Detailing of Steel Connections
Introduction of new IRC guideline

ING - IABSE

MORTH Government of India

PWD UTTARAKHAND

ING-IABSE Workshop on "Design, Construction and Maintenance of Steel Bridges" , Dehradun, 19th & 20th October, 2024

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Type details

GUIDELINES FOR DETAILING OF STEEL BRIDGES

IRC:SP:144-2024

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2.1 Scope: The scope of the document is outlined as follows:

2.1.1 This document gives non-contradictory complementary information for use with IRC:22 "Standard Specifications and Code of Practice for Road Bridges, Section VI – Composite Construction (Limit State Design) Third Revision", IRC:24 "Standard Specifications and Code of Practice for Road Bridges, Steel Road Bridges (Limit State Method) (Third Revision)" and IRC:SP:104 "Guidelines for Fabrication and Erection of Steel Bridges". The aim of this document is to provide guidance on detailing of typical steel road bridges along with a brief on the force transfer mechanisms.

2.1.2 The design criteria for steel bridges are covered in IRC:24.

2.1.3 The design criteria for composite bridges are covered in IRC:22.

2.1.4 The criteria for fabrication and erection of steel bridges are covered in IRC: SP:104.

2.1.5 Special requirements of seismic design are not covered in this document. Reference should be made to the requirements given in IRC:SP:114 "Guidelines for Seismic Design of Road Bridges".

2.1.6 This document states only the minimum requirements necessary.

Note - *The publication does not purport to include all the necessary provisions in a structure. Users are responsible for its correct application.*

2.1.7 The scope is restricted to detailing concept and design aspect for plate girders bridges and through type, semi through type & deck type Open Web Girder Bridges (truss bridges). This guideline does not cover the requirement for the following type of structure:

i) Tub type composite girder
ii) Single cell or multicell steel box girder
iii) Steel arch girders
iv) Cable supported bridges

2.1.8 The intent of this document is to guide designers for design and detailing of steel bridges with good engineering practices. These provisions are to be considered as recommendatory in nature. In case any of the provisions of this document is in conflict with the provision of code, the provisions of code shall prevail. Sample drawings, Connection detailing as shown in this document are only indicative and for guidance. Designers are free to use any other alternative detail which satisfies the intended purpose.

2.2 Limitations & Exclusions

The guidelines mainly aims to address the detailing requirement of typical steel road bridges along with a brief of the general force transfer mechanism at different types of joints & splices. The limitations mentioned in lause 501.2 provided in IRC:24 is also applicable for this code. It does not provide a detailed insight on the design parameters and design methodology for which needs to be referred to IRC:24 & IRC:22 as applicable.

Some typical methodology for erection has been covered as **Appendix - 1.** Erection methodology suitable for the site condition and considering time cycle may adopted by the designer and accordingly all detailing and design guideline provided may be modified. However, the fabrication & erection procedures shall be as per IRC:SP:104.

2.4.1 General

i) Verification of length for all inclined members and gusset plates need to be performed at shop prior to cutting the sections and plates as per the drawing.

ii) The material strength test and elongation have to be carried out.

iii) Prior to sending the fabricated material at site for erection, a trial assembly should be made at fabrication yard for checking and if required necessary corrections need to be carried out.

iv) Camber check need to be performed at shop on trial assembly at shop prior to transportation to site the fabricated material.

v) All workmen should use proper protective gear as per guideline.

vi) Quality Assurance plan for fabrication procedure need to be prepared, preapproved and to be followed.

vii) Group similar connections rather than have several different connections. Connections on a project should be as uniform as possible to save fabrication time and reduce the possibility of errors.

2.4.2 Welding

i) The sequence of welding needs to be followed as per instructions in drawings.
ii) The procedure for welding especially the return run for welding, back gouging etc. as applicable has to be provided as per provision in IRC:SP:104.
iii) All welding has to be tested as per provision of IRC:SP:104.
iv) During welding of thick plates more than 20 mm precaution to avoid warping due to temperature gradient need to be taken care by preheating as per provision of IS: 9595.
v) Welding Procedure Specification need to be prepared as per provisions of IS: 9595 & IS: 4353 & IRC:SP:104, preapproved and to be followed.
vi) Avoid overhead welding.
vii) Provide proper clearance for bolted and welded connections.

2.4.3 Bolts

i) Torque in HSFG bolt to be applied based on Slip factor and Tension required and manufacturer's recommendation with prior approval of Designer/ Engineer in Charge.

ii) All bolt tightening must be checked using filler gauge as per provision of IS: 4000 & IRC:SP:104 and by hammering the tightness.

iii) Permanent bolts need to be tightened finally or final torque to be applied after completing the alignment check after completion of erection. Till such time the bridge needs to be kept erected with 50% bolt snug tightened along with 50% drift.

iv) Limit the number of bolt diameters as far as possible, preferably one (a maximum of three sizes if necessary).

v) Avoid different grade bolts with the same diameter.

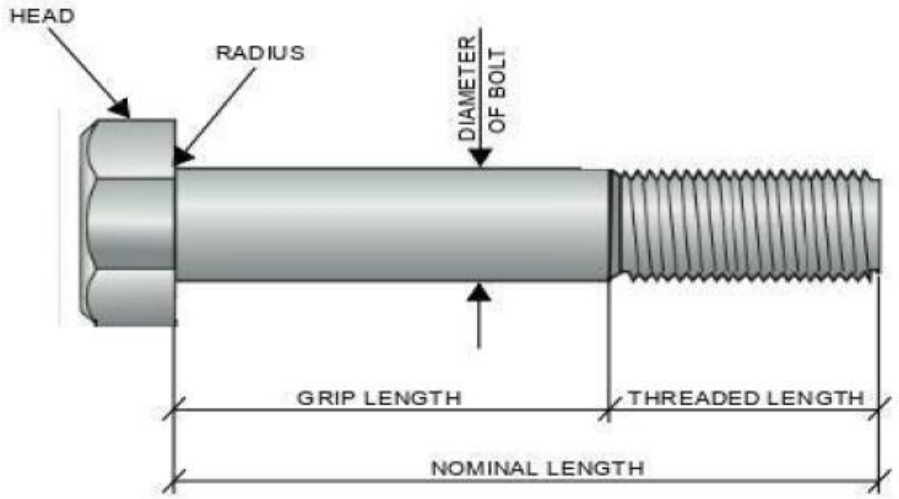
vi) Specify slip-critical bolts only when necessary. If slip-critical joints and bolts are needed, the steel detailer must indicate them on the erection and shop drawings.

vii) The structure needs to be checked for safety at erection condition with 50% HT bolt and 50% drift in place of 100% HSFG final bolt at joints.

There are two common ways to connect structural steel members - using bolts or welds. Rivets, while still available, are not currently used for new structures and will not be considered here. This chapter will presentthe basic properties and requirements for bolts and welds.

3.1 Bolts

A bolt is a mechanical fastener with a shaft having male threaded matching with female thread such as nut.



BOLT

NUT

Fig. 2 Bolt Head showing Bolt Grade

3.1.2 Basic Profile of Thread of Bolt (as per IS: 4218:2001)

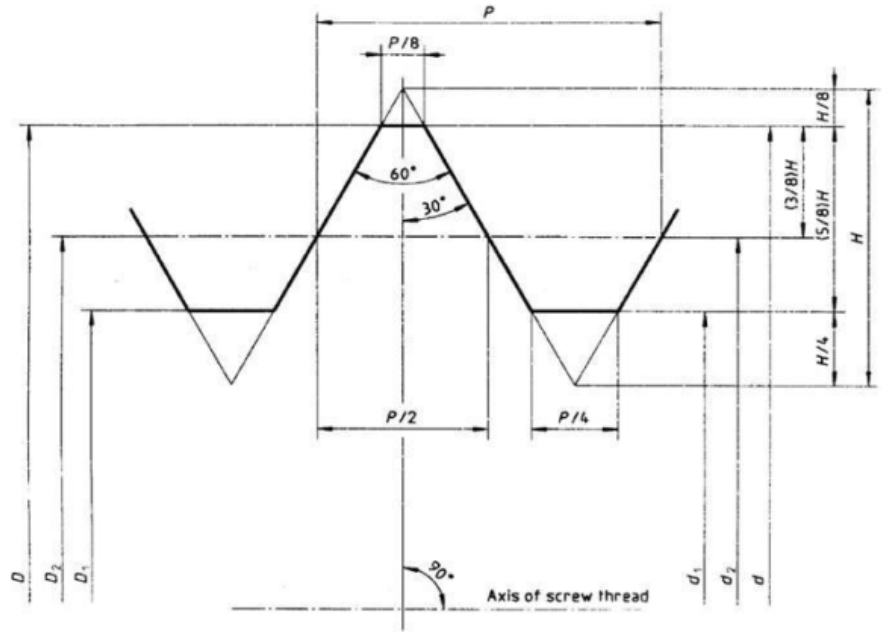


Fig. 3 Basic Profile of Thread

D	:	Basic major diameter of internal thread
d	:	Basic major diameter of external thread (nominal diameter)
D_2	:	Basic pitch diameter of internal thread.
d_2	:	Basic pitch diameter of external thread.
D_1	:	Basic minor diameter of internal thread
d_1	:	Basic minor diameter of external thread
H	:	Height of fundamental Triangle, $H = \sqrt{3}/2\, P$
P	:	Pitch

