MEM30001A

Use computer aided drafting systems to produce basic engineering drawings.

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Edition 2 – February 2013

Conditions of Use:

Unit Resource Manual

Manufacturing Skills Australia Courses

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Aims of the Competency Unit

This unit covers the skills and knowledge required to detail bolts and welds for structural steelwork connections consistent with design specifications.

This unit applies to a structural steel detailer who has to detail various types of bolts and welds for structural steelwork connections. The detailing may be done manually or by using CAD and/or proprietary steel detailing software.

The unit may apply to structural steel detailing carried out for residential, commercial, industrial or mining fabrication and construction projects. The unit assumes that knowledge of basic technical drawing conventions and procedures such as view, dimensioning, drawing layout, etc. is already held.

Work is conducted according to defined procedures. Work may be conducted in small to large scale enterprises and may involve individual and team activities.

This unit requires the application of skills associated with planning and organising to complete structural steel detail drawings. Communication and numeracy skills are used to refer to patterns and specifications and complete and label sketches. Self management skills are used to ensure conformance of own work to quality standards

Unit Hours

27 Hours

Prerequisites:

MEM09002B	***Interpret technical drawing***
MEM05051A	***Select welding processes***
MSATCS301A	***Interpret architectural and engineering design specifications for structural steel detailing***

Elements and Performance Criteria

1. Determine shop and field connections from design drawings	1.1	Fabrication shop capabilities and preferences are discussed with fabricator
	1.2	The CAD package is booted up in accordance Connections are allocated as shop or field welded in conjunction with fabricator
	1.3	Connections to be field bolted are allocated and extent of shop preparation of connections decided
	1.4	Connection fittings are allocated to either columns or beams to suit fabrication efficiency or design requirements
	1.5	A request for further information (RFI) is made to design engineer where clarification of requirements is needed
2. Detail bolts for connections	2.1	Knowledge of standard bolting category identification system is demonstrated
	2.2	Bolt types and sizes for each connection are specified using design information and consideration of commercial availability
	2.3	Bolt and thread lengths are selected according to design specifications, and connection requirements
	2.4	Bolt and bolt holes are detailed taking into account AS 4100 requirements, tightening and tensioning specifications and clearances
	2.5	Field bolt list is prepared and checked and sent to fabricator
3. Detail welds for connections	3.1	Knowledge of joint and weld types is demonstrated
	3.2	Shop and field welds are identified
	3.3	Standard welding symbols are used
	3.4	Clearances for welding are applied
	3.5	Field weld details are placed on erection plans and shop drawings and submitted to design engineer for approval

Required Skills and Knowledge

Required skills include:

- assess design information for adequacy of information needed for structural steel detailing
- liaise with design engineers
- assess scope of structural steel detailing tasks and priorities
- interpret design drawings, sketches and schedules
- determine bolt and thread length taking into account:
    - shank lengths as defined in AS 1111 and AS 1252
    - whether the thread is to be included or excluded in the shear plane
    - grip and ply thicknesses
    - thread projection as per AS 4100
    - nut and washer requirements
- detail welds consistent with design information and AS4100 and AS 1101 Part 3
- work according to OHS practices of the enterprise and workplace which may include requirements prescribed by legislation, awards, agreements and conditions of employment, standard operating procedures, or oral, written or visual instructions
- communicate at all levels about technical issues related to patterns and specifications
- reading and numeracy is required to the level of interpreting workplace documents and technical information

Required knowledge includes:

- architectural and engineering design drawings including standard symbols, terms, abbreviations and sketches
- structural steel members and connections used in structural steelwork
- the difference between design and detail drawing processes
- drawing office procedures
- fabrication processes and procedures
- the Australian steel structures limit state design code's (AS4100) requirements in so far as they impact on steel detailing
- Australian standard bolting category identification system
- bolt and thread length considerations including:
- shank lengths as defined in AS 1111 and AS 1252
- inclusion or exclusion of the shear plane in the thread
- grip and ply thicknesses
- thread projection requirements as per AS 4100
- nut and washer requirements
- standard welding symbols as described in AS 1101 Part 3 welding theory and processes

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Lesson 1 – Bolts

Required Skills

- Name the Australian standards used for bolts in the construction of steel structures.
- Specify the two types of bolts used in the construction of steel structures.
- Identify Commercial and High Strength Structural bolts.
- Select bolts to suit specific bolt categories.
- Calculate the length of a bolt to conform to structural requirements and Australian Standards.

Required Knowledge

- Australian Standards.
- Types of bolts and materials.
- Interpreting detail and design drawings to determine lengths of bolts.
- Reading tables associated with structural steel sections.

Introduction:

Bolts are used to connect beams, girders, trusses, columns, and other structural and non-structural members which form a complicated structure are designed to support certain loads. Each of these members must transmit its load through structural joints to supporting members.

Joints are formed by bolting or welding two or more members together where the connection material, dimensions, angles, plates and/or structural sections are detailed.

The two methods for connecting structural and non-structural members in this unit are Bolting and Welding:

Bolts:

Bolting creates a flexible or rigid connection that can be assembled or disassembled as required. Bolts are used widely for making connections in structural steelwork, especially field connections. An understanding of all aspects of the use of bolts is vital to the designing, detailing, fabrication and erection of steel structures.

Welds:

Welding forms a rigid connection and is the process in which fusion (melting) occurs by heating with an electrical arc that is generated between an electrode/rod and the surfaces of the parent materials.

