Design of Shear Connections using KSN Anchor Box
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- Halfen
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- Iosedio
- Plaka


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- Sales in 30+ locations
- 3000 people worldwide
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.

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.

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</tr>
</tbody>
</table>
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 torquing required
Reduces reinforcement congestion
EC2 indented construction joint
Independently-verified design method

KSN Anchor Technical Approval TA 5061
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 Anchor Dimensions

<table>
<thead>
<tr>
<th>Anchor Ref.</th>
<th>Nominal External Diameter (mm)</th>
<th>Metric Thread (mm)</th>
<th>Nominal Head Width (mm)</th>
<th>Nominal Head A/F (mm)</th>
<th>Anchor Length (mm)</th>
<th>Embedment h_eff* (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>KSN12S</td>
<td>22</td>
<td>M16 x 2.0</td>
<td>46</td>
<td>40</td>
<td>115</td>
<td>124</td>
</tr>
<tr>
<td>KSN12M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>150</td>
<td>159</td>
</tr>
<tr>
<td>KSN16S</td>
<td>28</td>
<td>M20 x 2.5</td>
<td>61</td>
<td>53</td>
<td>130</td>
<td>139</td>
</tr>
<tr>
<td>KSN16M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>160</td>
<td>169</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>190</td>
<td>199</td>
</tr>
<tr>
<td>KSN20S</td>
<td>32</td>
<td>M24 x 3.0</td>
<td>75</td>
<td>65</td>
<td>150</td>
<td>159</td>
</tr>
<tr>
<td>KSN20M</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>190</td>
<td>199</td>
</tr>
<tr>
<td>KSN20L</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>230</td>
<td>239</td>
</tr>
</tbody>
</table>

*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.

KSN Anchor Box Widths

<table>
<thead>
<tr>
<th>Box Width (mm)</th>
<th>Minimum Slab Thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>85</td>
<td>105</td>
</tr>
<tr>
<td>120</td>
<td>140</td>
</tr>
<tr>
<td>150</td>
<td>170</td>
</tr>
<tr>
<td>170</td>
<td>190</td>
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<tr>
<td>190</td>
<td>210</td>
</tr>
<tr>
<td>220</td>
<td>240</td>
</tr>
<tr>
<td>250</td>
<td>270</td>
</tr>
</tbody>
</table>
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.

Mid Slab Anchor Connection

Notes
Good bond conditions apply for hs ≤ 250mm
Bad bond conditions apply for hs > 250mm

* 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

<table>
<thead>
<tr>
<th>Anchor Ref.</th>
<th>Bar Diameter (D)</th>
<th>Thread Size (T)</th>
<th>Thread Length (TL)</th>
<th>Rebate Depth (RD)</th>
<th>EC2 Full Tension Lap C32/40 (Lp)</th>
<th>Length L1 Required C32/40</th>
<th>Minimum Bar Length (L)</th>
<th>Good Bond</th>
<th>Bad Bond</th>
<th>Good Bond</th>
<th>Bad Bond</th>
<th>Good Bond</th>
<th>Bad Bond</th>
</tr>
</thead>
<tbody>
<tr>
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<td>12mm M16</td>
<td>16mm</td>
<td>15mm</td>
<td>630mm</td>
<td>890mm</td>
<td>690mm</td>
<td>950mm</td>
<td>690mm + hs</td>
<td>950mm + hs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KSN12M</td>
<td>16mm M20</td>
<td>40mm</td>
<td>15mm</td>
<td>830mm</td>
<td>1190mm</td>
<td>910mm</td>
<td>1270mm</td>
<td>910mm + hs</td>
<td>1270mm + hs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KSN16S</td>
<td>16mm M20</td>
<td>40mm</td>
<td>15mm</td>
<td>830mm</td>
<td>1190mm</td>
<td>910mm</td>
<td>1270mm</td>
<td>910mm + hs</td>
<td>1270mm + hs</td>
<td></td>
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<tr>
<td>KSN16M</td>
<td>16mm M20</td>
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<td>15mm</td>
<td>830mm</td>
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<td>KSN20S</td>
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<td>24mm</td>
<td>17mm</td>
<td>1040mm</td>
<td>1480mm</td>
<td>1110mm</td>
<td>1550mm</td>
<td>1110mm + hs</td>
<td>1550mm + hs</td>
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</tr>
<tr>
<td>KSN20M</td>
<td>20mm M24</td>
<td>24mm</td>
<td>17mm</td>
<td>1040mm</td>
<td>1480mm</td>
<td>1110mm</td>
<td>1550mm</td>
<td>1110mm + hs</td>
<td>1550mm + hs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KSN20L</td>
<td>20mm M24</td>
<td>24mm</td>
<td>17mm</td>
<td>1040mm</td>
<td>1480mm</td>
<td>1110mm</td>
<td>1550mm</td>
<td>1110mm + hs</td>
<td>1550mm + hs</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.
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

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_{cmt}/f_{yk}) b_t b_d or 0.0013 b_t d, whichever is the greatest, where:
  - b_t denotes the mean width of the tension zone and d denotes the height of the tension zone;
  - f_{cmt} 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. Value B
- 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. Value D
- The tie force for the given configuration of reinforcement in the slab is determined using the expression A_s f_{yk} / 1.15.

