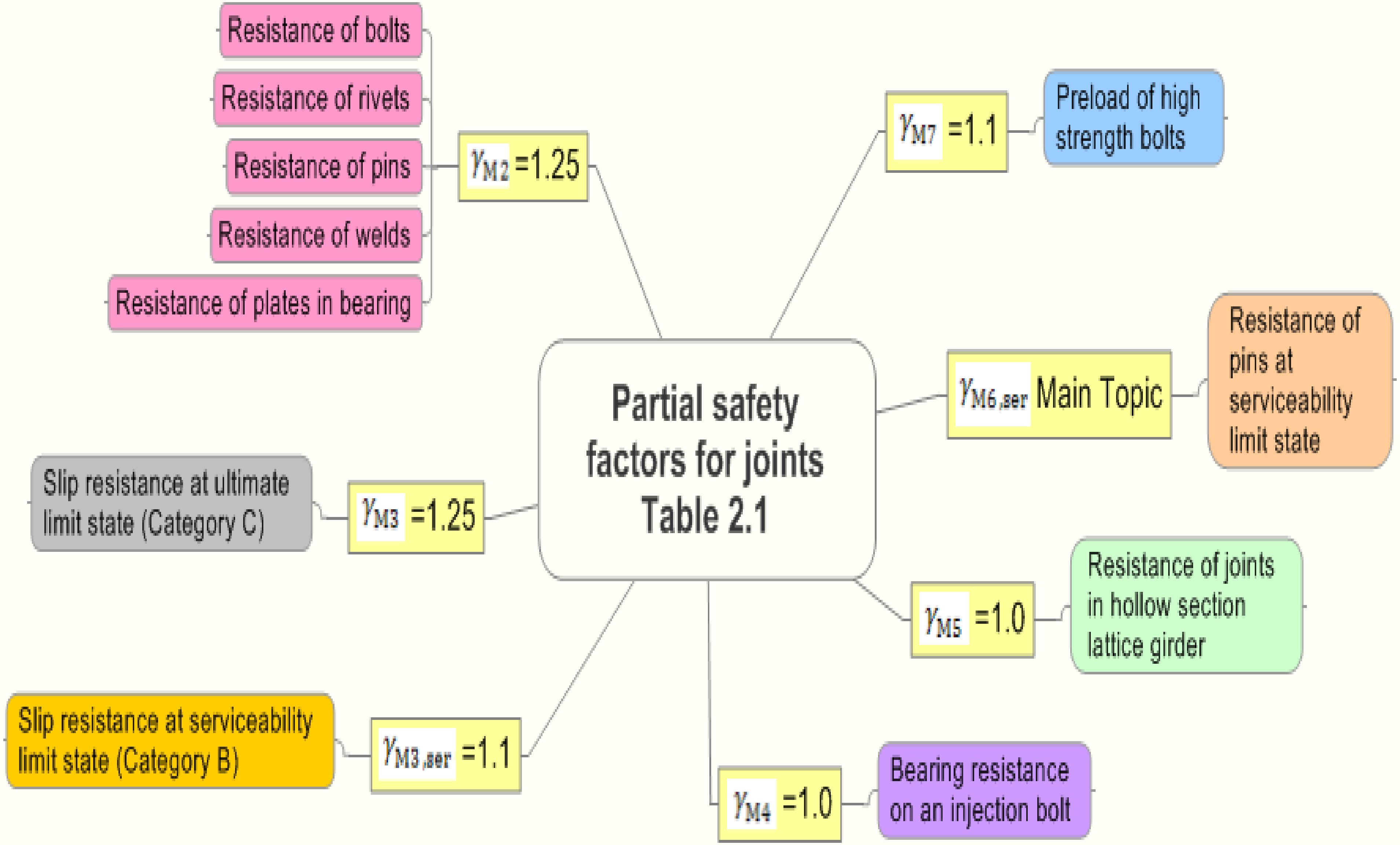
BS EN 1993-1-8:2005

Eurocode 3: Design of Steel Strutures
Part 1-8 : Design of Joints

- Connections, treated as structural elements
- Rules provided to determine the design parameters e.g. stiffness, strength and rotation capacity
- Connections modeled by using **component-based approach**

