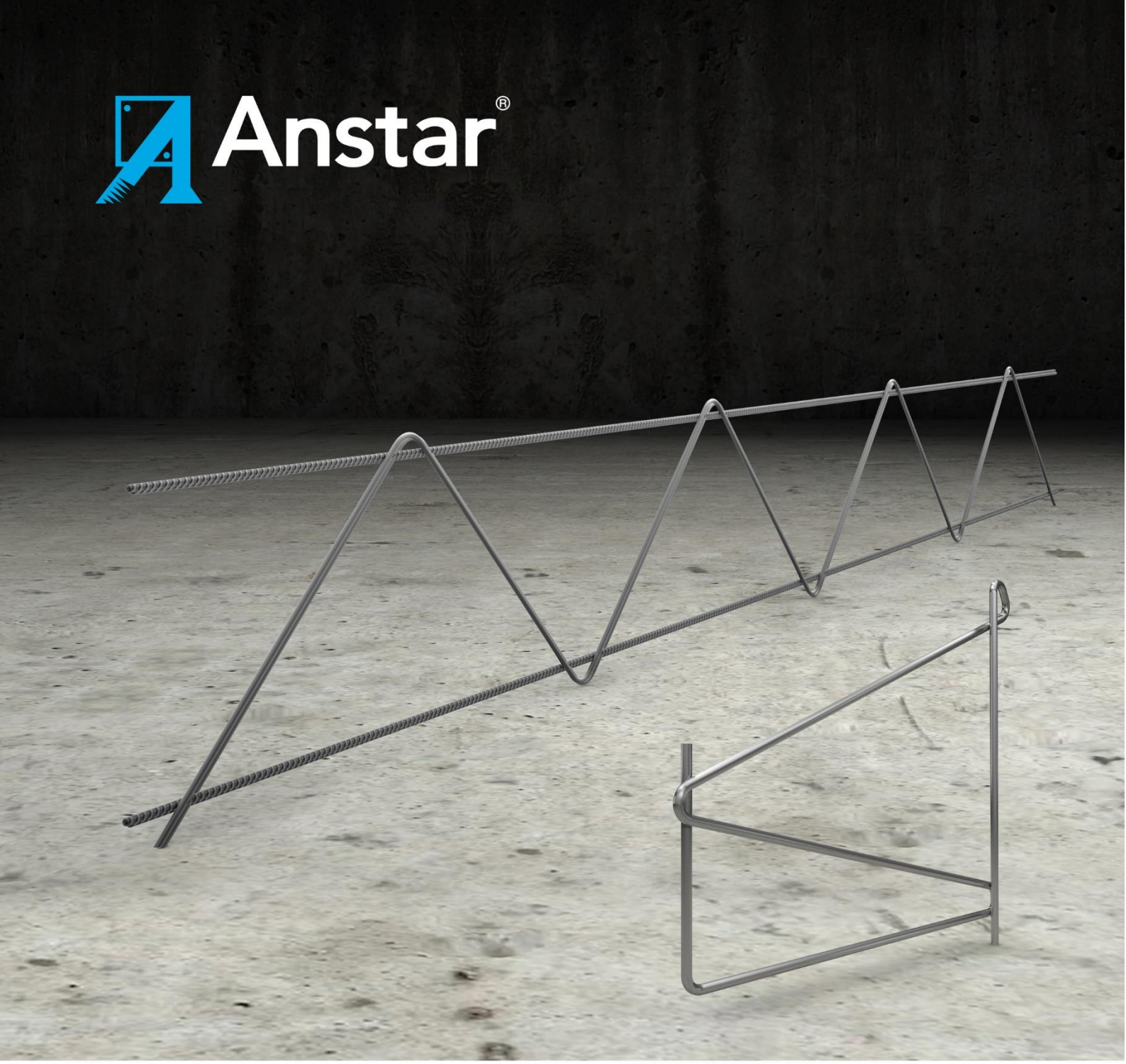
Anstar®



Ties

User manual

Version 2/2023

CE

Ties

Tie reinforcements for sandwich panels

- Ties suitable for all thermal insulation thicknesses and materials
- Quick and easy to install between thermal insulation boards
- Austenitic material guarantees corrosion resistance and 50 years of service life
- Automatic production line ensures precise dimensions and reliable welding
- Suitable for insulation thicknesses between 90 and 380 mm
- AD tie for sandwich panels
- APA beam tie for low apron cladding panels and lintels

TABLE OF CONTENTS

Revision A – 28 February 2023

The user manual for ties has been completely rewritten.
The AD and APA tie product range has been slightly expanded.
The APA beam tie has also been added to the manual.
Resistance values for the tie have been calculated according to standard SFS-EN 1992-1.
Product approval for manufacturing the ties is CE marking according to EN 1090-1.
The manufacture of the ties is monitored by an independent inspection body.
The ties have a product declaration by the Concrete Association of Finland.

This user manual only applies to designing and using the Anstar Oy products included in this document. The manual or parts of it cannot be adapted or applied to designing other manufacturers' products or manufacturing or using ties for concrete elements.

1 TIES

Ties are metal structures used in concrete sandwich panels to connect the outer skin with the inner skin through the insulation layer. The tie connects the skin structures of the wall panel to act jointly against the stresses caused by the structure's self-weight, wind load and physical environmental conditions.

The tie suspends and fastens the outer skin of the sandwich panel to the load-bearing inner skin and transfers loads from the outer skin to the inner skin. The tie also stiffens the outer and inner skins of the panel to act jointly as a bending-resistant structure.

