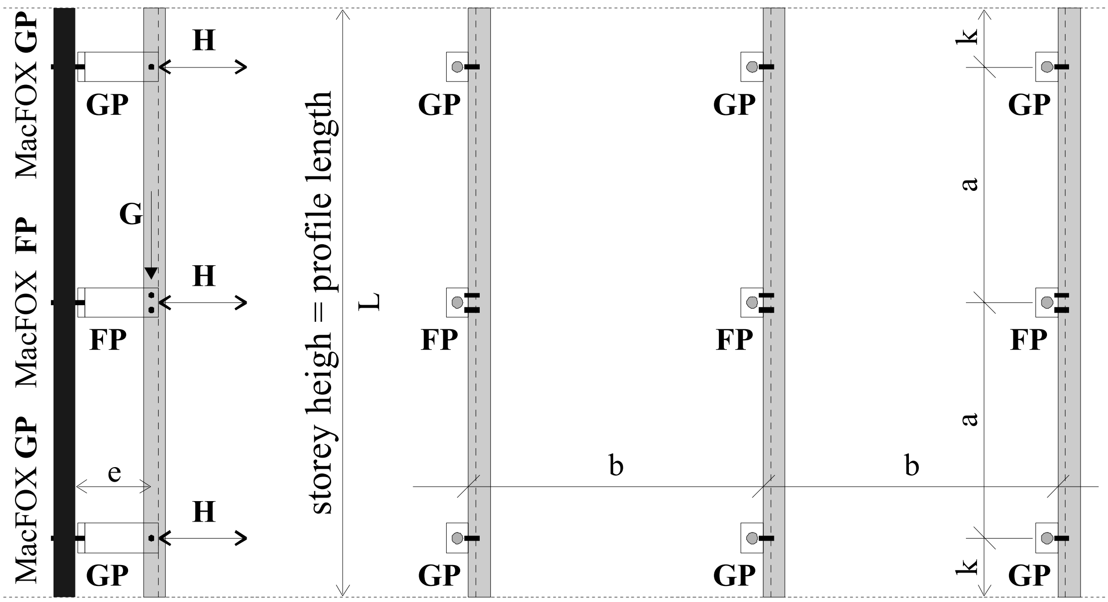
1 SYSTEM DESCRIPTION

1.1 System

The **MacFOX vertical** facade system is used to secure facades in front of masonry or concrete wall structures. The system essentially consists of L-shaped wall supports and vertical anchor girders, joined together with at least two self-drilling bolts or aluminium blind rivets. All wall supports are anchored with bolt dowels at their base.

Several wall supports are configured per storey, with one of them serving as the fixed point „**FP**“ and the others as flexible points „**GP**”. The arrangement of slots in the MacFOX bracket, together with the spaced connectors, allow vertical movement at the flexible points. This enables assembly without the need for force and guarantees provision for length changes resulting from temperature differentials between base and external wall covering.

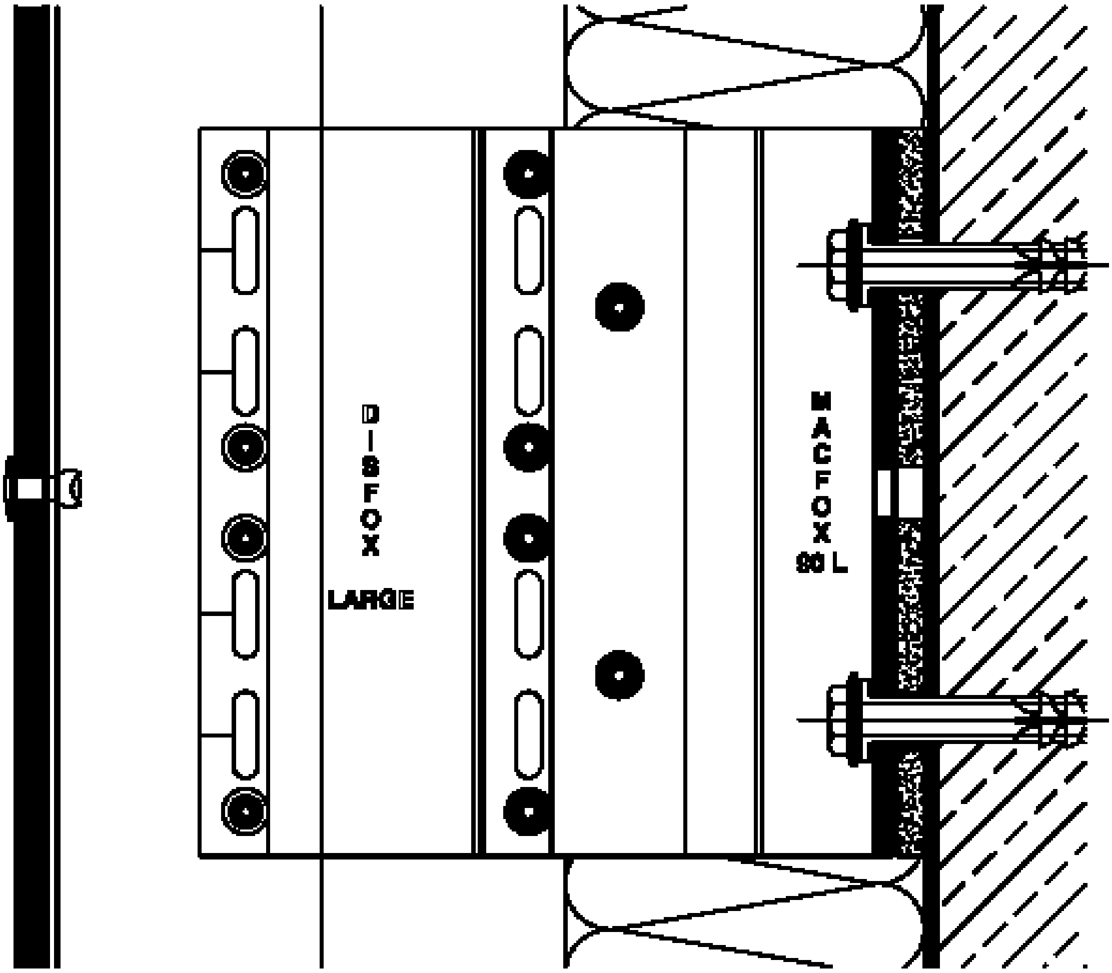
System diagram



Profile **Facade partial view**

To extend the wall support bracket by 60mm, the Mac-DISFOX spacer can be used. They need to be pushed into the lugs of the MacFOX elements by at least 40mm and to be secured with two vertical rows of bolts/rivets. Securing the anchor girder to the Mac-DISFOX element is achieved by joining the outer row in the same way. Two rows of bolts/rivets are always used for the inner row near the MacFOX lug. Bolting or riveting in this way ensures continuous bend rigidity over the entire bracket.