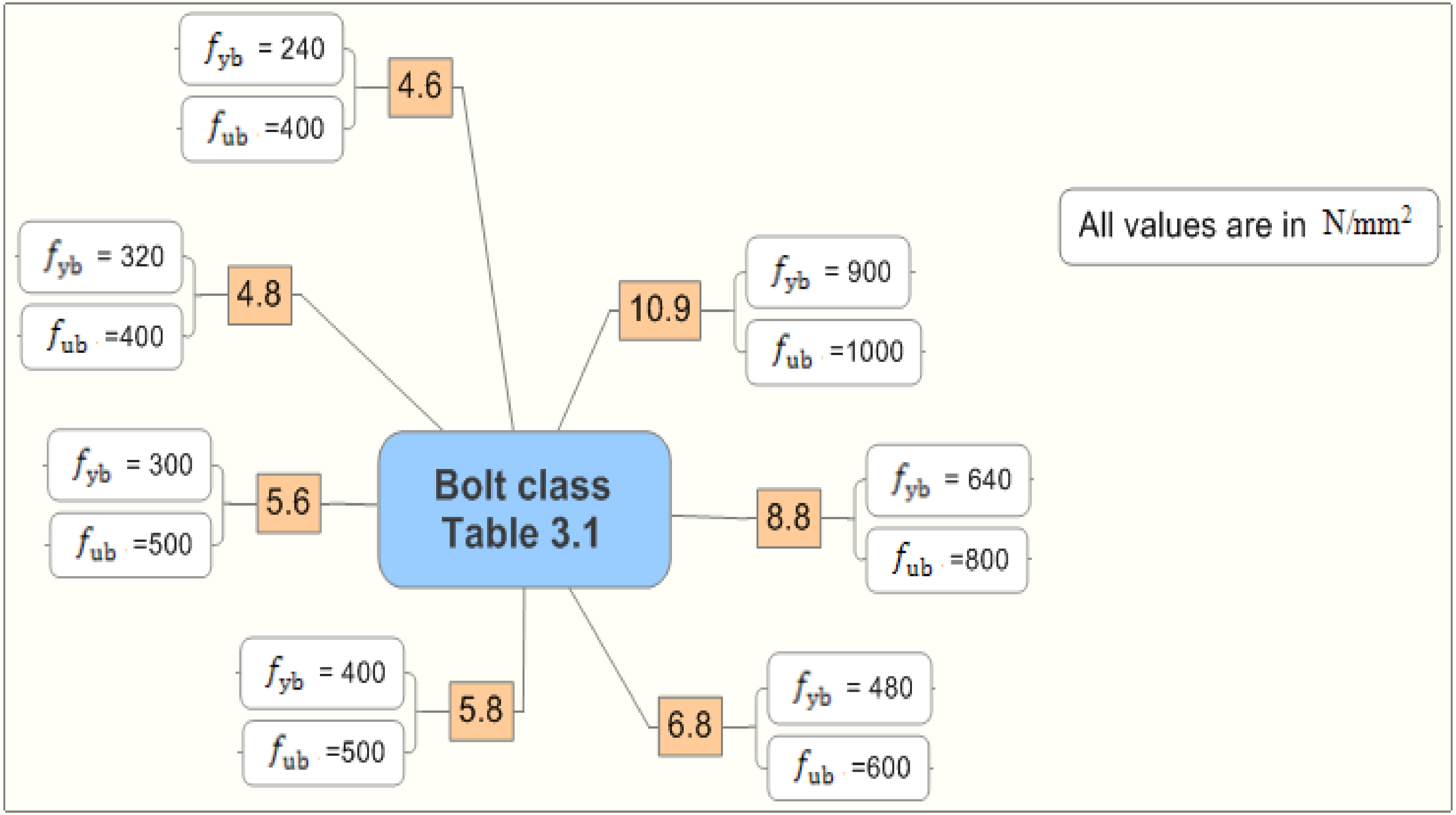
2. Basis of Design



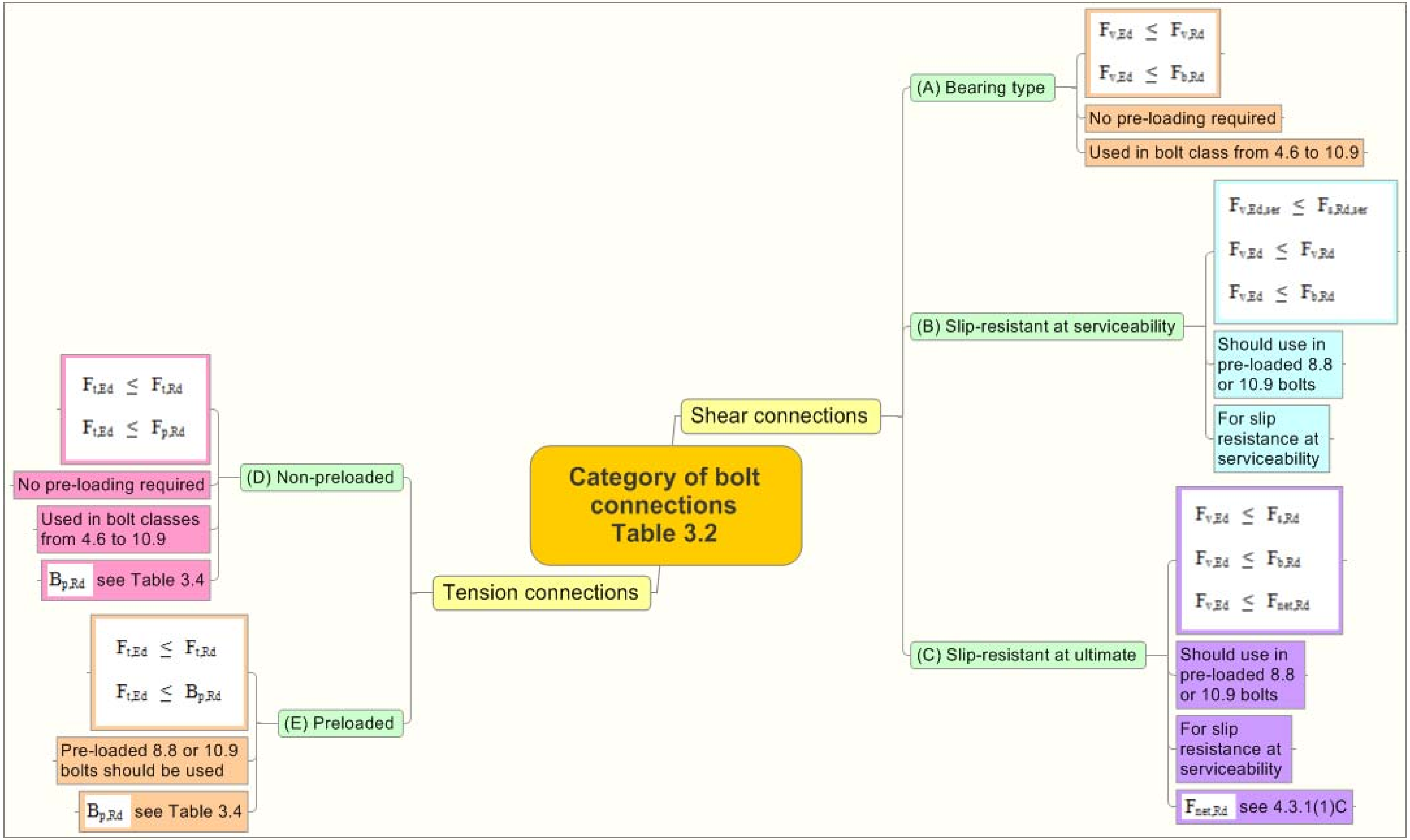
BOLTED CONNECTIONS

- Bolt classes 4.6, 4.8, 5.6, 5.8, 6.8, 8.8 and 10.9
- Bolted connection loaded in shear should be designed as:
  - Category A: Bearing type
  - Category B: Slip-resistant at serviceability limit state
  - Category C: Slip-resistant at ultimate limit state
- Bolted connection loaded in tension:
  - Category D: non-preloaded
  - Category E: preloaded

