WÜRTH GROUP

RETROFITTING SYSTEM FOR IMPROVING THE PUNCHING SHEAR AND SHEAR CAPACITY OF REINFORCED CONCRETE ELEMENTS

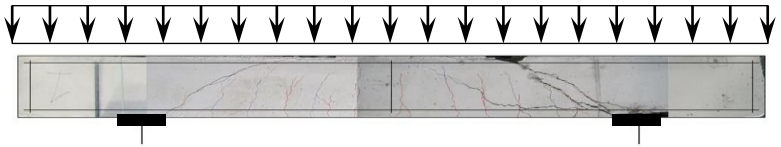
The RELAST system

Dr. Jochen Buhler

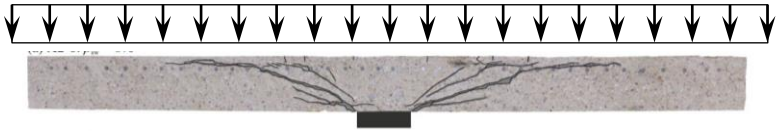
UN STOPP ABLE TOGETHER

STRENGTHENING WITH THE RELAST SYSTEM?

- **Shear resistance** of existing reinforced concrete (RC) elements.
- **Beam**



- **Punching shear resistance** of existing reinforced concrete (RC) elements.
- **Flat slab**



STRENGTHENING WITH THE RELAST SYSTEM?

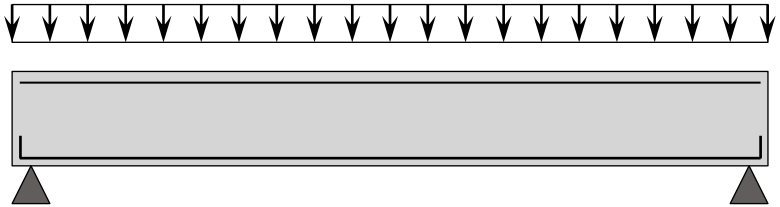
- **Shear resistance** of existing reinforced concrete (RC) elements.
- **Punching shear resistance** of existing reinforced concrete (RC) elements.

- **Beam**

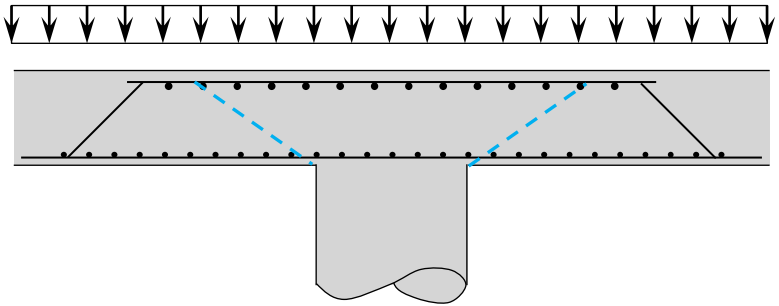
- **Flat slab**

STRENGTHENING WITH THE RELAST SYSTEM?

- **Shear resistance** of existing reinforced concrete (RC) elements.
- Beam **without** shear reinforcement

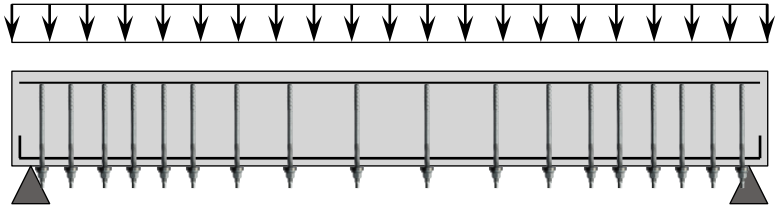


- **Punching shear resistance** of existing reinforced concrete (RC) elements.
- Flat slab **without** punching shear reinforcement



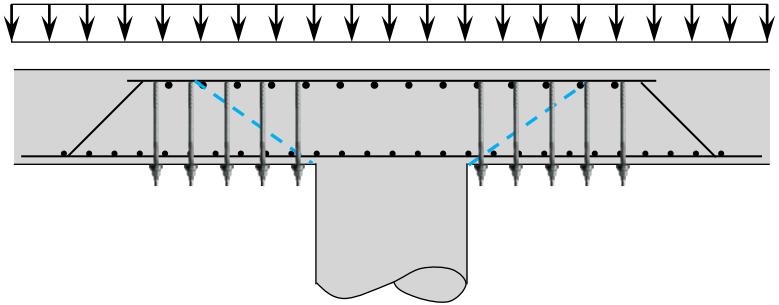
STRENGTHENING WITH THE RELAST SYSTEM?

- **Shear resistance** of existing reinforced concrete (RC) elements.
- Beam **with post-installed bonded concrete screw anchors used as shear** reinforcement



- **up-to 100% against "without shear reinforcement"**

- **Punching shear resistance** of existing reinforced concrete (RC) elements.
- Flat slab **with post-installed bonded concrete screw anchors used as punching shear** reinforcement



- **up-to 40% against "without shear reinforcement"**

THE RELAST SYSTEM? THE COMPONENTS.

Metric Hex Nut

Wedge lock washer

Pressure washer

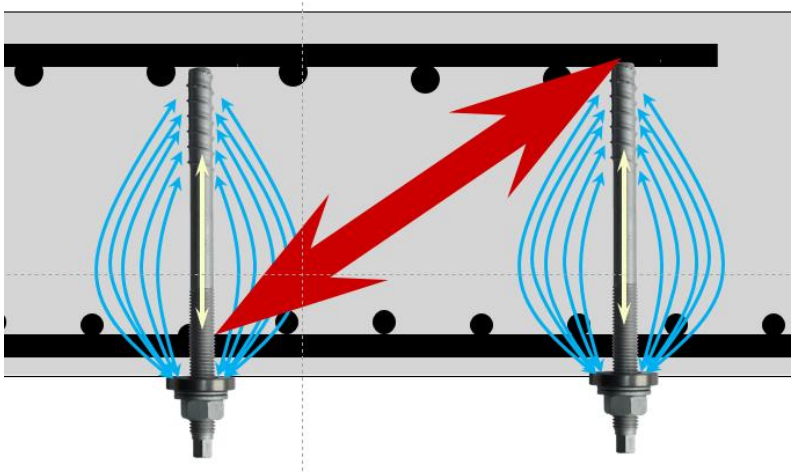
Fast curing Injectable Mortar

Metric stud

Concrete screw anchor with
concrete tapping thread

THE RELAST SYSTEM? LOAD TRANSFER

BONDED CONCRETE SCREW ANCHOR



DESIGNING EQUIVALENT TO EN1992-1-1

- **Shear resistance** of existing reinforced concrete (RC) elements:

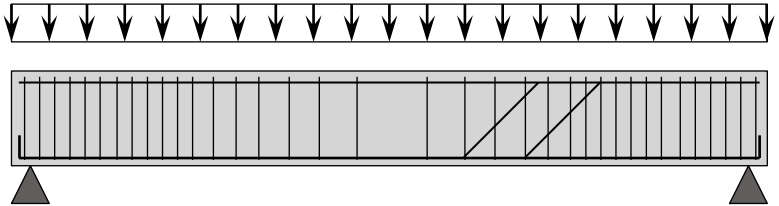
  Beam **with shear** reinforcement.

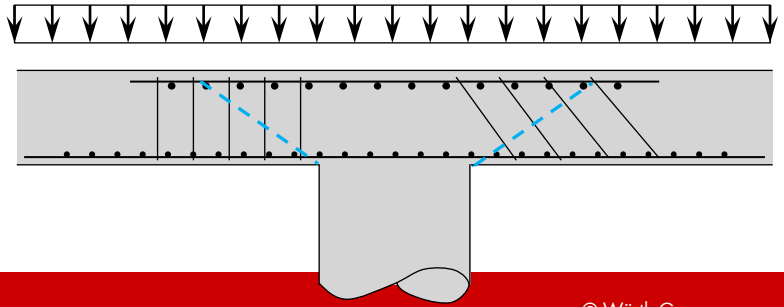
➢ **DESIGN CODE: EN1992-1-1, SECTION 6.2 Shear**

- **Punching shear resistance** of existing reinforced concrete (RC) elements:

  Flat slab **with punching shear** reinforcement.

➢ **DESIGN CODE: EN1992-1-1, SECTION 6.4 Punching**





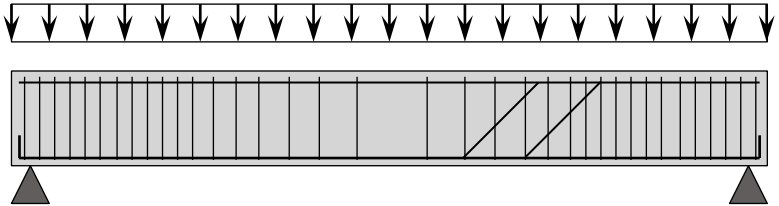
HOW DO YOU DESIGN THE SHEAR RESISTANCE?

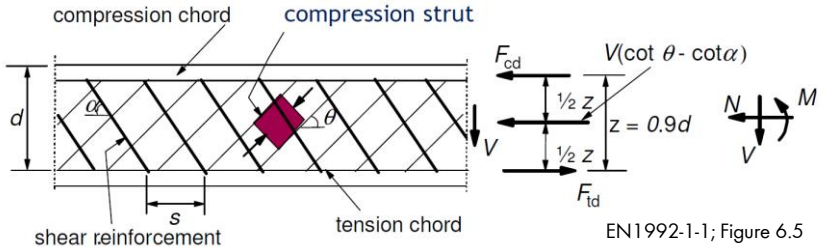
- **Shear resistance** of existing reinforced concrete (RC) elements:

  Beam **with shear** reinforcement.

➢ **DESIGN CODE: EN1992-1-1, SECTION 6.2 Shear**

- Strut-Tie model: Verification of
  - Compression strut $V_{Ed} \leq V_{Rd,c,\,max}$
  - Tension tie $V_{Ed} \leq V_{Rd,s}$





EN1992-1-1; Figure 6.5

HOW DO YOU DESIGN THE IMPORVEMENT OF SHEAR RESISTANCE WITH RELAST?

- **Shear resistance** of existing reinforced concrete (RC) elements:

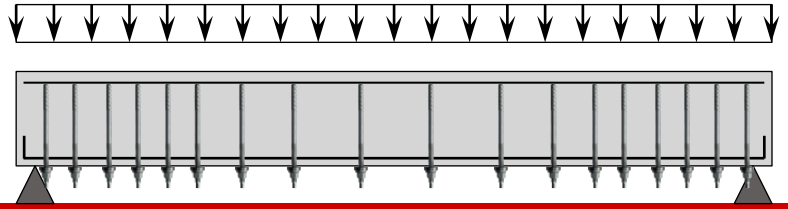
  Beam **with RELAST improved shear** resistance.

➢ **DESIGN CODE:** EN1992-1-1, SECTION 6.2 Shear

- Strut-Tie model: Verification of
  - Compression strut $V_{Ed} \leq V_{Rd,c,\ max}$
  - Tension tie $V_{Ed} \leq V_{Rd,s}$

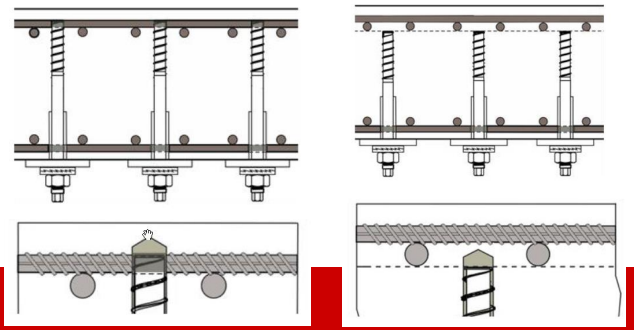
➢ **APPROVAL:**

  ➢ **Modification factors allowing an equivalent design.**



- $\theta = 45°$
- $\alpha = 90°$ (Drilling perpendicular to surface)
- Resistance of tension tie

  $V_{Rd,s} = a_{sw} \cdot z \cdot f_{ywd,ef}$
- Modification in regards to
  - Material parameter of screw anchor.
  - Minimum and maximum spacing requirements.
  - Embedment position of screw anchor.