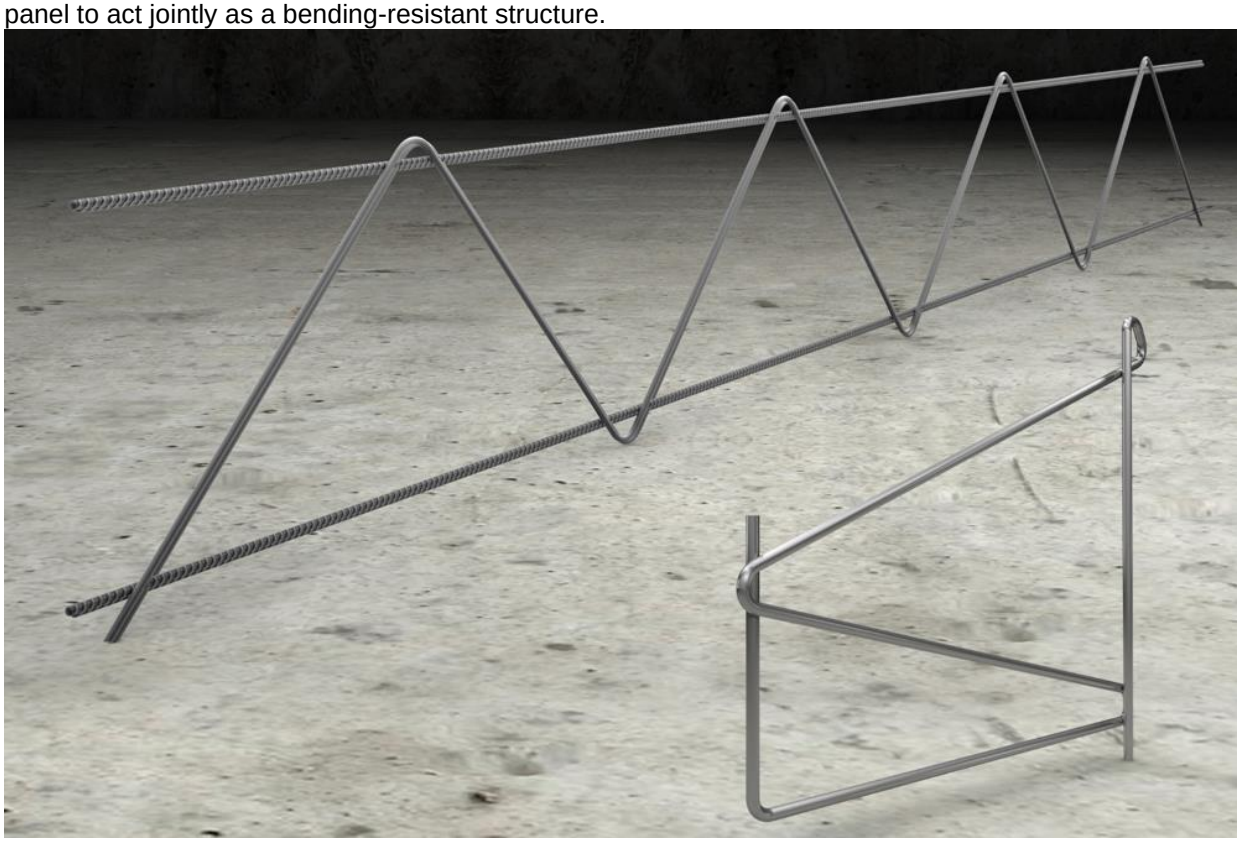


Figure 1. AD diagonal tie and APA beam tie.

2 APPLICATIONS

2.1 Diagonal tie

The tie is used as a load-bearing structure between the skins of concrete sandwich panels for the transfer of loads from the outer skin to the inner skin of the panel. The tie also binds the skins together to act jointly against physical loads from the operating environment.

The tie is installed in the cast concrete during the casting of the panel. The outer skin of the panel may be a normal concrete-faced panel or a brick-faced concrete panel. The hardening of the concrete connects the skins to each other with the tie through the insulation layer.

During manufacturing, the tie wires are cold-drawn, which significantly increases the yield strength and elongation of the wire material, reducing the displacement between the outer and inner skins under exceptional loading conditions.

AD	The diagonal tie's outer chord and diagonal wires are austenitic 1.4301 material. The inner chord wire is ferritic B500K. This is the minimum requirement for façade panels used in Finland.
ADR	The diagonal tie is made entirely of austenitic wire for demanding environmental conditions.
ADM	The diagonal tie's chord wires are ferritic B500K, and the diagonal wire is austenitic. The tie is only intended for lighter environmental conditions.

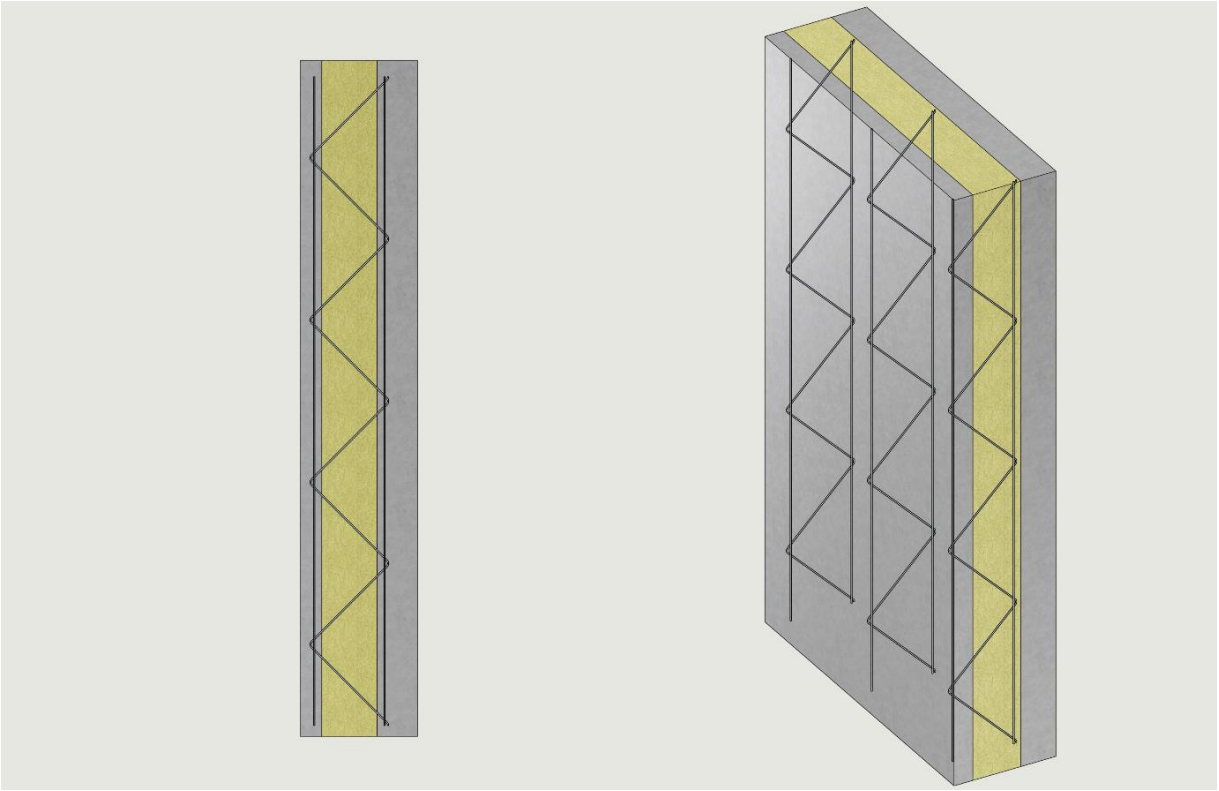


Figure 2. AD diagonal tie in a sandwich panel

2.2 Beam tie

APA beam ties are used as a load-bearing structure between the skins of beam-type wall panels for the transfer of loads from the outer skin to the inner skin of the panel. The tie also binds the skins together to act jointly against physical loads from the operating environment. The tie is installed in the cast concrete during the casting of the panel. The APA tie complements the diagonal tie in narrow structures where the diagonal tie does not fit.

The APA beam tie is made entirely of austenitic 1.4301 material.

