

Metal Structures

Lecture XX

Supporting joints

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Introduction

Two types of joint - shear and tension – were presented on two previous lectures (#18, #19).



Photo: uwyo.edu



Photo: gic-edu.com

Forces are applied axially to bolts in tension joints. Such type of joints is, according to initial assumptions, rigid joints.

Forces are applied transversally to bolts in shear joints.

Photo: amsd.co.uk

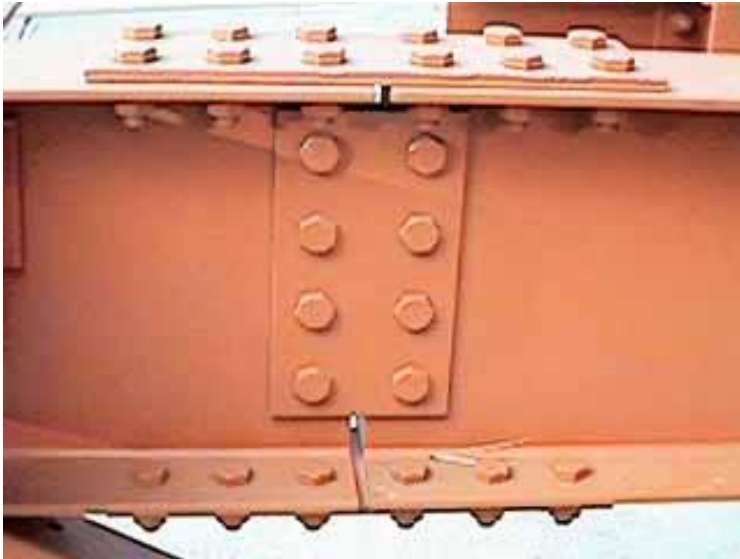


Photo: Author

Such type of joints could be, according to initial assumptions, rigid or hinge joints.

Name „supporting joints” is used in colloquial sense: as a situation, when upper part of structure is based on lower one.

This happens when we analyse:

- hinge / rigid support of column;
- hinge support of beam / truss on masonry structure (wall, column);
- hinge support of beam / truss on concrete structure (wall, column);
- hinge support of beam / truss on concrete primary beam;
- hinge support of beam / truss on steel column;



Photo: srt251fpaler.blogspot.com



Photo: formfindinglab.wordpress.com



Photo: Author



Photo: Author

Each above situations can be divided into two problems:

Contact with other material (masonry / concrete):	Resistance of steel structural bearings (rocker):
<ul style="list-style-type: none"> • support of beam / truss on masonry wall; • support of beam / truss on masonry column; • support of beam /truss on concrete wall; • support of beam / truss on concrete column; • support of beam /tru on concrete beam; 	
<ul style="list-style-type: none"> • hinge support of column on concrete base; • rigid support of column on concrete base; 	<ul style="list-style-type: none"> • support of beam on steel column; • support of truss on steel column; • support of truss on primary steel beam;

Specific phenomena, various for various groups, must be taken into consideration.

Very complicated part of issue are supports of steel structure, especially in case of contact with other type of material (masonry, concrete). There are three types of supports according to initial assumptions:



rigid,



pinned,



roller.

Photo: Author

The most complicated and often disregarded problem is to provide steel structures with sufficient freedom of rotation and translation in the last two types of supports.

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Support	Examples of supports
Rigid	Column;
Pinned	Column; Truss or beam on masonry, concrete or steel structure;
Roller	Truss or beam on masonry, concrete or steel structure;

For massive structures or structures with big loads (bridges), two various technical solutions are applied for pinned and roller supports.

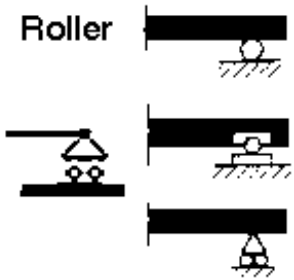


Photo: web.mit.edu



Photo: fbcdn-photos-g-a.akamaihd.net



Photo: texasescapes.com

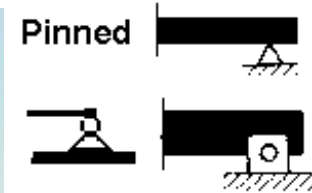


Photo: web.mit.edu



Photo: wikipedia



Photo: tatasteelconstruction.com

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Other materials

Two other materials are analysed as materials for support for steel structure: masonry (\rightarrow #t / 12 - 15) and concrete (\rightarrow #t / 16 - 55). In case of contact between steel and other materials, it is not only necessary to analyze steel structure. Concrete and masonry are weaker than steel and are usually destroyed earlier than steel structure. Resistance of concrete or masonry under local pressure must be analysed.



Photo: dailymail.co.uk



Photo: diy.stackexchange.com

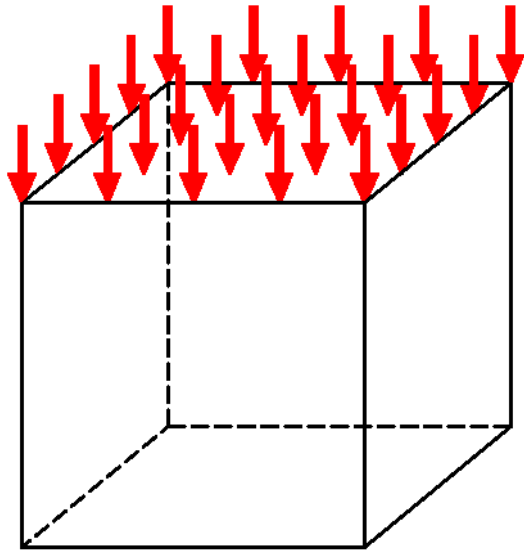


Photo: Author

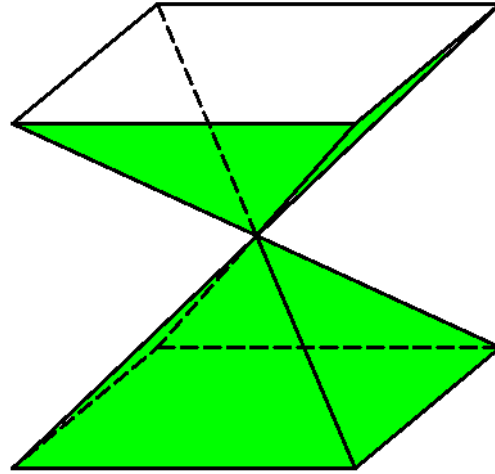


Photo: budopref.pl

Specific way of destruction for concrete and masonry under **compression**: break down by **secondary shear stresses**. Characteristic **diagonal cracs** can be observed.



Photo: researchgate.net

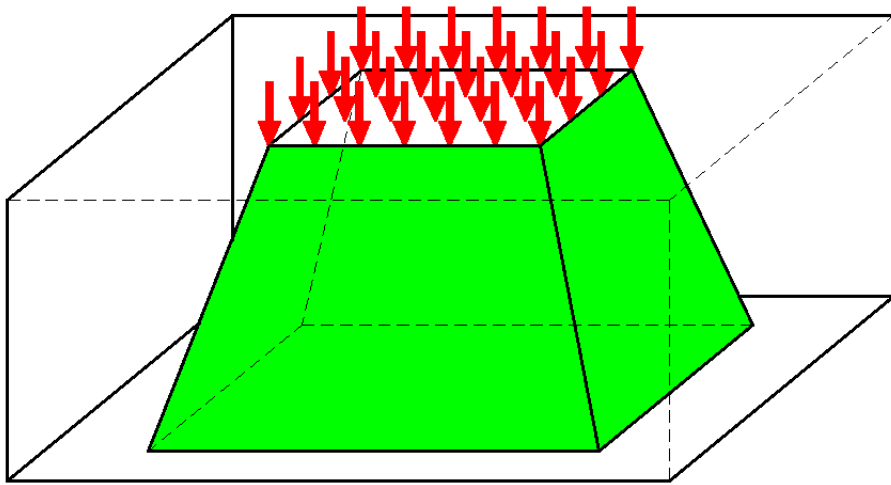
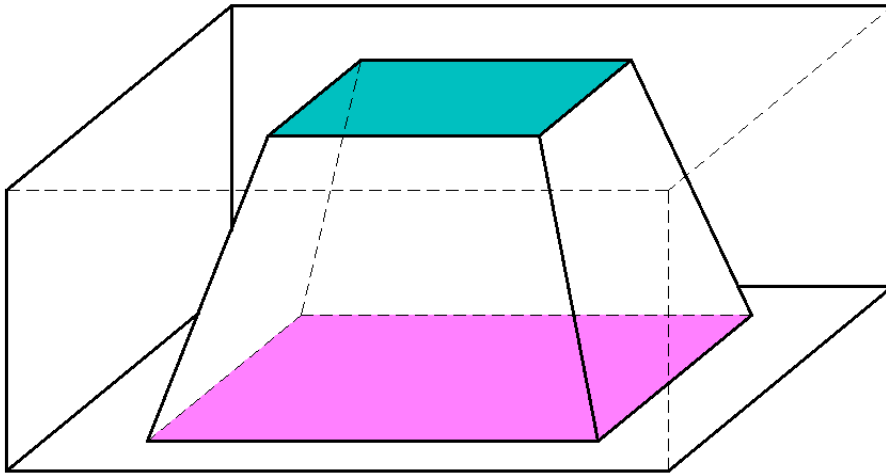


Photo: Author



Such phenomenon – way of action of **secondary shear stresses** - is taken into consideration during calculation of concrete or masonry supporting for steel structure. Measure of action of shear stresses is proportion between **top area** (treated as area of **direct contact** between steel and other material or area of **equivalent contact**) and **bottom: effective area inside material**.

Support on masonry structure

EN 1996-1-1 p.6.1.3

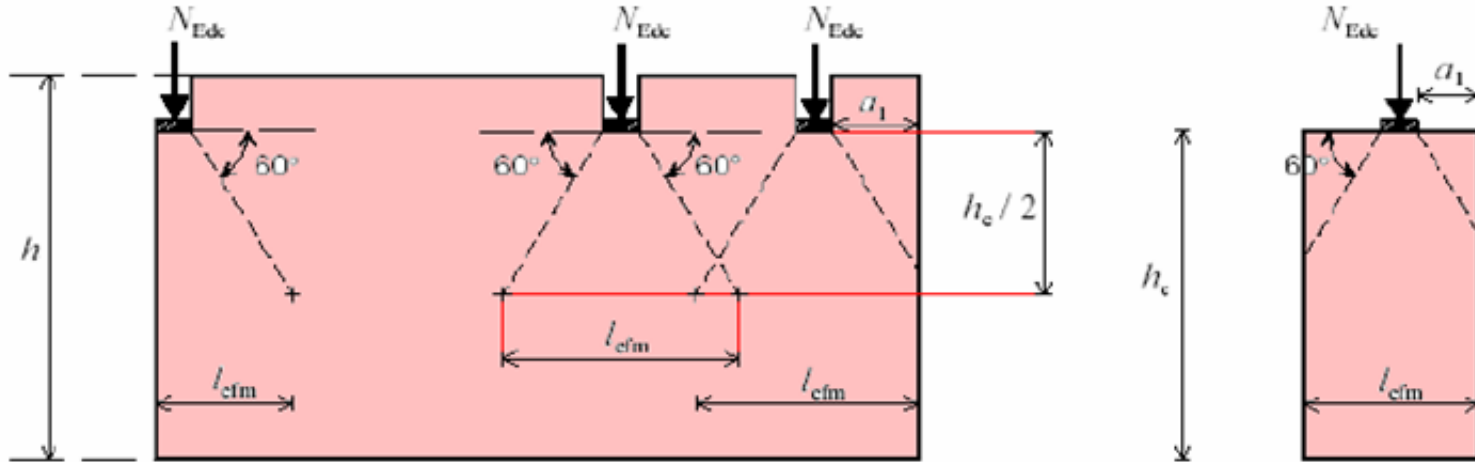


Photo: EN 1996-1-1 fig 6.2

Bottom area for masonry structure is defined by thickness of wall and effective length measured at level in half height between support of steel structure and wall base. Of course, effective length can't go beyond outline of masonry structure.

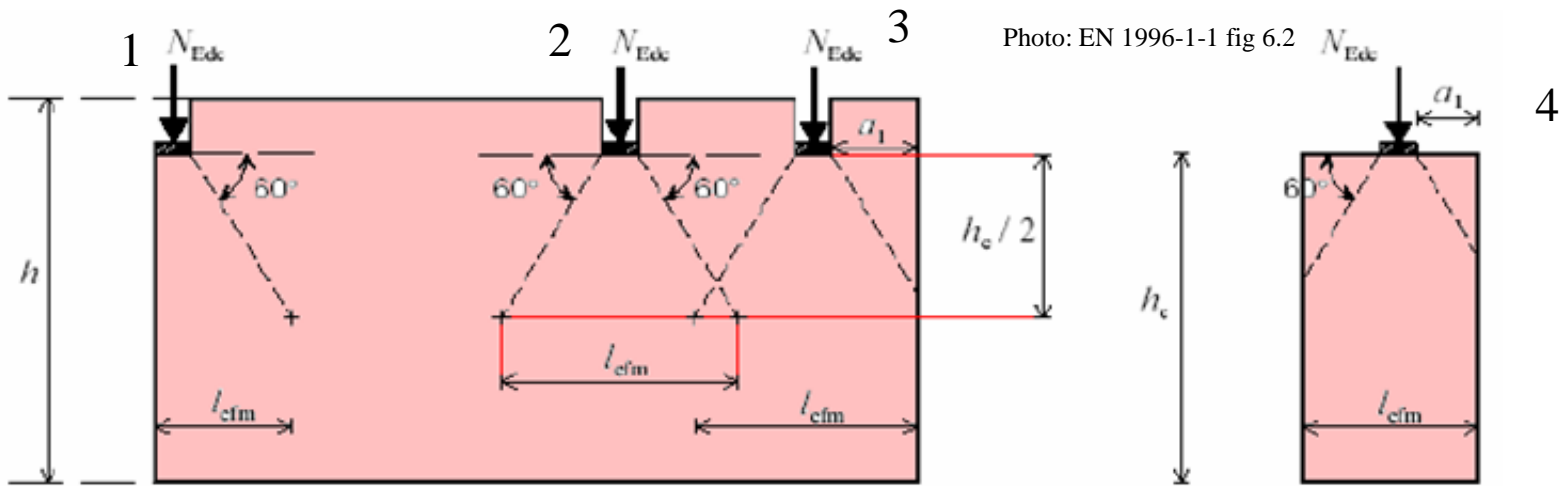


Photo: projektonwestor.pl



Photo: houzz.co.nz

Influence of masonry limits makes four situations: 1. steel structure at end or on corner of masonry structure; 2 in central part of masonry structure; 3 near to end or corner of masonry in distance a_1 ; 4 short masonry wall or column. Full effective length is taken into consideration in case 2 only. Effective length l_{efm} must be cut at end of masonry structure in rest cases.

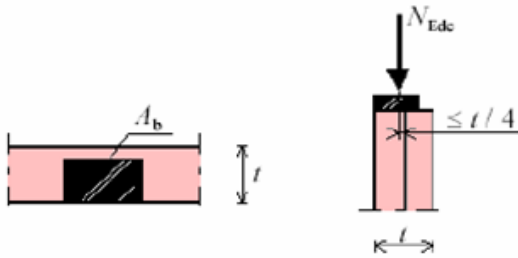


Photo: EN 1996-1-1 fig 6.2

Top area A_b (area of direct contact between steel and masonry) means:

(width of steel member) · (depth inside wall)

Theoretical point of force N_{Edc} application is in center of A_b (this means in half of depth). Distance between force and axis of wall can't be bigger than (thickness of wall) / 4.

$$N_{Edc} / N_{Rdc} \leq 1,0$$

$$N_{Rdc} = \beta A_b f_d$$

$$A_{ef} = l_{efm} t$$

$$\beta = \min \{ 1,25 + \mathbf{a}_1 / (2 h_c) \ ; \ 1,5 \ ; \ \max [(1 + 0,3 \mathbf{a}_1 / h_c) \cdot (1,5 - 1,1 A_b / A_{ef}) \ ; \ 0] \}$$

f_d according to EN 1996-1-1 NA

Distance \mathbf{a}_1 from support to end of wall is important for cases 3 and 4 only. For 1 is equal 0, for 3 is such big, than β will be equal 1,5.

If resistance of support is too small, we use additional horizontal plate to increase area A_b . It is wider than width of flange, its thickness is equal or bigger than thickness of flange. We must use vertical stiffeners too.

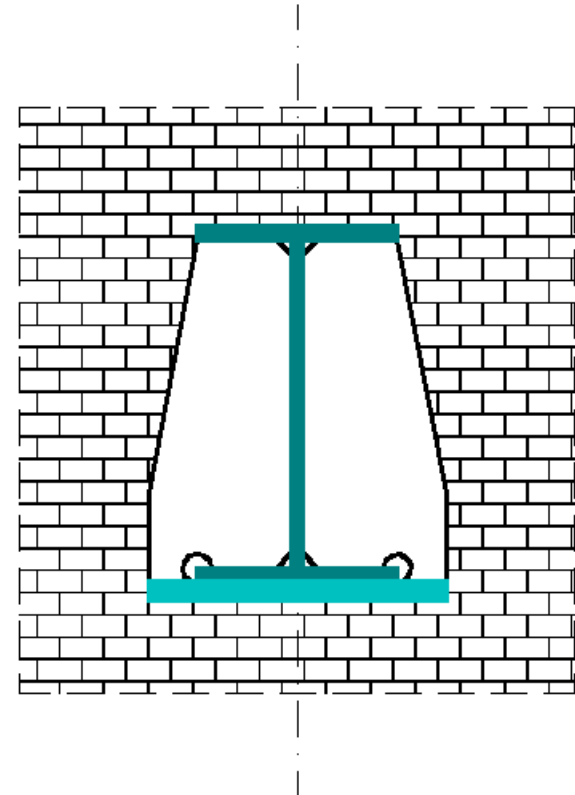


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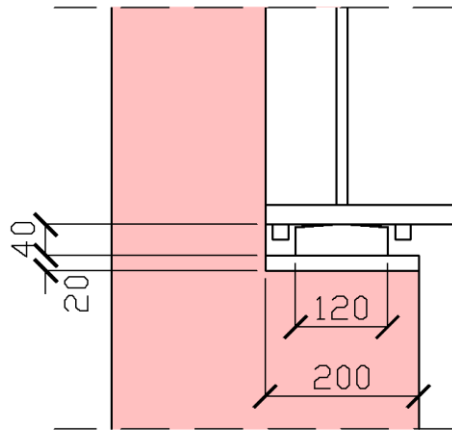
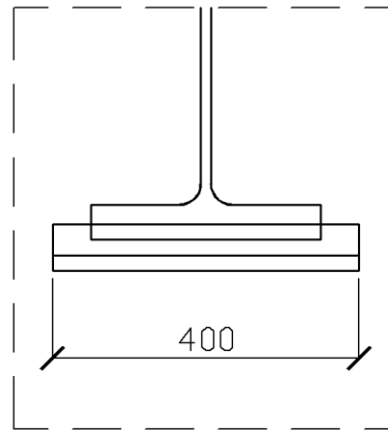


Photo: Author



Similar situation was presented on IInd project. Area of bottom plate of rocker was bigger, than area of flange inside wall.

Support on concrete structure

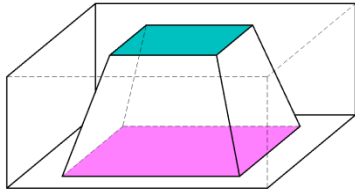


Photo: Author

1. **Top area** = effective area of contact steel-concrete. This is not equal total (real) area of contact steel plate – concrete.

2. Effective area of contact is area of cross-section of column t_f and its immediate neighborhood $c(t_p)$. This is result of linearisation of stress under base plate.

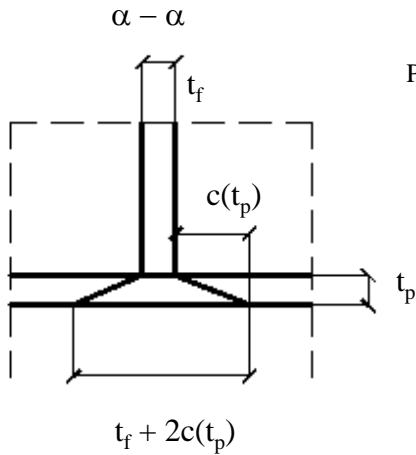


Photo: Author

3. Range of nearest neighborhood $c(t_p)$ is function of thickness of base plate t_p .

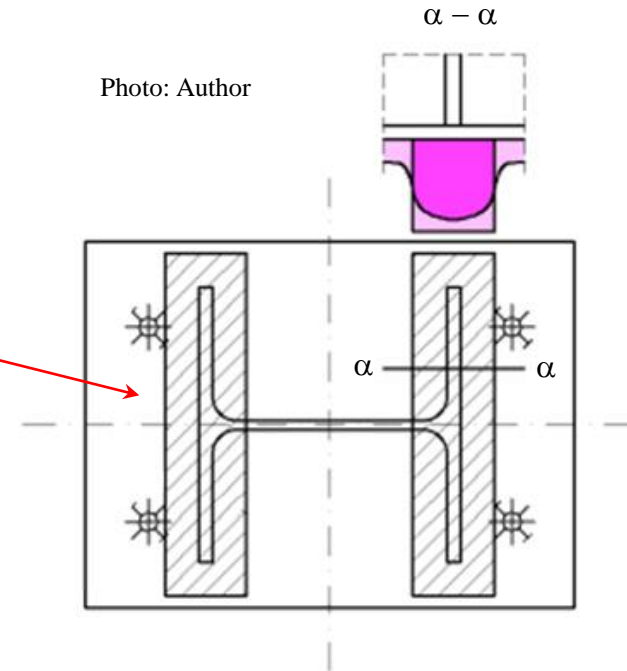


Photo: Author

Bottom area is defined in EN 1992 for concrete structures.

