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Authorised and notified according to Article 29 of the Regulation (EU) No 305/2011 of the European Parliament and of the Council of 9 March 2011

MEMBER OF EOTA

European Technical Assessment ETA-23/0353 of 2023/05/26

General Part

Technical Assessment Body issuing the ETA and designated according to Article 29 of the Regulation (EU) No 305/2011: ETA-Danmark A/S

Trade name of the construction product:	SIHGA MassX Hold Downs
Product family to which the above construction product belongs:	Three-dimensional nailing plate (hold-downs for timber-to-timber or timber-to-concrete or steel connections)
Manufacturer:	SIHGA GmbH Gewerbepark Kleinreith 4 A-4694 Ohlsdorf Tel. +49 7612 / 74370 - 0 Fax +49 7612 / 74370 - 10 Internet www.sihga.com
Manufacturing plant:	SIHGA GmbH Manufacturing plant II
This European Technical Assessment contains:	34 pages including 2 annexes which form an integral part of the document
This European Technical Assessment is issued in accordance with Regulation (EU) No 305/2011, on the basis of:	EAD 130186-00-0603 for Three-dimensional nailing plates
This version replaces:	The ETA with the same number issued on 2021-09-01

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II SPECIFIC PART OF THE EUROPEAN TECHNICAL ASSESSMENT

1 Technical description of product

SIHGA Mass-X Angle P-HB and Corner are one-piece welded or similarly joined face-fixed nailing plates to be used in timber to concrete or to steel or in timber to timber connections.

SIHGA Mass-X Angle Q, Angle Z, Pull HH, Pull HB and Shear HH are one-piece non-welded, face-fixed nailing plates to be used in timber to timber or in timber to concrete or to steel connections. They are connected to construction members made of timber or wood-based products with profiled (ringed shank) nails according to ETA-23/0352 or screws according to ETA-11/0425, bolts according to EN 14592 or Idefix connectors according to ETA-14/0160 and to concrete or steel members with bolts or metal anchors.

The angle brackets with a steel plate thickness between 2,5 and 4 mm are made from the following materials:

- Angle P-HB from pre-galvanized steel S355 Fe Zn 12c according to EN 10025
- Corner Hold downs from pre-galvanized steel S250GD / Z275 according to EN 10346
- Angle Q HH and HB from pre-galvanized steel S235 Fe Zn 12c according to EN 10025-2
- Angle Z, Share and Pull from pre-galvanized steel S250GD / Z275 according to EN 10346
- Base plates from pre-galvanized steel S355 Fe Zn 12c according to EN 10025

Dimensions, hole positions and typical installations are shown in Annex B. SIHGA MassX hold-downs, angle brackets, shear plates and Tension straps are made from steel with tolerances according to EN 10143.

2 Specification of the intended use in accordance with the applicable European Assessment Document (hereinafter EAD)

The SIHGA MassX are intended for use in making connections in load bearing timber structures, as a connection between a beam and a purlin, where requirements for mechanical resistance and stability and safety in use in the sense of the Basic Works Requirements 1 and 4 of Regulation (EU) 305/2011 shall be fulfilled.

The connection may be with a single nailing plate or with nailing plates on one or both sides of the fastened timber member (see Annex B).

The static and kinematical behaviour of the timber members or the supports shall be as described in Annex A and B.

The wood members may be of solid timber, glued laminated timber and similar glued members, or wood-based structural members with a characteristic density from 290 kg/m^3 to 460 kg/m^3. This requirement to the material of the wood members can be fulfilled by using the following materials:

- Structural solid timber according to EN 14081,
- Glulam according to EN 14080,
- Glued solid timber according to EN 14080,
- LVL according to EN 14374,
- Cross laminated timber according to ETA.

Annex B states the load-carrying capacities of the connections for a characteristic density of 350 kg/m^3. For timber or wood based material with a lower or higher characteristic density than 350 kg/m^3 the load-carrying capacities shall be reduced or may be increased by the factor k_{dens}:

$$k_{dens} = \left(\frac{\rho_k}{350}\right)^{0,5}$$

where ρ_k is the characteristic density of the timber in kg/m^3.

If a wood-based panel interlayer with a thickness of not more than 26 mm is placed between the connector plate and the timber member, the lateral load-carrying capacity of the nail or screw, respectively, has to take into account the effect of the interlayer.

The design of the connections shall be in accordance with Eurocode 5 or a similar national Timber Code. The wood members shall have a thickness which is larger than the penetration depth of the nails or screws into the members.

The nailing plates are primarily for use in timber structures subject to the dry, internal conditions defined by service classes 1 and 2 of Eurocode 5 and for connections subject to static or quasi-static loading.

The nailing plates can also be used in outdoor timber structures, service class 3, when a corrosion protection in accordance with Eurocode 5 is applied, or when stainless steel with similar or better characteristic yield strength and ultimate strength is employed.

The scope of the connectors regarding resistance to corrosion shall be defined according to national provisions that apply at the installation site considering environmental conditions and in conjunction with the admissible service conditions according to EN 1995-1-1 and the admissible corrosivity category as described and defined in EN ISO 12944-2.

The SIHGA MassX may also be used for connections between a timber member and a member of concrete or steel.

Assumed working life

The assumed intended working life of the connectors for the intended use is 50 years, provided that they are subject to appropriate use and maintenance.

The information on the working life should not be regarded as a guarantee provided by the manufacturer or ETA Danmark. An "assumed intended working life" means that it is expected that, when this working life has elapsed, the real working life may be, in normal use conditions, considerably longer without major degradation affecting the essential requirements.

3 Performance of the product and references to the methods used for its assessment

Characteristic	Assessment of characteristic
3.1 Mechanical resistance and stability (BWR 1)*)	
Joint Strength - Characteristic load-carrying capacity	See Annex B
Joint Stiffness	See Annex B
Joint ductility	No performance assessed
Resistance to seismic actions	No performance assessed
Resistance to corrosion and deterioration	See section 3.6
3.2 Safety in case of fire (BWR 2)	
Reaction to fire	The connectors are made from steel classified as **Euroclass A1** in accordance with EN 13501-1 and Commission Delegated Regulation 2016/364
3.3 General aspects related to the performance of the product	The SIHGA MassX have been assessed as having satisfactory durability and serviceability when used in timber structures using the timber species described in Eurocode 5 and subject to the conditions defined by service classes 1 and 2

*) See additional information in section 3.4 – 3.7

3.4 Methods of verification

Safety principles and partial factors

The characteristic load-carrying capacities are based on the characteristic values of the nailed or screwed connections and the steel plates. To obtain design values the capacities have to be divided by different partial factors for the material properties, the nailed or screwed connection in addition multiplied with the coefficient k_{mod}.

According to EN 1990 (Eurocode – Basis of design) paragraph 6.3.5 the design value of load-carrying capacity may be determined by reducing the characteristic values of the load-carrying capacity with different partial factors.

Thus, the characteristic values of the load–carrying capacity are determined also for timber failure $F_{Rk,H}$ (obtaining the embedment strength of fasteners subjected to shear or the withdrawal capacity of the most loaded fastener, respectively) as well as for steel plate failure $F_{Rk,S}$. The design value of the load–carrying capacity is the smaller value of both load–carrying capacities.:

$$F_{Rd} = \min\left\{\frac{k_{mod} \cdot F_{Rk,T}}{\gamma_{M,T}}; \frac{F_{Rk,S}}{\gamma_{Mi,S}}\right\}$$

Therefore, for timber failure or failure of the metal fasteners the load duration class and the service class are included. The different partial factors γ_M for steel or timber failure, respectively, are also correctly taken into account.

3.5 Mechanical resistance and stability

See annex B for the characteristic load-carrying capacity in the different directions F_1, F_2, F_3, F_4 and F_5

The characteristic capacities of the connectors are determined by calculation assisted by testing as described in the EAD 130186-00-0603 for Three-dimensional nailing plates. They should be used for designs in accordance with Eurocode 5 or a similar national Timber Code.

3.6 Aspects related to the performance of the product

In accordance with EAD 130186-00-0603 for Three-dimensional nailing plates the hold downs are produced from the following materials:

- Angle P-HB from pre-galvanized steel S355 Fe Zn 12c according to EN 10025
- Corner Hold downs from pre-galvanized steel S250GD / Z275 according to EN 10346
- Angle Q HH and HB from pre-galvanized steel S235 Fe Zn 12c according to EN 10025-2
- Angle Z, Shear and Pull from pre-galvanized steel S250GD / Z275 according to EN 10346
- Base plates from pre-galvanized steel S355 Fe Zn 12c according to EN 10025

3.7 General aspects related to the use of the product

The performance given in this ETA are based on the following:

- The structural members – the components 1 and 2 shown in the figure on page 13 – to which the brackets are fixed shall be:
  - Restrained against rotation.
  - Strength class C14 or better, see section 3 of this evaluation report
  - Free from wane under the bracket.
- The actual end bearing capacity of the timber member to be used in conjunction with the bracket is checked by the designer of the structure to ensure it is not less than the bracket capacity and, if necessary, the bracket capacity reduced accordingly.
- The gap between the timber members does not exceed 3 mm.
- There are no specific requirements relating to preparation of the timber members.

4 Assessment and verification of constancy of performance (AVCP)

4.1 AVCP system

According to the decision 97/638/EC of the European Commission1, as amended, the system(s) of assessment and verification of constancy of performance (see Annex V to Regulation (EU) No 305/2011) is 2+.

5 Technical details necessary for the implementation of the AVCP system, as foreseen in the applicable EAD

Technical details necessary for the implementation of the AVCP system are laid down in the control plan deposited at ETA-Danmark prior to CE marking.

Issued in Copenhagen on 2023-05-26 by

Thomas Bruun
Managing Director, ETA-Danmark

Annex A
Product details definitions

Table A.1 Materials specification

Nailing plate type	Thickness (mm)	Steel specification	Coating specification
Angle P-HB 340 or 440	3,0	S355	FeZn12c
Angle P-HB 750	3,0	S355	FeZn12c
Angle Q	3,0	S250GD	Z 275
Angle Q HH or HB	2,5	S235	FeZn12c
Angle Z	4,0	S250GD	Z 275
Corner	4,0	S250GD	Z 275
Shear HH	3,0	S250GD	Z 275
Pull HH60	3,0	S250GD	Z 275
Pull HH70	3,0	S250GD	Z 275
Pull HB60	3,0	S250GD	Z 275
Pull HB70	3,0	S250GD	Z 275
Base plate 60	10,0	S235	FeZn12c
Base plate 230	12,0	S235	FeZn12c
Base plate 130	40,0	S235	FeZn12c

Table A.2 Range of sizes

Angle Bracket type	Height (mm) vertical		Height (mm) horizontal		Width (mm)	
Angle P-HB 340 or 440	339	341	62	64	59	61
Angle P-HB 750	119	121	119	121	229	231
Angle Q	749	751	84	86	139	141
Angle Q HH or HB	69	71	69	71	229	231
Angle Z	95	97	69	71	229	231
Corner	119	121	79	81	229	231
Shear HH	119	121	119	121	119	121
Pull HH60	7,5	8,5	239	241	229	231
Pull HH70	7,5	8,5	679	681	59	61
Pull HB60	7,5	8,5	739	741	69	71
Pull HB70	7,5	8,5	505	507	59	61
Base plate 60	7,5	8,5	505	507	69	71
Base plate 230	9,5	10,5	49	51	57	59
Base plate 130	11,5	12,5	67	69	229	231
Angle P-HB 340 or 440	39,0	41,0	81	83	129	131

Table A.3 Fastener specification

Fastener	Length	Profiled Length	Fastener type
SIHGA Ankernägel 4.0 mm	40 mm	25 mm	Ringed shank nails according to ETA-23/0352
	50 mm	35 mm	
	60 mm	45 mm	
SIHGA WBS screw 5.0 mm	25 mm	16 mm	Self-tapping screws according to ETA-11/0425
	40 mm	31 mm	
	50 mm	41 mm	
	60 mm	51 mm	
	70 mm	61 mm	
SIHGA GoFix ZSS screw 5.0 mm	120 mm	70 mm	
SIHGA GoFix HK screw 6.0 mm	60 mm	53 mm	
SIHGA GoFix S+ screw 10.0 mm	125 mm	116 mm	

In the load-carrying-capacities of the nailed or screwed connection in Annex B the capacities calculated from the formulas of Eurocode 5 are used assuming a thick steel plate when calculating the lateral fastener load-carrying-capacity. The characteristic withdrawal capacity of the nails or screws is determined by calculation in accordance with EN 1995-1-1:2010, paragraph 8.3.2 (head pull-through is not relevant):

$F_{ax,Rk} = f_{ax,k} \cdot d \cdot t_{pen}$ for the SIHGA connector nails 4.0 mm

$F_{ax,Rk} = k_{ax} \cdot f_{ax,k} \cdot d \cdot \ell_{ef} \left(\frac{\rho_k}{\rho_a} \right)^{0,8}$ for the screws 5.0 mm

where:

k_{ax} Factor taking into account the angle between screw axis and grain direction; $k_{ax} = 1$ for $\alpha \leq 45°$
$f_{ax,k}$ Characteristic value of the withdrawal parameter in N/mm^2
d Nail or screw diameter in mm
t_{pen} Penetration depth of the profiled shank in mm
ρ_k Characteristic density of the timber in kg/m^3
ρ_a Characteristic density of the timber in kg/m^3 according to $f_{ax,k}$

Based on ETA-23/0352 the characteristic value of the withdrawal resistance and the characteristic value of fastener's yield moment for SIHGA connector nails d = 4.0 mm is:
$f^{ax,k}$ = 4,84 N/mm² for nails 4x40, f_{ax},k = 5,09 N/mm² for nails 4x50, $f_{ax,k}$ = 5,23 N/mm² for nails 4x60
$M_{y,k}$ = 6480 Nmm

Based on ETA-11/0425 the characteristic value of the withdrawal resistance and the characteristic value of fastener's yield moment for SIHGA screws d = 5.0 mm is:
$f_{ax,k}$ = 12,1 N/mm²
$M_{y,k}$ = 5910 Nmm

The shape of the nail or screw directly under the head shall be in the form of a truncated cone with a diameter under the head which fits or exceeds the hole diameter.