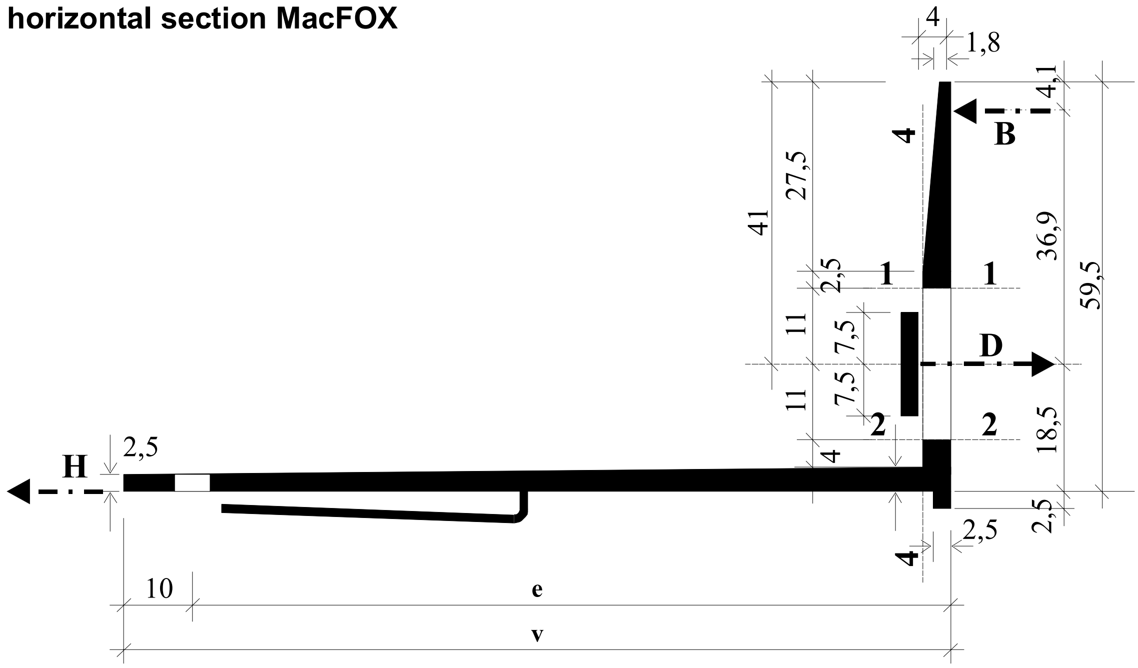
Joining DISFOX and MacFOX elements



1.2 Horizontal load diversion

MacFOX „GP“ wall supports are intended for deflection of horizontal wind loads only and not for weight diversion. Wind force tension or pressure has the usual effect on the outer surface of the facade. The design of the MacFOX wall support allows the pressure to be diverted directly into the supporting masonry without loading the wall dowel. As a result of the eccentric positioning of the dowel, the potential wind wake loads per wall support are lower than the permissible dowel extraction forces.

horizontal section MacFOX



H_{max} = 36,9 / 55,4 . D_{max} = 0,67 D_{max}

The flexible point wall supports are generally fixed with one dowel at the base and secured to the anchor girders in the slots with two rows of bolts/rivets.

1.3 Vertical load diversion

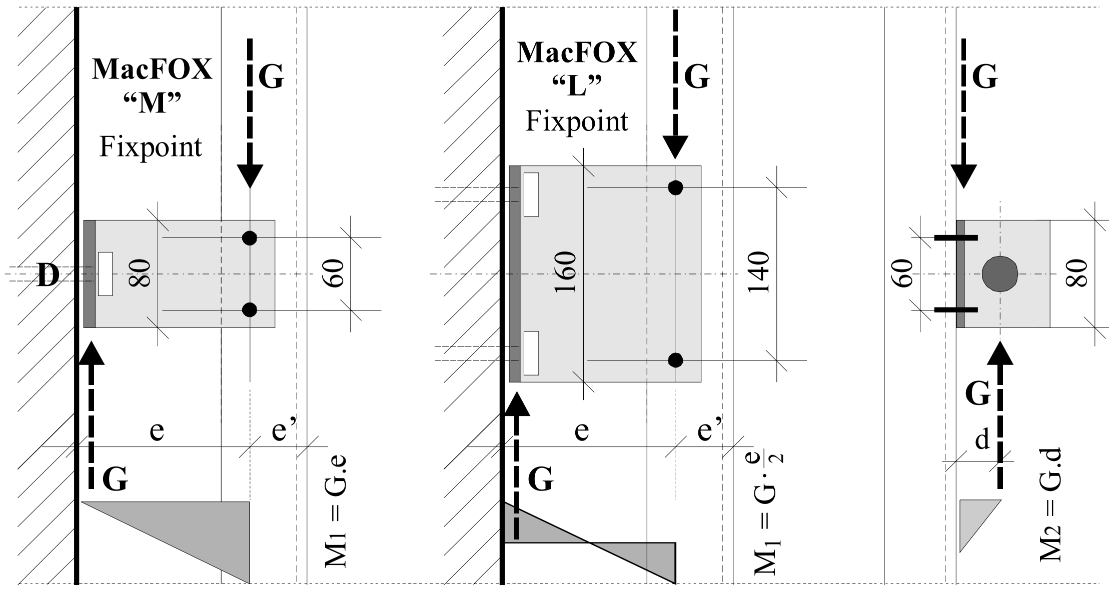
The weight at the outer wall covering is diverted into the **MacFOX „FP“** wall support rows via the perpendicular anchor girders. Depending on height, these wall supports are secured to the anchor girder with between 2 and 8 self-drilling bolts/rivets and are intended to divert the facade weight of one storey height. The proportionate horizontal loads from wind exposure are absorbed by the fixed points.

MacFOX M and ML fixed points are secured with only one dowel at the base, while MacFOX L fixed points are always secured with 2 dowels, one above the other and separated by 10cm.

At fixed points secured with only one dowel, the displacement moment M_1=G.e is absorbed by the anchor girder bolt/rivet joints, such that the wall dowel is not subject to any additional tension force according to moment stress. At fixed points secured with two dowels, the displacement moment is distributed across the bolt and dowel joint such that both joints are subject to M_1=G.e/2.

The displacement moment M_2= G.d is absorbed by the equal and opposite bending and torsion of the protruding Mac-FOX bracket.

weight diversion of MacFOX elements



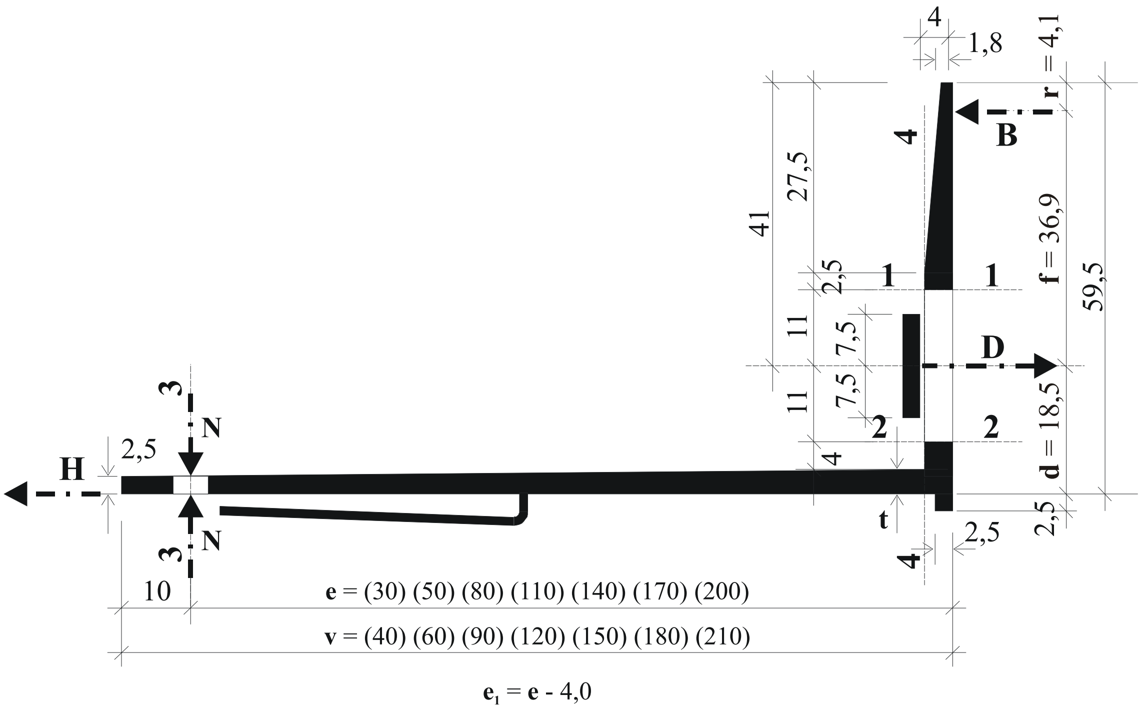
1.4 Dimensions of the MacFOX elements

The MacFOX wall support elements in the **S, M, ML** and **L** ranges are manufactured in bracket heights of 60, 80, 120 and 160mm. The most common applications use the M range elements for flexible and fixed points with one dowel, as well as the L range for fixed points with two dowels. S range elements are used only as flexible points. The drill-hole positioning for the bolt/rivet joints to the anchor girders are illustrated on the following pages.

