shall be seen for the following:
  - i. **Broken/ missing bolts.**
  - ii. **Loose bolts:** The identification of loose bolts shall not normally require testing by hitting etc. Looseness shall be identified by looking at the signs such as water ingress in the joint, signs of rust coming from inside the joint and fine powdery material coming out of joint etc. If loose bolts are found, the same shall be marked by a round circle all around and shall be replaced expeditiously. HSFG bolts are one time use item and retightening of these bolts is not allowed.
- c. **Use of HSFG bolts for repair/rehabilitation works:** Where any girder component/joint is to be replaced, HSFG bolts shall be used as follows:

(a) Complete joint shall have HSFG bolts. HSFG bolts cannot be used for replacement of isolated loose rivets.

(b) Proper surface preparation shall be done and joint design shall be done based on design provisions as per para 7.12 of Steel Bridge Code. Particular care shall be taken regarding use of appropriate slip factor for the surface preparation done.

d. **Painting over HSFG Bolting assemblies after its installation:** In case of new construction, the final coat in field applied on complete structure may be applied on HSFG bolts also. For in-service structures, HSFG bolts shall be painted as per normal painting schedule and painting methodologies as specified in the Indian Railways Bridge Manual for the girder as a whole.

e. **Retensioning/ Reuse of bolts:** The HSFG bolts are tightened beyond yield stress level and undergo plastic deformation once tightened fully. If the bolt is opened out after complete tightening, its length gets increased permanently as compared with the initial length. The initial few threads which transfer the load from the nut to the bolt suffer the maximum damage. Therefore, a bolt completely tightened shall not be reused under any circumstances.

The bolt tensioned completely can be identified by damage to the threads especially near the front end of nut where most of the load is transferred. The coating, if any, may also show signs of damage. The free running of the nut on the threads may also be affected.

A fully tensioned bolt, opened out for any reason whatsoever, needs to be rejected and removed from the site of work. Along with the bolt, the nut, washer(s) and DTI(s) used on that bolt also need to be rejected and removed from the site of work.

A HSFG bolting assembly which has been snug tightened (i.e. Tightened upto first stage as described above) and then opened out will not be considered to have been retensioned and reuse of such bolts will be permissible in the same or different holes, as required.

f. **Specifications and calibration of torque wrench:** Only mechanical torque wrenches (pneumatic, hydraulic, electronic etc.) shall be used for tightening of HSFG bolting assemblies, however preference should be given to electronic torque wrenches. Calibrated torque wrenches, accompanied with a certificate to the effect, shall be brought to site. Torque wrenches shall be calibrated periodically to an accuracy of  $\pm 10\%$ . These shall be re-calibrated in case of any incidence involving the wrench during use resulting in heavy impact (such as fall, mishandling etc.) or if the joint is found to have been improperly tightened using the same. The procedure for calibration of torque wrench shall be as specified by the manufacturer.

**Provisions for DESIGN of HSFG Bolts (as per IRS Steel Bridge Code)**

IS:4000 provides for both bearing type joints which work more or less like rivets and friction type joints which act on friction between plies. Bearing type joints as defined in IS 4000 shall not be provided using HSFG bolts on bridges covered by IRS Steel Bridge Code. Only friction type joints shall be provided using HSFG bolts for all structures covered under IRS Steel Bridge Code.

1. **Plies:** The plates/ members joined together through HSFG bolts are called plies. To join dissimilar members, suitable packing shall be provided if the difference in thickness is more than 1 mm. From maintenance considerations, too thin packing plates are not desirable. In design, no additional factor need be considered for the packing thickness.<sup>14</sup>
2. **Diameter of bolt:** Normally, for structural design, 20 mm or 22 mm dia bolts shall be chosen. However, if the joints are to be made smaller and for better detailing 24 mm and larger diameter bolts can be used. The bracing can also be design with 20 mm/ 22 mm dia bolts. However, if the load is too less, such as in foot over bridges, smaller diameter bolts can be used.
3. **Diameter of hole:** The nominal diameter of hole shall be 1.5 mm more than the bolt diameter<sup>15</sup> i.e. for 20 mm dia HSFG bolt, the hole shall be 21.5 mm in diameter. If the HSFG bolts are being used in existing structures, the oversize holes may be permitted subject to maximum of 1.25 d or d + 4 mm, whichever is less.
4. **Deduction for holes:** The deduction for holes and for asymmetric connections to get the effective area of the members shall be done in a manner similar to the one adopted for the holes for rivets and other bolts, i.e. the gross area may be considered in compression and net area in tension as per provisions of clause 4.3 of IRS Steel Bridge Code<sup>16</sup>.
5. **Property class to be chosen:** Property class 8.8 bolts are better as these are ductile and have good reserve strength. However, if the joints are to be made smaller and/or for better detailing, we can go for property class 10.9.
6. **Slip factor to be adopted:** Following values of slip factor shall be used in design:<sup>17</sup>

