Applications 2

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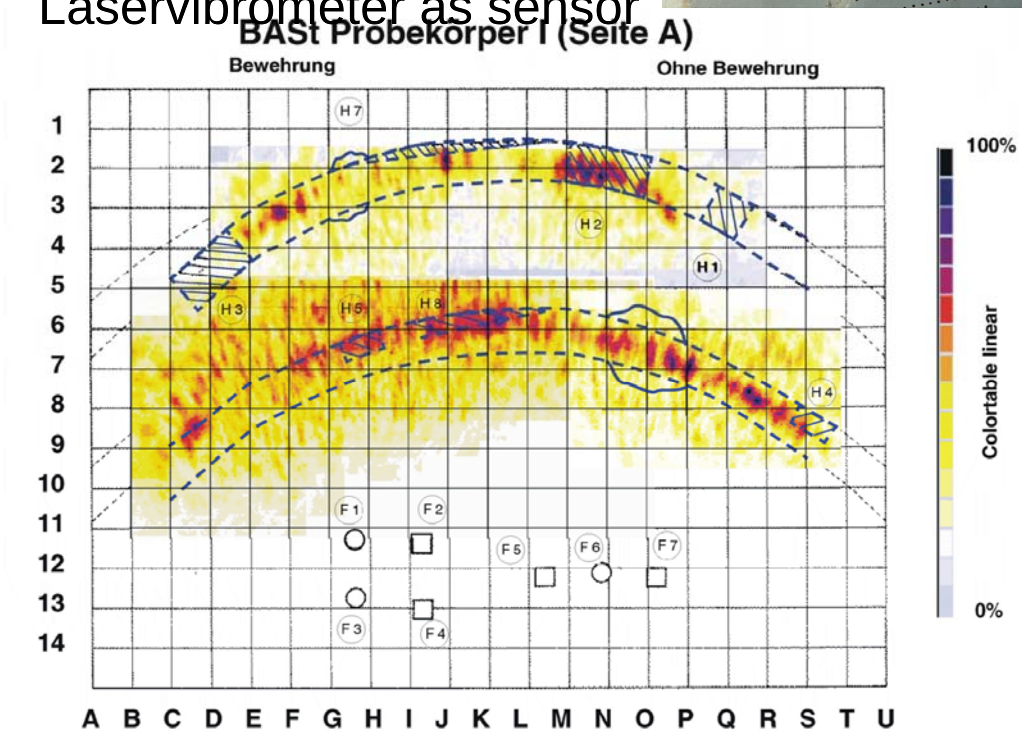
