EC2-Compliant Design Method

Design of Shear Connections
using KSN Anchor Box

Design method verified by
Dept. of Civil & Structural Engineering,
University of Sheffield

Ancon

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KSN Anchor Box

Cost-effective slab-to-wall continuity system with four-step EC2-compliant design method

In this document, we detail a four-step EC2-compliant design method for the use of its KSN Anchors at slab-to-wall connections subjected to a combination of shear and tensile loads.

The design method has been developed by us and independently verified by the Department of Civil and Structural Engineering at the University of Sheffield, UK.

Internally threaded Ancon KSC Anchors, supplied in a metal casing and used in combination with Bartec Plus parallel-threaded reinforcing bars, can now be detailed in a single row along the slab section centreline. The innovative KSN Anchor Box provides a cost-effective design solution that minimises rebar congestion in both the slab and the wall, simplifies bar scheduling and is quick and easy to install with no requirement for manual bar straightening on site.

UK CARES has independently assessed the Ancon KSN Anchor; refer to Technical Approval TA1-B 5061.

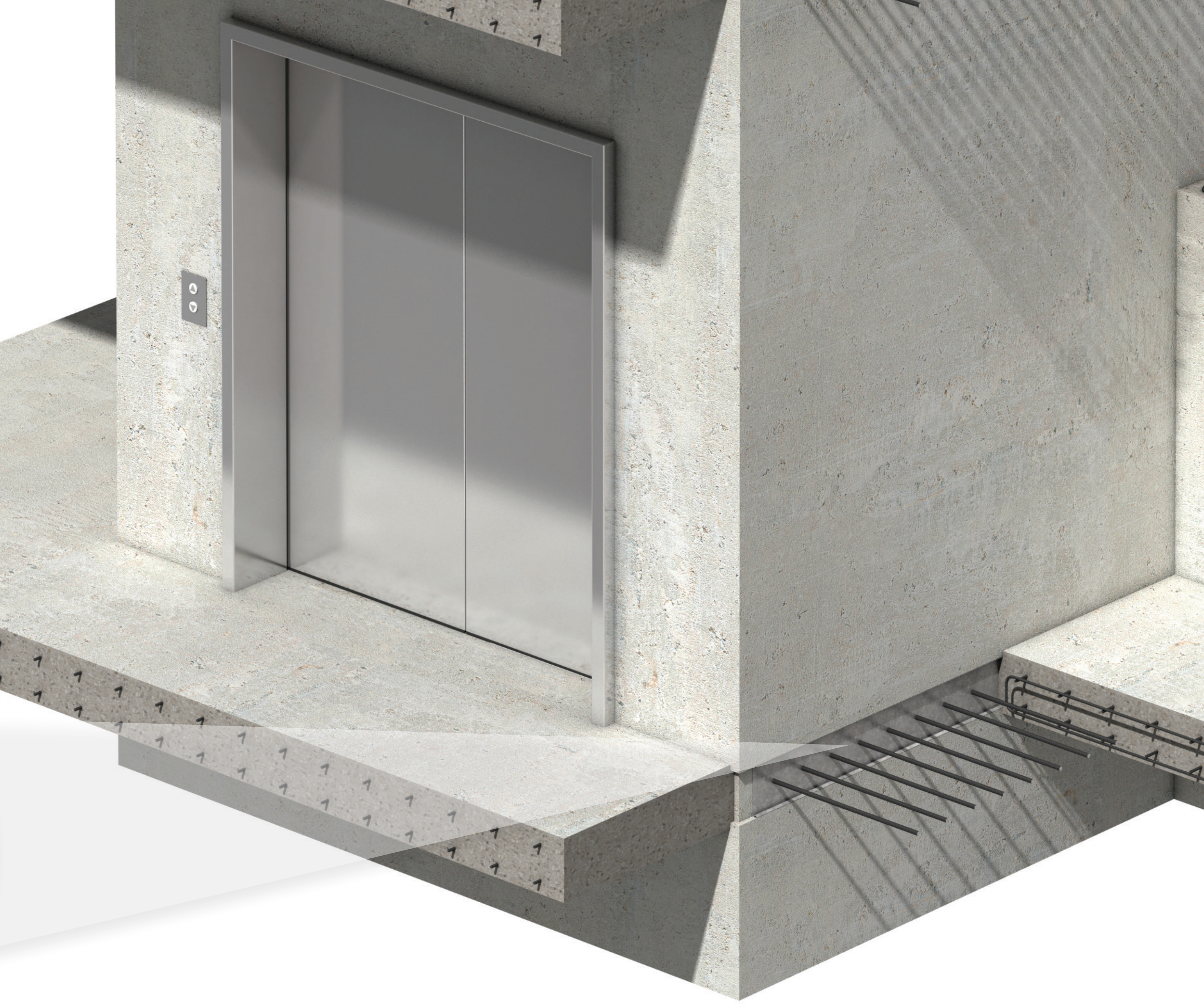
KSN Anchor Box, a single row of KSN Anchors positioned along the slab section centreline. Bartec Plus threaded reinforcing bars, also from Ancon, complete the connection

System Performance

The performance of KSN Anchors outlined in this document relates exclusively to slab-to-wall connections subjected to a combination of shear and tensile loads.

