JORDAHL® Punching Shear Reinforcement JDA
For Everyone Who Needs More Space in Less Time.

Technical Information
Quality since 1907.

The JORDAHL Company

JORDAHL connects: concrete, steel, heavy loads and a whole lot more. And of course numerous customers around the world who have already decided to use high-quality and individual products from fastening, reinforcement, connection, and mounting technology and facade connection systems. Customers who choose JORDAHL want more – higher quality, broader choice, better technical advice, wider experience. The company was founded in Berlin in 1907 and since that time we have been at the forefront of connection and reinforcement technology development. JORDAHL products such as anchor channels have become milestones in the evolution of structural engineering and have brought lasting changes to construction, shaping the way buildings are designed and making them safer, not just in Germany.

The JORDAHL Seal

JORDAHL has over 100 years of unique experience in the market. This experience forms the basis of our expertise and high standards. Whether high-quality products, service or consulting – we aim to do everything for our customers to the same demanding standard of excellence. This is what the JORDAHL seal stands for. It is a guarantee of quality for our customers and also the standard that we strive to adhere to each and every day.

The Invention of the Kahn Steel Reinforcement System

The German-born structural engineer Julius Kahn revolutionised construction with concrete with the invention of the Kahn steel reinforcement system – a steel reinforcement system with connecting stays or side “wings”. Using these, his brother Albert Kahn, one of the most prominent industry architects of his time, erected a few of his spectacular structures. In 1907 the Kahn steel reinforcement system finally arrived in Europe: the Swedish structural engineer Ivar Kreuger had secured the European rights and on that basis, together with his friend, the Norwegian structural engineer Anders Jordahl, founded the company “Deutsche Kahneisen Gesellschaft Jordahl & Co.” in Berlin. The Kahn steel reinforcement system, forerunner of today’s punching shear reinforcement, became a successful product on the booming German construction market, and the foundation on which JORDAHL’s success was built.
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Introduction to Punching Shear Reinforcement

Flat slab structures with large spans between supporting columns allow optimum use of factory or warehouse buildings with large floor space.

Even in the early days of concrete structures, the problem of punching shear at the column head area was already recognized (Fig. 1). Mushroom construction was introduced in around 1900 as a way of avoiding the arrangement with main transverse and auxiliary beams (Fig. 2).

Only a short time later the Kahn steel reinforcement system (Fig. 3) was used as tensile reinforcement. It possessed upturned wings which resisted transverse forces in the ceiling support area. The inventor of the Kahn steel reinforcement system, Julius Kahn, and his brother, the famous architect Albert Kahn, enjoyed great success with this product in the field of construction with reinforced steel concrete.

Using conventional methods it is often not possible to achieve thin slabs and wide spans between supporting columns or large slab breakthroughs close to the supporting column heads (Fig. 4). As an alternative, Andrä et al. have developed a solution in which the area at risk of punching shear is dowelled using dowel strips.

This solution was further developed for punching shear anchoring made from reinforcing steel with two swaged heads (Fig. 5) in each case. Following the introduction of the Eurocode, a fundamental reworking of the approval process became necessary. The current European Technical Approval ETA-13/0136 corresponds to the latest state of knowledge and is successfully applied in a number of areas.
Advantages of JORDAHL® Punching Shear Reinforcement JDA

For flat slab structures and foundations, JORDAHL® punching shear reinforcement JDA is used to transfer high transverse forces with low formwork and reinforcement requirements and also to optimise the use of space. The punching shear resistance can thus be increased by 50% when compared to foundations without punching shear reinforcement, even by 96% compared to ceiling slabs without punching shear reinforcement.

- European Technical Approval for static and dynamic effects (ETA-13/0136)
- concrete strengths C20/25 to C50/60
- design according to the safety concept of the Eurocode
- asymmetrical load applications are accurately taken into account for all support positions
- defined transition between punching shear and transverse force load-bearing capacity
- increase in load-bearing capacity compared to flat slabs and foundations without punching shear reinforcement
- suitable from a slab thickness of 18 cm
- level slab underside
- unimpeded construction below the slab
- optimum use of space
- higher load-bearing capacity than conventional reinforcement techniques
- low construction height of the concrete slabs
- simplified arrangement of the strips through arrangement of standard elements in a row
- reduced formwork requirements
- can be installed quickly and easily from above and below
- flexible fabrication depending on static requirements

The JORDAHL® punching shear reinforcement JDA are made of double-headed anchors which are connected by a perforated connecting strip. The double-headed anchors secure the transition between punching shear and transverse load-bearing capacity.