Bolt Connection



Bolt Connection



Positioning of holes

Table 3.3: Minimum and maximum spacing, end and edge distances

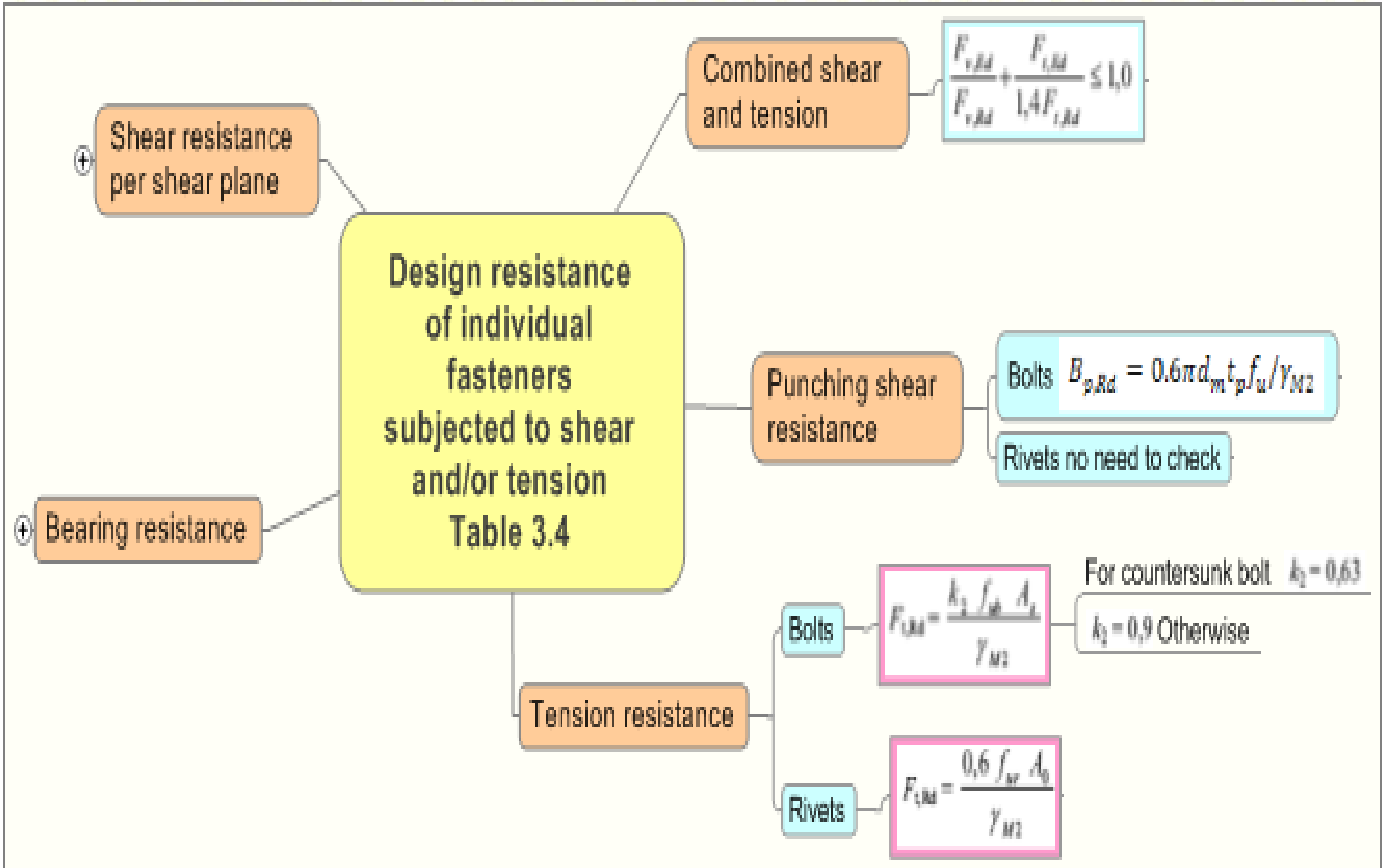
Distances and spacings, see Figure 3.1	Minimum	Maximum [1) 2) 3)]		
		Structures made from steels conforming to EN 10025 except steels conforming to EN 10025-5		Structures made from steels conforming to EN 10025-5
		Steel exposed to the weather or other corrosive influences	Steel not exposed to the weather or other corrosive influences	Steel used unprotected
End distance e_1	$1{,}2d_0$	$4t + 40$ mm		The larger of $8t$ or 125 mm
Edge distance e_2	$1{,}2d_0$	$4t + 40$ mm		The larger of $8t$ or 125 mm
Distance e_3 in slotted holes	$1{,}5d_0$ [4)]			
Distance e_4 in slotted holes	$1{,}5d_0$ [4)]			
Spacing p_1	$2{,}2d_0$	The smaller of $14t$ or 200 mm	The smaller of $14t$ or 200 mm	The smaller of $14t_{min}$ or 175 mm
Spacing $p_{1,0}$		The smaller of $14t$ or 200 mm		
Spacing $p_{1,i}$		The smaller of $28t$ or 400 mm		
Spacing p_2 [5)]	$2{,}4d_0$	The smaller of $14t$ or 200 mm	The smaller of $14t$ or 200 mm	The smaller of $14t_{min}$ or 175 mm

DESIGN RESISTANCE

Table 3.4: Design resistance for individual fasteners subjected to shear and/or tension