Bolts and welds are normally designed and specified by an engineer. The selection of the bolt is determined by:

- The nature of the forces to be resisted.
- Design capacity of available bolt types.
- Ammount of joint slippage desired.
- Degree of flexibility/rigidity desired in the joint.
- Cost of the installed fastener.

Types of Bolts:

Two types of metric bolts are used in the fabrication, erection of structural steel structures in Australia.

1. Commercial (Strength Grade 4.6) bolts to AS/NZS1111
2. High strength structural (Steel Grade 8.8) bolt to AS/NZS1252

Commercial bolts are made of low carbon steel with mechanical properties similar to that of Grade 250 (MPa) material.

High strength bolts are made by heat treating, quenching and tempering medium carbon steel. Accordingly, heating or welding a commercial bolt will cause no significant change in its properties (strength) but either process will cause a significant degradation in the mechanical properties of high strength structural bolts.

Structural steelwork uses a limited range of size of bolts. Commercial bolts are commonly used in the following diameters:

M12 – purlin, and girt applications.

M16 – cleats and relatively lightly loaded brackets.

M20 – general structural connections and holding down bolts.

M24 – general structural connections and holding down bolts.

M30 – holding down bolts.

M36 – holding down bolts.

The high strength structural bolt is most commonly used in the following diameters:

M16 – designed connections in small members.

M20 – flexible and rigid connections.

M24 – flexible and rigid connections.

M30 & M36 and larger – these sizes should be avoided when full tensioning is required, since on-site tensioning can be difficult and may require special equipment.

Dimensions of Bolts:

Identification of Bolts:

Structural bolts are easily recognised against a commercial bolt because the head is larger. Identification between the two types of bolt is also made by reading the markings on the head of the bolt.

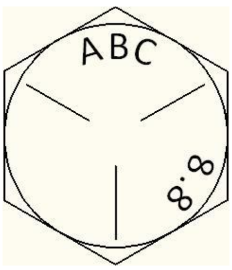


Figure 1

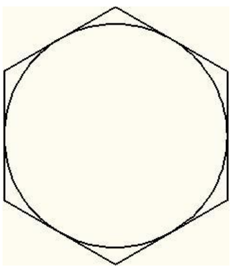


Figure 2

Figure 1 shows a High Strength Bolt where the manufacturer's name, the grade and three radial lines are displayed on the head while Figure 2 is a Commercial bolt with no distinguishing data.

Bolting Categories:

A standard bolting category identifying system is used throughout Australia for use by steel designers and detailers.

- Category 4.6/S refers to commercial bolts of Strength Grade 4.6 and tightened to a snug-tight condition with a standard torque wrench.
- Category 8.8/S refers to any bolt of Strength Grade 8.8 and tightened to a snug-tight condition with a standard torque wrench.
- Category 8.8/T and 8.8/TB (or 8.8T both types) refer specifically to high strength structural bolts of Strength Grade 8.8 and fully tensioned in a controlled manner to the requirements of AS4100.

The system of category designation identifies the bolt being used by its strength grade designation (4.6 or 8.8) and the installation procedure by a supplementary letter (s = snug, T = full tensioning). For 8.8/S categories, the type of joint is identified by an additional letter (F = friction type joint, B = bearing type point).

High strength bolts can be specified in three ways:

- Snug tightened – category 8.8/S.
- Fully tensioned, friction type – category 8.8/TF.
- Fully tensioned, bearing type – category 8.8/TB

The level of tensioning is the same for both 8.8/TF and 8.8/TB categories.

In practice, 8.8/S category would mainly be used in flexible joints where the extra capacity of the stronger bolt (compared to 4.6/S category) makes it economical. It is recommended that 8.8/TF category be used only on rigid joints where a no-slip joint is essential. 8.8/TF is the only category requiring attention to the faying surfaces. Design engineers' drawings and workshop detail drawings should both contain notes summarising the category designations.

Bolting Category	Method of Tensioning	Minimum Bolt Tensile Strength (MPa)	Minimum Bolt Yield Strength (MPa)	Bolt Name	Bolt Standard Specification
4.6/S	Snug	400	240	Commercial	AS/NZS1111
8.8/S		830	660	High Strength Steel	AS/NZS1252
8.8/T**	Full Tensioning				

** Includes 8.8/TF (friction type joint) and 8.8/TB (bearing type joint)

Bolt Length Selection:

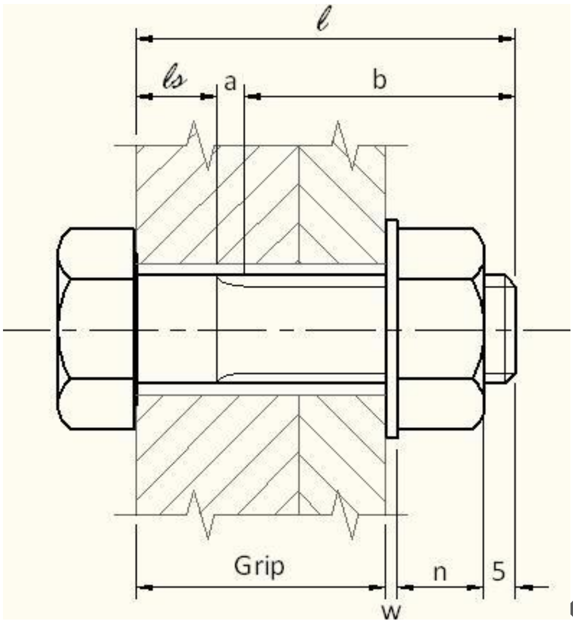
The responsibility for selecting bolt lengths for each connection usually rests with the steel detailer. In selecting bolt lengths, consideration must be given to whether the sheer plane cuts across the threaded or unthreaded section of the bolt. The advantages and disadvantages of both must be clearly understood by the steel detailer. Most connections are designed on the basis of threads being included in the shear plane. Where designers specifically require threads to be excluded, the steel detailer must take additional care when calculating bolt lengths to ensure this requirement is met.