For moment connections, please refer to the KSN Anchors Reinforcement Continuity System brochure.

Contents



KSN Anchor Technical Approval TA 5061

Eliminates risks associated with on-site bar straightening

Virtually unlimited continuation bar length. Suitable for EC2 lap lengths

Simple to schedule. Fast to install

Easy visual check of correct bar engagement

No torqueing required

Reduces reinforcement congestion

EC2 indented construction joint

Independently-verified design method

Ancon KSN Anchor Box

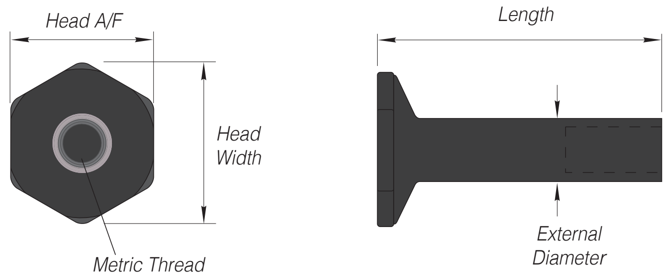
System Components

KSN Anchor Box

There are eight standard anchors in the KSN range. They are manufactured from highly reliable Cr-Mo alloy steel with a minimum 15% elongation. The head is formed by hot forging to minimise material usage and improve the strength characteristics. The anchor is subsequently machined to incorporate a metric thread. Independent tests have verified the direct pull out strength of the anchors.

UK CARES have independently assessed the KSN Anchor, refer to CARES Technical Approval TA1-B 5061.

KSN Anchors, eight standard sizes available from stock



KSN Anchor Dimensions

Anchor Ref.	Nominal External Diameter (mm)	Metric Thread (mm)	Nominal Head Width (mm)	Nominal Head A/F (mm)	Anchor Length (mm)	Embedment h_{eff}* mm
KSN12S KSN12M	22	M16 x 2.0	46	40	115 150	124 159
KSN16S KSN16M KSN16L	28	M20 x 2.5	61	53	130 160 190	139 169 199
KSN20S KSN20M KSN20L	32	M24 x 3.0	75	65	150 190 230	159 199 239

**With KSN Anchor Box*

When used for shear connections, KSN Anchors are delivered to site pre-assembled as independent rows of anchors fixed with hexagon head screws to the back of a galvanised metal casing featuring a dimpled surface to provide an effective concrete bond. The KSN Anchor Box is fitted with a protective cover and each end of the unit is sealed with a polystyrene block to prevent the ingress of concrete.

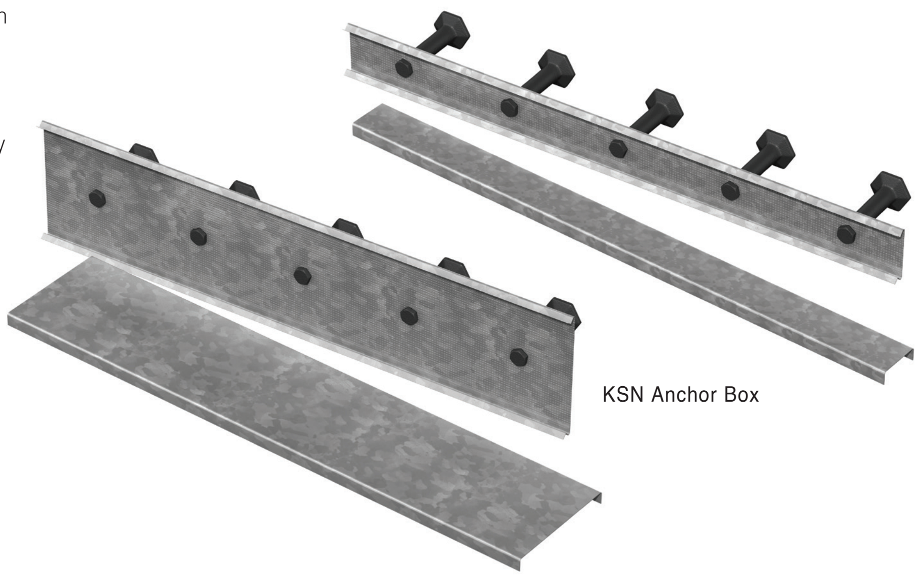
The KSN12 and KSN16 boxes provide an additional 15mm depth of embedment to each KSN anchor; the KSN20 provides 17mm. By increasing the embedment depth, the capacity of the KSN Anchor under direct pull out is improved. All boxes provide a shear key for the joint.