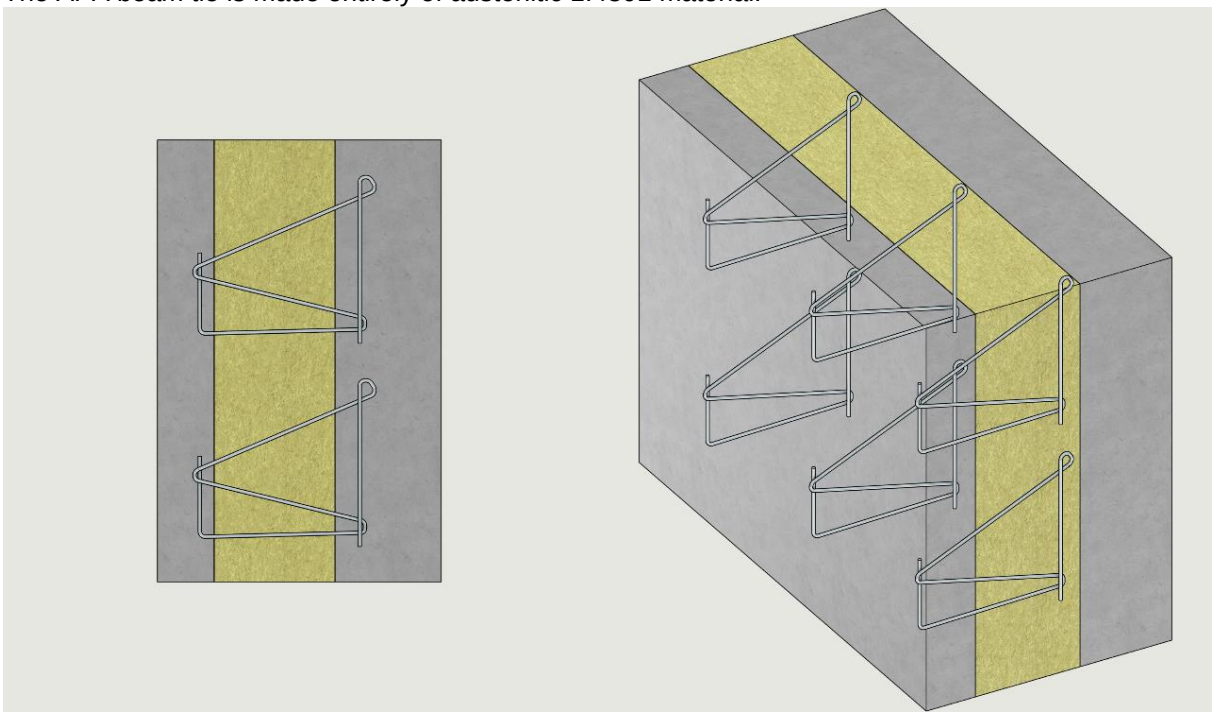


Figure 3. APA beam tie in a low beam-type sandwich panel

2.3 AD diagonal tie

Ties are metal structures used in concrete sandwich panels to connect the outer skin with the inner skin through the insulation layer. The tie suspends the outer skin of the panel on the load-bearing inner skin. It connects the concrete skins to act jointly as a bending-resistant structure. Joint action increases the compression and horizontal bending resistance of the panel. The material of the chord wires of the tie is selected according to the environmental conditions. The nominal thickness of the wire is Ø5 mm and cannot be changed.

Tie material options and type designations:

1. AD Finnish tie	- Diagonal, Austenitic 1.4301 - Inner chord, B500K - Outer chord, Austenitic 1.4301	*2. ADR*	- Diagonal, Austenitic 1.4301 - Inner chord, Austenitic 1.4301 - Outer chord, Austenitic 1.4301
3. ADM	- Diagonal, Austenitic 1.4301 - Inner chord, B500K - Outer chord, B500K		

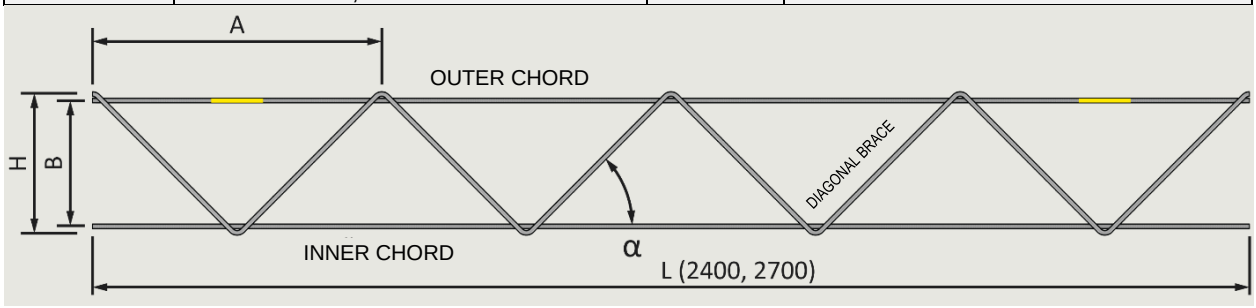


Figure 4. AD diagonal tie structure

Table 1. Tie dimensions

Tie dimensions AD, ADR, ADM				L=2400		L=2700	
	B mm	H mm	T mm	A mm	α degree	A mm	α degree
AD 150	150	180	90	600	31	675	28
AD 180	180	210	120	600	35	675	32
AD 200	200	230	140	600	38	675	35
AD 210	210	240	150	600	39	675	36
AD 220	220	250	160	600	41	675	37
AD 240	240	270	180	600	43	675	39
AD 260	260	290	200	600	45	675	41
AD 280	280	310	220	600	47	675	43
AD 300	300	330	240	600	49	675	45
AD 320	320	350	260	600	51	675	47
AD 340	340	370	280	600	52	675	49
AD 360	360	390	300	600	54	675	50
AD 380	380	410	320	600	55	675	52
AD 400	400	430	340	600	56	675	53
AD 420	420	450	360	600	58	675	54
AD 440	440	470	380	600	59	675	56

Legend:
L = Standard manufacturing length of tie
B, H = External width of chord wires and overall width of tie
T = Maximum thickness of insulation layer
A, α = Spacing and horizontal angle of diagonals
The yellow colour code is painted on the AD tie's austenitic outer chord wire.
The ADR tie has two colour marks next to each other.

Tie order markings:

AD 220-L1	The tie length L1 must be mentioned in the order.	Example: ***AD 220-2400***
ADR 300-L2	The tie length L2 must be mentioned in the order.	Example: ***ADR 300-2700***
ADM 150-L3	The tie length L3 must be mentioned in the order.	Example: ***ADM 150-2400.***

TS models and AutoCAD blocks for the tie: www.anstar.fi

2.4 APA beam tie

Beam ties are metal structures used in low, beam-type concrete sandwich panels to connect the outer skin with the inner skin through the insulation layer. The tie suspends the outer skin of the panel on the load-bearing inner skin. It connects the concrete skins to act jointly as a bending-resistant structure. Joint action increases the compression and horizontal bending resistance of the panel.
The tie material is austenitic 1.4301.

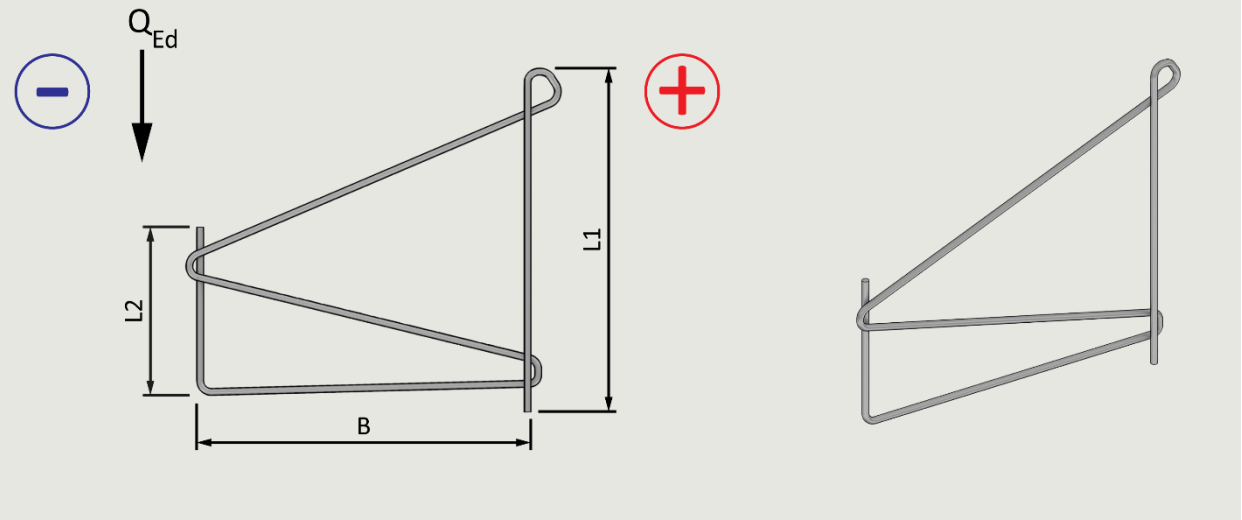


Figure 5. APA beam tie structure

Table 2. Beam tie dimensions

APA Order code	B mm	L1 mm	L2 mm	T mm	C_{nom} mm
APA 150	150	230	125	90	25
APA 180	180	230	130	120	25
APA 200	200	230	125	140	25
APA 210	210	250	140	150	25
APA 220	220	250	135	160	25
APA 240	240	250	130	180	25
APA 260	260	250	120	200	25
APA 280	280	300	155	220	25
APA 300	300	300	150	240	25
APA 320	320	300	140	260	25
APA 340	340	300	130	280	25
APA 360	360	300	120	300	25
APA 380	380	340	155	320	25
APA 400	400	340	145	340	25
APA 420	420	340	140	360	25
APA 440	440	340	130	380	25