S No	Surface Preparation of the interface between plies in a HSFG bolted joint	Slip factor
1	Surface blast cleaned and spray metallized with aluminium (thickness > 100 μm), with no overcoating	0.40
2	Surfaces cleaned by wire brushing or flame cleaning, with loose rust and paint layers removed (Only isolated patches of coatings/ rust can remain)	0.25
3	Any other surface preparation <sup>18</sup>	To be established as per procedure given in

<sup>14</sup> Clause 5.5.1 of IS 4000

<sup>15</sup> Clause 6.1 of IS 4000.

<sup>16</sup> Fatigue for joints with HSFG bolts shall be taken on gross area as per detail (4) in table 9.1 of revised Appendix G in IRS Steel Bridge Code.

<sup>17</sup> As per clause 7.12.6.4 of IRS Steel Bridge Code.

<sup>18</sup> Painting with alkali- zinc salicylate paint 50μ to 80μ is a very good option which can give good slip factor (refer table 18 (Clause 8.4) of EN 1090-2).



**Note:** If it is not possible to make proper surface preparations as given in 1 and 2 above, the slip factor shall be established as per 3 above and the same shall be used for design. Otherwise, the rivets shall be replaced by other modes such as by appropriate close tolerance turned bolts as per IS 1364 and para 28.6 and 28.7 of IRS B1.

The preparation of surface by removal of paint is not allowed for new construction. If interface has been painted inadvertently, the same shall be sand/grit blast cleaned and metallising shall be done, even if the surface was already metallised.

7. **Design of joints subject to shear:** Most of the bolts in girders such as those that connect the bracing, cross frames, flange angles with web etc are subject to pure shear loading only. The design of HSFG bolts for such applications shall be such as to ensure that the shear force applied does not exceed<sup>19</sup>:

$$\frac{\text{Slip factor} \times \text{Number of Effective Interfaces} \times \text{Minimum Bolt Tension}}{\text{Factor of Safety}}$$

The minimum bolt tension is as specified in table 3 of IS 4000 and factor of safety shall be 1.4 under normal loads. Where the effect of wind load has to be considered on the structure, this factor of safety may be reduced to 1.2, provided the connections are adequate when (i) wind forces are not considered, and (ii) wind load is not the primary loading for the purpose of design.<sup>20</sup>

In other words, the factor of safety shall be adopted as 1.4 or 1.2 as per load case in case of Railway girders, Road Over bridges and turn tables etc where wind load is not a primary load.

For Foot Over Bridges, where wind load is a primary load, the same may be taken as 1.4.

8. **Design of joints subject to shear as well as tension: Some joints such as the connection of the bracket sideways on a column are of the nature of partial fixity. The bolts might be subject to some axial loads along with shear in such a case.** Due to externally applied tension, the effective clamping action of a bolt is reduced. To account for this, bolt shall be proportioned to satisfy the expression:

$$\frac{\text{Calculated Shear}}{\text{Slip Factor} \times \text{No of Effective Interface}} \leq \frac{(\text{Proof Load} - \text{Calculated Tension} \times F)}{\text{Factor of Safety}}$$

The value of factor F shall be taken as 2.0 if external force is repetitive and 1.7 if non repetitive. A question might arise here in the mind of designers that the tension in bolt ought to be reduced to allow for the tension which is coming from the load. However, it has been found that the actual tension change in the bolt due to the applied load is very less and the full tension may be applied, provided the tensile load is not too much large as compared with the shear load.

9. **Limitation of Shear Transmitted to Plies:** The bearing force transmitted between any bolt and any ply shall not exceed  $1.2 f_y \times d \times t$  where  $f_y$  is yield stress of the ply,  $d$  is nominal dia. of HSFG

<sup>19</sup> Clause 5.4.2 of IS 4000.