Plain Shank Lengths:

Plain shank bearing lengths for each type of bolt are defined in the relevant Australian Standards (AS/NZS1111 and AS/NZS1252) as the distance from the bearing surface of the bolt head to the last scratch of the thread.

Threads Included in Shear Plane:

For the case of threads included in the shear plane as shown in Figure 3, the average minimum grip (assuming a 5mm projection of threads through the nut) is given in Ref. 7.



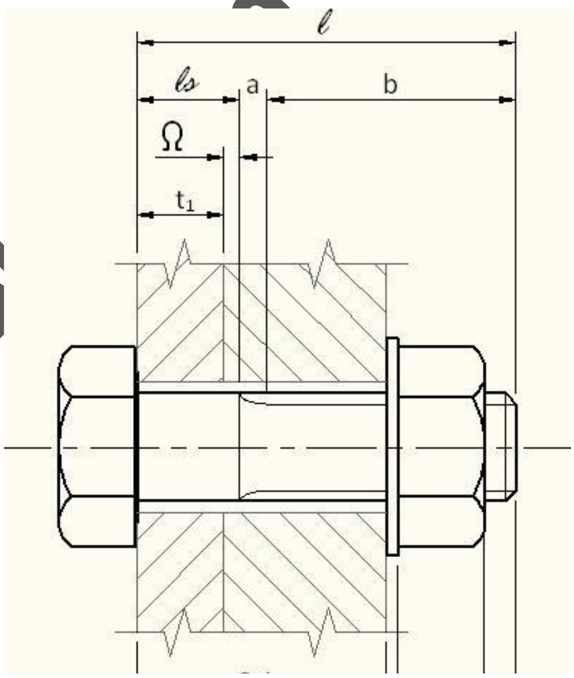
Legend

a = Thread runout
b = Length of thread
ℓs = Plain shank length
ℓ = Nominal bolt length
n = Nut length
w = Washer thickness

Figure 3 – Threads Included in Shear Plane

Threads Excluded From Shear Plane:

For the case of threads excluded from the shear plane, the situation is shown in Figure 4. The critical dimension is t_1, the thickness of the ply under the bolt head. Refer to Ref. 7 for examples of calculating bolt lengths.



Legend

a = Thread runout
b = Length of thread
ℓs = Plain shank length
ℓ = Nominal bolt length
n = Nut length
w = Washer thickness
Ω = Usually 3mm

t_1 = Thickness of ply under the bolt head.

Figure 4 – Threads Excluded From Shear Plane

To avoid having to calculate the bolt lengths on each occasion where threads are excluded from the shear plane, a simple table similar to that as shown in **Error! Reference source not found.** can be prepared.

Error! Reference source not found.lists the correct bolt length for various combinations of grip and minimum external ply thickness. Note the minimum external ply thickness is merely Grip minus the critical thickness. The critical thickness is the thinner ply thickness (or thickness under the heads of the bolt) for the single shear case, or the sum of the thickness of the thicker external ply and all internal plies for multiple shear cases; therefore, the table can be used for all shear cases.

It is essential that in selecting the bolt length for the case where threads are to be excluded from the shear plane, attention should be paid to the ply thicknesses as well as the total grip of the joint; this is an important consideration since bolts will normally be placed in joints from the more convenient side for the erector, or to provide nuts on the easier side for tensioning in the case of 8.8/T procedures.

The following points should be considered when detailing bolts with threads excluded from the shear plane:

1. Bolt length for the excluded case must be selected to provide plain shank in the shear plane for installation from either side of the joint – this usually results in longer bolts than would otherwise be required.
2. Due to the relatively long thread length of ISO metric bolts to AS/NZS1252 and AS/ANZ1111, a bolt with sufficient plain shank to exclude threads from the shear plane may project well past the nut-washer assembly. The additional length could cause difficulty in installation because adjacent bolts in a connection may foul one another as seen in Figure 5.