Material
The double-headed anchors are made of B500B steel, and the perforated connecting strip is also made of structural steel.
Design According to ETA-13/0136

A fundamental of the design against punching shear is a clear separation of flat slabs and foundations. The design is regulated in the European Technical Approval ETA-13/0136.

Summary of Proofs

Round Cut Guide

For Flat Slabs

For Foundations

Conditions: \( u_0 \leq 12 \, d \)
\( h \geq 180 \, \text{mm} \)
\( b \leq a \leq 2 \) for rectangular supports

For edge and corner supports the round cut is guided perpendicularly to the free edge (cf. example on page 13). However, the smallest, critical round cut is decisive.
Design Load

For Flat Slabs

\[ v_{ed} = \frac{\beta \times V_a}{u \times d} \quad [N/mm^2] \]

For Foundations

\[ v_{ed} = \frac{\beta \times V_{ed,red}}{u \times d} \quad [N/mm^2] \]

Load-Increase Factor

Simplified values are possible for support conditions for adjacent fields in the area \(0.8 < l_1/l_2 < 1.25\).

\[ \begin{align*}
\sigma_{od} & : \text{soil pressure} \\
A_f & : \text{contact area of the foundation; for foundation slabs the area delimited by the bending moment zero-points running in the radial direction}
\end{align*} \]

Alternatively or for a support span ratio of more than 25%, the more accurate process on the basis of a fully plastic shear stress distribution from EN 1992-1-1 can be used. The process with a reduced critical round cut is not admissible.

Punching Shear Resistance without Punching Shear Reinforcement

For Flat Slabs

\[ v_{ed,c} = C_{Rd,c} \times \kappa \times \left(100 \times \rho_l \times f_{ck}\right)^{1/3} \times v_{min} \quad [N/mm^2] \]

Size factor \( \kappa = 1 + \frac{200 \text{ mm}}{d} \quad \leq 2.0 \)

Longitudinal reinforcement ratio \( \rho_l = \sqrt{\rho_h \times \rho_v} \leq \begin{cases} 
0.5 \times f_{yd}/f_{cd} \\
0.02
\end{cases} \)

Minimum resistance \( v_{min} = \begin{cases} 
0.0525 \frac{\gamma_c}{\kappa} \times \sqrt{k^3 \times f_{ck}} & \text{for } d \leq 600 \text{ mm} \\
0.0375 \frac{\gamma_c}{\kappa} \times \sqrt{k^3 \times f_{ck}} & \text{for } d > 800 \text{ mm}
\end{cases} \)

Empirical Factor – For Flat Slabs

\[ C_{Rd,c} = \begin{cases} 
0.18 \frac{\gamma_c}{\kappa} & \text{for } u_0 \geq 4d \\
0.18 \frac{0.1 \times u}{d} + 0.6 & \begin{cases} 
0.15 \frac{\gamma_c}{\kappa} & \text{for } u_0 < 4d
\end{cases}
\end{cases} \]

Empirical Factor – For Foundations

\[ C_{Rd,c} = \begin{cases} 
0.15 \frac{\gamma_c}{\kappa} & \text{for compact foundations with } a_z \leq 2.0 \text{ d} \\
0.18 \frac{0.6 \times u}{d} & \begin{cases} 
0.18 & \text{for slender foundations with } a_z > 2.0 \text{ d}
\end{cases}
\end{cases} \]
Punching Shear Resistance with Double-Headed Anchors

For Flat Slab

\[ v_{Rd,max} = 1.96 \, v_{Rd,c} \, [N/mm^2] \]

For Foundations

\[ v_{Rd,max} = 1.50 \, v_{Rd,c} \, [N/mm^2] \]

Design in Area C or 0.8 d

For Flat Slab

\[ V_{bd,sy} = m \times n \times \frac{d^2 \times \pi \times f_{yd}}{4 \times \eta} \, [kN] \]

Slab thickness factor:

- \( h = 1.0 \) for \( d \leq 200 \, mm \)
- \( h = 1.6 \) for \( d \geq 800 \, mm \)

For Foundations

\[ V_{Rd,sy} = f_{yd} \times A_{s,0.8d} \, [kN] \]

\( A_{s,0.8d} \): steel cross-sectional area of the double-headed anchors in the area 0.8 d

\( f_{yd} \): design yield strength of the double-headed anchors

External Round Cut

\[ v_{bd,ca} = 0.15 \times \frac{1}{\gamma_c} \times (100 \times \rho_x \times f_{ck})^{1/3} \geq v_{\min} \, [N/mm^2] \]

Reduced Load-Increase Factor:

<table>
<thead>
<tr>
<th>Internal supports, wall ends, wall corners</th>
<th>Edge supports</th>
<th>Corner supports</th>
</tr>
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<tbody>
<tr>
<td>( \beta_{red} = \beta \geq 1.10 )</td>
<td>( \beta_{red} = \frac{\beta}{1.2 + \beta \times \frac{l}{d}} \geq 1.10 )</td>
<td>( \beta_{red} = \frac{\beta}{1.2 + \beta \times \frac{l}{d}} \geq 1.10 )</td>
</tr>
</tbody>
</table>

For Flat Slab

\[ u_{\text{set}} = \frac{\beta_{red} \times V_{td}}{v_{bd,ca} \times d} \]

For Foundations

\[ u_{\text{set}} = \frac{\beta_{red} \times V_{td,red}}{v_{bd,ca} \times d} \]

\[ V_{td,red} = V_{td} \times \sigma_{td} \times A_{set} = V_{td} \left( 1 - \frac{A_{set}}{A_{f}} \right) \, [kN] \]
Admissible Anchor Separations

For Flat Slab
- the first anchor is located between 0.35 d and 0.5 d from the support
- the radial anchor spacing may not exceed 0.75 d
- the maximum spacing of the anchors in the tangential direction at a spacing of 1.0 d from the support must be ≤ 1.7
- the tangential anchor spacing in area D may not exceed 3.5 d

For Foundations
- the first anchor is located 0.3 d from the support, the second anchor 0.8 d from the support
- the radial anchor spacing may not exceed 0.75 d for slender foundations and 0.5 d for compact foundations
- the tangential anchor spacing may not exceed 2.0 d
Schematic Layout

Shared Standard Elements in Flat Slabs

Piece-wise standard elements in flat slabs

edge of the anchor-reinforced slab area

additional element to fulfil the spacing regulations in area D

hₙ: anchors per element row in the area

m₀ or m₁: number of rows of elements in area C or D

eexternal proof cut

≤ 1.7d

≤ 3.5d

≤ 0.75d

≤ 0.75d

≤ 0.75d

≥ 0.35d

≤ 0.375 d

≤ 0.75d

≤ 0.75d

≤ 0.75d

≥ 0.35d

≤ 0.375 d

Section A-A

"Installation from above" strip above the upper reinforcement layer

"Installation from below" strip below the lower reinforcement layer

h: slab thickness
d: effective depth
cᵤ: upper concrete cover
cᵦ: lower concrete cover
hᵢₐ: anchor height
lₛ: strip-reinforced area
Continuous Elements in Flat Slabs

Section A-A

"Installation from above"
strip above the upper reinforcement layer

"Installation from below"
strip below the lower reinforcement layer

edge of the anchor-reinforced slab area

additional element to fulfil the separation regulations in area D

m₁ or m₂
number of rows of elements in area C or D

n₁ anchors per element row in the area

external proof cut

≤ 1.7d

≤ 3.5d

≤ 0.75d

≤ 0.75d

≤ 0.5d

≥ 0.35d

≤ 0.5d

≤ 1.125d

area C

area D

1.0 d

l₅

1.5 d

≤ 0.75 d

≤ 0.75 d

≤ 0.5d

≥ 0.35d

≤ 0.5d

≥ 0.35d

1.0 d

l₅

≤ 0.75 d

≤ 0.75 d

≤ 0.5d

≥ 0.35d

≤ 0.5d

sₐ

sₐ

0.5d
Continuous Elements in Footings and Ground Slabs

Compact foundation: \( \frac{a}{d} \leq 2.0 \)

Slender foundation: \( \frac{a}{d} > 2.0 \)