<sup>20</sup> Clause 5.4.2 of IS 4000.

bolt and t is the thickness of ply. In addition, the component of force acting on the edge of a bolt in the direction of the minimum distance toward the edge of a ply shall not exceed  $e \times t / 1.4$ .<sup>21</sup> (where e is edge distance of bolt plus half the bolt diameter, in mm). These provisions are meant to prevent failure of the steel members joined together by the HSFG bolts.

**10. Design of joints subject to pure tension:** Normally the bolts in railway application are not subject to pure tension. However, if such joints are to be designed, the tension in the bolts shall be limited to the values given in table 2 of IS 4000. (Which are equal to 0.6 times the minimum bolt tension specified in table 3 of IS 4000).<sup>22</sup> In case the bolts are subject to tension in fatigue conditions, the minimum tensile force in the bolt shall not exceed 50% of the minimum bolt tension values specified in table 3 of IS 4000.<sup>23</sup>

**11. Tension to be given in Bolts:** All HSFG bolts shall be tightened by procedure given in para 10 to impart the minimum tension specified in table 3 of IS: 4000 given in para 10.1.b). The torque corresponding to the bolt tension indicated shall be as specified by the manufacturer of torque wrench.

**12. Fatigue design:** The HSFG bolts are pre-tensioned and the level of this tension does not change much even when subjected to repetitive loads, so these need not be designed separately for fatigue.<sup>24</sup> The structural steel plies which are connected by the HSFG bolts shall be designed for fatigue, if these are subjected to fluctuating loads as given in IRS Steel Bridge code. The fatigue category of the steel members shall be as given in IRS Steel Bridge Code. It is worth mentioning here that the fatigue category of members connected by HSFG bolts is higher than that for the members connected by rivets. This is because the shank and hole edges, where stress concentration is there in case of rivets, do not come into action in case of HSFG bolts, resulting in better fatigue performance of members.

**13. Detailing:** The detailing of joints shall be done carefully ensuring that for all the bolts, access for fixing of torque wrench head (approximately 100 mm) is available on one side while the other side can be held with normal spanner. The detailing of the joints with HSFG bolts shall be done as per IRS Steel Bridge Code rather than IS 800 mentioned in clause 1.3 of IS 4000.<sup>25</sup> Some provisions of the IRS Steel Bridge Code are enumerated for information below:

	Provision	Reference
Edge distance (Minimum)	1.75 d for sheared or hand flame cut edges 1.5 d for rolled, machine flame cut, sawn or planed edge	Clause 7.5.1 of IRS Steel Bridge Code
Edge distance (Maximum)	4 t + 40 mm from nearest edge.	Clause 7.5.2 of IRS Steel Bridge Code
c/c spacing (Minimum)	2.5 d'	Clause 7.3 of IRS Steel Bridge Code

<sup>21</sup> Clause 5.3.4 of IS 4000.

<sup>22</sup> Clause 5.2 of IS 4000.

<sup>23</sup> Clause 5.2.1 of IS 4000.

<sup>24</sup> Clause 5.4.2 of IS 4000, subject to provisions of Clauses 5.2.1 and 5.4.3.

<sup>25</sup> As per clause 7.12.8 of IRS Steel Bridge Code.

	<b>Provision</b>	<b>Reference</b>
c/c spacing (Maximum) Adjacent rivets in tension/ compression	32 t or 300 mm whichever is lesser	Clause 7.4.1 of IRS Steel Bridge Code
c/c spacing (Maximum) Bolts lying in direction of stress tension/ compression	16 t or 200 mm whichever is lesser	Clause 7.4.2 of IRS Steel Bridge Code
c/c spacing (Maximum) Bolts lying in direction of stress compression	12 t or 200 mm whichever is lesser If load is transferred by butting in compression members, for a length equal to 1.5 times width, the spacing shall not exceed 4.5 d.	Clause 7.4.2 of IRS Steel Bridge Code
c/c spacing (Maximum) Staggered, gauge not exceeding 75 mm	50 % more than the values given in clause 7.4.2 and 7.4.3	Clause 7.4.3 of IRS Steel Bridge Code
Where d is diameter of hole t is thickness of thinner outside plate d' is the nominal diameter of the bolt/ rivet		

**Schedule of Technical Requirement for Fabrication of High Strength Friction Grip Bolting Assemblies with Direct Tension Indicator Washer (Suitable For Preloading) for Use in Railway Bridges, ROB, & FOB**

