AD 402:
Design of end plate joints made with preloaded bolts subject to coincident shear and tension.

Advisory Desk note AD373 gave a summary of the checks required on connections subject to combined shear and tension. This AD note discusses the behaviour of such a connection in more detail.

Where a preloaded bolt in a joint is subject to a tensile force, the preload is theoretically not affected but the clamping force between the plates is reduced. This is based on the assumption that the bolt acts as a spring and the plates are infinitely stiff. In reality, the plates are not infinitely stiff and the clamping force is only reduced by 80% of the applied tension. Where a bolted joint consisting of end plates and preloaded bolts is subject to both shear and tension, the applied tension reduces the clamping force between the faying surfaces and the shear resistance of the joint is therefore also reduced.

Bolted joints designed with preloaded bolts are categorized in Table 3.2 of BS EN 1993-1-8:2005 either as shear connections: B (slip-resistant at serviceability), C (slip-resistant at ultimate) or as tension connections: E (preloaded). If a joint of the type described is subject to both shear and tension, and it is necessary to eliminate slip at either serviceability or ultimate limit states (category B or C), additional preload is required in the joint which may mean additional bolts to ensure no slip occurs.

Clause 3.9.2 deals with this issue and formulae for the design slip resistance per bolt are given in equations 3.8a and 3.8b for category B and C connections respectively. In each case, the bolt preloading force is reduced by 80% of the tension force in the bolt as result of the design value of the loading (effect of actions), to allow for the flexibility of the end plates. For example, for the serviceability case, equation (3.8a) is:

$$F_{s,Rd} = \frac{k_s n \mu}{\gamma_{M3}} \left(F_{p,C} - 0.8F_{t,Ed,ser}\right)$$

Prying action results in an increased bolt tension and an equal and opposite compression between the plates in the joint. There is therefore no reduction in clamping force due to prying and $F_{t,Ed}$ does not need to include any prying force.

Consider an end plate joint made with eight M20 grade 8.8 bolts subject to a shear of 200 kN and a coincident tension of 500 kN. If we assume the holes are normal, there is one friction plane, the friction surface is class B and the joint is class C, the preloading force in a bolt is 137.2 kN. The tension per bolt is 62.5 kN so the reduction in preload per bolt is 50 kN.

The design slip resistance of a grade 8.8 or 10.9 preloaded bolt is given in clause 3.9.1(2) as:

$$F_{s,Rd} = \frac{k_s n \mu}{\gamma_{M3}} \left(F_{p,C} - 0.8F_{t,Ed}\right) = \frac{1.0 \times 1.0 \times 0.4}{1.25} \times (137.2 - 50) = 27.9\text{kN}$$

The design shear divided by the design slip resistance is 200/27.9 = 7.2 so eight bolts are required. If no tension were present, six bolts would be sufficient to carry the design shear force.

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