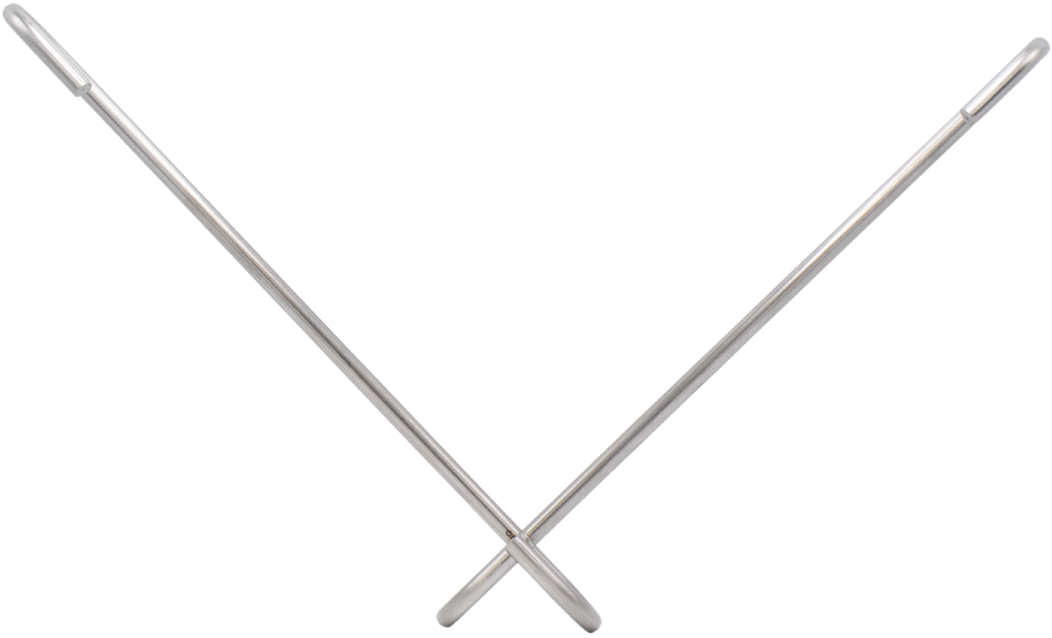
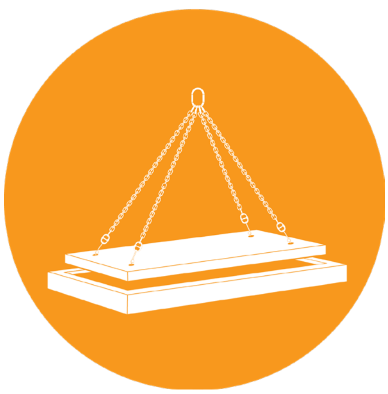
Design guidelines

PRETEC SANDWICH FACADE CONNECTIONS

Design guidelines SPA-anchor





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Innehållsförteckning

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Introduction

Pretecs Sandwich facade connections consist of two different systems. SPA-connectors with ties and ladder-system. Both systems are used to connect the outer layer to the inner layer of concrete sandwich panel and thereby transferring loads caused by deadweight, wind and temperature.

In this document the system SPA-connectors with ties described. The system consists of load carrying anchors (SPA-1) and connector ties (SPA-O/K/U). Beam ladders (PBS) can be used for carrying vertical loads in areas where SPA-1 anchors are too large to fit. Examples of that are above and below window openings.

1. Product overview

All the products in Pretec sandwich façade connection system are CE-marked according to SS-EN 1090-1. If nothing else is specified they are supplied in execution class 2 (EXC2). The declaration of performance (DoP) are available on Pretecs web page.

Material

Table 1.1

Anchors	Material	Yield point, f_{yk} (MPa)
Ties SPA-O/K/U	A2 or A4	Min 700
Load carrying anchors SPA-1	A2 or A4	Min 700
Beam ladder PBS	A2 or A4	Min 700

A2=1.4301/1.4307 according to EN 10088-3/5, A4=1.4401/1.4404 according to EN 10088-3/5. Standard stock items are A2 quality. A4 quality on request.

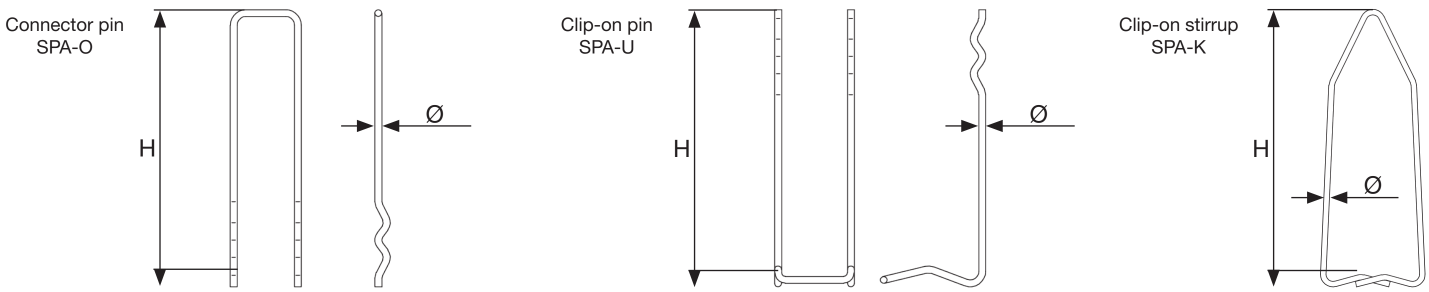
1.1 Connector ties

The ties are described as follows; “Type of tie (O/K/U)”-Ø-H-“Material”
For example, connector pin with Ø4, H=160 and material A2 => SPA-O-04-160-A2.