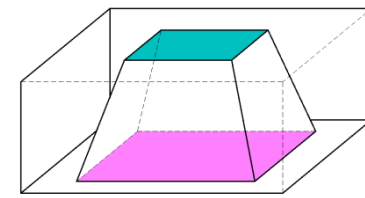


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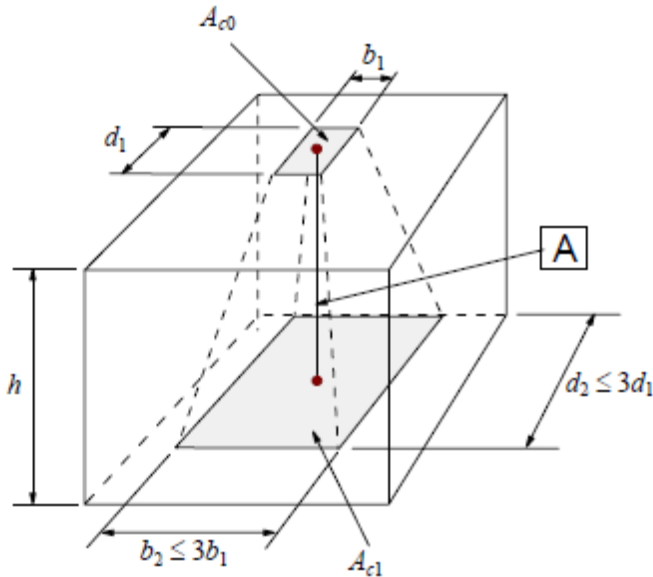
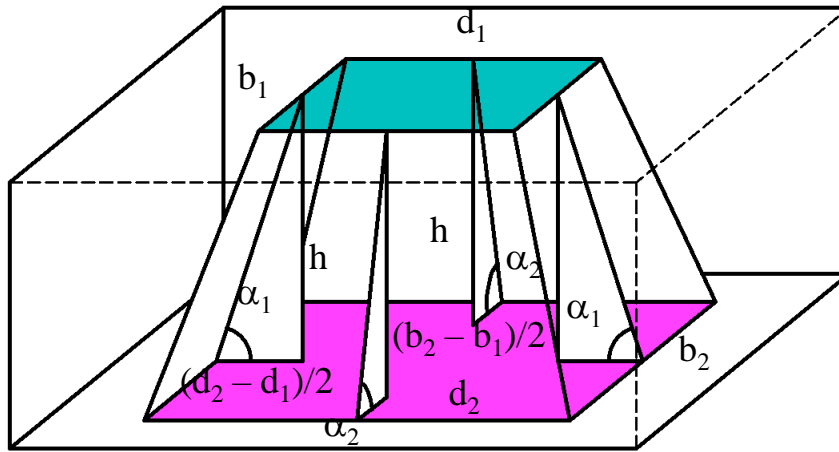


Photo: EN 1992-1-1 fig 6.29

$$h \geq (b_2 - b_1) \text{ i } h \geq (d_2 - d_1)$$

Definition of A_{c1} includes few requirements according to EN 1992:

- Vertical distance between top and bottom areas is limited;
- Centres of gravity for A_{c1} and A_{c0} must be at one vertical line;
- A_{c1} and A_{c0} have the same proportion;
- A_{c1} can't be too big;
- A_{c1} is the maximum possible area;
- For more than one force F_i , A_{c1}^i and A_{c0}^i should not overlap.



Vertical distance between top and bottom areas is limited:

$$h \geq b_2 - b_1 \quad \text{and} \quad h \geq d_2 - d_1$$

This means:

$$h \geq \max (b_2 - b_1 \ ; \ d_2 - d_1)$$

$$\text{tg } \alpha_1 = h / [(d_2 - d_1) / 2] = 2 [h / [(d_2 - d_1)]]$$

$$\text{tg } \alpha_2 = h / [(b_2 - b_1) / 2] = 2 [h / (b_2 - b_1)]$$

$$h \geq \max (b_2 - b_1 \ ; \ d_2 - d_1) \rightarrow h / (b_2 - b_1) \geq 1,0 \ ; \ h / (d_2 - d_1) \geq 1,0$$

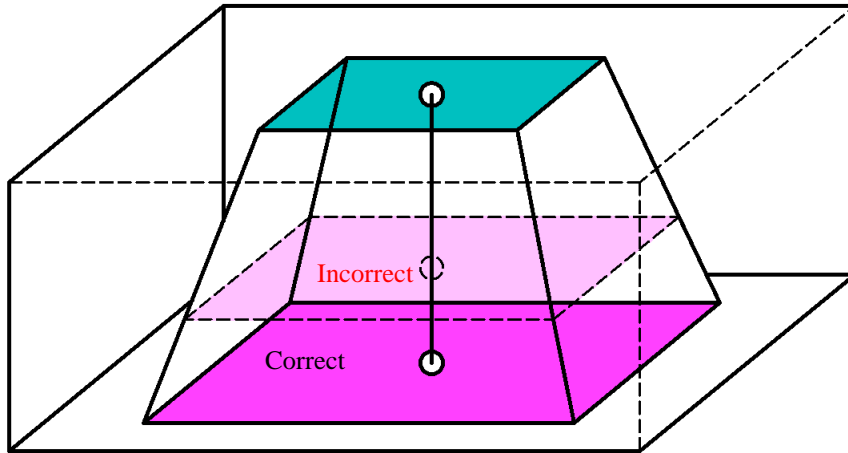
$$2 [h / [(d_2 - d_1)]] = 2 \cdot (\geq 1,0) \rightarrow \text{tg } \alpha_1 \geq 2,0$$

$$2 [h / [(b_2 - b_1)]] = 2 \cdot (\geq 1,0) \rightarrow \text{tg } \alpha_2 \geq 2,0$$

$$\text{tg } \alpha_1 \geq 2,0 \rightarrow \alpha_1 \geq 63^\circ 26'$$

$$\text{tg } \alpha_2 \geq 2,0 \rightarrow \alpha_2 \geq 63^\circ 26'$$

Photo: Author



Incorrect situation: too small vertical distance. Vertical distance is limited:

$$h \geq b_2 - b_1$$

$$h \geq d_2 - d_1$$

Photo: Author

Incorrect situation: centres of gravity of top and bottom areas aren't at one vertical line.

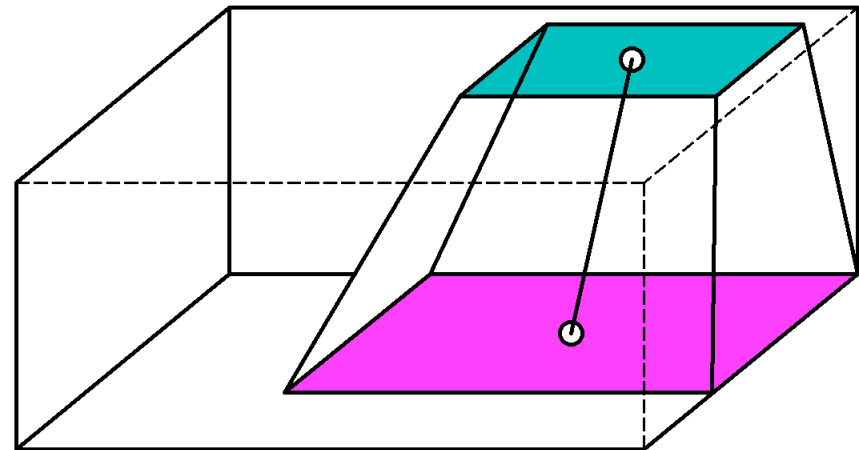
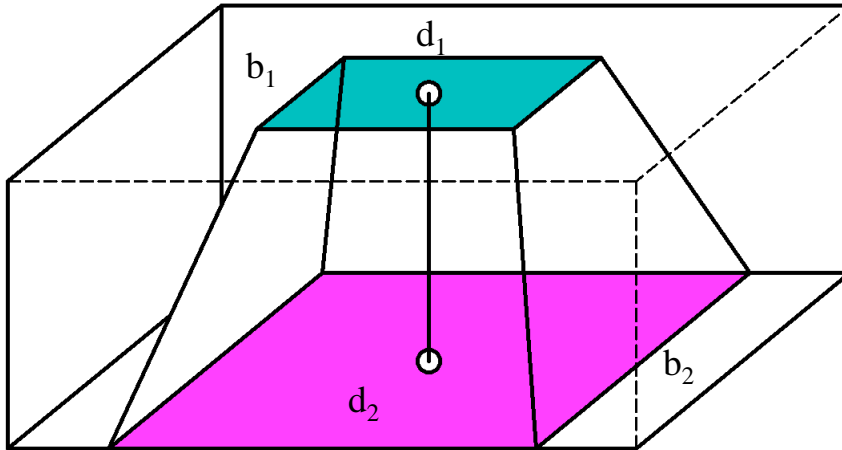


Photo: Author



Incorrect situation: shapes of top and bottom areas are not the same, this means:

$$(b_1 / d_1) \neq (b_2 / d_2)$$

Correct situation is, when only:

$$(b_1 / d_1) = (b_2 / d_2)$$

Incorrect situation: too big bottom area.
Dimensions for bottom area are limited:

$$b_2 \leq 3b_1$$

$$d_2 \leq 3d_1$$

Photo: Author

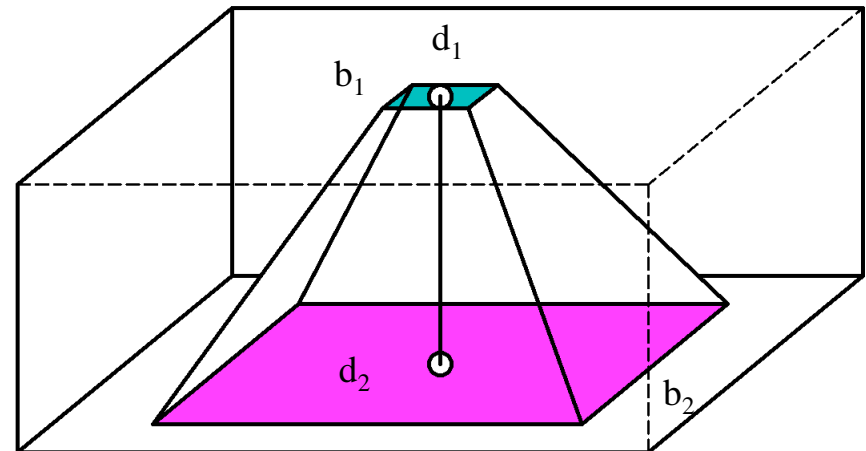
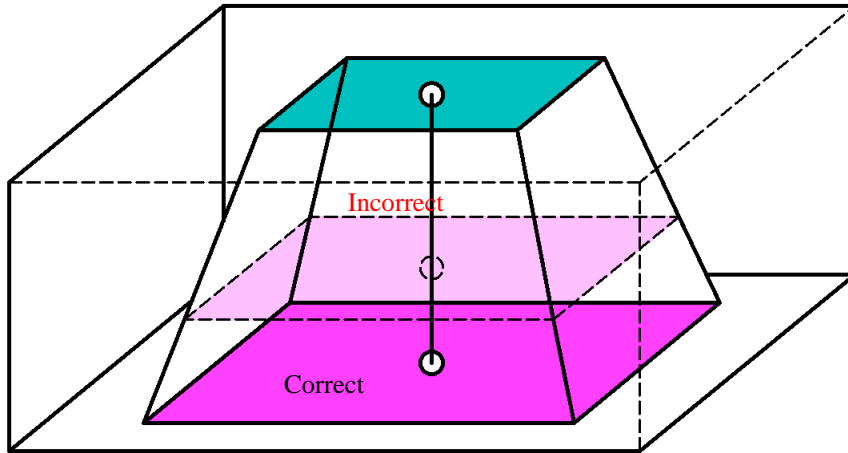


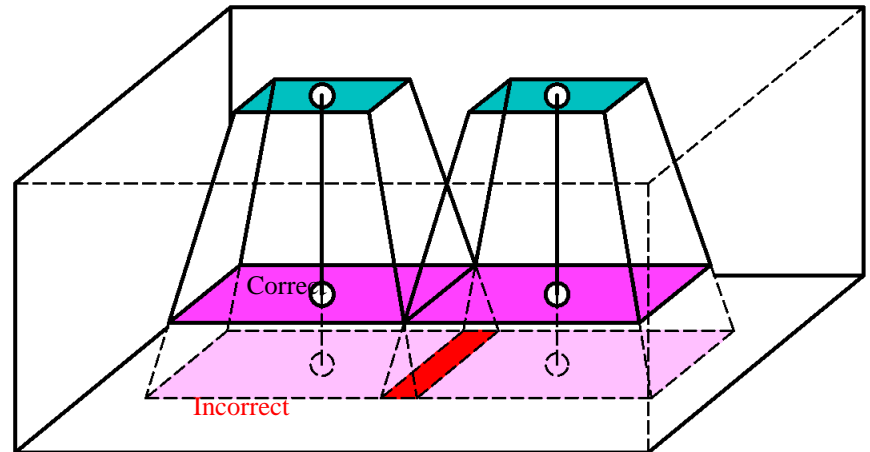
Photo: Author



Incorrect situation: too small bottom area. It is possible to lay out a larger bottom area in accordance with the requirements EN 1992.

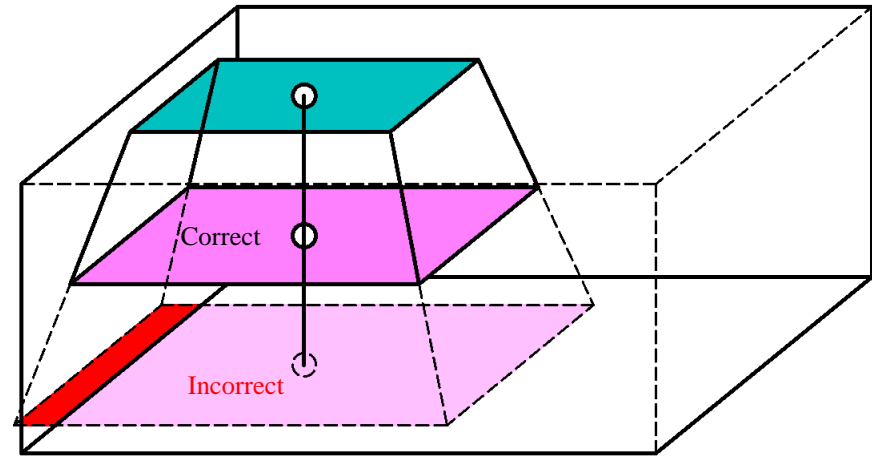
Photo: Author

Incorrect situation: two part of bottom areas are overlapped. Of course, for each of parts, treated separately, lower version is larger (as required). But requirement of no overlapping of both parts means, that smaller bottom areas should be taken into account, located slightly higher.



Incorrect situation: bottom area out of outline of concrete member.

Photo: Author



Generally, top area is function of geometry of column cross-section and thickness of base plate ($\rightarrow \#t / 17$). Geometry of top area could be analysed according to one of two ways of calculations:

- if we know nothing about dimension of concrete member (rough method);
- if we know everything about dimension of concrete member (accurate method);

Both methods based on geometry of members, thickness of base plate t_p , strength of steel f_y and strength of concrete f_{cd}

EN 1993-1-8 p.6.2.5:

$$c = t_p \sqrt{ [f_y / (3 f_{jd} \gamma_{M0})] }$$

A_{c0} = function (c ; cross-section of column)

$$f_{jd} = \beta_j F_{Rdu} / A_{c0}$$

$$\beta_j = 2/3$$

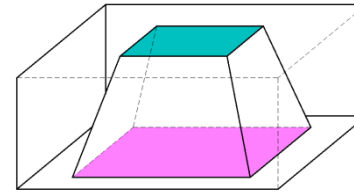
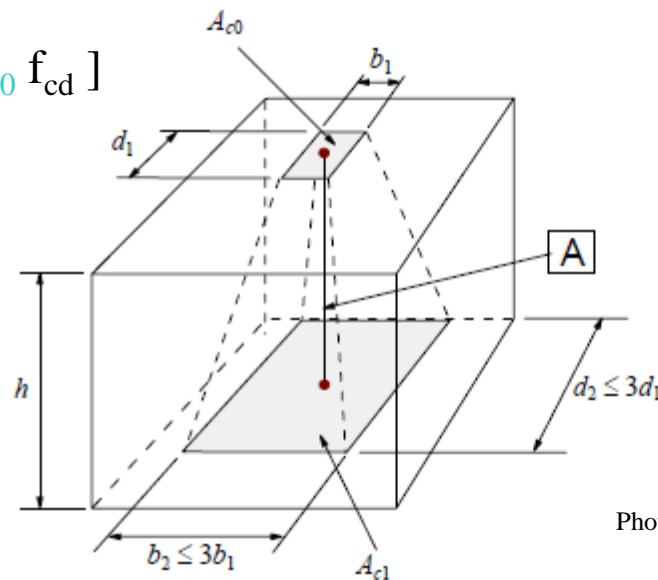


Photo: Author

EN 1992-1-1 p.6.7:

$$F_{Rdu} = \min [A_{c0} f_{cd} \sqrt{ (A_{c1} / A_{c0}) } ; 3 A_{c0} f_{cd}]$$

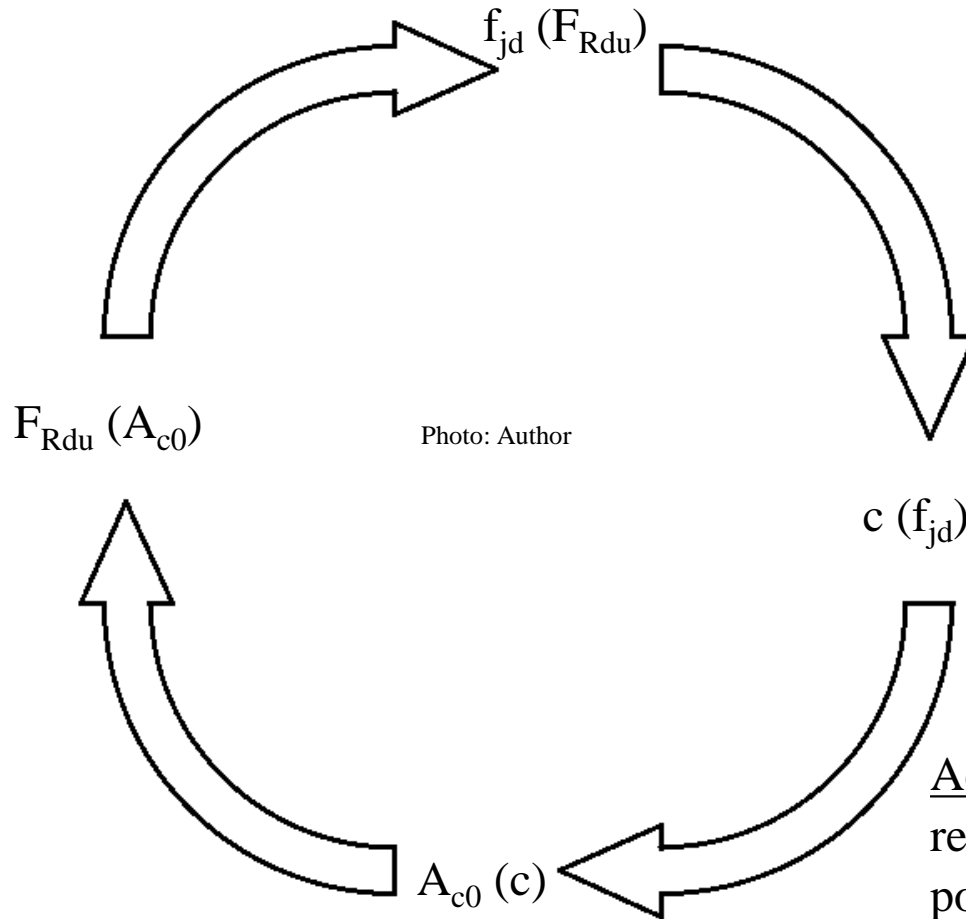
$$N_{Ed} / F_{Rdu} \leq 1,0$$



$$h \geq (b_2 - b_1) \text{ i } h \geq (d_2 - d_1)$$

Photo: EN 1992-1-1 fig 6.29

Problem is entanglement of variables in above nonlinear equations:



Rough method bases on two initial assumptions:

- $N_{Ed} = F_{Rdu}$
- $A_{c1} / A_{c0} = 2,25$

Solutions (values of c and F_{Rdu}) are presented in tables for selected types of bases.

Accurate method: iteration procedure for real shape of concrete member (is possible, than A_{c1} is reduced by outline of member) and real proportion A_{c1} / A_{c0}

Initial assumption „ $A_{c1} / A_{c0} = 2,25$ ” for rough method is true, only when concrete block is big enough to hold $A_{c1} = 2,25 A_{c0}$.

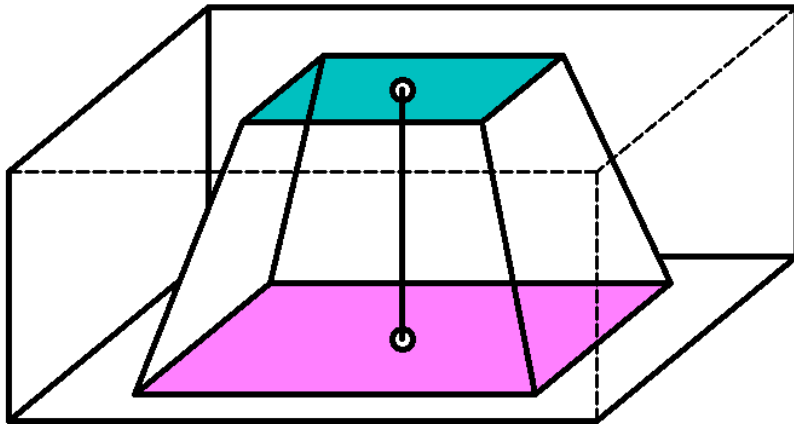
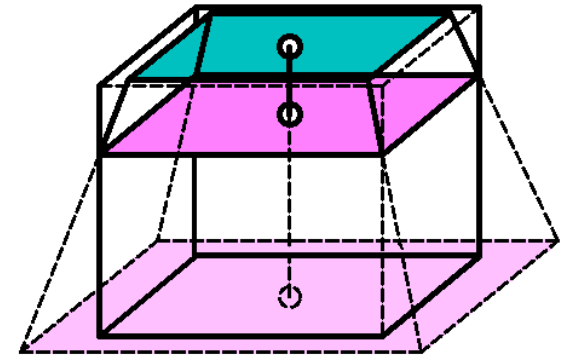
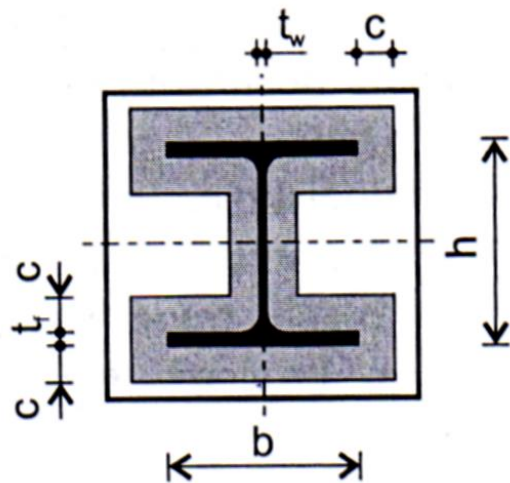


Photo: Author



If dimensions of concrete member are too small to hold such big A_{c1} (small concrete base, upper part of concrete column), accurate method must be used. The same, if type of steel base is not presented in table.