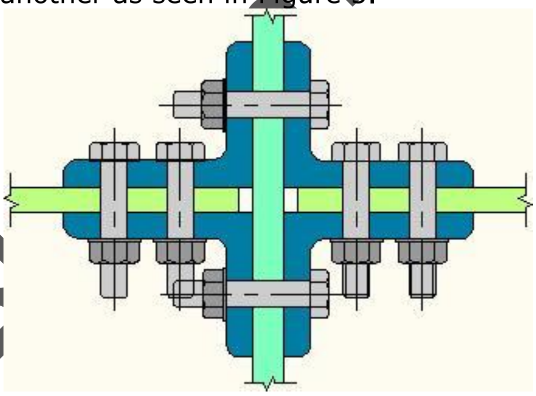


Figure 5

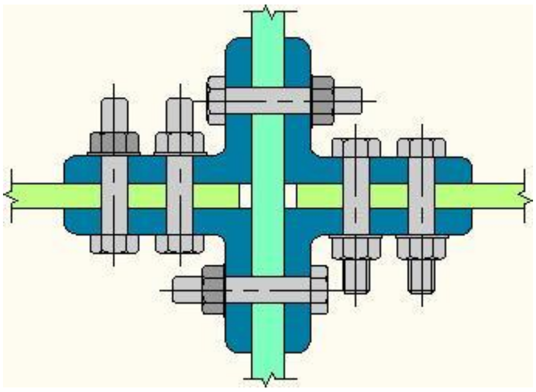


Figure 6

The physical interface of bolts can often be relieved by installing the bolts in the manner shown in Figure 6. In joints where tensioning to AS4100 is required (8.8/TF and 8.8/TB) it will not always be possible to apply the socket of an air wrench to the nuts of bolts with long thread overhang.

3. In joints with thin plies (e.g. 8mm angle legs or 8mm endplates), it is often necessary to use extra washers under the nut where threads are to be excluded from the shear plane in order to ensure the nut does not run up to the end of the thread.

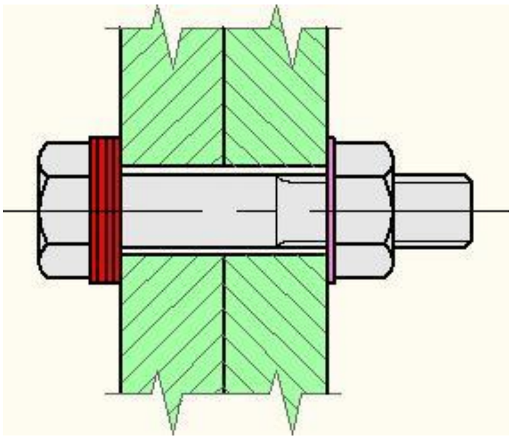


Figure 7

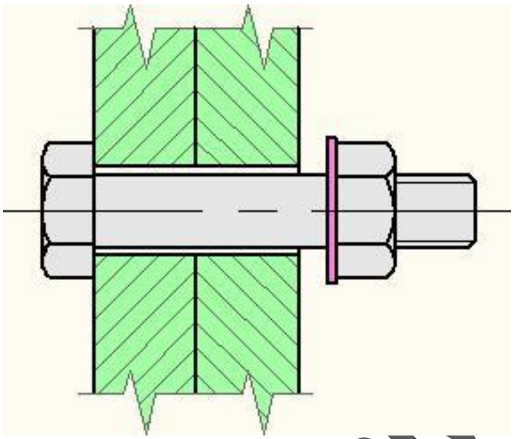


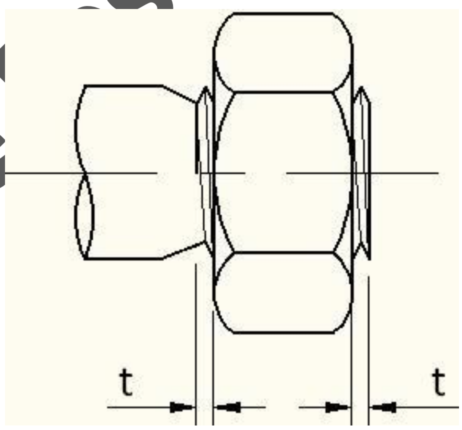
Figure 8

In Figure 8, the nut has been tightened to the end of the thread but there is a large gap between the washer and the connection resulting in the connection being loose which could cause failure in the connection. In Figure 7, additional washers have been added under the bolt head to move the thread into the connection to ensure a correct tightness is attained.

4. As the location of the plain shank relative to the shear plane position is critical for the threads excluded case, such a joint is very sensitive to the bolt length selection; this means that bolts have to be selected usually in length increments of 5mm and results in the stocking of a great number of bolt lengths and the subsequent difficulty in discharging correct bolts for a particular joint on site. Alternately, excessive 'sticking-through' must be accepted.

Thread Projection:

AS4100 requires that the length of a bolt be such that at least one clear thread projects through the nut and that at least one thread plus the thread run-out is clear beneath the nut after tightening to either /S or /T bolting category.



t = minimum one thread (one pitch)

Figure 9 – AS4100 Minimum Requirements for Thread Projection

The methods of calculation to meet the requirements are presented in Ref. 7.

The minimum projection through the nut of at least on thread pitch is intended to ensure that full engagement of the nut thread is achieved. While this is accepted good practice for /S bolting category, it is crucial with /T category in order to achieve the specified minimum bolt tension.

The clearance under the nut is intended to ensure that a nut is never tightened against the thread run-out on the bolt which constitutes the end of the threaded portion of the bolt. If the clearance is not provided, the nut will not sit firmly against the washer and, in the case of /T category, the necessary turn-of-nut may not have been achieved.

Available Bolt Sizes:

Where possible, bolt sizes that are readily available should be used. Table 1 provides a summary of readily available commercial grade bolt sizes, i.e. bolt diameter and length options while Table 2 shows the same information for high strength structural bolts.