Failure mode	Bolts	Rivets
Shear resistance per shear plane	$F_{v,Rd} = \frac{\alpha_v \; f_{ub} \; A}{\gamma_{M2}}$ - where the shear plane passes through the threaded portion of the bolt (A is the tensile stress area of the bolt A_s): - for classes 4.6, 5.6 and 8.8: $\alpha_v = 0{,}6$ - for classes 4.8, 5.8, 6.8 and 10.9: $\alpha_v = 0{,}5$ - where the shear plane passes through the unthreaded portion of the bolt (A is the gross cross section of the bolt): $\alpha_v = 0{,}6$	$F_{v,Rd} = \frac{0{,}6 \; f_{ur} \; A_0}{\gamma_{M2}}$
Bearing resistance [1), 2), 3)]	$F_{b,Rd} = \frac{k_1 \, \alpha_b \, f_u \, d \, t}{\gamma_{M2}}$ where α_b is the smallest of α_d ; $\frac{f_{ub}}{f_u}$ or 1,0; in the direction of load transfer: - for end bolts: $\alpha_d = \frac{e_1}{3d_0}$; for inner bolts: $\alpha_d = \frac{p_1}{3d_0} - \frac{1}{4}$ perpendicular to the direction of load transfer: - for edge bolts: k_1 is the smallest of $2{,}8\frac{e_2}{d_0} - 1{,}7$ or 2,5 - for inner bolts: k_1 is the smallest of $1{,}4\frac{p_2}{d_0} - 1{,}7$ or 2,5	
Tension resistance [2)]	$F_{t,Rd} = \frac{k_2 \; f_{ub} \; A_s}{\gamma_{M2}}$ where $k_2 = 0{,}63$ for countersunk bolt, otherwise $k_2 = 0{,}9$.	$F_{t,Rd} = \frac{0{,}6 \; f_{ur} \; A_0}{\gamma_{M2}}$
Punching shear resistance	$B_{p,Rd} = 0{,}6 \, \pi \, d_m \, t_p f_u / \gamma_{M2}$	No check needed
Combined shear and tension	$\frac{F_{v,Ed}}{F_{v,Rd}} + \frac{F_{t,Ed}}{1{,}4 F_{t,Rd}} \le 1{,}0$	

Design resistance



Design resistance : Shear resistance per shear plane

Shear resistance per shear plane

- **Bolts**

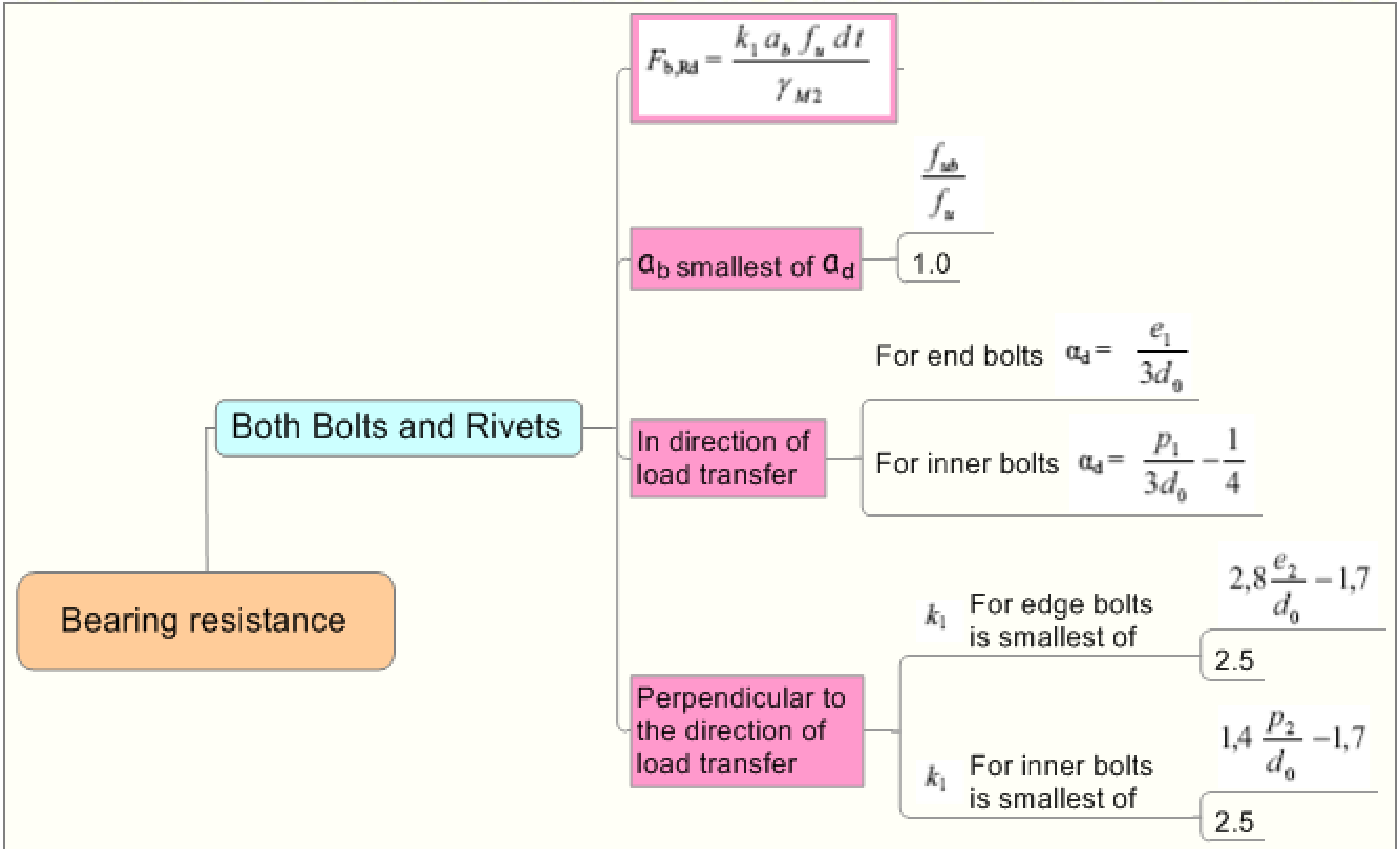
  $$F_{v,Rd} = \frac{\alpha_v \; f_{ub} \; A}{\gamma_{M2}}$$

