AD 373
Connections using preloaded bolts, subject to combined shear and tension

Queries have been raised regarding the verification of connections subject to combined shear and tension when using preloaded bolts, for connections designed in accordance with BS EN 1993 1 8:2005 (Amd 2010) and the UK National Annex.

This Advisory Desk note gives a summary of the checks required, where in BS EN 1993 1 8 the check is identified and where appropriate, provides guidance for such connections.

All the references are to BS EN 1993 1 8 unless otherwise stated.

All symbols are as defined in BS EN 1993-1-8 unless otherwise stated.

SLS refers to Serviceability Limit State (i.e. verify against SLS loads).

ULS refers to Ultimate Limit State (i.e. verify against ULS loads).

Combined shear and tension, slip-resistant at SLS

For shear:	**Category B: Slip resistant at SLS (3.4.1 (1) (b))**		
For tension:	**Category E (3.4.2 (1) (b))**		
$F_{v,Ed,ser} \le F_{s,Rd,ser}$	SLS		
$F_{v,Ed} \le F_{v,Rd}$	ULS		Table 3.2
$F_{v,Ed} \le F_{b,Rd}$	ULS		
$F_{t,Ed} \le F_{t,Rd}$	ULS	(*see comment below)	
$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4F_{t,Rd}} \le 1$	ULS	Table 3.4	

* The design tensile force, $F_{t,Ed}$, should include any force due to prying action. Alternatively in some cases, the design tensile force can be calculated by ignoring prying action, but in these cases the tensile resistance should be reduced. For more guidance, see Advisory Desk note AD354 (Resistance of bolted connections in tension for design to BS EN 1993 1 8), available at *www.steelbiz.org*.

Combined shear and tension, slip-resistant at ULS

For shear: Category C: Slip resistant at ULS (3.4.1 (1) (c))

For tension:	**Category E (3.4.2 (1) (b))**		
$F_{v,Ed} \le F_{s,Rd}$	ULS		Table 3.2
$F_{v,Ed} \le F_{b,Rd}$	ULS (**see comment below)		
$F_{v,Ed} \le N_{net,Rd}$	ULS		
$F_{t,Ed} \le F_{t,Rd}$	ULS (*see comment above)		
$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1.4F_{t,Rd}} \le 1$	ULS	Table 3.4	

** The verification of bearing resistance is required as a fail safe in case slip does occur in the connection. No separate verification is required for bolt shear resistance as it will always exceed the slip resistance, but the interaction between bolt shear and tension should be verified.

Slip resistances, Clause 3.9.2

$F_{s,Rd,ser} = \frac{k_s n \mu (F_{p,c} - 0.8F_{t,Ed,ser})}{\gamma_{M3,ser}}$	SLS	(Eq. 3.8a)
$F_{s,Rd} = \frac{k_s n \mu (F_{p,c} - 0.8F_{t,Ed})}{\gamma_{M3}}$	ULS	(Eq. 3.8b)

Shear, bearing and tension resistances

$F_{v,Rd} = \frac{\alpha_v f_{ub} A}{\gamma_{M2}}$	ULS		Table 3.4
$F_{b,Rd} = \frac{k_1 \alpha_b f_u dt}{\gamma_{M2}}$	ULS		
$F_{t,Rd} = \frac{k_2 f_{ub} A_s}{\gamma_{M2}}$	ULS		
$N_{net,Rd} = \frac{A_{net} f_y}{\gamma_{M0}}$	ULS	(Eq. 6.8, BS EN 1993 1 1: 2005)	

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