Nośność podstawy słupa:

$$N_{Rd} = f_{cd} \left[2(b + 2c)(t_f + 2c) + (t_w + 2c)(h - 2c - 2t_f) \right]$$

Maksymalny wysięg strefy docisku:

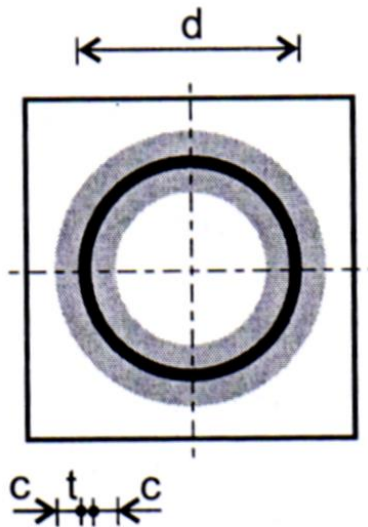
$$c = \frac{X_2 - \sqrt{X_2^2 - 4X_1X_3 + 4X_1N_{Rd}^*}}{2X_1}$$

$$X_1 = 4f_{cd}$$

$$X_2 = 4bf_{cd} + 2hf_{cd} - 2t_w f_{cd}$$

$$X_3 = 2bt_f f_{cd} + ht_w f_{cd} - 2t_f t_w f_{cd}$$

There is an error in source, it should be N_{Ed} , not N_{Rd}



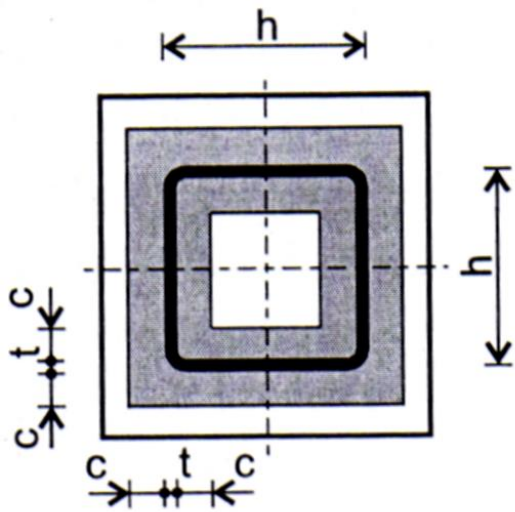
Nośność podstawy słupa:

$$N_{Rd} = f_{cd} \left[\frac{\pi(d + 2c)^2}{4} - \frac{\pi(d - 2c - 2t)^2}{4} \right]$$

Maksymalny wysięg strefy docisku:

$$c = \frac{\pi f_{cd} t^2 - \pi d f_{cd} t + N_{Rd}^*}{2\pi d f_{cd} - 2\pi f_{cd} t}$$

Photo: "Konstrukcje stalowe, przykłady obliczeń według PN-EN 1993-1, część II, stropy i pomosty", A. Kozłowski & all, Rzeszów 2009.



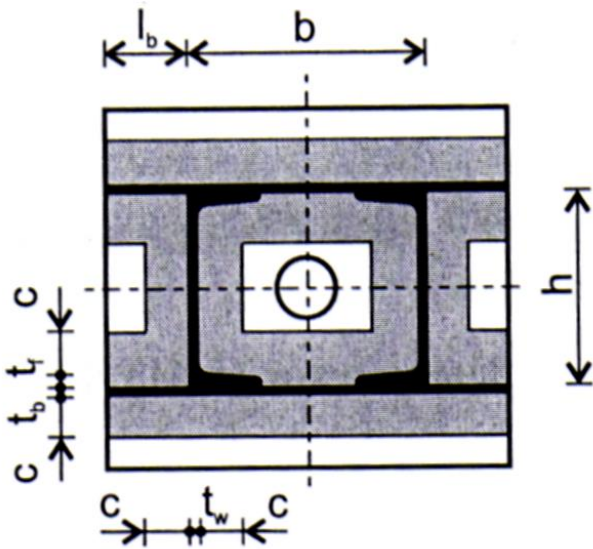
Nośność podstawy słupa:

$$N_{Rd} = f_{cd} \left[(h + 2c)^2 - (h - 2t - 2c)^2 \right]$$

Maksymalny wysięg strefy docisku:

$$c = \frac{N_{Rd}^* - 4f_{cd}t(h - t)}{8f_{cd}(h - t)}$$

There is an error in source, it should be N_{Ed} , not N_{Rd}



Nośność podstawy słupa:

$$N_{Rd} = f_{cd} \left[2(b + 2l_b)(2c + t_b + t_f) + 2(2c + t_w)(h - 2c - 2t_f) \right]$$

Maksymalny wysięg strefy docisku:

$$c = \frac{B - \sqrt{B^2 - 4AC + 4AN_{Rd}^*}}{2A}$$

$$A = 8f_{cd}; \quad B = 4f_{cd}(b + h + 2l_b - 2t_f - t_w)$$

$$C = 2f_{cd}(bt_b + bt_f + ht_w + 2l_bt_b + 2l_bt_f - 2t_ft_w)$$

Photo: "Konstrukcje stalowe, przykłady obliczeń według PN-EN 1993-1, część II, stropy i pomosty", A. Kozłowski & all, Rzeszów 2009.

Accurate method:

EN 1992-1-1 $\rightarrow f_{cd}$

$A_{c0}^0 = b_1 d_1$ (flange or web I-beam)

$A_{c1}^0 = b_2 d_2$ (according to dimensions of concrete base and A_{c0}^0)

1st iteration:

$F_{Rdu} = \sqrt{(A_{c1} / A_{c0})} A_{c0} f_{cd}$

$f_{jd} = \beta_j F_{Rdu} / A_{c0} = \beta_j 1,5 A_{c0} f_{cd} / A_{c0} = \sqrt{(A_{c1} / A_{c0})} \beta_j f_{cd}$

$c^I = t_p \sqrt{[f_y / (3 f_{jd} \gamma_{M0})]}$

$A_{c0}^I = A_{c0}^I$ (flange or web I-beam, c^I)

$A_{c1}^I = b_2^I d_2^I$ (according to dimensions of concrete base and A_{c0}^I)

IInd iteration:

$$f_{jd} = \sqrt{(A_{c1}^I / A_{c0}^I)} \beta_j f_{cd}$$

$$c^{II} = t_p \sqrt{[f_y / (3 f_{jd} \gamma_{M0})]}$$

$$A_{c0}^{II} = A_{c0}^{II} \text{ (flange or web I-beam, } c^{II}\text{)}$$

$$A_{c1}^{II} = b_{2}^{II} d_{2}^{II} \text{ (according to dimensions of concrete base and } A_{c0}^{II}\text{)}$$

IIIrd iteration:

$$f_{jd} = \sqrt{(A_{c1}^{II} / A_{c0}^{II})} \beta_j f_{cd}$$

$$c^{III} = t_p \sqrt{[f_y / (3 f_{jd} \gamma_{M0})]}$$

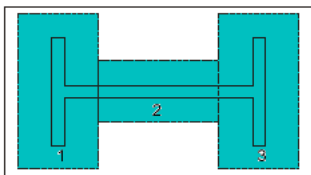
$$A_{c0}^{III} = A_{c0}^{III} \text{ (flange or web I-beam, } c^{III}\text{)}$$

$$A_{c1}^{III} = b_{2}^{III} d_{2}^{III} \text{ (according to dimensions of concrete base and } A_{c0}^{III}\text{)}$$

IVth iteration:

...

Hinge support



EN 1993-1-8 6.2.8.2.(1) – effective area under flanges and web of column is taken into consideration.

Photo: EN 1993-1-8 fig. 6.19

It is inconsequence in Eurocode: bottom area for part 2 has different proportion than top area, or there must be overlapping bottom 2-1 and bottom 2-3.

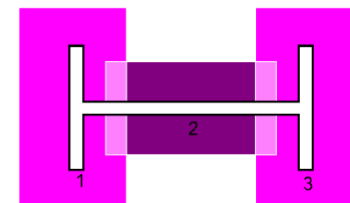
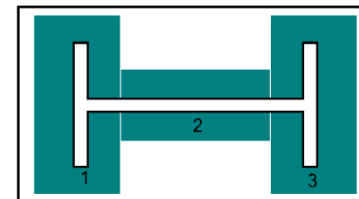
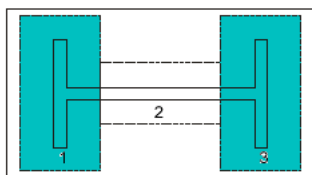


Photo: Author

Rigid support



EN 1993-1-8 6.2.8.3.(1) – only effective area under flanges of column is taken into consideration.

Photo: EN 1993-1-8 fig. 6.19

Hinge support: resistance of concrete only is analysed. Anchor bolts are applied in strong axis of column.

Rigid support: presence of bending moment makes, than few additional phenomena must be analysed; including stiffness of joint. Anchor bolts are out of strong axis of column.

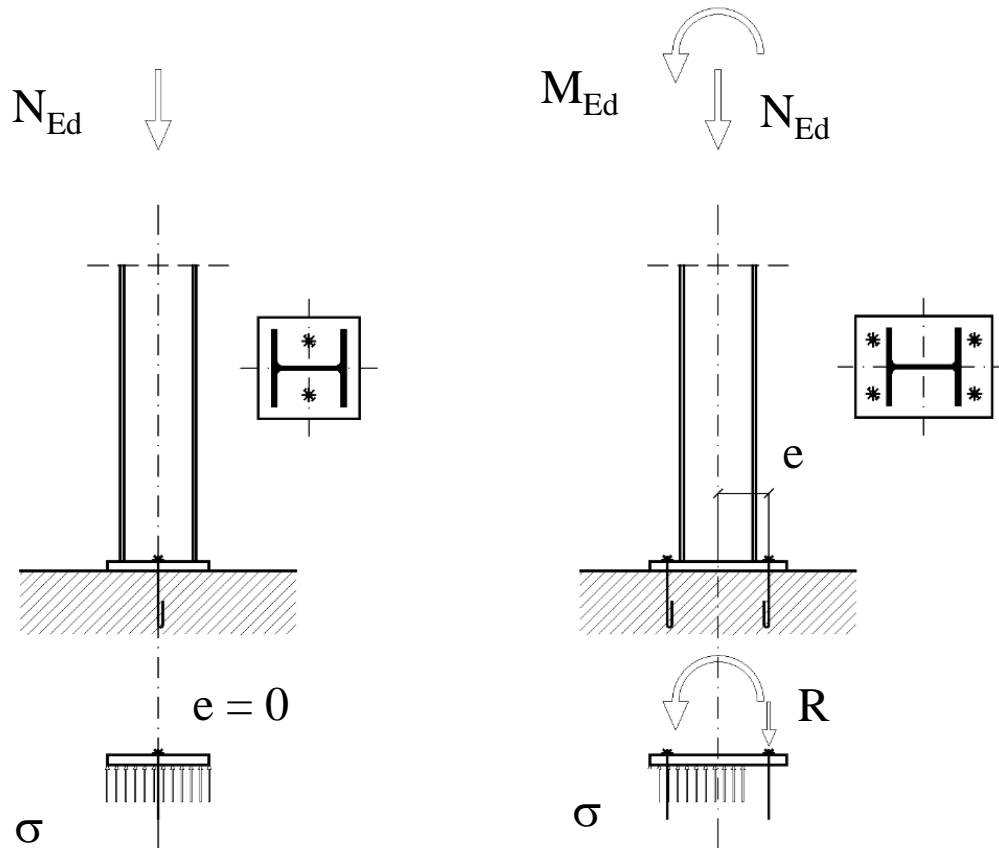


Photo: Author



Photo: j-p.com.ua



Photo: srt251fpaler.blogspot.com

Parts important for stiffness and resistance:

#	Stiffness	Resistance
1	concrete in compression, k_{13}	concrete in compression
2	base plate in bending under compression, k_{14}	
3	base plate in bending under tension, k_{15}	base plate in bending under tension
4	anchor bolt in tension, k_{16}	
5		column web in tension
6		column flange in compression

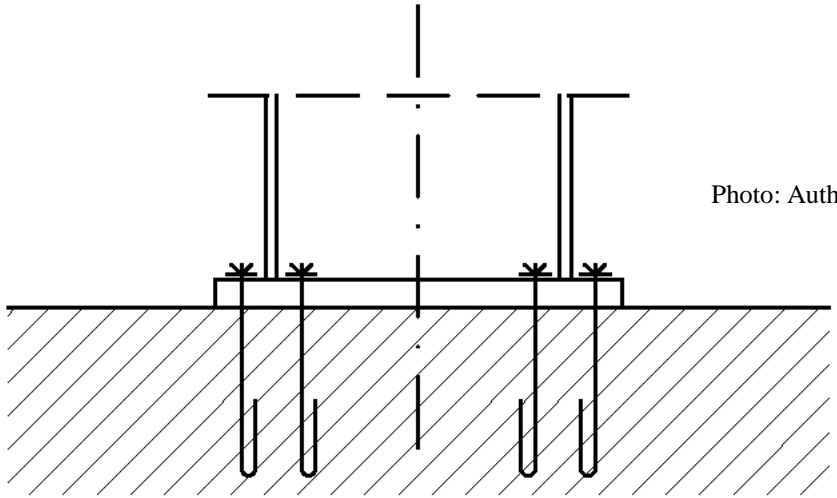
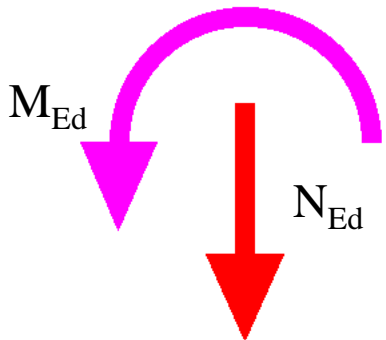
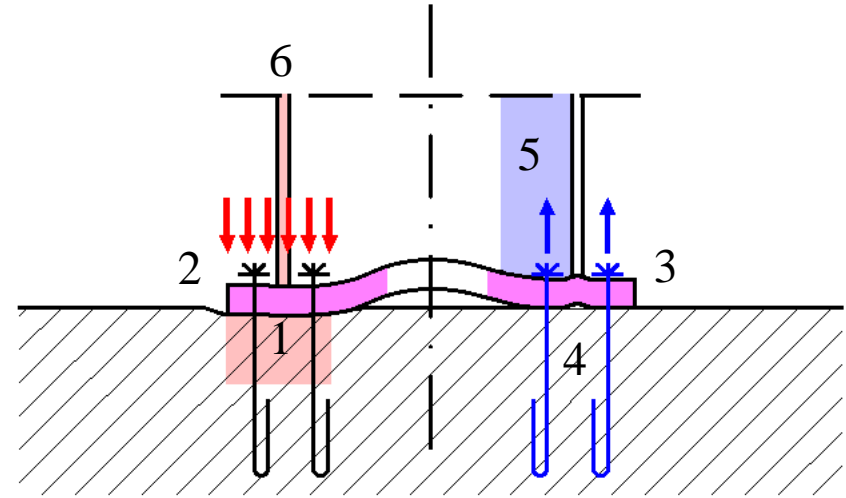


Photo: Author



Stiffness of rigid support is presented on Lectures #14 and #15:

- $S_{j, ini}$ in #14 / 94 and #15 / 42-44, 61-63;
- limits in #14 / 91-93

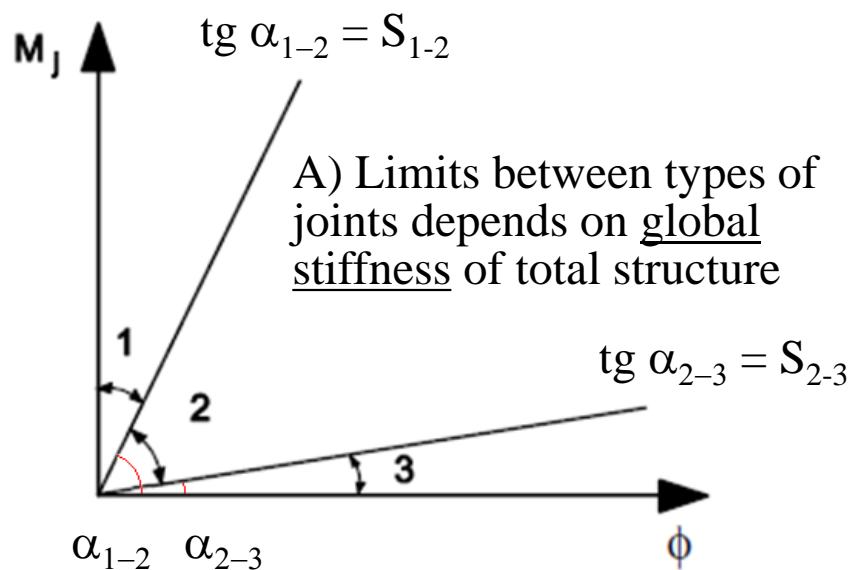
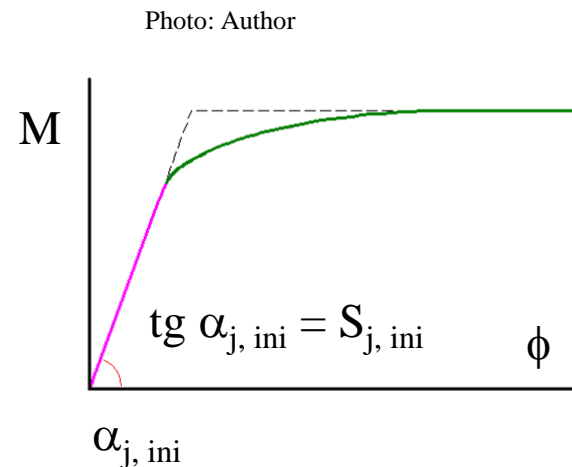


Photo: EN 1993-1-8 fig 5.4



Analysis of resistance depends on shape of stresses under base plate:

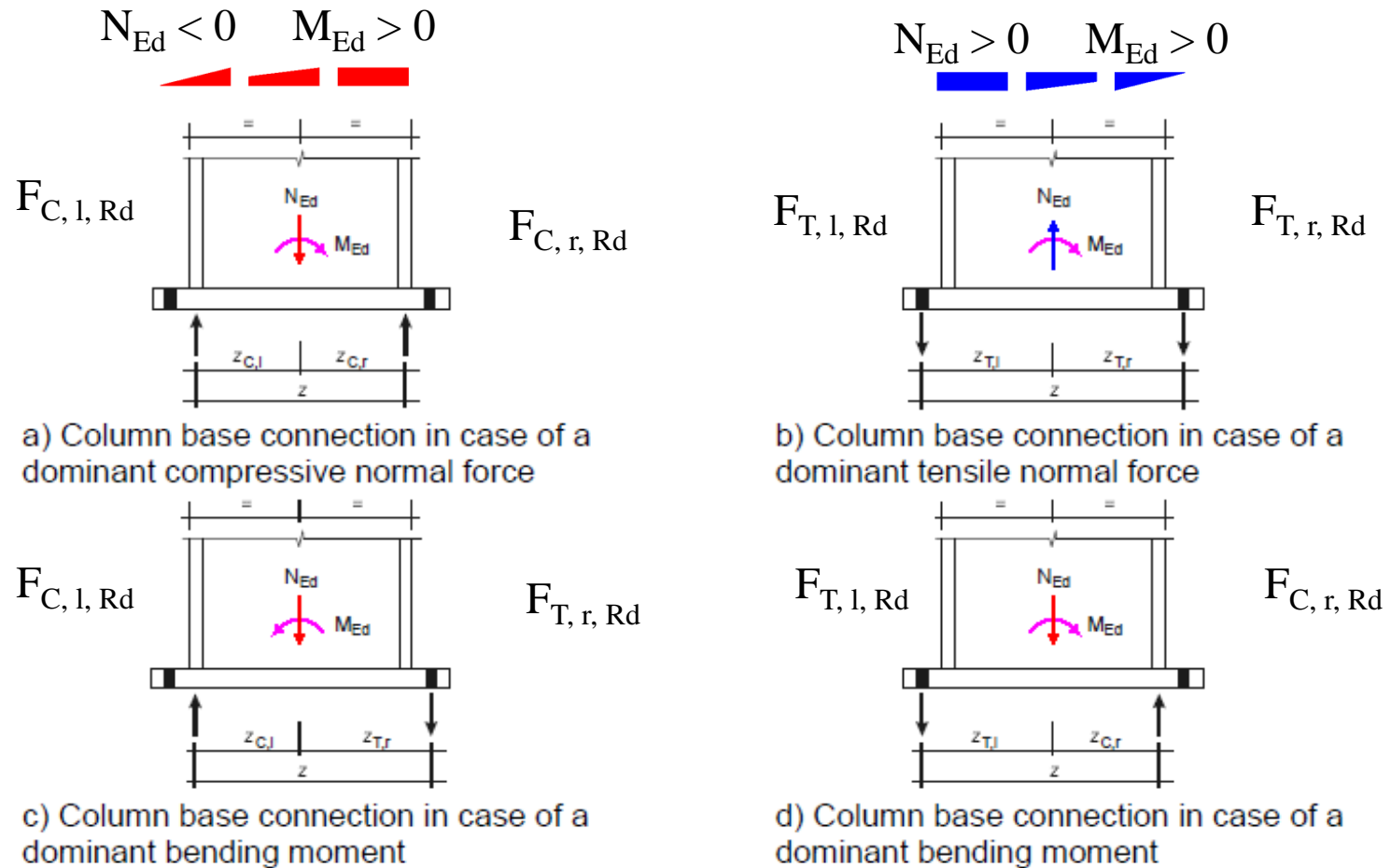
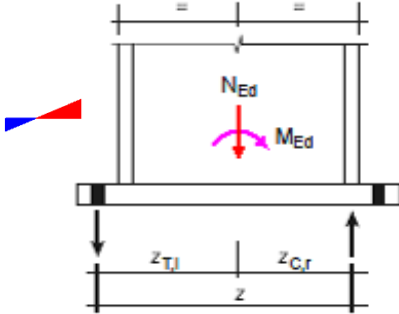
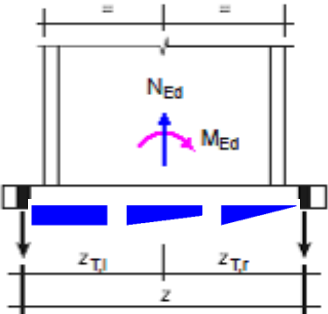
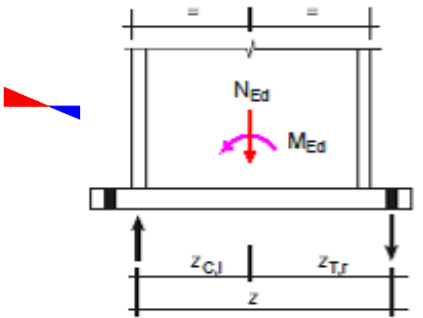
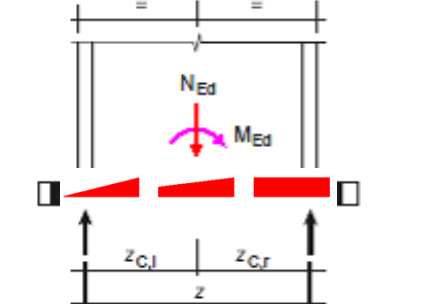