**(As per ISO document No. BS-S-7.5.3.1-7 Ver. 1.0)**

**1. Scope**

This specification covers the norms for objective evaluation of capability and capacity of any firm for manufacture and supply of HSFG bolting assemblies with direct tension indicator washer (suitable for preloading) for use in railway bridges, ROB & FOB

**2. Procedure for Registration of Firms for manufactures and supply of HSFG bolting assemblies with direct tension indicator washer (suitable for preloading) for use in railway bridges, ROB, & FOB.**

**2.1 The firm interested in getting registered shall study this document carefully and will ensure availability of:**

- (i) The required infrastructure, machinery, tools & plant.
- (ii) Space required for manufacturing, testing and storage viz. manufacturing floor, Godown, store, office and test lab etc.
- (iii) Testing and measuring equipment duly calibrated.
- (iv) Trained technical manpower.
- (v) Past Experience Criteria
- (vi) Quality Assurance Aspects.

**2.2 In case manufacturer is satisfied that the infrastructure and other available requirements listed above are commensurate with the stated requirements, then firm shall apply for registration ON-LINE on the RDSO website. All relevant documents like vendor approval guidelines, application form, schedule of technical requirement (STR), latest version of relevant specifications (if applicable), etc. are available on the RDSO website. The requisite charges as specified on website are to be deposited through the means as specified on the RDSO website.**

**2.2.1 The firm has to submit ONLINE the complete application form, self compliance of STR along with all necessary documents in support of self compliance of STR and documents in support of other important aspects of application. The firm has also to submit the undertakings as mentioned in Document No. BS-G-4.2.3-1 (latest version) titled "Guidelines for Registration and Quality Audit of Vendors in Bridge & Structure Directorate" available on RDSO Website.**

**2.2.2 For detailed procedure for Registration and other related aspects, refer to Document No. BS-G-4.2.3-1 (latest version) titled "Guidelines for Registration and Quality Audit of Vendors in Bridge & Structure Directorate" available on RDSO Website.**

**3. Norms for Acceptance:**

To qualify for manufacture and supply of HSFG bolting assemblies with direct tension indicator washer (suitable for preloading) for use in Railway Bridges, ROB, & FOB, the firm must satisfy the requirements laid down in para 4, 5, 6, 7, 8, 9 & 10 below. The specifications/codes commonly referred in this document considered with latest correction slips/Versions in vogue.

**Note:** Kindly note that after registration, the firm has to supply the HSFG Bolts, Nuts & Washers for use in Railway Bridges, ROB & FOB as per approved QAP of RDSO, which is available on RDSO Website.

**4. General and Infrastructural Requirements:**

Detailed information with necessary documents in support is required for following items:-

- 4.1** The manufacturer must have adequate organization including supervisors, skilled worker and other categories of manpower to execute the work in competent manner.(Enclose list of staff along with Qualification & experience of employees).
- 4.2** A proper organization must exist to perform the functions of purchasing of various raw materials, bought-out components, consumables, etc. and for maintaining the purchasing documents including inspection certificates, test certificate etc.(Enclose list of staff along with Qualification & experience of employees).
- 4.3** A proper procedure for maintenance of records for receipt and consumption of raw material including steel should be in vogue or developed so as to allow verification by railway's representative.
- 4.4** Adequate power supply should be arranged through distribution agencies with back up through captive generation.(Necessary documents in support to be enclosed).
- 4.5** Covered bay area with proper handling facilities should be available to handle day-to-day manufacturing of HSFG Bolts, Nuts & Washers for use in Railway Bridges, ROB&FOB.
- 4.6** The premises should have covered storage area to store raw material and finished products.
- 4.7** Covered shed area protected from rain, dust etc. should be provided for surface preparation and coating. Adequate space for storing manufactured component awaiting painting shall be available.

**Note:** For para 4.5 to 4.7 Applicant has to submit ONLINE a neat copy of plan of work premises & show detail of items given below:-

- (a)** Covered bay area with proper handling facilities available to handle day-to-day production of HSFG bolting assemblies with direct tension indicator washer (suitable for preloading) for use in railway bridges, ROB,& FOB.
  - (b)** Area for storing raw material& finished products etc.
  - (c)** Area for separate line for inspection and testing of HSFG bolting assemblies.
  - (d)** Covered shed area protected from rain, dust etc, available for surface preparation and Hot dip galvanization and Zinc flakes.
- 4.8** An adequately equipped and drawing Office is required for preparation of drawings. (Enclose list of staff along with Qualification & experience of employees).
  - 4.9** The manufacturer should be capable of designing required fixtures, templates etc. as required for manufacturing work (Enclose list of staff with qualification and experience).
  - 4.10** Firm should submit the details of equipments/machinery i.e. make, model, year of manufacture, machine no. etc. for Equipments and Machineries mentioned in para 5 to 7 preferably in a chart form (machinery owned by sister concerns will not be accepted).