Bolt diameter	Correspondent hole diameter	Bolts type
12.0 to 28.0 mm	Max. 2 mm larger than the bolt diameter	See specification of the manufacturer

Metal Anchor diameter	Correspondent Hole diameter	Anchors type
12.0 to 28.0 mm	Max. 2 mm larger than the anchor diameter	See specification of the manufacturer

Annex B
Characteristic load-carrying capacities

Table 1: $F_{1,Rk}$ per nailing plate with washer or base plate / connection timber to timber or timber to concrete or steel

Type	Timber ρ_k = 350 kg/m³						steel	bolt	concrete
	capacity per fastener in the vertical flange $F_{v,Rk}$ [kN]						$F_{t,Rk}$ [kN]	$k_{t,II}$	ℓ_D [mm]
	Nails			Screws					
	4x40	4x50	4x60	5x40	5x50	5x60			
Angle P-HB 340 or 440 + washer 30x3 or base plate 60	1,90	2,26	2,45	2,14	2,28	2,43	57,1	1,4	10
Angle P-HB 750 + base plate 130	1,90	2,26	2,45	2,14	2,28	2,43	See equation (B.1)	1,4	10
Angle Q + base plate 230	1,90	2,26	2,45	2,14	2,28	2,43	116	1,7	10
	capacity per shear angle $F_{1,Rk}$ [kN]						$F_{t,Rk}$ [kN]	$k_{t,II}$	ℓ_D [mm]
Angle Q HB * + base plate 230 + 2 bolts M12 close to bend line	30,0						120	2,0	10
* 6 screws 5x120 and 3 screws 5x25 per flap									

Characteristic load-carrying capacity $F_{t,Rk}$ for Hold-down Angle P-HB 750:

$$F_{t,Rk} = \min\left\{A \cdot f_{y,k}; 0{,}9 \cdot A_{net} \cdot f_{u,k}\right\} \quad \text{(B.1)}$$

Where:

A	Cross-section area of the vertical flap in mm² $A = 210 \cdot (1+h_f/600)$ in mm²
h_f	Distance of the lowermost nail or screw from the upper end of the vertical flap in mm
$f_{y,k}$	Characteristic yield strength of vertical flap in N/mm², $f_{y,k}$ = 355 MPa
$f_{u,k}$	Characteristic ultimate strength of vertical flap in N/mm², $f_{u,k}$ = 510 MPa
A_{net}	Net cross-section area of the vertical flap in mm² $A_{net} = 210 \cdot (1+h_f/600) - n_h \cdot 15$ in mm²
n_h	Number of nail or screw holes in the cross-section at the lowermost fastener

Table 2: $F_{1,Rk}$ per nailing plate / timber to timber connection

Type	Timber ρ_k = 350 kg/m³	steel
	capacity per inclined screw 5x120 $F_{v,Rk}$ [kN]	$F_{t,Rk}$ [kN]
Pull HH60 or HB60	3,74	28,5
Pull HH70 or HB70	3,74	37,4
Angle Q HH *	capacity per shear angle $F_{1,Rk}$ [kN]	120
	30,0	
* 6 screws 5x120 and 3 screws 5x25 per flap and 5 screws 10x125 per angle		

$F_{1,Rk}$ per Angle Z fastened with bolts or Idefix connectors / CLT to CLT connection:

Without bolts or Idefix connectors in the horizontal flap:

$$F_{1,Rk} = \min\left\{\frac{1,25 \cdot n_s \cdot F_{ax,screw,Rk}}{\sqrt{2}}; n_v \cdot F_{v,IB,Rk}\right\} \quad (B.1)$$

With bolts or Idefix connectors in the horizontal flap:

$$F_{1,Rk} = \min\left\{\frac{n_s \cdot F_{ax,screw,Rk}}{\sqrt{2}} + 8\,kN; k_{IL} \cdot n_h \cdot F_{v,IB,Rk}; n_v \cdot F_{v,IB,Rk}\right\} \quad (B.2)$$

$F_{1,Rk}$ per Angle Z fastened with 5 mm screws in each 5 mm hole/ CLT to CLT connection:

Without 5 mm screws in the horizontal flap:

$$F_{1,Rk} = \frac{1,25 \cdot n_s \cdot F_{ax,screw,Rk}}{\sqrt{2}} \quad (B.3)$$

With 5 mm screws in the horizontal flap:

$$F_{1,Rk} = \min\left\{\frac{n_s \cdot F_{ax,screw,Rk}}{\sqrt{2}} + 11 \cdot F_{ax,5mm,Rk}\right\} \quad (B.4)$$

Where:

n_s	Number of SIHGA GoFix S+ screws arranged under 45°, $2 \le n_s \le 4$
n_h	Number of bolts or Idefix connectors in the horizontal flap, $2 \le n_h \le 3$
n_v	Number of bolts or Idefix connectors in the vertical flap, $2 \le n_v \le 3$
$F_{ax,screw,Rk}$	Characteristic axial capacity of a 45° SIHGA GoFix S+ screw according to ETA-11/0024,
$F_{ax,5mm,Rk}$	Characteristic axial capacity of a 5 mm screw according to ETA-11/0425,
$F_{v,IB,Rk}$	Characteristic lateral load-carrying capacity of a bolt ($F_{v,IB,Rk} = F_{v,bolt,Rk}$) for thick steel plates according to EN 1995-1-1 or an Idefix connector ($F_{v,IB,Rk} = F_{v,Idefix,Rk}$),
$F_{v,Idefix,Rk}$	= 20,8 kN for CLT member (ρ_k = 400 kg/m³) and α = 0°,
$F_{v,Idefix,Rk}$	= 16,9 kN for CLT member (ρ_k = 400 kg/m³) and α = 90°,
α	Angle between load and grain direction of the outer CLT layer, linear interpolation should be applied for 0° < α < 90°,
k_{IL}	Modification factor for the fastener's capacity reduction due to a 6 mm interlayer,
k_{IL}	= 0,9 for bolts or Idefix connectors.

$F_{1,Rk}$ per Corner / CLT to CLT wall-wall-floor connection, ρ_k = 400 kg/m³:

$$F_{1,Rk} = 30\,kN \text{ for fastener configuration 1} \quad (B.5)$$

$$F_{1,Rk} = 40\,kN \text{ for fastener configuration 2} \quad (B.6)$$

$$F_{1,Rk} = 50\,kN \text{ for fastener configuration 3} \quad (B.7)$$

$$F_{1,Rk} = 60\,kN \text{ for fastener configuration 4} \quad (B.8)$$

Where:

Fastener configuration 1: Two 40 mm Idefix connectors with 8 SIHGA GoFix HK screws 6x60 each or two 16 mm bolts 8.8 per vertical flap arranged in 17 mm holes, four SIHGA GoFix S+ screws per horizontal flap arranged under 45 ° in 11 mm holes.

Fastener configuration 2: Two 40 mm Idefix connectors with 8 SIHGA GoFix HK screws 6x60 each or two 16 mm bolts 8.8 per vertical flap arranged in 17 mm holes, two 40 mm Idefix connectors with 8 SIHGA GoFix HK screws 6x60 each or two 16 mm bolts 8.8 per horizontal flap arranged in 17 mm holes, four SIHGA GoFix S+ screws per horizontal flap arranged under 45 ° in 11 mm holes.

Fastener configuration 3: 17 WBS screws 5x50 per vertical flap arranged in 5 mm holes, 31 WBS screws 5x50 per horizontal flap arranged in 5 mm holes, four SIHGA GoFix S+ screws per horizontal flap arranged under 45 ° in 11 mm holes.

Fastener configuration 4: Two 40 mm Idefix connectors with 8 SIHGA GoFix HK screws 6x60 each or two 16 mm bolts 8.8 per vertical flap arranged in 17 mm holes, two 40 mm Idefix connectors with 8 SIHGA GoFix HK screws 6x60 each or two 16 mm bolts 8.8 per horizontal flap arranged in 17 mm holes, 13 WBS screws 5x50 per vertical flap arranged in 5 mm holes, 31 WBS screws 5x50 per horizontal flap arranged in 5 mm holes, four SIHGA GoFix S+ screws per horizontal flap arranged under 45 ° in 11 mm holes.

Table 3: $F_{23,Rk}$ per nailing plate / timber-timber connection, ρ_k = 350 kg/m³

Type	Fastener pattern	Number of nails or screws per flap n_{na}	Number of inclined screws 5x120 per flap n_{Sc}	F_{23Rk} [kN] with n_{na} nails			F_{23Rk} [kN] with n_{na} screws		
				4x40	4x50	4x60	5x40	5x50	5x60
Angle Q 230x120	Full	41	6	37,3	44,3	47,9	41,9	44,6	47,6
	Partial 1	34	6	29,1	34,6	37,4	32,7	34,9	37,2
	Partial 2	29	4	23,6	28,0	30,4	26,5	28,3	30,1
Angle Q with 6 mm interlayer	Full	41	6	28,9	34,4	37,4	32,7	34,8	37,1
	Partial 1	34	6	22,6	26,9	29,4	25,5	27,2	29,0
	Partial 2	29	4	18,3	21,8	23,9	20,7	22,1	23,5
Shear HH 240x230	Full	41	6	37,3	44,3	47,9	41,9	44,6	47,6
	Partial 1	34	6	29,1	34,6	37,4	32,7	34,9	37,2
	Partial 2	29	4	23,6	28,0	30,4	26,5	28,3	30,1

$F_{23,Rk}$ per Angle Q HH with full screw pattern / timber-timber connection, ρ_k = 350 kg/m³ (6 screws 5x120 and 3 screws 5x25 per flap and 5 screws 10x125 per angle):

$F_{23,Rk}$ = 40 kN without interlayer
$F_{23,Rk}$ = 36 kN with interlayer under the horizontal flap

$F_{23,Rk}$ per Angle Q HB with full screw pattern* / timber-to-concrete or steel connection, ρ_k = 350 kg/m³ (6 screws 5x120 and 3 screws 5x25 per vertical flap):

$F_{23,Rk} = \min \{40 \text{ kN}; n_{ef} \cdot F_{v,bolt,Rk}\}$
Where n_{ef} = 1,89 for two bolts close to bend line, n_{ef} = 1,48 for two bolts away from bend line

$F_{23,Rk}$ per Angle Z / CLT to CLT connection:

With bolts or Idefix connectors only in the vertical flap:

$$F_{23,Rk} = \min \left\{ k_{IL} \cdot n_s \cdot F_{v,screw,Rk} ; \frac{F_{v,IB,Rk}}{\sqrt{\frac{1}{n_v^2} + 0,28}} \right\} \qquad \text{(B.9)}$$

With bolts or Idefix connectors in the vertical and horizontal flap:

$$F_{23,Rk} = \min \left\{ k_{IL} \cdot n_s \cdot F_{v,screw,Rk} + \frac{k_{IL} \cdot F_{v,IB,Rk}}{\sqrt{\frac{1}{n_h^2} + 0,1}} ; \frac{F_{v,IB,Rk}}{\sqrt{\frac{1}{n_v^2} + 0,28}} \right\} \qquad \text{(B.10)}$$

With 43 SIHGA GoFix ZSS or WBS screws each in the vertical and horizontal flap:

$F_{23,Rk} = 71,8\ \text{kN}$ for 5x120 mm SIHGA GoFix ZSS screws without interlayer (B.11)

$F_{23,Rk} = 63,6\ \text{kN}$
for 5x120 mm SIHGA GoFix ZSS screws with 6 mm interlayer under horizontal flap (B.12)

$F_{23,Rk} = 68,1\ \text{kN}$ for 5x70 mm WBS screws without interlayer (B.13)

$F_{23,Rk} = 58,4\ \text{kN}$ for 5x70 mm WBS screws with 6 mm interlayer under horizontal flap (B.14)

Where:

n_s	Number of SIHGA GoFix S+ screws arranged under 45°, $2 \leq n_s \leq 4$
n_h	Number of bolts or Idefix connectors in the horizontal flap, $2 \leq n_h \leq 3$
n_v	Number of bolts or Idefix connectors in the vertical flap, $2 \leq n_v \leq 3$
$F_{v,screw,Rk}$	Characteristic lateral capacity of a 45° SIHGA GoFix S+ screw according to ETA-11/0024, For CLT ($\rho_k = 400$ kg/m³): $F_{v,screw,Rk} = 5,28$ kN,
$F_{v,IB,Rk}$	Characteristic lateral load-carrying capacity of a bolt ($F_{v,IB,Rk} = F_{v,bolt,Rk}$) for thick steel plates according to EN 1995-1-1 or an Idefix connector ($F_{v,IB,Rk} = F_{v,Idefix,Rk}$),
$F_{v,Idefix,Rk}$	= 20,8 kN for CLT member ($\rho_k = 400$ kg/m³) and $\alpha = 0°$,
$F_{v,Idefix,Rk}$	= 16,9 kN for CLT member ($\rho_k = 400$ kg/m³) and $\alpha = 90°$,
α	Angle between load and grain direction of the outer CLT layer, linear interpolation should be applied for $0° < \alpha < 90°$,
k_{IL}	Modification factor for the fastener's capacity reduction due to a 6 mm interlayer,
k_{IL}	= 0,9 for bolts or Idefix connectors.