All MacFOX elements are available with bracket lengths of 40, 60, 90, 120, 150, 180 and 210mm. The bracket thicknesses in cross-section 4-4 (see illustration below) are 2.5mm for MacFOX 40 and 60, 3.0mm for MacFOX 90, 3.5mm for MacFOX 120 and 150 and 4.0mm for MacFOX 180 and 210. With the exception of bracket thickness and bracket length, all dimensions are the same for all MacFOX elements.

It is possible to extend the bracket length by 60mm on all MacFOX elements with the Mac-DISFOX spacer.

Cross-section of the MacFOX elements



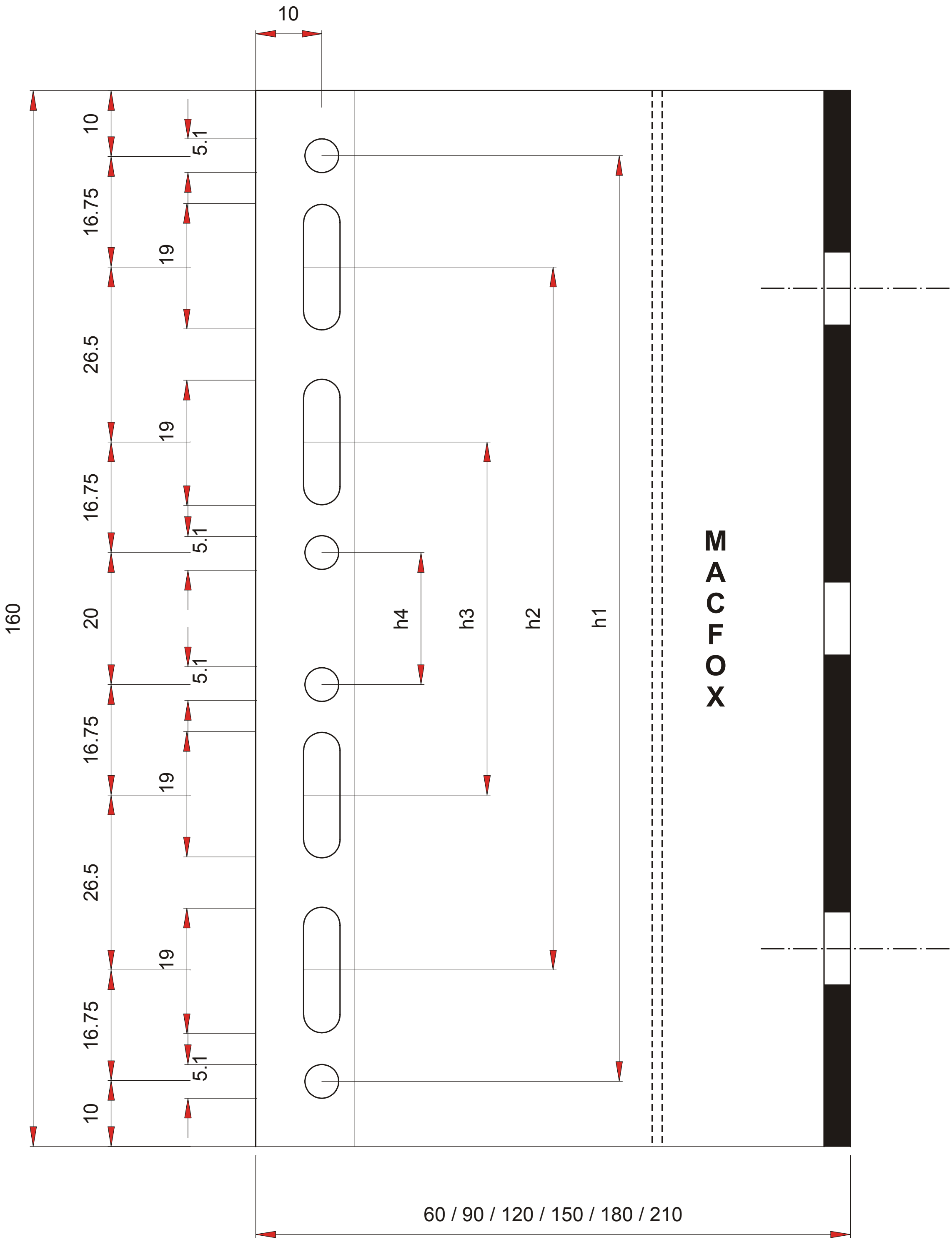
Dimensions for MacFOX

Type: L h = 160mm	Type: ML h = 120mm	Type: M h = 80mm	Type: S h = 60mm			
V	t	e	e_1	d	f	r
40	2.5	30	26	18.5	36.9	4.1
60	2.5	50	46	18.5	36.9	4.1
90	3.0	80	76	18.5	36.9	4.1
120	3.5	110	106	18.5	36.9	4.1
150	3.5	140	136	18.5	36.9	4.1
180	4.0	170	166	18.5	36.9	4.1
210	4.0	200	196	18.5	36.9	4.1