Table 1.2

	Tie type	Diameter Ø (mm)	Height H* (mm)
Connector pin	SPA-O	04	120-400
		05	200-430
Clip-on stirrup	SPA-K	04	120-340
		05	200-420
Clip-on pin	SPA-U	04	160-360
		05	150-420

*Ties are available in different heights with 20 mm interval (160, 180, 200, …..). If other heights or dimensions are requested, contact us.



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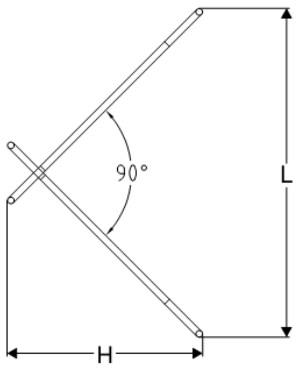
1.2 SPA-1, Load carrying anchors



The load carrying anchors are described SPA-1-ø-H-"Material".
For example, load carrying anchor SPA-1 with H=220, diameter 7 mm and A2 => SPA-1-07-220-A2

SPA-1-07 standard H=160
SPA-1-08 standard H=180-320
SPA-1-09 standard H=300-360
SPA-1-10 standard H=340-440
Height intervall 20 mm. Other heights on request.

Contact us, or look at our web page, to see current standard dimensions on stock.

Table 1.3

H (mm)	Recommended isolation thickness b (mm)	L (mm)			
		ø7 SPA-1-07	ø8 SPA-1-08	ø9 SPA-1-09	ø10 SPA-1-10
160	40-50	256	–	–	–
180	60-70	296	294	–	–
200	80-90	336	334	330	–
220	100-110	376	374	370	–
240	120-130	416	414	410	–
260	140-150	456	454	450	–
280	160-170	496	494	490	–
300	180-190	536	534	530	–
320	200-210	576	574	570	–
340	220-230	616	–	610	608
360	240-250	656	–	650	648
380	260-270	696	–	690	688
400	280-290	–	–	730	728
420	300-310	–	–	770	768
440	320-330	–	–	810	808

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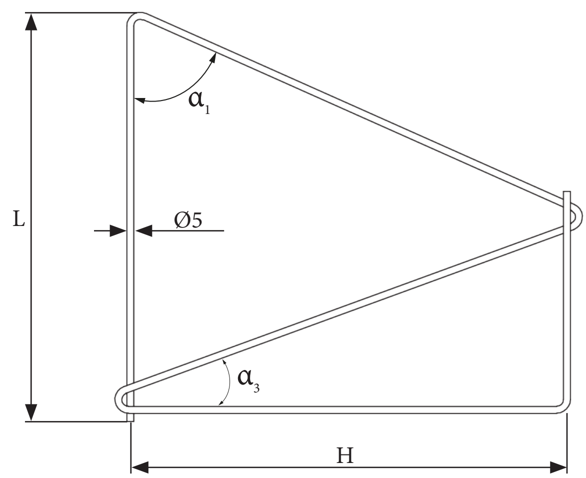
1.3 PBS, Beam tie

The beam ties are described PBS-Hx-Lx-"material".
For example PBS beam tie with H=240, L=250 and material A2 => PBS-H240-L250-A2.

Table 1.4

Description	Height H* (mm)	Lenght L (mm)	Recommended isolation thickness b (mm)	α_1 (°)	α_3 (°)
PBS-H140-L250	140	250	80	49.4	32.5
PBS-H150-L250	150		90	51.4	30.9
PBS-H160-L250	160		100	53.2	29.4
PBS-H180-L250	180		120	56.5	26.7
PBS-H190-L250	190		130	58	25.6
PBS-H200-L250	200		140	59.3	24.5
PBS-H210-L250	210		150	60.6	23.5
PBS-H220-L250	220		160	61.7	22.6
PBS-H240-L250	240		180	63.8	20.9
PBS-H260-L250	260		200	65.6	19.5
PBS-H280-L250	280		220	67.2	18.2
PBS-H300-L250	300		240	68.6	17.1
PBS-H320-L250	320		260	69.9	16.1
PBS-H340-L300	340	300	280	67.3	19
PBS-H360-L300	360		300	68.4	18
PBS-H380-L300	380		320	69.5	17.2
PBS-H400-L300	400		340	70.4	16.4
PBS-H420-L300	420		360	71.3	15.6

*The measurement H is between the centre of the straight bars. This gives an anchoring depth of 30 mm in both inner and outer concrete layer when the recommended insulation thickness is used.