Photo: EN 1993-1-8 fig. 6.18
Author

Loading	Lever arms	Resistance $M_{j, Rd} =$	
<p>Left-T, Right-C, exampe: $M_{Ed} > 0$; $N_{Ed} < 0$</p> 	<p>$z = z_{T,l} + z_{C,r}$</p> <p>$e = M_{Ed} / N_{Ed}$</p>	<p>$N_{Ed} > 0 \quad e > z_{T,l}$</p>	<p>$N_{Ed} \leq 0 \quad e \leq -z_{C,r}$</p>
		<p>min [$z F_{T,l,Rd} / (1 + z_{C,r} / e)$; $-z F_{C,r,Rd} / (-1 + z_{T,l} / e)$]</p>	
<p>Left-T, Right-T, exampe: $M_{Ed} > 0$; $N_{Ed} > 0$</p> 	<p>$z = z_{T,l} + z_{T,r}$</p> <p>$e = M_{Ed} / N_{Ed}$</p>	<p>$N_{Ed} > 0 \quad 0 < e < z_{T,l}$</p>	<p>$N_{Ed} > 0 \quad -z_{T,r} < e \leq 0$</p>
		<p>min [$z F_{T,l,Rd} / (1 + z_{T,r} / e)$; $z F_{T,r,Rd} / (-1 + z_{T,l} / e)$]</p>	<p>min [$z F_{T,l,Rd} / (1 + z_{T,r} / e)$; $z F_{T,l,Rd} / (-1 + z_{T,l} / e)$]</p>

EN 1993-1-8 tab. 6.7, first part

Loading	Lever arms	Resistance $M_{j, Rd} =$	
<p>Left-C, Right-T, example:</p> <p>$M_{Ed} < 0$; $N_{Ed} < 0$</p> 	<p>$z = z_{C,l} + z_{T,r}$</p> <p>$e = M_{Ed} / N_{Ed}$</p>	<p>$N_{Ed} > 0 \quad e \leq -z_{T,r}$</p>	<p>$N_{Ed} \leq 0 \quad e > z_{C,l}$</p>
		<p>$\min [-z F_{C,l,Rd} / (1 + z_{T,r} / e) ; z F_{T,r,Rd} / (-1 + z_{C,l} / e)]$</p>	
<p>Left-C, Right-C, example:</p> <p>$M_{Ed} > 0$; $N_{Ed} < 0$</p> 	<p>$z = z_{C,l} + z_{C,r}$</p> <p>$e = M_{Ed} / N_{Ed}$</p>	<p>$N_{Ed} \leq 0 \quad 0 < e < z_{C,l}$</p>	<p>$N_{Ed} \leq 0 \quad -z_{C,r} < e \leq 0$</p>
		<p>$\min [-z F_{C,l,Rd} / (1 + z_{C,r} / e) ; -z F_{C,r,Rd} / (-1 + z_{C,l} / e)]$</p>	<p>$\min [-z F_{C,l,Rd} / (1 + z_{C,r} / e) ; -z F_{C,r,Rd} / (-1 + z_{C,l} / e)]$</p>

EN 1993-1-8 tab. 6.7, second part

Tensed part:

$F_{T, l, Rd} = \min$ (column web in tension, left ; base plate in bending, left)

$F_{T, r, Rd} = \min$ (column web in tension, right ; base plate in bending, right)

Compressed part:

$F_{C, l, Rd} = \min$ (concrete in compression, left ; column flange in compression, left)

$F_{C, r, Rd} = \min$ (concrete in compression, right ; column flange in compression, right)

Concrete in compression \rightarrow #t / 16-31 for area under compressed flange;

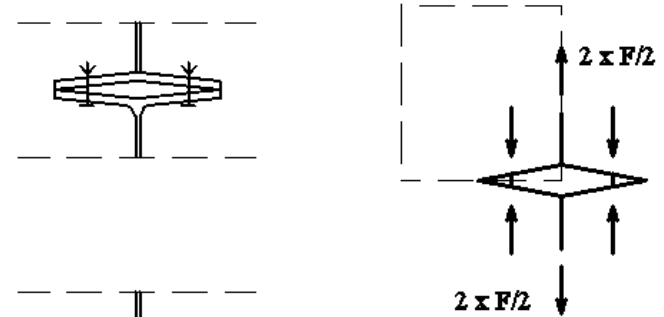
Column web in tension \rightarrow #19 / 64 (but force applied longitudinally, so calculation for column according to rules for beam);

Column flange in compression \rightarrow #19 / 49 (but force applied longitudinally, so calculation for column according to rules for beam);

Base plate in bending \rightarrow #19 / 67 (calculation is the same as for end plate in bending).

For base plate, the same as for end plate, three mechanisms of destruction (plate + anchor bolts, plate, anchor bolts only) must be analysed.

Mode 2 – plate / flange destruction and bolts destruction



Mode 1 – plate / flange destruction, no bolt destruction

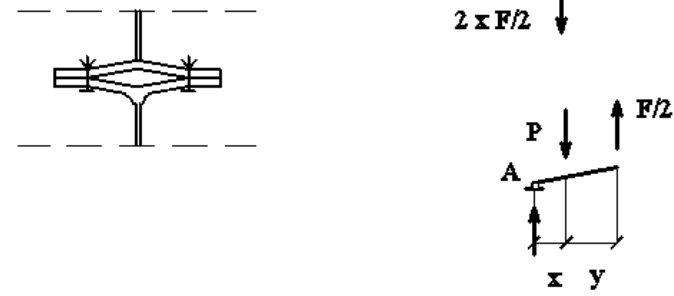


Photo: Author

Mode 3 – bolts destruction, no plate destruction

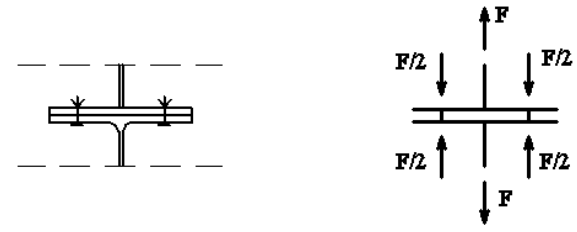




Photo: osha.gov

Additional mechanism for destruction anchor bolts, apart from too big tensile force or punching, is pulls them out of concrete member.



Photo: peikko.ca



Photo: homemadetools.net

J-anchor bolts must be used for big value of force. These anchors can be weld to the reinforced steel of base

The same, there can be used massive anchor assembly (retaining plates).

Interaction $N_{Ed} - M_{Ed}$

Common effect of N_{Ed} and M_{Ed} in rigid support is checked only as $M_{Ed} / M_{Rd} \leq 1,0$

What about N_{Ed} / N_{Rd} ?

Interaction between N_{Ed} and M_{Ed} must be taken into consideration always, when both types of cross-sectional forces act simultaneously.

- For members, Ist and IInd class of cross-section: formula

$$M_{y, Ed} / M_{N, y, Rd} \leq 1,0$$

is calculated; where $M_{N, y, Rd}$ is resistance of cross-section under bending moment and axial force (increasing value of axial force makes decreasing $M_{N, y, Rd}$; → #13 / 17-20).

- For members, IIIrd and IVth class of cross-section, general formula:

$$N_{Ed} / N_{Rd} + M_{Ed} / M_{Rd} \leq 1,0$$

is calculated (→ #13 / 22).

- For welds, simultaneously effect for stresses from N_{Ed} and M_{Ed} must be calculated (\rightarrow #17 / 6 - 92).
- For shear bolted joints, simultaneously effect for components of loads from N_{Ed} and M_{Ed} must be calculated (\rightarrow #19 / 18-19).
- For tension bolted joint, general formula

$$M_{j, Ed} / M_{j, Rd} + N_{j, Ed} / N_{j, Rd} \leq 1,0$$
 is calculated (\rightarrow #19 / 84-90).

Calculation of support is similar to calculation of member:

- Condition for bending moment $M_{j, Ed} / M_{j, Rd} \leq 1,0$ is analysed;
- No direct reference to axial force $N_{j, Ed}$;
- Axial force affects on value $M_{j, Rd}$;

Value of $M_{j, Rd}$ is generally presented as

$$z F_{R, min} / (1 + z_1 / e)$$

where $F_{R, min}$ - resistance of the weakest subpart, $e = M_{j, Ed} / N_{j, Ed}$

Change of axial force changes resistance for bending moment.

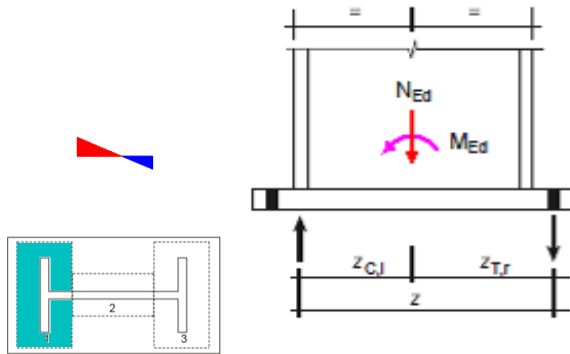
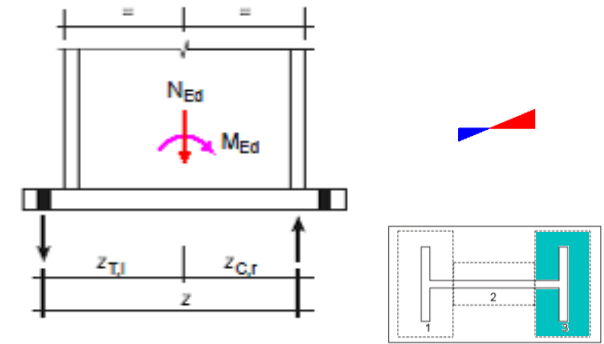


Photo: Author

Photo: EN 1993-1-8 tab. 6.7



1st possibility: big bending moment in comparison to small axial force:

$$N_{j, Ed} \rightarrow 0$$

$$e = M_{j, Ed} / N_{j, Ed} \rightarrow \infty$$

$$M_{j, Rd} = z F_{R, min} / (1 + z_1 / e) = z e F_{R, min} / (z_1 + e)$$

$$\text{For } e \rightarrow \infty, (z_1 + e) \rightarrow e$$

$$M_{j, Rd} = z e F_{R, min} / (z_1 + e) = z F_{R, min} [e / (z_1 + e)] \rightarrow z F_{R, min} [e / e] \rightarrow z F_{R, min}$$

In case of small axial force, resistance of bending moment depends on resistance the weakest subpart (probably: resistance of concrete under one flange) and its arm of action.

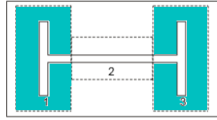
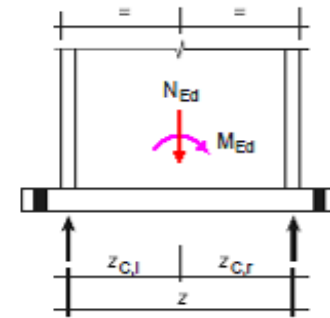


Photo: Author

Photo: EN 1993-1-8 tab. 6.7



IInd possibility: small bending moment in comparison to big compressive axial force: $M_{j, Ed} \rightarrow 0$

$$e = M_{j, Ed} / N_{j, Ed} \rightarrow 0 \quad ; \quad M_{j, Ed} = e N_{j, Ed}$$

$$M_{j, Rd} = z F_{R, min} / (1 + z_1 / e) = z e F_{R, min} / (z_1 + e)$$

$$\text{For } e \rightarrow 0, (z_1 + e) \rightarrow z_1 \quad ; \quad z_1 \rightarrow z / 2$$

$$M_{j, Ed} / M_{j, Rd} \rightarrow (e N_{j, Ed}) / (z e F_{R, min} / z_1) = \{ (N_{j, Ed}) / [z F_{R, min} / (z / 2)] \} (e / e) \rightarrow N_{j, Ed} / (2 F_{R, min})$$

In case of domination of compressive axial force, condition for bending moment transforms to condition for axial force to 2x resistance of the weakest part of support. Probably, the weakest part of joint is concrete under flange. In such case, resistance of concrete base under both flanges must be calculated. This is difference from case of axial force only, when resistance is calculated for concrete base under both flanges and web. Calculations only for concrete under flanges have greater safety margin than calculations for flanges and web.

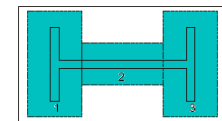
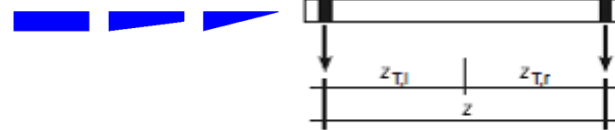


Photo: EN 1993-1-8 fig. 6.19

Photo: Author

Photo: EN 1993-1-8 tab. 6.7



IIIrd possibility: small bending moment in comparison to big tensile axial force: $M_{j, Ed} \rightarrow 0$

Rare case, for example situation when wind suction on roof is bigger than dead weight of structure.

$$e = M_{j, Ed} / N_{j, Ed} \rightarrow 0 \quad ; \quad M_{j, Ed} = e N_{j, Ed}$$

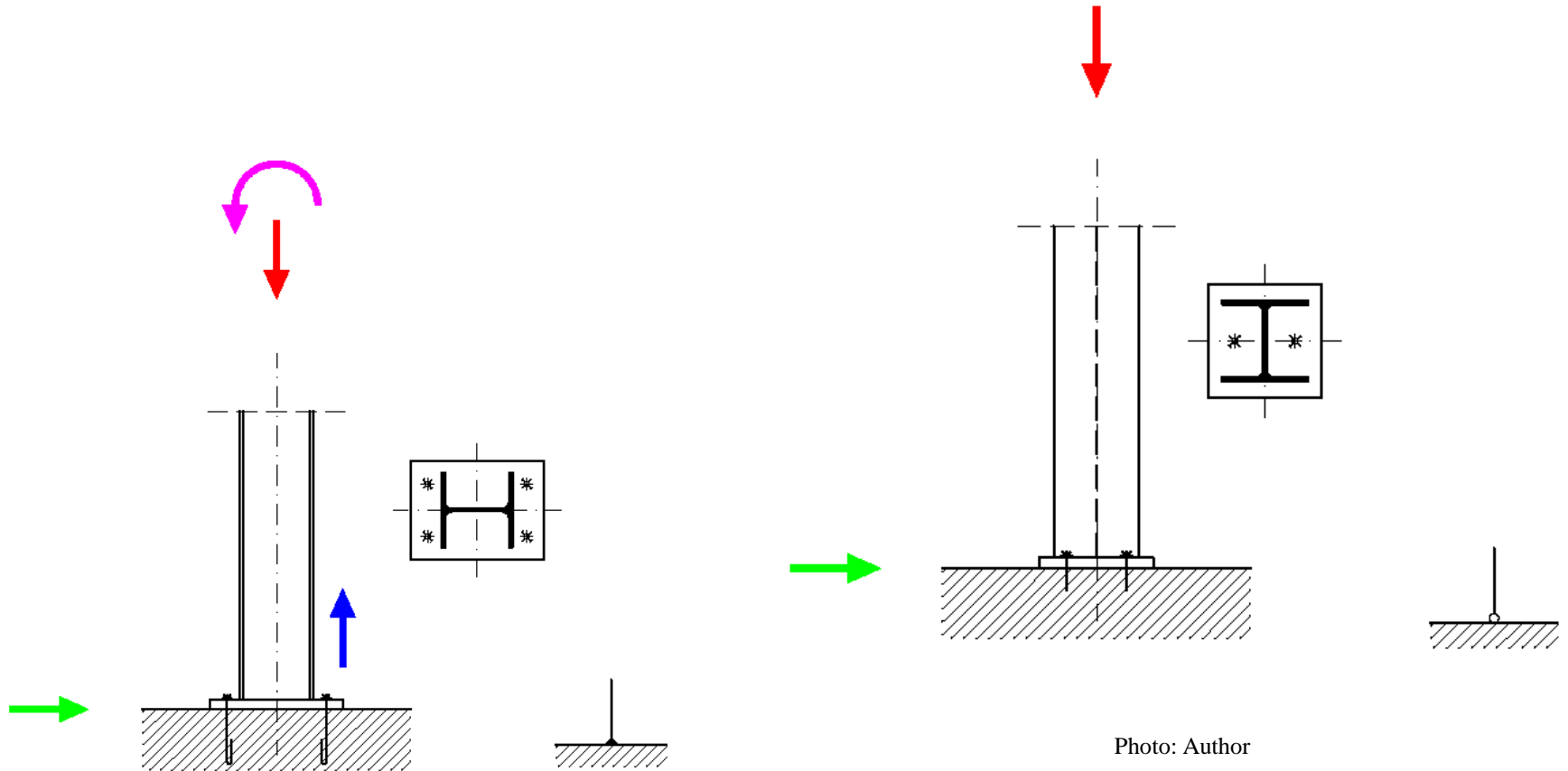
$$M_{j, Rd} = z F_{R, min} / (1 + z_1 / e) = z e F_{R, min} / (z_1 + e)$$

$$\text{For } e \rightarrow 0, (z_1 + e) \rightarrow z_1 \quad ; \quad z_1 \rightarrow z / 2$$

$$\begin{aligned} M_{j, Ed} / M_{j, Rd} &\rightarrow (e N_{j, Ed}) / (z e F_{R, min} / z_1) = \{(N_{j, Ed}) / [z F_{R, min} / (z / 2)]\} (e / e) \rightarrow \\ &\rightarrow N_{j, Ed} / (2 F_{R, min}) \end{aligned}$$

Conclusion the same as for previous case: condition for bending moment transforms to condition for axial force to 2x resistance of the weakest part of support. At now, the weakest part could be web of column or base plate under bending.

Shear force can occur in hinge and support column bases. Resistance for shear force is calculated, based on resistance of anchor bolts, friction steel-concrete and, sometimes, resistance of additional shear studs.



$$F_{v, Rd} = F_{f, Rd} + n F_{vb, Rd}$$

$F_{f, Rd} = C_{f, d} N_{c, Ed}$; $C_{f, d} = 0,2$ friction force for compressive force $N_{c, Ed}$ in column

$F_{f, Rd} = 0$ for tensile force in column

n – number of anchor bolts

Type	$F_{vb, Rd}$
Fit bolts; Normal round holes	<p>min [shear resistance of anchor bolt (\rightarrow #18 / 51 - 56); $\alpha_b f_{ub} A_s / \gamma_{M2}$]</p> <p>$\alpha_b = 0,44 - 0,0003 f_{yb}$ [MPa] $\gamma_{M2} = 1,25$</p>
Oversized round holes; Slotted short / long holes	0

EN 1993-1-8 6.2.2

Accuracy for steel structures - to 1 mm. Accuracy for concrete structures (also for position of anchor bolts) - to 10 mm. Diameter of holes for bolts must be very big to enable compensate imperfection for position of anchor bolts (oversized round holes). Of course, for this situation $F_{vb, Rd} = 0$. There are applied additional washers ($d_0 = d$), which can be welded to base plate.

Then $F_{vb, Rd}$ is calculated as for fit bolts or normal round holes.

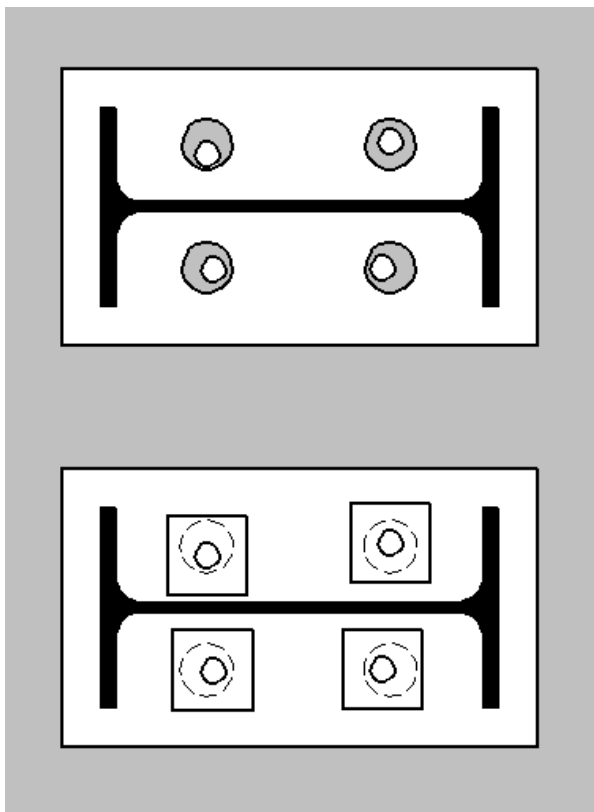


Photo: Author



Photo: nees.org

Additional shear stub, increasing shear resistance, could be applied in case of problems with resistance of anchor bolts.