**Section A-A**

- "Installation from above": Strip above the upper reinforcement layer
- "Installation from below": Strip below the lower reinforcement layer

1.5d
0.8d
0.8d
1.5d

\( \leq 0.5d \)
\( \leq 0.75d \)

\( 0.3d \)

\( \leq 0.5d \)
\( \leq 0.75d \)

\( l \)

\( \frac{c}{2} \) or \( \frac{c}{2} \)

\( \frac{cx}{2} \) or \( \frac{cy}{2} \)

\( a \)

\( d \)
**Calculation Example**

1. **Given values:**
   - Slab height \( h = 350 \text{ mm} \)
   - Effective static depth \( d = 305 \text{ mm} \)
   - Concrete C35/45
   - Reinforcement ratio \( \rho = 1.0\% \)
   - Punching shear load \( V_{Ed} = 800 \text{ kN} \)

   Round cut normal to the edge:
   \[
   u_1 = 2 \times 300 + 2 \times 400 + 2 \times 200 + 2.0 \times \pi \times 305 = 3316 \text{ mm} < 5233 \text{ mm}
   \]
   Full round cut:
   \[
   u_1 = 2 \times 300 + 2 \times 400 + 2 \times 2.0 \times \pi \times 305 = 5233 \text{ mm}
   \]

2. **Punching shear verifications**
   2.1 Minimum resistance
   \[
   V_{min} = \frac{1}{1.50} \times \sqrt{(1.81^3 \times 35.00 \text{ N/mm}^2) \times 0.0525} = 0.50 \text{ N/mm}^2
   \]
   2.2 Critical round cut
   \[
   V_{Ed} = 1.40 \times 800.00 \text{ kN} / (3316 \text{ mm} \times 305 \text{ mm}) = 1.11 \text{ N/mm}^2
   V_{Ed,c} = \max \left[ 0.12 \times 1.81 \times (100 \times 0.0100 \times 35.00 \text{ N/mm}^2)^{1/3}; 0.50 \text{ N/mm}^2 \right] = 0.71 \text{ N/mm}^2
   V_{Ed,\max} = 1.96 \times 0.71 \text{ N/mm}^2 = 1.39 \text{ N/mm}^2
   V_{Ed} / V_{Ed,c} = 1.56 > 1 \quad \text{JDA required}
   V_{Ed} / V_{Ed,\max} = 0.80 \leq 1 \quad \text{OK}
   \]
   2.3 Area C
   \[
   \beta \cdot V_{Ed} = 1120.00 \text{ kN}
   V_{Ed,sy} = 4 \times 2 \times 490.87 \text{ mm}^2 \times 434.78 \text{ N/mm}^2 / 1.11 = 1545.15 \text{ kN}
   \beta \cdot V_{Ed} / V_{Ed,sy} = 0.72 \leq 1 \quad \text{OK}
   \]
   2.4 External round cut
   \[
   l_s = 770 \text{ mm}
   V_{Ed} = 1.10 \times 800.00 \text{ kN} / (5256 \text{ mm} \times 305 \text{ mm}) = 0.55 \text{ N/mm}^2
   V_{Ed,ca} = \max \left[ 0.10 \times 1.81 \times (100 \times 0.0100 \times 35.00 \text{ N/mm}^2)^{1/3}; 0.50 \text{ N/mm}^2 \right] = 0.59 \text{ N/mm}^2
   V_{Ed} / V_{Ed,ca} = 0.93 \leq 1 \quad \text{OK}
   \]

3. **Selected strip elements**
   8 \( JDA-2/25/295-440 \) (110/220/110)

Dimensioning can be undertaken with the aid of the software JORDAHL® EXPERT Punching shear reinforcement JDA.
The basis for the program is the European Technical Approval ETA-13/0136 based on the Eurocode 2 (EN 1992-1-1).