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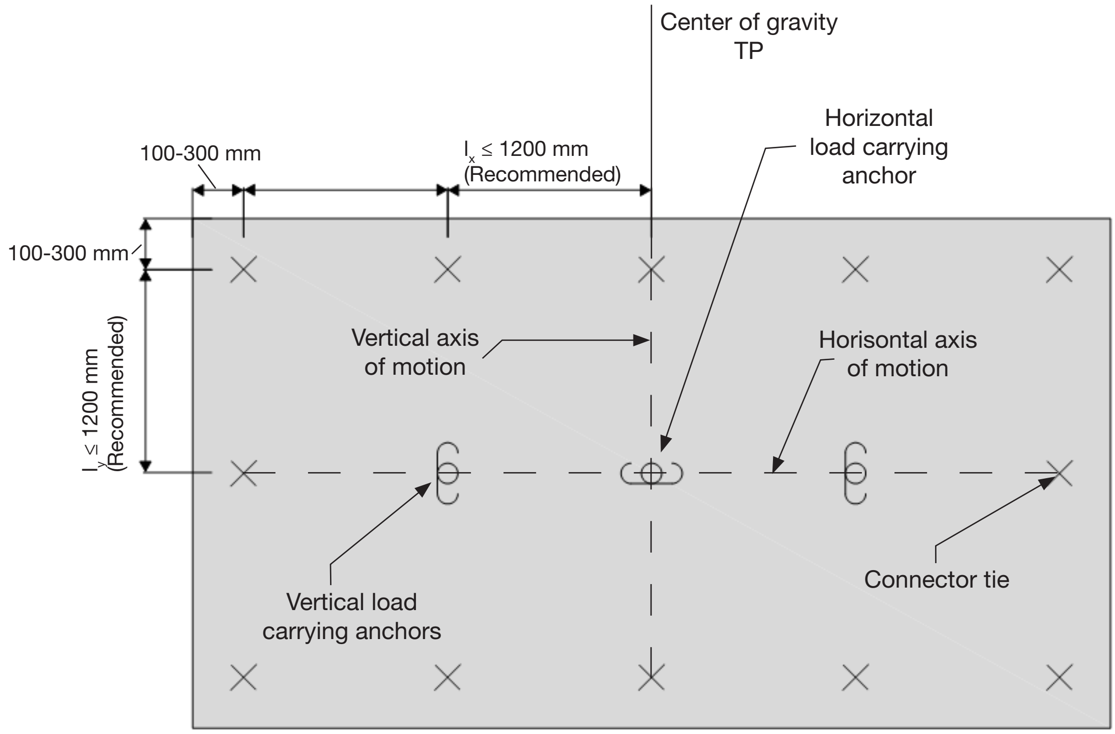
2. Installation



When placing load carrying anchors and ties it is recommended to create a “mesh pattern” over the panel, with anchor points where vertical and horizontal lines crosses.

All load carrying anchors (SPA-1) should be placed on the same horizontal line, to minimize the effects from temperature impact and control the movement of the outer layer. The placement of these anchors decides where the theoretical centre of motion of the outer layer is located. In other words, the point that stands still when the outer layer is affected by temperature.

The load carrying anchor installed horizontally in the panel fixates and gives a “zero point” for the horizontal movement of the outer skin. This minimize the movements in the joints and also controls the inclination of the load carrying anchors and the ties.

The vertically installed load carrying anchors carry the deadweight and fix the outer layer vertically. The placing of the anchors relative to the vertical centre of gravity of the outer skin, should be considered with regard to the load distribution between the anchors.

Where the vertical and horizontal motion axes are crossed, the theoretical centre of motion is created. Consider that other unexpected locking effects between outer and inner layer can affect the position of the centre of motion and create unnecessary stresses in the panel.

When additional anchors are placed horizontally close to each other in high loaded points, they should not be placed closer than 200 mm.

2.1 Load carrying anchors, SPA

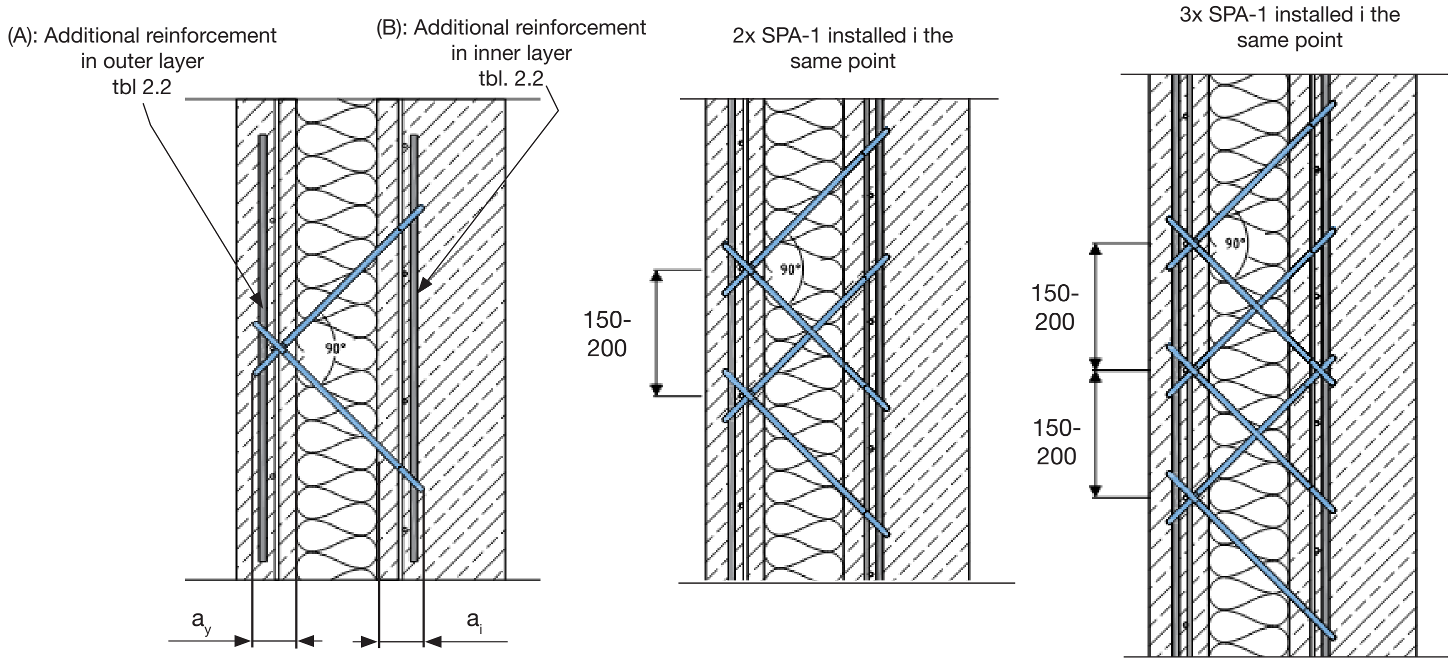


Table 2.1 Cast in depth load carrying anchors (SPA-1)