Legend:
B = External width of chord wires
L1 = Height of inner chord wire
L2 = Height of outer chord wire
T = Maximum thickness of insulation layer
C_{nom} = Minimum concrete layer for chord wire

The ties are not surface treated.
TS models and AutoCAD blocks for the tie: www.anstar.fi

3 MANUFACTURING INFORMATION

ANSTAR Oy has entered into a quality control agreement with KIWA Inspecta Oy regarding the manufacture of ties. The manufacturing information for the ties is as follows:

Manufacturing markings	Tie manufacturing markings: - ANSTAR Oy's code - Manufacture according to SFS-EN 1090-2:2018 for steel parts. [2] - The ties are bound into a bundle with the following markings: product type, manufacturer ID, week of manufacture and KIWA Inspecta Oy control mark. The chord wires of the AD diagonal tie are cold-rolled with the identifier 9+3. The mark is displayed on the bar at intervals of approximately half a metre. The stainless outer chord of the AD type tie is marked with yellow paint. The ADR tie has two colour marks next to each other. - Packaging: pallet
Materials	Manufacturing materials: AD, ADR, ADM - Wire rod: VIRAJ Smooth Stainless Steel Wire rod The wire is cold-drawn, $R_{m0.2}$ ≥ 500 MPa, Re ≥ 600 MPa. - Wire rod: CELSA Smooth MESH GRADE PS50. $R_{m0.2}$ ≥ 500 MPa The wire is cold-drawn and profiled, $R_{m0.2}$ ≥ 500 MPa, Re ≥ 600 MPa. APA - Wire rod: Wire rod 1.4301 SFS-EN 10088 $R_{m0.2}$ ≥ 600 MPa. The wire is cold-drawn, $R_{m0.2}$ ≥ 700 MPa, Re ≥ 830 MPa.
Manufacturing method	Tie manufacture: Automatic welding and bending machine. - Execution class EXC2. SFS-EN 1090-2:2018 By special order, the product can be manufactured in execution class EXC3. [2] - Shear-tension test for joint resistance welding according to EN 16530-2 - Manufacturing tolerances SFS-EN 1090-2:2018 [2]
Surface treatment methods	Standard delivery: - No surface treatment - The austenitic outer chord is painted with a yellow colour code at its ends.
Traceability	Based on order number.
Product approval and quality control	- Manufacture according to SFS-EN 1090-2:2018 in execution class EXC2 or EXC3. - Manufacture CE marking according to standard EN 1090-1. CE marking certificate: 0416-CPR-7247-03. Product declaration by the Concrete Association of Finland.

Support, fastening and anchoring products manufactured by Anstar Oy:

Table 3. Manufacturing programme and user manuals for support and fastening products.

	Product	User manual	Typical application
1	*A*KL, KL, AKLC, JAL	*Standard fastening plates*	- Anchor plates placed in concrete structures. - Project-specific custom anchor plates.
3	*AVTR*	*Balcony hinge*	- The balcony hinge is used to fasten the balcony floor element to the load-bearing frame of the building.
4	*AR*	*Suspended connection*	- The suspended connection is used to support the outer skin panel of the wall on the inner skin.
5	*AR*	*Masonry support*	- The masonry support is used to suspend the masonry outer skin of the wall panel from the inner skin of the wall panel.
6	*AOK support*	*Hollow-core slab support*	- The hollow-core slab support is designed to support the end of the hollow-core slab in a floor opening where an opening the width of 1–4 hollow-core slabs is required in the floor.
7	*AVT ASKT*	*Standard steel parts*	- Standard steel parts are various connection pieces for fastening to concrete and are specifically designed for this purpose.

4 DESIGN

4.1 Design standard

1. Finnish standards

SFS-EN 1991-1+NA	Actions on structures. Part 1–1: General actions. [5]
SFS-EN 1992-1+NA	Design of concrete structures. Part 1–1: General rules and rules for buildings. [6]
SFS-EN 1993-1-1+NA	Design of steel structures. Part 1–1: General rules and rules for buildings. [7]
SFS-EN 13670	Execution of concrete structures, execution class 2 or 3, [17]
SFS 5975	Use of standard SFS-EN 13670 in Finland [20]
Decree 629/1994	Government Decree on 4 times the safety factor level in a lifting situation

2. Other countries in the European Standards area

Basic Eurocode	EN-1992-1-1:2004/AC:2010
Sweden	SS-EN 1992-1:2005/AC:2010+A1/2014 + EKS 11
Norway	EN-1992-1-1:2004/AC:2010
Baltic region	EN-1992-1-1:2004/AC:2010
Germany	DIN-EN 1992-1 +NA/2013–04

3. Tie manufacture

SFS-EN 1090-1	Execution of steel structures. Part 1: Requirements for conformity assessment of structural components. [1]
SFS-EN 1090-2:2018	Execution of steel structures. Part 2: Technical requirements for steel structures. Execution classes EXC2 and EXC3. [2]
SFS-EN 13670	Execution of concrete structures. Execution class 2 or 3. [17]
SFS-EN-ISO 5817	Welding. Fusion-welded joints in steel, nickel, titanium and their alloys. Weld classes. [11]
SFS-EN 17760-1	Welding. Welding of reinforcing steel. Part 1: Load-bearing welded joints. [16]

4.2 Basis of design.

4.2.1 Manufacture, transport and erection

1. General	The ties are designed for loads occurring during the manufacture, transport and erection stages of the panel:
2. Loads	Design bases of the ties in panel manufacture: - The minimum strength of concrete when lifting the panel is C16/20. - Minimum concrete cover for the tie's chord wire in the outer and inner skin $C_{nom} \geq 25$ mm. - Lifting the panel is done from the inner skin alone, and alternatively it can be done from two sides. - The suction load of the formwork acts as a tensile force on the outer skin during lifting. - The design value of the maximum formwork suction load is F = 2.0 kN/m^2 - Panel manufacturing temperature +20 ^{o}C.
3. Breaking resistance	Decree 629/1994. The tensile resistance of the tie's diagonal and the extraction resistance of the tie from concrete are dimensioned to 4 times the resistance of the wire to material break.

4.2.2 Ultimate limit state

1. General	The ties are designed for the following loads in the ultimate limit state of the panel:
2. Loads	Design bases of the ties in the ultimate limit state of the panel: - The minimum design strength of concrete is C25/30.