  - Classes 4.6, 5.6 and 8.8: $\alpha_v = 0,6$
  - Class 4.8, 5.8, 6.8 and 10.9: $\alpha_v = 0,5$
  - Shear plane passes through the unthreaded portion of bolt: $\alpha_v = 0,6$

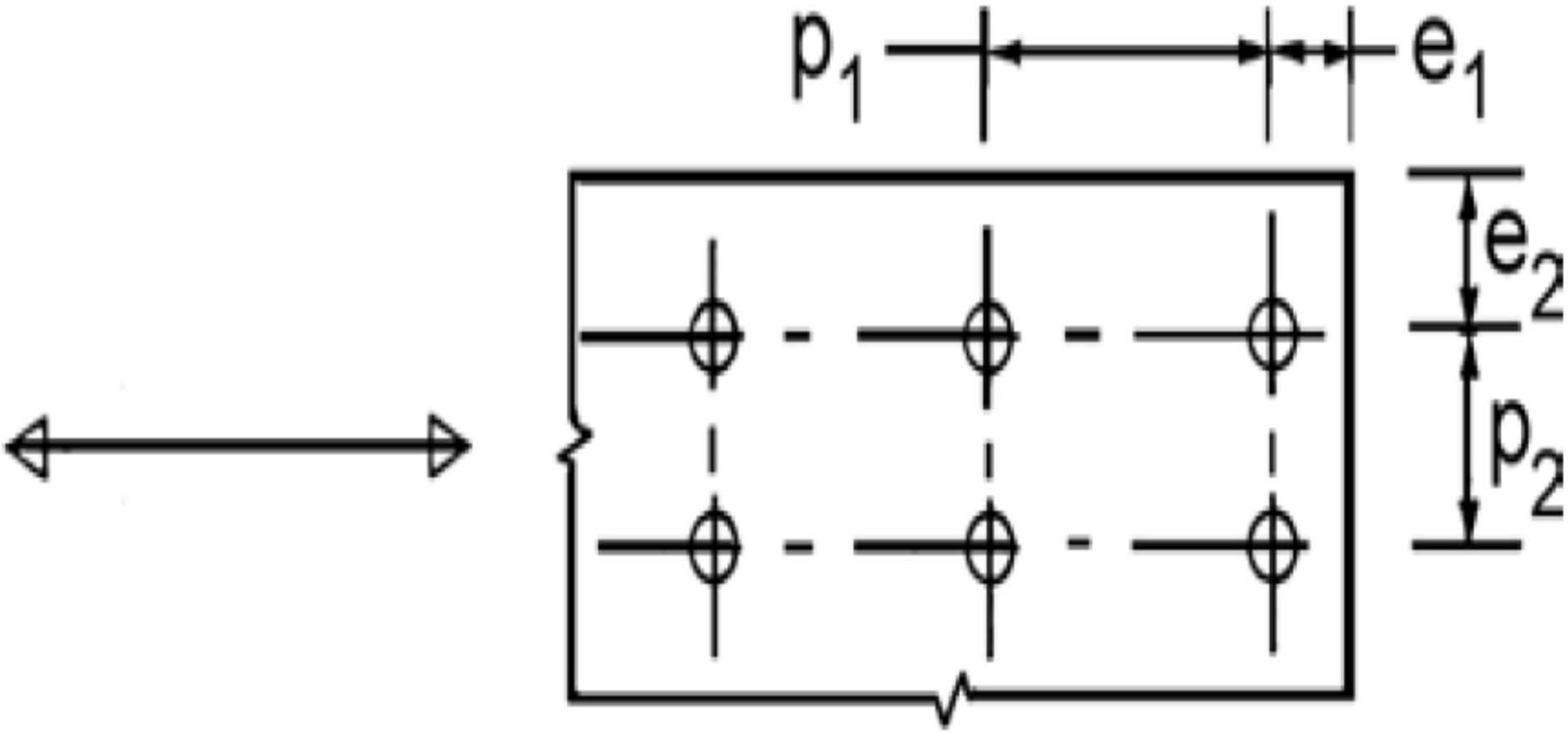
- **Rivets**

  $$F_{v,Rd} = \frac{0,6 \; f_{ur} \; A_0}{\gamma_{M2}}$$

Design resistance : Bearing resistance

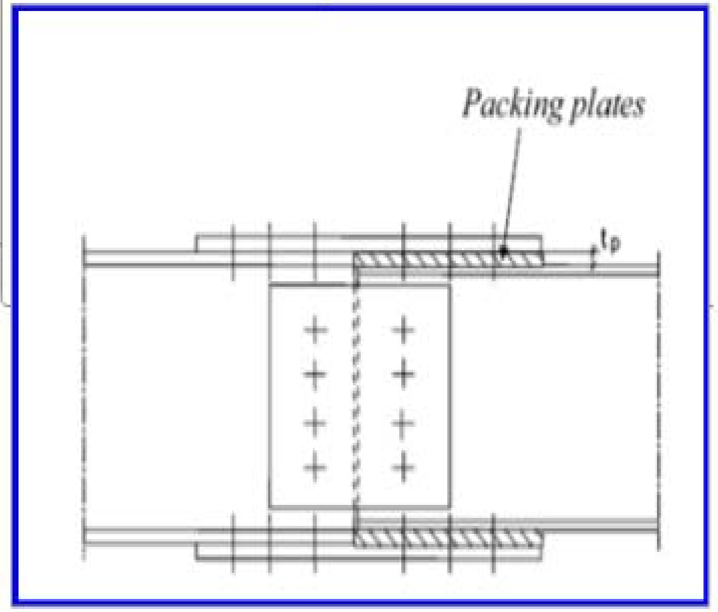


Definition of p1, e1, p2 and e2



Other conditions of resistance in bolt connection

Other conditions of resistance in bolt connection

- Long joints
  - Design shear resistance of all fastener should be reduced by factor β_{Lf}
  - $\beta_{Lf} = 1 - \dfrac{L_j - 15d}{200d}$ but $0.75 \le \beta_{Lf} \le 1.0$
- Bolts transmit load in shear and bearing and pass through packing of total thickness to t_p
  - $\beta_p = \dfrac{9d}{8d + 3t_p}$ but $\beta_p \le 1.0$
  - 

- Preloaded bolts
  - $\beta_{Lf} = 1 - \dfrac{L_j - 15d}{200d}$ but $0.75 \le \beta_{Lf} \le 1.0$

Slip resistant connections

Slip resistant connections using 8.8 or 10.9 bolts (cl.3.9)

- Design slip resistance
  - $F_{s\,Rd} = \frac{k_s n \mu}{\gamma_{M3}} F_{p,C}$
    - k_s given in table 3.6
    - n is the number of friction surfaces