Diameter mm	Nominal Lengths																	
	40	45	50	55	60	65	70	75	80	85	90	95	100	110	120	130	140	150
M12	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M16	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M20	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M24			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M30							X	X	X	X	X	X	X	X	X	X	X	X
M32										X	X	X	X	X	X	X	X	X
	Usually supplied as full thread bolts																	

Table 1 – Readily Available Commercial Grade Bolt Sizes

Diameter mm	Nominal Lengths																	
		45	50	55	60	65	75	75	80	85	90	95	100	110	120	130	140	150
M16		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M20		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M24		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M30			X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
M36							X	X	X	X	X	X	X	X	X	X	X	X
	Bolts with shortened thread lengths Minimum body length = 0.5 x bolt diameter																	

Table 2 - Readily Available Structural High Strength Grade Bolt Sizes

Coronet Load Indicators:

Coronet Load Indicators are designed for use with High Strength Structural Bolts and provide a simple, and accurate aid to tightening and inspection; being supplied with a galvanised coating provides good corrosion resistance.

The Load Indicators are special hardened washers carrying 4 to 7 protrusions (bulges), depending on the diameter of the bolt and are assembled with the protrusions bearing against the underside of the bolt head, leaving a gap. The nut is then tightened until the protrusions are flattened and reduced to that shown in **Error! Reference source not found.**. The induced bolt tension at this average gap will not be less than the minimum specified tension in **Error! Reference source not found.**. In applications where it is necessary to tighten by rotating the bolt head rather than the nut, the Coronet Load Indicator can be fitted under the nut using an extra hard round washer under the nut and protrusions bearing against the washer (Figure 14).

Figure 10

In tightening with the Load Indicators, it is still required that this tightening be carried out in two stages. The first stage involves a preliminary tightening to a "snug tight" condition using a podge spanner or a pneumatic impact wrench.

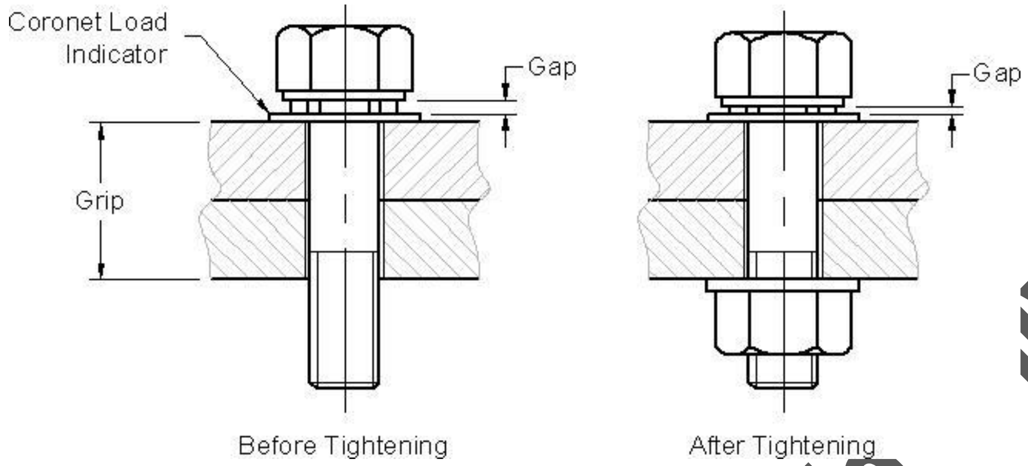


Figure 11

Figure 12 – Podge Spanner

Figure 13 – Pneumatic Impact Wrench

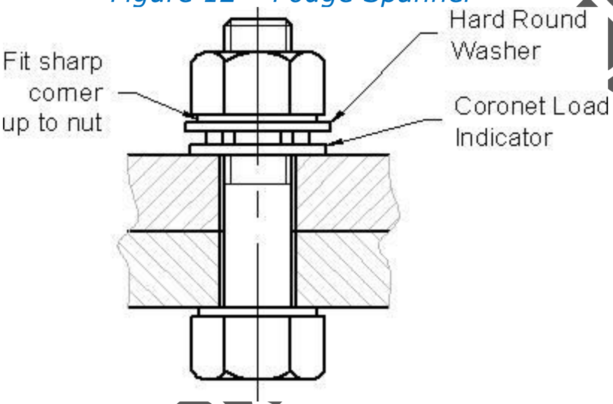


Figure 14

The object of the initial tightening is to draw the mating surfaces into effective contact. On large joints, take a second run to ensure that all the bolts are "snug tight". Carry out the final tightening by reducing the gap between the bolt head and the load indicator to 0.40mm or less and this can be checked with a feeler gauge (Figure 11 & Figure 15).

