Structural Bolt Assemblies – **EN14399-3 HR System used in Australia**

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Background

Most high strength structural bolt assemblies available on the Australian market today are manufactured overseas. The quality of such products is dependent on the quality culture of the manufacturer. Large manufacturers who supply the European markets have to maintain factory production control (FPC) and initial type testing (ITT) when a change is made in the process as well as third party accreditation of the manufacturing facilities to satisfy rigorous quality assurance standards set up in Europe. These systems ensure that a traceable consistent quality is maintained in the production line.

The requirements of fastener manufacturing standards such as ISO16426 are satisfied by these manufacturing facilities of quality products. Also they provide documentation that can be verified and are related to each manufacturing/assembly lot. These manufacturers supply high strength structural bolt assemblies that meet all necessary requirements of the Euronorm standards such as EN14399.

The previous Australian high strength structural bolting standards AS/NZS 1252:1983 and AS/NZS 1252:1996 are outdated by two decades and did not have a rigorous compliance regime suitable for imported products. To fill this gap, AS/NZS 1252 was completely overhauled and a more comprehensive standard AS/NZS 1252.1/.2:2016 was released.

Major changes in this revision were inclusion of product compliance requirements and a mandatory assembly test. This standard was formulated as a stepping stone to eventual alignment with European standards, which were well accepted and tested in Europe.

The AS/NZS 1252.1:2016 allows alternative assembly type EN14399-3 HR PC8.8/8 HDG to be used in Australia. This product is a matured product in European countries with manufacturing already set up with quality assurance systems to suit comprehensive European requirements. Australia now has access to such product to be used in Australia under the guidance of AS/NZS 1252.1/.2:2016. There are reputable Australian fastener distributors who are currently supplying such product sourced from quality overseas manufacturers. The product comes with traceable authentic quality assurance documentation.

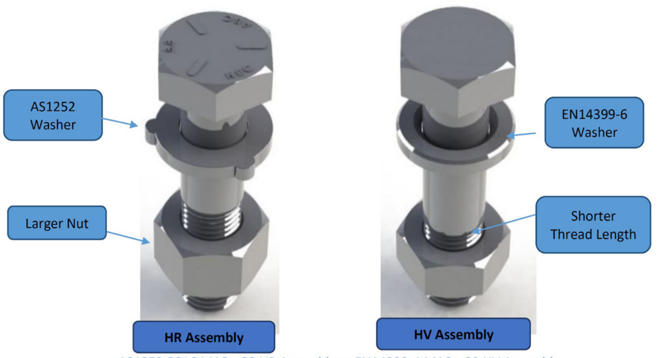
Furthermore AS/NZS 1252.1 allows the use of additional assembly type EN14399-3 HR PC10.9/10 HDG to be used in Australia. The details of system HR and system HV as introduced by EN14399-3 and EN14399-4 respectively will be discussed in the following sections.

EN14399-3 System HR PC8.8/8 HDG - AS/NZS1252.1:2016 Alternative assembly type

European standard EN14399 uses two systems, namely System HR and System HV, based on the way they achieve the necessary ductility in the joint. System HR has at least four threads between bearing face of the nut and the thread run-out. During loading, this free thread section deforms to provide necessary ductility. As necking would occur in free thread section, the engaged threads with the thicker nut remain free from deformation. As a result, the nut can be removed easily. Thread stripping is not an acceptable mode of failure. This is similar to the principles used by AS4100/NZS3404 for achieving ductility in the joint.

> System HR is fully compatible with the existing design practice in Australia and New Zealand. This is why PC8.8 EN14399-3 HR bolts are nominated as alternative assembly type for AS/NZS 1252.1:2016 bolts.

High strength bolt assemblies made and which conform to EN14399-3 via the conformity requirements set up by the same standard are considered to be conforming to AS/NZS1252.1:2016.



AS1252:2016 M16 x 80 HR Assembly vs EN14399-4 M16 x 80 HV Assembly

Figure 1: AS1252:2016 M16 x 80 HR Assembly vs EN14399-4 M16 x 80HV Assembly

EN14399-3 System HR PC10.9/10 HDG - AS/NZS1252.1:2016 Additional Assembly Type

Similarly, AS/NZS 1252.1:2016 recognizes EN14399-3 System HR PC10.9/10 as an additional assembly type. As System HR has longer unused thread length between the nut bearing face and thread run-out to provide necessary ductility, it is quite possible that a shear plane of the joint would go through the threaded area. Due to increased brittleness in PC10.9, a reduction factor of 0.833 should be used (Based on Eurocode 3 1-8 and AS4100) when calculating the shear area, thus making the shear capacity more or less similar to that of PC8.8. For friction grip joints, the maximum tension of additional assembly type bolts will be that of PC10.9, but the shear capacity would be very close to that of PC8.8, thus nullifying the benefit of using PC10.9 if the shear plane crosses the thread area. If the shear plane does not cross the thread area, it can have the full shear capacity of a PC10.9 bolt.

What is EN14399.4 System HV PC10.9/10 HDG?