	- The loads on the outer skin are transferred to the inner skin through the tensile resistance of the ties and the compression resistance of the insulation layer. - The panel is only fastened to the building frame from the inner skin. - The operating temperature of the panel's inner surface is +20 °C. - The operating temperature range of the panel's outer surface (concrete) is –30...+50 °C.
3. Wind load	The wind load is applied to the outer skin of the panel. - Wind pressure. Maximum design value for wind load according to SFS-EN 1991-1. The wind load is transferred from the outer skin to the inner skin through the insulation layer. The load is not expected to be transferred through the tie, and the effect of the wind load pressure on the ties does not need to be specified. - Wind suction load. Maximum design value for suction load according to SFS-EN 1991-1+NA. If the wind load exceeds the value of 2.0 kN/m^2 (= suction load designing the erection stage for the formwork), its impact on the resistance of the ties must be specified.
4. Temperature and drying shrinkage gradient	Physical deformations and the constraint actions they cause to the structures of the ties must be taken into account according to the project-specific conditions. These include the temperature, temperature differences, intermittent wetting and drying. Drying and creep of concrete as well as distortion of the panel caused by these phenomena.
5. Ultimate limit state resistance	The tensile resistance of a welded connection on the tie's diagonal and the fastening of the tie to concrete are dimensioned to the safety factor level according to European standards [6] and [7].

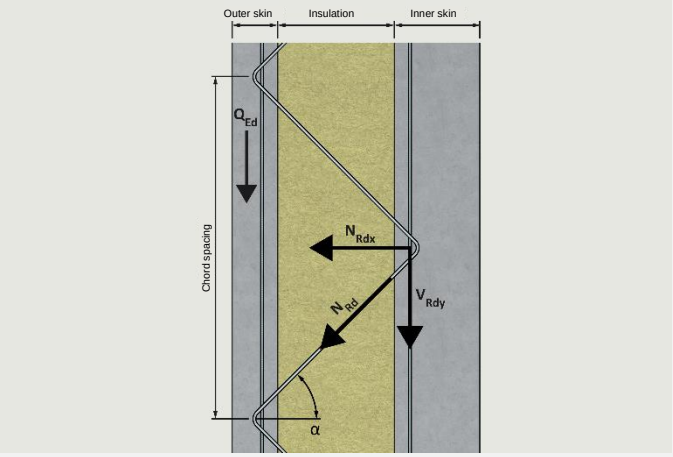
4.2.3 Accident limit state

1. General	The ties are designed for the following loads in the accident limit state:
2. Characteristic resistance	The action of the tie in a lifting situation of the panel is "lifting accessory" in accordance with Decree 629/1994. This requires the following design requirement for the tie: - The characteristic tensile resistance of the tie's diagonal and the fastening of the tie from concrete are designed to 4 times the resistance of the wire to material break. - Other accident limit state loads can also be used up to this level of resistance.
3. Fire resistance	In fire design, the concrete layer required for fire resistance on the outer surface of the panel also applies to the outer surface of the closest wire of the tie. The thermal insulation must be non-combustible.

4.3 Resistances

4.3.1 AD diagonal tie. Resistance

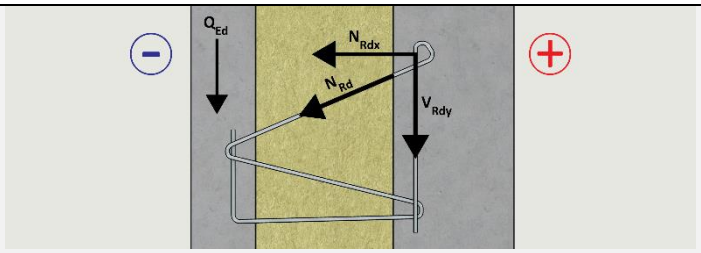
1. General	For the final stage, the ties are designed for the following loads and resistances.	Formulas/Resistances
2. Force diagram	The loads for the tie are defined as follows: - Tie loaded by self-weight of outer skin. - Outer skin weight transferred as tensile force to diagonal. - Tensile force transferred to inner chord. - Extraction force of diagonal and chord weld.	Q_{Ed}. $N_{Rd} = Q_{Ed} / \sin \alpha$ $V_{Ry} = Q_{Ed}$ $N_{Rdx} = N_{Rd} / \cos \alpha$
3. Load state	Tie load range = Diagonal pitch * Tie pitch	

	 Figure 6. AD diagonal tie design forces	
4. Resistances Ultimate limit state	Tie resistances: - Calculation value for diagonal wire tensile resistance. - Calculation value for chord wire tensile resistance. - Calculation value for steel tensile resistance of weld. - Extraction resistance of connection from concrete. $C_{nom} \geq 25$ mm. **Note:** When using the resistance values, observe the maximum allowable tie pitch according to the thickness of the outer skin. The tie pitch must not be exceeded.	N_{Rd} = 5.8 kN V_{Rdy} = 5.8 kN N_{Rdx} = 5.8 kN N_{Rdx} = 4.1 kN
5. Resistances Accident limit state	AD tie resistances: - Characteristic tensile resistance of diagonal wire - Characteristic tensile resistance of chord wire - Characteristic steel tensile resistance of weld - Characteristic tensile resistance of connection from concrete	N_{Rk} = 11.7 kN V_{Rky} = 11.7 kN N_{Rdx} = 7.0 kN N_{Rkx} = 7.6 kN
6. Maximum c/c distances of ties	The ultimate and accident limit state resistance values of the AD tie according to the loads on the outer skin can be achieved when the positioning of ties is based on the following principle according to the thickness of the outer skin. The effect of other exceptional temperature and shrinkage loads must be considered separately.	c/c tie pitch must not be exceeded

Outer skin thickness mm	Tie pitch c/c mm	Diagonal pitch mm
60–100	600	600–800
100–150	450	600–800
150–200	300	600–800

4.3.2 APA beam tie. Resistance

1. General	For the final stage, the ties are designed for the following loads and resistances.	
2. Force diagram	The loads for the tie are defined as follows: - Tie loaded by self-weight of outer skin. - Outer skin weight transferred as tensile force to diagonal. - Tensile force transferred to inner chord. - Extraction force of diagonal and chord connection	Q_{Ed}. N_{Rd} = Q_{Ed} / sin α V_{Ry} = Q_{Ed} N_{Rdx} = N_{Rd} / cos α
3. Load state	Tie load range = Diagonal pitch * Tie pitch	

	 Figure 7. APA beam tie design forces	
4. Resistances Ultimate limit state	APA tie resistances: - Calculation value for diagonal wire tensile resistance. - Calculation value for chord wire tensile resistance. - Calculation value for steel tensile resistance of weld. - Extraction resistance of connection from concrete. $C_{nom} \geq 25$ mm. - **Note:** When using the resistance values, observe the maximum allowable tie pitch according to the thickness of the outer skin.	N_{Rd} = 8.1 kN V_{Rdy} = 8.1 kN N_{Rdx} = 8.1 kN N_{Rdx} = 4.1 kN
5. Resistances Accident limit state	APA tie resistances: - Characteristic tensile resistance of diagonal wire - Characteristic tensile resistance of chord wire - Characteristic steel tensile resistance of weld - Characteristic tensile resistance of connection from concrete **Note:** When using the resistance values, observe the maximum allowable tie pitch according to the thickness of the outer skin.	N_{Rk} = 15.6 kN V_{Rky} = 15.6 kN N_{Rdx} = 9.2 kN N_{Rkx} = 7.6 kN
6. Maximum c/c distances of ties	The ultimate and accident limit state resistance values of the APA beam tie according to the loads on the outer skin can be achieved when the positioning of ties is based on the following principle according to the thickness of the outer skin. The effect of other exceptional loads must be considered separately.	c/c tie pitch must not be exceeded