    - μ is the slip factor given in table 3.7
    - $F_{p,C}$
      - $F_{p,C} = 0.7 \times 800 A_s$
      - $F_{p,C} = 0.7\, f_{ub} A_s$
- Combined tension and shear
  - $F_{s\,Rd,ser} = \frac{k_s n \mu (F_{p,C} - 0.8 F_{t,Ed,ser})}{\gamma_{M3}}$ Category B connections
  - $F_{s\,Rd} = \frac{k_s n \mu (F_{p,C} - 0.8 F_{t,Ed})}{\gamma_{M3}}$ Category C connections

Table 3.6: Values of k_s

Description	k_s
Bolts in normal holes.	1,0
Bolts in either oversized holes or short slotted holes with the axis of the slot perpendicular to the direction of load transfer.	0,85
Bolts in long slotted holes with the axis of the slot perpendicular to the direction of load transfer.	0,7
Bolts in short slotted holes with the axis of the slot parallel to the direction of load transfer.	0,76
Bolts in long slotted holes with the axis of the slot parallel to the direction of load transfer.	0,63

Slip resistant connections (continue)

Table 3.7: Slip factor, μ, for pre-loaded bolts

Class of friction surfaces (see 1.2.7 Reference Standard: Group 7)	Slip factor μ
A	0,5
B	0,4
C	0,3
D	0,2

NOTE 1: The requirements for testing and inspection are given in 1.2.7 Reference Standards: Group 7.