$F_{2/3/4,Rk}$ per Corner / CLT to CLT wall-wall-floor connection, ρ_k = 400 kg/m³:

$F_{2/3/4,Rk} = 15\ \text{kN}$ for fastener configuration 1 (B.15)

$F_{2/3/4,Rk} = 52\ \text{kN}$ for fastener configuration 2 (B.16)

$F_{2/3/4,Rk} = 65\ \text{kN}$ for fastener configuration 3 (B.17)

$F_{2/3/4,Rk} = 70\ \text{kN}$ for fastener configuration 4 (B.18)

$F_{2/3/5,Rk}$ per Corner / CLT to CLT wall-wall-floor connection, ρ_k = 400 kg/m³:

$F_{2/3/5,Rk} = 10\ \text{kN}$ for fastener configuration 1 (B.19)

$F_{2/3/5,Rk} = 28\ \text{kN}$ for fastener configuration 2 (B.20)

$F_{2/3/5,Rk} = 44\ \text{kN}$ for fastener configuration 3 (B.21)

$F_{2/3/5,Rk} = 50\ \text{kN}$ for fastener configuration 4 (B.22)

Fastener configurations are defined below equation (B.8).

$F_{4,Rk}$ per Angle Q HH with full screw pattern / timber-timber connection,
ρ_k = 350 kg/m³ (6 screws 5x120 and 3 screws 5x25 per flap and 5 screws 10x125 per angle):

$F_{4,Rk}$ = 40 kN without interlayer
$F_{4,Rk}$ = 36 kN with interlayer under the horizontal flap

$F_{4,Rk}$ per Angle Q HB with full screw pattern* / timber-to-concrete or steel connection,
ρ_k = 350 kg/m³ (6 screws 5x120 and 3 screws 5x25 per vertical flap):

$F_{4,Rk}$ = min {40 kN; $n_B \cdot F_{v,bolt,Rk}$} with or without interlayer
Note: $F_{v,bolt,Rk}$ depends on the interlayer thickness

$F_{45,Rk}$ per Angle Z / CLT to CLT connection with or without interlayer:

With 5 mm screws, bolts or Idefix connectors only in the vertical flap:

$$F_{4,Rk} = \frac{n_s \cdot F_{ax,screw,Rk}}{\sqrt{2}} \tag{B.23}$$

$$F_{5,Rk} = 0 \tag{B.24}$$

With 5 mm screws, bolts or Idefix connectors in the horizontal and vertical flap:

$$F_{4,Rk} = 54\ \text{kN} \tag{B.25}$$

$$F_{5,Rk} = 4{,}8\ \text{kN for bolts or Idefix connectors} \tag{B.26}$$

$$F_{5,Rk} = 6{,}9\ \text{kN for SIHGA GoFix ZSS or WBS screws} \tag{B.27}$$

$$F_{45,Rk} = F_{4,Rk} + F_{5,Rk} \tag{B.28}$$

Where:

n_s	Number of SIHGA GoFix S+ screws arranged under 45°, $2 \leq n_s \leq 4$
$F_{ax,screw,Rk}$	Characteristic axial capacity of a 45° SIHGA GoFix S+ screw according to ETA-11/0024.

Static ductility for Angle Q or Angle Z in timber-to-timber connections with interlayer
When 4 mm ringed shank nails or 5 mm WBS or SIHGA GoFix ZSS screws are used to fix Angle Q or Angle Z, the static ductility ratio for shear forces (load direction F_{23}) between CLT shear walls and timber floors exceeds 4. Consequently, ductility class DCM may be assumed in the design of these structures under earthquake loading.

Slip moduli

The slip modulus per Angle Q HH or HB may be assumed as:

$K_{1,ser} = 5$ kN/mm $\quad K_{23,ser} = 15$ kN/mm $\quad K_{4,ser} = 10$ kN/mm

The slip modulus per Angle Z may be assumed as:

$K_{1,ser} = \frac{F_{1,Rk}}{6\ \text{mm}} \quad K_{23,ser} = \frac{F_{23,Rk}}{2\ \text{mm}} \quad K_{4,ser} = \frac{F_{4,Rk}}{2{,}5\ \text{mm}} \quad K_{5,ser} = \frac{F_{5,Rk}}{2{,}5\ \text{mm}}$

The slip modulus per Mass-X Corner may be assumed as:

Fastener configuration 1: $K_{1,ser} = 6\ kN/mm$ $K_{234,ser} = 2{,}5\ kN/mm$ $K_{235,ser} = 5\ kN/mm$

Fastener configuration 2: $K_{1,ser} = 10\ kN/mm$ $K_{234,ser} = 10\ kN/mm$ $K_{235,ser} = 2{,}5\ kN/mm$

Fastener configuration 3: $K_{1,ser} = 20\ kN/mm$ $K_{234,ser} = 18\ kN/mm$ $K_{235,ser} = 10\ kN/mm$

Fastener configuration 4: $K_{1,ser} = 20\ kN/mm$ $K_{234,ser} = 18\ kN/mm$ $K_{235,ser} = 10\ kN/mm$

Combined forces in Angle Z

If the forces F_1, $F_{2/3}$ or F_4/F_5 act at the same time, the following inequality shall be fulfilled:

$$\left(\frac{F_{1,Ed}}{F_{1,Rd}}\right)^2 + \left(\frac{F_{23,Ed}}{F_{23,Rd}}\right)^2 + \left(\frac{F_{4,Ed}}{F_{4,Rd}}\right)^2 + \left(\frac{F_{5,Ed}}{F_{5,Rd}}\right)^2 \leq 1$$

The forces F_4 and F_5 are forces with opposite direction. Therefore, only one force F_4 or F_5 is able to act simultaneously with F_1 or F_{23}, while the other shall be set to zero.

Combined forces in Mass-X Corner

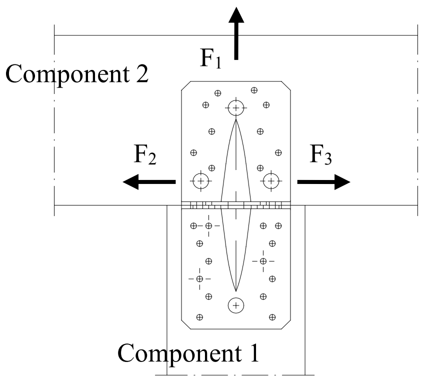
If the forces F_1, $F_{2/3/4}$ or $F_{2/3//5}$ act at the same time, the following inequality shall be fulfilled:

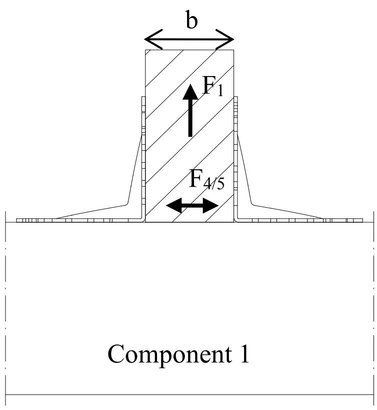
$$\left(\frac{F_{1,Ed}}{F_{1,Rd}}\right)^2 + \left(\frac{F_{234,Ed}}{F_{234,Rd}}\right)^2 + \left(\frac{F_{235,Ed}}{F_{235,Rd}}\right)^2 \leq 1$$

The forces F_{234} and F_{235} are forces with opposite direction. Therefore, only one force F_{234} or F_{235} is able to act simultaneously with F_1, while the other shall be set to zero.

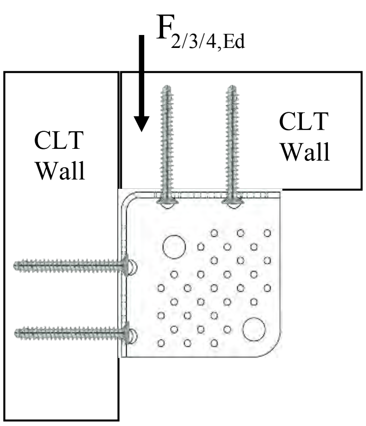
Definitions of forces, their directions and eccentricity

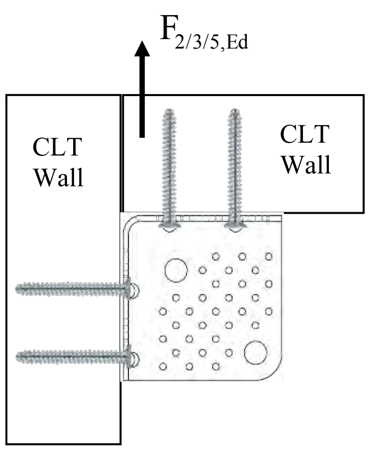
Forces - Beam to beam connection





Forces – CLT wall to CLT wall to CLT floor connection





Fastener specification
Holes are marked referring to the fastener pattern.

Double angle brackets per connection
The angle brackets must be placed at each side opposite to each other, symmetrically to the component axis.

Acting forces

F_1	Lifting force acting along the central axis of the joint.
F_2 and F_3	Lateral force acting in the joint between the component 2 and component 1 in the component 2 direction
$F_{4/5}$	Lateral force acting in the joint between the component 2 and component 1 in the component 1 direction

Single angle bracket per connection
Acting forces

F_1	Lifting force acting in the central axis of the angle bracket. The component 2 shall be prevented from rotation.
F_2 and F_3	Lateral force acting in the joint between the component 2 and the component 1 in the component 2 direction. The component 2 shall be prevented from rotation.
F_4	Lateral force acting perpendicular to the central axis of the joint towards a shear angle.
F_5	Lateral force acting perpendicular to the central axis of the joint away from a Angle Z.

Mass-X Corner
Acting forces

F_1	Lifting force perpendicular to the CLT floor. The walls shall be prevented from rotation.
$F_{2/3/4}$	Lateral force acting parallel to one wall and perpendicular to the other wall towards a Mass-X Corner. The walls shall be prevented from rotation.
$F_{2/3/5}$	Lateral force acting parallel to one wall and perpendicular to the other wall away from a Mass-X Corner. The walls shall be prevented from rotation.

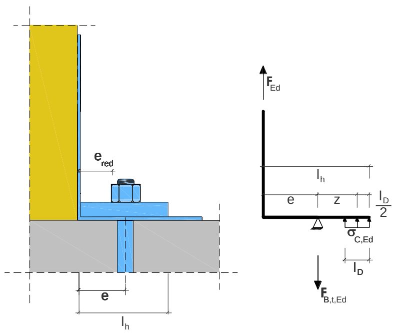
Wane
Wane is not allowed; the timber has to be sharp-edged in the area of the angle brackets.

Timber splitting
For the lifting force F_1 it must be checked in accordance with Eurocode 5 or a similar national Timber Code that splitting will not occur.

Connection of timber to concrete or steel with bolts or metal anchors
The load $F_{B,Ed}$ for the design of the maximally loaded bolt or metal anchor is calculated as:

$$F_{B,t,Ed} = k_{t,II} \times F_{1,Ed}$$

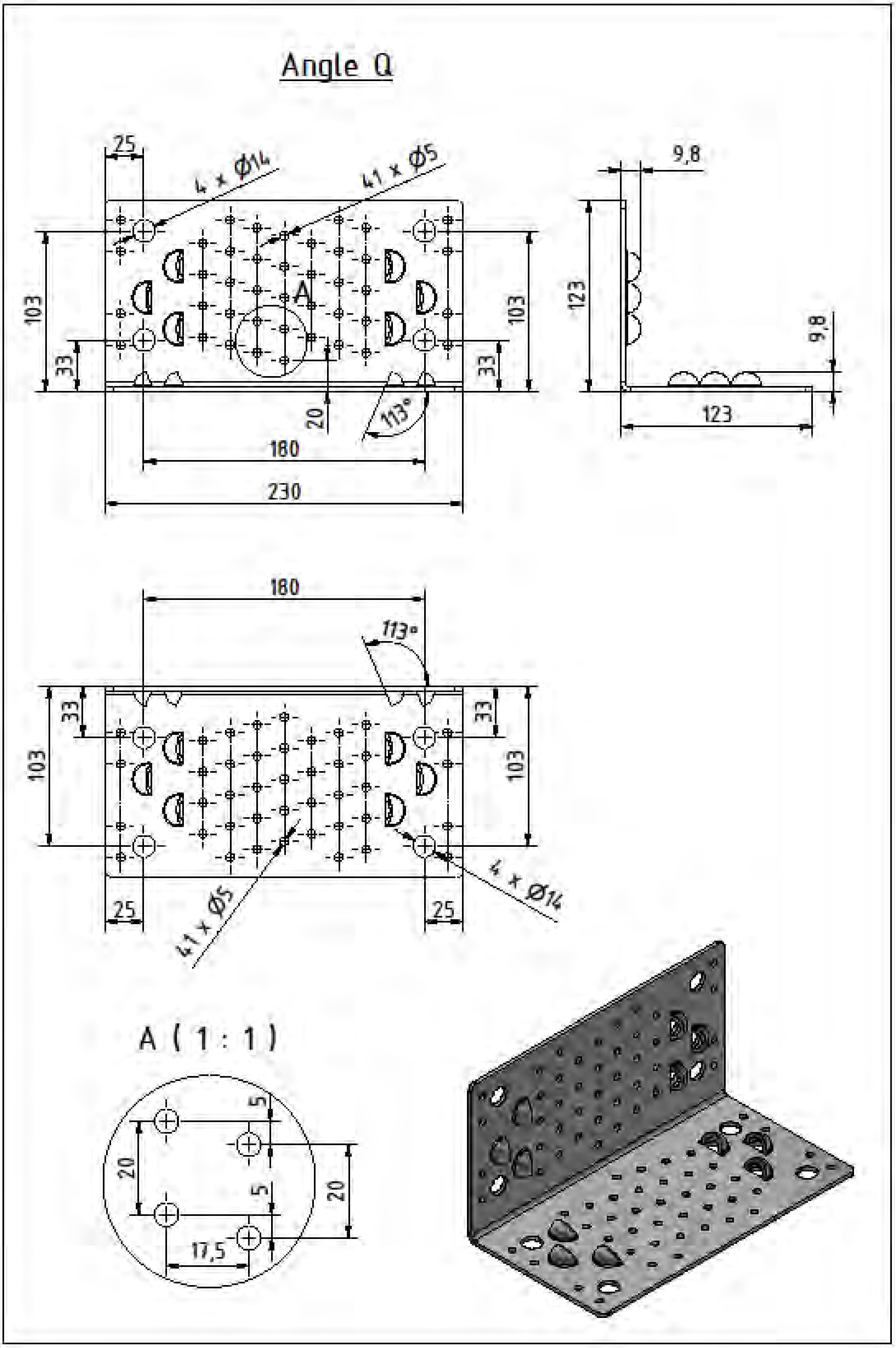
$$\sigma_{C,Ed} = \frac{F_{1,Ed} \times (k_{t,II} - 1)}{b \times l_D}$$