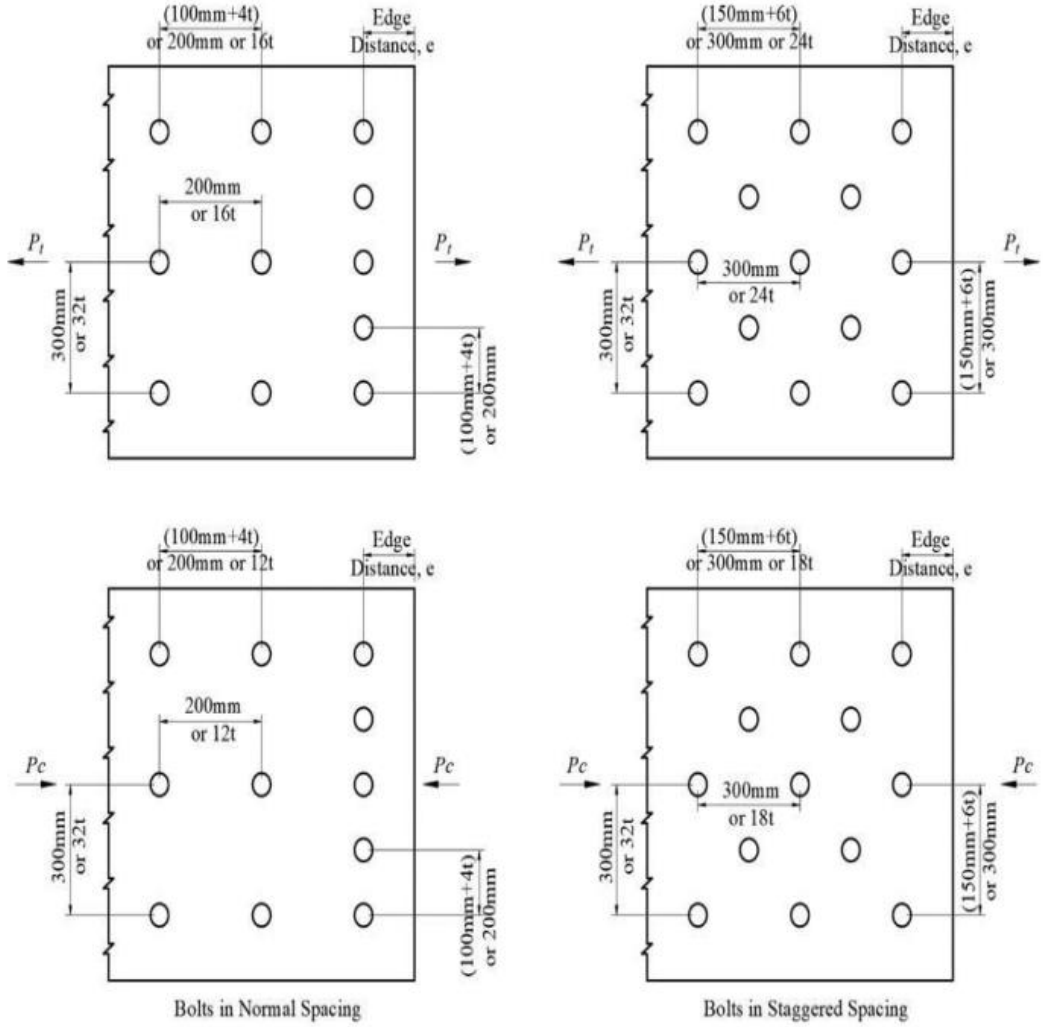
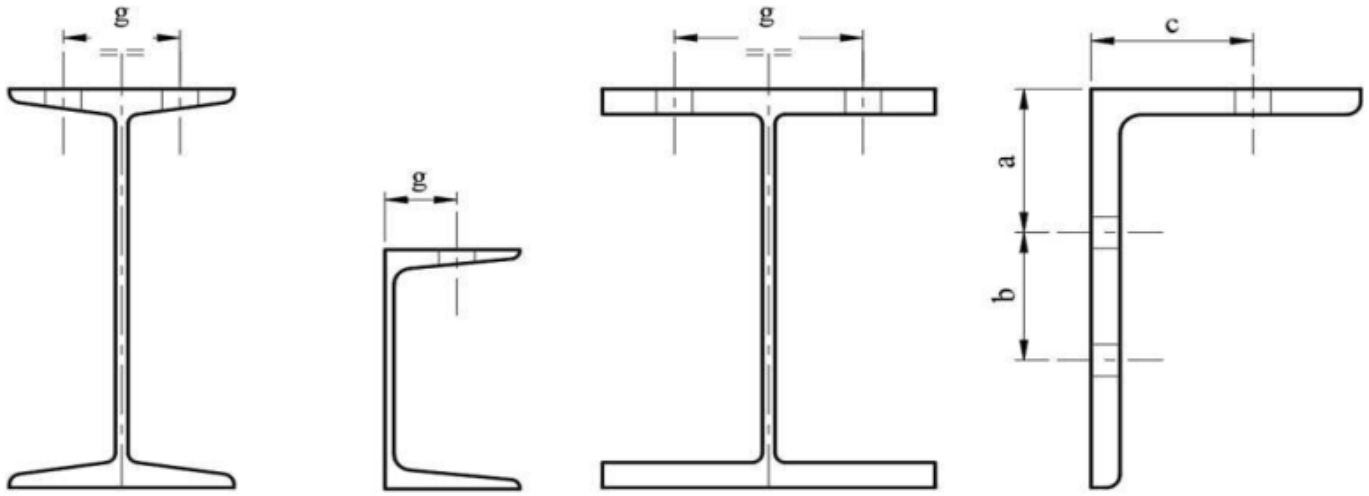


Fig. 4 Maximum Pitch of Bolts



Gauge Distance for ISMB Sections | Gauge Distance for ISMC Sections | Gauge Distance for UB/WPB/UC Sections | Gauge Distance for Angle Sections

Fig. 5 Gauge Distance for Rolled Section

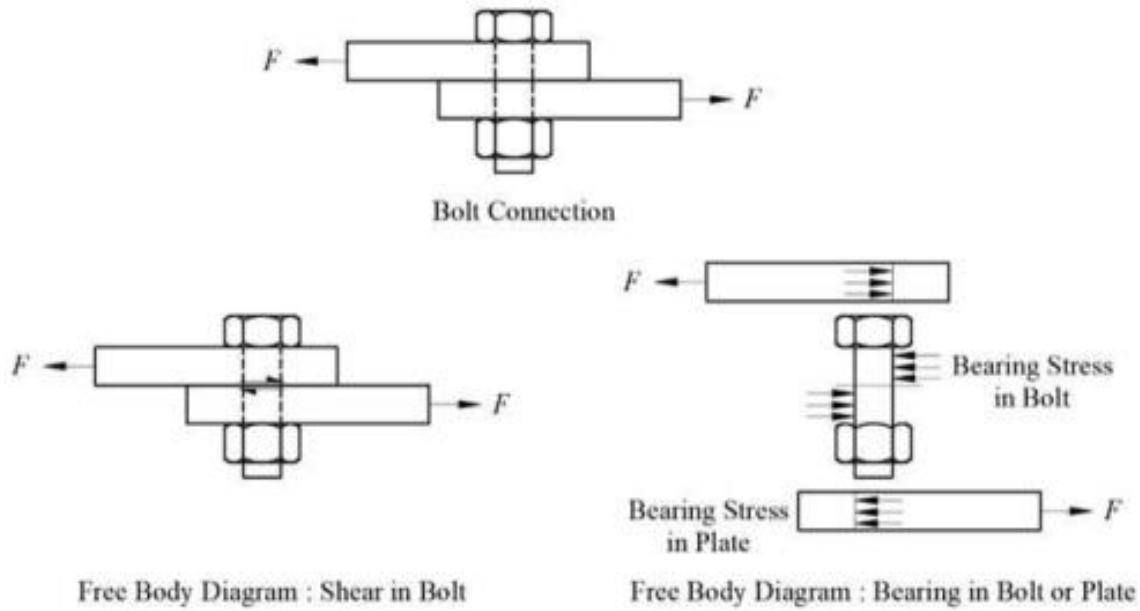


Fig. 7 Bolts in Shear and Bearing

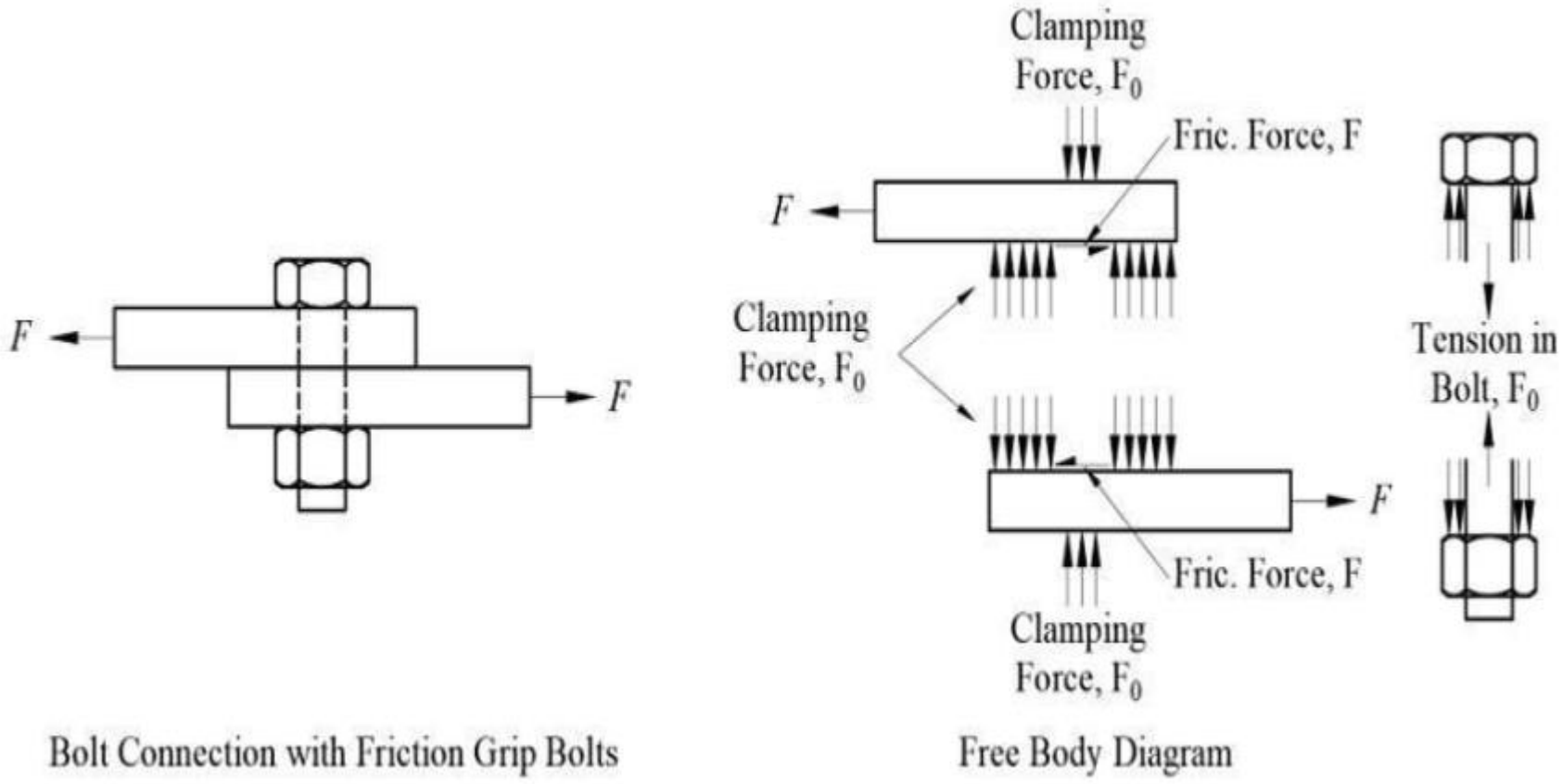
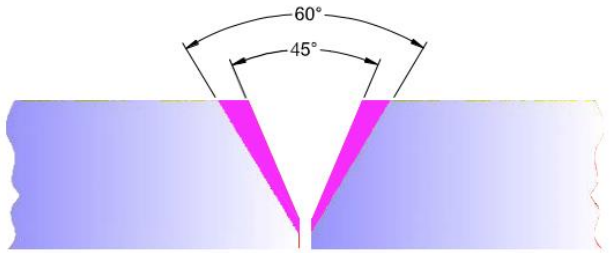
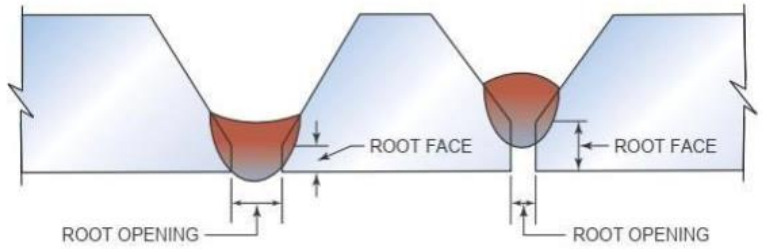


Fig. 8 Bolted Connection with HSFG Bolts.



Even a slight change in groove angle can save time and money.

Fig. 11 Typical Groove Joint



Effect that root dimensioning can have on groove weld penetration.