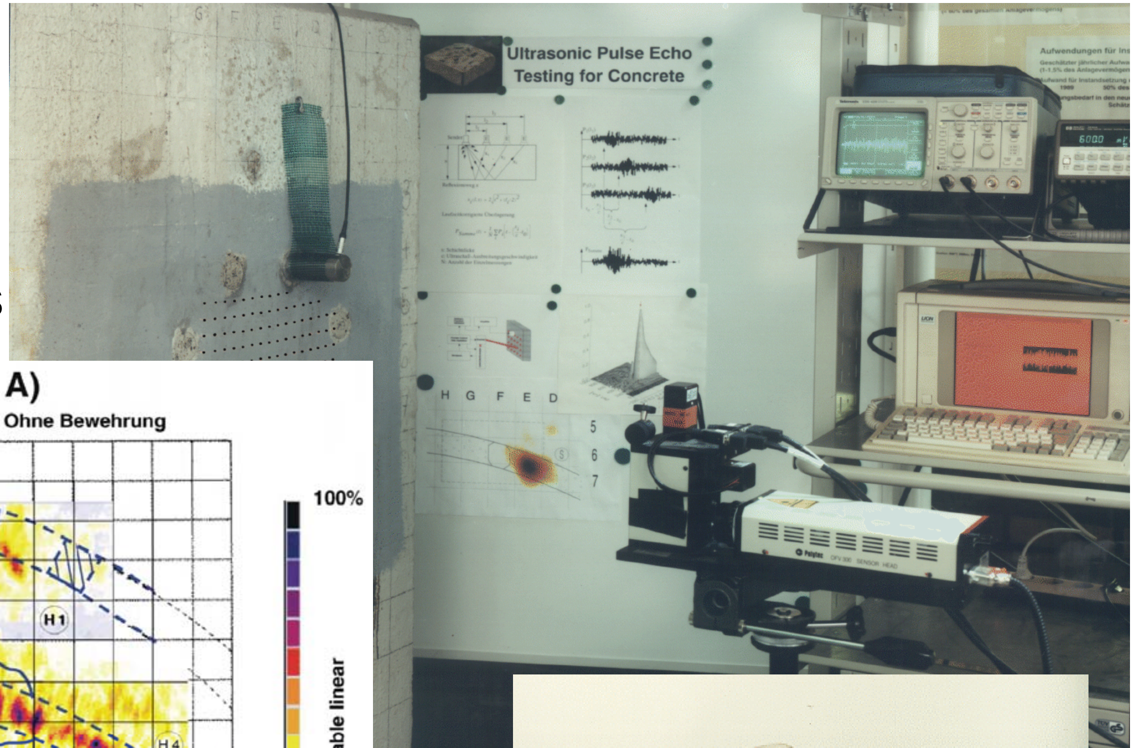
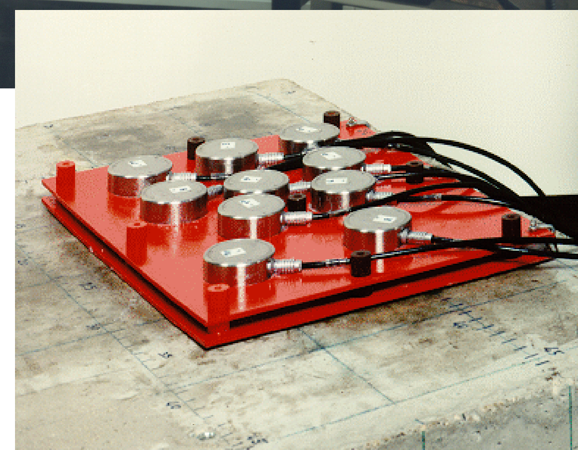
History: Imaging Ultrasound (Pulse-Echo)