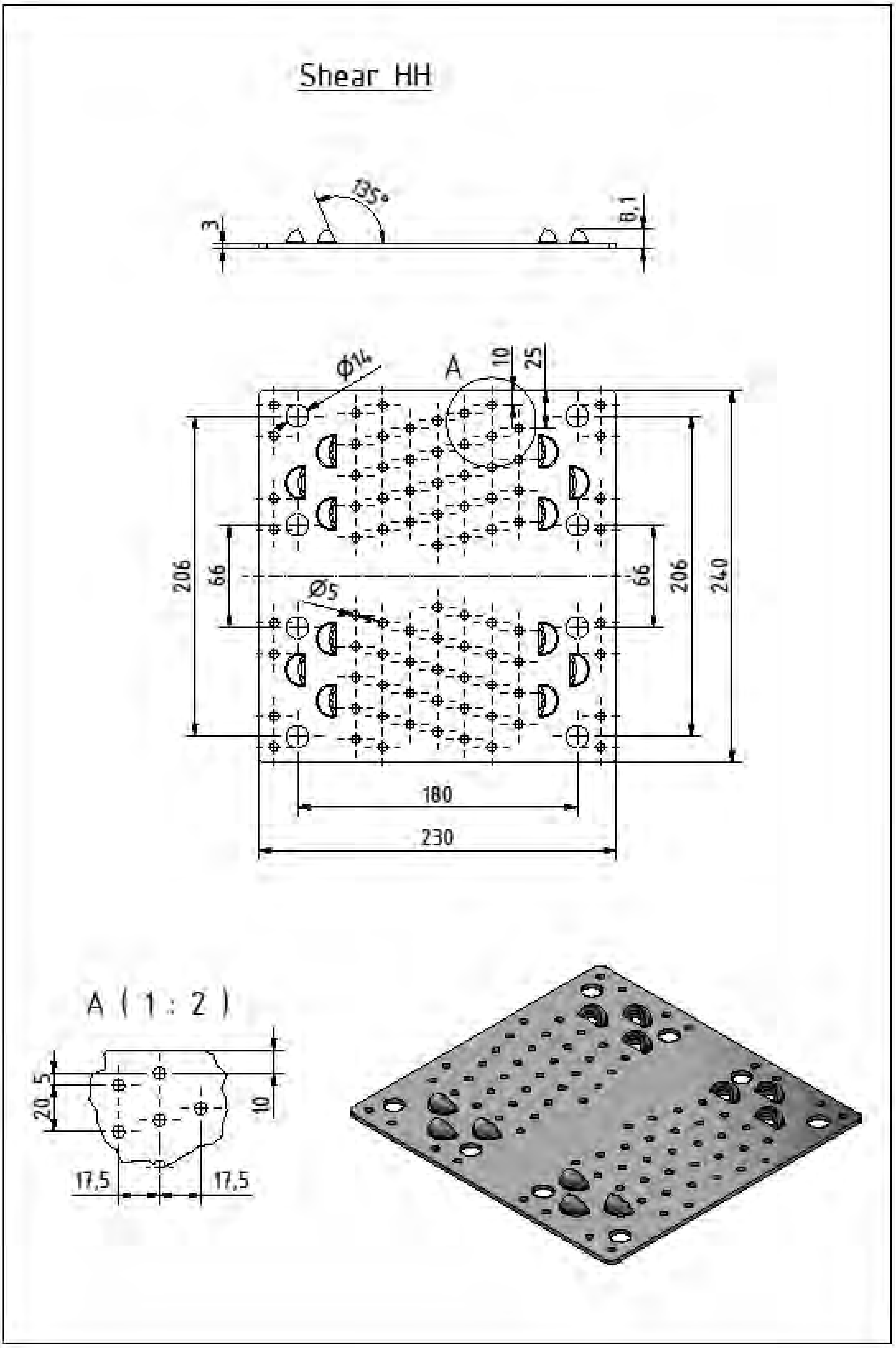


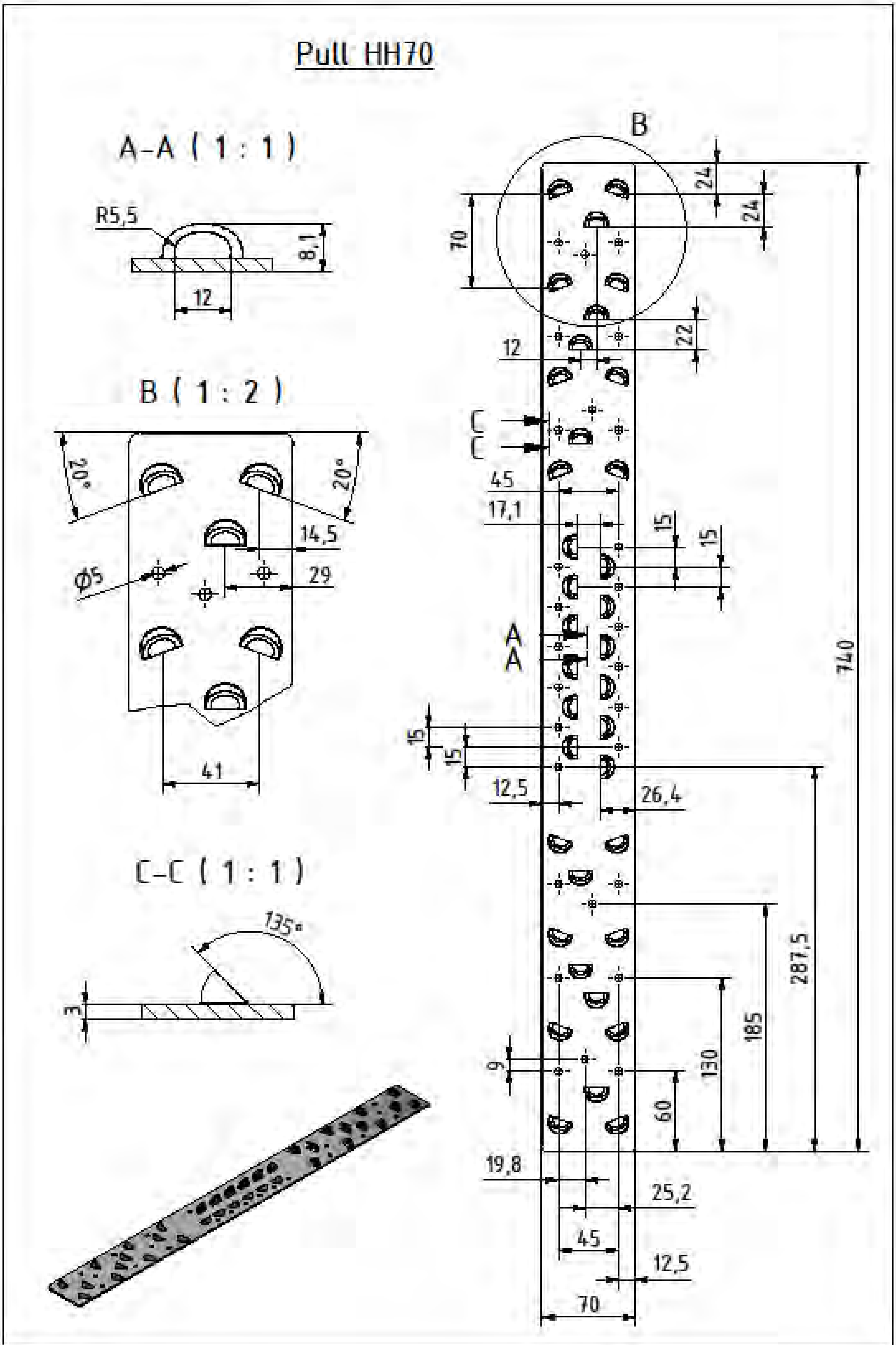
where:

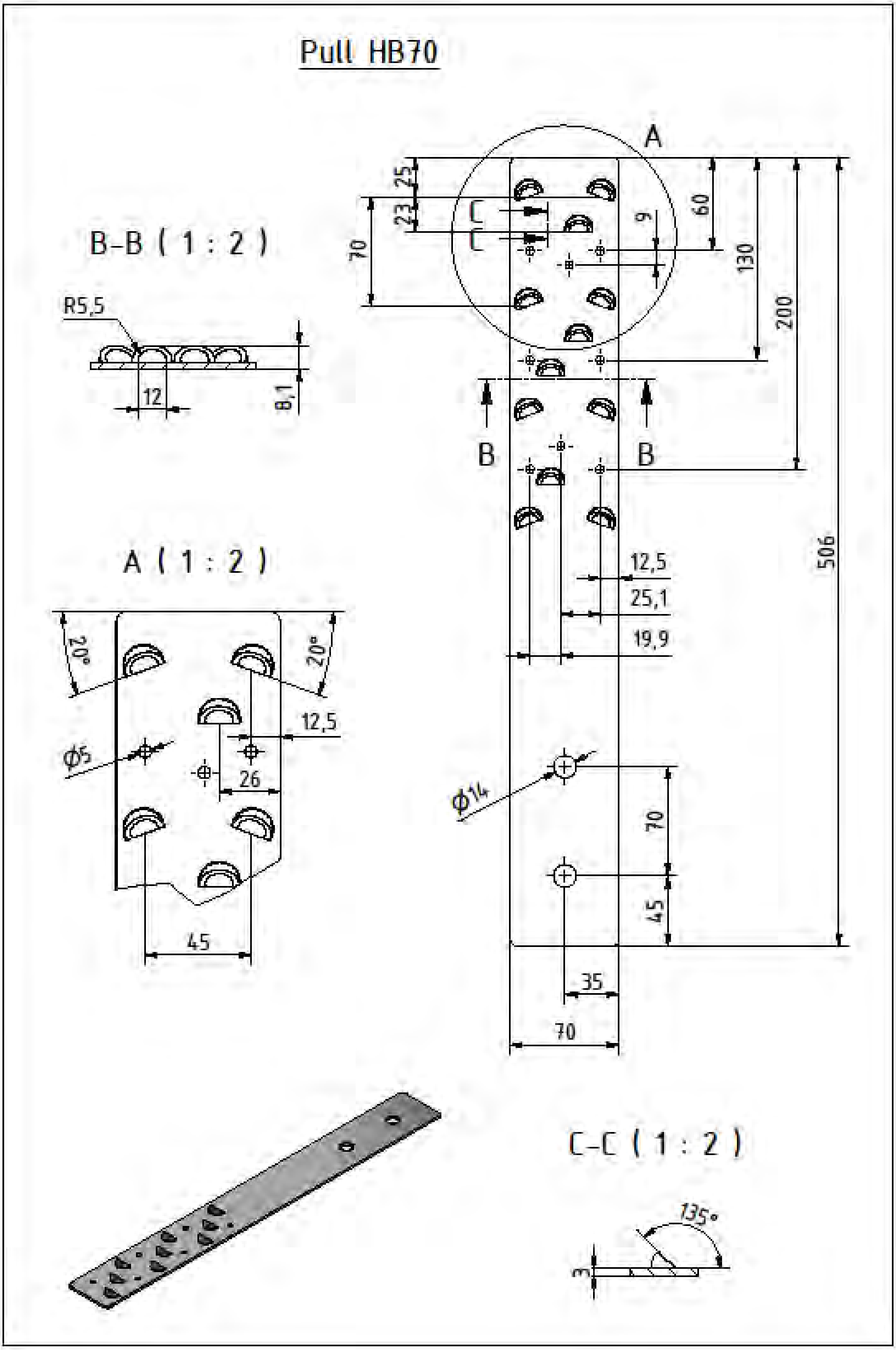
$F_{B,t,Ed}$	Resulting tensile load on the maximally loaded bolt in the group in N
$k_{t,II}$	Coefficient taking into account the resulting axial bolt force
$F_{1,Ed}$	Tensile load F_1 on vertical flap of the angle bracket in N
b	Width of the washer in mm
$\sigma_{C,Ed}$	compressive stress on the support in N/mm^2