**Advantages**
- The most cost-effective solution is displayed first
- Fast and clear entry of load specifications
- Simple entry and structuring of projects
- Printout of a verifiable structural calculation
- Design load case earthquakes and fatigue
- 3D view of the support
- Interactive insertion of edges
- Influence of entered data is immediately visible and understandable
- For static calculation of site-placed concrete slabs, foundation slabs, precast planks/topping slabs and foundation blocks

**Settings**
Via Options / Settings users can define how the results of the calculations are determined:
- Split standard elements
- Piece-wise standard elements
- Optimised separated elements
- Continuous standard elements

**Type of Support**
- Inner, edge and corner supports
- Ends of walls and inner corners of walls

**Load Increase**
For the load increase factor $\beta$ three selection possibilities exist:
- Constant factor according to ETA-13/0136
- Fully plastic shear stress distribution
- User-defined entry

**Earthquake**
The minimum degree of reinforcement for transverse forces is calculated in accordance with DIN 4149, and a detailed and easy to follow proof is provided.

**Recesses**
The effectiveness of the recess is checked automatically
- Recesses can be easily inserted or moved at the click of a mouse
- The program automatically detects overlapping recesses
- Manual entry of lengths to be subtracted for round cut
- Direct correction of measured values within the drawing
- The locations of the opening are included on the printout of the recesses
Result
The presentation of the punching shear area in the plan view and the cross-sectional view provides an immediate overview of the arrangement of the JDA elements. Advantages:
- verifiable printout of result
- interim results, final results and proofs can be followed and understood very easily (punching shear, earthquake and bond proof)
- graphic result can be transmitted as *.DXF data file or *.DWG data file.

Printout of Result
Reproducible and comprehensive design printout with all of the information relevant to the test.

Manual Arrangement
JDA elements can be moved manually at the click of a mouse.

Parts List / Invitation to Tender Form
All calculated items can be added to the parts list, which can also be called up as an ordering list. In addition, an invitation to tender form is automatically generated.

Bond Proof
The load-bearing capacity of the mounting and shear lattice girders can be calculated. The bond proof is carried out cost-effectively taking into account the double-headed anchors and lattice girders (expert report from RWTH Aachen). The provided output is a meaningful printout of the results.

Determination of the Punching Shear Load
The punching shear load can be estimated with the aid of load collection surfaces.
Positioning of the JDA Reinforcing Elements
For site-placed concrete ceilings we recommend installing the JDA elements from above. They can be positioned after completion of the entire reinforcement assembly.

Safe Height Positioning
The double-headed anchors extend through the reinforcement layers.

Alignment of the Strip Overhang to the Edge of the Supporting Column
It is possible to check the position of the JDA elements and to correct them as required.

Concreting the Slab
After alignment of the JDA elements the slab can be concreted.
Installation in Site-Placed Concrete

The JDA elements can be inserted in site-placed concrete optionally with the strips facing either up or down. In all cases the heads of the JDA anchors must extend through both layers of the bending reinforcement.

Pre-assembly with JDA-Q Installation Aids

1) Installation from above:
   If the JDA reinforcing elements are arranged parallel to the upper reinforcement layer, the JDA-Q installation aid should be used and fastened with cotter pins.

2) Installation from below:
   JDA-Q installation aids can also be used here in order to improve the stability of the elements. The AH-DA spacers must be used in order to achieve the required concrete cover.

Note

Prior to installation, please compare the anchor diameters, anchor spacing and anchor height with the specifications in the formwork and reinforcement plans: the lower anchor heads must reach at least as far as the lower edge of the lowest reinforcement layer, the upper anchor heads at least as far as the upper reinforcement layer. All of the anchors used in the punching shear area of a supporting column must have the same diameter.

Layout

The reinforcing elements should be positioned in accordance with the planning requirements. If asymmetrical elements are used, the section marked in blue must be positioned facing the support.

The first strip protrusion is positioned flush against the edge of the support. If several standard elements are arranged in a row, the strips must butt up flush.

AH-DA Spacers

Suitable AH-DA spacers must be used for the installation of the JDA elements on the formwork. JORDAHL® offers spacers for concrete covers of 15, 20, 25, 30 and 35 mm.
The JDA-FT-KL system has been specially developed for precast plank / topping slabs: the JDA elements are supplied unmounted, i.e. together as a kit comprising the anchors + connecting strips + spacers. This avoids any disruption of the automatic manufacturing process and prevents any fouling between the bending reinforcement and lattice girder with the JDA elements. On the construction site, the upper reinforcing layer can be installed without additional work and without assembly strips which get in the way.

