Equivalent T-stubs (Component Method) as per DIN EN 1993-1-8

Nemetschek Frilo GmbH
www.frilo.de
info@frilo.de
As of 23/11/2012

Contents

Introduction

According to EN 1993-1-8, the load-bearing capacity and stiffness of connections in steel engineering are determined by calculating the basic components of a connection. The basic components are listed in table 6.1.

The model of the equivalent T-stub (para. 6.2.4) can be used to calculate the load-bearing capacity of the basic components of screwed connections.

The failure mechanism of an equivalent T-stub is described by yield line models.

The component method is suitable to determine the deformation behaviour of the connection in addition to the moment resistance. Therefore, it allows the consideration of yielding connections. The connecting stiffness of the joints is considered in the calculation by means of springs and leads to an optimisation of the entire construction in the iterative calculation.

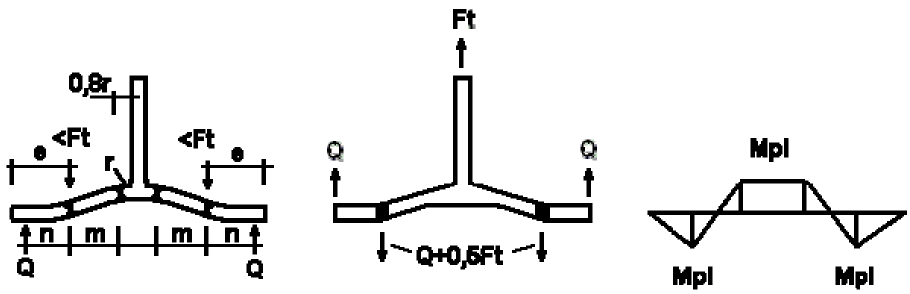
T-stub model

A T-stub consists of a tension-loaded web and a bending-loaded flange. The screw axes are subjected to tension that is counteracted by supporting forces at the outer edges, which are idealised as rigid supports.

A particularity is the screw row in the unbraced projection of the face plate. Here, a T-stub is assumed the tension-loaded web of which does rather correspond to the flange of a beam than to its web. The flange is assumed as rotated by 90°.

The T-stub model distinguishes three different failure modes:

Failure mode 1: full yielding of the flanges



$$Ft1_{Rd} = \frac{4 \cdot Mpl1_{Rd}}{m}$$

with $Mpl1_{Rd} = 0{,}25 \cdot \sum leff{,}1 \cdot t_f^2 \cdot 1{,}1 \cdot fy_d$

and leff1 : effective length of the T-stub for failure mode 1

t_f : thickness of the stub flange

The limit tensile force Ft1Rd can be increased by using backplates:

$$Ft1_{Rd} = \frac{4 \cdot Mpl1_{Rd} + 2 \cdot Mbp_{Rd}}{m}$$

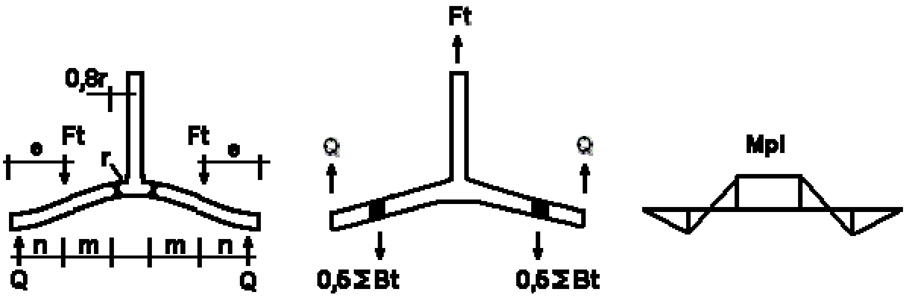
with $Mbp_{Rd} = 0{,}25 \cdot \sum leff{,}1 \cdot t_{bp}^2 \cdot 1{,}1 \cdot fy_d$

and leff1 : effective length of the T-stub for failure mode 1

t_{bp} : thickness of the backplate

The backplate shall cover the entire width of the stub flange and its length shall correspond at least to the effective length for the bolt rows in the area of the T-stub with a minimum projection of 2*d over the outer bolts (d is the nominal diameter of the bolts).