Dimension	SPA-1-07	SPA-1-08	SPA-1-09	SPA-1-10
a_y (outer layer)	≥50	≥52	≥53	≥54
a_i (inner layer)	≥55	≥55	≥55	≥55

Table 2.2 Additional reinforcement for load carrying anchors (SPA-1)

H (mm)	1x SPA-1 (mm)		2x SPA-1 s150 (mm)		3x SPA-1 s150 (mm)	
	A (1Ø8)	B (1Ø10)	A (1Ø8)	B (1Ø10)	A (1Ø8)	B (1Ø10)
≤280	l = 700	l = 700	l = 850	l = 850	l = 1000	l = 1000
300-320	l = 700	l = 800	l = 850	l = 950	l =1000	l = 1100
340-360	l = 700	l = 900	l = 850	l = 1050	l = 1000	l = 1200
380-400	l = 700	l = 950	l = 850	l = 1100	l = 1000	l = 1250
420-440	l = 700	l = 1050	l = 850	l = 1200	l = 1000	l = 1350

*When 2x SPA-1 or 3x SPA-1 are mounted at the same point with 200 mm between them (s200 mesh), instead of 150 mm, the length of the extra reinforcement (Table 2.2) should be extended by 50 mm and 100 mm respectively.

For calculation of minimum height of the load carrying anchor: $H \geq a_y + b + a_i$ (b = insulation thickness).

The outer layer shall have a thickness of minimum 70 mm and the inner layer minimum 100 mm.

Load carrying anchors shall be installed with the crossed legs in the outer layer (see picture), to obtain its full function. If they are mounted with the crossed legs in the inner layer, the specified capacities are not valid and the rotating moment must be taken by the ties installed in the other horizontal lines. The additional reinforcement according table 2.2 shall be placed in the anchors end hooks (in contact), not outside them.

Reinforcement in the outer- and inner layer should be a mesh with minimum Ø5s200. Quality minimum K500B.

2.2 Connector ties

ti= thickness inner layer
ty= thickness outer layer

Nominal anchorage lengths shall be considered when choosing the connector tie.

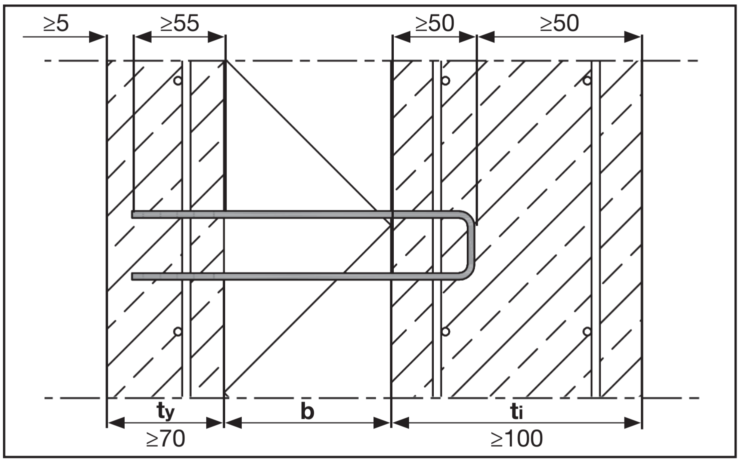
Ties should not be placed closer than c/c 200 mm.

Clip on ties (type K and type U) is connected to the crosses in the wire mesh, which means that the placing follows the modules and placement of the mesh.

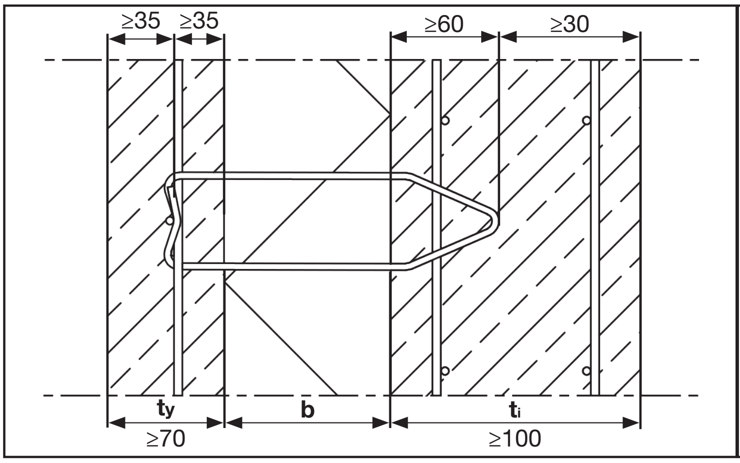
All ties can be installed in both directions, althought must the concrete cover towards the outside, in the outer layer be considered regarding pressure from the tie.

Reinforcement in outer and inner layer minimum Ø5s200.