Outer skin thickness mm	Tie pitch c/c mm	Diagonal pitch mm
60–100	600	300
100–150	450	300
150–200	300	300

4.4 Tie positioning in the structure

4.4.1 Concrete strength, tie overlap and supplementary reinforcement

1. General	Section 4.3 provides the resistance values for the tie. The resistance values may be corrected in the following cases:
2. Concrete strength	Resistances calculated with two minimum concrete strengths. - Erection stage C16/20, SFS-EN 1992-1. Lifting from formwork - Ultimate limit state C25/30, SFS-EN 1992-1. Using the panel
3. Adjustment of concrete strength	- For other higher strengths, the resistance values can be corrected with the ratio of concrete compressive strength f_{cd}: $n1 = \sqrt{f_{cd}}\ C_{lask} / \sqrt{f_{cd\ C25/30}}$. This correction only affects the fastening of the tie N_{Rdx} to concrete. An increase can only be made up to the value of the wire's tensile resistance. Concrete strength does not affect the steel tensile strength of the wire.
4. Bonding condition η	- The bonding condition of the reinforcement does not affect tie designing. The design values for resistance are the same in all states.
5. Lap joint coefficient	- The lap joint coefficient of the reinforcement does not affect tie

α_6	designing. The design values for resistance are the same in all states. - Note: See Section 4 for tie overlap.
6. Supplementary reinforcement	- The resistance values for the tie are valid if the outer and inner skins of the panel are reinforced with at least the minimum reinforcement according to the concrete standards. The tie does not require any further reinforcement. - The resistance values of ties have not been specified for a non-reinforced concrete structure.

4.4.2 Minimum/maximum edge and centre distances

1. Minimum/maximum distance and concrete cover requirement	- The maximum edge distance of the tie to the vertical edge is no more than half of the centre distance used for the tie in the panel. The distance is usually 100–300 mm. - The minimum edge distance of the tie to the vertical edge of the panel is 100 mm, which is determined by the concrete attachment of the tie's diagonal joint. - The minimum concrete cover edge distance C_{nom} in accordance with the standards is also followed for the tie. - On the bottom surface of the panel, the minimum edge distance C_{nom} is determined by the concrete cover. - On the top surface of the panel, the tie is positioned such that the chord/diagonal joint is topmost in the inner skin. In this case, the minimum edge distance from the top surface of the panel is 100 mm, which is determined by the extraction resistance of the diagonal joint in concrete. - The concrete cover of the tie's chord wire against mineral wool is also $C_{nom.}$
2. Minimum centre distance	- The minimum centre distance of the tie is 200 mm between two ties. - The requirement is due to the anchoring of the tie's diagonal joint to concrete. - By bundling, two ties can be placed next to each other. (Refer to Section 4.)
3. Maximum centre distance	- The maximum centre distance of the tie is 600 mm, a pitch determined by the normal thermal insulation width. - The maximum centre distance of the tie is determined by a requirement in Decree 629/1994, according to which the tie must have at least 4 times the safety factor level to break. This requirement is achieved without separate calculation if the centre spacing of the ties and the thickness of the outer skin do not exceed the following limits. Refer to the tables in sections 4.3.1.6 and 4.3.2.6. - The centre distance can also be reduced if the size of the panel and the environmental condition loads so require.
4. Bundling ties	Standard ties cannot usually be bundled but must always be used individually due to the joint's anchoring resistance to concrete. In special cases, however, bundling is possible as follows: - If two ties are bundled at the same point, this must be done by turning one of the ties and placing its concrete fastening points halfway between the chord spacing of the diagonals. - However, the turned tie must be a fully austenitic ADR tie. - The resistance values of the tie then apply to both ties.
5. Extending ties	Ties must normally be ordered with fixed dimensions for the panel. If it is necessary to extend the tie, this must be done as follows. - The tie can be extended by overlapping. The recommended extension method is by overlapping the tie for at least one diagonal chord spacing length (= 600–800 mm). The concrete fastening points are then located next to each other. - Extension by butt joint is possible, but it must be limited to a maximum of every other tie/panel. Extension by butt joint weakens the panel's deformation/temperature load action and must be taken into account in the desining of the panel, because a tie extended by butt joint does

	not work against deformation loads. - However, a tie extended by butt joint transfers the vertical load of the outer skin like a non-extended tie, and the resistance values of a single tie can be used for it. - It is recommended that extension be always done by overlapping.
6. Fire design	- Fire design of the tie must only be done with a sufficient layer of concrete. - In fire design, the concrete layer required on the outer surface of the panel applies to the outer surface of the closest wire of the tie. - The thermal insulation used must be non-combustible.

4.4.3 Temperature and drying gradient

1. Constraint actions and their design requirement	Between the outer and inner skins of the panel, there is a temperature gradient resulting from temperature differences and drying of the concrete, which tends to curve the outer skin in different seasons. - According to studies, the maximum shrinkage and temperature differences do not appear at the same time. When the outer skin is the longest in winter due to humidity, the temperature is low and the outer skin is shortened. In the summer, the heat expands the outer skin and the low humidity tends to cancel out the expansion. - According to studies, the curvature caused by shrinkage is clearly greater than that caused by temperature. In practice, only the curvature caused by shrinkage is taken into consideration. The outer skin tends to curve in at the middle and out at the outer edges of the panel and at the edges of openings. - Design information on these phenomena is available online (in Finnish): *https://www.elementtisuunnittelu.fi/julkisivut/julkisivujarjestelmat/sandwich-julkisivut* - Physical constraint actions must be taken into account in the design of the panels' ties in accordance with the building regulations and generally accepted design guidelines, and at least according to the standard requirements.

4.5 Tie design instructions for the main structural designer

1. Design standards	Tie structure design. - Loads for ties are determined according to SFS-EN 1992-1. - Use of ties is designed according to SFS-EN 1992-1+NA and SFS-EN 1993-1-1+NA. - Decree 629/1994 stipulates that the tie must have 4 times the resistance to material break.
2. Erection stage	Tie design criteria for the erection stage and transport: - The minimum strength of concrete when lifting the panel is C16/20. - Lifting the panel is done from the inner skin alone, and alternatively it can be done from two sides. - The suction load of the formwork acts as a tensile force on the outer skin during lifting. The design value of the maximum formwork suction load is F = 2.0 kN/m^2
3. Ultimate limit state (ULS)	Tie design criteria for the ultimate limit state: - The minimum design strength of concrete is ≥ C25/30. - The loads on the outer skin are transferred to the inner skin through the tensile resistance of the ties and the compression resistance of the insulation layer. - The panel is only fastened to the building frame from the inner skin.
4. Accident limit state (ALS)	The action of the tie in a lifting situation of the panel is "lifting accessory" in accordance with Decree 629/1994. This requires the following design requirement for the tie: - The characteristic steel tensile resistance of the tie's diagonal and the fastening of the tie from concrete are designed to 4 times the resistance of the wire to material break. - Other accident limit state loads can also be used up to this level of