The KSN Anchor Box is available in the following range of widths: 85mm, 120mm, 150mm, 170mm, 190mm, 220mm and 250mm.

For optimum performance of the KSN Anchor Box, the largest box width that can be fitted within the thickness of the slab being connected should be selected (allowing for a 20mm site tolerance, see table for box widths and minimum slab depths).

KSN Anchor Box Widths

Box Width (mm)	Minimum Slab Thickness (mm)
85	105
120	140
150	170
170	190
190	210
220	240
250	270



KSN Anchor Box

Bartec Plus Continuation Bars

Unlike re-bend continuity systems where bar lengths are restricted to the box dimensions, there is virtually no restriction on continuation bar length with KSN Anchors.

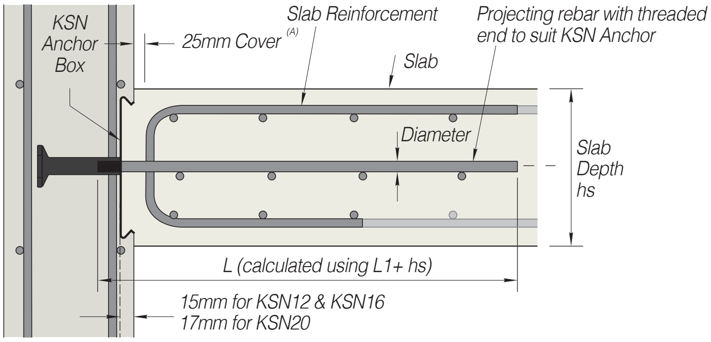
Ancon KSN Anchors are designed for use with 12mm, 16mm and 20mm diameter grade B500B or B500C reinforcing bar, threaded with a metric thread, supplied by us.

The Bartec Plus system produces a full strength joint. The bar end is cut square and enlarged by cold forging. This increases the core diameter of the threaded portion of the bar to ensure that the strength of the bar is maintained. A parallel metric thread is rolled onto the enlarged end. A 12mm bar is provided with an M16 thread, a 16mm bar with an M20 thread and a 20mm bar with an M24 thread.

Bar lengths to BS EN 1992:1-1 (Eurocode 2) are given in the table below.

12, 16, 20mm diameter Bartec Plus continuation bars, available in EC2 lap lengths

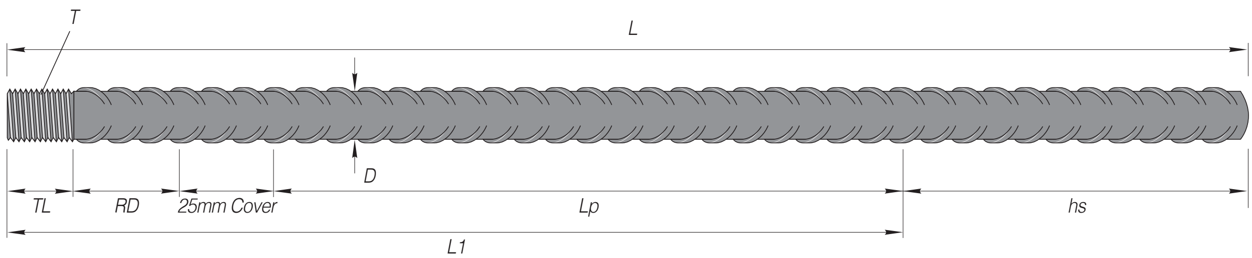
Mid Slab Anchor Connection



Notes
Good bond conditions apply for hs ≤ 250mm
Bad bond conditions apply for hs > 250mm
[A] The U shaped end rebars to be 12mm diameter minimum. The bars may be formed from the top steel reinforcement.

Bartec Plus Continuation Bar Dimensions for use with KSN Anchor Box

Anchor Ref.	Bar Diameter (D)	Thread Size (T)	Thread Length (TL)	Rebate Depth (RD)	EC2 Full Tension Lap C32/40 (Lp)		Length L1 Required C32/40		Minimum Bar Length (L)	
					Good Bond	Bad Bond	Good Bond	Bad Bond	Good Bond	Bad Bond
KSN12S KSN12M	12mm	M16	16mm	15mm	630mm	890mm	690mm	950mm	690mm + hs	950mm + hs
KSN16S KSN16M KSN16L	16mm	M20	40mm	15mm	830mm	1190mm	910mm	1270mm	910mm + hs	1270mm + hs
KSN 20S KSN 20M KSN 20L	20mm	M24	24mm	17mm	1040mm	1480mm	1110mm	1550mm	1110mm + hs	1550mm + hs



L1 = TL + RD + Cover + Lp
Overall length of continuation bar required L = L1 + hs, where hs = slab thickness

Specifying and Ordering

An Ancon KSN Anchor Box for shear connections can be specified and ordered using the following identification method:

Anchor Ref. / KSN Anchor Box / Single Row / Box Width / Horizontal Spacing (mm)

e.g. KSN20S / KSN Anchor Box / Single Row / 120 / 150

This is the reference for a KSN Anchor Box comprising KSN20S anchors installed in a 120mm box width at 150mm horizontal spacing.