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.
Step 2: Determination of KSN Shear Capacity

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

\[ NR_{k,s} = \sum_{KSN} A_s \frac{f_{uk}}{\gamma_{Ms}} \]

where:
- \( \sum_{KSN} \) is the number of KSN anchors per linear metre of joint;
- \( f_{uk} \) is the characteristic ultimate tensile strength of the Bartec Plus continuation bar, taken as 540 N/mm² for Grade B500B reinforcement and 575 N/mm² for Grade B500C reinforcement.
- \( \gamma_{Ms} \) 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 pry-out VRk,cp is governed by the equation

\[ VR_{k,p} = k \cdot NR_{k,c} \]

where:
- \( k \) is taken as 2 for \( h_{eff} \geq 60\text{mm} \).

The KSN shear capacity \( VRd \) is the lesser of Values H and J. The equation \( VRd \geq VEd \) must be verified.

The KSN tensile capacity \( NRd \) is the lesser of Values E, F and G. The equation \( NRd \geq NEd \) must be verified.
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:
  \[ VRd,s = \sqrt{1-(NEd / Value E)^2} \]. Value H

- In accordance with clause 7.2.3.1 of BS EN 1992-4:2018 – table 7.3, the available capacity for concrete VRd,c must fulfil the following equations:
  \[ VRd,c = (1-(NEd / (\text{min. of Value F and G}))^{1.5})^2/3 \]. 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:
  \[ Ai \cdot (c f_{ctd} + \mu \sigma_n + \rho f_{yd} (\mu \sin \alpha + \cos \alpha)) \]

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

\[ Ai \cdot \rho f_{yd} (\mu \sin \alpha + \cos \alpha) \]

where:
- \( \rho \) 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 \( f_{yk}(500 \text{ N/mm}^2) / 1.15 \);
- \( \mu \) is taken as 0.7 for the type of dimpled KSN Anchor Box used;
- \( \alpha \) 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

- The following anchor spacing and edge distances must be adhered to for guaranteed full design capacity:
  \( S_x \text{ min.} = 1.5 \text{ } h_{\text{eff}} \)
  \( C_x \text{ min.} = C_y \text{ min.} = 1.5 S_x \text{ min.} \)

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

For situations where \( C_x \) and/or \( C_y \) are less than 1.5 \( S_x \text{ min.} \), the following additional reinforcement must be used within the wall:

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

<table>
<thead>
<tr>
<th>Anchor Ref.</th>
<th>Length L1 Required C32/40</th>
<th>Good Bond</th>
<th>Bad Bond</th>
</tr>
</thead>
<tbody>
<tr>
<td>KSN12S</td>
<td>690mm</td>
<td>950mm</td>
<td></td>
</tr>
<tr>
<td>KSN12M</td>
<td>690mm</td>
<td>950mm</td>
<td></td>
</tr>
<tr>
<td>KSN16S</td>
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<td></td>
</tr>
<tr>
<td>KSN16M</td>
<td>910mm</td>
<td>1270mm</td>
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<tr>
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<td>910mm</td>
<td>1270mm</td>
<td></td>
</tr>
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<td>KSN20S</td>
<td>1110mm</td>
<td>1550mm</td>
<td></td>
</tr>
<tr>
<td>KSN20M</td>
<td>1110mm</td>
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<td></td>
</tr>
<tr>
<td>KSN20L</td>
<td>1110mm</td>
<td>1550mm</td>
<td></td>
</tr>
</tbody>
</table>

*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.

\( A = 870 \text{mm} \) and \( B = 175 \text{mm} \).
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/mm²)
Slab bottom reinforcement in span: H12 B500C at 200mm c/c (f_yk = 500 N/mm²)

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

Value C for a 1.00m length of slab:
Value C for H12 at 200mm c/c top and bottom is 1,130.8mm

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 12²/4 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:
KSN16 head A/F dimension 40.0mm; shank diameter 22.0mm
NRk,p = 5 x (10.5 x 30 x π/4 (40² – 22²)/1.2)/1000 = 1,150.4 kN/m

Value G for a 1.00m length of slab:
NRK,c = 12.7 x √30 x 139 x 1.5 x (1/(3 x 139))/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 12²/4 x 575 / 1.5)/1000 = 108.4 kN/m < VEd = 155.0 kN/m, therefore KSN12S unsuitable

Re-assess Value E for KSN16S at 200mm c/c:
NRk,s = (5 x π x 16²/4 x 575 / 1.5)/1000 = 192.7 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 (53² – 28²)/1.2)/1000 = 2,087.4 kN/m

Re-assess Value G for KSN16S at 200mm c/c:
NRK,c = 12.7 x √30 x 139 x 1.5 x (1/(3 x 139))/1.2 = 227.8 kN/m

Determination of KSN system shear capacity VRd:
the lesser of Values E, F and G i.e. 227.8 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)²) x 455.6 = 325.4 kN/m

Value M for a 1.00m length of slab:
VRd,i = (1-(122.9 / 306.0)²) x 306.0 = 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

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 = 670mm
B = 225 – (2 x 25) = 175mm
* 1 No. each side of KSN anchor
Installation Guidance

**KSN Anchor Box**

1. 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.