Failure mode 2: failure of the bolts and yielding of the flanges



$$Ft2_{Rd} = \frac{2 \cdot Mpl2_{Rd} + n \cdot \sum Bt_{Rd}}{m+n}$$

with $Mpl2_{Rd} = 0{,}25 \cdot \sum leff{,}2 \cdot t_f^2 \cdot 1{,}1 \cdot fy_d$

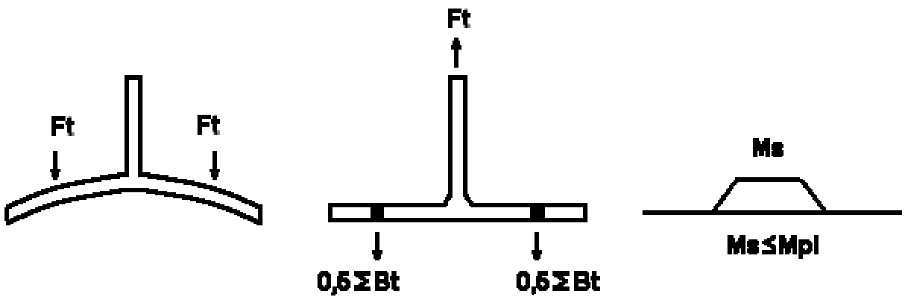
and leff1 : effective length of the T-stub for failure mode 2

t_f : thickness of the stub flange

Bt_{Rd} : design value of the tension resistance of the screw, min ($F_{b,Rd}$, $F_{t,Rd}$ $B_{p,Rd}$).

Bt_{Rd} : total Bt_{Rd} of all bolts in the T-stub

Failure mode 3: failure of the bolts

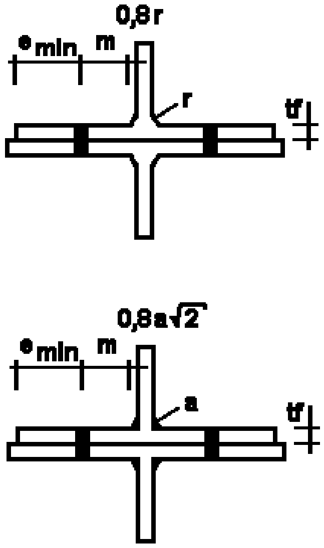


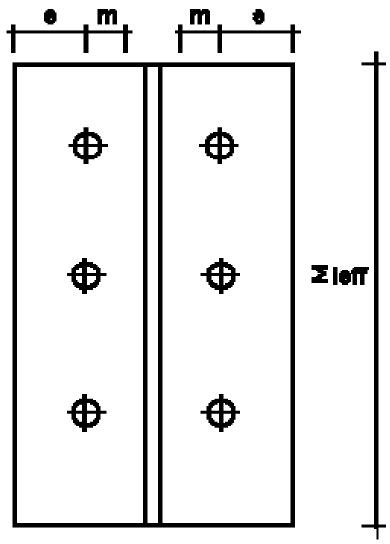
$$Ft3_{Rd} = \sum Bt_{Rd}$$

with $\Sigma\, Bt_{Rd}$: see failure mode 2

Dimensions in the T-stub:

n = e,min und n ≤ 1,25*m





Alternative method for the calculation of **failure mode 1** in accordance with table 6.2: method 2

By mapping more accurately the behaviour of the yield lines in the load distribution area of the screw heads, the load-bearing capacity can be increased in failure mode 1. In the enhanced model the screw forces apply below the washer and the screw head or nut uniformly over the flange instead of concentrating in the screw axis.

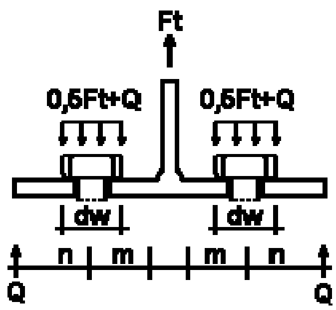
$$Ft1_{Rd} = \frac{(8 \cdot n - 2 \cdot ew) \cdot Mpl1_{Rd}}{2 \cdot m \cdot n - ew \cdot (m + n)}$$

with ew = dw / 4

dw diameter of the washer or width of the screw head or nut. For screws of the strength classes FK 4.6 and 5.6, the software application takes the width of the screw head (across corners) into account, because there are no washers.

When using backplates, the limit tensile force Ft1Rd results from:

$$Ft1_{Rd} = \frac{(8 \cdot n - 2 \cdot ew) \cdot Mpl1_{Rd} + 4 \cdot n \cdot Mbp_{Rd}}{2 \cdot m \cdot n - ew \cdot (m + n)}$$



Effective lengths l_{eff} of the T-stubs

The effective lengths in the model of the equivalent T-stub correspond to the lengths of the yield lines of each failure mode and may differ from the geometrical lengths of the connection. The yield line length of a screw is determined by the location of the latter, i.e. whether it is near to the edge, next to a bracing, at the beginning/end of a group or inside a group.

It is distinguished between circular and non-circular yield-line patterns.

The effective length l_{eff} of failure mode 2 corresponds to the line length of the non-circular patterns, whereas l_{eff} of failure mode 1 corresponds to the smaller line length of either the circular or non-circular patterns. The effective lengths of T-stubs with several screw rows are the sum of the lengths of the individual rows, which is determined by their location.