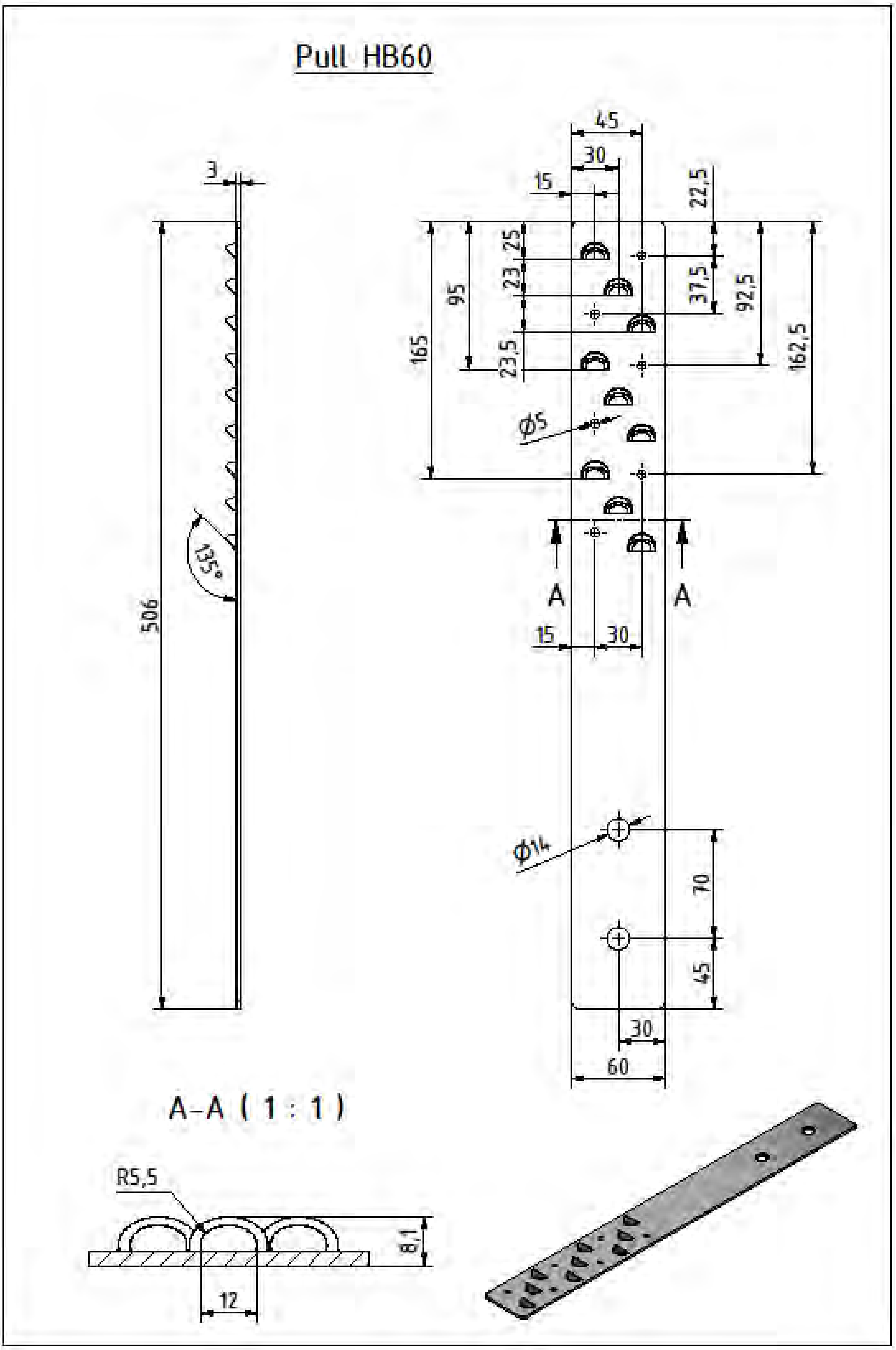
SIHGA MassX Nailing Plates

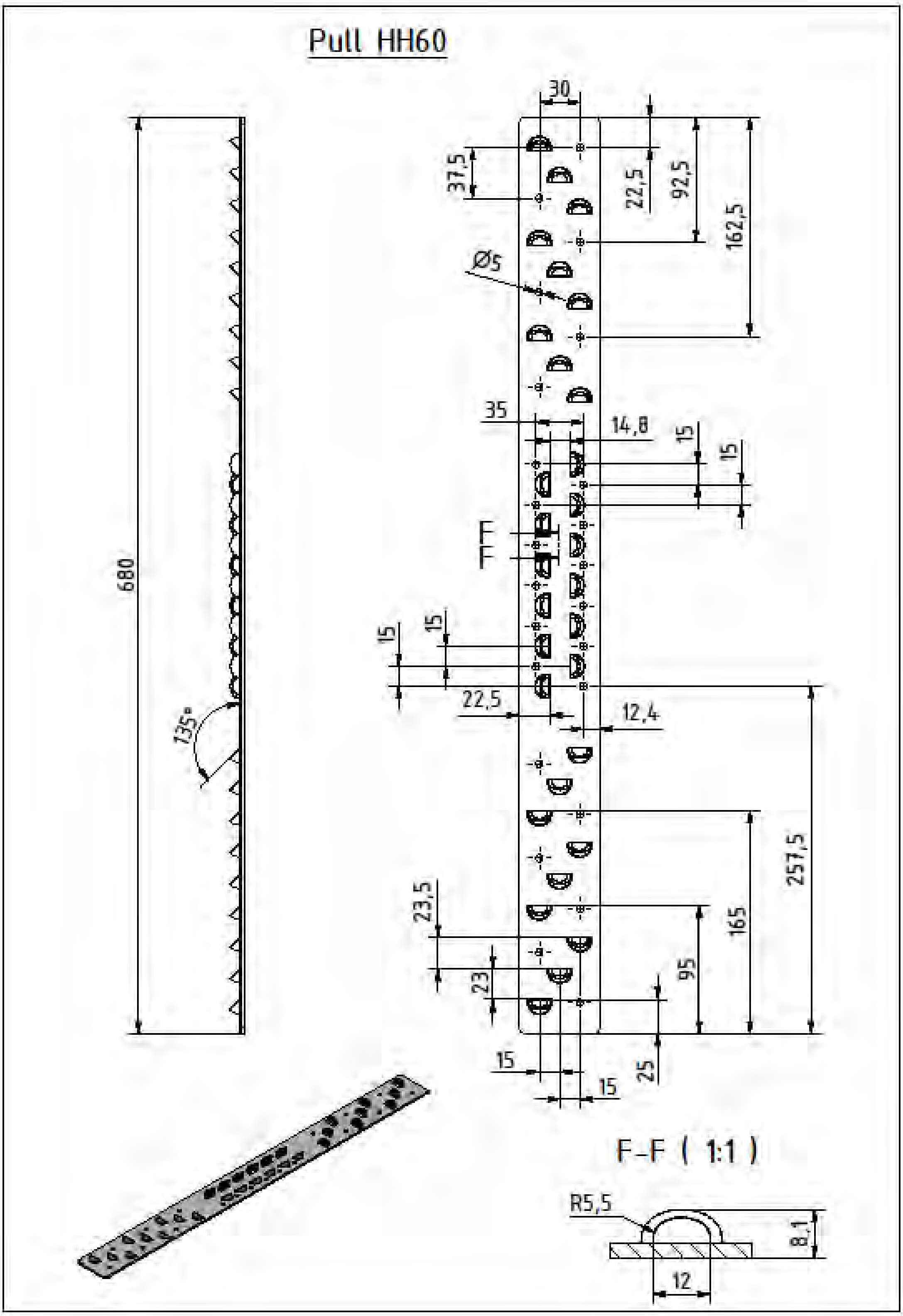



Shear HH
135°
3
8,1
Ø14
A
10
25
206
66
Ø5
66
206
240
180
230
A (1 : 2)
20
5
10
17,5
17,5


Pull HH70
A-A (1 : 1)
R5,5
8,1
12
B (1 : 2)
20°
20°
14,5
Ø5
29
41
C-C (1 : 1)
135°
3
B
24
24
70
12
22
C
C
45
17,1
15
15
A
A
15
15
12,5
26,4
740
287,5
185
130
9
60
19,8
25,2
45
12,5
70

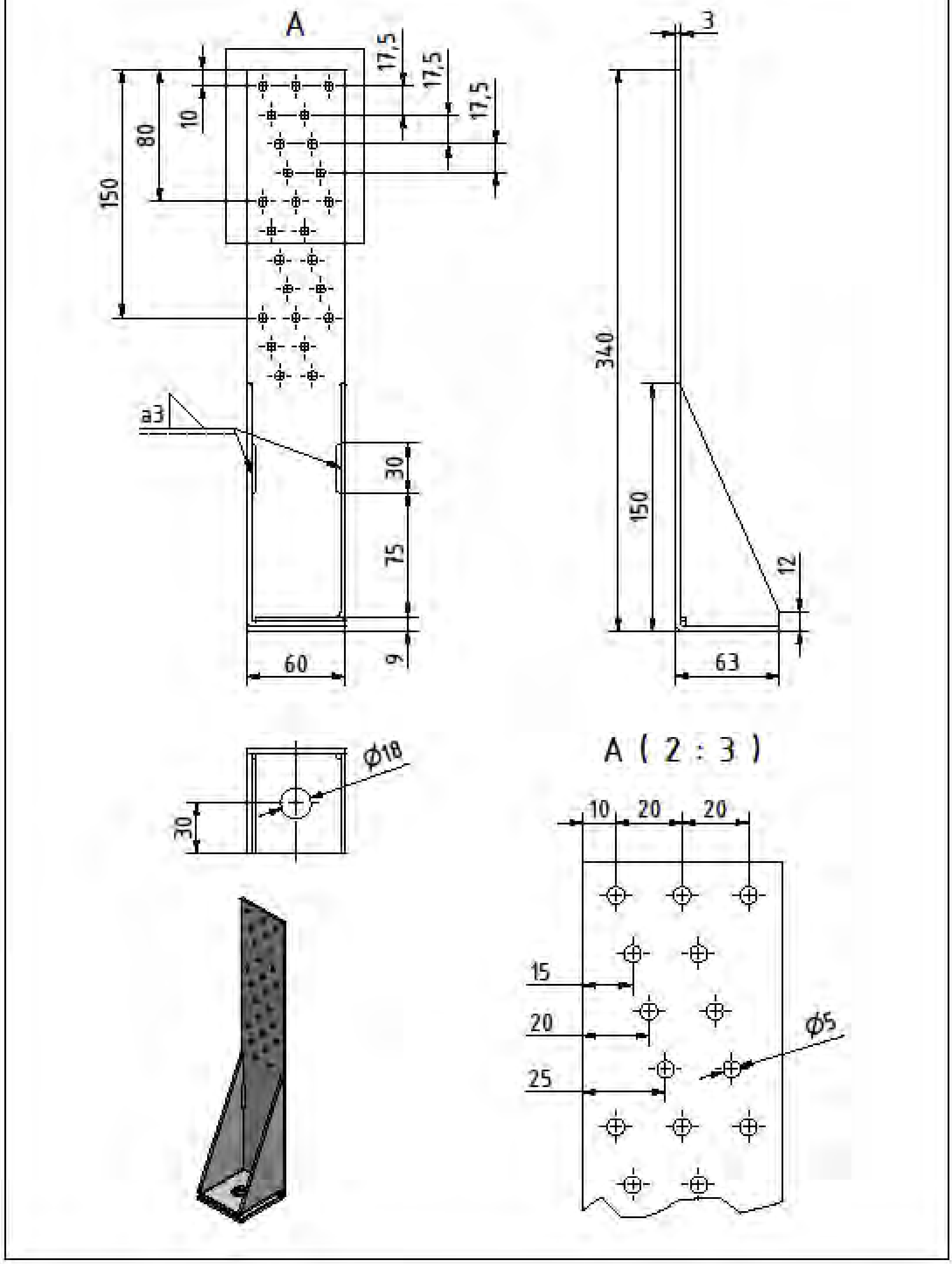

Pull HB70
B-B (1 : 2)
R5,5
12
8,1
A (1 : 2)
20°
20°
12,5
ϕ5
26
45
A
25
23
70
C
C
9
60
130
200
B
B
12,5
25,1
19,9
506
ϕ14
70
45
35
70
C-C (1 : 2)
135°
3


Pull HB60
3
506
135°
45
30
15
22,5
25
23
95
165
23,5
37,5
92,5
162,5
Ø5
A
A
15
30
Ø14
70
45
30
60
A–A (1 : 1)
R5,5
8,1
12