Fig. 12 Root Face

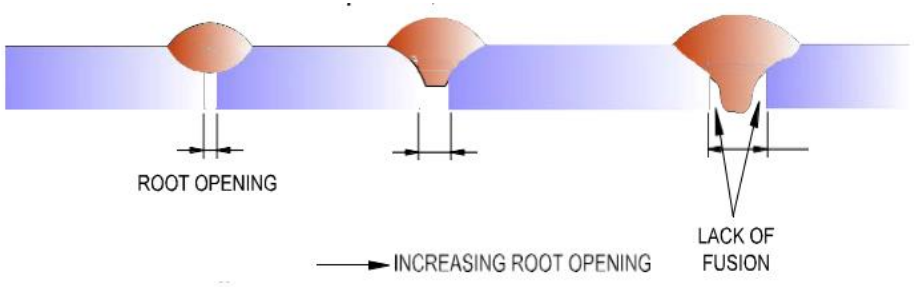
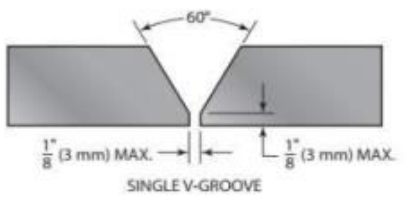
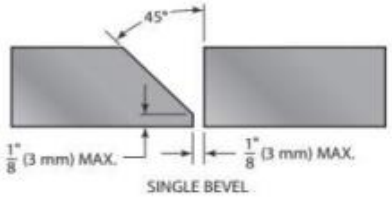
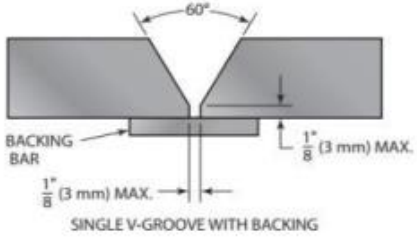
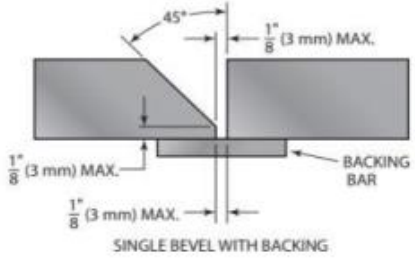


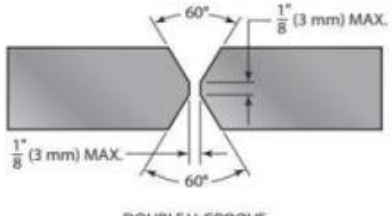
Fig. 13 Root Gap or Root Opening

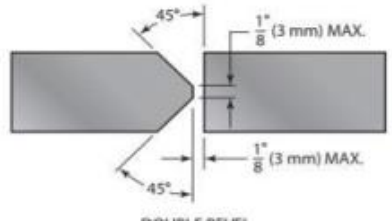


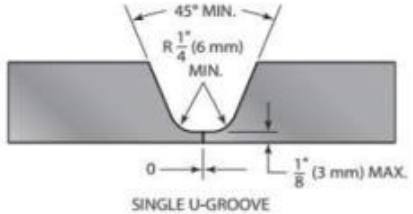


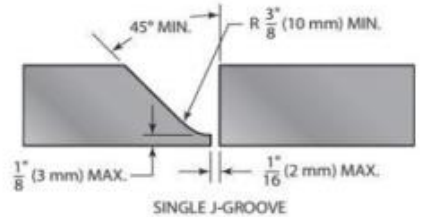


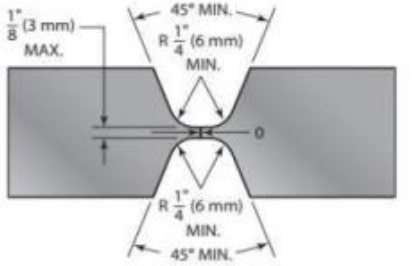












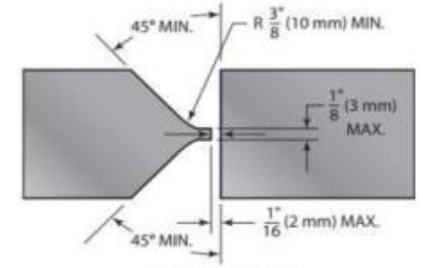


Fig. 14 Root Radius

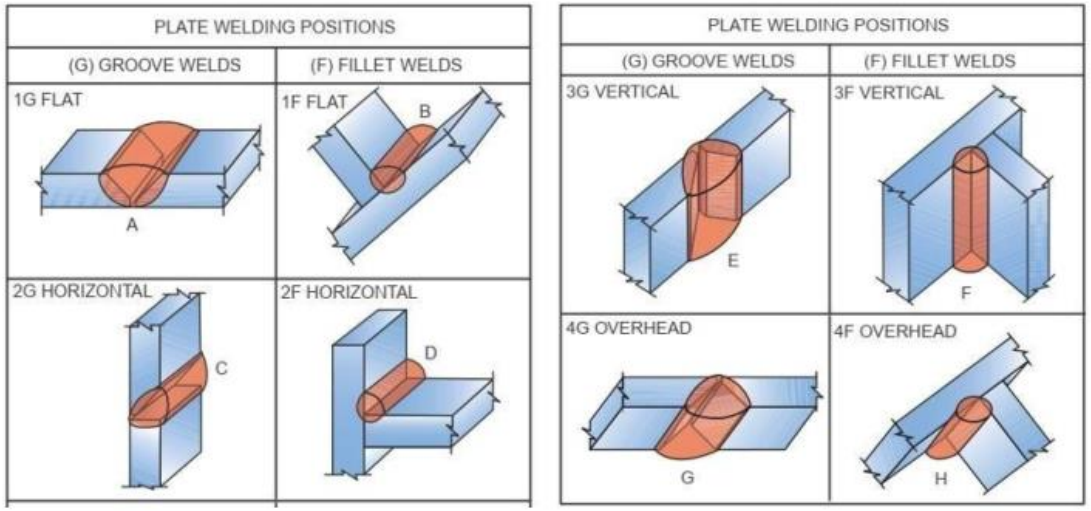


Fig. 15 Plate Welding Positions

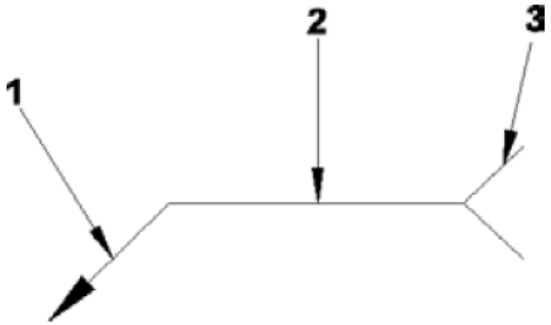


Fig. 17 Base Platform

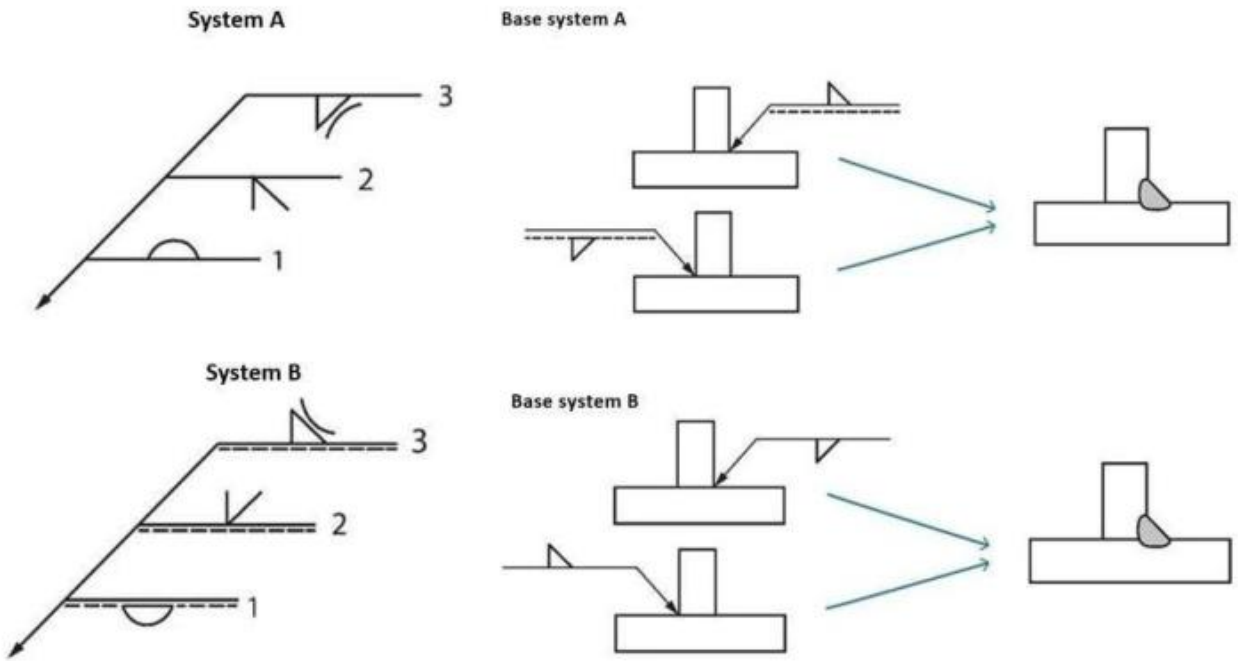
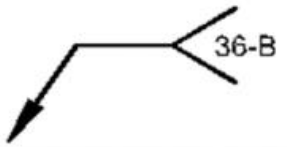
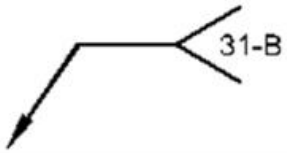
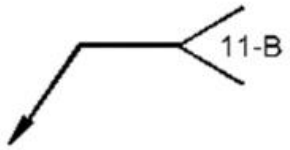
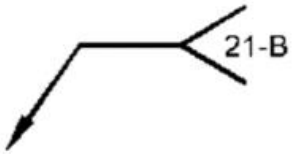
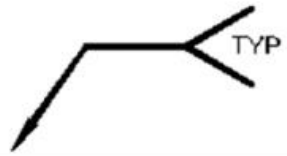


Fig. 16 Base Systems for Interpretation of Weld

Table 17 Detailing Convention

Sl. No.	Name	Nomenclature	Application/ Grade	Symbol	Characteristics of consumables
1	Flux Cored Arc Welding (FCAW)	136	Construction: both Inside & Outside/ CLASS B		Continuous consumable electrode filled with flux. Manual & Automatic Process.
2	Gas Metal Arc Welding (GMAW)	131	Construction: both Inside & Outside/ CLASS B		Continuous consumable electrode and shielding gas. Manual & Automatic Process.
3	Shielded Metal Arc Welding (SMAW)	111	Construction: Outside/ CLASS B		Consumable electrode covered in flux, can weld any metal as long as they have the right electrode. Manual Process.
4	Submerged Arc Welding (SAW)	121	Construction: Inside/ CLASS B		Arc submerged in granular flux. Automatic Process.
5	Unspecified		Construction: both Inside & Outside and any position/ CLASS B		Typ. denotes any of the welding process serial No from 1 to 4 can be adopted.