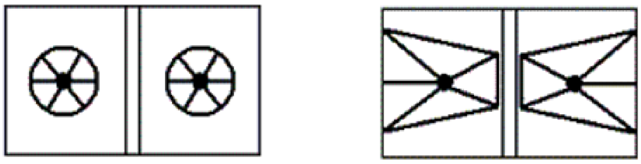
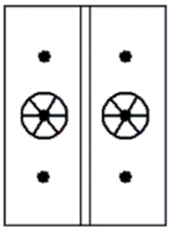
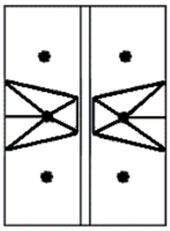
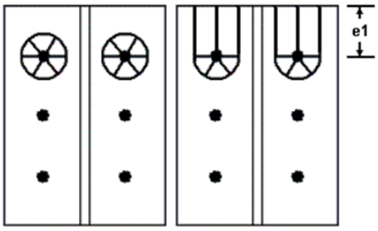
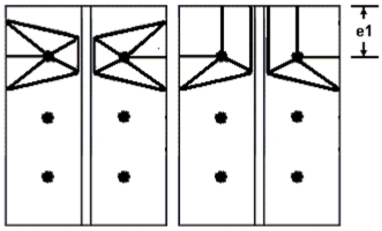
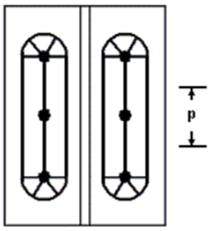
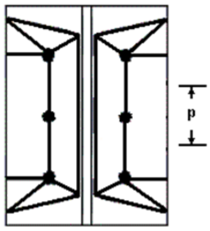
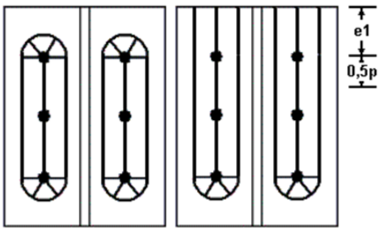
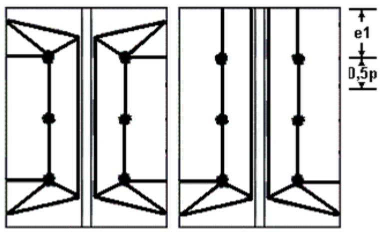


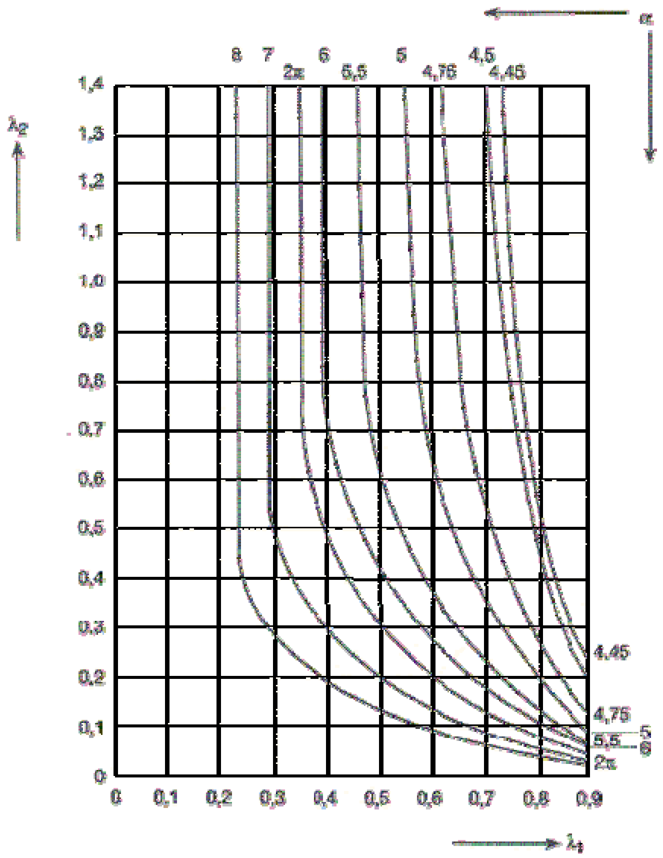
Fig.: circular patterns $l_{eff,cp}$ non-circular patterns $l_{eff,nc}$

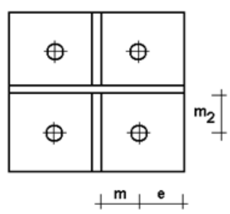
Example yield-line pattern on an unbraced column:

Circular patterns $l_{eff,cp}$	Non-circular patterns $l_{eff,nc}$
Individual screw row	
Inside 	
At the edge 	
Group of screw rows	
Inside 	
At the edge 	

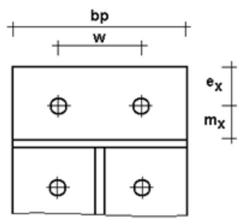
<u>Effective lengths</u> l_{eff}:

Location of the screw row	Individual rows		Group	
	Circular $l_{eff,cp}$	Non circular $l_{eff,nc}$	Circular $l_{eff,cp}$	Non circular $l_{eff,nc}$
Inner screw row next to a stiffener	$2 \cdot \pi \cdot m$	$\alpha \cdot m$	$\pi \cdot m + p$	$0{,}5 \cdot p + \alpha \cdot m - (2 \cdot m + 0{,}625 \cdot e)$
Other inner screw row	$2 \cdot \pi \cdot m$	$4 \cdot m + 1{,}25 \cdot e$	$2 \cdot p$	p
Other outer screw row	$\min\begin{bmatrix} 2 \cdot \pi \cdot m \\ \pi \cdot m + 2 \cdot e_1 \end{bmatrix}$	$\min\begin{bmatrix} 4 \cdot m + 1{,}25 \cdot e \\ 2 \cdot m + 0{,}625 \cdot e + e_1 \end{bmatrix}$	$\min\begin{bmatrix} \pi \cdot m + p \\ 2 \cdot e_1 + p \end{bmatrix}$	$\min\begin{bmatrix} 2 \cdot m + 0{,}625 \cdot e + 0{,}5 \cdot p \\ e_1 + 0{,}5 \cdot p \end{bmatrix}$
Outer screw row next to a stiffener	$\min\begin{bmatrix} 2 \cdot \pi \cdot m \\ \pi \cdot m + 2 \cdot e_1 \end{bmatrix}$	$e_1 + \alpha \cdot m - (2 \cdot m + 0{,}625 \cdot e)$	-	-
Mode 1	$l_{eff,1} = l_{eff,nc}$ but $l_{eff,1} \le l_{eff,cp}$		$\Sigma l_{eff,1} = \Sigma l_{eff,nc}$ but $\Sigma l_{eff,1} \le \Sigma l_{eff,cp}$	
Mode 2	$l_{eff,2} = l_{eff,nc}$		$\Sigma l_{eff,2} = \Sigma l_{eff,nc}$	





Stiffener in the flange

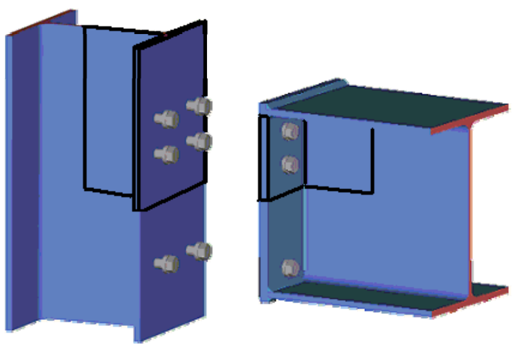


T-stub in the projection of the face plate

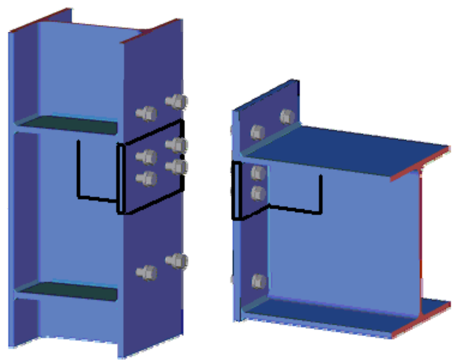
The auxiliary value α for T-stubs in the area of stiffeners can be obtained in accordance with illustration J 27 in [8] with the help of the following λ values:

$$\lambda_1 = \frac{m}{m+e} \quad \text{and} \quad \lambda_2 = \frac{m_2}{m+e}$$

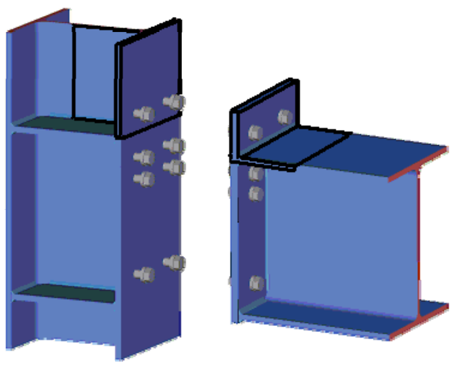
Examples for the T-stub model



Example: T-stub in unbraced column



Example: T-stub in braced column part 1



Example. T-stub in braced column part 2