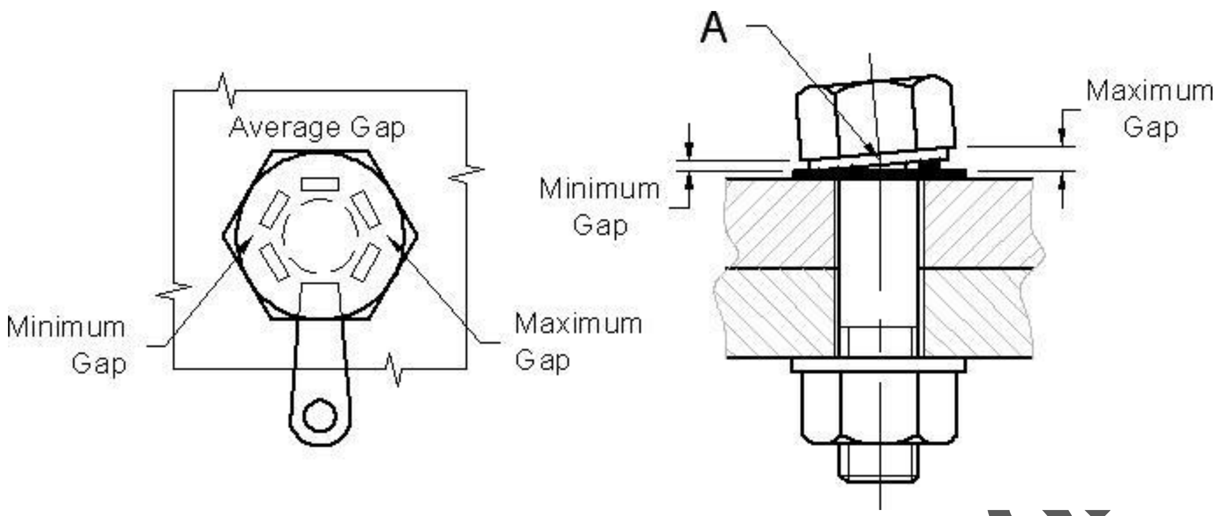


Figure 15

When the gap is not uniform, the average gap should be measured midway between the maximum and minimum gaps with a feeler gauge.

Bolt Designation on Drawings:

All bolts must be indicated on detail, assembly, installation on erection drawings as shown below:

12-M20x2x150x100

Where:

12 = The number of bolts.

M = Type of thread (Metric).

20 = Diameter in millimetres.

2 = Pitch of thread in millimetres.

150 = Total length of the shank and bolt.

100 = Length of thread on shank.

Letters designating the type of bolt can also be added:

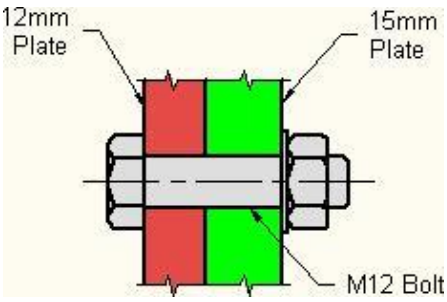
HSFG

HSGF = High Strength Friction Grip.

Skill Practice Exercise MSATCS302-SP-101:

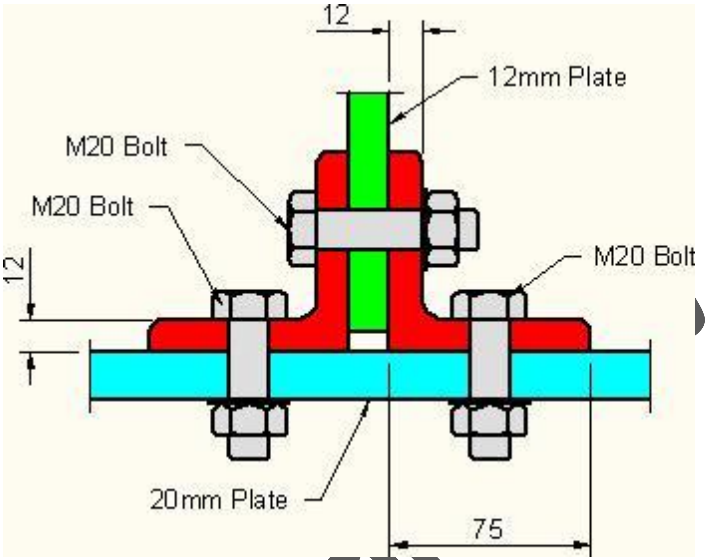
Calculate the length of bolt required to assembly the following connection joints:

1.



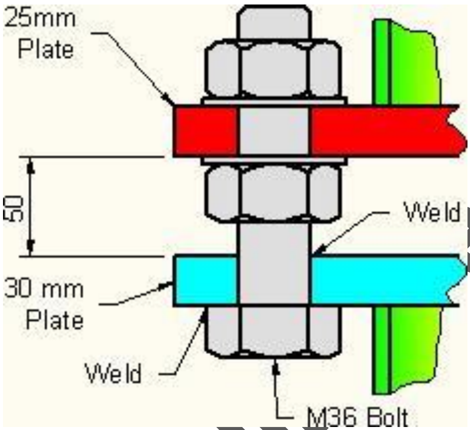
M12 Commercial Bolt

2.



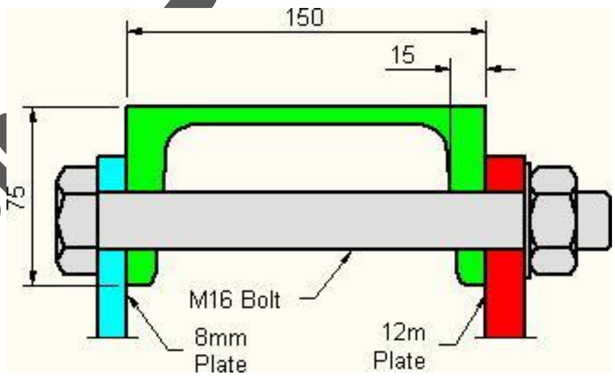
M20 Structural High Strength Bolt

3.