BAM
Zerstörungsfreie Schadensdiagnose und Umweltmessverfahren
VIII.2

Round robin test
BAST 1996
Detection of voids in
Tendon Ducts
Use of coupled transducers
Laservibrometer as sensor

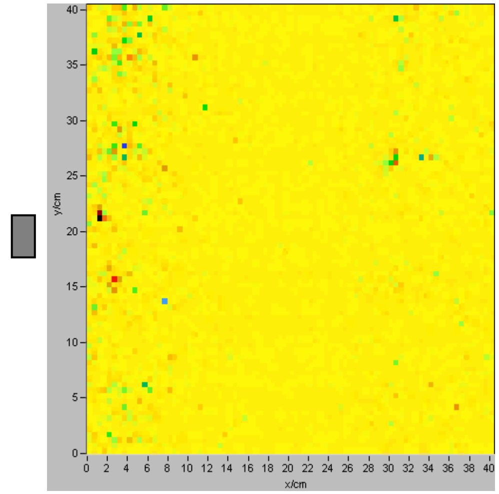


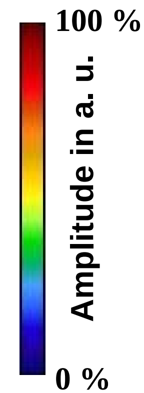




Visualization of the US wave propagation

Standard Low frequency probe

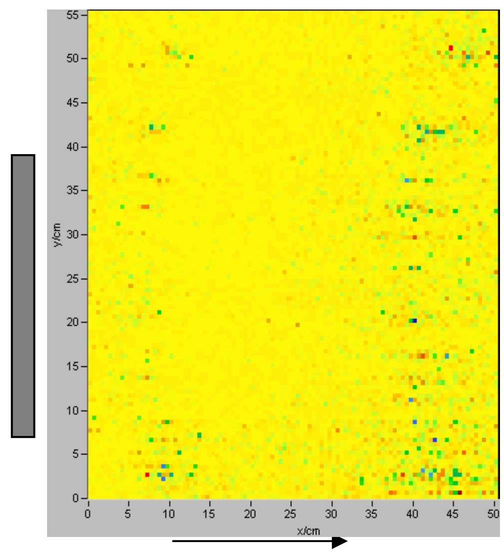


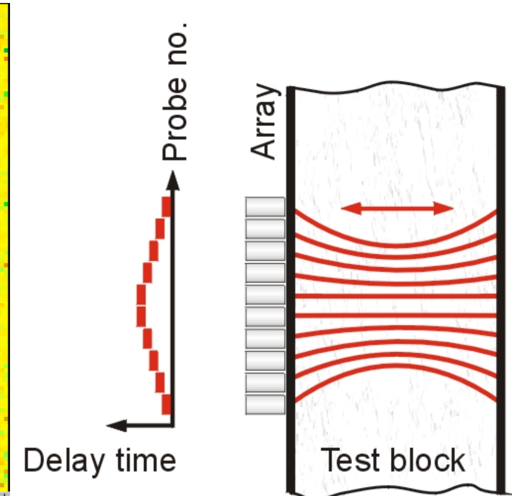


Sound beam control using a phased array

Array

Laservibrometer



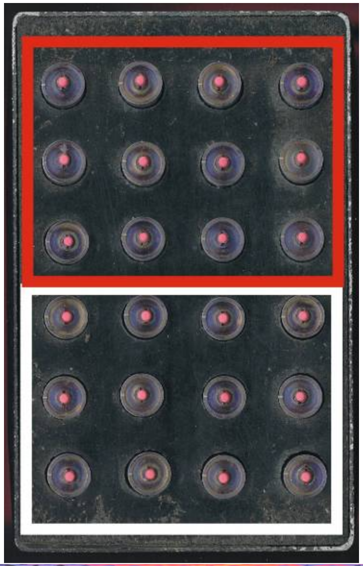


BAM NDT Stepper with A1220 and Impact-Echo

US Device with Dry Coupling

Hand Held Device A1220

Transmission
12 Shear Wave
Transducers



Reveiving
12 Shear Wave
Transducers

Frequeny Range: 33 kHz - 250 kHz
Max Depth Range: 700 mm (B35)

Min Size of Defect for 500 mm Depth:
Air filled cylinder: 12 mm
Air filled sphere: 55 mm

Accuracy: +/- 10%
Power supply: Battery

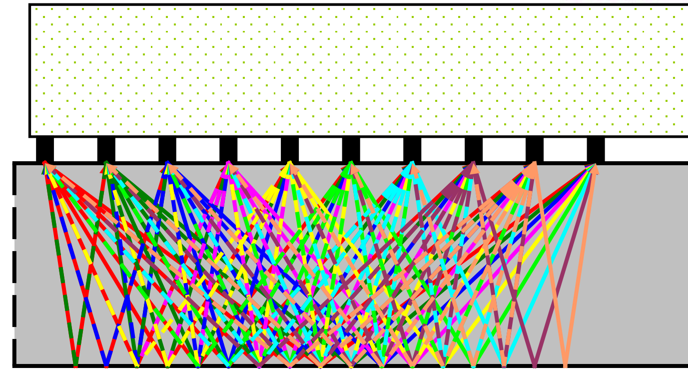
Dimensions:
Handheld: 235 x 98 x 33 mm
Sensor: 145 x 90 x 75 mm

Weight:
Handheld 0,8 kg
Sensor: 0,76 kg

Dust and Water Class: Schutzart IP65

US Linear Array for Concrete (Sampling Phased Array)