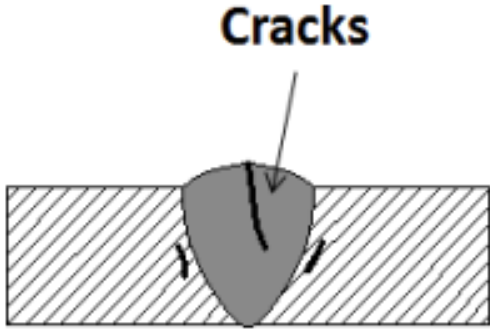


Fig. 29 Weld Crack

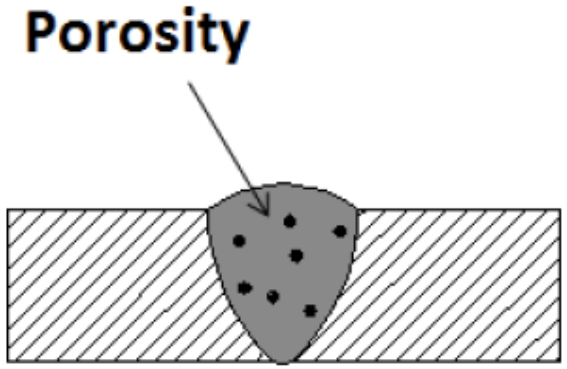


Fig. 30 Porosity in Weld

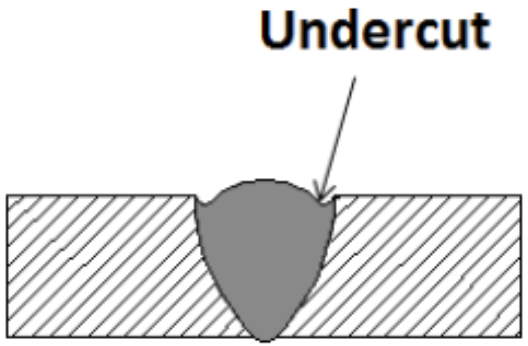


Fig. 31 Undercut in Weld

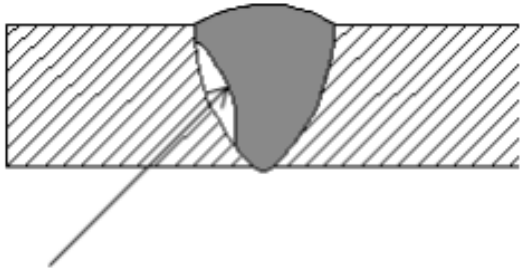


Fig. 32 Incomplete Fusion in Weld

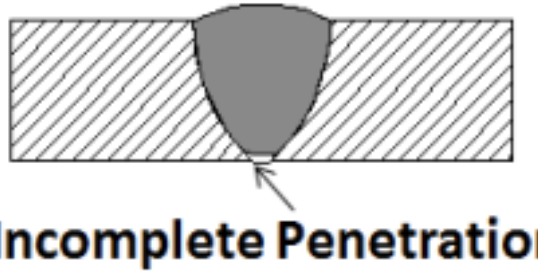


Fig. 33 Incomplete Penetration of Weld

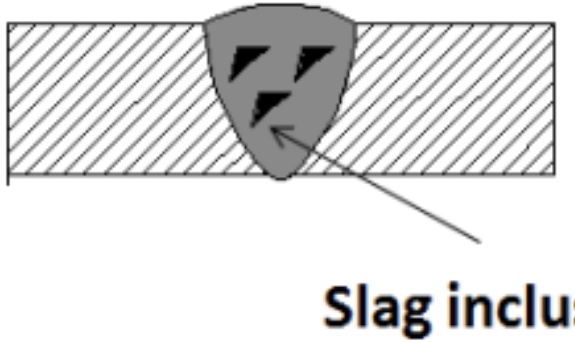


Fig. 34 Slag Inclusion in Weld

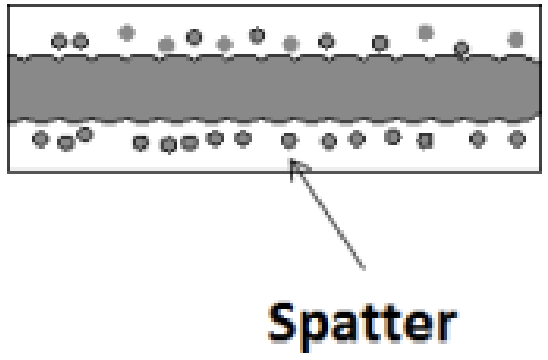


Fig. 35 Spatter in Weld

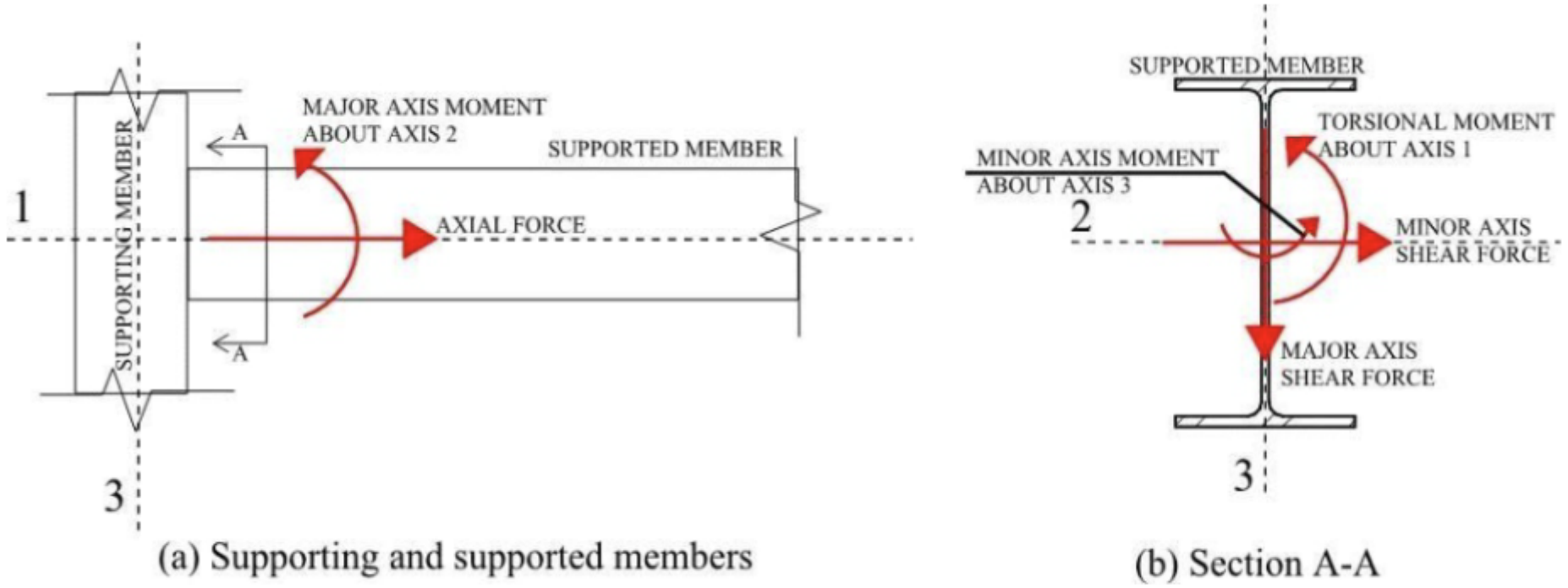
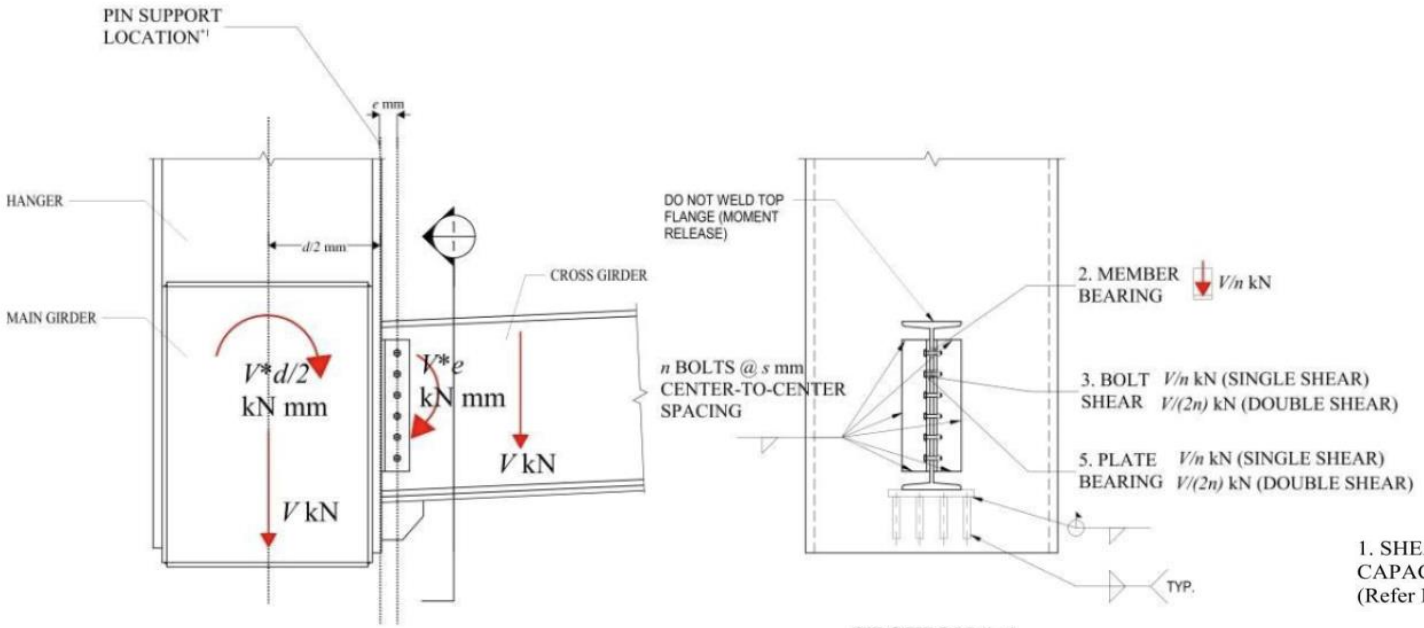


Fig. 39 Coordinate System and Force Component Definitions



SECTION 1-1

NOTE: THIS SECTION IS SHOWN FOR DISCUSSING CONNECTION LOAD PATH ONLY. MAIN GIRDER AND ITS CONNECTIONS ARE NOT SHOWN IN THIS SECTION (FOR CLARITY).

1. SHEAR FORCE AND BENDING MOMENT CAPACITY AT NET SECTION
(Refer IRC:24-2010 Section 509)

2. MEMBER BEARING ON BOLT CAPACITY
(Refer IRC:24-2010 Section 512.5)

3. BOLT SHEAR CAPACITY (SINGLE OR DOUBLE)*2
(Refer IRC:24-2010 Section 512.5)

4. ECCENTRICALLY LOADED BOLT GROUP CAPACITY

5. BOLT BEARING ON PLATE CAPACITY
(Refer IRC:24-2010 Section 512.5)

6 PLATE NET SECTION SHEAR + ECCENTRIC MOMENT INTERACTION CAPACITY
(Refer IRC:24-2010 Section 510)

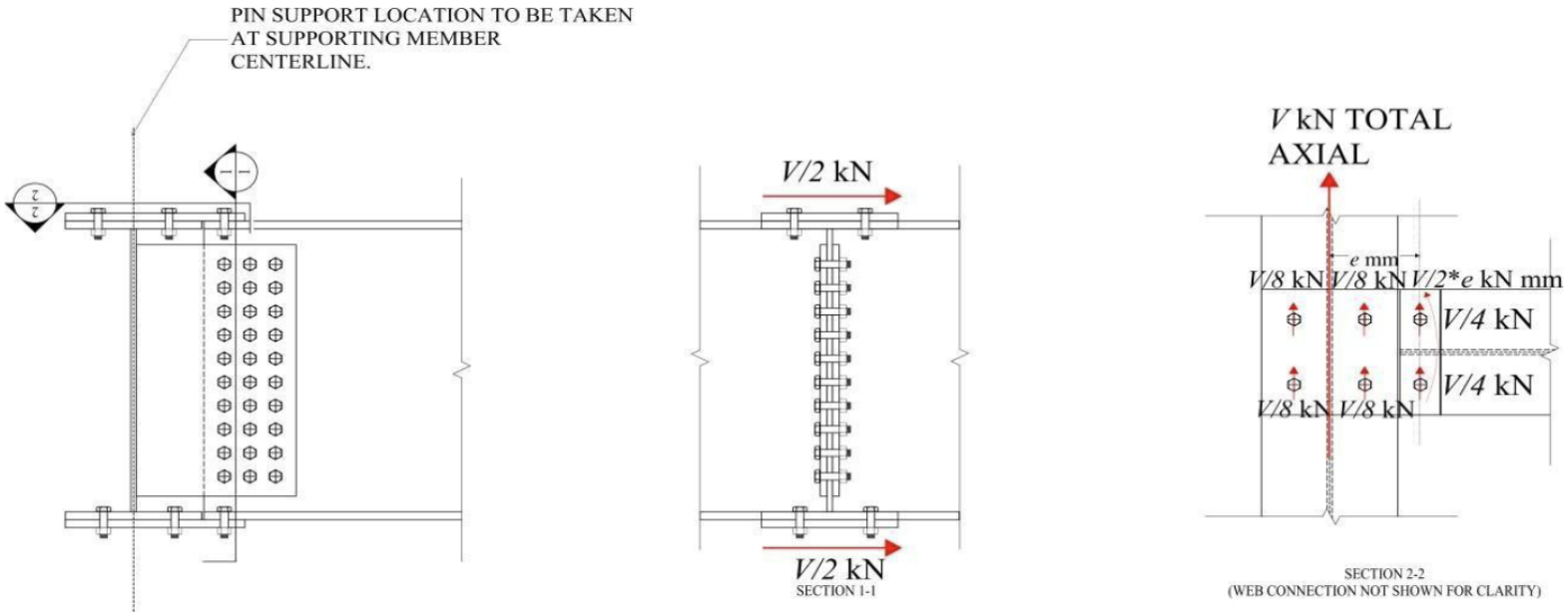
NOTES:

*1) REMAINING ELEMENTS IN-BETWEEN PIN SUPPORT LOCATION AND CENTERLINE OF SUPPORTING MEMBER (INCLUDING PLATE, BOLTS, WELDS AND SUPPORTING MEMBER) ARE TO BE DESIGNED FOR MOMENT DUE TO ECCENTRICITY OF SHEAR FORCE TRANSFER. NOTE THAT THIS MAY ACT AS A TORSIONAL OR MINOR AXIS MOMENT ON THE SUPPORTING MEMBER, DEPENDING UPON THE CONFIGURATION.

*2) FOR BOLTED CONNECTIONS WHERE SLIP IS NOT PERMITTED, BOLT SHEAR CAPACITY IS LIMITED BY FRICTION GRIP SLIP CAPACITY (REFER IRC:24-2010 Section 512.6)

3) PLATE ELEMENTS OF CROSS SECTIONS IN THE LOAD PATH ARE TO BE CHECKED FOR LOCAL INSTABILITIES PER IS 800 2007 Section 3.7 AND OTHER RELEVANT CODAL PROVISIONS

Fig. 40 Load Path Detailing Considerations for Major Axis Shear Force Transfer (Bearing Type Bolts)



AT SUPPORTED MEMBER

1. MINOR AXIS SHEAR FORCE CAPACITY FOR MEMBER
(Refer IRC:24-2010 Section 509 considering minor axis shear area)

2. MEMBER BEARING ON BOLT CAPACITY
(Refer IRC:24-2010 Section 512.5)

3. BOLT SINGLE SHEAR CAPACITY (IF SINGLE FLANGE PLATE IS USED)
(Refer IRC:24-2010 Section 512.5, see Note 2 on Bolted Shear Connection Detail)

4. ECCENTRICALLY LOADED BOLT GROUP CAPACITY

5. BOLT BEARING ON PLATE CAPACITY
(Refer IRC:24-2010 Section 512.5)

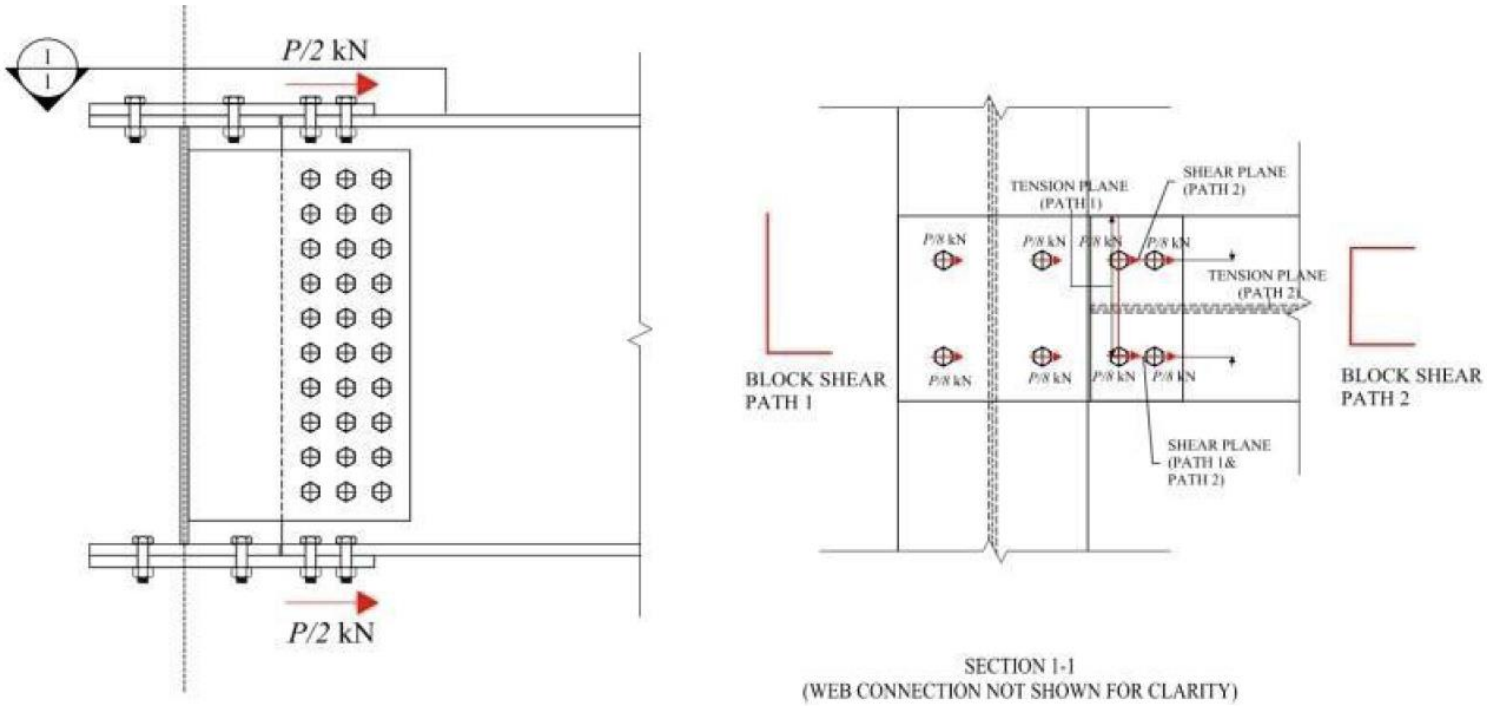
6. PLATE NET SECTION SHEAR + ECCENTRIC MOMENT INTERACTION CAPACITY
(Refer IRC:24-2010 Section 510)

AT SUPPORTING MEMBER

11. BOLT BEARING ON SUPPORTING MEMBER CAPACITY
(Refer IRC:24-2010 Section 512.5)

12. SUPPORTING MEMBER SECTION AXIAL CAPACITY
(Refer IRC:24-2010 Sections 506 and 507)

Fig. 41 Load Path Detailing Considerations for Minor Axis Shear Force Transfer (Bearing Type Bolts)



SECTION 1-1
(WEB CONNECTION NOT SHOWN FOR CLARITY)

AT SUPPORTED MEMBER

1. AXIAL FORCE CAPACITY OF MEMBER
(Refer IRC:24-2010 Sections 506 and 507)

2. MEMBER BEARING ON BOLT CAPACITY
(Refer IRC:24-2010 Section 512.5)

3. BOLT SINGLE SHEAR CAPACITY (IF SINGLE FLANGE PLATE IS USED)
(Refer IRC:24-2010 Section 512.5, see Note 2 on Bolted Shear Connection Detail)

4. BOLT BEARING ON PLATE CAPACITY
(Refer IRC:24-2010 Section 512.5)

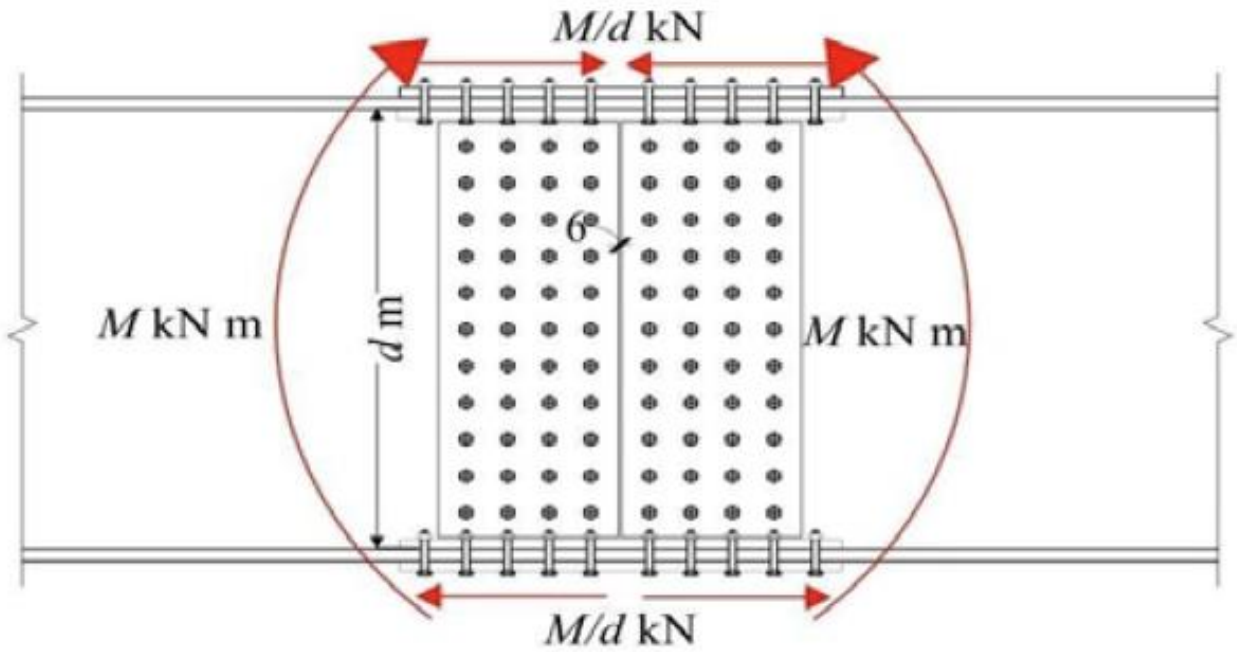
6. PLATE TENSILE CAPACITY (Refer IRC:24-2010 Section 506)

AT SUPPORTING MEMBER

7. BOLT BEARING ON SUPPORTING MEMBER CAPACITY
(Refer IRC:24-2010 Section 512.5)

8. SUPPORTING MEMBER WEAK AXIS SHEAR CAPACITY
(Refer IRC:24-2010 Section 509 considering minor axis shear area)

Fig. 42 Load Path Detailing Considerations for Axial Force Transfer (Bearing Type Bolts)