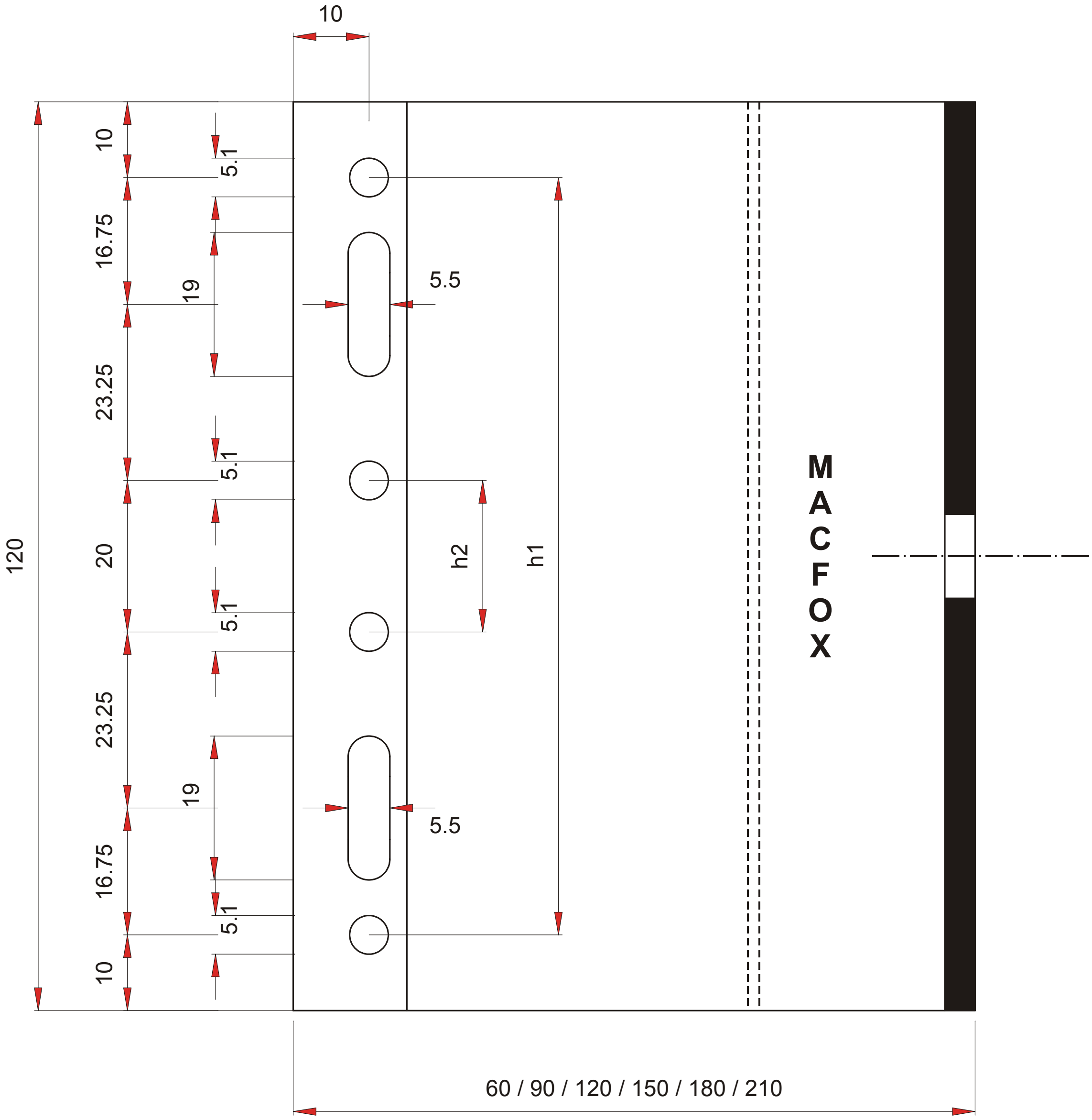
Dimensions for MacFOX+DISFOX

Type: L h = 160mm	Type: ML h = 120mm	Type: M h = 80mm	Type: S h = 60mm			
V	t	e	e_1	D	f	r
40	2.5	90	86	18.5	36.9	4.1
60	2.5	110	106	18.5	36.9	4.1
90	3.0	140	136	18.5	36.9	4.1
120	3.5	170	166	18.5	36.9	4.1
150	3.5	200	196	18.5	36.9	4.1
180	4.0	230	226	18.5	36.9	4.1
210	4.0	260	256	18.5	36.9	4.1

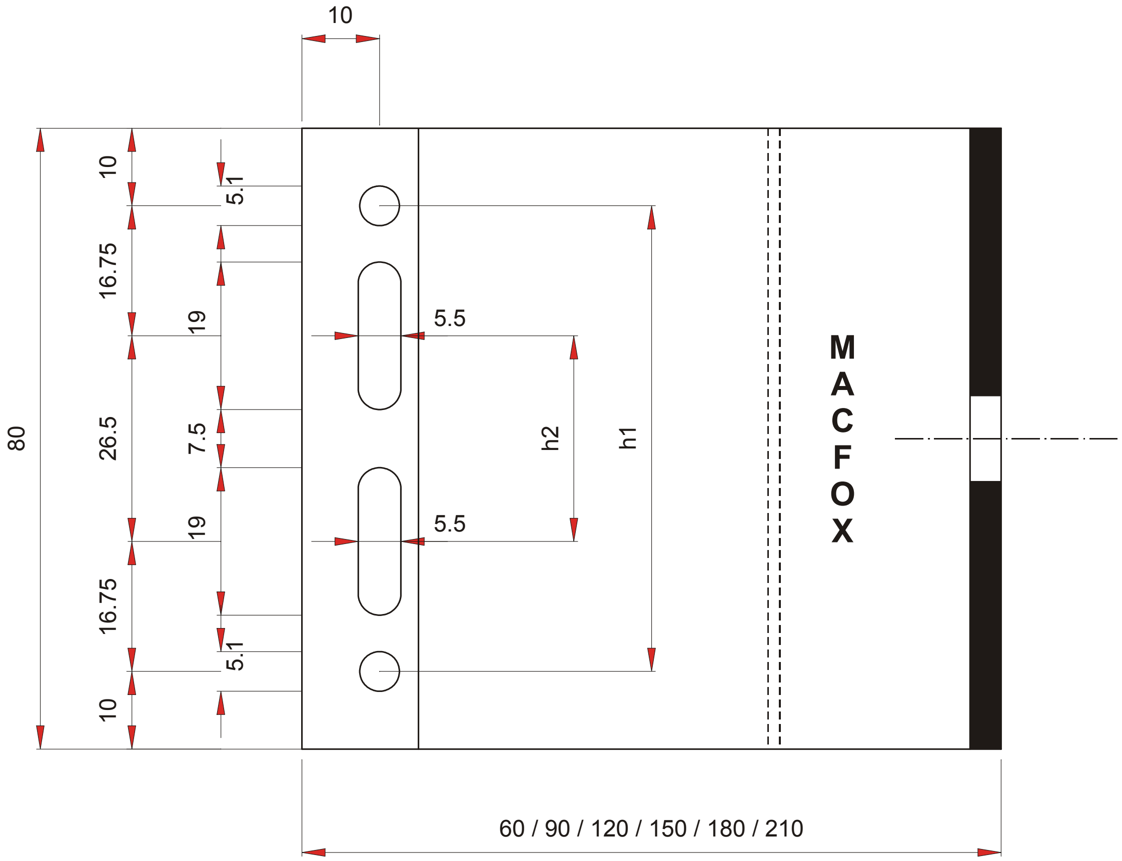
MacFOX element type L



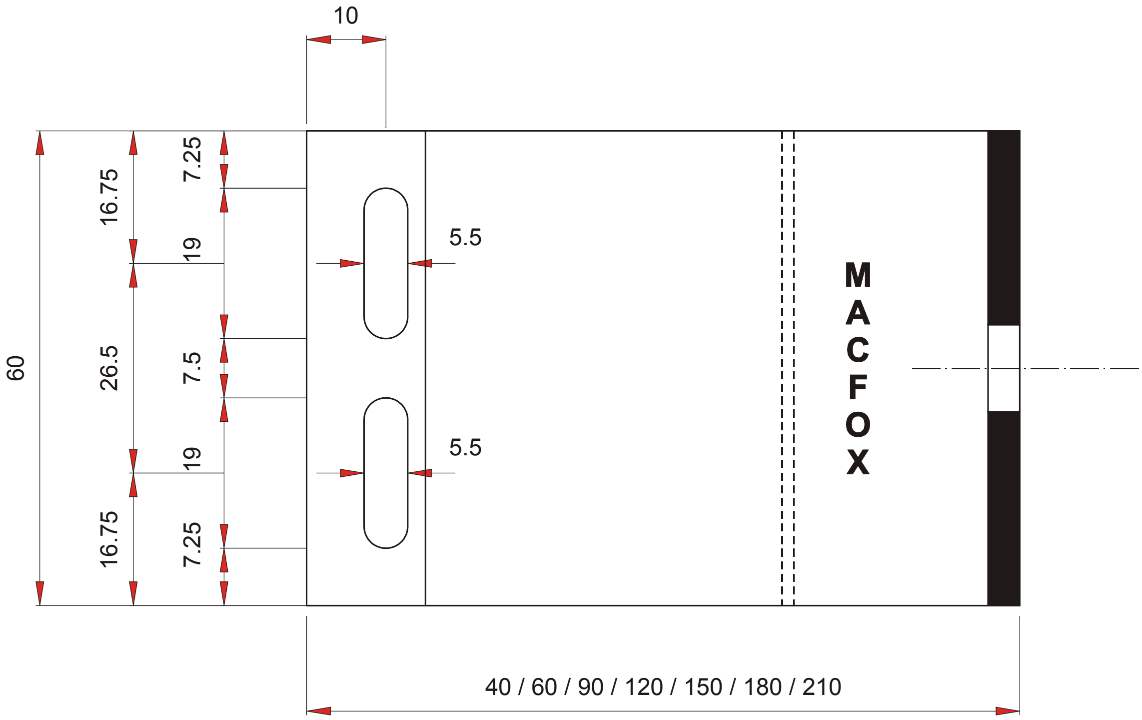
MacFOX element type ML



MacFOX element type M



MacFOX element type S



2 STANDARDS AND REGULATIONS

DIN 18516, Part 1:	Outer wall covering, ventilated at rear
DIN 1748, Part 1:	Extrusion profile made from aliminium and aliminium wrought alloy
DIN 4113, Part 1:	Aluminium constructions predominantly under static load, calculation and structural design
Factory certificate from June 2003:	Aluminium Al Mg Si0,5 F25
IFBT Test report Nr. 04-049:	EJOT: Drill bolts JT4-2-4,8x19
Regulation Z-14.1-4:	EJOT: AVEX blind rivets 4.8mm
Regulation Z-21.2-589:	EJOT: SDF bolt dowel for masonry and concrete
DIN 1055, Part 4:	Wind loads