Photo: steelconstruction.info

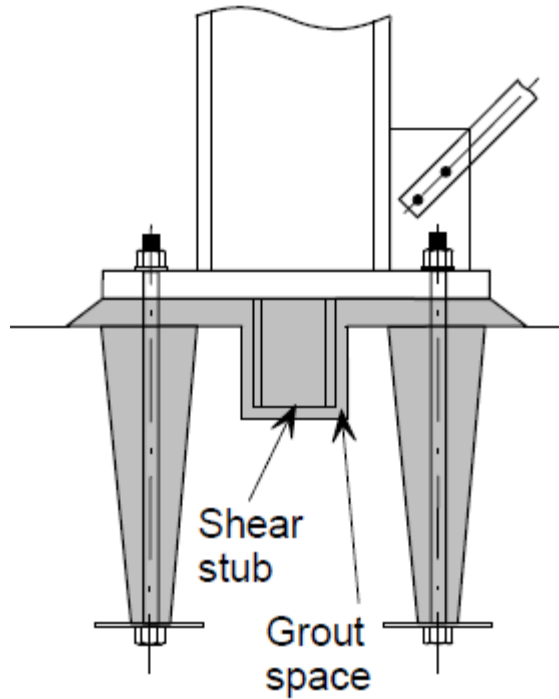


Photo: heronjournal.nl

Photo: asmedigitalcollection.asme.org

Classification of column's bases according to old Polish Standards

Value of eccentricity

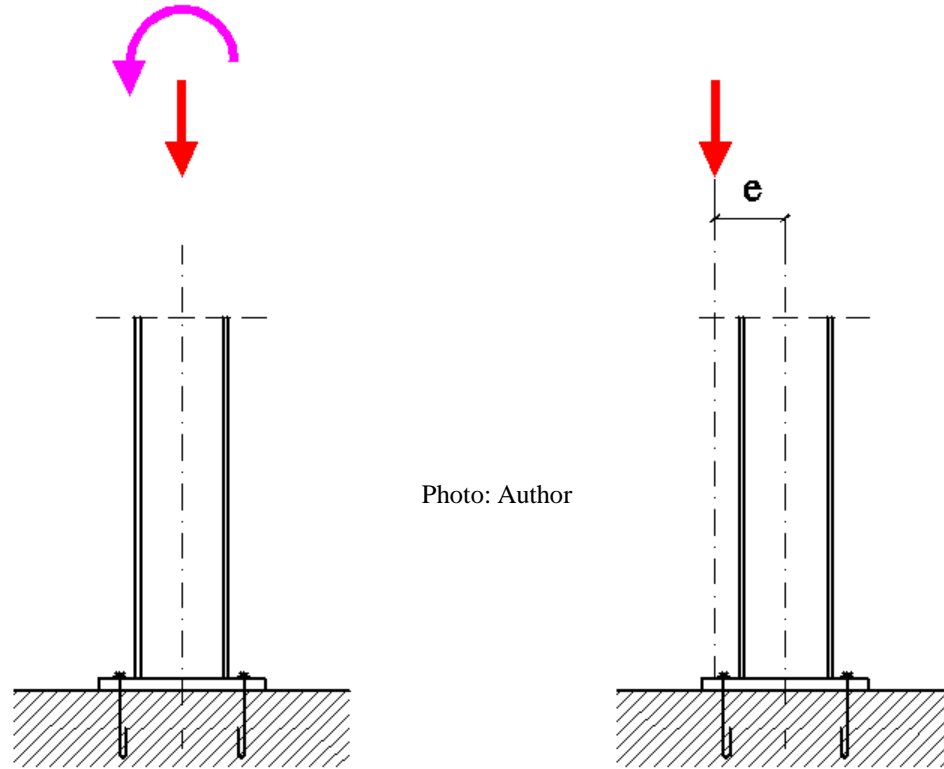


Photo: Author

$$| M_{Ed} / N_{Ed} | = e$$

According to old Polish Standards, contact between steel and concrete occurs under total area of base plate. Core of a rectangular cross-section is very important for such case.

$$e_{\text{core}} = L / 6$$

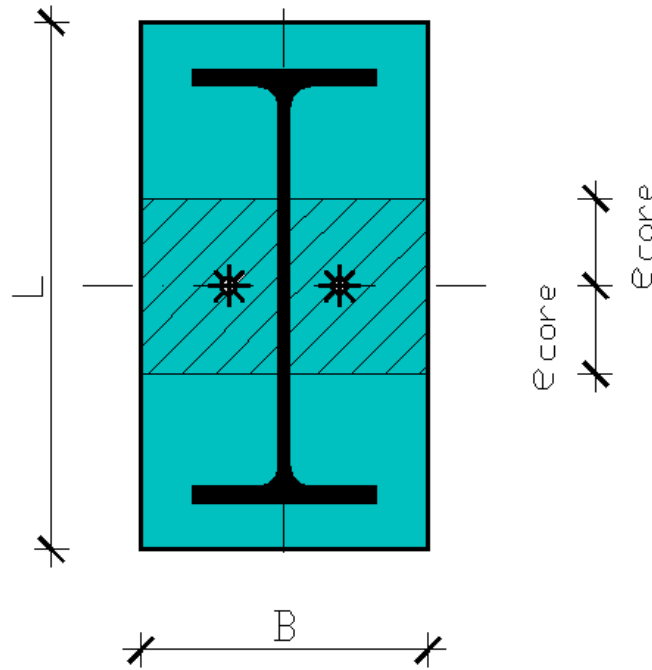


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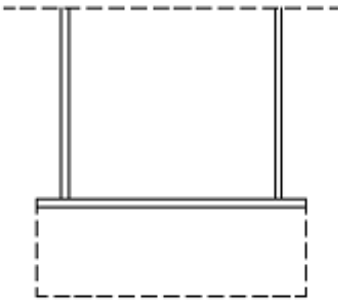
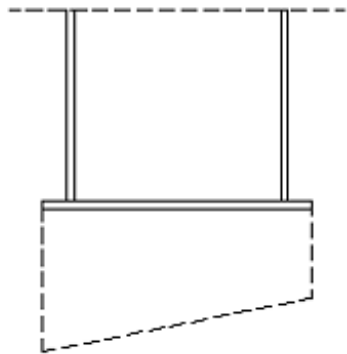
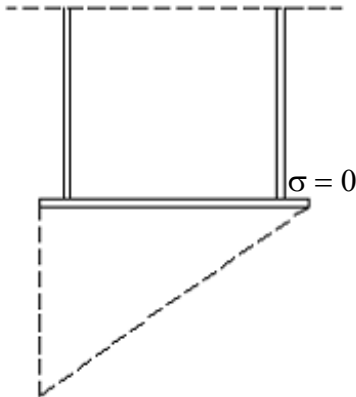
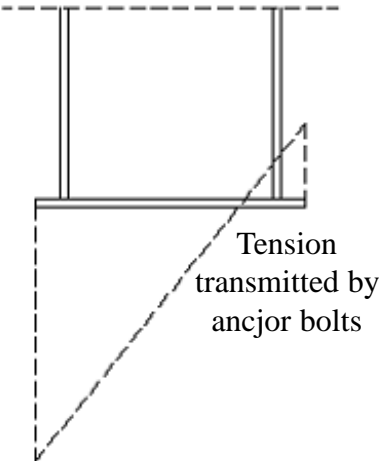
Force inside core		Force outside core	
Axial force	Small eccentricity		Large eccentricity
Hinge support	Rigid support		
 <p>Compression only</p>	 <p>Compression only</p>	 <p>Compression only</p>	 <p>Tension transmitted by anchor bolts</p> <p>Compression</p>
$e = 0$	$0 < e < L / 6$	$e = L / 6$	$e > L / 6$

Photo: Author

Technical solutions recommended according to old Polish Standard:

Photo: Author

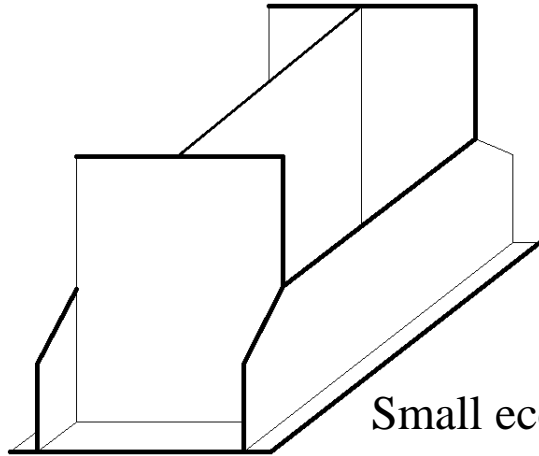


Photo: sefindia.org

Small eccentricity
(vertical plate stiffeners)

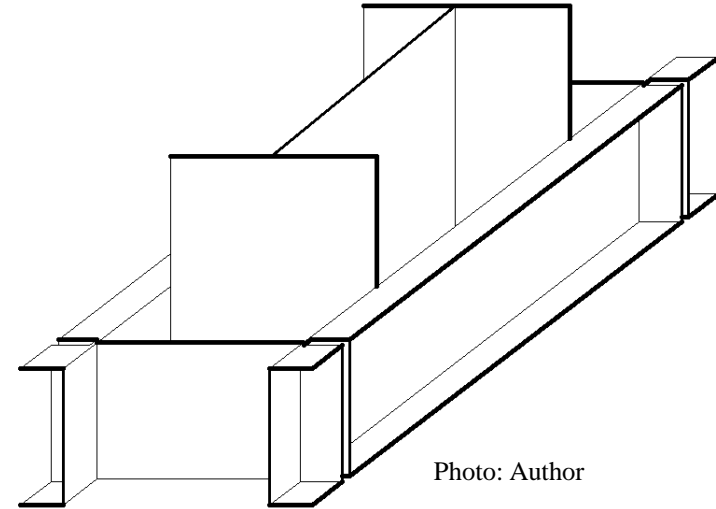
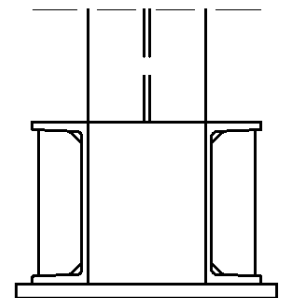
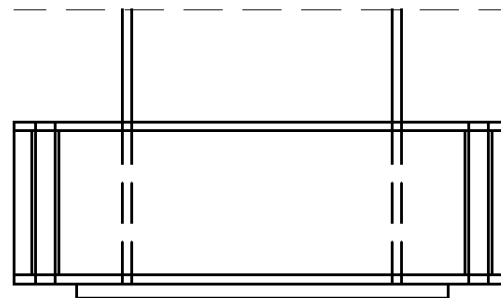
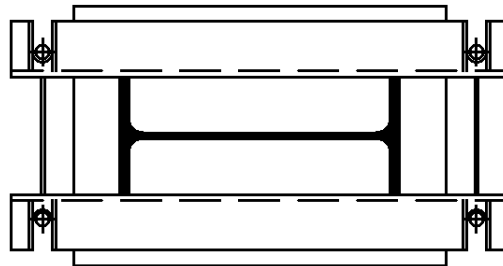


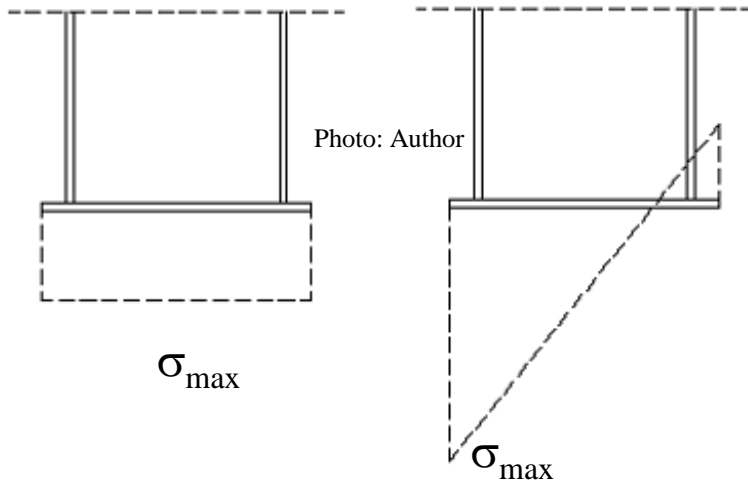
Photo: Author

Big eccentricity (massive C-section stiffeners)



Photo: i.pining.com





Calculation of resistance according to old Polish Standards:

Resistance of concrete: $\sigma_{max} / f_c \leq 1,0$

Resistance of steel plate: base plate is divided along web, flanges and stiffeners into sub-plates with one, three or four edges **rigidly supported** by stiffeners, flanges or web. These plates are calculated for continuous load = reaction from concrete base = σ_{max} . Bending moments m_{pl} [kNm/m] for plates are calculated.

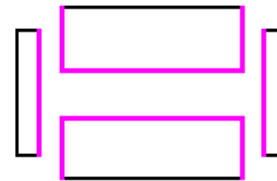
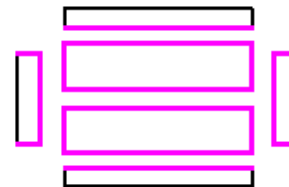
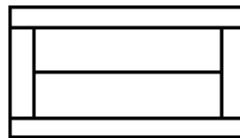
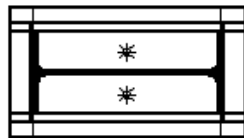


Photo: Author



Thickness of base plate t_{bp} is calculated from condition:

$$m_{max} / m_{Rd} \leq 1,0$$

$$m_{Rd} = t_{bp}^2 f_y / 6$$

Reaction from concrete and force in anchor bolts make bending moment and shear force, act in cross-section a-a and b-b (on surface of column flange).

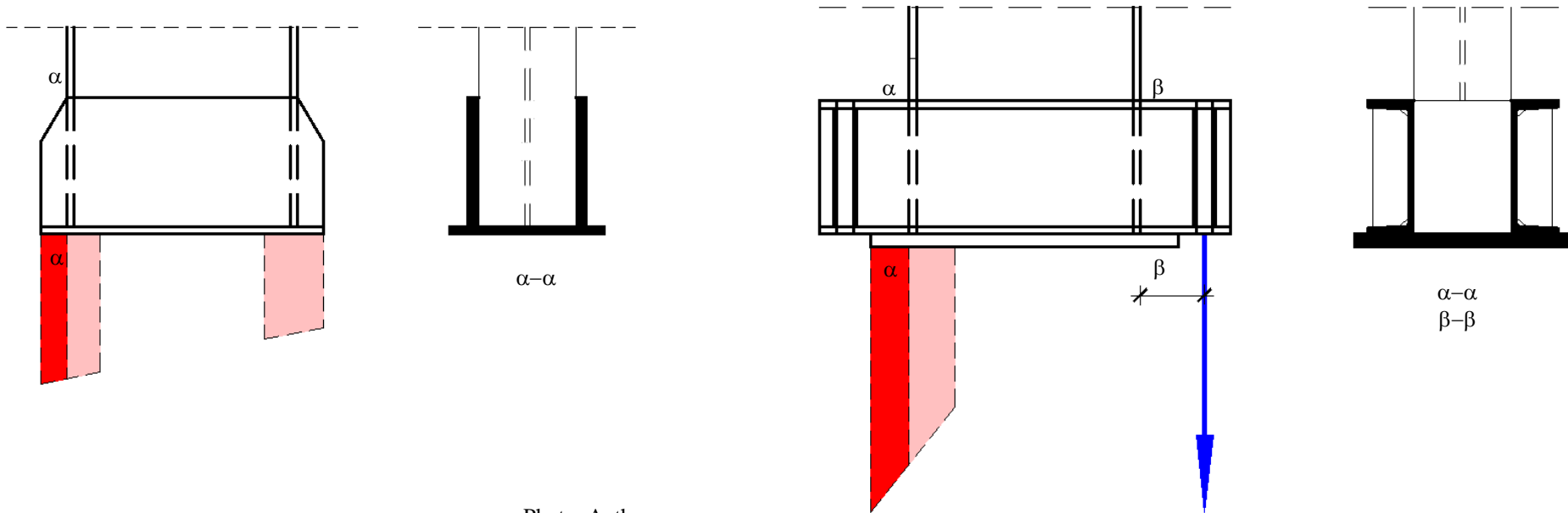


Photo: Author

Cross-section base plate + stiffeners and welds must be checked for resistance under these cross-sectional forces.

Structural bearings

Specific complex of steel sub-elements, creating pinned or roller support for steel beams or truss. Below structural bearing (rocker) could be column (steel, concrete, masonry), beam (steel, concrete) or wall (concrete, masonry). Many various technical solutions are taken into consideration, depending on various criteria.



Photo: formfindinglab.wordpress.com

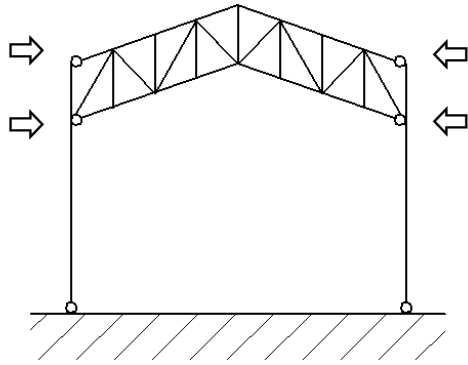


Photo: Author

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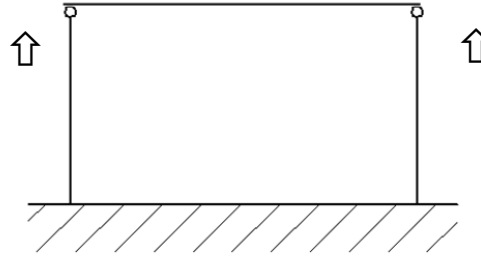


Directions of support

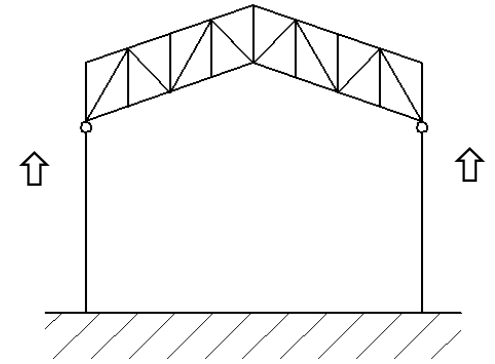


Truss: lateral supports

Photo: Author



Beam: support from below only



Truss: support from below

Support from below → #t / 58 - 84

Lateral supports → #t / 85 - 87

Types of support for beams and trusses

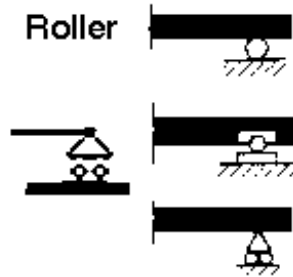


Photo: web.mit.edu

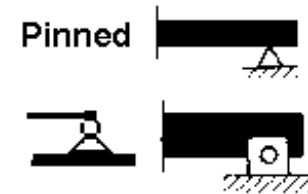


Photo: web.mit.edu

Strict execution of pinned or roller supports is very important for bridge structures. For rest structures, this is the same important for structures of 3 Consequence Class. For CC1, these issues may be omitted. In case of CC2, solution depends on experience of designer (it is not always necessary to thoroughly analyze type of nodes).

Numerical model

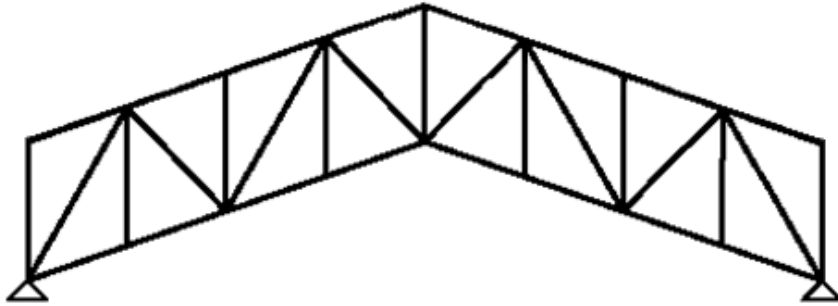
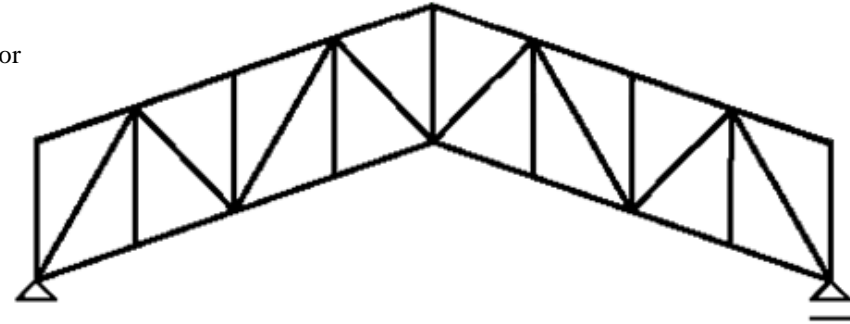
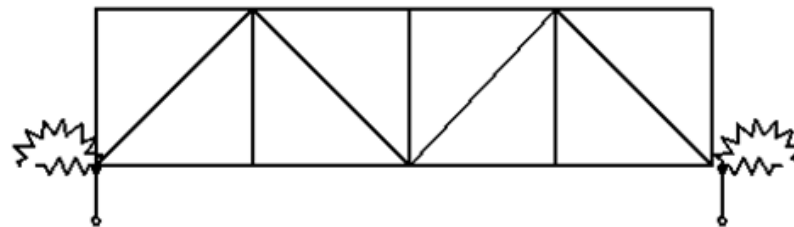


Photo: Author



Distribution of forces in top and bottom chords is completely different in case of symmetrical supports (pinned-pinned) and unsymmetrical (pinner-rolled). The most important question is, which one model is closer to real behaviour of truss.