AT SUPPORTED ./ SUPPORTING MEMBER

1. MAJOR AXIS MOMENT CAPACITY FOR MEMBER
(Refer IRC:24-2010 Section 509)

2. BEAM FLANGE NET SECTION TENSION AND COMPRESSION CAPACITY
(Refer IRC:24-2010 Sections 506 and 507)

3. MEMBER BEARING ON BOLT CAPACITY
(Refer IRC:24-2010 Section 512.5)

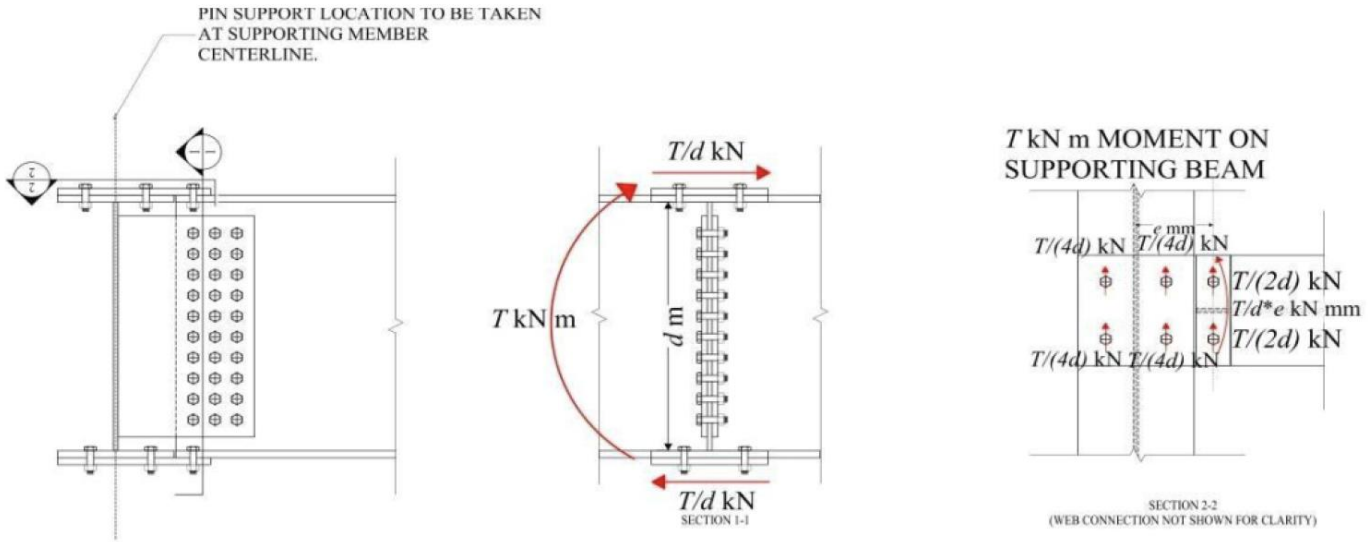
4. BOLT DOUBLE SHEAR CAPACITY
(Refer IRC:24-2010 Section 512.5, see Note 2 on Bolted Shear Connection Detail)

5. BOLT BEARING ON PLATE CAPACITY
(Refer IRC:24-2010 Section 512.5)

6. PLATE NET SECTION TENSION AND COMPRESSION CAPACITY
(Refer IRC:24-2010 Sections 506 and 507)

7. LOCAL STABILITY CHECKS ON SUPPORTED MEMBER AND PLATE
(Refer IS 800 2007 Section 3.7)

Fig. 43 Load Path Detailing Considerations for Major Axis Moment Transfer in Bolted Connections



AT SUPPORTED MEMBER

1. TORSION CAPACITY FOR MEMBER

2. MEMBER BEARING ON BOLT CAPACITY
(Refer IRC:24-2010 Sections 512.5)

3. BOLT SINGLE SHEAR CAPACITY (IF SINGLE FLANGE PLATE IS USED)
(Refer IRC:24-2010 Sections 512.5, see Note 2 on Bolted Shear Connection Detail)

4. ECCENTRICALLY LOADED BOLT GROUP CAPACITY

5. BOLT BEARING ON PLATE CAPACITY
(Refer IRC:24-2010 Sections 512.5)

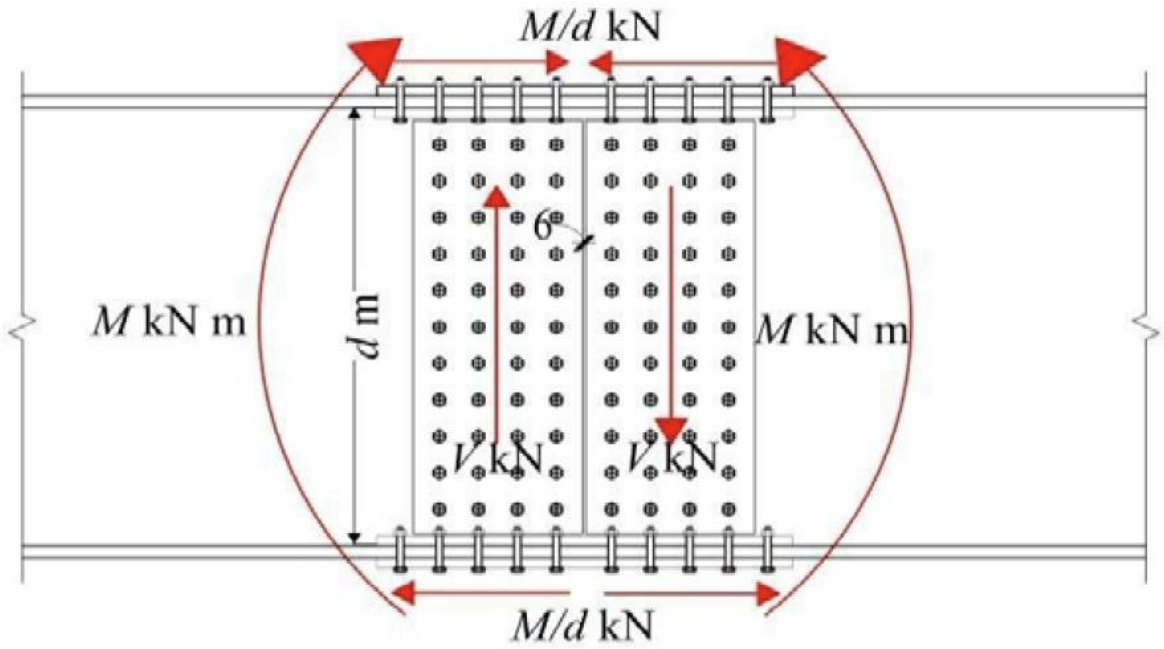
6. PLATE NET SECTION SHEAR + ECCENTRIC MOMENT INTERACTION CAPACITY (Refer IRC:24-2010 Sections 510)

AT SUPPORTING MEMBER

11. BOLT BEARING ON SUPPORTING MEMBER CAPACITY
(Refer IRC:24-2010 Sections 512.5)

12. SUPPORTING MEMBER MAJOR AXIS MOMENT CAPACITY
(Refer IRC:24-2010 Sections 509)

Fig. 44 Load Path Detailing Considerations for Torsional Moment Transfer (Bearing Type Bolts)



LOAD PATH FOR MAJOR AXIS SHEAR

1. SHEAR FORCE AND BENDING MOMENT INTERACTION CAPACITY AT BEAM CRITICAL NET SECTIONS
(Refer IRC:24-2010 Section 509)

2. BEAM BEARING ON BOLT CAPACITY
(Refer IRC:24-2010 Section 512.5)

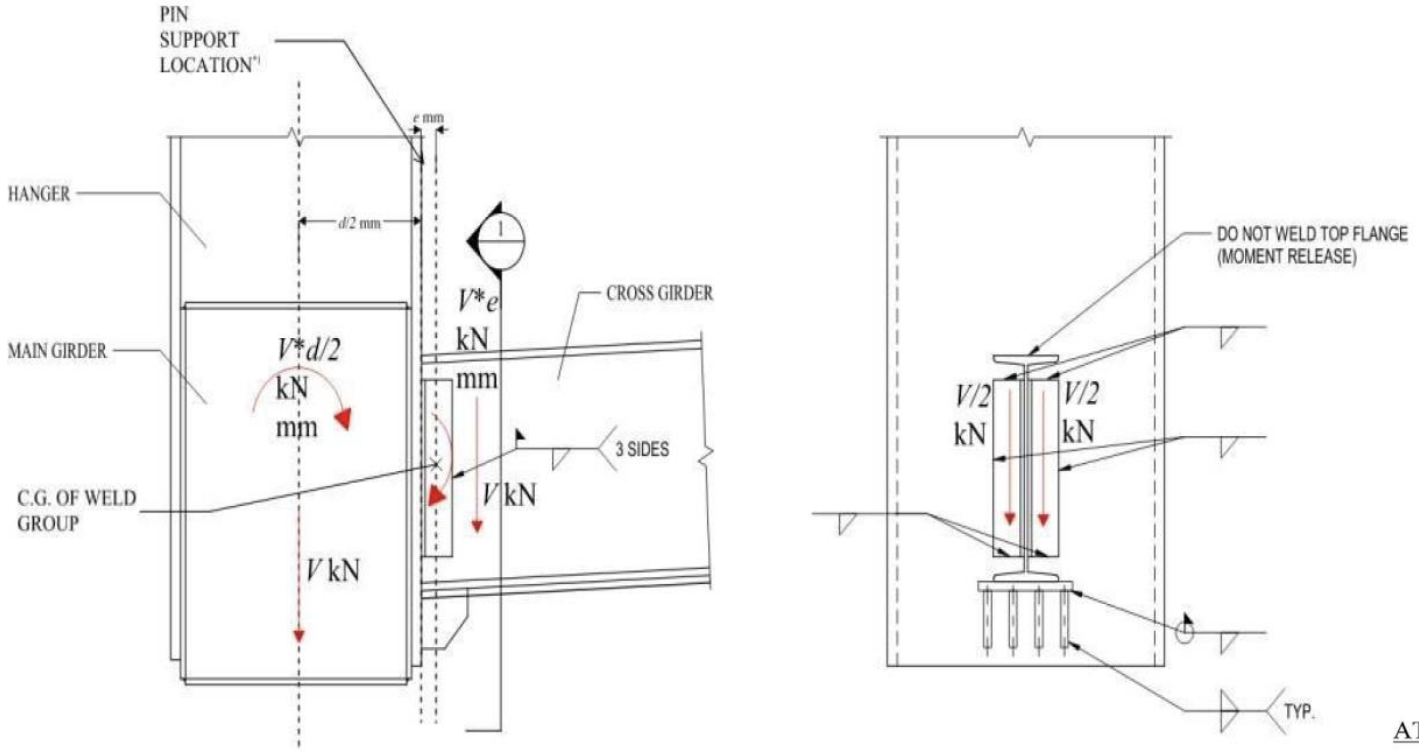
3. BOLT DOUBLE SHEAR CAPACITY (IF TWO WEB PLATES ARE PROVIDED, ONE ON EITHER SIDE)
(Refer IRC:24-2010 Section 512.5, see Note 2 on Bolted Shear Connection Detail)

4. BOLT BEARING ON PLATE CAPACITY
(Refer IRC:24-2010 Section 512.5)

5. PLATE NET SECTION SHEAR AND MOMENT INTERACTION CAPACITY
(Refer IRC:24-2010 Section 510)

LOAD PATH FOR MAJOR AXIS MOMENT -- SEE BOLTED MAJOR AXIS MOMENT DETAIL

Fig. 45 Load Path Detailing Considerations for Major Axis Moment + Shear Transfer in Bolted Splice Connection



AT SUPPORTED MEMBER (CROSS GIRDER)