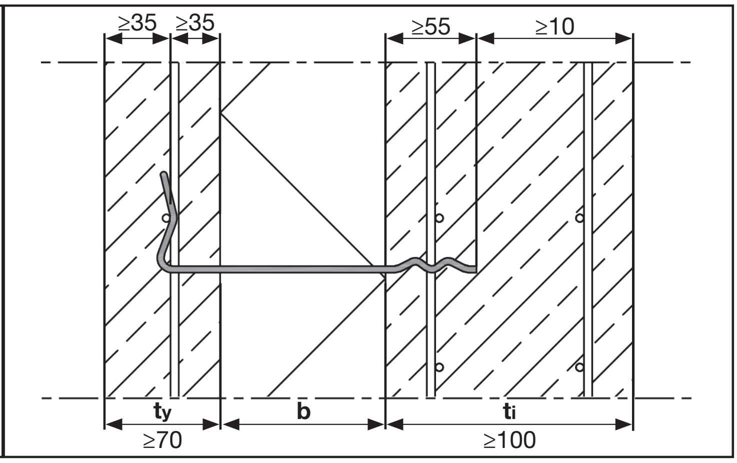
Connector pin
SPA-O



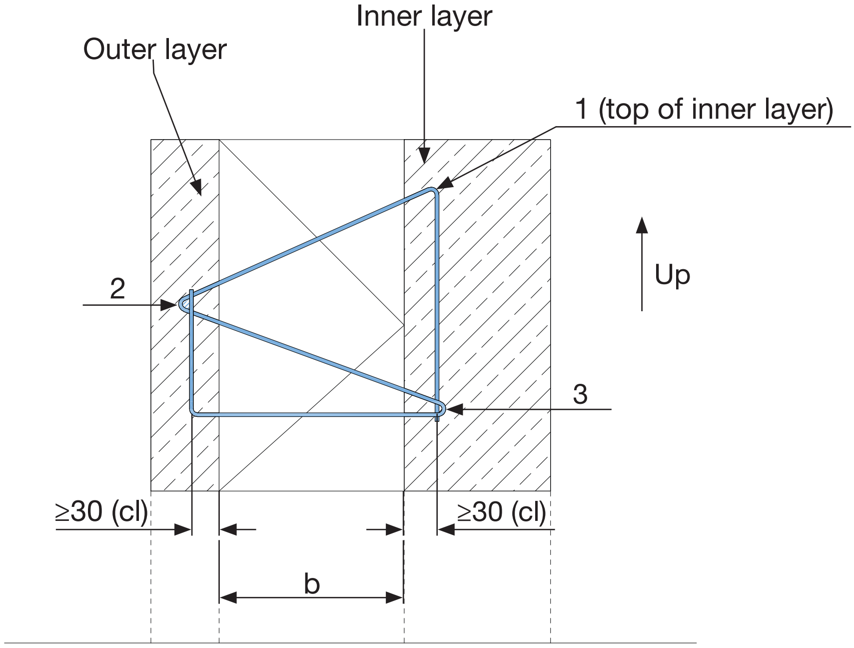
Clip-on stirrup
SPA-K



Clip-on pin
SPA-U



2.3 Beam ladder (PBS)



Beam ladder
PBS

Beam ladders can be used over and under windows and doors, where the outer layer needs support to carry itself. Recommended height, H, for beam ladders is the insulation thickness b, +60 mm.

It is important to install the beamladders with the connection points 1 and 3 in the inner layer, with point 1 up (see the picture above).

Reinforcement in outer layer minimum Ø5s200.

Centre distance: 100-600 mm
Edge distance sideways: 100-300 mm
Edge distance up/down: 50-200 mm

3. Capacities

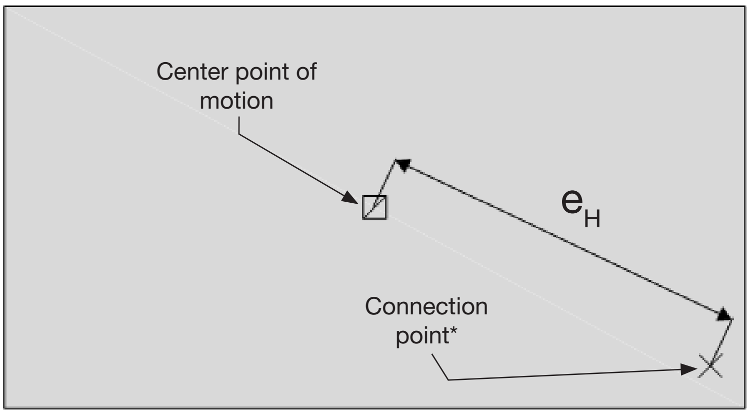
The outer layer in a sandwich panel is affected by its deadweight, wind loads and loads created by temperature variations.

Temperature loads

Differences in temperature between the outer and inner concrete layer create relative movements in the panel. The outer layer tends to curve because the difference in temperature on the outside of facade layer and the inside towards the insulation. There is also an effect from the difference in the temperatures on the outside and inside of the panel. This difference varies over the year (summer/winter).
Load carrying anchors and ties are connected in both outer and inner layer, which creates a connection point for each anchor and tie. When the outer layer expand/shrink relative to the inner layer the connection point has a relative displacement which creates a bending of the anchors. The larger the temperature difference, ΔT, and the distance from the centre of motion of the outer layer, e_H is, the bigger is the relative displacement. The stress in the steel of the anchors gets higher with an increased relative movement and with thinner insulation.

Where the theoretical centre of motion is located depends on where the vertical and horizontal load carrying anchors are placed.