→ #9 / 81

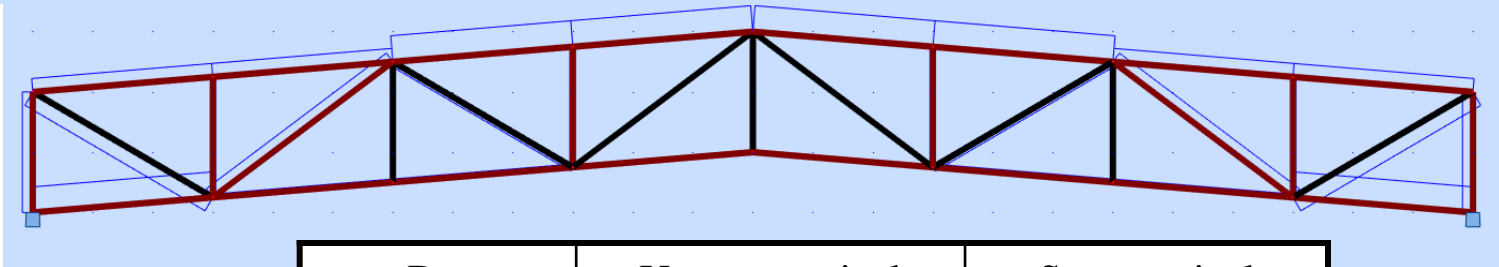
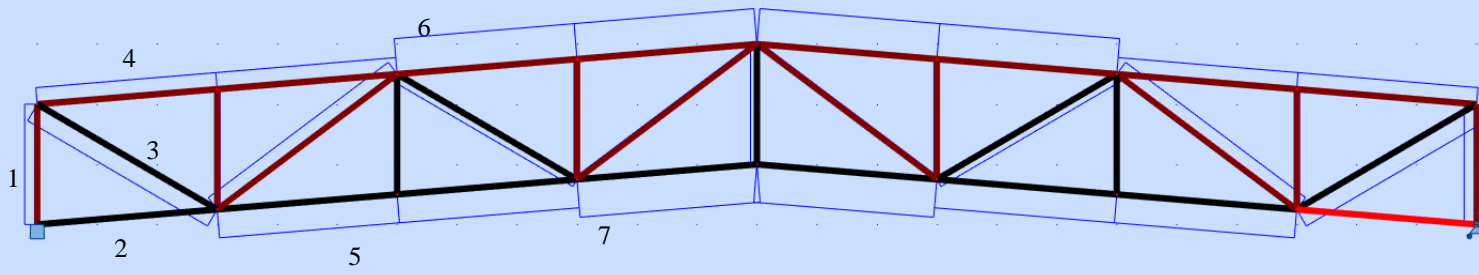


Photo: Author

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Compression
Tension

Bar	Unsymmetrical	Symmetrical
1	72,82	60,59
2	0,00	147,30
3	111,04	89,79
4	96,24	77,83
5	164,99	19,14
6	206,24	151,00
7	220,00	0,95

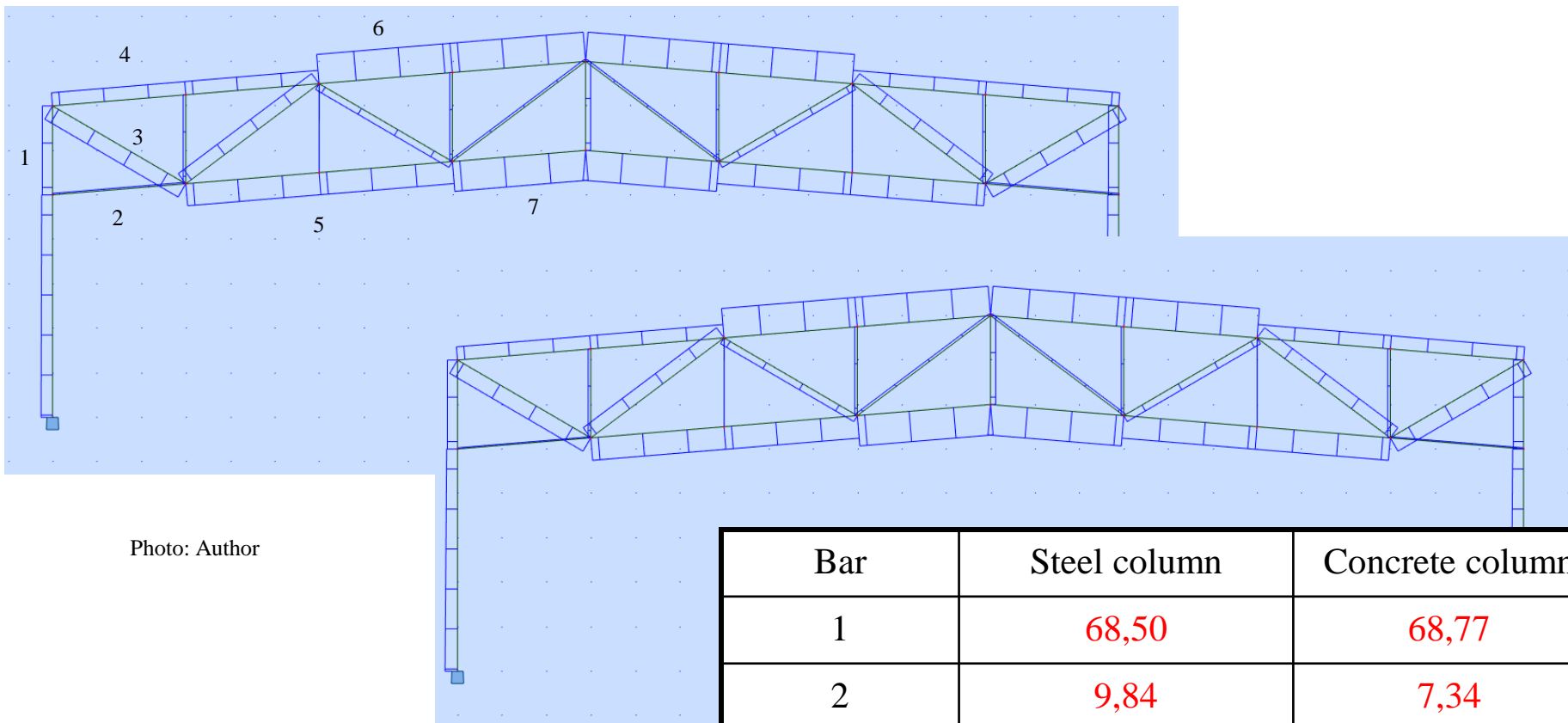


Photo: Author

Compression
Tension

→ #9 / 87

Bar	Steel column	Concrete column
1	68,50	68,77
2	9,84	7,34
3	103,75	104,22
4	89,11	89,54
5	149,18	152,33
6	197,78	198,61
7	201,79	205,56

Bar	Steel column	Concrete column	Average	Unsymmetrical	Symmetrical
1	68,50	68,77	68,64	72,82	60,59 (-12%)
2	9,84	7,34	8,59	0,00	147,30 (+1 715 %)
3	103,75	104,22	103,99	111,04	89,79 (-14%)
4	89,11	89,54	89,33	96,24	77,83 (-13%)
5	149,18	152,33	150,76	164,99	19,14 (+113%)
6	197,78	198,61	198,20	206,24	151,00 (-24%)
7	201,79	205,56	203,68	220,00	0,95 (+100%)

Differences between unsymmetrical model of truss and full model (truss + column) are small; generally cross-sectional forces are a little bigger for unsymmetrical model (safe side results).

Between full model and symmetrical model are big differences, very big differences or even completely opposite direction of cross-sectional forces.

→ #9 / 88

Bar	Steel column	Concrete column	Unsymmetrical	Symmetrical
Top chord	197,78	198,61	206,24	151,00
Bottom chord	201,79	205,56	220,00	147,30

Max values of axial forces in top and bottom chords show problems, which occurs after application wrong stati model: symmetrical supports.

Top chord will be designed for force about 75% of real force: it means big probability of destruction of cord and truss.

Bottom chord will be designed for opposite (compressive, not tensile) force: it means big probability of oversizing for chord.

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Conclusion: elastic supports in horizontal direction are simplified by pinned-rolled supports with very big accuracy.

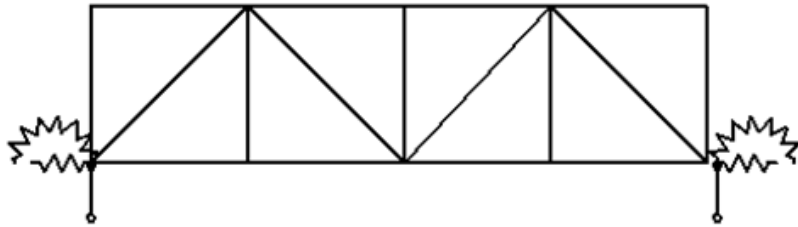
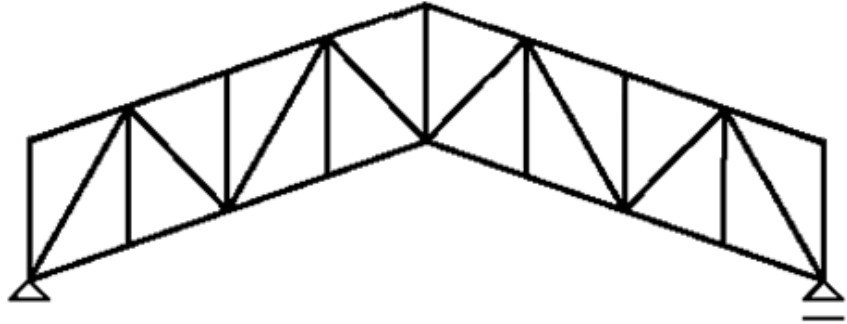
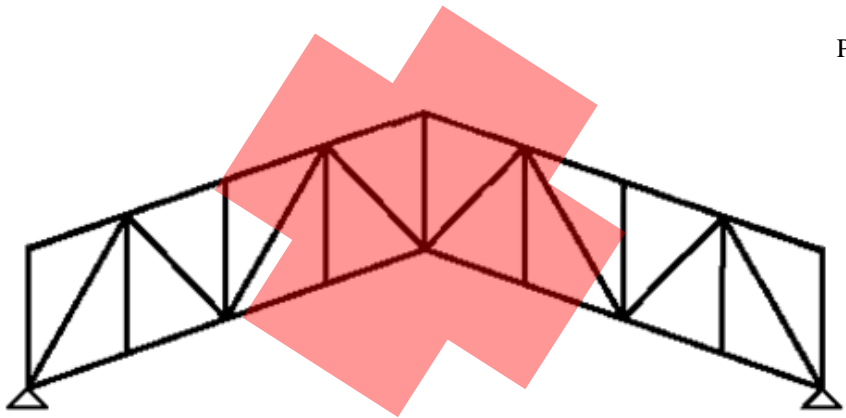


Photo: Author



→ #9 / 90

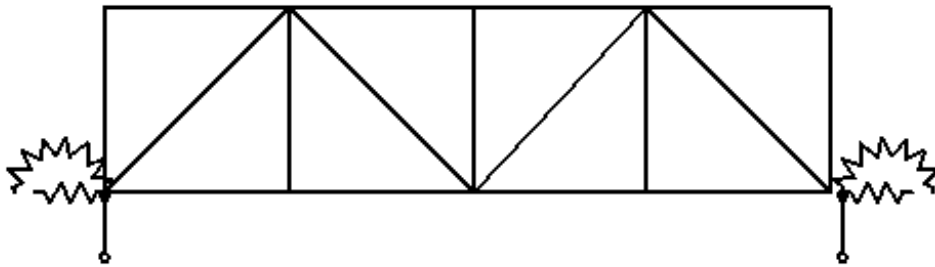
Example of effects of wrong technical solution in support of long-span truss (> 100 m length). In theory – pinned support ($M = 0$), but technical solution is very massive, such as for rigid support. Big bending moment, unforeseen in calculations, occurs in support. Left anchor bolt is destructed by plastic cutting of threaden portion (small gap between plate nad nut). It makes series of secondary failures in whole structure.



Photo: mojafirma.infor.pl

Analysed structure (entertainment center) could be classified as CC3. Detailed analysis of technical solution for support is required. Used solution – no possibility of rotation – is wrong. There should be applied round rocker or even elastomeric bearing.

Photo: Author



Because of susceptibility of column / wall, anchor bolts there are spring supports for horizontal direction and rotation in real truss.

One roller and one pinned support is good approximation and idealisation for this situation.

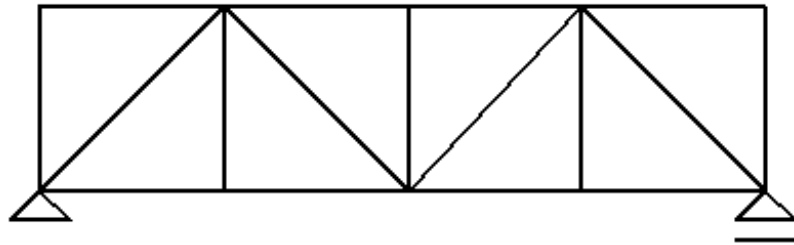


Photo: prof. M. Gwózdź

Even if no specific structural solutions are used (which make support similar to roller or pinned support), susceptibility of supports is usually sufficient to adopt the scheme as above. Roller support must be made only for very solid supports or incorrect supports (too rigid).

As with rotation ($\rightarrow \#t / 75$), a technical solution as for roller support for CC3 is also mandatory.

An important feature of structure CC3 is large safety margin. Real behavior of supports must be as close as possible to theoretical one, to avoid secondary effects come from supports different from the assumed one. They are usually impressive structures with large spans (and large reactions in the supports). Large reactions with other than ideal supports may cause significant secondary effects, dangerous for structure. That is why for CC3 it is so important to shape supports as close as possible to ideal.



Photo: alcoxsteel.com

Photo: cnxzf.com



Photo: wikipedia

→ #14 / 32

On lecture will present recommendations applicable in civil engineering for structures of CC3. In case of CC2 and CC1 designs, it is possible to depart from strict compliance with recommendations. Recommendations are based only on engineering experience and are not mandatory. However, compliance with them allows you to avoid potential problems during exploitation of the structure.

For „normal” truss and beams important factor is proportion between stiffness of Girder (truss or I-beam) and Support (column, wall...):

$$S_G / S_S$$

$$S_G = E_G J_G / L_G$$

$$S_S = E_S J_S / h_S$$

Stiffness of truss could be approximated by:

$$S_{\text{truss}} \approx 3,5 q L_G^2 \quad ; \quad q = (\Sigma F_i) / L_G$$

or (\rightarrow #9 / 11):

$$J_{\text{truss}} \approx 0,35 h_{1, \text{truss}}^2 A_{\text{chord}}$$

\rightarrow #14 / 29

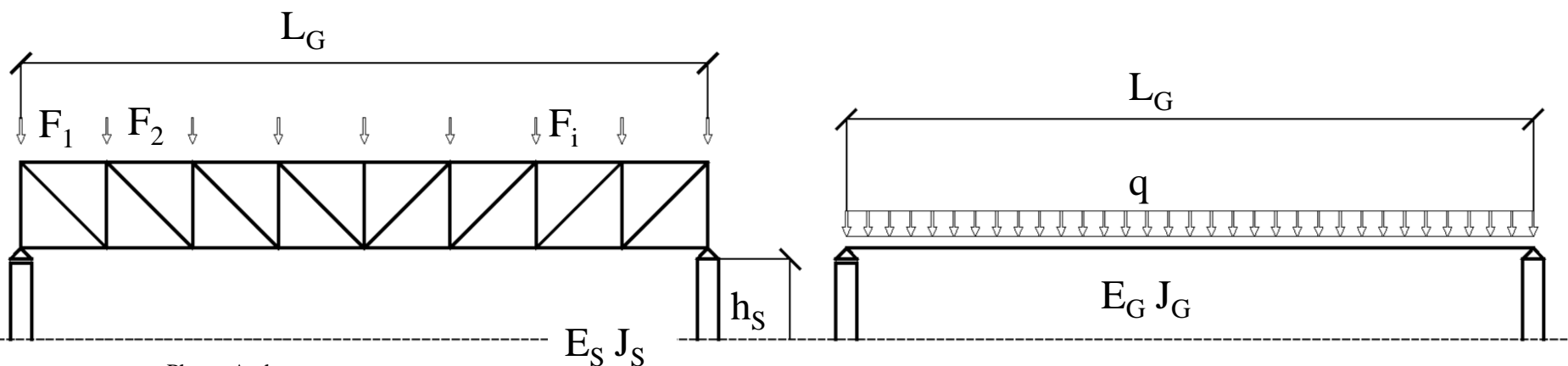
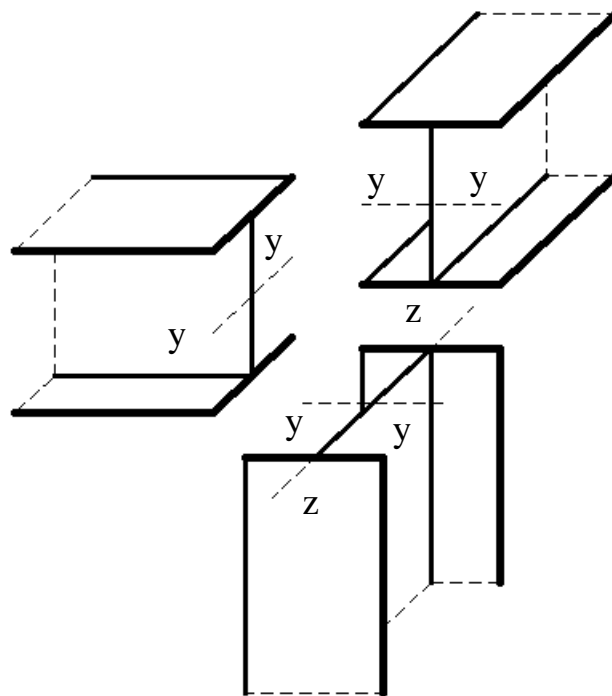


Photo: Author

Calculation for stiffness of support (column in this case) depends on direction of joint girder-support

$$S_G = E_G J_{G,y} / L_G$$

$$S_S = E_S J_{S,z} / h_S$$



$$S_G = E_G J_{G,y} / L_G$$

$$S_S = E_S J_{S,y} / h_S$$

Photo: Author

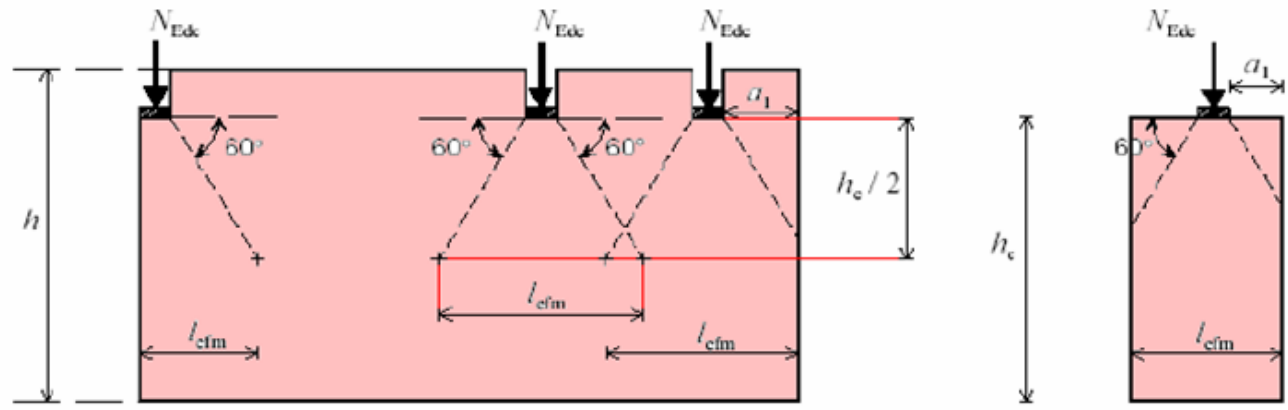


Photo: EN 1996-1-1 fig 6.2

Moment of inertia for masonry wall is calculated for rectangular t per l_{efm} :

$$J_S = l_{efm} t^3 / 12$$

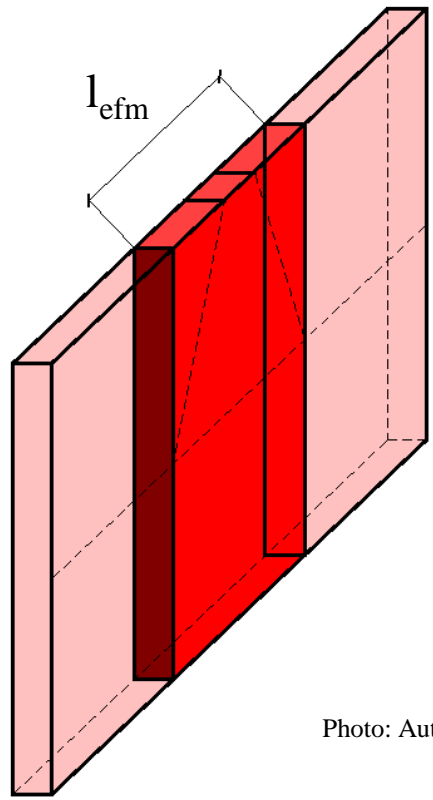


Photo: Author



Photo: buildingcommittee.wordpress.com

Moment of inertia for masonry wall is calculated for rectangular t per l :

$$J_S = 1 t^3 / 12$$

$$l = 2x + b_f$$

$$x \approx (1/10 - 1/16) h$$



Photo: studio-tm.com

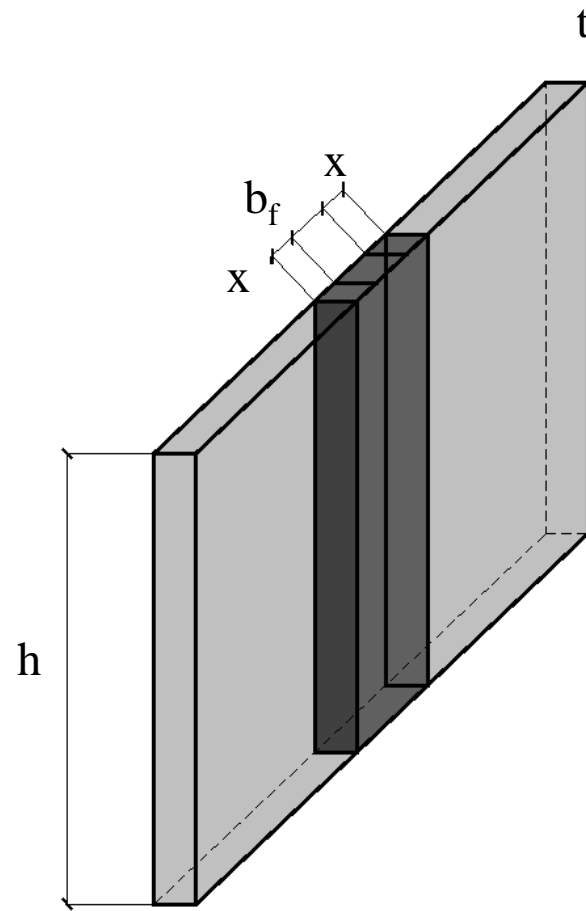


Photo: Author



Photo: formfindinglab.wordpress.com



Photo: canamjoist.co.uk

Stiffness of concrete beam (type of support):

$$S_S = G_S J_{S,T} / L_S$$

G_S - Kirchhoff modulus

$J_{S,T}$ – torsional moment of inertia

Recommended technical solutions (based on experience):

(Big)	Various proportion S_G / S_S		(Small)
No rocker	Flat rocker	Round rocker	Elastomeric rocker

Elastomeric rocker is used, first of all, for bridges. For other type of structures is used very rare.