1. SHEAR FORCE AND BENDING MOMENT CAPACITY AT CRITICAL SECTION
(Refer IRC:24-2010 Section 509)

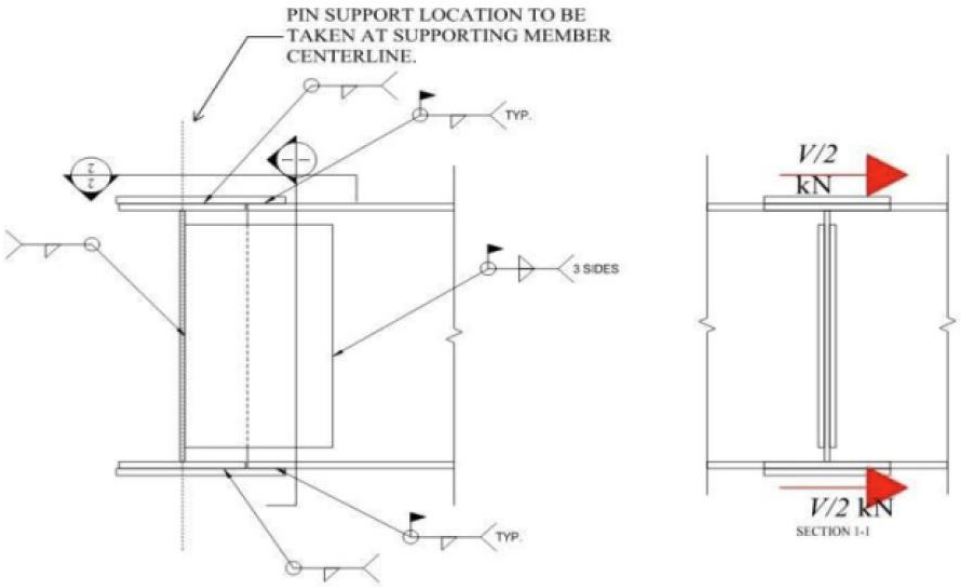
2. ECCENTRICALLY LOADED WELD GROUP SHEAR CAPACITY
(Refer IRC:24-2010 Section 512.4)

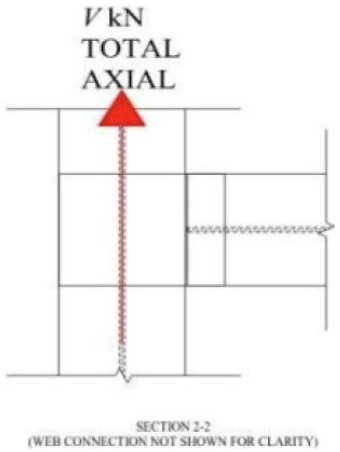
3. PLATE SECTION SHEAR + ECCENTRIC MOMENT INTERACTION CAPACITY
(Refer IRC:24-2010 Section 510)

NOTES:
*1) SEE NOTE 1 ON BOLTED SHEAR CONNECTION DETAIL

2) SEE NOTE 3 ON BOLTED SHEAR CONNECTION DETAIL

Fig. 46 Load Path Detailing Considerations for Welded Major Axis Shear Transfer





AT SUPPORTED MEMBER

1. WEAK AXIS SHEAR FORCE CAPACITY FOR MEMBER
(Refer IRC:24-2010 Section 509 considering minor axis shear area)

2. ECCENTRICALLY LOADED WELD GROUP CAPACITY
(Refer IRC:24-2010 Section 512.4)

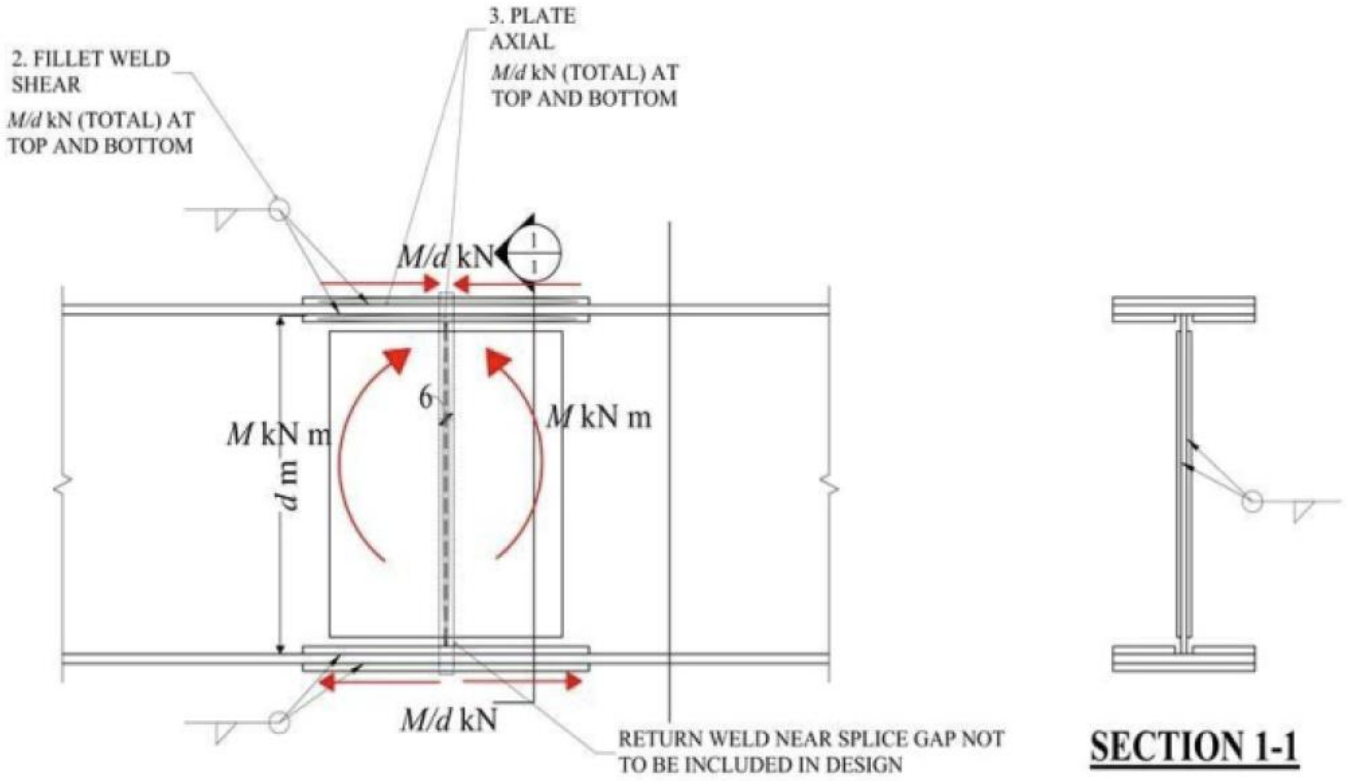
3. PLATE SHEAR + ECCENTRIC MOMENT INTERACTION CAPACITY
(Refer IRC:24-2010 Section 510)

AT SUPPORTING MEMBER

11. WELD GROUP SHEAR CAPACITY
(Refer IRC:24-2010 Section 512.4)

12. SUPPORTING MEMBER SECTION AXIAL CAPACITY
(Refer IRC:24-2010 Sections 506 and 507)

Fig. 47 Load Path Detailing Considerations for Welded Minor Axis Shear Transfer



LOAD PATH FOR MAJOR AXIS MOMENT

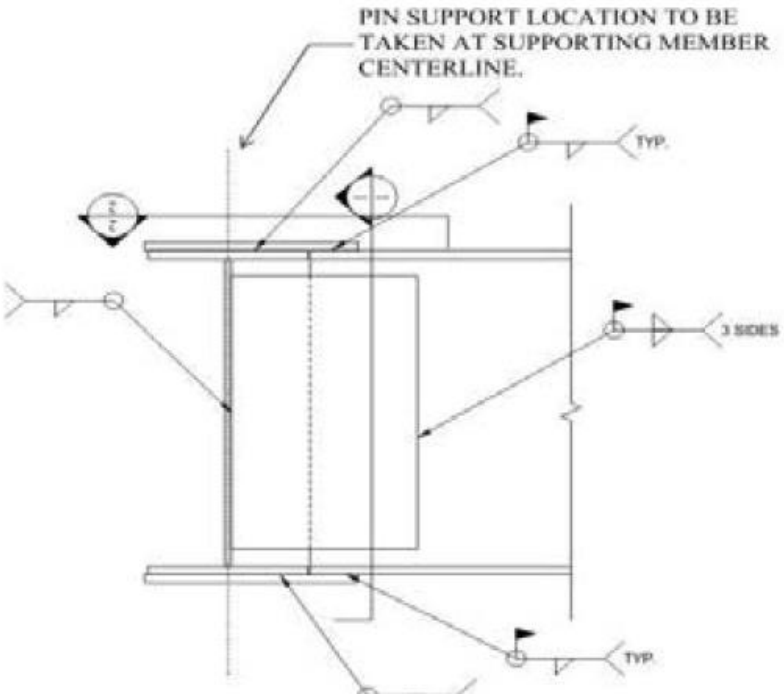
SECTION 1-1

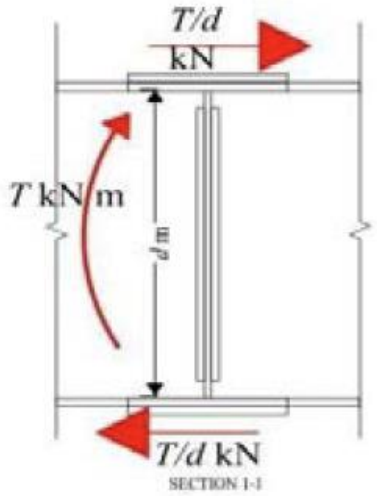
1. MAJOR AXIS MOMENT CAPACITY FOR MEMBER
(Refer IRC:24-2010 Section 509)

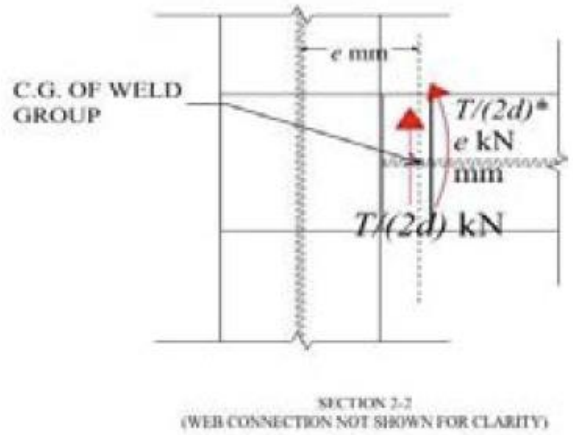
2. FILLET WELD SHEAR CAPACITY BETWEEN BEAM AND FLANGE PLATE
(Refer IRC:24-2010 Section 512.4)