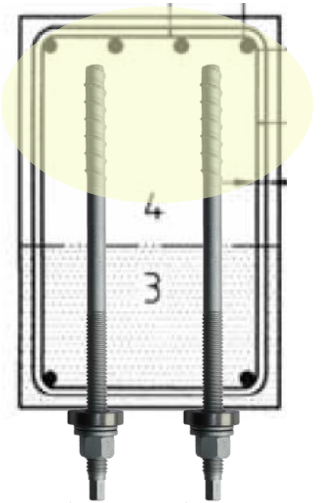
HOW DO YOU DESIGN THE IMPORVEMENT OF SHEAR RESISTANCE WITH RELAST?

- $\theta = 45°$
- $a = 90°$ (Drilling perpendicular to surface)
- Resistance of tension tie

  $V_{Rd,s} = a_{sw} \cdot z \cdot f_{ywd,ef}$

- **Effective yield strength $f_{ywd,ef}$**

- Sufficient anchorage



HOW DO YOU DESIGN THE IMPORVEMENT OF SHEAR RESISTANCE WITH RELAST?

- θ = 45°
- a = 90° (Drilling perpendicular to surface)
- Resistance of tension tie

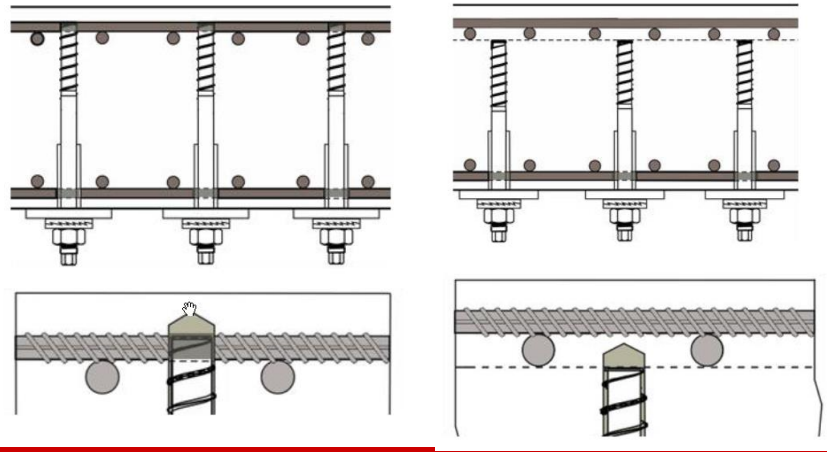
$$V_{Rd,s} = a_{sw} \cdot z \cdot f_{ywd,ef}$$

- **Effective yield strength $f_{ywd,ef}$**

$$f_{ywd,ef} = c_1 \frac{f_{ywk}}{\gamma_s} + c_2 \frac{1}{\rho_{sw}} v_1 f_{cd,\cdot}$$

- Load factor c_1 the utilization of the screw

Screw	Core diameter $d_{K,1}$ [mm]	Screw-in depth (in relation to the facing longitudinal reinforcement, see Annex 7)	Load factors c_1 [-]
Würth RELAST 22	20.5	above	0.4097
		below	0.2384
Würth RELAST 16	14.8	above	0.3925
		below	0.3130



HOW DO YOU DESIGN THE IMPORVEMENT OF SHEAR RESISTANCE WITH RELAST?

WÜRTH GROUP

- θ = 45°
- a = 90° (Drilling perpendicular to surface)
- Resistance of tension tie

$$V_{Rd,s} = a_{sw} \cdot z \cdot f_{ywd,ef}$$

- **Effective yield strength $f_{ywd,ef}$**

$$f_{ywd,ef} = c_1 \frac{f_{ywk}}{\gamma_s} + c_2 \frac{1}{\rho_{sw}} \nu_1 f_{cd,\cdot}$$

- Load factor c_2 = 0.046 related to concrete

f_{ywk} = 500N/mm²; C20/25

22	above	178N/mm²
22	below	104N/mm²
16	above	171N/mm²
16	below	136N/mm²

HOW DO YOU DESIGN THE PUNCHING SHEAR RESISTANCE?

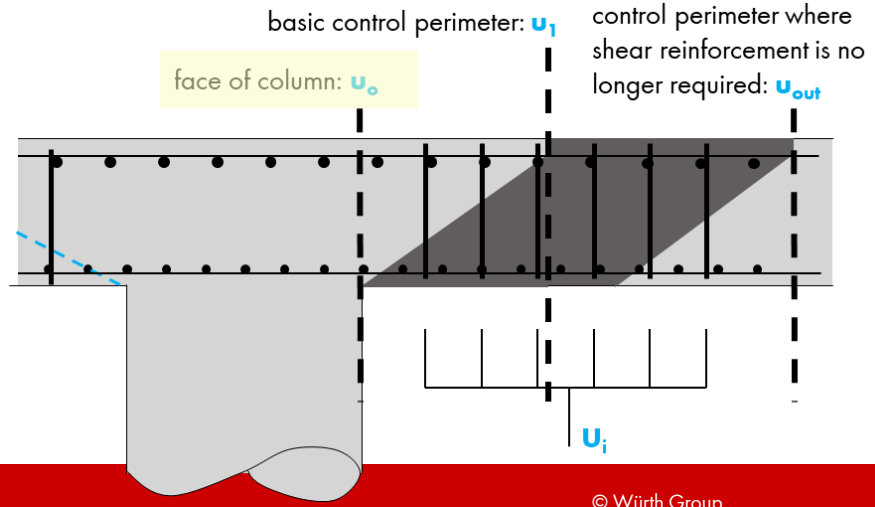
Check punching shear resistance at

- Face of column u_0: $v_{Ed} \leq v_{Rd,c,max}$

- **Punching shear resistance** of existing reinforced concrete (RC) elements:

  Flat slab **with punching shear** reinforcement.