Unit lengths for KSN Anchor Box are determined by us for each specific application, with a maximum unit length of 600mm.

Ancon KSN Anchor Box

Design Method

The design method for slab-to-wall connections subjected to a combination of shear and tensile loads was developed by us in collaboration with the Department of Civil & Structural Engineering at the University of Sheffield. It is to be adopted for the use of KSN anchors under predominant shear load conditions and makes reference to the following design codes:

- BS EN 1992-1-1-1: Eurocode 2
- BS EN 1992-4:2018
- ETAG 001-1997 Annex C

The design method is aimed at providing continuity to the structure through simply-supported slabs: all relevant anchorage and shear checks are performed within the limits of the aforementioned design codes.

In addition to providing a solution for the transfer of shear loads, the method also makes provision for a tie force in order to meet disproportional collapse requirements: buildings are assumed to be Class 3 according to UK Building Regulations.

In specific instances, tensile forces may develop due to shrinkage strains: such forces depend on many factors which are not addressed by the design codes, such as the size of the structure and restraint offered to the slab, the concrete properties, reinforcement ratio and concrete curing regime. Though the design guidelines do not specify a value for such tensile forces, a provision has been made in the calculations to allow engineers to provide a figure, if they can calculate it.

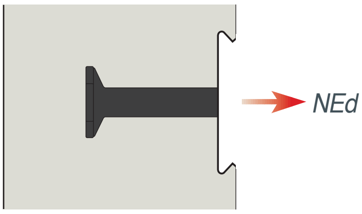
KSN Design Method for Connections Under Predominant Shear

Main Assumptions

- The design method assumes a single row of KSN Anchors positioned along the slab section centreline.
- The structural designer must ensure that the slab contains sufficient reinforcement to resist punching shear and edge failure, should this be required.
- Unless otherwise stated, slab and wall concrete are assumed as non-cracked in all calculation reports submitted by us.
- The slab is assumed as subjected to vertical shear loads and tie forces only: no provision is made for bending moments or lateral loads.
- Loads are static or quasi static.
- Minimum material requirements are:
  - Concrete strength class C30/37.
  - Reinforcement grade B500B or B500C to BS 4449:2005.

The design method comprises four steps:

Step 1: Determination of Tie Force and Corresponding KSN Tensile Capacity



- The minimum tie force required corresponds to the disproportional collapse requirements for Class 3 buildings according to UK Building Regulations: the value is set at 70 kN/m. **Value A**

- Clause 9.2.1.1 of BS EN 1992:2001 stipulates that the minimum area of longitudinal tension reinforcement should not be taken as less than either 0.26 (f_{ctm}/f_{yk}) b_t d or 0.0013 b_t d, whichever is the greatest, where: **Value B**

  b_t denotes the mean width of the tension zone and d denotes the height of the tension zone;

  f_{ctm} is taken as 2.9 for a strength class 30 concrete according to table 3.1 of BS EN 1992:2001;

  f_{yk} is the characteristic yield strength of the reinforcement bar used.

- Clause 9.2.1.4 of BS EN 1992:2001 stipulates that the area of bottom reinforcement provided at end supports with little or no fixity should be at least β2 multiplied by the area of steel provided in the span. For the UK, β2 is taken as 0.25. **Value C**

- The minimum cross-sectional area of steel [A_s] to provide to resist the tie force should be:

  Value B divided by 2, or

  Value C divided by 4, whichever is the greatest.

- The tie force for the given configuration of reinforcement in the slab is determined using the expression A_s f_{yk} / 1.15. **Value D**

Unless a higher value for the tie force has been specified, the minimum tie force NEd is the greatest of either Value A or Value D.

The tensile capacity NRd of the KSN system required to resist the tie force, expressed per linear metre of construction joint, is determined as follows:

- In accordance with clause 7.2.1.3 of BS EN 1992-4:2018, the tensile capacity for steel NRk,s is determined using the equation **Value E**

  $NRk,s = \Sigma_{KSN} A_s\ 1.15\ f_{yk} / \gamma_{Ms}$, where:

  Σ_{KSN} is the number of KSN anchors per linear metre of joint;

  γ_{Ms} is taken as 1.4.

  It must also be checked that the spacing of the KSN anchors matches the spacing of primary reinforcing bars within the slab section at the support location.

- In accordance with clause 7.2.1.5 of BS EN 1992-4:2018, the resistance against concrete pull-out NRk,p is governed by the equation **Value F**

  $NRk,p = \Sigma_{KSN}\ k2\ f_{ck}\ \pi/4\ (d_h^2 - d^2) / \gamma_{Mp}$ where:

  Σ_{KSN} is the number of KSN anchors per linear metre of joint;

  k_2 is taken as 7.5 for cracked concrete and 10.5 for non-cracked concrete;

  f_{ck} is the minimum concrete strength class, taken as 30;

  γ_{Mp} is taken as 1.2;

  d and d_h are, respectively, the KSN anchor shank diameter and head diameter.