> Assumed values:
> Thermal expansion coefficient of concrete, $\alpha_T = 10 \cdot 10^{-6}$ 1/°C
> Temperature difference between inner and outer layer, ΔT= 45°C
> (No extra partial factor is added in the calculations for temperature movement, $\Delta T \cdot \alpha_T \cdot e_H$)



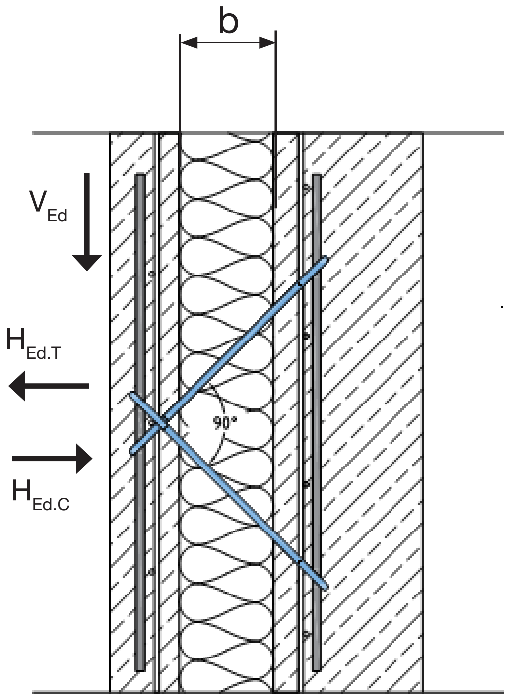
*A connection point can be a load carrying anchor or a tie.

3.1 Load carrying anchors (SPA-1)

The capacities in table 3.1 – 3.4 state the allowed vertical design load (e.g. deadweight multiplied with a factor) from the outer layer per connection point with load carrying anchors (1, 2 or 3 load carrying anchors per connection point). Horizontal loads from wind and curvature caused by the temperature gradient in the outer layer, is included and deducted from the capacity.

Conditions for table 3.1 (see also chapter 3)

- Concrete quality minimum C30/37
- Installation according chapter 2.1
- Temperature difference in outer layer ±5 °C, dark color ($H_{T.k}$ =2.4 kN)
- Thickness outer layer 70-80 mm
- Form factor -1.4 for wind suction and +1.0 for wind pressure, load area= 1.44 m²
- Safety class 3



$H_{Ed.T}$ = Design load, tension
$H_{Ed.C}$ = Design load, compression
V_{Ed} = Vertical design load

Tension and compression load is a combination of wind ($H_{w.k}$) and temperature load ($H_{T.k}$). The temperature load comes from the curvature of the outer layer.

The loads are per connection point. 1, 2 or 3 SPA-1 added at the same place is calculated as one connection point in the capacity tables.

3.1.1 SPA-1-07 and SPA-1-08, wind and temperature load

- Conditions according to chapter 3 and 3.1.

Table 3.1 Allowed vertical load SPA-1-07 (7 mm)

Isolation thickness b (mm)	Rek. dimension SPA-1-07 H (mm)	Allowed vertical load V_{Ed} (kN)						e_H max (m)
		v_b=26 m/s Terrain category I Buildning height 20 m			v_b=24 m/s Terrain category III Buildning height 30 m			
		1st	2st s150/ s200	3st s150/s200	1st	2st s150/s200	3st s150/s200	
50	160	1.8	13.5	25.2	4.0	15.7	27.4	1,5
60	180	1.8	13.5	25.2	4.0	15.7	27.4	2
80	200	1.8	13.5	25.2	4.0	15.7	27.4	2
100	220	1.8	13.5	25.2	4.0	15.7	27.4	3
120	240	1.8	13.5	25.2	4.0	15.7	25.9	4
140	260	1.8	11.9	20.3	4.0	12.6	21.0	5
150	260	1.8	11.3	19.3	3.9	12.0	20.1	5
160	280	1.8	10.5	18.3	3.6	11.3	19.0	5
180	300	1.8	9.0	16.0	2.8	9.8	16.7	5
200	320	1.3	7.5	13.7	2.0	8.3	14.5	5
220	340	0.6	6.2	11.7	1.4	6.9	12.5	5
240	360	–	5.0	9.9	0.8	5.7	10.7	5
260	380	–	3.9	8.4	–	4.7	9.1	5

Table 3.2 Allowed vertical load SPA-1-08 (8 mm)

Isolation thickness b (mm)	Rek. dimension SPA-1-08 H (mm)	Allowed vertical load V_{Ed} (kN)						e_H max (m)
		v_b=26 m/s Terrain category I Building height 20 m			v_b=24 m/s Terrain category III Building height 30 m			
		1st	2st s150/ s200	3st s150/s200	1st	2st s150/s200	3st s150/s200	
60	180	2.1	15.6	29.1	4.7	18.2	31.7	2
80	200	2.1	15.6	29.1	4.7	18.2	31.7	2
100	220	2.1	15.6	29.1	4.7	18.2	31.7	3
120	240	2.1	15.6	29.1	4.7	18.2	31.7	4
140	260	2.1	15.6	29.1	4.7	18.2	31.7	5
150	260	2.1	15.6	29.1	4.7	18.2	31.7	5
160	280	2.1	15.6	29.1	4.7	18.2	31.0	5
180	300	2.1	15.6	27.4	4.7	17.4	28.2	5
200	320	2.1	14.6	24.4	4.7	15.4	25.1	5

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3.1.2 SPA-1-09 och SPA-1-10,wind and temperature load

- Conditions according to chapter 3 and 3.1.

Table 3.3 Allowed vertical load

Isolation thickness b (mm)	Rek. dimension SPA-1-09 H (mm)	Allowed vertical load V_{Ed} (kN)						e_H max (m)
		v_b=26 m/s Terrain category I Building height 20 m			v_b=24 m/s Terrain category III Building height 30 m			
		1st	2st s150/ s200	3st s150/s200	1st	2st s150/s200	3st s150/s200	
80	200	2.1	15.6	29.1	4.7	18.2	31.7	2
100	220	2.1	15.6	29.1	4.7	18.2	31.7	3
120	240	2.1	15.6	29.1	4.7	18.2	31.7	4
140	260	2.1	15.6	29.1	4.7	18.2	31.7	5
150	260	2.1	15.6	29.1	4.7	18.2	31.7	5
160	280	2.1	15.6	29.1	4.7	18.2	31.7	5
180	300	2.1	15.6	29.1	4.7	18.2	31.7	5
200	320	2.1	15.6	29.1	4.7	18.2	31.7	5
220	340	2.1	15.6	29.1	4.7	18.2	31.7	5
240	360	2.1	15.6	29.1	4.7	18.2	31.5	5
260	380	2.1	15.6	27.4	4.7	17.4	28.2	5
280	400	2.1	14.7	24.4	4.7	15.4	25.2	5
300	420	2.1	12.9	21.8	4.7	13.6	22.5	5
320	440	2.1	11.3	19.4	3.9	12.0	20.2	5