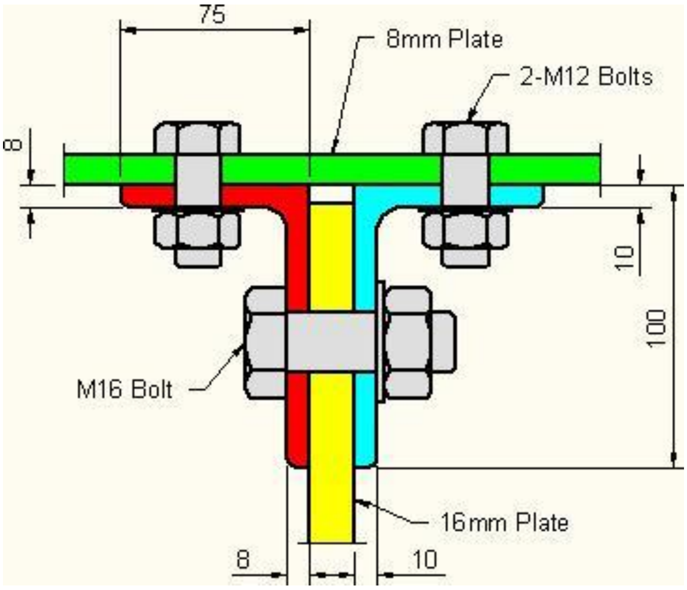
M36 Structural High Strength Bolt

4.



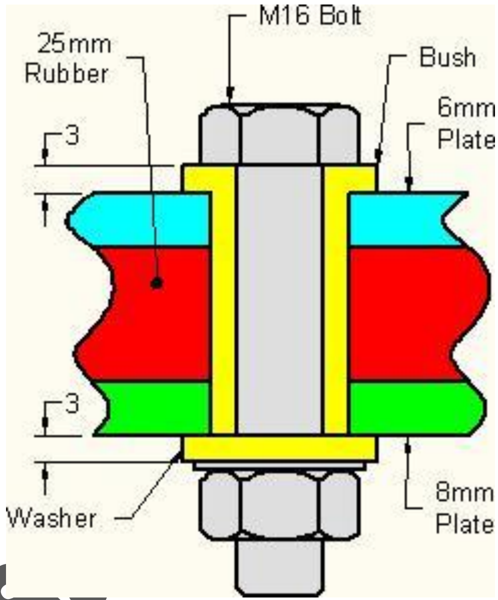
M16 Structural High Strength Bolt

5.



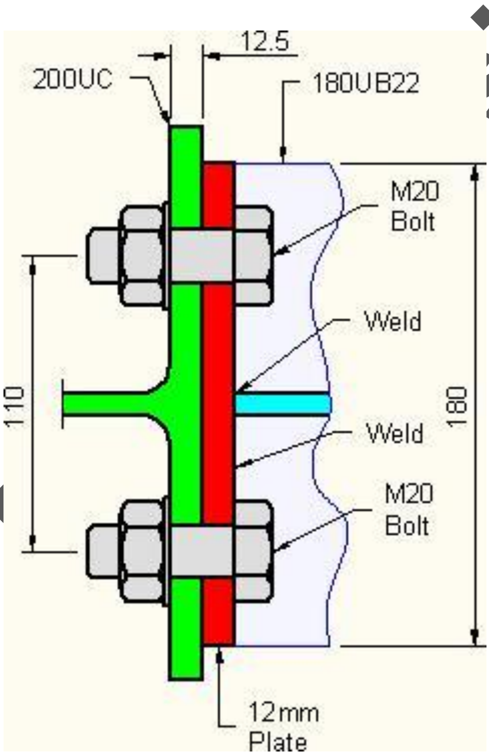
M12 Commercial Bolt and M16 Structural High Strength Bolt

6.



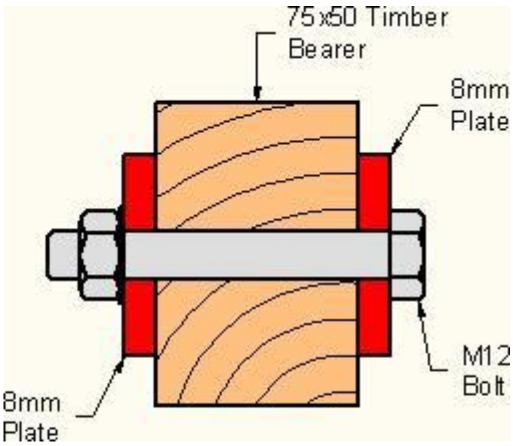
M16 Commercial Bolt

7.



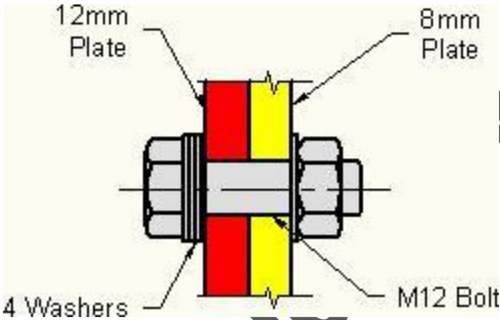
M20 Structural High Strength Bolt

8.