- In accordance with clause 7.2.1.4 of BS EN 1992-4:2018, the resistance against concrete cone failure NRk,c is governed by the equation **Value G**

  $NRk,c = \Sigma_{KSN}\ k1\ \sqrt{f_{ck}}\ h_{eff}^{1.5}\ Ac,N/A^0c,N / \gamma_{Mp}$, where:

  Σ_{KSN} is the number of KSN anchors per linear metre of joint;

  k_1 is taken as 8.9 for cracked concrete and 12.7 for un-cracked concrete;

  f_{ck} is the minimum concrete strength class, taken as 30;

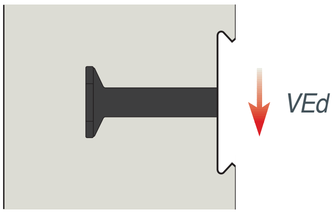
  h_{eff} is the embedment depth of the anchor;

  $Ac,N/A^0c,N$ is a measure of the geometric effect of axial spacing and edge distance on the characteristic resistance of the system: for headed anchors the expression $Ac,N/A^0c,N$ is taken as 1/3 h_{eff} ;

  γ_{Mp} is taken as 1.2;

The KSN tensile capacity NRd is the lesser of Values E, F and G. The equation NRd ≥ NEd must be verified.

Step 2: Determination of KSN Shear Capacity



- In accordance with clause 7.2.2.3.1 of BS EN 1992-4:2018, the shear capacity for steel VRk,s is determined using the equation **Value H**

  $VRk,s = \Sigma_{KSN}\ k_6\ A_s\ \ f_{uk} / \gamma_{Ms}$, where:

  Σ_{KSN} is the number of KSN anchors per linear metre of joint;

  k_6 is taken as 0.5;

  f_{uk} is the characteristic ultimate tensile strength of the Bartec Plus continuation bar, taken as 540 N/mm_2 for Grade B500B reinforcement and 575 N/mm_2 for Grade B500C reinforcement.

  γ_{Ms} is taken as 1.5.

- In accordance with clause 7.2.2.4 of BS EN 1992-4:2018 and clause 5.2.3.3 of ETAG 001-1997 Annex C, the resistance against concrete pry-out VRk,cp is governed by the equation **Value J**

  VRk,cp =k NRk,c,

  where k is taken as 2 for $h_{eff} \geq$ 60mm.

The KSN shear capacity VRd is the lesser of Values H and J. The equation VRd ≥ VEd must be verified.

Ancon KSN Anchor Box

Step 3: Available Shear Capacity for KSN System after Deduction of Tie Force

- In accordance with clause 7.2.3.1 of BS EN 1992-4:2018– table 7.3, the available capacity for steel VRd,s must fulfil the following equation: **Value K**

  $VRd,s = \sqrt{(1-(NEd / \text{Value E})^2)}$. Value H

- In accordance with clause 7.2.3.1 of BS EN 1992-4:2018 – table 7.3, the available capacity for concrete VEd,c must fulfil the following equations: **Value L**

  $VRd,c = (1-(NEd / (\text{min. of Value F and G}))^{1.5})^{2/3}$. Value J

- In accordance with clause 6.2.5 of BS EN 1992:2001, the available shear capacity at wall-slab interface is determined as follows: **Value M**

  $Ai\ .\ (c\ f_{ctd} + \mu\ \sigma_n\ + \rho\ f_{yd}\ (\mu \sin \alpha + \cos \alpha))$

  As in this specific instance c = 0 and $\sigma_n = 0$, the expression can be simplified as follows:

  $Ai\ .\ \rho\ f_{yd}\ (\mu \sin \alpha + \cos \alpha)$ where:

  ρ is equal to A_s / A_i, with A_s corresponding to the area of reinforcement crossing the interface, and A_i corresponding to the area of the joint;

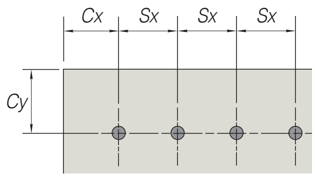
  f_{yd} is the design yield strength of the Bartec Plus continuation bars, taken as f_{yk} (500 N/mm²) / 1.15;

  μ is taken as 0.7 for the type of dimpled KSN Anchor Box used;

  α is taken as 90˚.

The KSN shear capacity after deduction of the tie force VRd,comb. is the lesser of Values K, L and M.
The equation VRd,comb. ≥ VEd must be verified.