**4.11** After registration of firm it is mandatory to inform RDSO through FAX (followed by confirmation copy through courier/speed post) as soon as any machinery is removed from the firm's premise (even for repair etc.). RDSO should be informed again, when the machinery is brought back and made operational.

**4.12** Firm is required to give an undertaking that if at any time after approval is accorded, some machinery is found deficient without intimation to RDSO, then it will be presumed that machinery was not there since beginning and firm's approval will be withdrawn immediately.

**5. Facilities required for manufacturing and supply of HSFG Bolts, Nuts & Washers for use in Railway Bridges, ROB, FOB.**

**5.1** Following machines/equipment shall be available with the manufacturers for supply of HSFG bolting assemblies with direct tension indicator washer (suitable for preloading).

Provide quantity, make, model no., S.No., capacity, year of manufacture/commissioning, Machine number etc. preferably in a chart form as applicable):

- i. Continuous Heat Treatment Furnace (Hardening, Oil Quenching & Tempering) + Thermal Blackening.
- ii. Cold Forging Machines with min. & max. Dia. & Length.
- iii. Hot Forging Machines with min. & max. Dia. & Length.
- iv. Head Trimming Machines
- v. Threads Rolling Machines
- vi. Bull block wire drawing machine
- vii. Hot dip galvanizing facilities in accordance to ISO 10684 (Latest version)
- viii. Zinc flake coating facility in accordance to ISO 10683. (Latest version)
- ix. Elcometer.
- x. Adequate no. of measuring instruments (micrometers, dial gages, vernier calipers, Go-No-Go gauges).
- xi. Automatic weighing system.

**Note:** If Zinc flake coating facility is not in house, it can be outsourced. If outsourced, submit a copy of MOU with outsourced agency, and copy of some previous satisfactory completion certificate work of Zinc Flaking by outsourced agency. The MOU should have validity of minimum 66 months. The outsourced agency shall have Zinc flake coating facility in accordance to ISO 10683, and it shall be clearly mentioned in MOU.

**5.2 (a)** Heat mark of the raw material shall be embossed on the bolt head, Apart from heat mark, length of bolt shall also be embossed on the bolt head, in addition to name of manufacturer and grade of bolt material. [Refer specification no BS-S-7.5.3.1-5 Latest Version Available on RDSO Website]

**(b)** Preferably the heat mark of the raw material shall also be embossed on the nut and washers. [Refer specification no BS-S-7.5.3.1-5 Latest Version Available on RDSO Website]

**5.3** Material to be procured and manufacturing process must meet the requirement of relevant specifications (Latest version).

**6. Testing facilities required for manufacturing and supply of HSFG Bolts, Nuts & Washers for use in Railway Bridges, ROB & FOB**

**6.1** Following machines/equipment shall be available with the manufacturer, as required in manufacturing of HSFG bolts as per EN 14399: (Provide quantity, make, model no., S.No., capacity, year of manufacture/commissioning, Machine number etc. preferably in a chart form as applicable).

- Microscope/Profile projector for threads laps.
- Spectroscope (For chemical composition testing)
- Hardness Tester
- Universal/Tensile testing machine
- Impact testing machine
- Microscope for measurement of decarburization
- Hardness testing and tempering furnace
- Magna Flux for crack detection.
- Adequate no. of measuring instruments and gauges (Vernier calipers/Screw Gauges, Thread Plug Gauge, Thread Ring Gauge, Go-No-Go gauges).
- Elecometer.
- Torque Tester
- Electric torch wrench

**6.2** The following requirements specified in 4.2 to 4.5 of EN 14399-1:2015, are assessed through the verification of the properties of the involved components and/or bolting assemblies, as applicable