NOTE 2: The classification of any other surface treatment should be based on test specimens representative of the surfaces used in the structure using the procedure set out in 1.2.7 Reference Standards: Group 7.

NOTE 3: The definitions of the class of friction surface are given in 1.2.7 Reference Standards: Group 7.

NOTE 4: With painted surface treatments a loss of pre-load may occur over time.

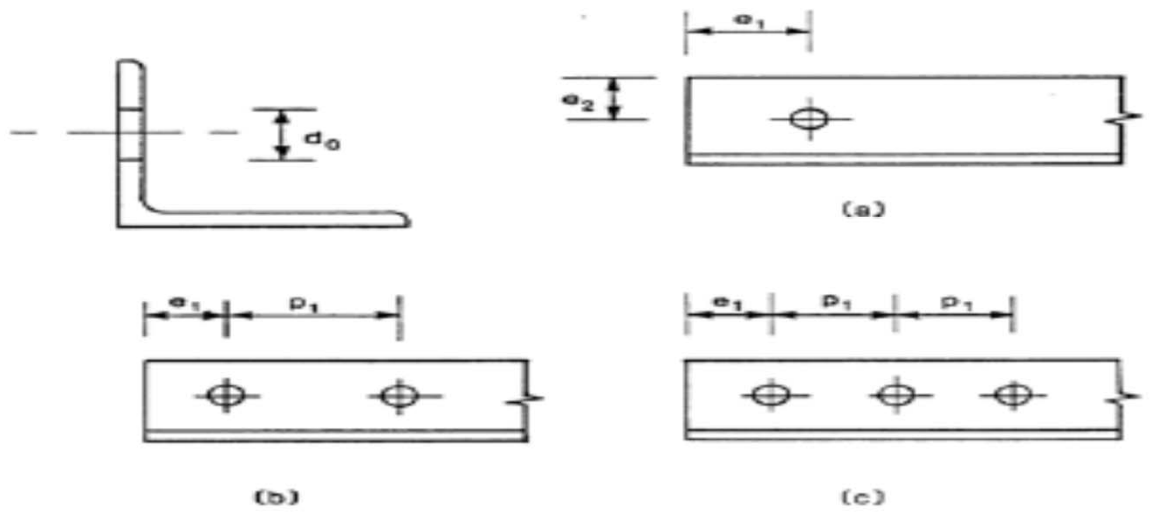
Deduction for fastener holes

Deduction for fastener holes (Cl.3.10)

- **Design for block tearing**
  - Symmetric bolt group subject to concentric loading. $V_{eff,1,Rd} = \dfrac{f_u A_{nt}}{\gamma_{M2}} + \dfrac{(1/\sqrt{3}) f_y A_{nv}}{\gamma_{M0}}$
  - Bolt group subject to eccentric loading. $V_{eff,2,Rd} = \dfrac{0.5 f_u A_{nt}}{\gamma_{M2}} + \dfrac{(1/\sqrt{3}) f_y A_{nv}}{\gamma_{M0}}$
  - A_{nt} is net area subjected to tension
  - A_{nv} is net area subjected to shear
- **Angles connected by one leg and other un-symmetrically connected members in tension**
  - Design ultimate resistance for single angle in tension
    - With 1 bolt: $N_{u,Rd} = \dfrac{2.0\,(e_2 - 0.5 d_0) t f_u}{\gamma_{M2}}$
    - With 2 bolts: $N_{u,Rd} = \dfrac{\beta_2 A_{net} f_u}{\gamma_{M2}}$
    - With 3 or more bolts: $N_{u,Rd} = \dfrac{\beta_3 A_{net} f_u}{\gamma_{M2}}$
  - refer to Table 3.8 for values of β_2 and β_3

Table 3.8: Reduction factors β_2 and β_3

Pitch	p_1	$\leq 2,5\ d_o$	$\geq 5,0\ d_o$
2 bolts	β_2	0,4	0,7
3 bolts or more	β_3	0,5	0,7



a) 1 bolt
b) 2 bolts
c) 3 bolts

Figure 3.9: Angles connected by one leg