Controlling Linear Arrays over TCP/IP



unit with 55 kHz shear wave transducers

Controller with 10 transducer units

Imaging Ultrasound on Concrete

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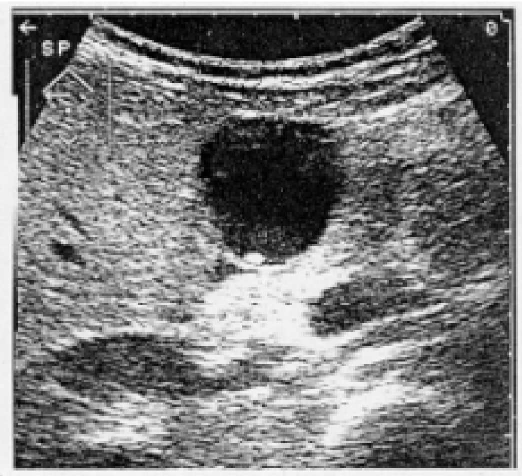
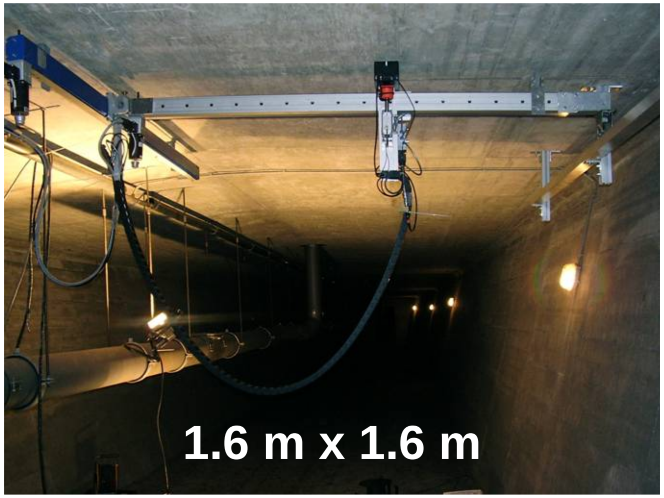


www.acsys.ru/eng/

Linear array (Sampling Phased Array) with parallel sampling sensor elements
System commercially available with >10 elements and wireless data collection

BAM Scanner Systems

1.6 m x 10 m



Scanning Area Speed:

- **Ultrasonic Echo/Impact Echo**
  $1 m^2/h$, 0.02 m point grid
- **Radar**
  $15 m^2/h$, 0.05 m line grid

BAM Scanner Systems: Data Processing

2-dimensional measurement on the surface of structures

- B-Scan

  plots perpendicular to the measurement surface (x-y plane)

- C-Scan

  plots parallel to the measurement surface (x-y plane)

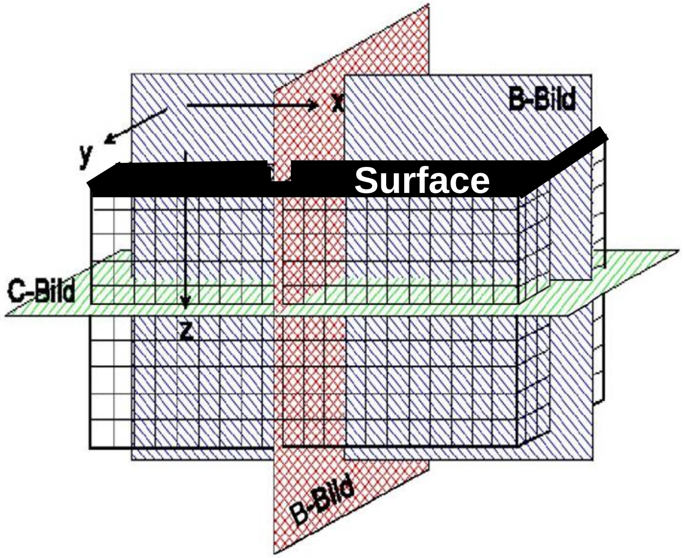
Projections and Animations of consecutive scans

3D-Reconstruction

Focusing of reflected signals using SAFT
(Synthetic Aperture Focusing Technique)

Data Fusion

Superposition of data



Reconstruction of 1D- and 2D-scanned data sets

- SAFT (synthetic aperture focussing technique) has become a standard data analysis tool
- 3D reconstruction of large data sets is possible in minutes
  (compare to weeks 10 years ago)
- Data evaluation and reconstruction is being done during testing on site