SN	Type (bolting Assemblies)	Test procedure	Testing Apparatus	Result after testing
1	Angle to failure during tightening	Bolting assemblies shall be tested according to EN 14399-2:2015, 6.5, to evaluate the margin against over tightening.	Testing apparatus and set up shall be in accordance with EN 14399-2:2015, Clause 6.	The results shall meet the requirements specified in EN 14399-3, EN 14399-9 for the relevant type.
2	Axial load	Suitability for preloading of bolting assemblies shall be carried out in accordance with EN 14399-2:2015, Clause 6.	Testing apparatus and set up shall be in accordance with EN 14399-2:2015, Clause 6.	The results shall meet the requirements specified in EN 14399-3, for the relevant type.
3	Compression load (Bolting assembly with DTI)	Compression load testing of assemblies which include direct tension indicators shall be carried out in accordance with EN 14399-9:2009, 5.3.	Testing apparatus and set up shall be in accordance with EN 14399-9:2009, 5.3.	The results shall meet the requirements specified in EN 14399-9.

**6.3** The following requirements specified EN 14399-1:2015 are assessed through the verification of the properties of the involved components and/or bolting assemblies, as applicable:

SN	Property class (bolting assemblies)	Test procedure	Testing Apparatus	Result after testing
1	Elongation (bolts)	Testing shall be carried out in accordance with EN ISO 898-1:2013,9.7.	Tensile test meter shall be in accordance with ISO 7500-1	The results shall meet the requirements specified in EN 14399-3, for the relevant property class.
2	Tensile strength (bolts)	Testing shall be carried out in accordance with EN ISO 898-1:2013, 9.2 or 9.7.	Tensile test meter shall be in accordance with ISO 7500-1	The results shall meet the requirements specified in EN 14399-3, for the relevant property class.
3	Strength under wedge loading (bolts)	Testing shall be carried out in accordance with EN ISO 898-1:2013, 9.1.	Tensile test meter shall be in accordance with ISO 7500-1	The results shall meet the requirements specified in EN 14399-3, for the relevant property class.
4	Tensile yield strength (bolts)	Testing shall be carried out in accordance with EN ISO 898-1:2013, 9.7.	Tensile test meter shall be in accordance with ISO 7500-1	The results shall meet the requirements specified in EN 14399-3, for the relevant property class.
5	Proof load (bolts)	Testing shall be carried out in accordance with EN ISO 898-1:2013, 9.6.	Tensile test meter shall be in accordance with ISO 7500-1	The results shall meet the requirements specified in EN 14399-3, for the relevant property class.
6	Proof load (nuts)	Testing shall be carried out in accordance with EN ISO 898-2:2012, 9.1.	Tensile test meter shall be in accordance with ISO 7500-1, Class 1 or better	The results shall meet the requirements specified in EN 14399-3, for the relevant property class.
7	Impact strength (bolts)	Testing shall be carried out in accordance with EN ISO 898-1 :2013, 9.14.	Impact testing machine shall be in accordance with ISO 148-1	The results shall meet the requirements specified in EN 14399-3, for the relevant property class.
8	Hardness (bolts)	Testing shall be carried out in accordance with EN ISO 898-1 :2013, 9.9.	Hardness tester shall be in accordance with ISO 6507-1, ISO 6506-1, ISO 6508-1.	The results shall meet the requirements specified in EN 14399-3, for the relevant property class.
9	Hardness (nuts)	Testing shall be carried out in accordance with EN ISO 898-2:2012,9.2.	Hardness tester shall be in accordance with ISO 6507-1, ISO 6506-1, ISO 6508-1.	The results shall meet the requirements specified in EN 14399-3, for the relevant property class
10	Hardness	Testing shall be carried out in accordance with EN ISO	Hardness tester shall be in accordance with ISO 6507-1 or	The results shall meet the requirements specified in EN



	(washers)	6507-1 or EN ISO 6508-1.	ISO 6508-1.	14399-5, or EN 14399-6.
11	Hardness (direct tension indicators and nut face washers)	Testing shall be carried out in accordance with EN ISO 6507-1.	Hardness tester shall be in accordance with ISO 6507-1.	The results shall meet the requirements specified in EN 14399-9.
12	Compression load (direct tension indicators)	Testing shall be carried out in accordance with EN14399-9:2009, Clause 3.4.	Testing shall be carried out in accordance with EN14399-9:2009, Clause 3.4.	The results shall meet the requirements specified in EN 14399-9 for the relevant property designation.

**6.4** The manufacturer shall submit relevant documents related to compliance of testing equipment/ apparatus as per specification given in EN 14399 or referred specification.

**6.5** The chemical composition of materials used in manufacturing of HSFG bolting assemblies shall be in accordance to IS 898-1:2013, 6.