3 MATERIAL

The material used is aluminium Al Mg Si0,5 F25. According to the manufacturer specifications the minimum tensile strength is 250 N/mm^2, the yield point 195 N/mm^2. The following permitted tensions result according to DIN 4113 Part 1:

σ_{zul} = **10.0 kN/cm^2**

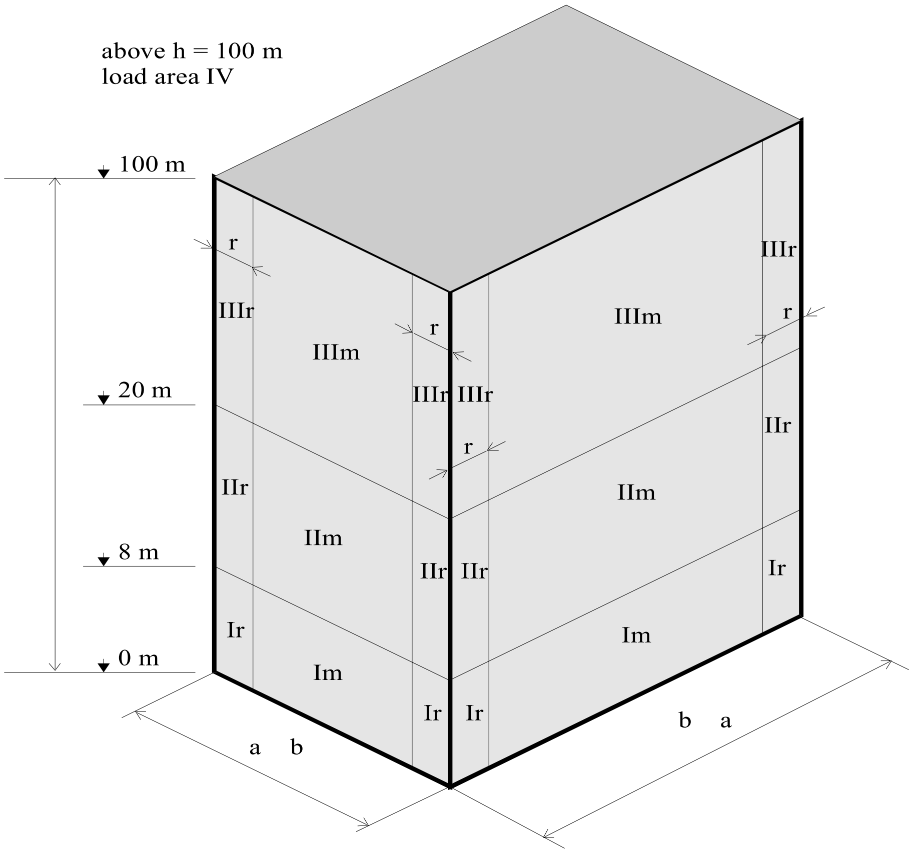
τ_{zul} = **6.0 kN/cm^2**

$\sigma_{v,zul}$ = **14.6 kN/cm^2**

4 BASIC LOAD PARAMETERS

Wind loads according to DIN 1055 Part 4

Clearancer: $1{,}00m \geq \frac{a}{8} \leq 2{,}00m$



n_1 for $\frac{h}{a} \geq 0{,}5$ n_2 for $\frac{h}{a} \leq 0{,}25$

Height area	Height	Dynamic Pressure	Wake loads in the areas			Pressure
	[m]	[kN/m²]	n1	n2	r	
			-0.7	-0.5	-2.0	1.00
I	bis 8	0.50	-0.35	-0.25	-1.00	0.50
II	8 - 20	0.80	-0.56	-0.40	-1.60	0.80
III	20 - 100	1.10	-0.77	-0.55	-2.20	1.10
IV	> 100	1.30	-0.91	-0.65	-2.60	1.30

5 LOADING OF THE MacFOX WALL SUPPORTS

5.1 Static systems of the anchor girders

One, two, three and four-field systems with overhang are used for the anchor girder static systems. The anchor girder overhangs are selected such that the moments over all supports are roughly equal. See also explanations in sections 8 and 8.2 „*Anchor girder calculation* “

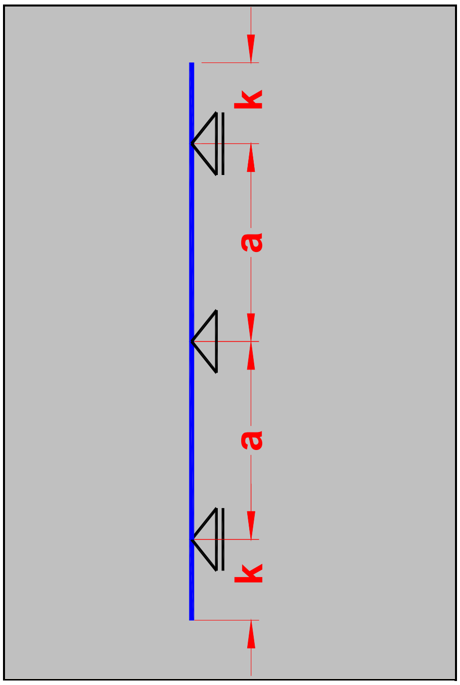
Input values:

Length of the anchor girder = Storey height:

Clearance of the anchor girder:

Supporting range of the anchor girder:

Overhang of the anchor girder:



The following support ranges and overhangs result and are dependent on the anchor girder length L.

Fields	k	a
One-field support	0.200xL	L-2x0.200xL
Two-field support	0145xL	1/2(L-2x0.145xL)
Three-field support	0.107xL	1/3(L-2x0.107xL)
Four-field support	0.085xL	1/4(L-2x0.085xL)

5.2 Bearing load per wall support

Wall support horizontal bearing loads of the multi-field supports are calculated approximately as H = w x b x a. For the one-field support with overhang, H = w x b x L/2. See also explanations in sections 8.1 and 8.2.

The diverted weight at the fixed point in all systems is calculated as G=gxbxL.

6 CALCULATION OF THE FLEXIBLE POINTS

6.1 Cross-section values for MacFOX elements

Cross-sections 1-1 and 2-2 are significant in calculating the bend of MacFOX elements, as is 4-4 for the verification of buckling in the protruding bracket (see also diagram on page 5).

$$W_{1,2} = \frac{(h - n \times 1{,}1) \times 0{,}4^2}{6}$$

$$A_4 = h \times t$$

6.2 Evaluation of MacFOX elements under wake conditions

Tolerance from load bearing capacity of MacFOX elements:

$$M_{\max} = \sigma_{zul} \times W_{1,2}$$

$$B_{\max} = \frac{M_{\max}}{(f - 0{,}75)}$$

$$\boxed{H_{zul,1} = \frac{B_{\max} \times f}{d} = \frac{\sigma_{zul} \times W_{1,2}}{(f - 0{,}75)} \times \frac{f}{d}}$$

$$\boxed{H_{zul,2} = \frac{M_{\max}}{(d - 0{,}75)} = \frac{\sigma_{zul} \times W_{1,2}}{(d - 0{,}75)}}$$

Tolerance from dowel bearing capacity:

n	Number of dowels
D_{zul}	Maximum bevel torsion for dowel according to regulation

$$\boxed{H_{zul,D} = n \times D_{zul} \times \frac{f}{(f + d)}}$$

6.3 Evaluation of MacFOX elements under wind load

As previously mentioned, the shaping of the MacFOX elements prevents any loading of the wall dowel. Load occurs only in the bolt/rivet joint connecting the anchor girder. Furthermore the protruding bracket of the MacFOX elements should be inspected for buckling.