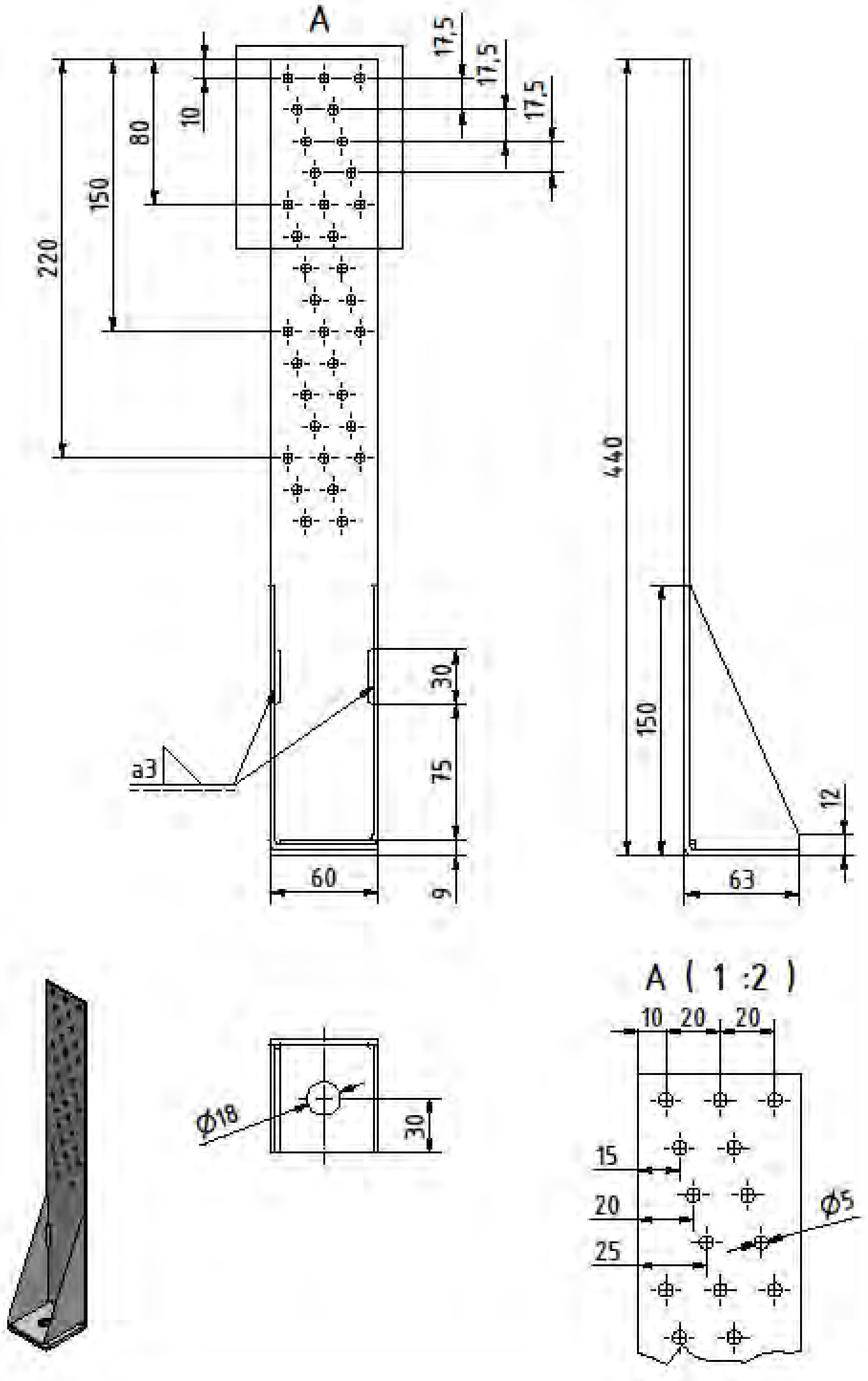


Pull HH60
30
37,5
22,5
92,5
162,5
Ø5
35
14,8
15
15
F
F
15
15
22,5
12,4
680
135°
23,5
23
95
165
257,5
15
25
15
F-F (1:1)
R5,5
8,1
12

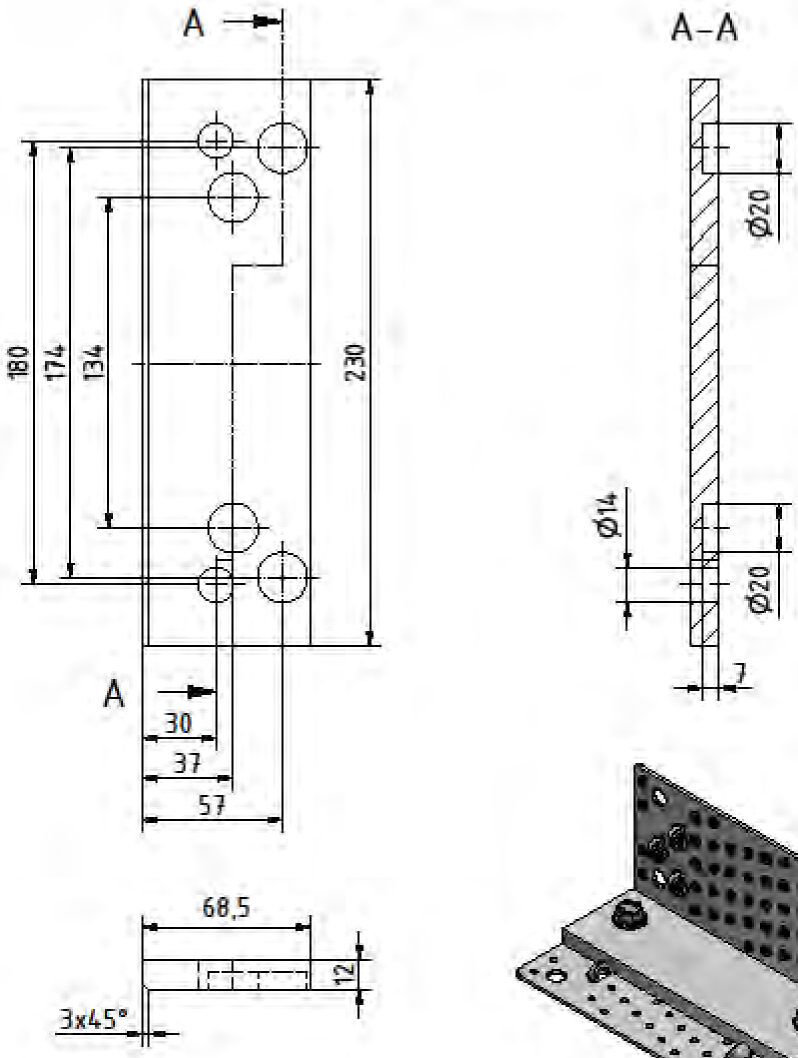
Angle P-HB 340



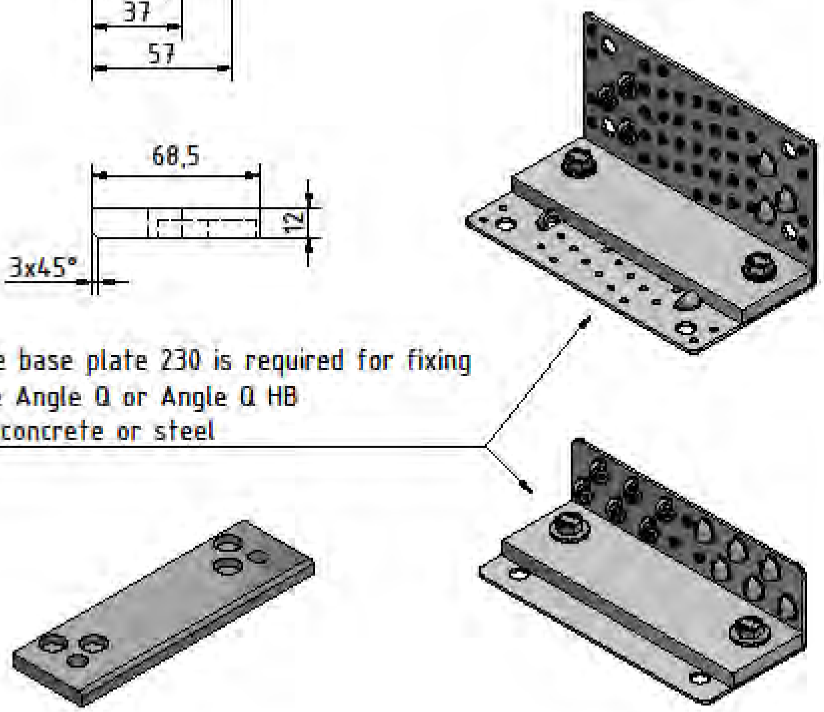
Angle P-HB 440

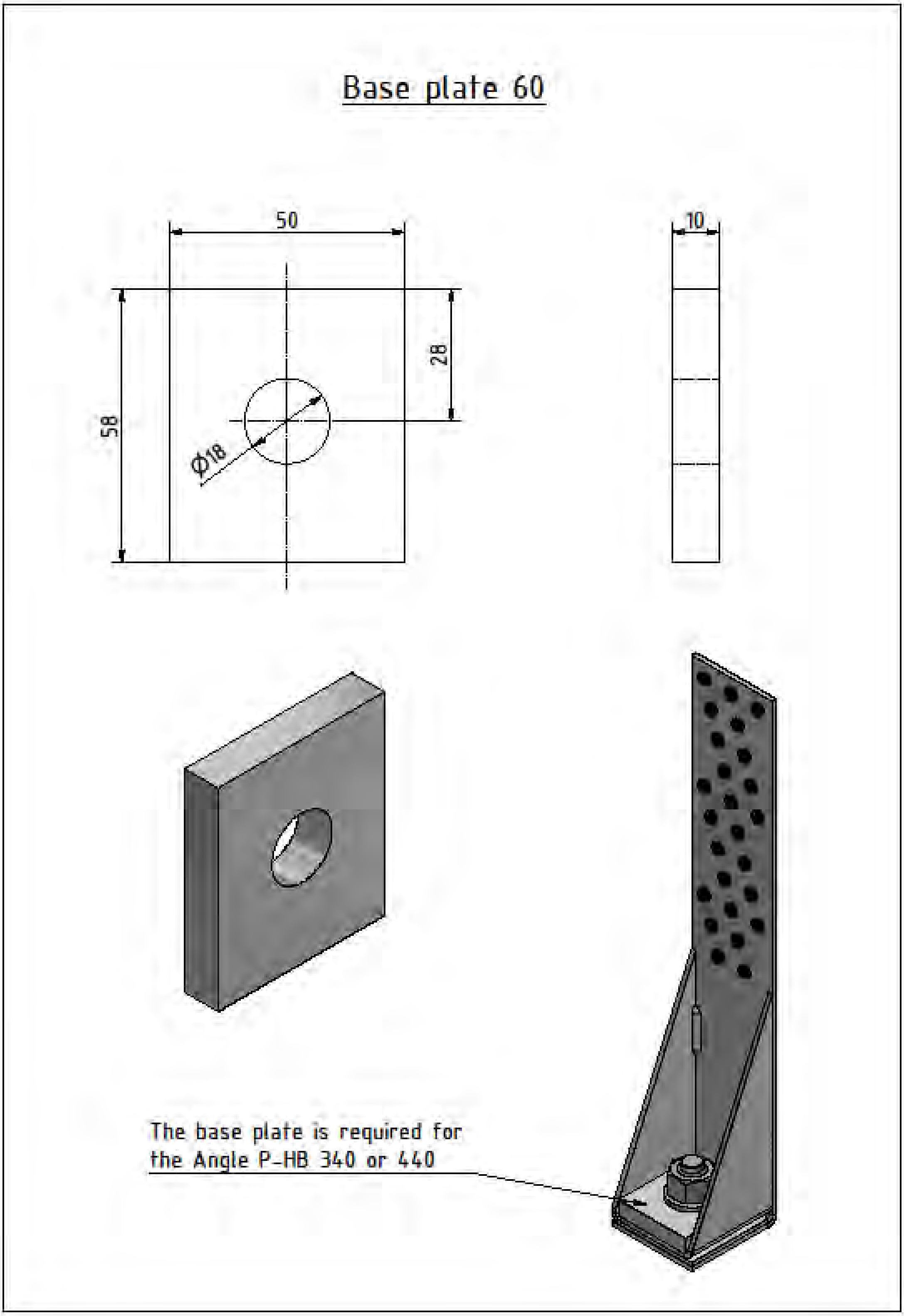


Base plate 230

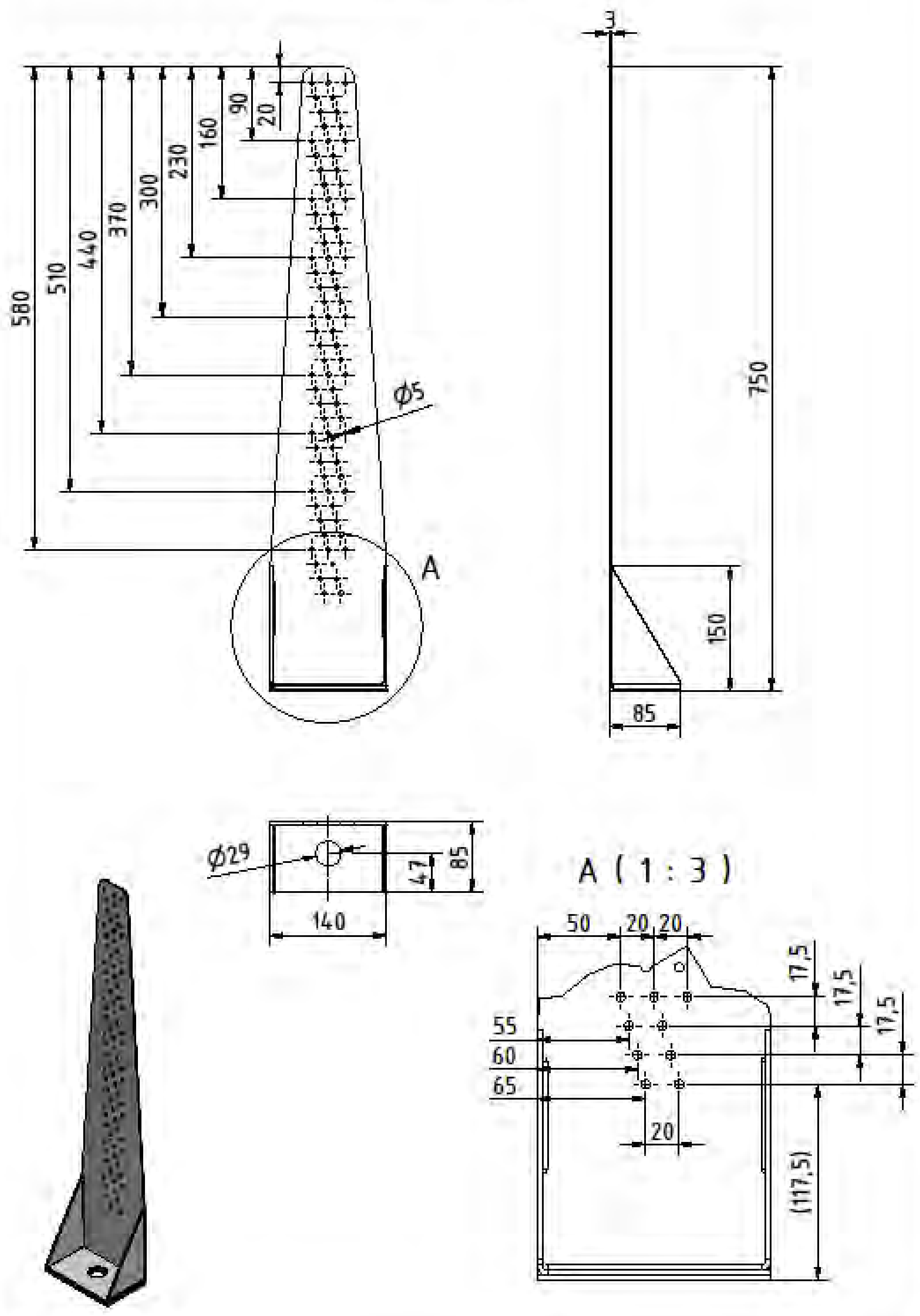


The base plate 230 is required for fixing the Angle Q or Angle Q HB to concrete or steel