**6.6** The HSFG bolting assemblies shall meet all the applicable mechanical and physical properties in accordance to IS 898-1:2013, 7.

**7. Qualifying criterion:**

Firm should have certified "Satisfactory Performance" of these Bolts from at least three past users at the time of application. Satisfactory Performance certificate issued by Government organizations, Public sector undertakings or corporations, Private companies having minimum annual turnover of Rs. 500 crores will only be considered valid for this requirement.

**8. Quality Assurance:**

To ensure good and consistent quality of product, there shall be:

**8.1** Assessment and Verification of Constancy of Performance (AVCP) shall be strictly followed in accordance to Clause 6 of EN 14399-1:2015.

**8.2** Proper packing procedure to avoid corrosion during transportation and storage before actual use of HSFG bolts assembly is required .HSFG bolt, nut ,plain washer and DTI washes should be assembled in manufacturer's premises and packed in carton box . Weight of each carton box shall not exceed 20 Kg. These carton boxes should be packed in wooden box and should be transported to site.

**8.3** HSFG bolts, nuts, washers, and DTI shall cover tolerances on dimensions and shape as specified in Clause 4.4 of EN 14399-1:2015. It is relevant for the ability of components to be matched together in order to provide the declared performances of the bolting assemblies.

**8.4** The number of samples of high-strength structural bolting assemblies for preloading to be

tested and/or assessed shall be in accordance with Table 6 of EN 14399-1:2015 . The results of the determination of the product-type shall be part of the test reports. All test reports shall be retained by the manufacturer for at least 10 years after the last date of production of the high-strength structural bolting assemblies for preloading to which they relate.

- 8.5** All weighing, measuring and testing equipment shall be calibrated and regularly inspected according to documented procedures, frequencies and criteria.
- 8.6** All equipment used in the manufacturing process shall be regularly inspected and maintained to ensure use; wear or failure does not cause inconsistency in the manufacturing process. Inspections and maintenance shall be carried out and recorded in accordance with the manufacturer's written procedures and the records retained for the period defined in the manufacturer's FPC procedures.
- 8.7** The specifications of all incoming raw materials and components shall be documented, as shall the inspection scheme for ensuring their compliance.
- 8.8** Individual components of high-strength structural bolting assemblies as well as their packages shall be identifiable and traceable with regard to their manufacture (manufacturer's identification mark). The manufacturer shall have written procedures ensuring that processes related to affixing traceability codes on labels and markings on high-strength structural bolting assemblies are inspected regularly.
- 8.9** A system should be in force for analysis of defects noticed during internal and external inspections of the final product and sub-assemblies. A dynamic arrangement for a feed back to the source of defects and for rectification should be in vogue. Performa which is being followed shall be enclosed.
- 9.0 Quality Audit**
- 9.1** Quality Audit of the Registered Vendors will be done every five year.
- 9.2** The firm should satisfy the following requirements to continue as approved vendor
- a) The firm should continue to maintain the infrastructure, facilities and Machineries & plants as required at the time of Quality Audit as per prevailing STR.
  - b) The firm should have successfully executed/completed at least three works of Railway Bridge HSFG bolting assemblies with direct tension indicator washer. For the purpose of this clause, successful fabrication of at least one span against a multiple span will be considered/treated as completed work.
  - c) The firm should not have any adverse report from any of the Railways.
- 9.3** For Quality Audit, firm will be inspected for facilities provided as per para 4 to 8 of this STR, which in turn will be verified, after inspection by the RDSO team. The firm should also give an undertaking that organizational and infrastructural requirement as required at the time of Quality Audit have been maintained.
- 9.4** If the firm does not satisfy the criteria given in prevailing STR, its name will be removed from approved list and firm shall have to apply afresh in case it desires to be registered again.

**10.0** Following specifications/codes (Latest version) commonly referred in connection with manufacturing of HSFG bolt must be available with manufacturer.

EN 14399 with following parts

Part 1: General requirements

Part 2: Suitability of preloading

Part 3: System HR-Hexagon bolt and nut assemblies

Part 5: Plane washers

Part 6: Plain chamfered washers

Part 9: System HR or HV –Direct tension indicators for nut and bolt assemblies

Notes:-1. The other specifications mentioned in above specifications are also to be adhered as detailed in the relevant specifications.

2. Above codes/documents are to be considered with latest correction slips/Versions in vogue.