Step 4: Anchor Spacing, Edge Distance Check and Local Reinforcement Detailing



Wall elevation

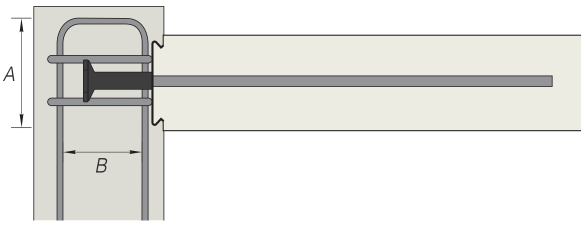
- The following anchor spacing and edge distances must be adhered to for guaranteed full design capacity:

  Sx min. = 1.5 h_{eff}

  Cx min. = Cy min. = 1.5 Sx min.

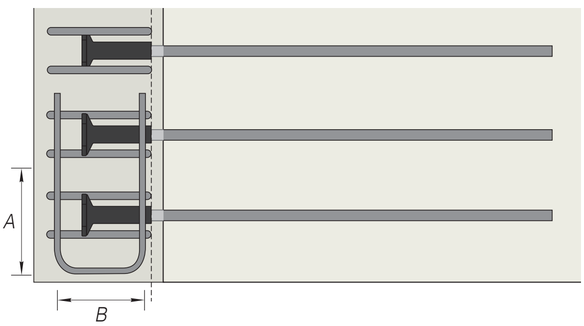
  For situations where Sx is less than 1.5 h_{eff} , the minimum tie force NEd defined in Step 1 above can be used.

  For situations where Cx and / or Cy are less than 1.5 Sx min., the following additional reinforcement must be used within the wall:



Side elevation

1 U-bar either side of each KSN anchor; cross-sectional area of reinforcement to match cross-sectional area of KSN continuation bar.



Plan

1 U-bar above and under each KSN anchor; cross-sectional area of reinforcement to match cross-sectional area of KSN continuation bar.

Anchor Ref.	Length L1 Required C32/40 Good Bond	Bad Bond
KSN12S KSN12M	690mm	950mm
KSN16S KSN16M KSN16L	910mm	1270mm
KSN20S KSN20M KSN20L	1110mm	1550mm

*Dimension A = L1
*Dimension B = wall thickness – 2 x concrete cover

Example Specification
In the design example on page 9, the KSN Anchor Box specified is:

KSN16S / KSN Anchor Box / Single Row / 190 / 200

i.e. KSN16S Anchors, a 190mm box width and a horizontal anchor spacing of 200mm.

A = 870mm and B = 175mm.