Tolerance from load bearing capacity of MacFOX elements:

Should the MacFOX bracket be clamped at cross-section 4-4 or if there is no sideways movement of the wall covering, a unit buckle length of the brackets can be assumed.

$$\lambda = e_1 \times \frac{\sqrt{12}}{t}$$

$$\boxed{H_{zul,4} = A_4 \times \frac{\sigma_{zul}}{\omega}}$$

The ϖ-values are taken from DIN 4113 Part 1, Table 12a.

Tolerance from bolt/rivet load bearing capacity:

m Number of bolts/rivets

S_{zul} Permissible shearing force according to regulation

$$\boxed{H_{zul,S} = S_{zul} \times m}$$

7 CALCULATION OF THE FIXED POINTS

7.1 Cross-section values for MacFOX elements

The eccentricity moment M_e = G x d is deflected by torsion and an equal and opposite bending of the protruding bracket. Half the bracket height is therefore used for the bend resistance.

$$W_{b,4} = \frac{h}{2} \times \frac{t^2}{6}$$

$$W_{t,4} = \frac{1}{3} \times h \times t^2$$

7.2 Calculation of the MacFOX- M fixed points

Maximum weight for MacFOX at eccentric effective dowel force:

$$M_e = G \times d = N \times h_1$$

$$N = \frac{G \times d}{h_1}$$

$$M_4 = N \times e_1 = \frac{G \times d \times e_1}{h_1}$$

$$\sigma = \frac{M_4}{W_{b,4}} = \frac{G \times d \times e_1}{h \times W_{b,4}}$$

$$\tau = \frac{Me}{W_{t,4}} = \frac{G \times d}{W_{t,4}}$$

$$\sigma_v = G \times \sqrt{\left(\frac{d \times e_1}{h_1 \times W_{b,4}}\right)^2 + 3 \times \left(\frac{d}{W_{t,4}}\right)^2}$$

$$\boxed{G_{zul} = \frac{\sigma_{v,\,zul}}{\sqrt{\left(\frac{d \times e_1}{h_1 \times W_{b,4}}\right)^2 + 3 \times \left(\frac{d}{W_{t,4}}\right)^2}}}$$

Maximum weight from permissible shearing force with 2 bolts/rivets:

The displacement moment M_1=G.e is absorbed by the bolt/rivet pair.

$$\alpha = \frac{H_{d,\max}}{G}$$

$$S = \sqrt{S_H{}^2 + S_V{}^2}$$

$$S_v = \frac{G}{2}$$

$$S_H = \frac{G \times e}{h_1} + \frac{\alpha \times G}{2}$$

$$S = G \times \sqrt{\left(\frac{e}{h_1} + 0{,}5 \times \alpha\right)^2 + 0{,}5^2}$$

$$\boxed{G_{zul,S} = \frac{S_{zul}}{\sqrt{\left(\frac{e}{h_1} + 0{,}5 \times \alpha\right)^2 + 0{,}5^2}}}$$

Maximum weight from permissible shearing force with 4 bolts or rivets:

The displacement moment M_1=G.e is absorbed by 4 bolts/rivets.

$$S_v = \frac{G}{2}$$

Because of the slots, allowance can only be made for 2 connectors for the deflection of the facade weight.

$$S_H = \frac{G \times e \times h_1}{h_1{}^2 + h_2{}^2} + \frac{\alpha \times G}{4}$$

$$S = G \times \sqrt{\left(\frac{e \times h_1}{h_1{}^2 + h_2{}^2} + 0{,}25 \times \alpha\right)^2 + 0{,}5^2}$$

$$\boxed{G_{zul,S} = \frac{S_{zul}}{\sqrt{\left(\frac{e \times h_1}{h_1{}^2 + h_2{}^2} + 0{,}25 \times \alpha\right)^2 + 0{,}5^2}}}$$

Maximum weight from permissible dowel extraction force:

The wall dowel is not subject to any further torsion from moment loading.

$$\alpha_1 = \frac{H_{s,\max}}{G}$$

$$D = \sqrt{D_H^2 + D_V^2}$$

$$D_V = G$$

$$D_H = G \times \alpha_1 \times \frac{f+d}{f}$$

$$D = G \times \sqrt{\left(\alpha_1 \times \frac{f+d}{f}\right)^2 + 1}$$

$$\boxed{G_{zul,D} = \frac{D_{zul}}{\sqrt{\left(\alpha_1 \times \frac{f+d}{f}\right)^2 + 1}}}$$

7.3 Calculation of the MacFOX- ML fixed points

The formulae described in section 7.2 are also to calculate the MacFOX tolerance, I.e. from permissible shearing force when using 2 bolts/rivets as well as from permissible dowel extraction force. When using 4 bolts/rivets the weight can be distributed across all the connectors because they are not slotted into the holes.

Maximum weight from permissible shearing force with 4 bolts/rivets:

$$S_v = \frac{G}{4}$$

$$S_H = \frac{G \times e \times h_1}{h_1^2 + h_2^2} + \frac{\alpha \times G}{4}$$

$$S = G \times \sqrt{\left(\frac{e \times h_1}{h_1^2 + h_2^2} + 0,25 \times \alpha\right)^2 + 0,25^2}$$

$$\boxed{G_{zul,S} = \frac{S_{zul}}{\sqrt{\left(\frac{e \times h_1}{h_1^2 + h_2^2} + 0,25 \times \alpha\right)^2 + 0,25^2}}}$$

7.4 Calculation of the MacFOX- L fixed points

The formula in section 7.2 also applies for the maximum weight of the MacFOX element as a result of bend and torsion from eccentric effective dowel force.

Since 2 dowels are always used with this element, the displacement moment M_1=G.e is distributed across the dowel or bolt/rivet joints connecting the anchor girder according to section 1.2. In this case the upper wall dowel is subject to additional tension force from moment stress in the form of D_H = ½ G x e / h', where h' is the distance between tension force and the equal and opposite pressure in the lower area of the wall supports. A value of approximately 11.5 cm is used.