3. FLANGE PLATE TENSION AND COMPRESSION CAPACITY
(Refer IRC:24-2010 Sections 506 and 507)

Fig. 48 Load Path Detailing Considerations for Welded Major Axis Moment Transfer







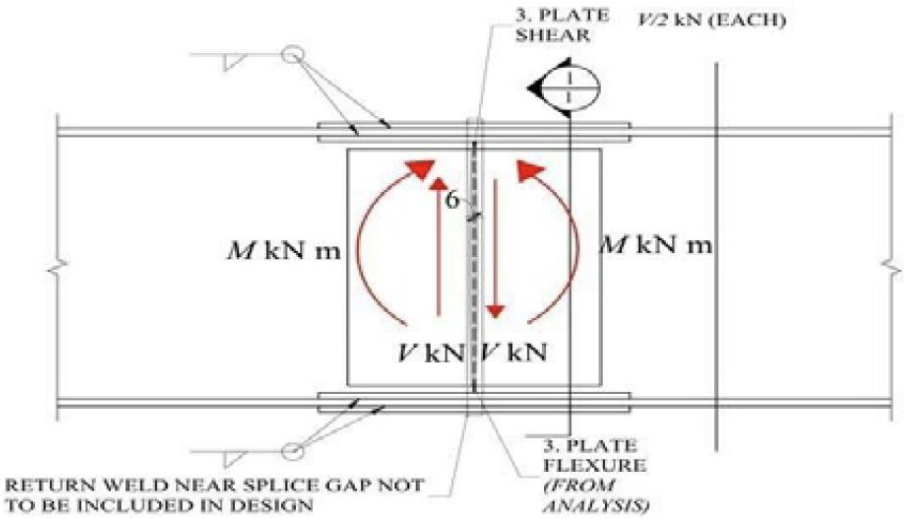
AT SUPPORTED MEMBER

1. TORSION CAPACITY FOR MEMBER
2. ECCENTRICALLY LOADED WELD GROUP CAPACITY
3. PLATE SHEAR + ECCENTRIC MOMENT INTERACTION CAPACITY

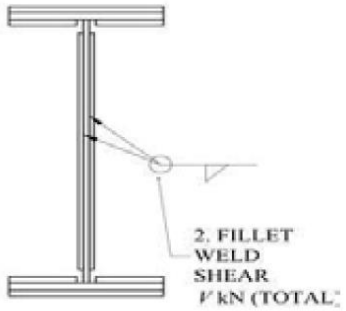
AT SUPPORTING MEMBER

11. WELD GROUP SHEAR CAPACITY
12. SUPPORTING MEMBER MAJOR AXIS MOMENT CAPACITY

Fig. 49 Load Path Detailing Considerations for Welded Torsion Transfer



LOAD PATH FOR MAJOR AXIS SHEAR



SECTION 1-1

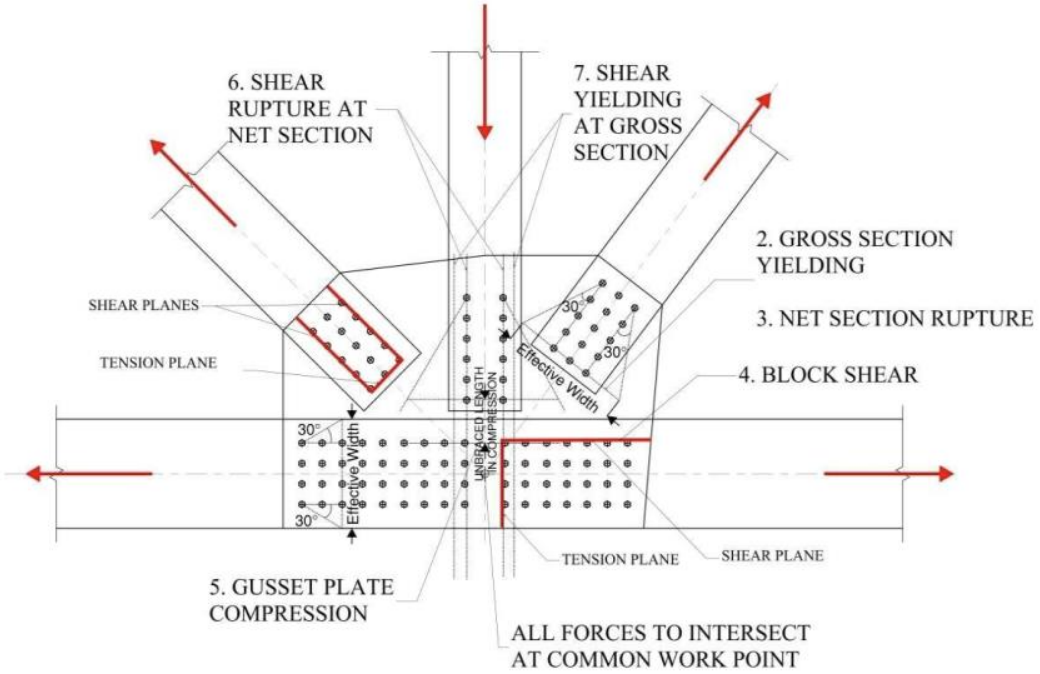
1. SHEAR FORCE AND BENDING MOMENT INTERACTION CAPACITY AT BEAM SECTION
(Refer IRC:24-2010 Section 510)

2. FILLET WELD SHEAR CAPACITY BETWEEN BEAM AND WEB PLATE
(Refer IRC:24-2010 Section 512.4)

3. PLATE MAJOR AXIS SHEAR + MOMENT INTERACTION CAPACITY
(Refer IRC:24-2010 Section 510)

LOAD PATH FOR MAJOR AXIS MOMENT -- SEE WELDED SPLICE MAJOR AXIS MOMENT LOAD DETAIL

Fig. 50 Load Path Detailing Considerations for Major Axis Moment + Shear Transfer in Welded Splice Connection



AT GUSSET PLATE

1. BOLT BEARING
(Refer IRC:24-2010 Section 512.5)

2. GROSS SECTION YIELDING
(Refer IRC:24-2010 Clause 506.1.1)

3. NET SECTION RUTURE INCLUDING SHEAR LAG EFFECTS
(Refer IRC:24-2010 Clause 506.1.2)

4. BLOCK SHEAR
(Refer IRC:24-2010 Clause 506.1.3)

5. COMPRESSION
(Refer IRC IRC:24-2010 Section 507)

6 and 7. SHEAR DESIGN
(Refer IRC:24-2010 Clause 509.4)

Fig. 55 Gusset Plate Load Path Detailing

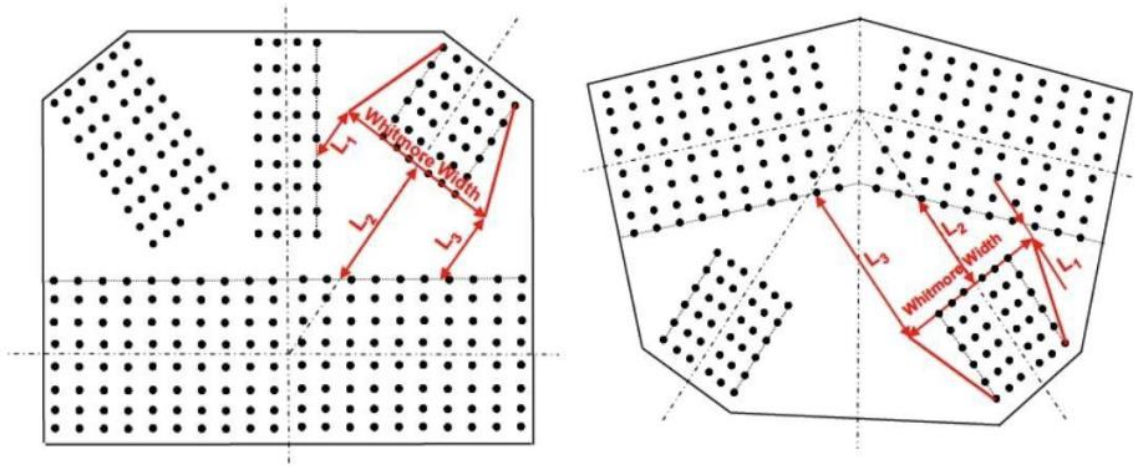


Fig. 56 Gusset Plate Unbraced Length Examples Unbraced Length shall be Taken as the Largest Among L1, L2 and L3

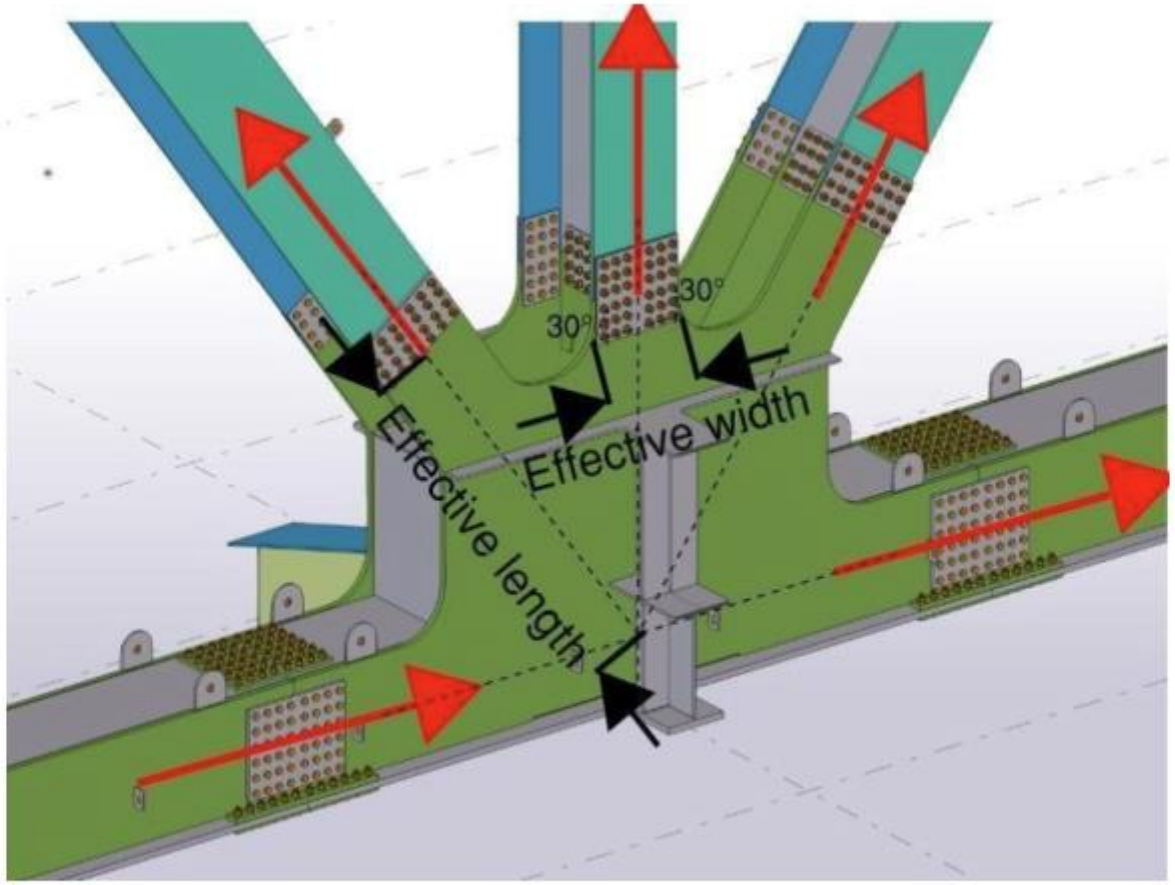


Fig. 57 Gusset Plate Detail with Splices on Members, Force Directions and Dimensions are for an Example Scenario

- Plate Girder Bridges

- Open Web Girder Bridges

Quality Assurance	Quality Control
QA is an ongoing management responsibility that involves planning and implementing systematic actions	QC is the system used by Designer/ Contractor/ Fabricator to monitor, assess, and adjust their production or placement processes
Assures that the work processes and designed elements are functioning as intended. Will eliminate construction delays.	Ensures final product will meet the specified level of quality

QA/QC is applicable for all stages of a project such as:

- Planning, Design and Drawing
- Documents for shop Fabrication
- Transportation, erection and final joining (bolting/ welding) at the site

Appendices

- Appendix-1: Typical Methodology for Erection
- Appendix-2: Typical General notes for Steel Constructed Road Bridges
- Appendix-3: Typical General Arrangement of a Plate Girder Bridge
- Appendix-4: General Arrangement of an open Web Girder Bridge