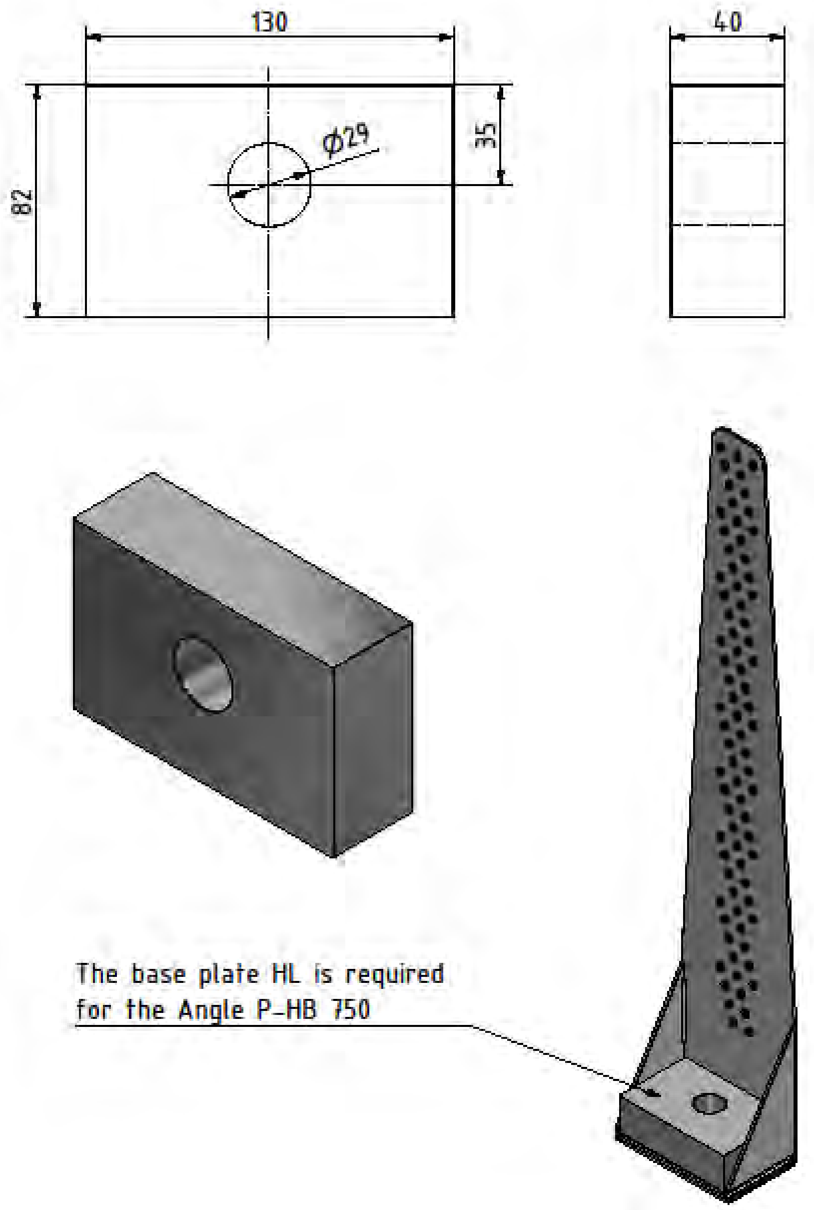


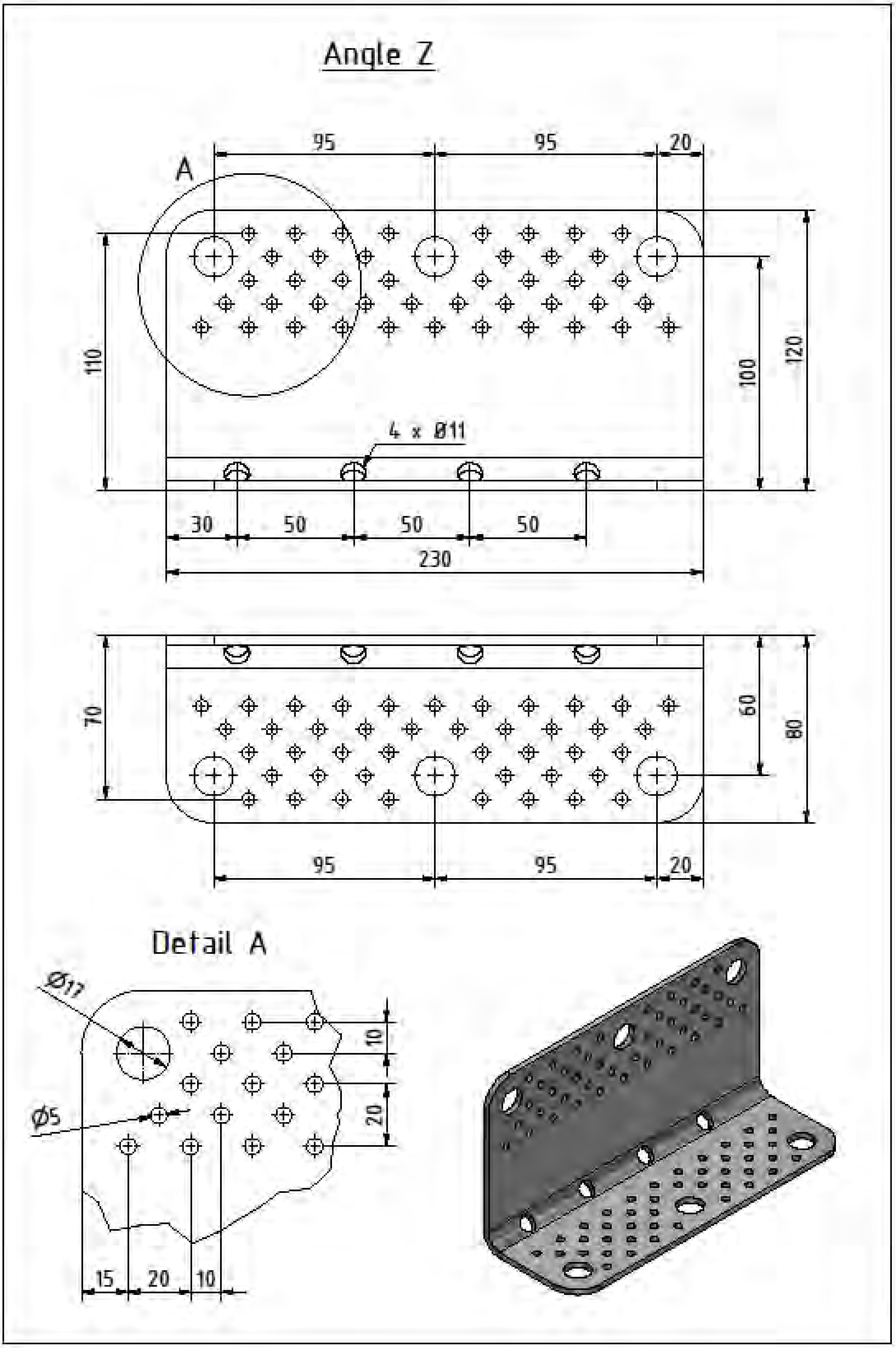

Base plate 60
50
10
28
58
Ø18
The base plate is required for
the Angle P-HB 340 or 440