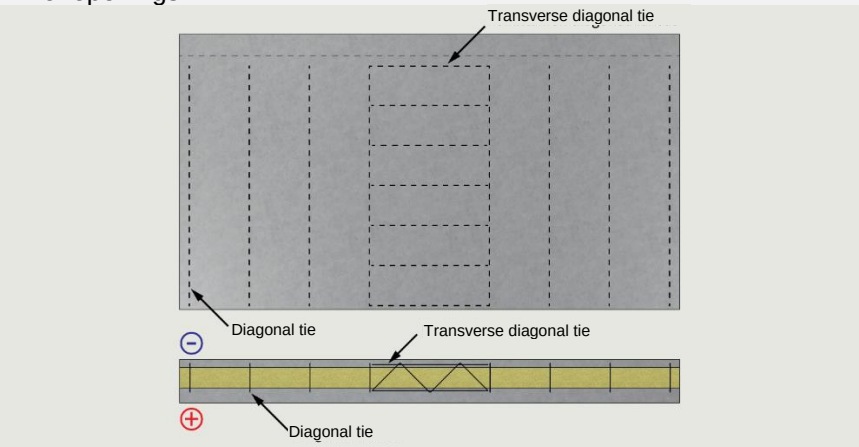
	resistance.
5. Fire scenario	In fire design, the concrete layer required for fire resistance on the outer surface of the panel also applies to the outer surface of the closest wire of the tie. - Fire design is done with a sufficient concrete layer to the surface of the tie.
6. Dynamic and fatigue actions	Forces including dynamic effects. - Forces including dynamic effects are taken into account according to SFS-EN 1990-1, Section 4.1.5, by multiplying the static specific loads by the corresponding dynamic enlargement factors. With the forces calculated in this way, the design is performed as a static situation. The loads must not be fatiguing. - The tie resistance values have not been specified for fatigue actions. In structures with fatigue loads, the tie cannot be used without special analysis.
7. Earthquake	Earthquakes are taken into account in the ultimate limit state calculation. - Design is performed according to SFS-EN 1991-1 in formulas for the load combination. [5] With the forces calculated in this way, the design is performed as a static situation. - Ties can be designed for earthquakes only in countries that are suitable for this method (e.g., Finland) where the earthquake design is performed separately on a site-specific basis as a static design process, if so required. (The lateral force method.) - In structures located in areas that are highly susceptible to earthquakes, a separate analysis must be carried out on the use and resistance of the tie.
8. Low temperature	- No separate operating temperature examination is necessary for the tie material. The low temperature designing instructions for rebar are followed.
9. Supplementary reinforcement for the tie.	The following must be taken into account in supplementary reinforcement for the tie: - The panel is reinforced according to the normal reinforcement instructions in EN 1992-1. - The resistance values for the tie are valid if the outer and inner skins of the panel are reinforced with at least the minimum reinforcement according to the standards. - No separate supplementary reinforcements are needed for the tie. - The resistance values of the tie are not valid in non-reinforced concrete.
10. Tie positioning and minimum distances	- The ties are positioned in the structure in accordance with the minimum edge and centre distances specified in Section 4.4.3. - The minimum concrete cover edge distance C_{nom} in accordance with the standards is also followed for the ties.
11. Service life and durability of the tie	Service life and durability design for the tie is performed according to SFS-EN 1992-1. - The principles and recommended methods are presented in Section 5.3 of this manual.

5 DETAIL DESIGN

5.1 Design stages and parties

1. General	Ties are part of the product delivery procedure. This influences the design responsibilities and delivery procedures.
2. Product deliveries	- Deliveries of AD and APA ties are part of Anstar's product delivery procedure. The ties are delivered to the factory that manufactures the panels.
3. Designing the use of products and using them	- Designing the use of ties is part of the tasks and responsibilities of the main structural designer of the construction project. - The use/erection of ties is the responsibility of the factory that manufactures the panels for the construction project. - Anstar has prepared this manual for the design and erection of ties. The ties have a product declaration by the Concrete Association of Finland.

5.2 Tie positioning in a sandwich panel

1. General	Principles of designing ties for concrete panels.
2. Tie positioning	The positioning of ties is designed for the forces affecting the outer skin of the panel and for physical loads from the environment. - The pitch of the ties is determined according to the loads. - The minimum edge distances and protective concrete layers for ties are specified in Section 4.4.2. - The tie must be placed in the panel such that its first chord/diagonal joint starts from the top surface of the inner skin, where the top joint of the diagonal and the chord goes.
3. Window and door openings in panels	There must be enough ties around window and door openings to cover for the weakening effect of the opening on the sufficient resistance of the element. - Above and below the opening, use short AD ties with at least two intact diagonal spacing lengths. - Instead of these ties, APA beam ties can be used, which must always have at least two ties on top of each other. Beam ties must be overlapped if they cannot fit on top of each other.
4. Transverse ties	If the panel is lifted or turned from two sides during manufacture, transverse ties must be placed in the panel for this load. Figure 8. A transverse tie does not transfer a vertical load. - With normal panels, transverse ties are not required.
5. Outer skin reinforcement principle	- The outer skin is reinforced with central mesh, with the chord wire of the tie placed on the surface of the mesh. - The use of side steels in the outer skin must be considered site-specifically.
6. Inner skin reinforcement principle	- The inner skin is reinforced with mesh, with the chord wire of the tie placed on the surface of the mesh. - Side steels are used on the outer edges of the panel and on the edges of openings.  Figure 8. Principle of positioning ties in a sandwich panel
7. APA beam tie positioning	- The APA beam tie is used in a low structure with no room for a standard tie. The beam tie complements the normal AD tie.

5.3 Serviceability limit state design of the tie

1. Instructions to be followed.

1. Ties in a concrete panel	**Concrete panel review** - The serviceability limit state and durability design for tie connections is made according to [6]. - The inner and outer skin are reviewed separately, since they are in different exposure classes. - Serviceability limit state and durability design for ties is performed according to SFS-EN 1992-1, [6] Section 4. In addition, the instructions in the SFS-EN 13670 [17] standard and Finnish National Annex SFS 5796 [20] are observed. For element structures, the SFS-EN 13369:2018 [19]

	standard and Finnish National Annex SFS 7026 are applied.

2. Recommended material options.

1. Tie material	- The standard material of the outer chord is always austenitic 1.4301 SFS-EN 10088. It is a regulation in accordance with the National Building Code of Finland. - The diagonal material is always austenitic 1.4301 SFS-EN 10088. - The standard material of the inner chord is B500K, which must be increased according to the exposure classes in Table 4.
2. Thickness of concrete cover	- Table 4 shows the nominal value C_{nom} required for the tie's concrete cover by exposure class according to minimum value $C_{min,cur}$. The nominal value for the concrete cover is $C_{nom} = C_{min,cur} + \Delta C_{dev}$ (=5 mm). The concrete cover must extend to the surface of the tie's diagonal. The table shows the recommended materials for the ties in various exposure classes.

Table 4. Required nominal value C_{nom} for the concrete cover and tie material recommendations.

Exposure class SFS-EN 1992-1	50-year service life C_{nom} mm	100-year service life C_{nom} mm	Material recommended for products	
			Tie concrete cover requirement.	Tie material requirement
X0	20	35	Sufficient concrete cover	AD standard material
XC1	25	40	Sufficient concrete cover	AD standard material
XC2	35	45	Sufficient concrete cover	AD standard material
XC3–XC4	40	50	Sufficient concrete cover	AD standard material
XS1–XD1	45	55	Sufficient concrete cover	ADR standard material
XD2	50	60	Sufficient concrete cover	ADR standard material
XD3	55	65	Sufficient concrete cover	ADR standard material
XS2–XS3 XA1–XA3 XF1–XF4	–	–	The ties are used based on a site-specific special analysis. The nominal value for the tie's concrete cover and its wire material are specified according to the site requirements.	