➢ **DESIGN CODE: EN1992-1-1, SECTION 6.4 Punching**



HOW DO YOU DESIGN THE PUNCHING SHEAR RESISTANCE?

Check punching shear resistance at

- Face of column u_0: $v_{Ed} \leq v_{Rd,c,max}$

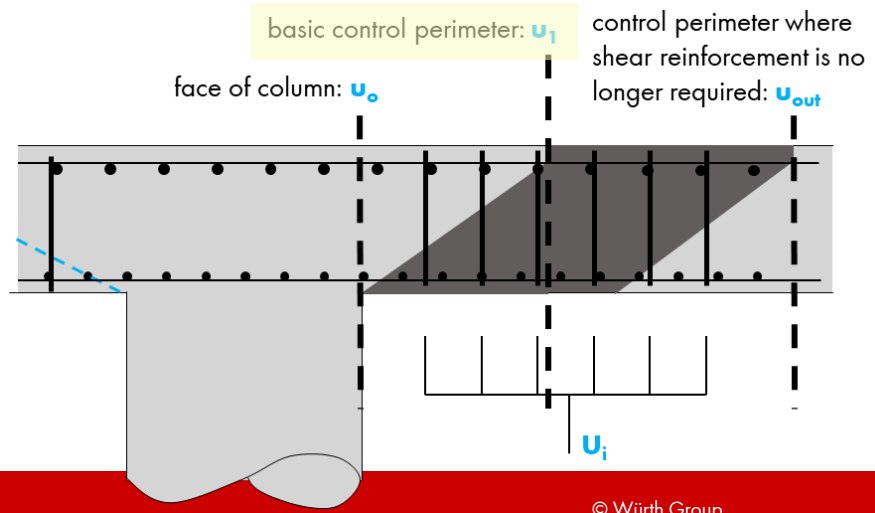
Check if punching shear reinforcement is required at

- Basic control perimeter u_1: $v_{Ed} \leq v_{Rd,c}$

- **Punching shear resistance** of existing reinforced concrete (RC) elements:

  Flat slab **with punching shear** reinforcement.

➢ **DESIGN CODE: EN1992-1-1, SECTION 6.4 Punching**



HOW DO YOU DESIGN THE PUNCHING SHEAR RESISTANCE?

Check punching shear resistance at

- Face of column u_0: $v_{Ed} \leq v_{Rd,c,max}$

Check if punching shear reinforcement is required at

- Basic control perimeter u_1: $v_{Ed} \leq v_{Rd,c}$

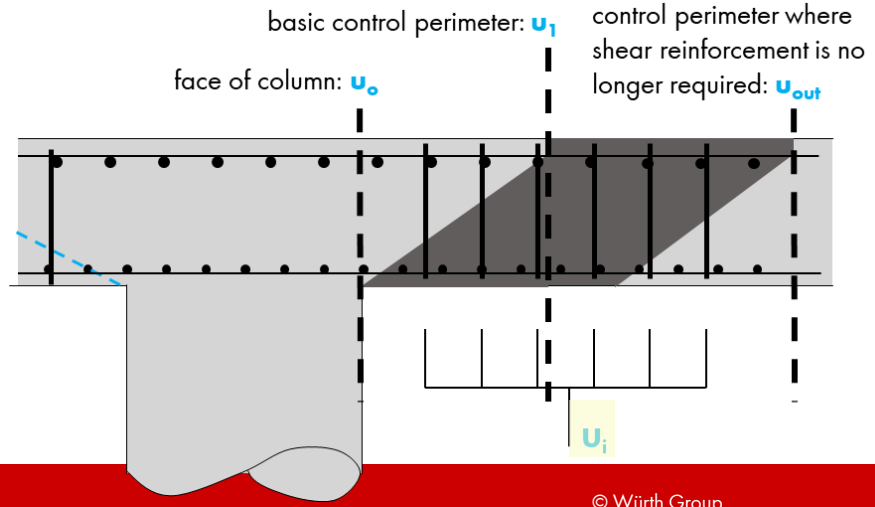
Check the improvement k_{max} with punching shear reinforcement and calculate it's required cross section at

- Positions U_i: $v_{Ed} \leq \begin{cases} v_{Rd,cs} \\ k_{max} \cdot v_{Rd,c} \end{cases}$

- **Punching shear resistance** of existing reinforced concrete (RC) elements:

  Flat slab **with punching shear** reinforcement.

➢ **DESIGN CODE: EN1992-1-1, SECTION 6.4 Punching**



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Check punching shear resistance at

- Face of column u_0: $v_{Ed} \leq v_{Rd,c,max}$

Check if punching shear reinforcement is required at

- Basic control perimeter u_1: $v_{Ed} \leq v_{Rd,c}$

Check the improvement k_{max} with punching shear reinforcement and calculate it's required cross section at

- Positions U_i: $v_{Ed} \leq \begin{cases} v_{Rd,cs} \\ k_{max} \cdot v_{Rd,c} \end{cases}$

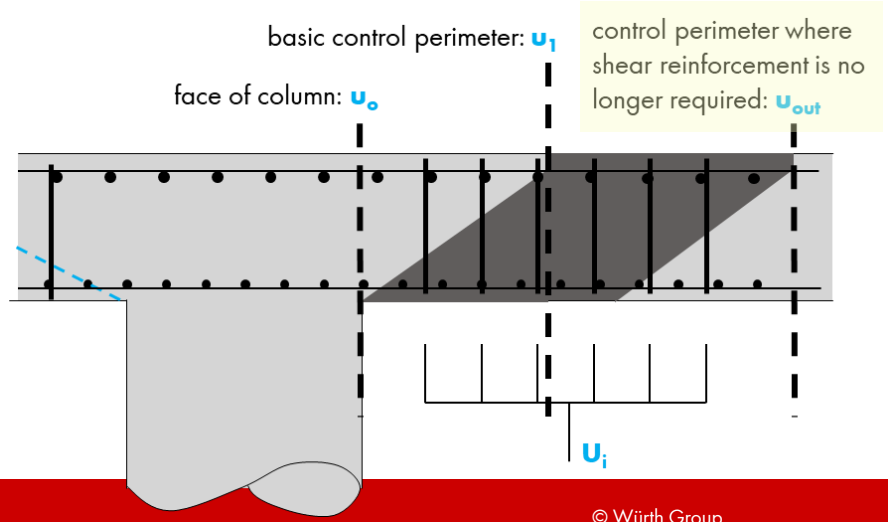
Calculate the perimeter where shear reinforcement is no longer required

- Outermost control perimeter u_{out}: $u_{out,ef} = \beta \frac{V_{ed}}{v_{Rd,c} \cdot d}$

- **Punching shear resistance** of existing reinforced concrete (RC) elements:

  Flat slab **with punching shear** reinforcement.