Tasks

- Tendon ducts
  - Grouting defects
  - Position
  - Cover
- Reinforcement
  - Position
  - Cover
- Structure
  - Thickness
  - Honeycombs
  - Delaminations
  - Cracks
  - Bonding
- Material
  - Strength
  - Moisture

Applications

BAM has made a number of investigations on bridges and other structures in the past years

- Bridge Haiger
- Bridge Eichenzell
- Bridge Vienna
- Bridge Schwerte
- Foundation Horstwalde
- Large Concrete Specimen

Validation: Large Concrete Slab (LCS) of BAM

1. Section - Tendon ducts

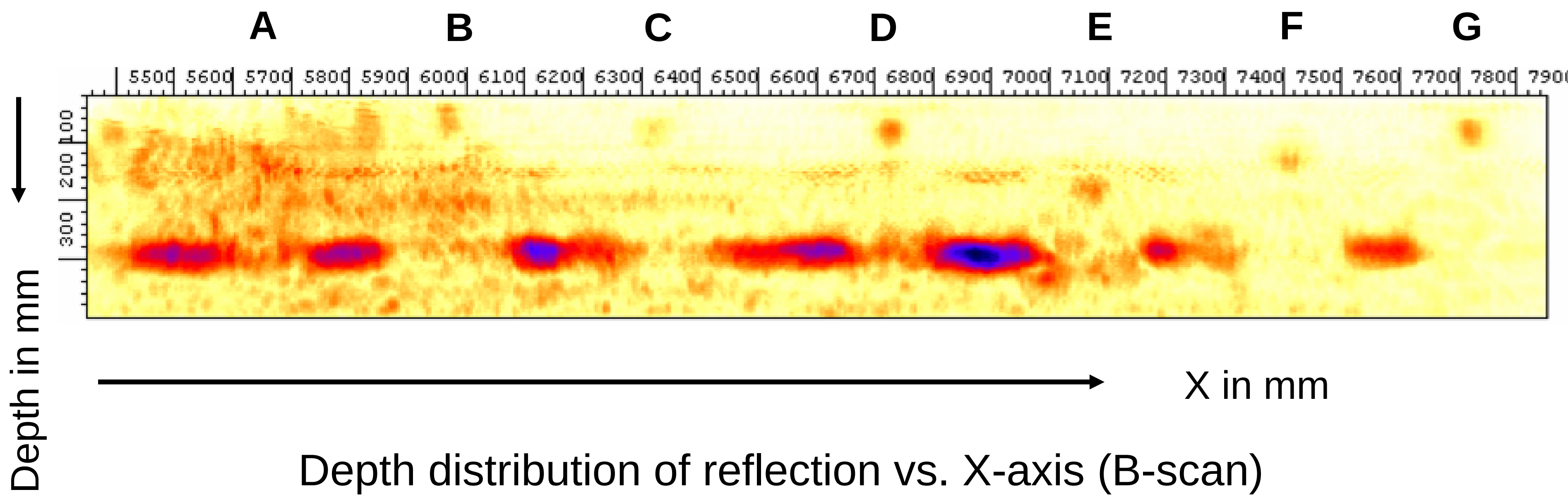
11 Tendon ducts with strands
(length 4 m, diameter 40 … 100 mm)
Grouting defects, Grouting by DSI

Facility for various tests and measurements for the improvement of NDT-CE methods

Reference specimen for comparison of different methods (=> Validation)