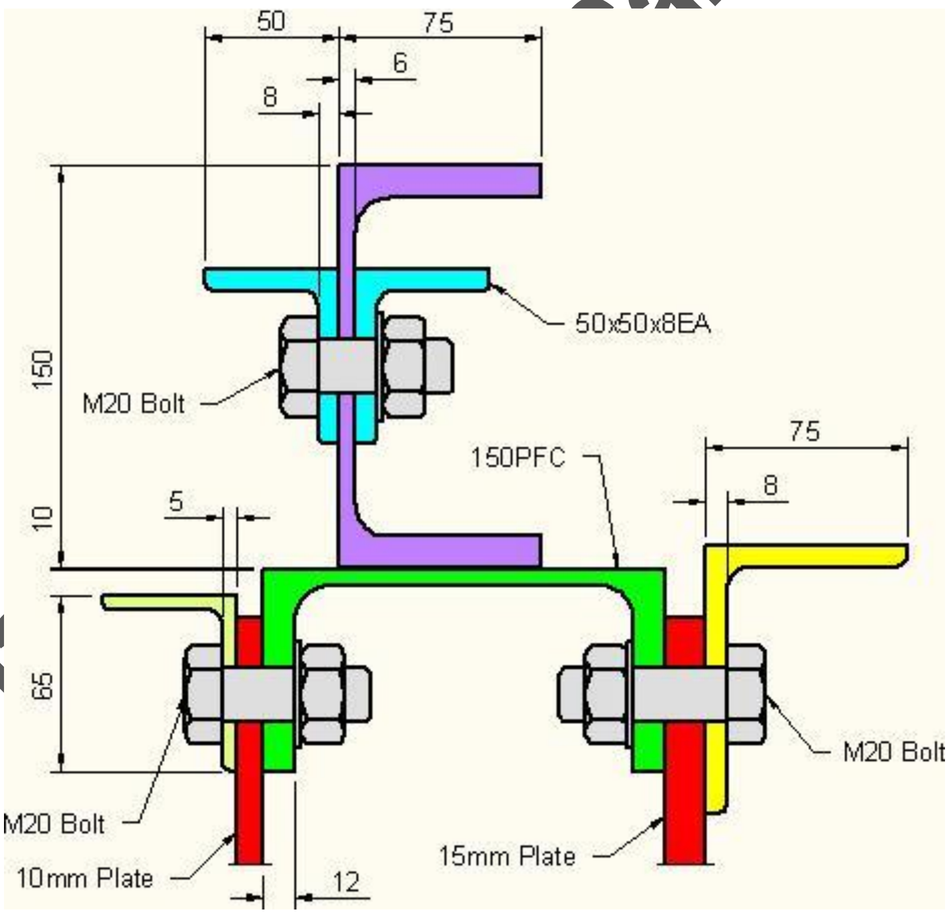
M12 Commercial Bolt

9.



M12 Commercial Bolt

10.



M20 Structural High Strength Bolt

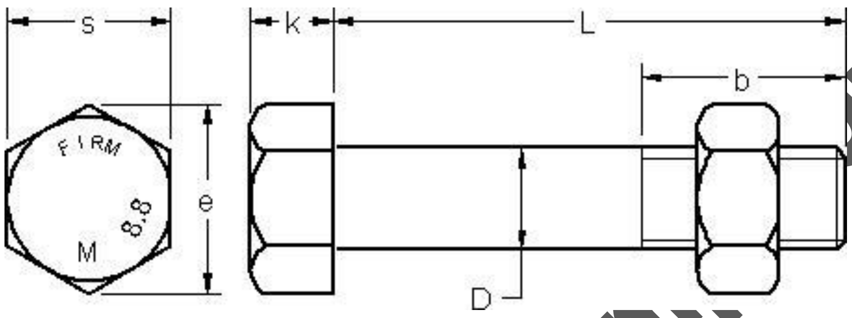
Addendums:

Addendum 1 – Metric Hexagon Commercial Bolts & Set Screws:

Thread ISO Metric Coarse Pitch Series

Thread Class 8g, Property Class 4.6

Dimensions to AS1111-1996



Size D	Pitch of Thread	Body Diameter (On Bolts) Ds		Width Across Flats s		Head Thickness k		Across Corners e
		Max	Min	Max	Min	Max	Min	Min
M6	1.0	6.48	5.52	10.0	9.64	4.38	3.62	10.89
M8	1.25	8.58	7.42	13.0	12.57	5.68	4.92	14.20
M10	1.5	10.58	9.42	16.0	15.57	6.85	5.95	17.59
M12	1.75	12.70	11.30	18.0	17.57	7.95	7.05	19.85
M14	2.0	14.70	13.30	21.0	20.16	9.25	8.35	22.78
M16	2.0	16.70	15.30	24.0	23.16	10.75	9.25	26.17
M18	2.5	18.70	17.30	27.0	26.16	12.40	10.60	29.56
M20	2.5	20.84	19.13	30.0	29.16	13.40	11.60	32.95
M22	2.5	22.84	21.16	34.0	33.00	14.90	13.10	37.29
M24	3.0	24.84	23.16	36.0	35.00	15.90	14.10	39.55
M27	3.0	27.84	26.16	41.0	40.00	17.90	16.10	45.20
M30	3.5	30.84	29.16	46.0	45.00	19.75	17.65	50.85
M33	3.5	34.00	32.00	50.0	49.00	22.50	19.95	55.37
M36	4.0	37.00	35.00	55.0	53.80	23.55	21.45	60.79
M36	4.0	40.00	38.00	60.0	58.80	26.05	23.95	66.44
M42	4.5	43.00	41.00	65.0	63.10	27.67	24.35	71.30
M48	5.0	49.00	47.00	75.0	73.10	31.65	28.35	82.60
M56	5.5	57.20	54.80	85.0	82.80	36.95	33.05	93.56

M64	6.0	65.20	62.80	95.0	92.8	41.95	39.05	104.86

All dimensions are in millimetres. See **Error! Reference source not found.** for nominal thread lengths.