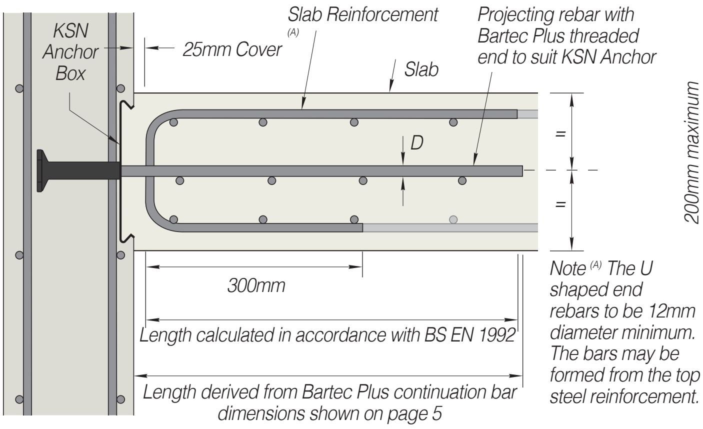
Design Example

Load condition:	**Vertical Shear with Nominal Horizontal Tie Force**
Wall depth:	225mm
Wall concrete:	C30/37
Minimum nominal tie force required:	70 kN/m – from page 6, Value A
Shear applied:	VEd = 155 kN/m
Slab thickness:	225mm
Reinforcement cover:	25mm
Slab top reinforcement at support:	H12 B500C at 200mm c/c (f_{yk} = 500 N/mm^2)
Slab bottom reinforcement in span:	H12 B500C at 200mm c/c (f_{yk} = 500 N/mm^2)
Step 1	**Determination of Tie Force and Corresponding KSN System Tensile Capacity**
Value B for a 1.00m length of slab is the greater of:	0.0013 b_t d = 0.0013 x 1000 x (225-25-(12/2)) = 252.2mm^2 0.26 (f_{ctm}/f_{yk}) b_t d = 0.26 x (2.9/500) x 1000 x (225-25-(12/2)) = 292.6mm^2 therefore Value B = 292.6mm^2
Slab top reinforcement at support:	H12 at 200mm c/c corresponds to 565.5mm^2 > 292.6mm^2, therefore OK
Value C for a 1.00m length of slab:	Value C for H12 at 200mm c/c top and bottom is 1,130.8mm^2
Minimum area of steel required across joint:	A_s is the greater of Value B divided by 2 and Value C divided by 4, i.e. 282.7mm^2
Value D for a 1.00m length of slab:	A_s f_{yk} / 1.15 = (282.7 x 500 / 1.15)/1000 = 122.9 kN/m
Minimum design tie force NEd:	the greater of Value A and Value D, i.e. 122.9 kN/m
Value E for a 1.00m length of slab:	verifying condition using KSN12S at 200mm c/c, NRk,s = (5 x π x 12^2/4 x 1.15 x 500 / 1.4)/1000 = 232.3 kN/m > 122.9 kN/m, therefore OK
Value F for a 1.00m length of slab:	assuming non-cracked concrete, KSN12 head A/F dimension 40.0mm; shank diameter 22.0mm NRk,p = 5 x (10.5 x 30 x π/4 (40^2 – 22^2)/1.2)/1000 = 1,150.4 kN/m
Value G for a 1.00m length of slab:	NRK,c = 12.7 x √30 x 124$^{1.5}$ x (1/(3 x 124))/1.2 = 215.2 kN/m
Determination of KSN system tensile capacity NRd:	the lesser of Values E, F and G i.e. 215.2 kN/m > NEd = 122.9 kN/m, therefore OK
Step 2	**Determination of KSN System Shear Capacity**
Value H for a 1.00m length of slab:	VRk,s = (5 x 0.5 x π x 12^2/4 x 575 / 1.5)/1000 = 108.4 kN/m < VEd = 155.0 kN/m, therefore KSN12S unsuitable verify condition for KSN16S at 200mm c/c: VRk,s = (5 x 0.5 x π x 16^2/4 x 575 / 1.5)/1000 = 192.7 kN/m
Re-assess Value E for KSN16S at 200mm c/c	NRk,s = (5 x π x 16^2/4 x 1.15 x 500 / 1.4)/1000 = 412.8 kN/m
Re-assess Value F for KSN16S at 200mm c/c	KSN16 head A/F dimension 53.0mm; shank diameter 28.0mm NRk,p = 5 x (10.5 x 30 x π/4 (53^2 – 28^2)/1.2)/1000 = 2,087.4 kN/m
Re-assess Value G for KSN16S at 200mm c/c (h_{eff} = 139.0mm)	NRK,c = 12.7 x √30 x 139$^{1.5}$ x (1/(3 x 139))/1.2 = 227.8 kN/m
Determination of KSN system tensile capacity NRd:	the lesser of Values E, F and G i.e. 227.8 kN/m > NEd = 122.9 kN/m, therefore OK
Value J for a 1.00m length of slab:	VRk,cp = 2 x Value G = 2 x 227.8 = 455.6 kN/m
Determination of KSN system shear capacity VRd:	the lesser of Values H and J i.e. 192.7 kN/m > VEd = 155.0 kN/m, therefore OK
Step 3	**Available Shear Capacity for KSN System after Deduction of Tie Force**
Value K for a 1.00m length of slab:	VRd,s = √(1-(122.9 / 412.8)^2) x 192.7 = 183.9 kN/m
Value L for a 1.00m length of slab:	VRd,c = (1-(122.9 / 227.8)$^{1.5}$)$^{2/3}$ x 455.6 = 325.4 kN/m
Value M for a 1.00m length of slab:	VRd,i = 190 x 0.7 x 5 x (π x 16^2/4)/(190 x 1000) x 500/1.15 = 306.0 kN/m
Determination of KSN system shear capacity after deduction of tie force VRd,comb	the lesser of Values K, L and M i.e. 183.9 kN/m > VEd = 155.0 kN/m , therefore OK
Step 4	**Anchor Spacing, Edge Distance Check and Local Reinforcement Detailing**
KSN16S anchor spacing 200mm c/c	as this is less than 1.5 x h_{eff} = 208.5mm, the tie force is limited to the minimum tie force for KSN12S at 200mm c/c i.e. 122.9 kN/m
Edge distances Cx and Cy	to avoid the use of local reinforcement must be greater than 1.5 Sx i.e. 300mm. if Cx or Cy is less than 300mm, provide 2 No. H12 U-bars * with dimensions as follows: A = 870mm B = 225 – (2 x 25) = 175mm * 1 No. each side of KSN anchor