Table 3.4 Allowed vertical load SPA-1-10 (10 mm)

Isolation thickness b (mm)	Rek. dimension SPA-1-10 H (mm)	Allowed vertical load V_{Ed} (kN)						e_H max (m)
		v_b=26 m/s Terrain category I Building height 20 m			v_b=24 m/s Terrain category Building height 30 m			
		1st	2st s150/s200	3st s150/s200	1st	2st s150/s200	3st s150/s200	
220	340	2.1	15.6	29.1	4.7	18.2	31.7	5
240	360	2.1	15.6	29.1	4.7	18.2	31.7	5
260	380	2.1	15.6	29.1	4.7	18.2	31.7	5
280	400	2.1	15.6	29.1	4.7	18.2	31.7	5
300	420	2.1	15.6	29.1	4.7	18.2	31.7	5
320	440	2.1	15.6	29.1	4.7	18.2	31.3	5

3.1.3 SPA-1 without reduction with regard to H_{Ed} from temperature and wind

The values in the tables concern “clean” capacities. No reduction with regard to H_{Ed} has been done. This can be used for own calculations with loads that are different from the ones described in table 3.1-3.4.

- Concrete quality minimum C30/37
- Installation according chapter 2.1
- Thickness outer layer minimum 70 mm

Table 3.5 Steel capacities

Isolation thickness b (mm)	SPA-1-07 $V_{Rd.s}$= $H_{Rd.s}$ (kN)	SPA-1-08 $V_{Rd.s}$= $H_{Rd.s}$ (kN)	SPA-1-09 $V_{Rd.s}$= $H_{Rd.s}$ (kN)	SPA-1-10 $V_{Rd.s}$= $H_{Rd.s}$ (kN)	e_H max (m)
40	7.9	–	–	–	1,5
50	12.5	–	–	–	1,5
60	11.9	14.8	–	–	2
70	13.9	18	–	–	2
80	14.9	20	25.4	–	2
90	11.9	16	20.3	–	3
100	12.1	16.8	22	–	3
110	10.1	14.2	18.6	–	4
120	10	14.4	19.4	–	4
130	8.6	12.4	16.8	–	5
140	8.4	12.3	17	–	5
150	8	12.1	16.9	–	5
160	7.7	11.7	16.6	–	5
170	7.3	11.2	16.1	–	5
180	6.9	10.7	15.6	–	5
190	6.5	10.2	15	–	5
200	6.2	9.7	14.3	–	5
210	5.8	9.2	13.7	–	5
220	5.5	–	13.1	18.5	5
230	5.2	–	12.4	17.7	5
240	4.9	–	11.9	16.9	5
250	4.6	–	11.3	16.2	5
260	4.4	–	10.7	15.5	5
270	4.1	–	10.2	14.8	5
280	–	–	9.7	14.1	5
290	–	–	9.3	13.5	5
300	–	–	8.9	12.9	5
310	–	–	8.4	12.3	5
320	–	–	8.1	11.8	5

The following interaction formulas shall be checked:

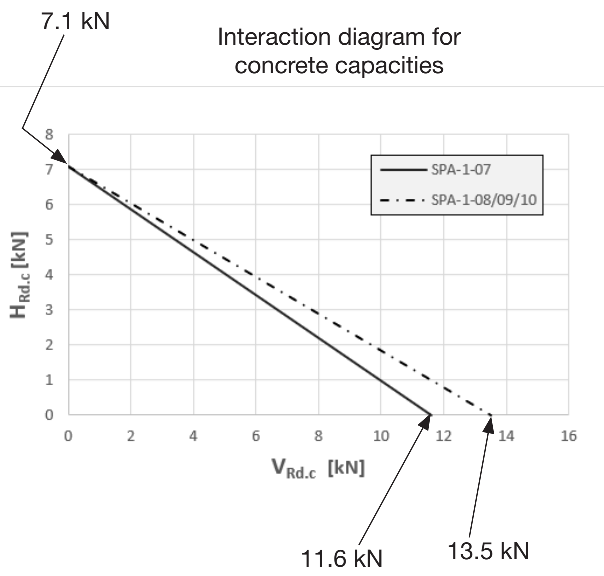
(1) $V_{Ed}/V_{Rd.s} + H_{Ed}/H_{Rd.s} \leq 1$

(2) $V_{Ed}/V_{Rd.c} + H_{Ed}/H_{Rd.c} \leq 1$

Table 3.6 Concrete capacities

	$V_{Rd.c}$ (kN)	$H_{Rd.c}$ (kN)
SPA-1-07	11.6	7.1
SPA-1-08	13.5	7.1
SPA-1-09	13.5	7.1
SPA-1-10	13.5	7.1

Interaction diagram for concrete capacities



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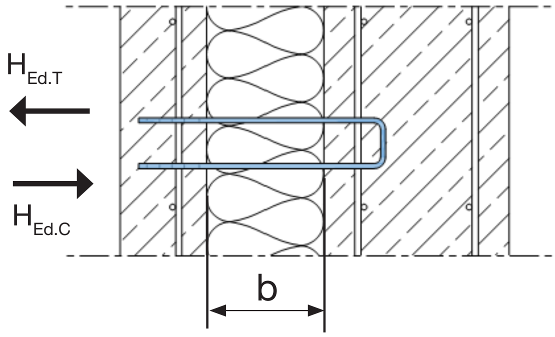
3.2 Connector ties

Table 3.7 and 3.8 specifies allowed horizontal design load per tie (SPA-O/U/K). It is assumed that the insulation takes no pressure load. Allowed horizontal load is shown both as compression ($H_{Ed.C}$) and tension ($H_{Ed.T}$).