➢ **DESIGN CODE: EN1992-1-1, SECTION 6.4 Punching**



HOW DO YOU DESIGN THE IMPROVEMENT OF PUNCHING SHEAR RESISTANCE WITH RELAST?

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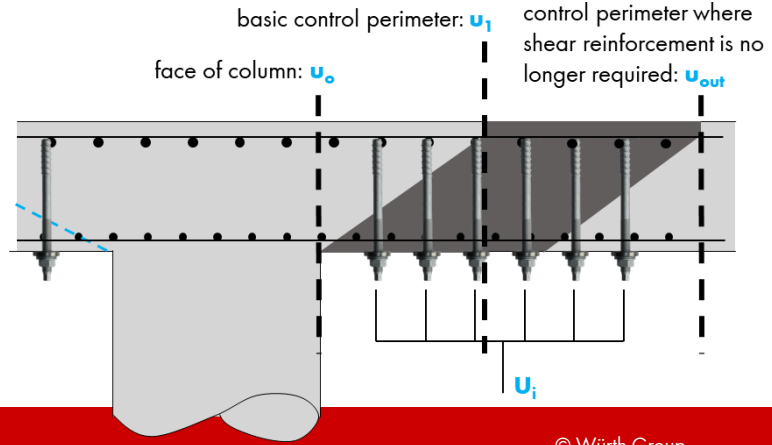
- Face of column u_0: $v_{Ed} \leq v_{Rd,c,max}$
- Basic control perimeter u_1: $v_{Ed} \leq v_{Rd,c}$
- Positions U_i: $v_{Ed} \leq \begin{cases} v_{Rd,cs} \\ k_{max} \cdot v_{Rd,c} \end{cases}$
- Outermost control perimeter u_{out}: $u_{out,ef} = \beta \frac{V_{ed}}{v_{Rd,c} \cdot d}$

- **Punching shear resistance** of existing reinforced concrete (RC) elements:

  Flat slab **with RELAST improved punching shear** resistance.

  - **DESIGN CODE: EN1992-1-1, SECTION 6.4 Punching**
  - **APPROVAL:**
  - **Modification factors allowing an equivalent design.**



HOW DO YOU DESIGN THE IMPROVEMENT OF PUNCHING SHEAR RESISTANCE WITH RELAST?

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- Positions U_i:

$$v_{Ed} \leq \begin{cases} v_{Rd,cs} \\ k_{max} \cdot v_{Rd,c} \end{cases}$$

- Effectiveness factor: $k_{max} = 1.4$
- Calculation of the required reinforcement

$$v_{Rd,cs} = 0.75 \cdot v_{Rd,c} + 1.5 \cdot \frac{d}{s_r} \cdot A_{SW} \cdot f_{ywd,ef} \cdot \frac{1}{u_1 d}$$

- Modification in regards to
  - Material parameter of screw anchor.
  - Minimum and maximum spacing requirements.

- **Punching shear resistance** of existing reinforced concrete (RC) elements:

  Flat slab **with RELAST improved punching shear** resistance.