6 WORK AT PREFABRICATION FACTORY

6.1 Standards and plans to be followed during work.

The following standards, instructions and project-specific structural plans are to be followed when installing the ties.

1. Implementation breakdown Quality plan	- Erection plan prepared by the contractor. - Concrete structure implementation breakdowns prepared for the project. - Quality inspection plan prepared for the project and site.
2. Drawings	- Work and erection drawing prepared by the structural designer. - Structure sections and erection details prepared by the frame designer.
3. Work instructions	- Tie user manual, whose sections 6, 7 and 8 apply to the erection of the tie at the factory.

6.2 Delivery, storage and identification

1. Delivery	The ties are delivered on a pallet. Longer-term storage protected from rain.
2. Identification	The tie type and size can be identified as follows: The pallet is equipped with identifying information and each coupler features a colour-coded plastic shield. The tie is identified by the product code attached to the bundle.

6.3 Tie erection in formwork

1. Start	- The ties are installed in the fresh concrete mix of the outer skin, alternating with the concrete slabs. - When installing, ensure that the position of the chord wire and the protective concrete layer will correspond to the plans.

	- The next thermal insulation is installed tightly in the tie so that there are no air gaps.
2. Inner skin casting	- Before casting, ensure that the distance of the tie's chord wire from the mineral wool meets the requirements.

6.4 Corrective measures allowed for ties at the prefabrication factory

1. General	- The structures of the tie must not be modified without the designer's and/or tie manufacturer's permission. - The following measures are allowed at the prefabrication factory. - A non-conformity report must be prepared for each change, and the changes must be documented in the project's quality documentation.
2. Allowable corrective measure	- If necessary due to space requirements, the tie can be curved slightly to the side. No sharp bending of the tie is allowed. - The tie can be cut mechanically. Cutting must be done outside the joint spot welds.

3. Non-allowable corrective measure	- No other reinforcements can be welded to the tie wire. - Load-bearing joints must not be welded to the tie. - Ties must also not be heated with gas or other equipment.

7 SAFETY MEASURES

7.1 Information for preparing work safety instructions for the site.

1. General	- Appointed by the developer, the project's work safety coordinator is responsible for ensuring work safety during the building work. When preparing work safety instructions for the project, the following must be taken into account in the erection of the connected structures.
2. Erection	- Structures are installed by following the contractor's erection plan and the requirement for stability during erection determined by the designer. - Sandwich panels must not be loaded in deviating ways or with deviating forces.
3. Stability	- The stability of the structures under exceptional natural forces must be ensured at the end of the shift, particularly if the erectionwork is not completed.
4. Measures on the site	- The concrete must reach the planned strength before the panel can be lifted from the formwork. - The erection work is carried out in accordance with the working order in the panel erection instructions and the support plan. - In storage, the panels must be supported from the inner skin by wooden supports. The support must not be on the outer skin only. - Repairs needed for exceeding the erection tolerances require the designer's permission.

7.2 Product commissioning during construction

1. Structure	- The concrete panel can be lifted from the formwork when the concrete strength has reached the formwork removal strength. - The concrete panel can be installed in the frame when the panel has reached the design strength.

8 ERECTION QUALITY CONTROL

8.1 Instructions for monitoring product erections

1. General	- Erection quality control for the products is carried out in accordance with the quality control plan prepared for the project and site. For concrete structures, the requirements of standard SFS-EN 13670 are to be observed, whereas for steel structures, the instructions in SFS-EN 1090-2 and the implementation breakdown must be followed. - An inspection report is prepared for the product quality control and dimensional inspections and saved in the project's quality documentation. Inspections to be performed on the coupler and its application products:
2. Before tie erection	- Ensure that the ties are not damaged. - Follow the erection plan regarding the erection order. - Check the position of the ties and the required embedment depth in concrete.
3. Tie erection	- Check that the ties have been installed according to the plans. - Ensure that the depth of the tie in concrete is in accordance with the plans.
4. Lifting from formwork	- Ensure that the concrete strength has reached the required level before lifting the panel.
5. Deviations	If the prefabrication factory deviates from the approved plans and documents in any of the following tasks: - implementation of the erestion, materials, lifting and moving procedures, and quality control - required inspections and their documentation, the contractor is obliged to start documenting the non-conformity upon observing the deviation from the plan and to have the client approve the resulting measures. Non-conformity reports are saved in the project's quality documentation.

8.2 Final documentation of erection quality control

1. General	- When the job has been accepted, the prefabrication factory is required to provide the client with the inspection and quality control documentation created during manufacture.
2. Readiness inspection records	- Record of grouting readiness inspections.
3. Non-conformity reports	- Any non-conformity reports prepared during the tie erection are handed over.
4. Product approval as-built	- CE marking certificates or corresponding product approval information for materials purchased for the site. - As-built documentation for changes made to the structure.

REFERENCES

[1] SFS-EN 1090-1 Execution of steel structures and aluminium structures. Part 1: Requirements for conformity assessment of structural components.
[2] SFS-EN 1090-2:2018 Execution of steel structures and aluminium structures. Part 2: Technical requirements for steel structures.
[3] SFS-EN ISO 3834 Quality requirements for fusion welding of metallic materials. Part 1: Criteria for the selection of the appropriate level of quality requirements, and parts 2–5
[4] SFS-EN 1990, Eurocode. Basis of structural design
[5] SFS-EN 1991-1, Eurocode 1. Actions on structures, parts 1–7
[6] SFS-EN 1992-1, Eurocode 2. Design of concrete structures. Part 1: General rules and rules for buildings.
[7] SFS-EN 1992-2, Eurocode 2. Design of concrete structures. Part 2: General rules. Structural fire design.
[8] SFS-EN 1993-1-1, Eurocode 3. Design of steel structures. General rules and rules for buildings. Parts 1–10
[9] Removed
[10] Removed
[11] SFS-EN ISO 5817, Welding. Fusion-welded joints in steel, nickel, titanium and their alloys. Weld classes.
[12] SFS-EN ISO 12944, Paints and varnishes. Corrosion protection of steel structures by protective paint systems. Part 1: General, and parts 2–7.
[13] SFS-EN ISO 1461, Hot dip galvanized coatings on fabricated iron and steel articles. Specifications and test methods.
[14] SFS-EN 10025, Hot rolled products of structural steels. Part 1: General technical delivery conditions.
[15] SFS-EN ISO 1684 Fasteners. Hot dip galvanized coating.
[16] SFS-EN 17760-1 Welding. Welding of reinforcing steel. Part 1: Load-bearing welded joints.
[17] SFS-EN 13670 Execution of concrete structures
[18] Removed
[19] SFS-EN 13369:2018 Common rules for precast concrete products
[20] SFS 5975. Execution of concrete structures. Use of standard SFS-EN 13670 in Finland
[21] Removed
[22] RIL 201-4-2017 Rakenteiden vaurionsietokyvyn varmistaminen onnettomuustilanteessa (Ensuring the failure tolerance of structures in the accident limit state).
[23] SFS-EN 1992-4, Eurocode 2. Design of concrete structures. Part 4: Design of fastenings for use in concrete

LIST OF TABLES

PICTURES

Anstar Oy is a Finnish family business specialising in the sales and manufacture of concrete structure connections and composite beams. We are an international operator, and one of the pioneers in the field. Anstar will help you with all your questions relating to concrete connections. Anstar's specialists may also develop solutions to customer-specific connection problems.

Anstar®

SMART STEEL.
SINCE 1981.

ANSTAR OY
Erstantie 2
FIN-15540 Villähde

Tel. +358 3 872 200
anstar@anstar.fi
www.anstar.fi