System HV tries to overcome this problem. It has short thread lengths and thinner nuts, forcing the ductile deformation to occur in the engaged thread. As such, thread damage would occur in the nut during tightening, making it not readily removable. For System HV, thread stripping failure is acceptable. If removal is necessary, System HV is not suitable, as it almost always has a jammed nut. The assembly test for System HV is identical to that of System HR, and therefore the total ductility available in both assemblies will be similar. As it was designed for a specific purpose, System HV is only available in PC10.9. Due to short thread lengths, shear plane passing the threaded area could be avoided, thus achieving a higher shear capacity to match the higher tension capacity.

However, due to possible thread stripping failure, current AS/NZS 1252.1:2016 and AS4100/AS5100/NZS3404 do not allow the use of system HV bolts. The reliability factors established in AS4100/AS5100/NZS3404 design standards are based on bolt assemblies where thread stripping failure is unacceptable and ductility is achieved via deformation of the free thread length between nut bearing face and thread run-out.

k-Classes and Assembly Testing

Both system HR and HV define k-classes through either the basic (K0) or extended (K1, K2) assembly test as referred by AS/NZS 1252.1:2016. EN14399-2 provides the full details of the assembly test. The k-classes are defined by the information provided from the assembly test.

k-Class	Assembly Testing Information		
	Min. Nut Rotation ($\Delta\Theta 2i$)	k factor (k_m)	Coefficient of Variation (V_k)
K0	✓	X	X
K1*	✓	✓	X
K2	✓	✓	✓

*K1 – Not used or specified in the Australian market.

Table 1: Assembly test information required for each k-class

The following is a description of k-class.

For all k-classes nut rotation ($\Delta\Theta 2i$) should be greater than a prescribed value dependent on the bolt length. Longer bolts require greater nut rotation. These values are given in AS/NZS 1252.1:2016, EN14399.3 HR and EN14399.4 HV for respective bolt assemblies.

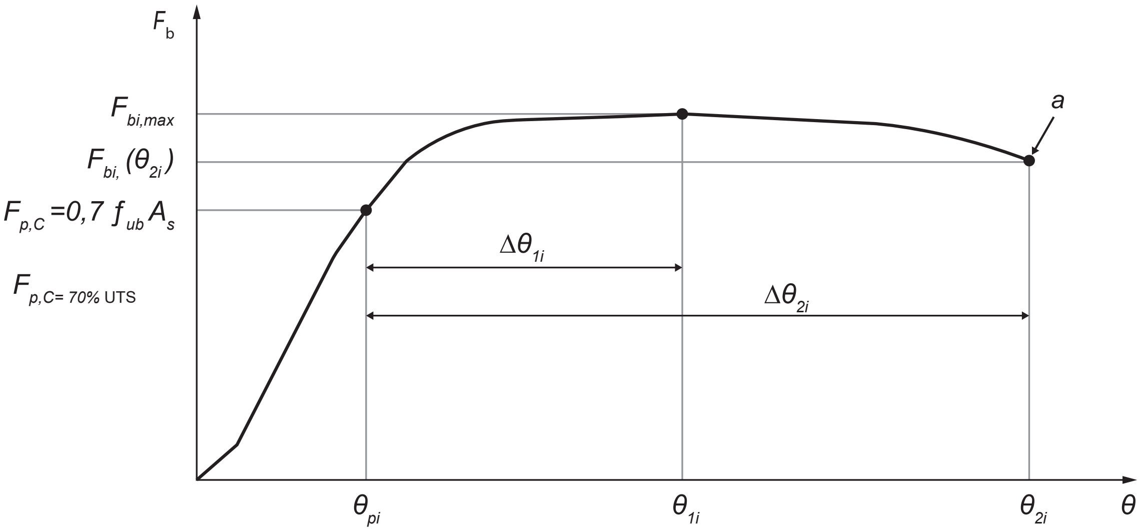


Figure 2: A typical Bolt force vs Rotation Curve for System HR and HV structural bolt assemblies.

For class K0 the only requirement is to have a nut rotation (ΔΘ2i) greater than the prescribed value. Class K0 can be fully tensioned using part-turn or direct tension indicator (DTI) methods as described in AS4100/NZS3404. The assembly test makes sure the product is suitable for preloading by confirming that the minimum bolt tension and nut rotation can be achieved. Unlike other k classes, additional lubrication may be used with K0 class to make the assembly process easier. A good quality K0 product should not need any further lubrication.

For class K1 and K2 the bolt force vs tightening torque curve is required (Figure 3).