➢ **DESIGN CODE: EN1992-1-1, SECTION 6.4 Punching**

➢ **APPROVAL:**

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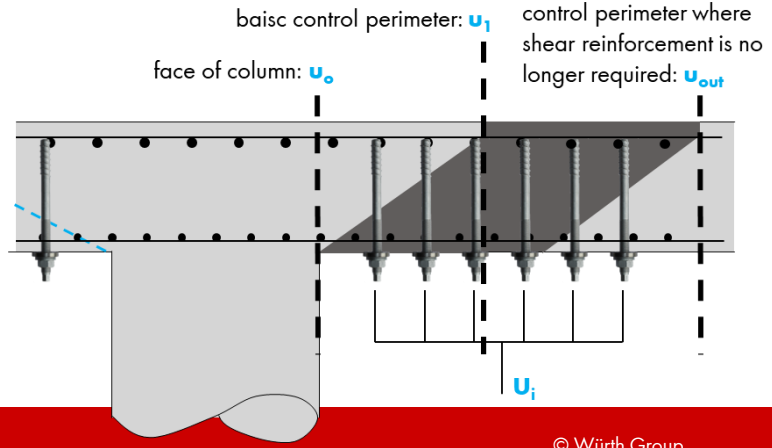
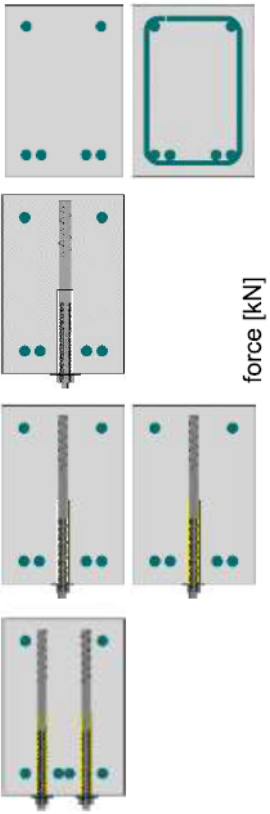
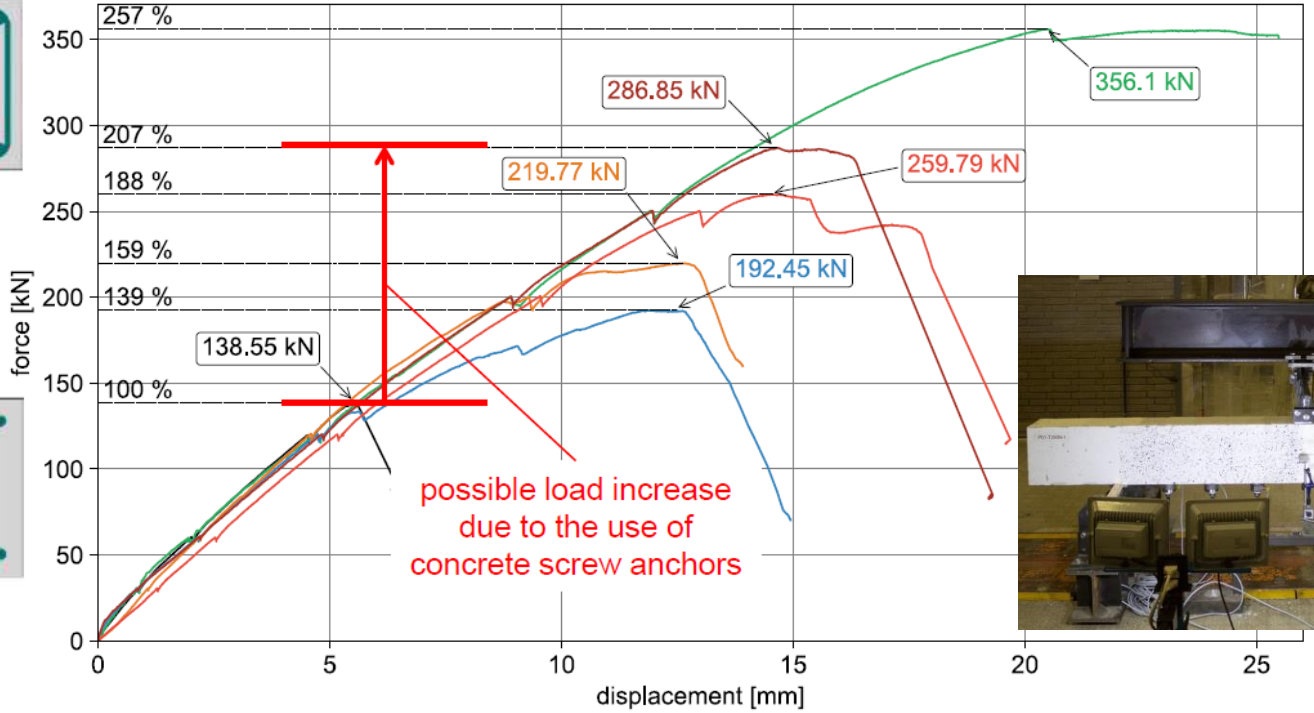
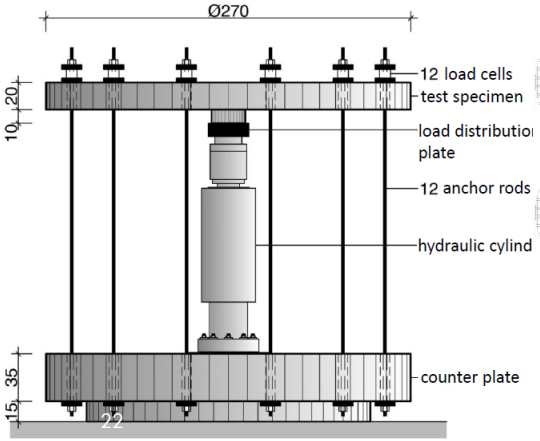