**Advantages during Installation**
- all parts of the element are supplied together as a kit
- colour coding is used to ensure clear assignment of components
- easy “click” installation even over longer distances
- anchor spacing always matches the quality requirements exactly
- no prohibited deviation in the anchor spacing
- spacers can be used universally
- the ceiling slab is ready for transport after concreting, no finishing is required
- perfect for keeping in storage
- technical training provided by JORDAHL employees, quality agreement

**FBA Spacers**
Suitable spacers have to be used for installation of the JDA elements in the prefabricating plant. JORDAHL offers fibre reinforced concrete spacers for concrete covers of 15, 20, 25 and 30 mm.

**AH-FT Spacers**
Alternatively, plastic AH-FT spacers are available for installation of the JDA elements in the prefabricating plant. Each spacer can be used variably for four different thicknesses of concrete cover (c = 15, 20, 25 and 30 mm). These components offer maximum flexibility whilst minimizing storage space requirements.
Standard Elements Product Range

Punching Shear Reinforcement JDA, Dual Element

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Connecting strip length l_L

Is the size or design you require not included? No problem! Simply contact our JORDAHL experts, e.g. by e-mail at experten@jordahl.de. They provide friendly, fast and competent advice, and will also gladly develop an individual solution for your very specific application.

x on order: length according to customer request
- not possible
- elements in stock, e.g. strip length 220 mm
- product range JDA-FT-KL, only up to d_A 16 mm
other anchor lengths on request
Service

Ordering Examples

Standard Element (with 2 or 3 Anchors)

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<tr>
<th>Type</th>
<th>Number of anchors</th>
<th>Anchor dA</th>
<th>Anchor length hA</th>
<th>Connecting strip length lL</th>
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Continuous Element

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JDA-FT-KL (for Semi-Prefabricated Slab)
(for precast planks/topping slabs)

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Spacer AH-DA

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Installation Instructions/Videos
In order to obtain the best results when using JORDAHL products, various installation instructions and 3D videos are available at www.jordahl.de.

Invitation to Tender Forms
The pre-printed invitation to tender forms for all JORDAHL product ranges are available from www.jordahl.de with all of the relevant technical information on material, load-bearing capacity, sizes, as well as installation instructions.
The data can be exported, for example in GAEB format, and sent as an e-mail attachment or stored as a data file.

Catalogues
Are you interested in other JORDAHL products or would you like additional information on a specific product? Why not access our website? There are numerous brochures available to download from www.jordahl.de ➔ download.

Approval
The JORDAHL® punching shear reinforcement JDA has the European Technical Approval (ETA-13/0136). This is available to download from www.jordahl.de.
JDA Punching Shear Reinforcement

Sender: ____________________________  Address: ____________________________

Company: ____________________________  ____________________________

Contact Person: ____________________________  ____________________________

Tel/Fax: ____________________________  ____________________________

Construction Project: ____________________________  ____________________________

Space for a Diagram of the Distances between Supporting Edges and the Type of Support

Request for a Design Proposal:

The following starting data are required in order to perform a verifiable calculation:

Concrete Strength  \( C_{\text{___/_______}} \)

Supporting Column dim.  \( a / b = \text{_______ cm} \)

Slab Dimensions  \( h = \text{_______ cm} \)

\( c_{o}/c_{u} = \text{_______ cm} \)

Punching Shear Load:  \( V_{\text{Ed}} = \text{_______ kN} \)

Dynamic Load Range  \( V_{\text{Ed, dyn}} = \text{_______ kN} \)

Reinforcement Ratio  \( \rho = \text{_______ \%} \)

or detailed reinforcement specifications:

Resulting moment load on the supporting column (where known): \( \text{_______ kNm} \)
Advice

The JORDAHL Experts
You are always well advised when you choose JORDAHL products. Whether from the point of view of static calculations, general technical advice/service or the development of customised solutions – competent and experienced JORDAHL product specialists offer you state-of-the-art, flexible and customised solutions for all your needs.

Throughout Europe and Around the World
JORDAHL products have proven themselves in use around the world because German quality standards are in demand everywhere. We can also guarantee perfect delivery of our products to you thanks to our reliable logistics partners and a perfectly functioning logistics chain (certified in accordance with DIN EN ISO 9001), because personalised, high-quality, customer-focused service is essential to us when it comes to delivery, too.