2. 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.

3. 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/mm²
- Standard KSN Anchor Box is used (15mm/17mm rebate depths)

2. Design Conditions

Please enter values in all boxes

Wall

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

Comments

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
Innovative engineered products and construction solutions that allow the industry to build safer, stronger and faster.
Worldwide contacts for Leviat:

Australia
Leviat
98 Kurrajong Avenue,
Mount Druitt Sydney, NSW 2770
Tel: +61 - 2 8808 3100
Email: info.au@leviat.com

Austria
Leviat
Leonard-Bernstein-Str. 10
Saturn Tower, 1220 Wien
Tel: +43 - 1 - 259 8770
Email: info.at@leviat.com

Belgium
Leviat
Industrielaan 2
1740 Ternat
Tel: +32 - 2 - 582 29 45
Email: info.be@leviat.com

China
Leviat
Room 601 Tower D, Vantone Centre
No. A6 Chao Yang Men Wai Street
Chaoyang District
Beijing · P.R. China 100020
Tel: +86 - 10 5907 3200
Email: info.cn@leviat.com

Czech Republic
Leviat
Business Center Šafínánova
Šafínánova 1238/1
155 00 Praha 5
Tel: +420 - 311 - 690 060
Email: info.cz@leviat.com

Finland
Leviat
Vädersgatan 5
412 50 Göteborg / Sweden
Tel: +358 (0)10 633 8781
Email: info.fi@leviat.com

France
Leviat
6, Rue de Cabanis
FR 31240 L’Union
Toulouse
Tel: +33 - 5 - 34 25 54 82
Email: info.fr@leviat.com

Germany
Leviat
Liebigstrasse 14
40764 Langenfeld
Tel: +49 - 2173 - 970 - 0
Email: info.de@leviat.com

India
Leviat
309, 3rd Floor, Orion Business Park
Ghodbunder Road, Kapurbawdi,
Thane West, Thane,
Maharashtra 400607
Tel: +91 - 22 2589 2032
Email: info.in@leviat.com

Italy
Leviat
Via Fili Bronzetti 28
24124 Bergamo
Tel: +39 - 035 - 0760711
Email: info.it@leviat.com

Malaysia
Leviat
28 Jalan Anggerik Mokara 31/59
Kota Kemuning, 40460 Shah Alam
Selangor
Tel: +603 - 5122 4182
Email: info.my@leviat.com

Netherlands
Leviat
Oostermaat 3
7623 CS Borne
Tel: +31 - 74 - 267 14 49
Email: info.nl@leviat.com

New Zealand
Leviat
2/19 Nuttall Drive, Hillsborough,
Christchurch 8022
Tel: +64 - 3 376 5205
Email: info.nz@leviat.com

Norway
Leviat
Vestre Svanholmen 5
4313 Sandnes
Tel: +47 - 51 82 34 00
Email: info.no@leviat.com

Philippines
Leviat
2933 Regus, Joy Nostalg,
ADB Avenue
Ortigas Center
Pasig City
Tel: +63 - 2 7957 6381
Email: info.ph@leviat.com

Poland
Leviat
Ul. Obornicka 287
60-691 Poznań
Tel: +48 - 61 - 622 14 14
Email: info.pl@leviat.com

Singapore
Leviat
14 Benoi Crescent
Singapore 629977
Tel: +65 - 6266 6802
Email: info.sg@leviat.com

Spain
Leviat
Poligono Industrial Santa Ana
c/ Ignacio Zuloaga, 20
28822 Rivas-Vaciamadrid
Tel: +34 - 91 632 18 40
Email: info.es@leviat.com

Sweden
Leviat
Vädursgatan 5
412 50 Göteborg
Tel: +46 - 31 - 98 58 00
Email: info.se@leviat.com

Switzerland
Leviat
Grenzstrasse 24
3250 Lyss
Tel: +41 - 31 750 3030
Email: info.ch@leviat.com

United Arab Emirates
Leviat
RA08 TB02, PO Box 17225
JAFZA, Jebel Ali, Dubai
Tel: +971 (0)4 883 4346
Email: info.ae@leviat.com

United Kingdom
Leviat
President Way, President Park,
Sheffield, S4 7UR
Tel: +44 - 114 275 5224
Email: info.uk@leviat.com

United States of America
Leviat
6467 S Falkenburg Rd.
Riverview, FL 33578
Tel: (800) 423-9140
Email: info.us@leviat.us

For countries not listed
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For more information on these products, contact:

Leviat
President Way
President Park
Sheffield, S4 7UR
United Kingdom
Tel: +44 (0) 114 275 5224
Fax: +44 (0) 114 276 8543
Email: info.ancon.uk@leviat.com

For sales and technical enquiries:
Email: reinforcement.uk@leviat.com
Ancon.co.uk
Leviat.com