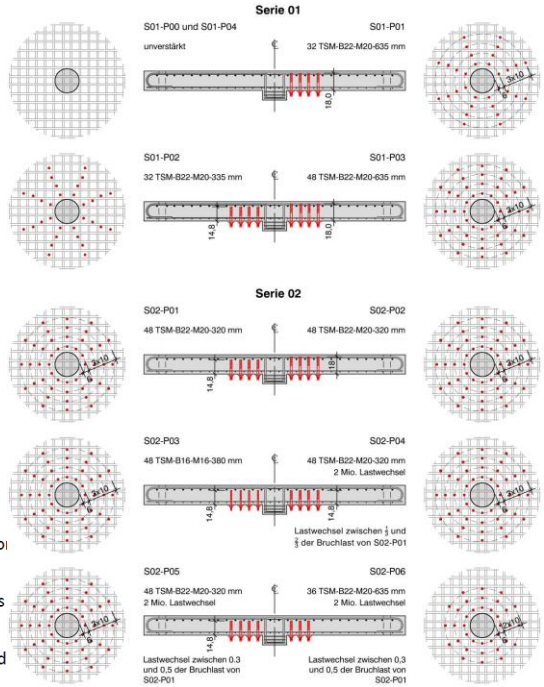
ASSESSMENT TESTS FOR SHEAR

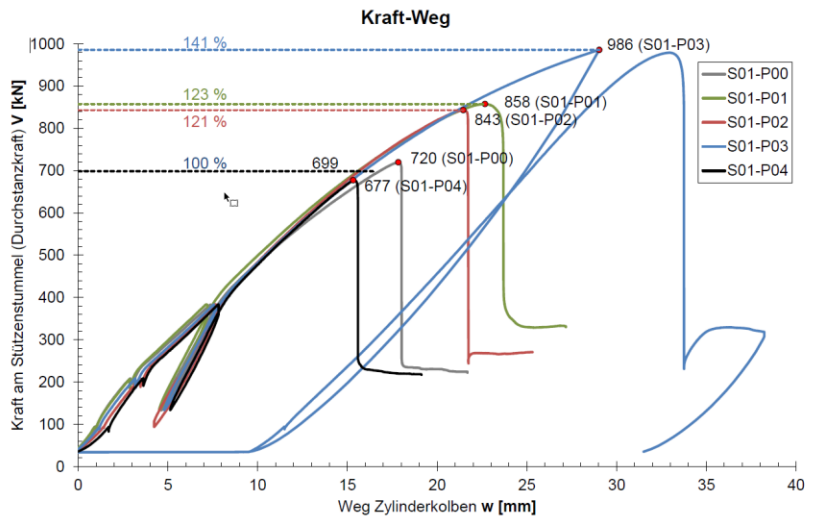




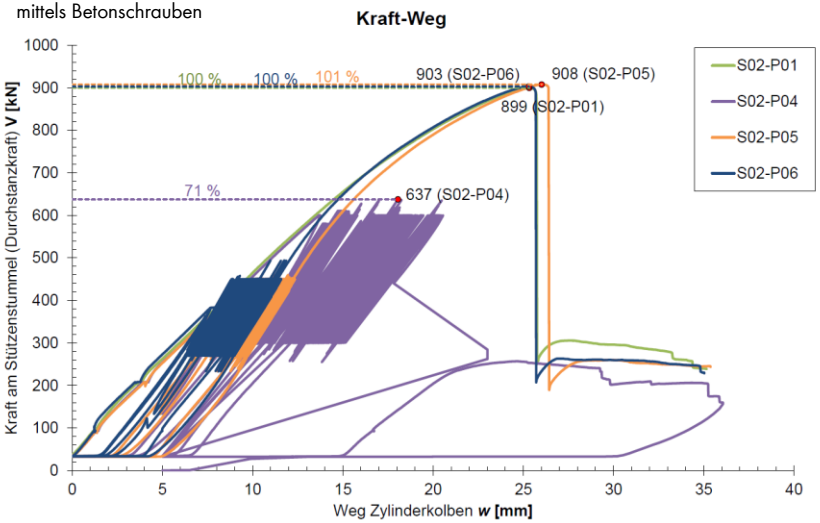
ASSESSMENT TESTS FOR PUNCHING SHEAR





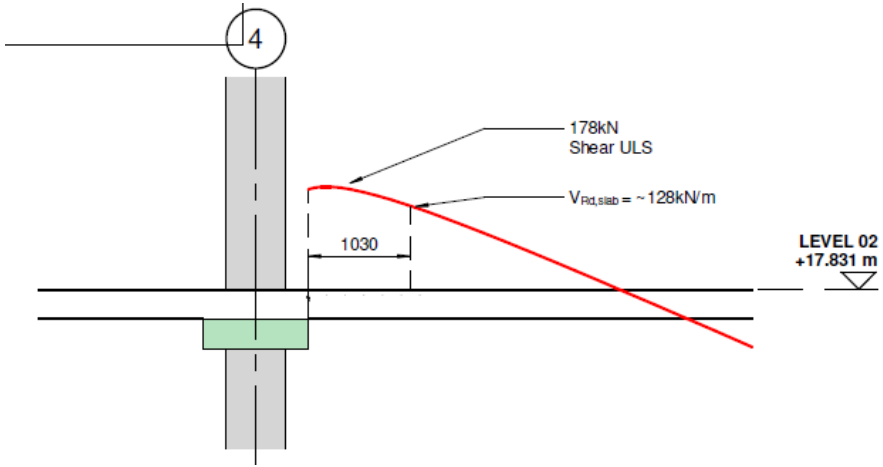


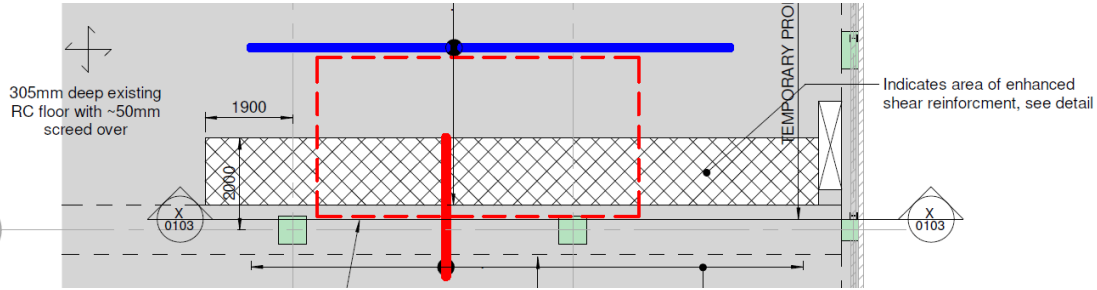
Feix: Innovative Durchstanzertüchtigung von Plattenbrücken mittels Betonschrauben



STRENGTHENING OF THE NEW BOILER ROOM

CAMBRIDGE UNIVERSITY HOSPITALS ADDENBROOKE'S, UK

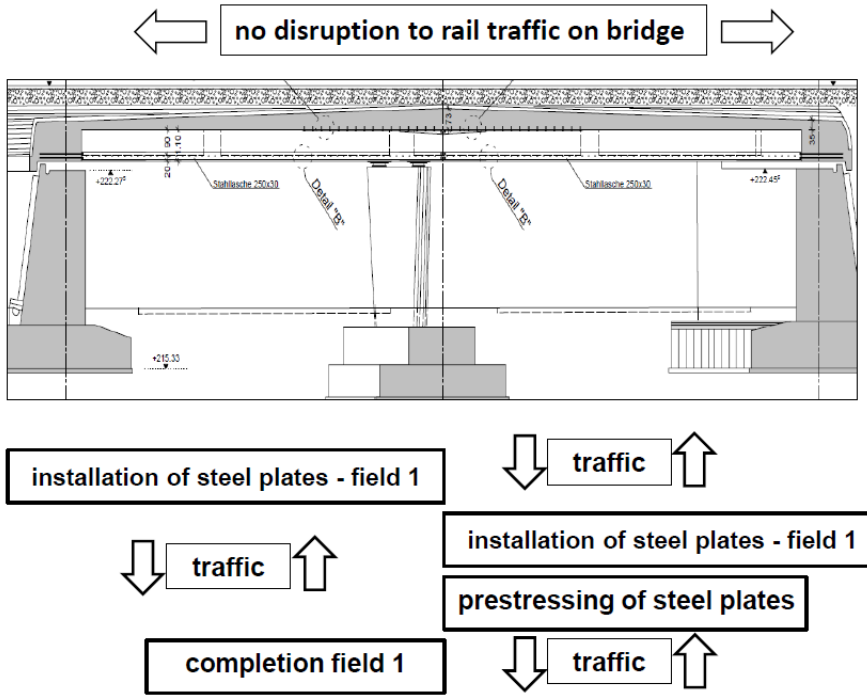




STRENGTHENING OF THE A70 RAILWAY BRIDGE

- Bridge designed for 35 passenger trains and 20 freight trains per day.
- Existing reinforcement shows stress corrosion.
- Risk of sudden collapse.