Photo: anthony-johnson-engineering.co.uk

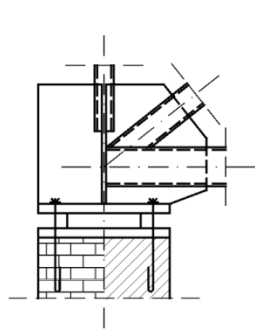


Photo: Author

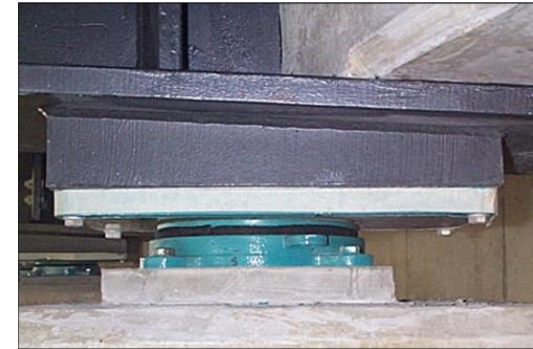
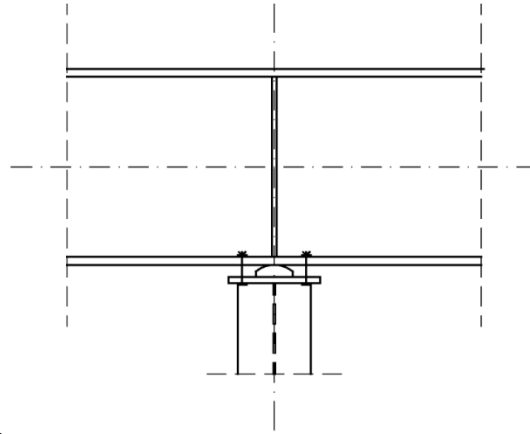


Photo: steelconstruction.info

→ #14 / 30

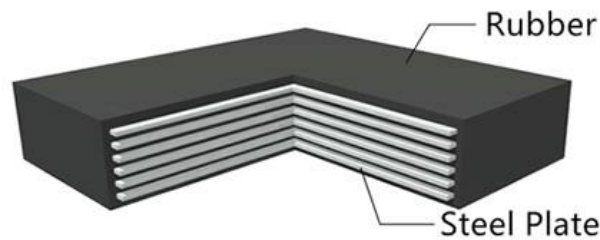


Photo: bridgebearing.org

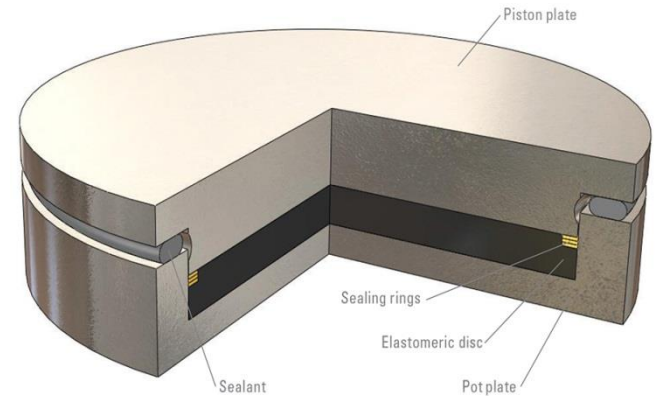


Photo: canambridges.com

Elastomer bearing consists of layers of steel and rubber. Provides good vertical load transfer. Work in horizontal direction and rotation is very close to ideal roller support.

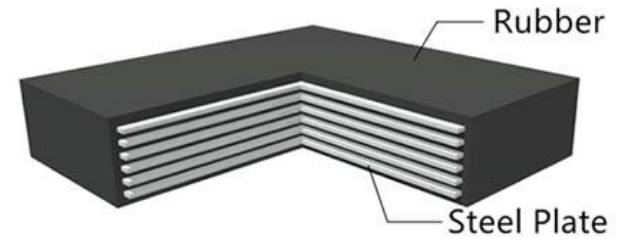


Photo: bridgebearing.org

→ #14 / 31

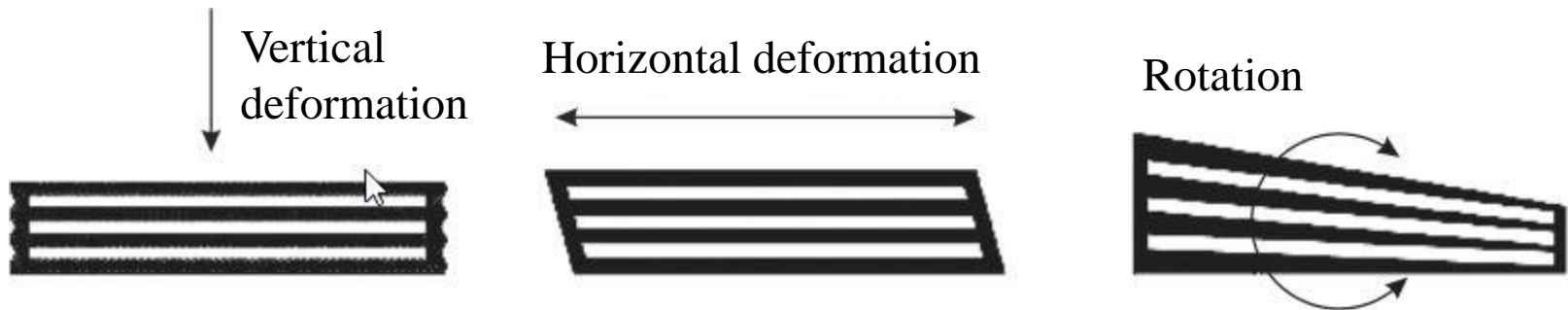


Photo: forbuild.eu

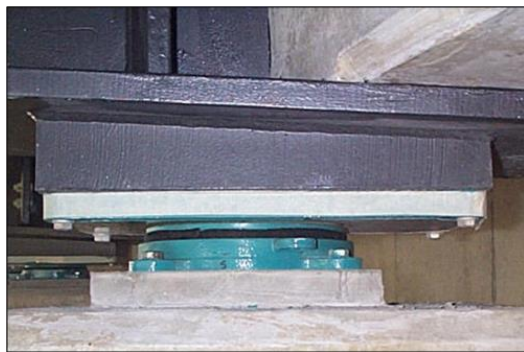


Photo: steelconstruction.info

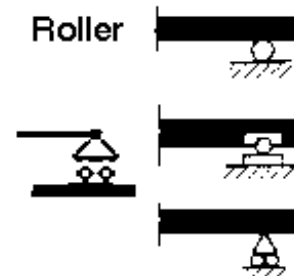


Photo: web.mit.edu

Recommendations for CC3 are not necessarily valid for lower Consequence Classes. Structure should be as cheap as possible. Detailed design of supports can be very important for CC3. For lower classes, with a smaller assumed safety margin, it may not be necessary: too expensive in relation to safety of structure. Small differences between ideal and real behavior of structure can be accepted. Carrying out / resigning from thorough analysis should result from experience of designer.

CC	$S_G / S_S > 20$	$20 \geq S_G / S_S > 10$	$10 \geq S_G / S_S > 5$	$5 \geq S_G / S_S$
3	No rocker	Flat rocker	Round rocker	Elastomeric rocker
2	No rocker	No rocker / flat rocker	Flat rocker / round rocker	Round rocker
1	There is usually no detailed analysis			

→ #14 / 33



Photo: fbcdn-photos-g-a.akamaihd.net

Examples of roller (left) and pinned (right) old-fashion supports for bridge structures. Two completely various technical solutions for analysed problem. More information is presented on separated subject → Bridges.



Photo: texasescapes.com



Photo: wikipedia



Photo: tatasteelconstruction.com

Examples of hinge support in structures CC3:

Photo: Author

Enter to metro station

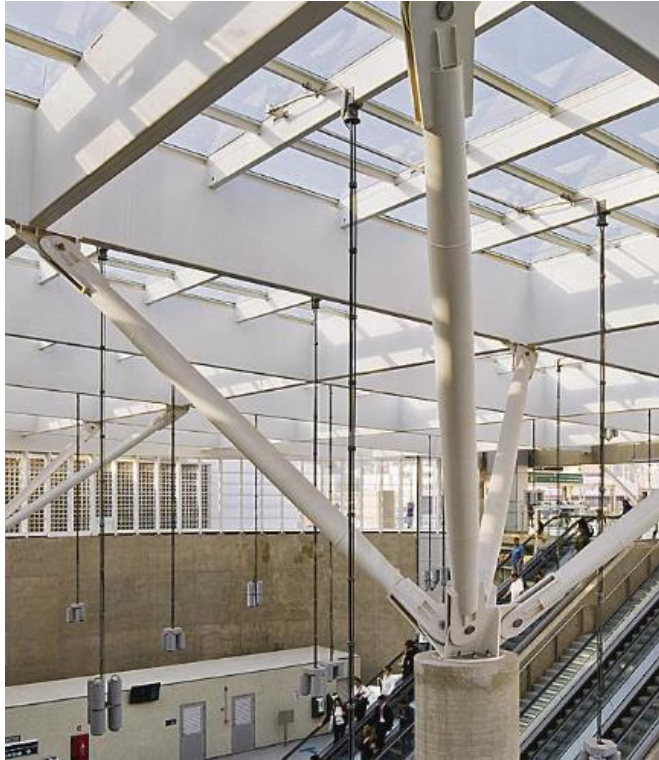


Photo: arcoweb.com.br



Photo: Author



Entertainment center

Airport

Hinge support for structure CC3

Modern structural bearings for steel structures are very similar to old-fashion structural bearings for bridges.

Photo: nipponchuzo.co.jp



Photo: tzsunruitech.weebly.com



Photo: Author



Photo: tboake.com

Such type of support bases on pin joint. Resistance of pin joint is presented on #18 / 59-61, 75-76.

Pins can't be replaced, because of this „normal” pin must be taken into consideration.



Photo: tboake.com



Photo: Author

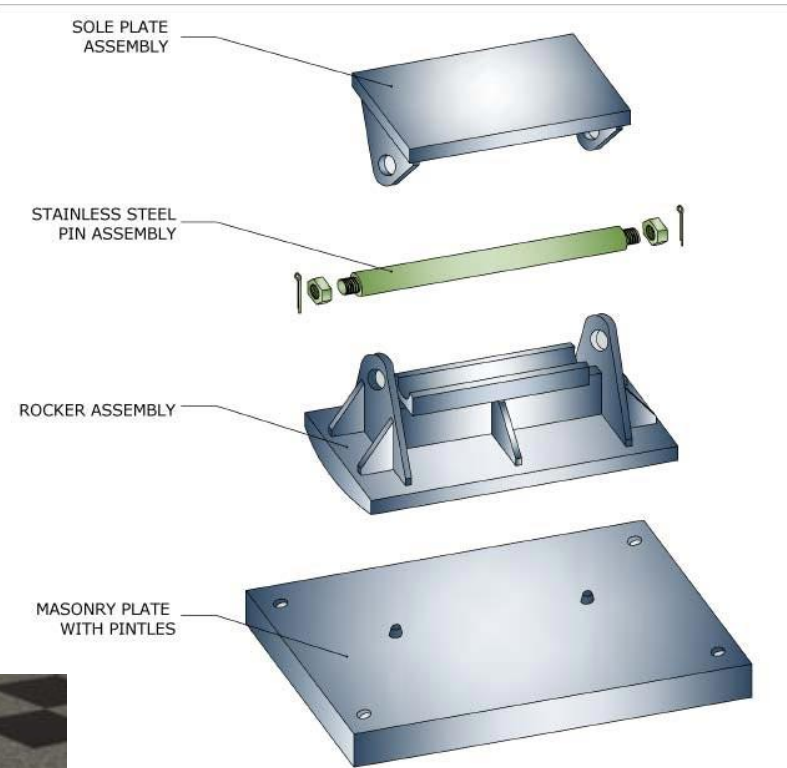


FIGURE 1: TYPICAL ROCKER "PIN" BEARING ASSEMBLY

Photo: cosmecinc.com

Formulas in PN B 03200 for contact flat-cylindrical and formulas in EN 1993-1-8 for bearing stress for pins based on Hertz theory of contact. Strength f_{contact} could be defined in various ways ($3,6 f_y$ in PN B 03200 or $2,5 f_y$ in EN 1993-1-8)


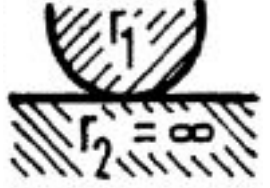

Type of contact	Hertz theory	PN B 03200	EN 1993-1-8
	$0,175 N_{Ed} E (r_1 + r_2) / (f_{\text{contact}}^2 L r_1 r_2) \leq 1,0$	$0,175 N_{Ed} E (r_1 + r_2) / (f_{\text{contact}}^2 L r_1 r_2) \leq 1,0$	
	$0,175 N_{Ed} E / (f_{\text{contact}}^2 L r_1) \leq 1,0$	$0,175 N_{Ed} E / (f_{\text{contact}}^2 L r_1) \leq 1,0$	
	$0,175 N_{Ed} E (r_2 - r_1) / (f_{\text{contact}}^2 L r_1 r_2) \leq 1,0$	$0,175 N_{Ed} E (r_2 - r_1) / (f_{\text{contact}}^2 L r_1 r_2) \leq 1,0$	$0,175 N_{Ed} E (r_2 - r_1) / (f_{\text{contact}}^2 L r_1^2) \leq 1,0$

Photo: chodor-projekt.net



Photo: studio-tm.com



Photo: aleo.com

Photo: Author



Popular solution for supporting trusses in case of **CC2** structure: plate-plate or plate-rocker-plate.



Reconstruction of residential house, steel beam supported on masonry wall. No expertly designed bearings. Acceptable solution: construction on border between **CC1** and **CC2**, rigid enough to ensure resistance even of incorrect estimation of type of supports (pinned? rigid?) and values cross-sectional forces.



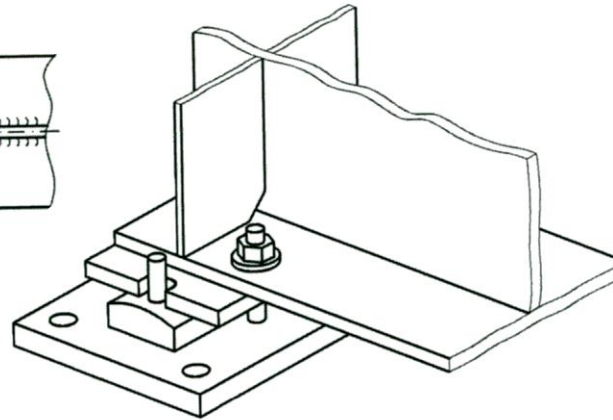
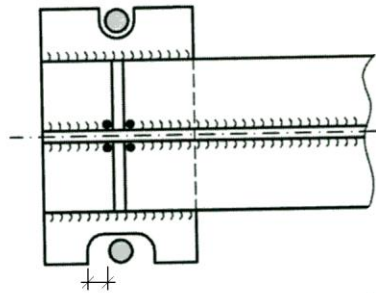
Photo: anthony-johnson-engineering.co.uk

Translational degree of freedom for elastomeric rocker is achieved by specific shaping the bearing details. It is often the manufacturer's secret.

Translational degree of freedom for rest types of supports is achieved by slotted holes for anchor bolts.

Photo: K. Rykaluk, Konstrukcje metalowe cz I., DWS, Warszawa2016

Pinned support



→ #14 / 34

Roller support Δ

$$\Delta = q L^3 / (12 E W_{pl}) + \Delta T L \alpha_T$$

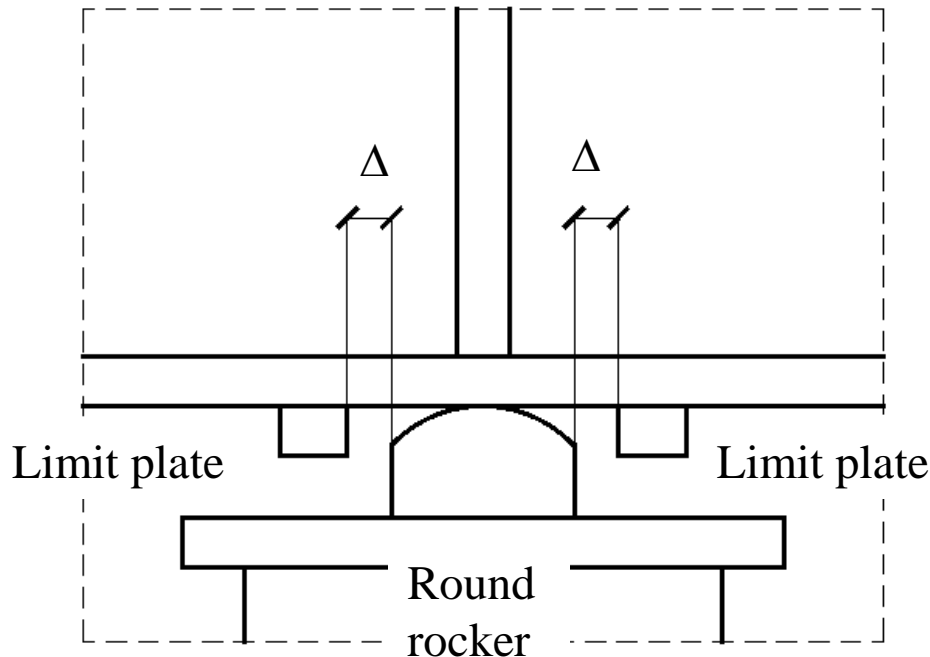
$\Delta T = |$ difference between 8°C and working temperature of structure $|$

For truss:

$$W_{pl} \approx J_{truss} / h_{1, truss}$$

Other example of roller support: round rocker bearing with limit plates

Photo: Author



$$\Delta = q L^3 / (12 E W_{pl}) + \Delta T L \alpha_T$$

$\Delta T = |$ difference between 8°C and working temperature of structure $|$

Photo: Historia współczesnych łożysk mostowych.
J. Niemirko, Drogownictwo 1/2015



Solution applied the same for elastomeric bearing

Trusses – lateral supports



Photo: wasatchsteel.blogspot.com

The most often: by gusset plate, welds made on construction side.



Photo: fireengineering.com

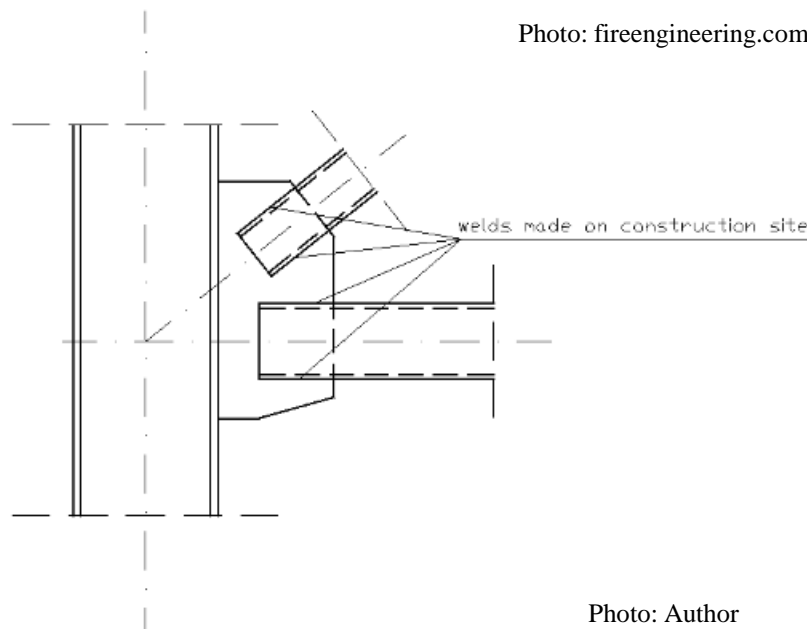
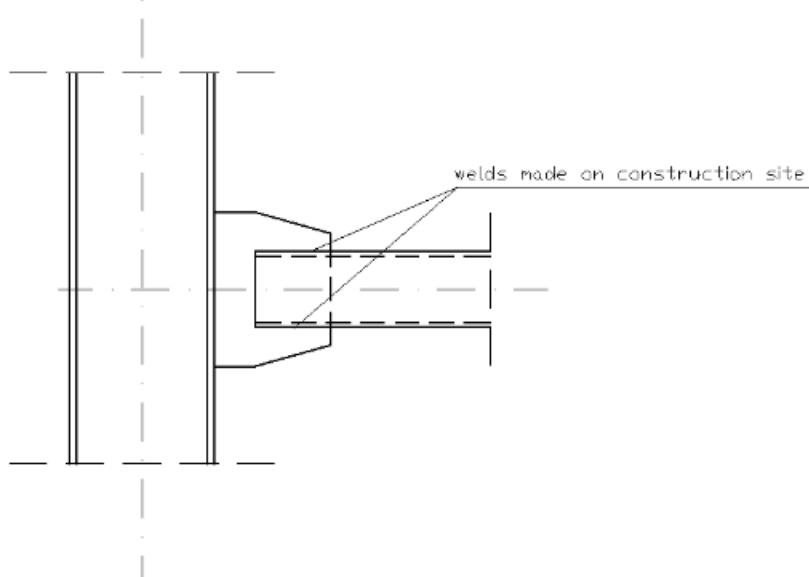


Photo: Author



Photo: Author



Photo: Author

Other solution: by additional short cantilever or by bolts to flange or web.

Concrete column: the same by gusset plate, welds made on construction side.



Photo: i.pinimg.com

Lateral supports of trusses do not follow hinge joints as accurately as supports from below. However, these are solutions analogous to joints in truss – welded joints. Their characteristics should be checked in the same way as other joints in truss (→ lec #21). In case of a problem, we must make corrections to static model.



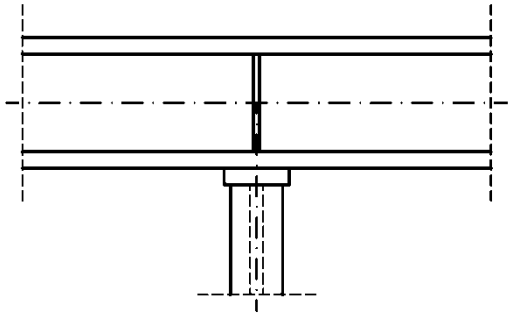
Photo: tboake.com



Differences (additional bending moments) between ideal (hinge) and real (rigid) support focus on bars directly adjacent to joint. These are chords, i.e. bars with the highest load-bearing capacity in scale of the entire truss; and extreme diagonal bars, also more massive than diagonal bars in central part of truss. Overload, caused by differences between theory and reality, can be easily assimilated by high resistance.