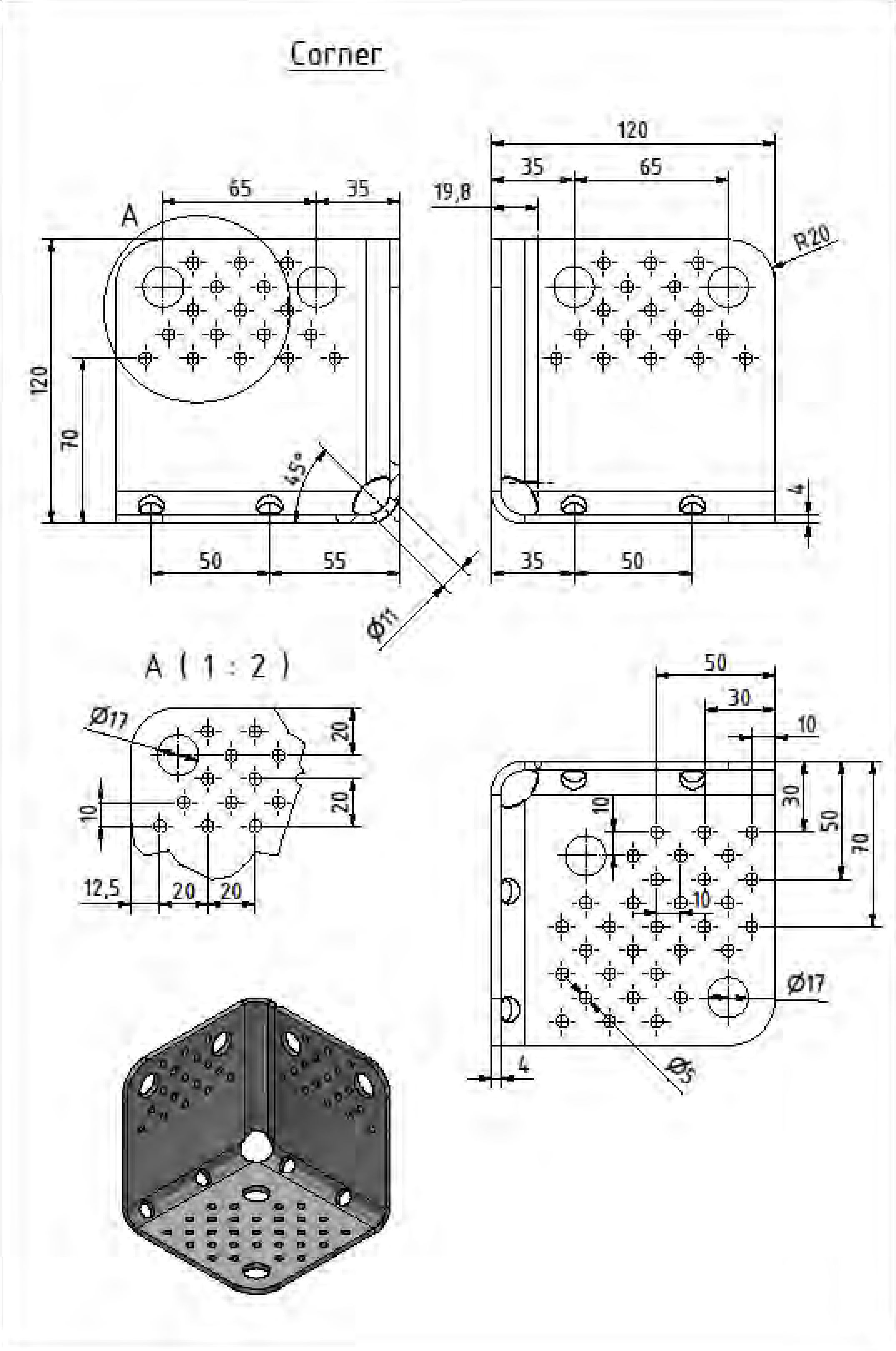
Angle P-HB 750

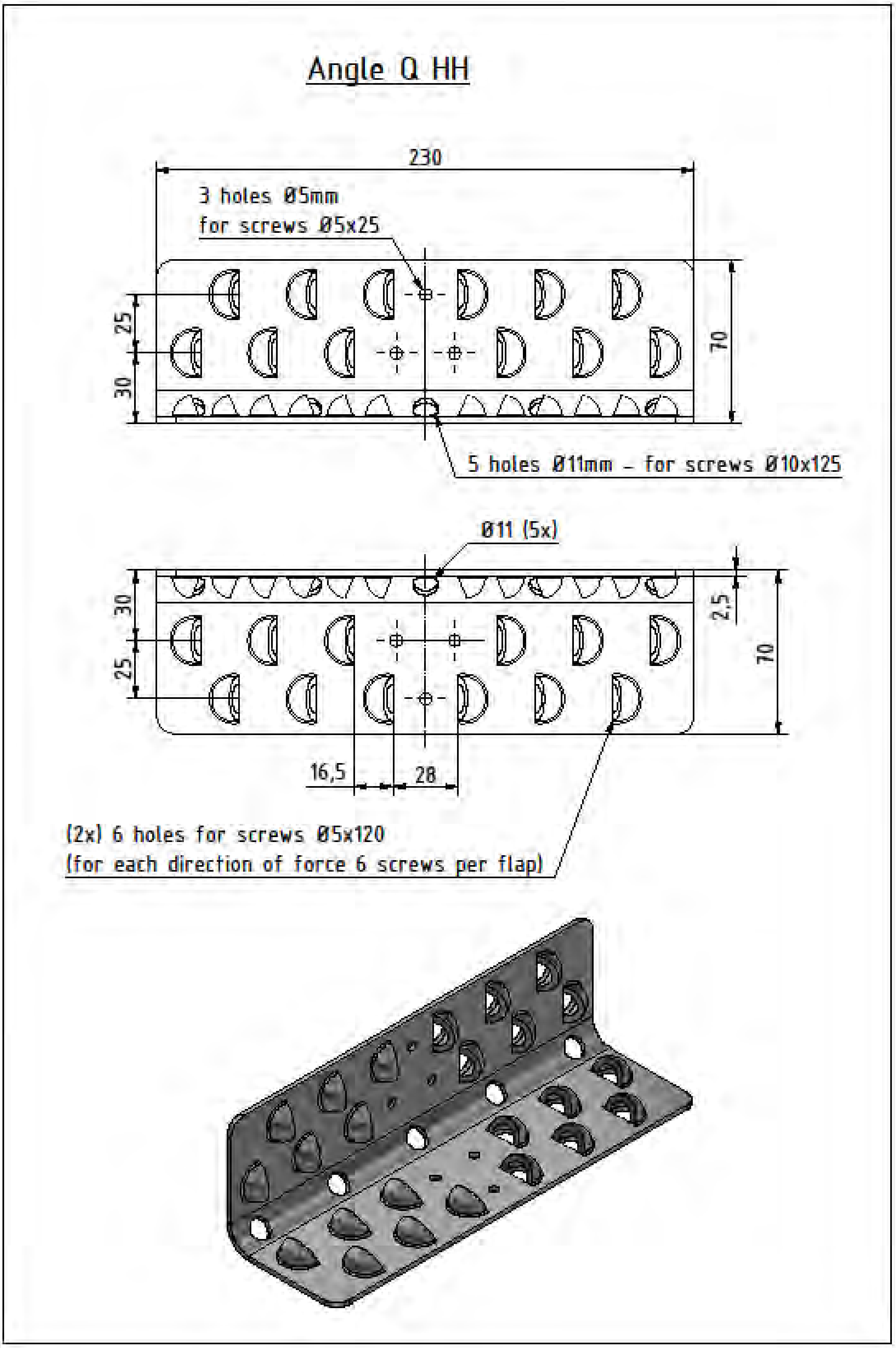


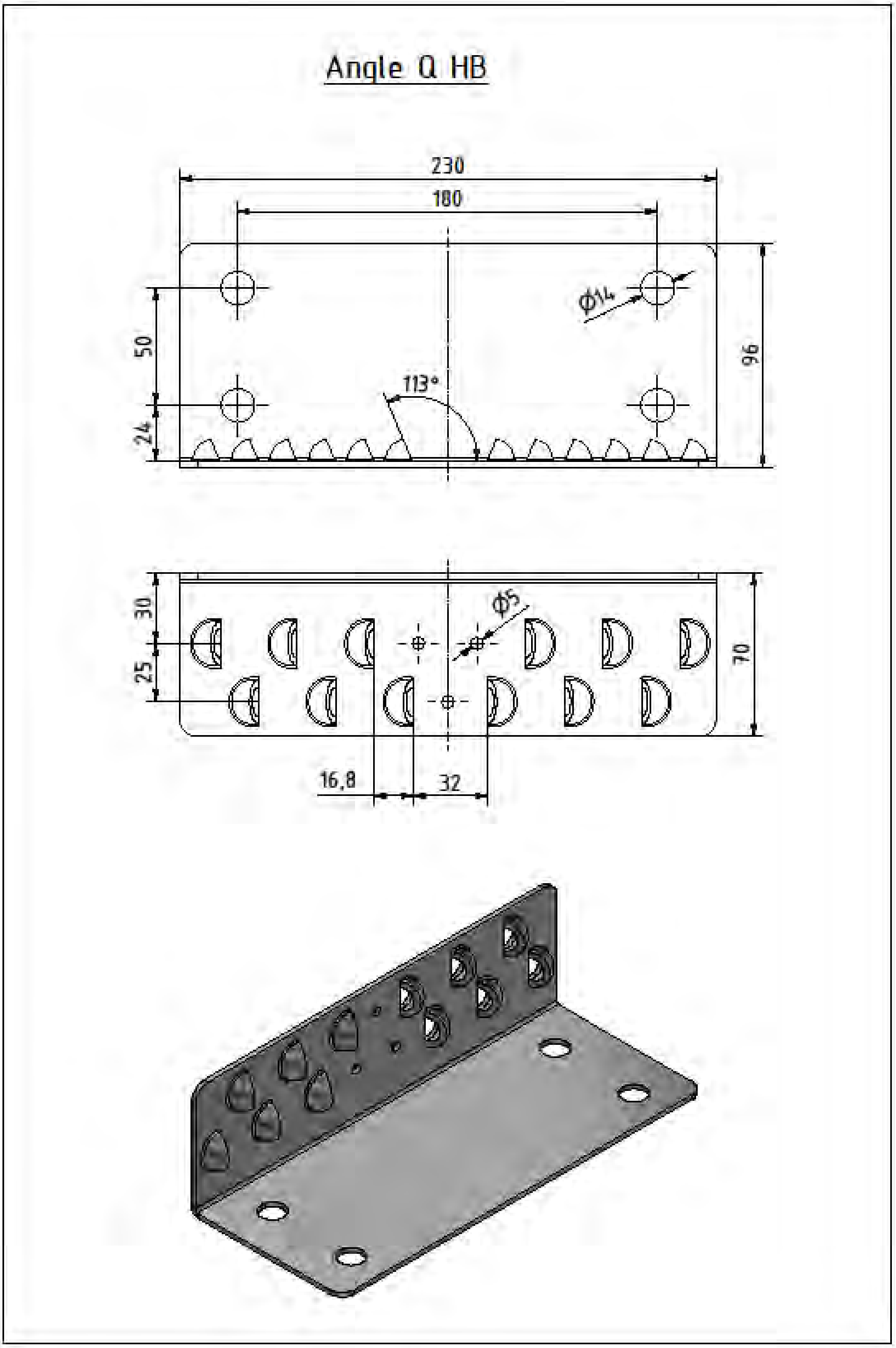
Base plate 130

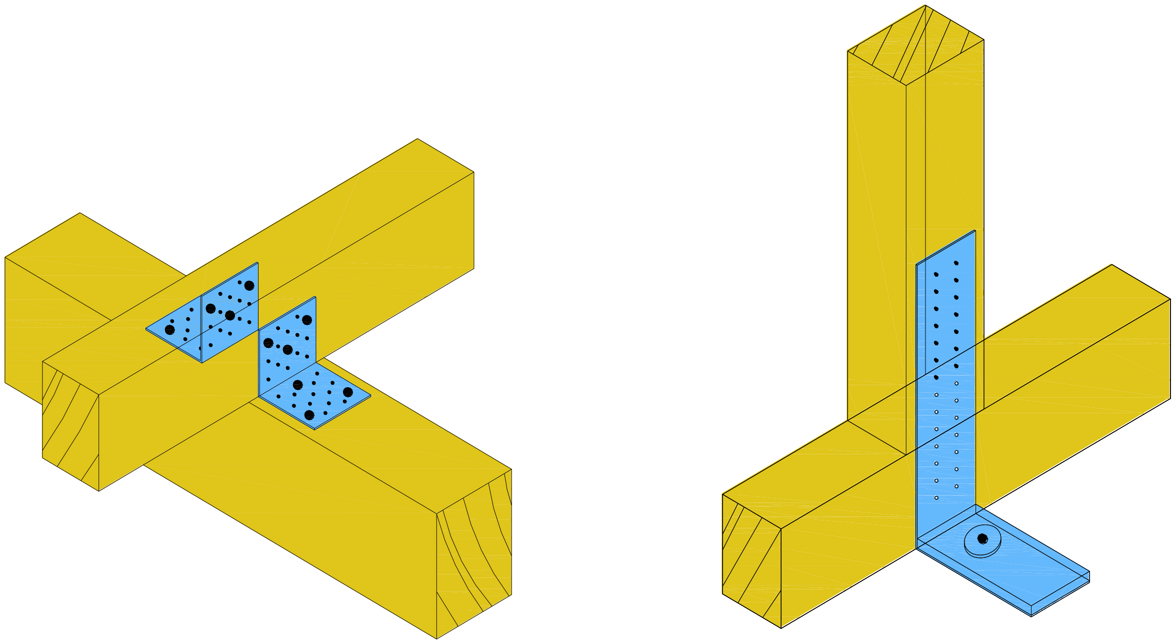



Angle Z
A
95
95
20
110
100
120
4 x Ø11
30
50
50
50
230
70
60
80
95
95
20
Detail A
Ø17
Ø5
10
20
15
20
10

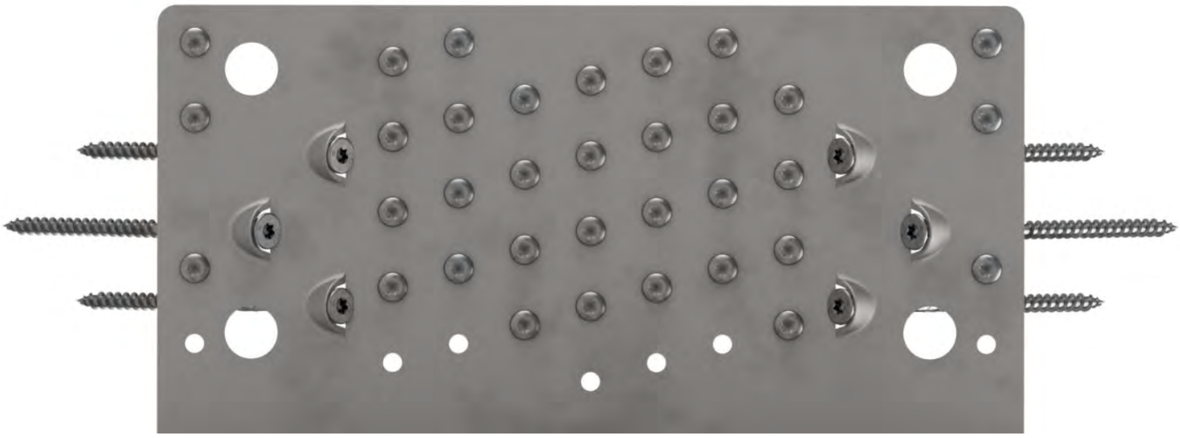

Corner
120
35
65
65
35
19,8
A
R20
120
70
45°
4
50
55
35
50
Ø11
A (1 : 2)
Ø17
20
20
10
12,5
20
20
50
30
10
10
30
50
70
10
Ø17
4
Ø5


Angle Q HH
230
3 holes Ø5mm
for screws Ø5x25
25
30
70
5 holes Ø11mm - for screws Ø10x125
Ø11 (5x)
30
25
2,5
70
16,5
28
(2x) 6 holes for screws Ø5x120
(for each direction of force 6 screws per flap)

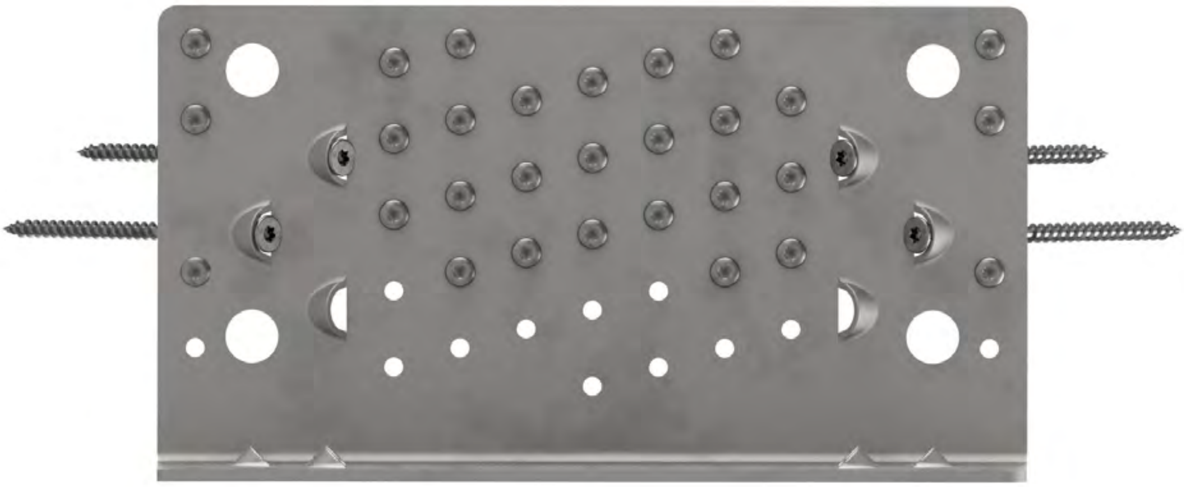

Angle Q HB
230
180
Φ14
50
96
113°
24
30
Φ5
25
70
16,8
32



Typical installation



Fastener Pattern Partial 1 for Shear HH and Angle Q in timber to timber connections
(Symmetrical hole-pattern for both flanges)



Fastener Pattern Partial 2 for Shear HH and Angle Q in timber to timber connections
(Symmetrical hole-pattern for both flanges)