- Estimated cost of strengthening EUR 130‘000. (4 weeks / CO_2 295to.)
- Estimated cost of new bridges EUR 2.5m (1.5yrs / CO_2 24‘961to.)



REFERENCES

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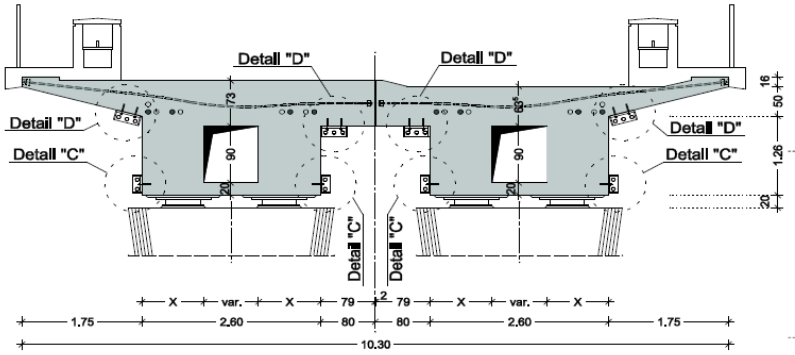
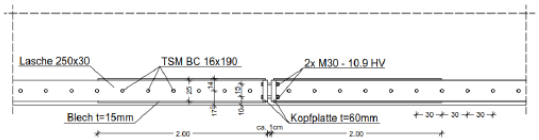


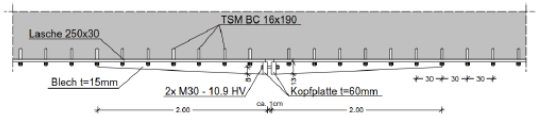
railway bridge over A70

Bending reinforcement - bridge construction

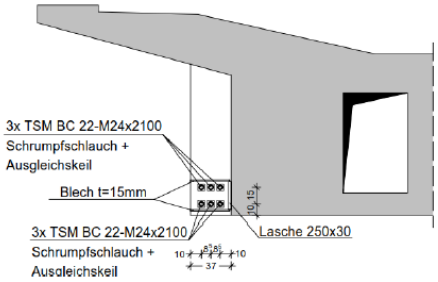
side view



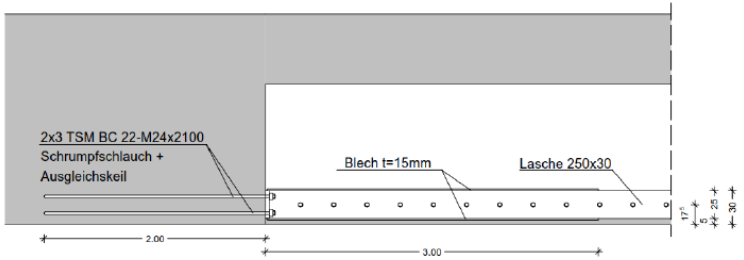
longitudinal section



view



section



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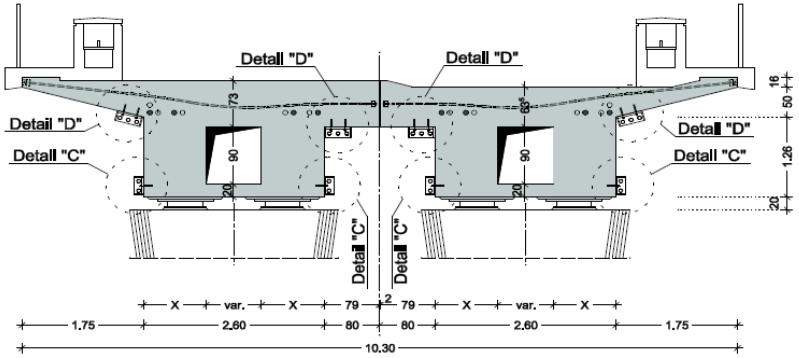
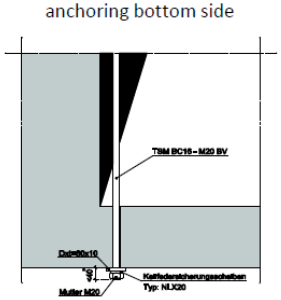
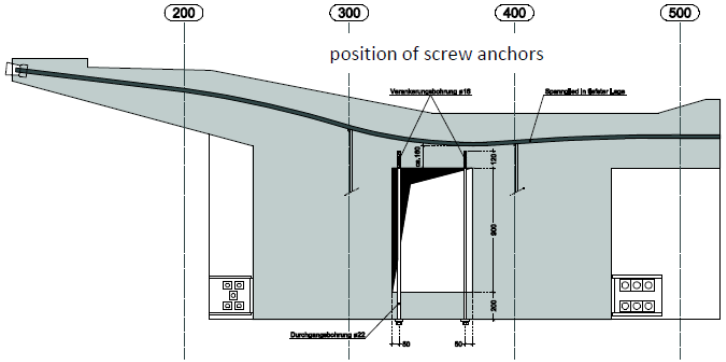


Shear reinforcement - bridge construction





railway bridge over A70

REFERENCES

WÜRTH GROUP

Railway Bridge A70 – Retrofitting of Bridge in Service

SUMMARY

- Easy to install from where ever it is most convenient.
- Suitable for all type of static loads and fatigue with $5x10^6$ load cycles.
- Uses a standardized design concept EN1992. The improvement does not take existing reinforcement into account. Advantage when RC members were designed with different codes.
- RELAST system is independently assessed and approved.
- Maximum shear resistance improvement of **100%** for member thickness ≥ 200mm.
- Maximum punching shear resistance improvement of **40%**. For member thickness between 200 and 1100mm.
- Can be used in C5 environments (very strong corrosivity) acc. to ISO 9223.
- Improvement is activated immediately after installation.