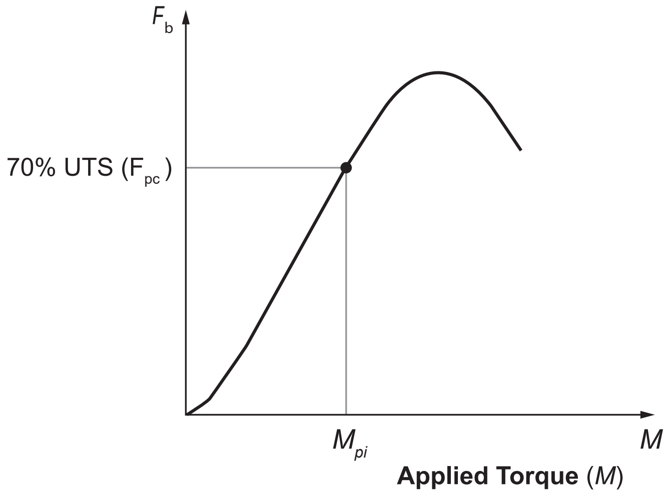


Figure 3: Bolt force Fb vs Tightening torque M

$$K_i = \frac{M_{pi}}{d.\ F_{pC}}$$

An individual k factor (ki) is obtained as follows:

Where M_{pi} is the torque at a bolt force of F_{pC} and d is the nominal diameter of the fastener.

Then the mean value of k factor km (ki) is defined as;

$$K_m = \frac{\Sigma_{i=1}^{n} K_i}{n}$$

For k-class K1 all ki values should be in the range 0.10 ≤ ki ≤ 0.16.

Class K1 can be used with combined torque and part-turn tightening procedures as prescribed in EN1993-1-8 (Eurocode 3). This product should be kept at ‘as supplied’ conditions in a sealed container. No further lubrication should be added during assembly process. **Currently K1 is not used or specified in the Australian market.**

The coefficient of variation (Vk) of the above ki values is given by the ratio of their estimated standard deviation (sk) and its mean value $k_{m.}$

$$S_k = \sqrt{\frac{\Sigma_{i=1}^{n} (k_i - k_m)^2}{(n-1)}}$$

$$\text{Now } V_k = \frac{S_k}{k_m}$$

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For k-class K2;

$0.10 \le km \le 0.23$ and

$Vk \le 0.06$

For class K2 product the torque M_{spec} required to achieve a desired bolt force of F_{spec} can be calculated using the formula.

$$M_{spec} = k_m d F_{spec}$$

Where d is the nominal diameter of the bolt.

When Class K2 product is used with a calibrated torque wrench as a tightening method, it will satisfy AS4100 definition of a direct tension measuring device since the above calibration verifies the torque-tension relationship.

It is paramount that the lubrication of the bolt assembly should not be altered in anyway and the product kept in a sealed container from calibration to the point where it is used.

In general, the quality of the bolt assembly is somewhat related to the k class as a higher k class requires more stringent tests. At the same time, handling of higher k class product should be done with extreme care as the torque-tension relationship is highly dependent on the lubrication of the assembly. The lubrication level of the assembly shall not be altered under any circumstances. Even handling the product with greasy hands could alter the torque-tension relationship.

Potential for Hydrogen Embrittlement of PC10.9 HDG product

Hot dip galvanised (HDG) PC10.9 bolts has been used in construction around the world successfully over the past three decades. The modern standards such as ISO10684 provide methods of eliminating the risk of Hydrogen Embrittlement in PC10.9 bolts. Inhibited acids, mechanical means or alkaline solutions are used for cleaning the products prior to hot dip galvanising, minimising the risk of hydrogen atoms coming in contact with the surface. Subsequent baking process introduced in the HDG coating process by above standards, when applied correctly, would completely eliminate the risk of Hydrogen Embrittlement. Countries such as Japan and Korea have been using HDG PC10.9 bolts extensively without any reported HE related failures. EN14399-3 specifies hot dip galvanised bolts via ISO10684 standard for both PC8.8 and PC10.9 assemblies.

Design preload values on 14399.3 System HR PC10.9/10 bolt assemblies

Guidance has been taken from Eurocode 3 1-8 (EN1993 1-8) to determine the design preload requirement for PC10.9/10 HR bolt assemblies. Table 2 shows the design preload values for EN14399.3 PC10.9/10 HRC bolt assemblies. This requires a minimum pre-tension of $0.7f_{ub}A_s$ (70% of nominal ultimate tensile load) and a minimum mean value of pretension of $0.77f_{ub}A_s$ suitable for TF/TB fully preloaded bolted joints.

14399-3 = HR = GOOD
14399-4 = HV = BAD

Table 2: Design preload values for EN14399.3 PC10.9/10 HRC bolt assemblies.

f_{ub} is the nominal tensile strength of the bolt ($R_{m,\ nom}$).
= 1000MPa for PC10.9.

Nominal Size	Nominal stress area of standard test mandrel	Minimum Individual Bolt Tension	Minimum Mean Bolt Tension
	A_s [mm²]	$F_{r\ min}$ $0{,}7\ f_{ub}\ A_s$ [kN]	$F_{r\ mean\ min}$ $0{,}77\ f_{ub}\ A_s$ [kN]
M12	84.3	59.10	64.91
M16	157	109.90	120.89
M20	245	171.50	188.65
M22	303	212.10	233.31
M24	353	247.10	271.81
M27	459	321.30	353.43
M30	561	392.70	431.97
M36	871	517.9	629.09

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