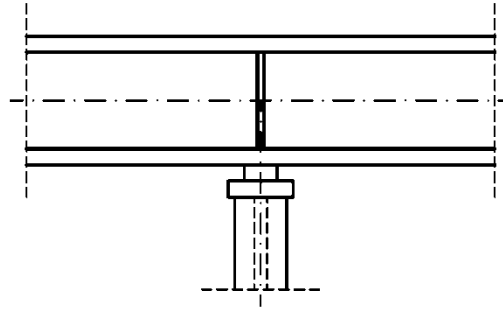
For bars located further away, differences quickly disappear and no make impact on efforts of members.

Beam supported by column

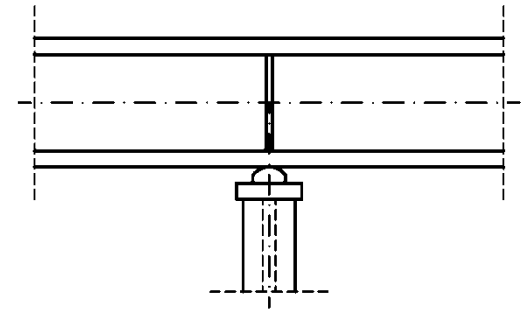


No bearing

Photo: Author



Flat bearing



Round bearing

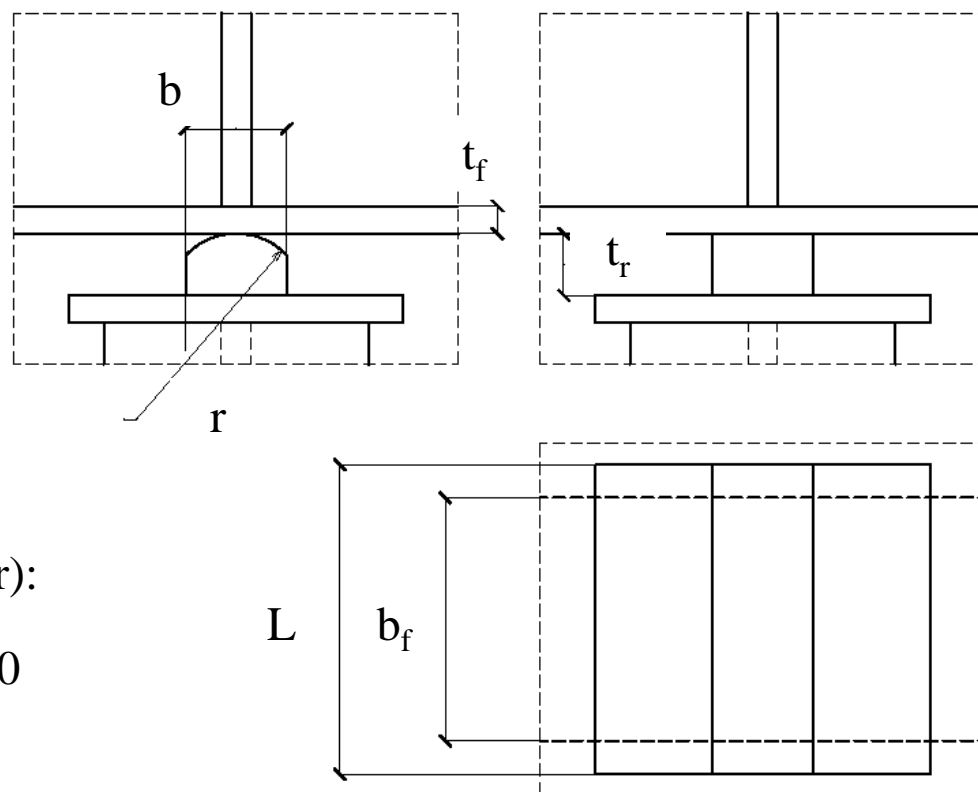
- ◆ Rocker - beam compression
- ◆ Rocker - cap plate welds
- ◆ Rocker - cap plate compression
- ◆ Resistance of support

- ◆ Rocker - beam compression
- ◆ Rocker - cap plate welds
- ◆ Rocker - cap plate compression
- ◆ Resistance of support

Rocker-beam contact

EN 1337-6

Structural bearings; rocker bearings



Beam resistance (contact with round rocker):

$$(N_{Ed} / b_f) / [23 r f_u^2 / (E \gamma_M)] \leq 1,0 \quad \gamma_M = 1,0$$

or (contact with flat rocker):

$$(N_{Ed} / b_f) / [f_y (2 t_r + b) / \gamma_M] \leq 1,0 \quad \gamma_M = 1,1$$

Photo: Author

Rocker resistance (round and flat):

$$(N_{Ed} / b_f) / [f_y (2 t_r + b) / \gamma_M] \leq 1,0 \quad \gamma_M = 1,1$$

Alternatively, according to PN B 03200:

Contact round - flat element:

$$N_{Ed} E / (73,5 b_f r f_y^2) \leq 1,0$$

In comparison to EN 1337-6:

$$N_{Ed} E / (23 b_f r f_u^2) \leq 1,0$$

$$f_u \approx 1,5 f_y$$

Both formulas can be presented as:

$$\text{PN B 03200: } N_{Ed} E / (73,5 b_f r f_y^2) \leq 1,0$$

$$\text{EN 1337-6: } N_{Ed} E / (52 b_f r f_y^2) \leq 1,0$$

EN 1337-6 gives lower resistance

Contact flat - flat element:

$$N_{Ed} / (1,25 f_y b b_f) \leq 1,0$$

In comparison to EN 1337-6:

$$1,1 N_{Ed} / [f_y (2 t + b) b_f] \leq 1,0$$

$$2 t + b \approx 1,6 b$$

Both formulas can be presented as:

$$\text{PN B 03200: } N_{Ed} / (1,25 f_y b b_f) \leq 1,0$$

$$\text{EN 1337-6: } N_{Ed} / (1,45 f_y b b_f) \leq 1,0$$

PN B 03200 gives lower resistance

Welds between rocker and cap plate

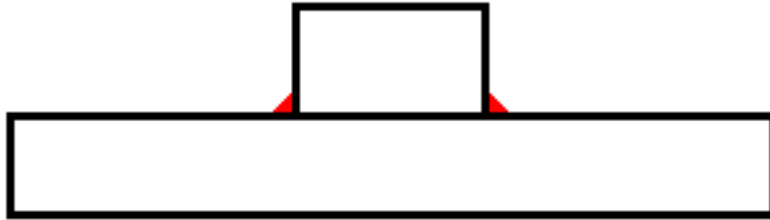
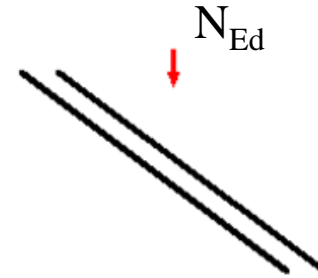


Photo: Author



Pair of rectangular welds under vertical force

Lecture #17, example #3:

$$M_{Ed} = 0 \text{ kN}$$

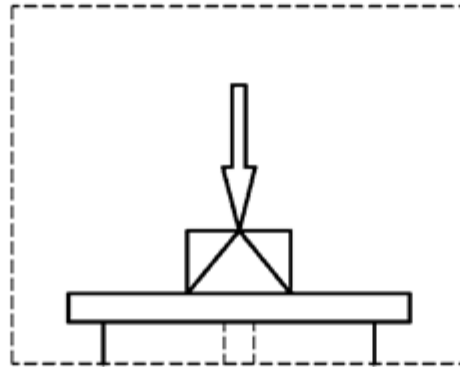
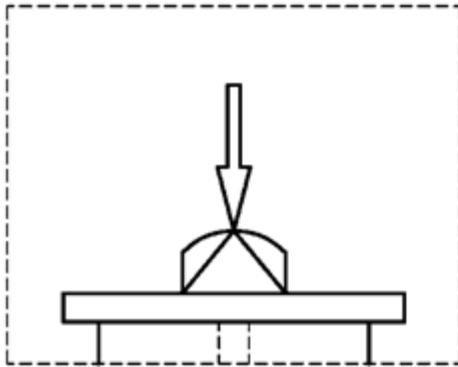
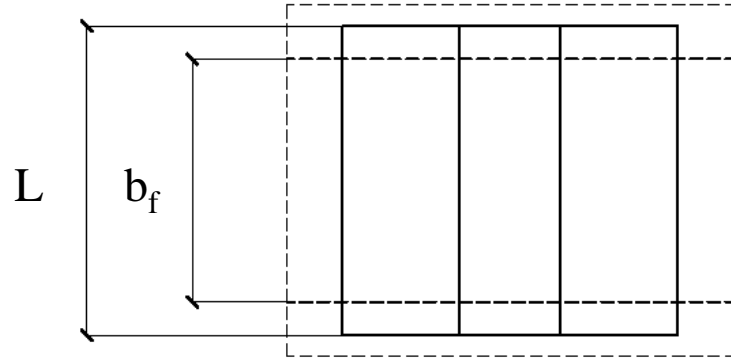
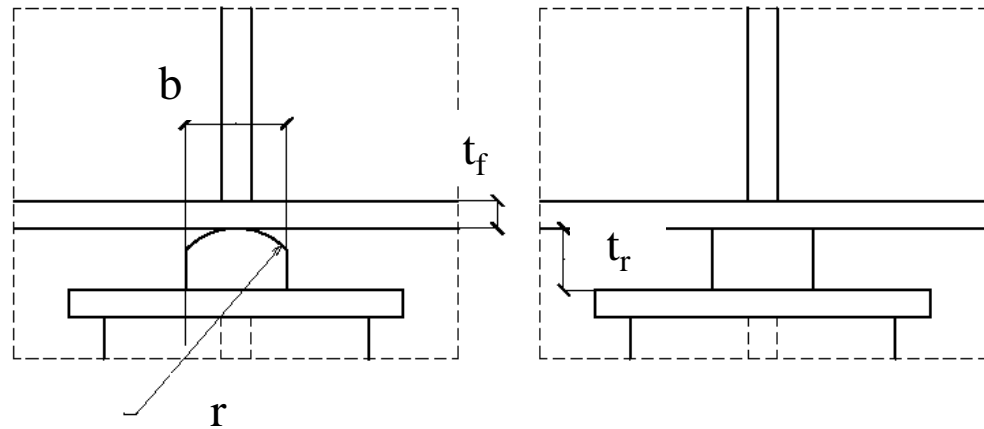
$$F_x = N_{Ed}$$

$$F_z = 0 \text{ kN}$$

Rocker-cap plate compression

Rocker - narrow thick member;
stress between rocker and cap plate
has nearly constant value.

$$\sigma \approx \text{constans} = N_{Ed} / (L b)$$



$$\sigma / (f_y / \gamma_{M0}) \leq 1,0$$



Photo: Author

Resistance of support

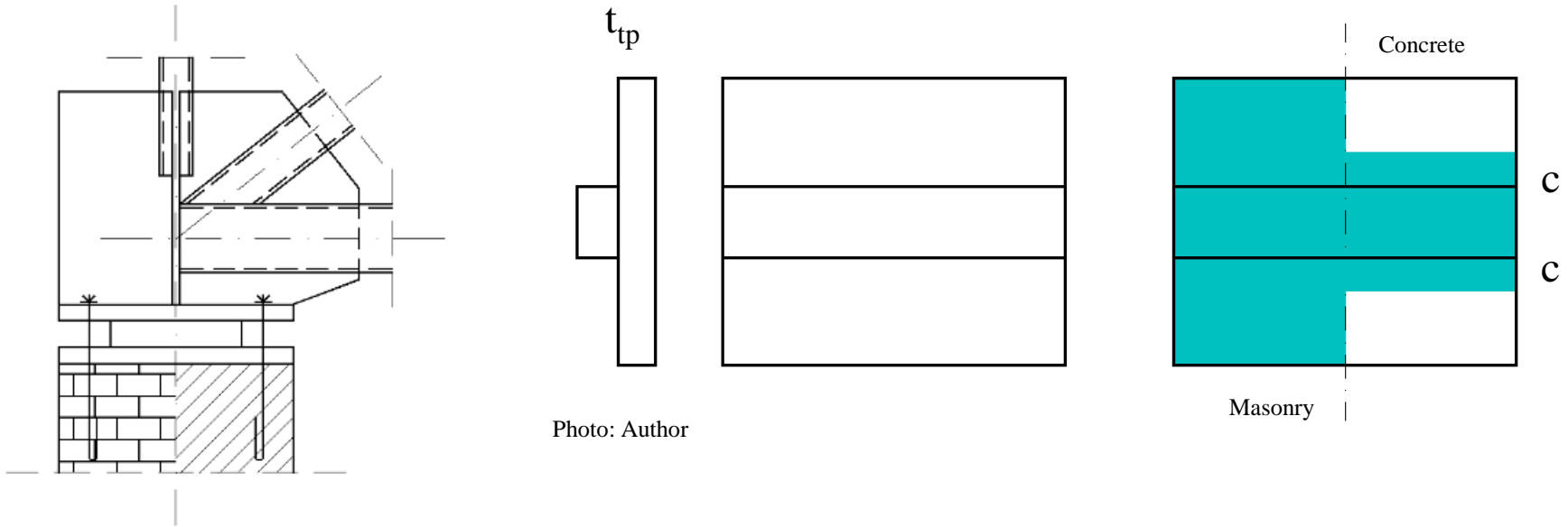


Photo: Author

Resistance of masonry or concrete structure (wall or column) under structural bearing must be calculated according to #t / 9 - 49. In case of rocker (flar or round), resistance is calculated for two various ways.

- Masonry structure : A_b is defined as total area of top plate;
- Concrete structure: A_{c0} is defined as area of rocker and cooperated area of top plate in distance c ; c if funcion of thickness of top plate t_{tp}

Steel I-column shaft: „resistance of support” means resistance of cup plate, welds between cup plate and column and local resistance of column.

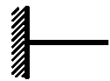
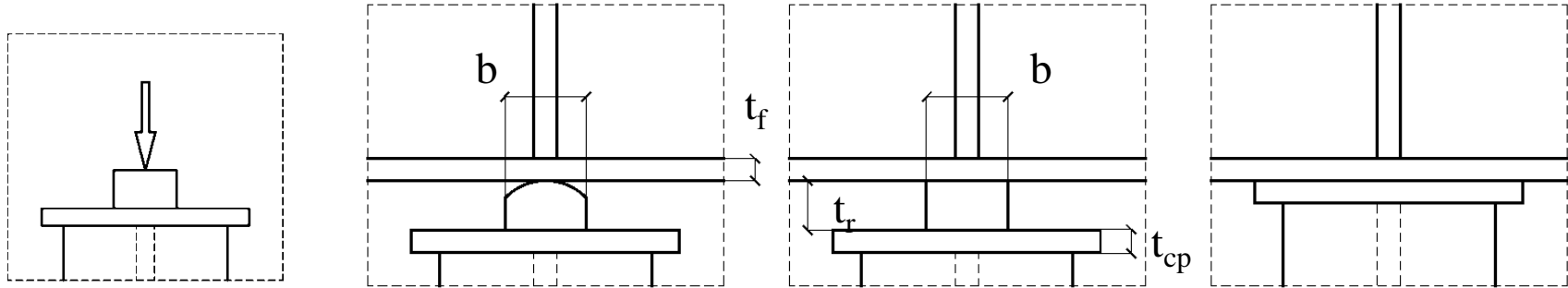
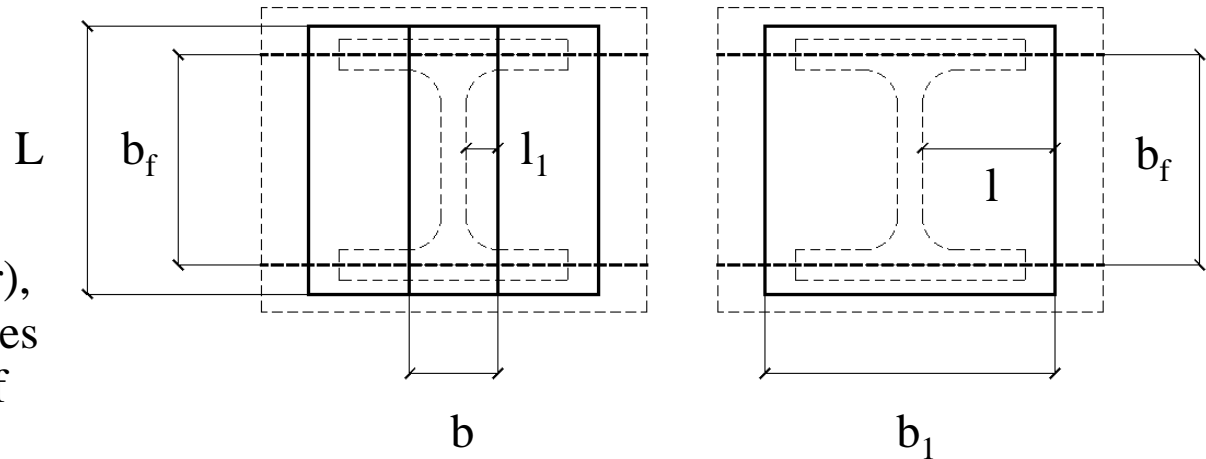


Photo: Author

Cup plate between flanges is treated as short cantilever of length l_1 (rocker) or l (no rocker), loaded by constant load = stresses between top and bottom plate of rocker



$$L = l \text{ or } l_1 \quad B = b \text{ or } b_1$$

$$q = \sigma = N_{Ed} / (L B)$$

$$M_{Ed, \max} (\text{cantilever}) = q a L^2 / 2$$

$$\begin{aligned}
M_{\text{Ed, max}} / M_{\text{Rd}} &\leq 1,0 \rightarrow M_{\text{Ed, max}} / [f_y a t_{p1}^2 / (6 \gamma_{M0})] \leq 1,0 \rightarrow \\
&\rightarrow 6 \gamma_{M0} M_{\text{Ed, max}} / (f_y a t_{p1}^2) \leq 1,0 \rightarrow \\
&\rightarrow t_{p1} \geq \sqrt[3]{(6 M_{\text{Ed, max}} / (a f_y \gamma_{M0}))}
\end{aligned}$$

With rocker:

$$t_{cp} \geq \max \{ 0,75 t_f ; \sqrt[3]{(3 N_{\text{Ed}} l_1^2) / (L b f_y)} - t_r \}$$

Without rocker:

$$t_{cp} \geq \max \{ 0,75 t_f ; \sqrt[3]{(3 N_{\text{Ed}} l^2) / (L b_1 f_y)} \}$$

Cap plate-column local compression

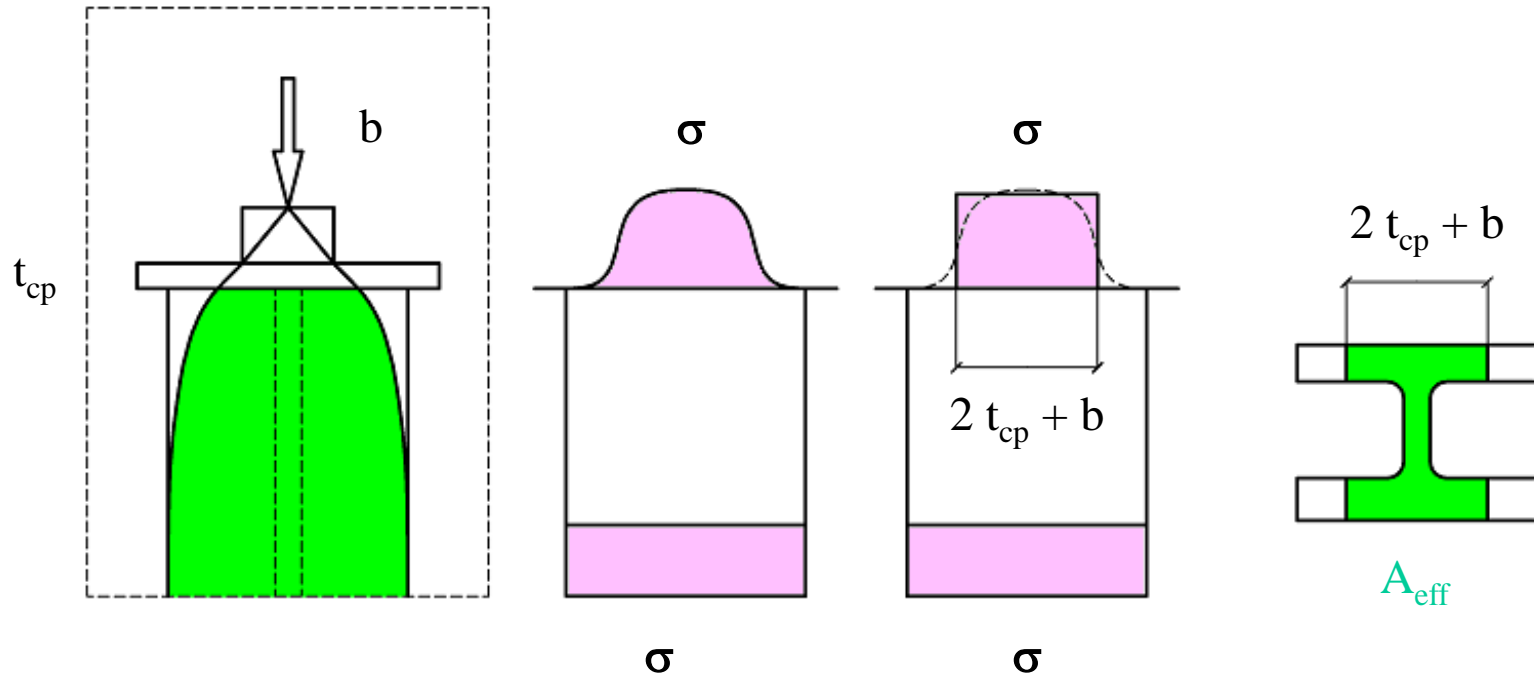


Photo: Author

Cap plate - wide thin member; stress between cap plate and column has strongly non-linear character; we assume big constant value in central part and zero at ends of flange. Constant value of stress exists in distance from end of column.

$$N_{Ed} / (A_{eff} f_y \gamma_{M0}) \leq 1,0$$

Examination issues

Resistance of masonry structure in contact with steel - algorithm

Resistance of concrete structure in contact with steel - algorithm

Resistance of hinge support of column - algorithm

Resistance of rigid support of column - algorithm

Types of structural bearings

Technical solutions for pinned and rolled supports

Resistance of structural bearing - algorithm

Base – fundament

Masonry – konstrukcja murowa

Concrete – beton, żelbet

Primary beam - podciąg

Retaining plate – płytką oporowa

Gusset plate - blacha węzłowa

Stub – króciec

Structural bearing – łożysko

Rocker – łożysko, wałek łożyska

Thank you for attention

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