Conditions for table 3.7 and 3.8 (see also chapter 3)
- Concrete quality minimum C30/37
- Installation according chapter 2.2



3.2.1 Connector ties, tension loads

- Conditions according table 3.2 and chapter 3.

Table 3.7 Allowed dimensioned tension load $H_{Ed.T}$ SPA-O/U/K (kN)						
Dimension	Diameter 4 mm (04)			Diameter 5 mm (05)		
Isolation thickness b (mm)	Distance e_H			Distance e_H		
	3m	4m	5m	3m	4m	5m
50	3.3	–	–	1.4	–	–
60	6	3.7	0.3	6.1	1.9	–
70	6	6	4.4	6.1	6.1	3
80	6	6	6	6.1	6.1	6.1
≥90	6	6	6	6.1	6.1	6.1

3.2.2 Connector ties, compression loads

- Conditions according table 3.2 and chapter 3.

Table 3.8 Allowed dimensioning pressure load $H_{Ed.C}$ SPA-O/U/K (kN)						
Dimension	Diameter 4 mm (04)			Diameter 5 mm (05)		
Isolation thickness b (mm)	Distance e_H			Distance e_H		
	3m	4m	5m	3m	4m	5m
50	–	–	–	–	–	–
60	1.78	0.29	–	1.62	–	–
70	2.87	1.52	0.49	3.78	1.32	–
80	3.51	2.33	1.41	4.90	3.05	1.30
90	3.81	2.81	2.01	4.90	4.28	2.67
100	3.88	3.05	2.37	4.90	4.90	3.64
110	3.81	3.13	2.55	4.90	4.90	4.28
120	3.67	3.10	2.62	4.90	4.90	4.66
130	3.48	3.01	2.61	4.90	4.90	4.84
140	3.27	2.89	2.55	4.90	4.90	4.89
150	3.07	2.75	2.46	4.90	4.90	4.85
160	2.86	2.60	2.36	4.90	4.90	4.75
170	2.67	2.45	2.25	4.90	4.90	4.60
180	2.49	2.30	2.13	4.90	4.87	4.43
190	2.32	2.16	2.02	4.90	4.63	4.25
200	2.17	2.03	1.91	4.75	4.39	4.06
210	2.02	1.91	1.80	4.47	4.16	3.87
220	1.89	1.79	1.70	4.21	3.94	3.69
230	1.77	1.69	1.61	3.96	3.73	3.51
240	1.66	1.59	1.52	3.74	3.53	3.34
250	1.56	1.5	1.43	3.52	3.35	3.18
260	1.47	1.41	1.36	3.33	3.17	3.02
270	1.38	1.33	1.29	3.15	3.01	2.88
280	1.3	1.26	1.22	2.98	2.85	2.74
290	1.23	1.19	1.16	2.82	2.71	2.61
300	1.16	1.13	1.1	2.67	2.58	2.48
310	1.1	1.07	1.04	2.54	2.45	2.37
320	1.04	1.02	0.99	2.41	2.34	2.26

Let's connect

3.3 Beam ladders

The beam ladder carries vertical loads from the outer layer and is affected by wind loads.

Design load capacity after reduction from wind loads:
V_{Rd} = 0.9 kN per beam ladder (= allowed vertical design load from the outer layer per beam ladder)

Conditions for capacity:
- Concrete quality minimum C30/37
- Compression loads are resisted by the insulation (hard insulation)
- Installation according chapter 2.3 (cast in depth 30 mm)
- Wind speed 26 m/s, Terrain category I, Building height maximum 20 m, Pressure coefficient -1.4
- Load area from wind = 0,42 m^2
- Distance to centre of motion, e_H maximum 5 m

Design load capacity without reduction from wind loads:
V_{Rd} = 1.1 kN per beam ladder (= allowed vertical design load from the outer layer per beam ladder)

4. Standards and partial factors

Standards
- EN 1990
- EN 1991-1-1
- EN 1991-1-4
- EN 1991-1-5 (modified)
- EN 1992-1-1
- EN 1993-1-4
- EN 1993-1-8
- EKS 11

Peak velocity pressure, q_p, for given environments:
v_b=26 m/s, Terrain category I, Building height 20 m: q_p= 1.26 kPa
v_b=24 m/s, Terrain category III, Building height 30 m: q_p= 0.82 kPa

Partial factors
Horisontal loads: $H_{Ed} = 1.5*(H_{w.k}$ alt. $H_{T.k}) + 1.5*\psi_0*(H_{w.k}$ alt. $H_{T.k})$
Wind: ψ_0= 0.3
Temperature: ψ_0= 0.6
(Is not used with regards to horizontal movement,
relative movement in connection point= $\Delta T \bullet \alpha_T \bullet e_H$)

$H_{T.k}$ = Load from temperature curvature of outer layer
$H_{w.k}$= Load from wind

Capacities:
Steel, bar (stainless): $\gamma_{M0} = 1$, $\gamma_{M1} = 1$
Steel, weld (stainless): $\gamma_{M2} = 1.25$
Concrete: γ_c = 1.5 (compression) / 1.5 (tension)