Maximum weight from permissible shearing force with 4 bolts/rivets:

$$\alpha = \frac{H_{d,\max}}{G}$$

$$S = \sqrt{S_H{}^2 + S_V{}^2}$$

$$S_v = \frac{G}{4}$$

$$S_H = \frac{G \times \frac{e}{2} \times h_1}{h_1^2 + h_4^2} + \frac{\alpha \times G}{4}$$

$$S = G \times \sqrt{\left(\frac{\frac{e}{2} \times h_1}{h_1^2 + h_4^2} + 0{,}25 \times \alpha \right)^2 + 0{,}25^2}$$

$$\boxed{G_{zul,S} = \frac{S_{zul}}{\sqrt{\left(\frac{\frac{e}{2} \times h_1}{h_1^2 + h_4^2} + 0{,}25 \times \alpha \right)^2 + 0{,}25^2}}}$$

Maximum weight from permissible shearing force with 8 bolts/rivets:

$$S_v = \frac{G}{4}$$ because 4 connectors are slotted into the holes.

$$S_H = \frac{G \times \frac{e}{2} \times h_1}{h_1^2 + h_2^2 + h_3^2 + h_4^2} + \frac{\alpha \times G}{8}$$

$$S = G \times \sqrt{\left(\frac{\frac{e}{2} \times h_1}{h_1^2 + h_2^2 + h_3^2 + h_4^2} + 0{,}125 \times \alpha \right)^2 + 0{,}25^2}$$

$$G_{zul,S} = \frac{S_{zul}}{\sqrt{\left(\frac{\frac{e}{2} \times h_1}{h_1^2 + h_2^2 + h_3^2 + h_4^2} + 0{,}125 \times \alpha \right)^2 + 0{,}25^2}}$$

Maximum weight from permissible dowel extraction force:

$$\alpha_1 = \frac{H_{s,\max}}{G}$$

$$D = \sqrt{D_H^2 + D_V^2}$$

$$D_V = \frac{G}{2}$$

Distribution of the weight on 2 dowels.

$$D_H = \frac{1}{2} \times \left(G \times \alpha_1 \times \frac{f + d}{f} + \frac{G \times e}{h'} \right)$$

additional tension from M = ½ G x e

$$D = \frac{1}{2} \times G \times \sqrt{\left(\alpha_1 \times \frac{f + d}{f} + \frac{e}{h'} \right)^2 + 1}$$

$$G_{zul,D} = \frac{n \times D_{zul}}{\sqrt{\left(\alpha_1 \times \frac{f + d}{f} + \frac{e}{h'} \right)^2 + 1}}$$

The MacFOX_14 calculation program incorporates all the formulae used for calculating flexible and fixed points. Individual expressions in formulae have however been partially calculated beforehand and replaced by new terms so as to make them usable in a variety of situations.

8 CALCULATION OF THE ANCHOR GIRDERS

8.1 Cutting forces for multi-field supports with overhang

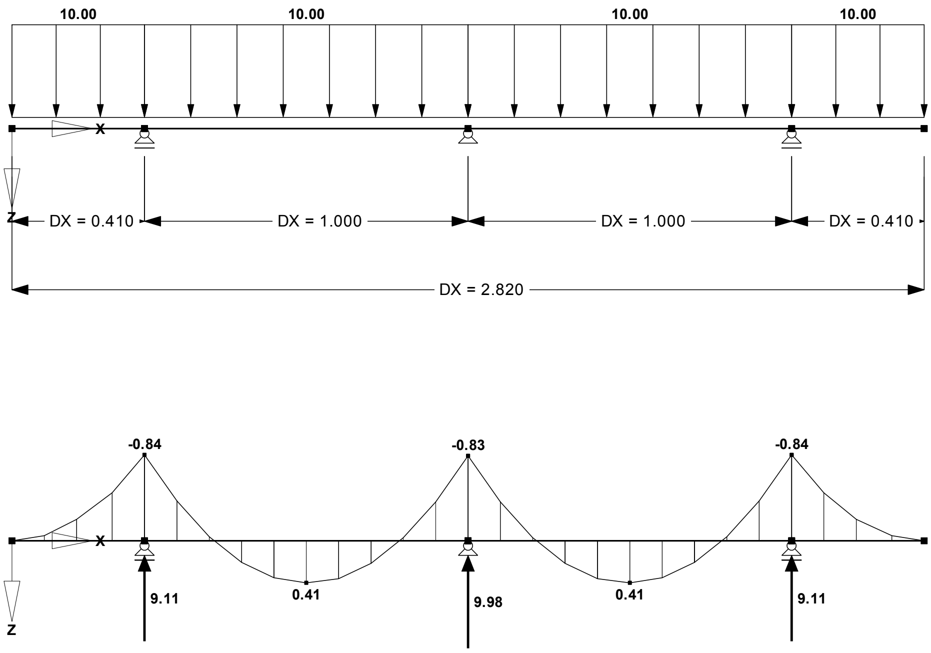
As previously mentioned in section 5.1, the overhangs of the multi-field supports were selected such that all support moments are roughly equal. The field moments are always less than the support moments and are therefore not significant in the calculation. From the following diagrams of the cutting forces for a 10-fold unit load, it is clear that the support moments for all systems, as a result of wind loading, can be calculated approximately using the following formula:

$$M_{St} = 0{,}085 \times w \times b \times a^2$$

Since the bolt/rivet joint connecting the anchor girder must also absorb the displacement moment M_1 = G.e, the anchor girder in the fixed point is subject to an additional loading of M_{st} = G.e/2. The support moment required for the calculation of the anchor girder is calculated as:

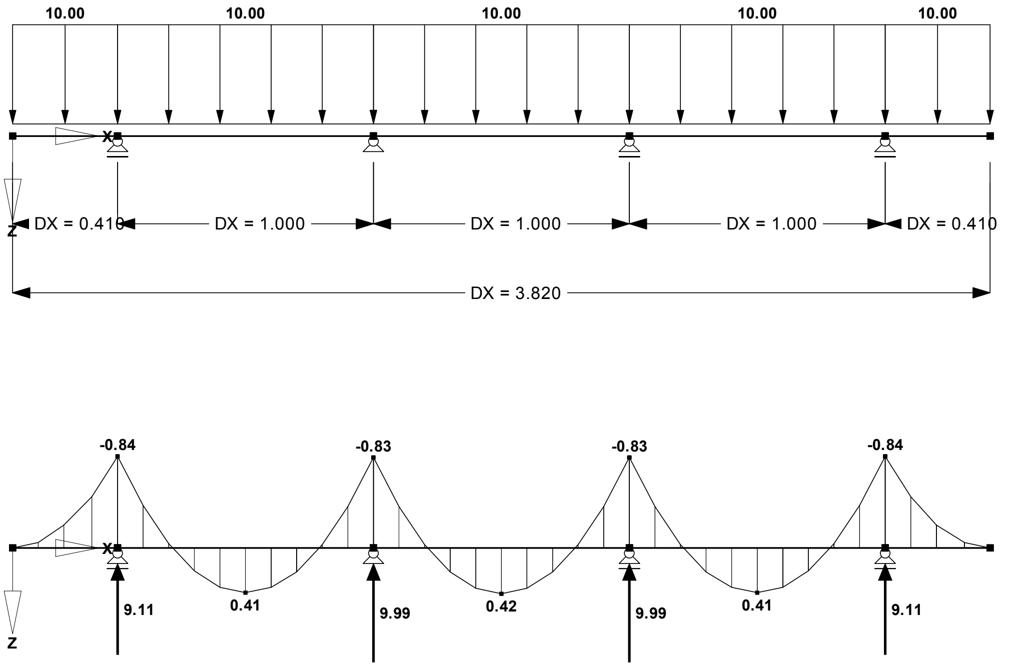
$$\boxed{M_{St} = 0{,}085 \times w \times b \times a^2 + G \times \frac{e}{2}}$$

Moments for two-field support with overhang:



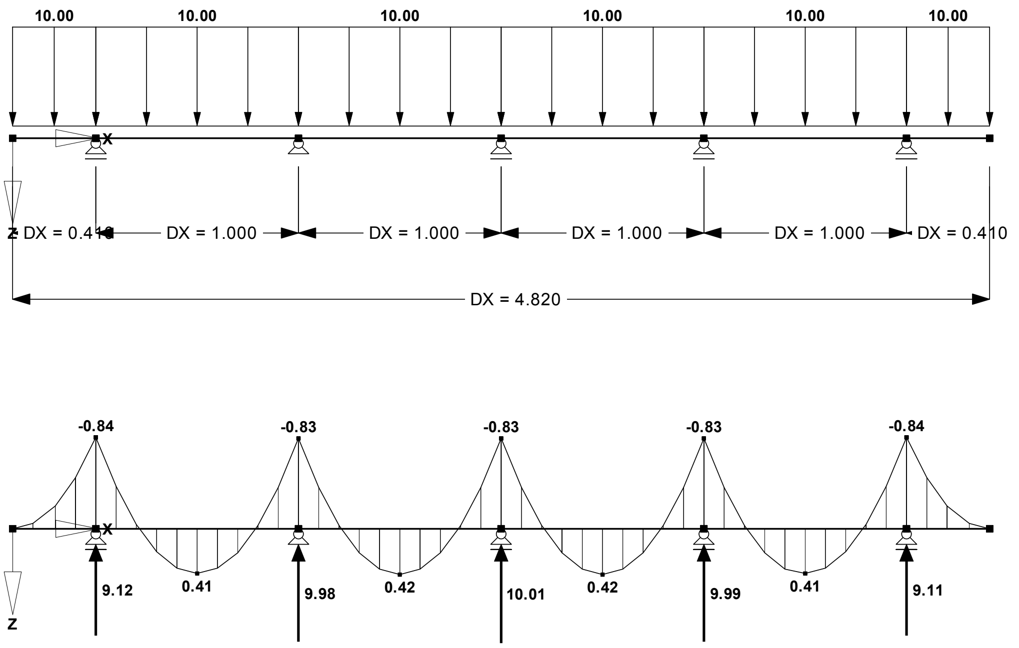
Max M-2: 0.41, Min M-2: -0.84 kNm

Moments for three-field support with overhang:



Max M-2: 0.42, Min M-2: -0.84 kNm

Moments for four-field support with overhang:



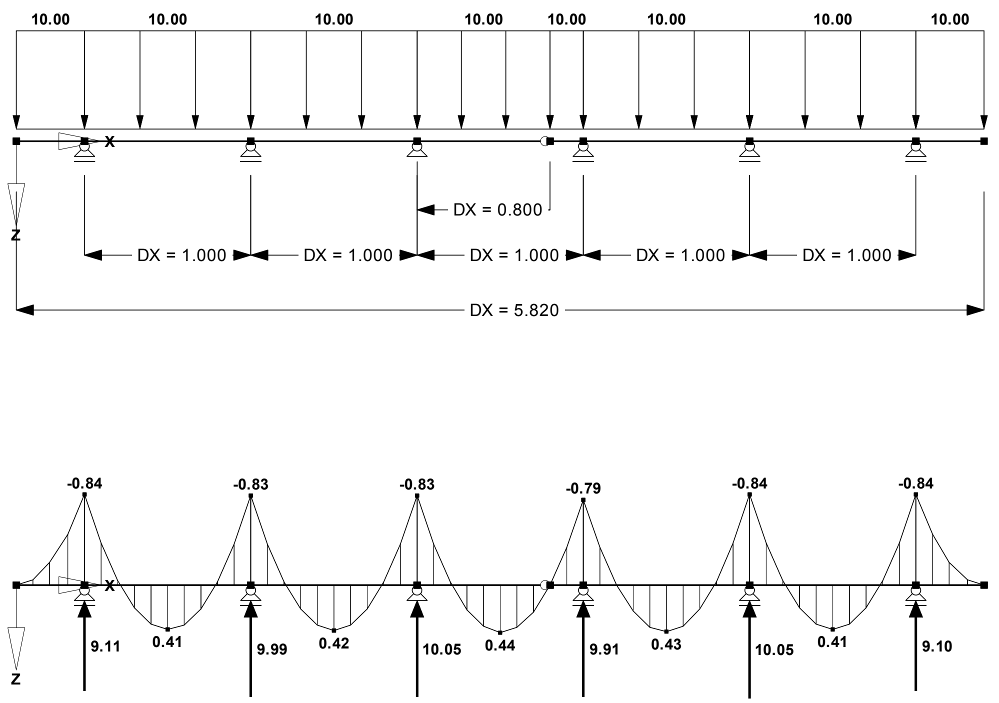
Max M-2: 0.42, Min M-2: -0.84 kNm

8.2 Cutting forces for multi-field support in the Gerber system

With the help of CONFOX joint elements, anchor girders can be connected together to form any length required. Since the joint element has no moment bearing capacity, a Gerber support system results. Connection to the CONFOX element is always at a distance of a/5 away from the support (corresponds roughly to the moment zero-point of the continuous support system). As shown in the following diagrams, the formula for the maximum support moment according to section 8.1 remains the same.

$$M_{St} = 0{,}085 \times w \times b \times a^2 + G \times \frac{e}{2}$$

Moments for multi-field support in the Gerber system:



Max M-2: 0.44, Min M-2: -0.84 kNm

8.3 Cutting forces for one-field support with overhang

For one-field supports with a selected overhang of 0.2.L, the support and field moments as a result of wind load are calculated as follows from the following moment curve for 10-fold unit load:

$$M_{St} = 0{,}055 \times w \times b \times a^2$$

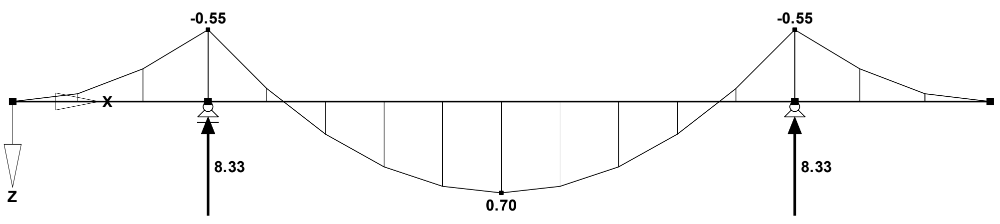
$$M_F = 0{,}070 \times w \times b \times a^2$$

As mentioned above, the anchor girder is subjected to an additional load by the displacement moment M_1 = G.e. At the fixed point this results in an additional moment of equal magnitude. An additional moment of half the magnitude remains in the field due to the linear moment curve. The support and field moments required for the calculation of the anchor girders are calculated as follows:

$$\boxed{M_{St} = 0{,}055 \times w \times b \times a^2 + G \times e}$$

$$\boxed{M_F = 0{,}070 \times w \times b \times a^2 + G \times \frac{e}{2}}$$

Moments for one-field supports with overhang:



Max M-2: 0.70, Min M-2: -0.55 kNm

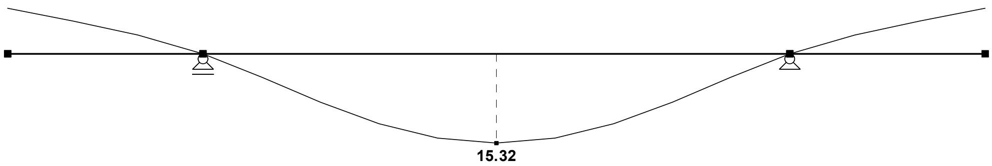
8.4 Deflections

When taking into account the anchor cross-sectional values (EI = 3.98 kN/m^2) used, computer calculations of individual systems having 10-fold unit load and unit support range of a = 1.0 show that the following deflections resulting from wind load can be diverted.

One-field support with overhang

The maximum deflection for the one-field support in the field centre is calculated as:

$$f = 0{,}006 \times w \times b \times a^4 \times \frac{1}{EI}$$

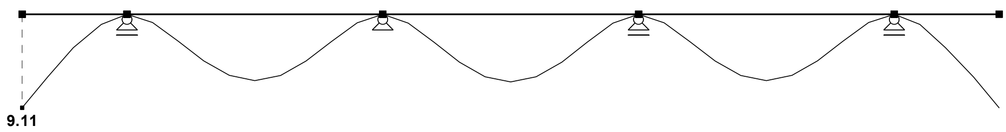


Max u: 15.32 mm
Faktor für Verschiebungen: 9.999999

Multi-field support with overhang

The maximum deflection for the multi-field support at the cantilever end is calculated as:

$$f = 0{,}128 \times w \times b \times k^4 \times \frac{1}{EI}$$



Max u: 9.11 mm
Faktor für Verschiebungen: 40