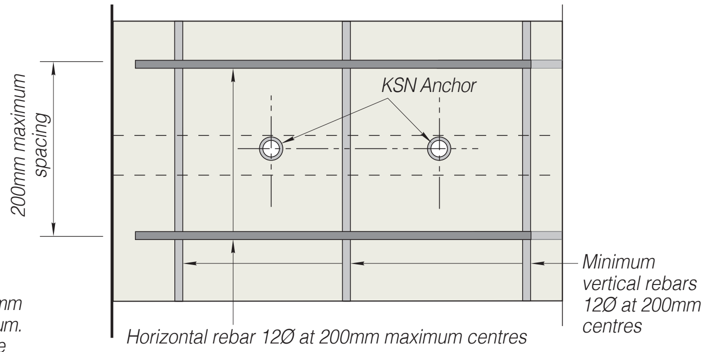
Ancon KSN Anchor Box

Reinforcement Details

Mid Slab Anchor Connection

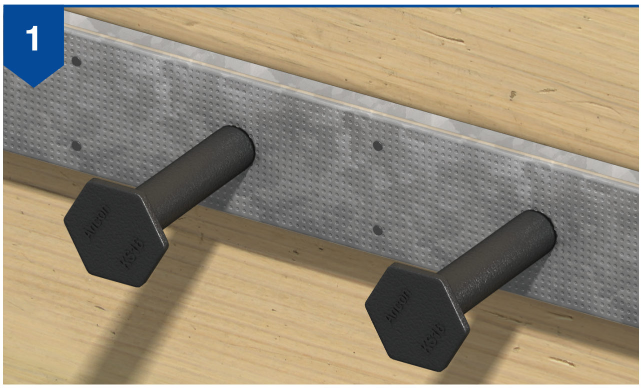


Wall-Part Edge Elevation



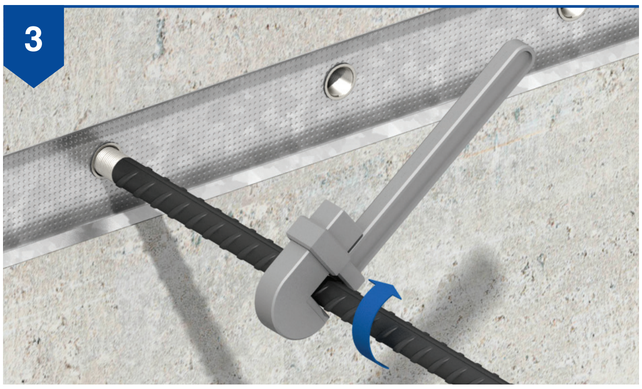
Installation Guidance

KSN Anchor Box



Nail the KSN Anchor Box to the formwork. The wall reinforcement is installed to which the anchors are tied. The concrete is cast and once it reaches sufficient strength, the formwork is removed to reveal the steel cover.

When a connection is required, the cover is removed and the bolts which held the Anchors to the box prior to installation are removed to reveal the threads.



The Bartec Plus parallel-threaded continuation bars are inserted into the KSN Anchors and hand-tightened until fully locked using a wrench. Lap and fix the slab reinforcement and pour the concrete to complete the installation.

Design Sheet - KSN Anchor Box

Please provide: contact details; project details and design conditions

1. Contact Details

Contact Name ....

Company ....

Address ....

....

Tel. ....

Email. ....

Project Name and Town. ....

....

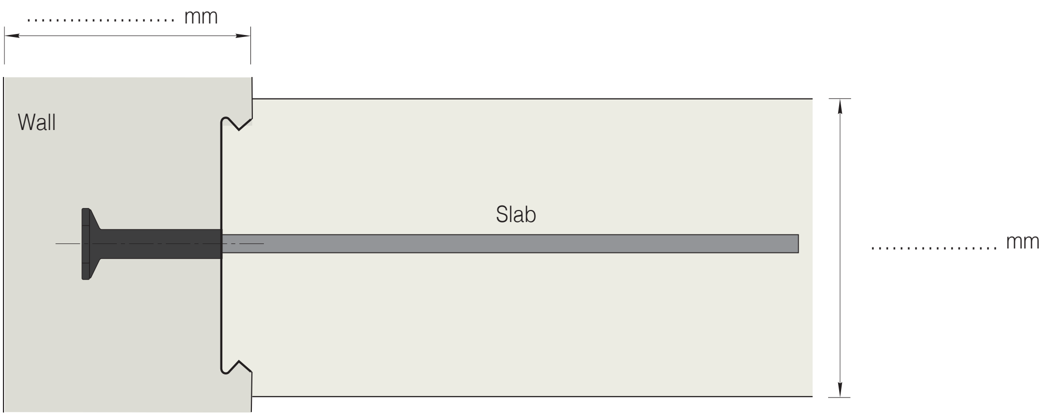
The following design assumptions are made unless advised otherwise:

- Reinforcement yield stress = 500 N/mm^2
- Standard KSN Anchor Box is used (15mm/17mm rebate depths)

Comments

2. Design Conditions

Please enter values in all boxes



Concrete grade	C .... /...............			
Slab top reinforcement provided at support	....	dia.@	.... centres	.... cover
Slab bottom reinforcement provided in span	....	dia.@	.... centres	.... cover
Vertical shear at joint VEd	....	kN/m ULS		
Horizontal tie force at joint T	....	kN/m ULS		

Email to reinforcement.uk@leviat.com
Leviat, President Way, President Park, Sheffield, S4 7UR, UK.
Tel: +44 (0) 114 238 5224, Web: Ancon.co.uk | Leviat.com

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