LCS: Ultrasonic echo

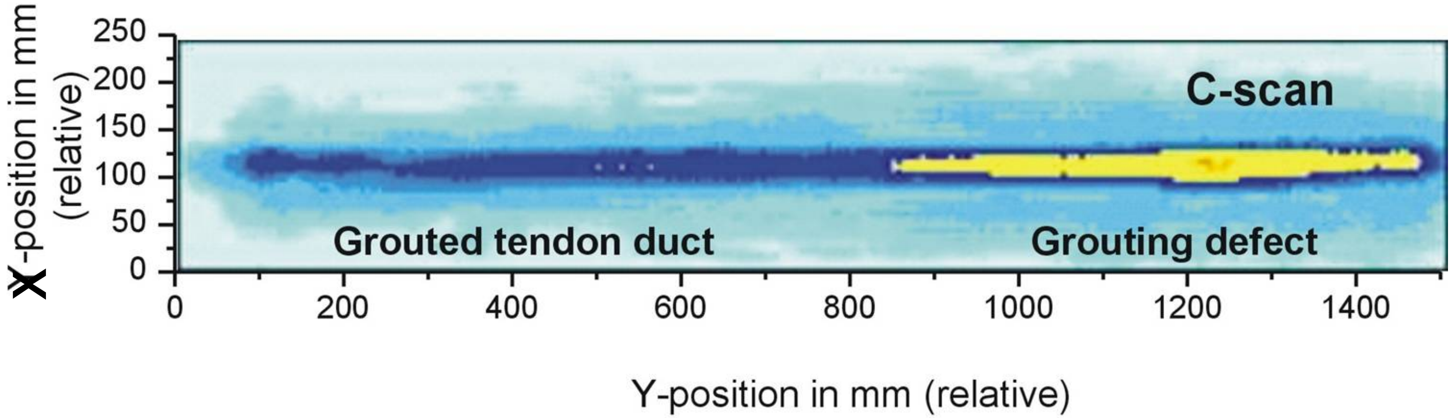
Acoustical imaging of 6 tendon ducts in LCS:
2 D Scanning and 3D-SAFT
(**S**ythetic **A**perture **F**ocusing **T**echnique)

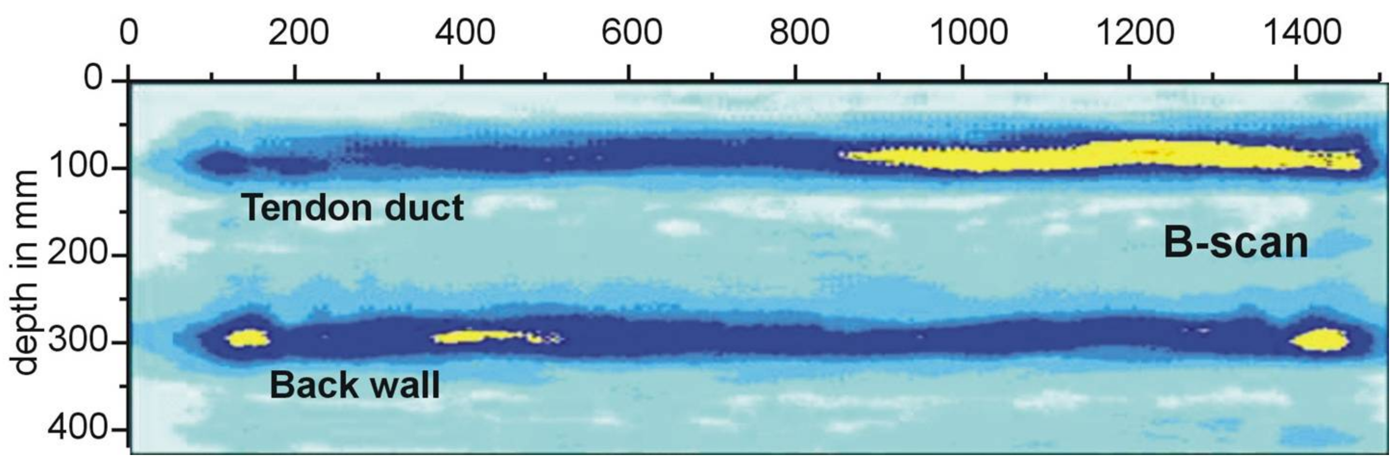


Depth distribution of reflection vs. X-axis (B-scan)
Shadowing additionally caused by reinforcing bar spacer

LCS: Localization of artificial grouting defects

LCS, Tendon duct G





Polarisation parallel to the duct, threshold value 6 dB

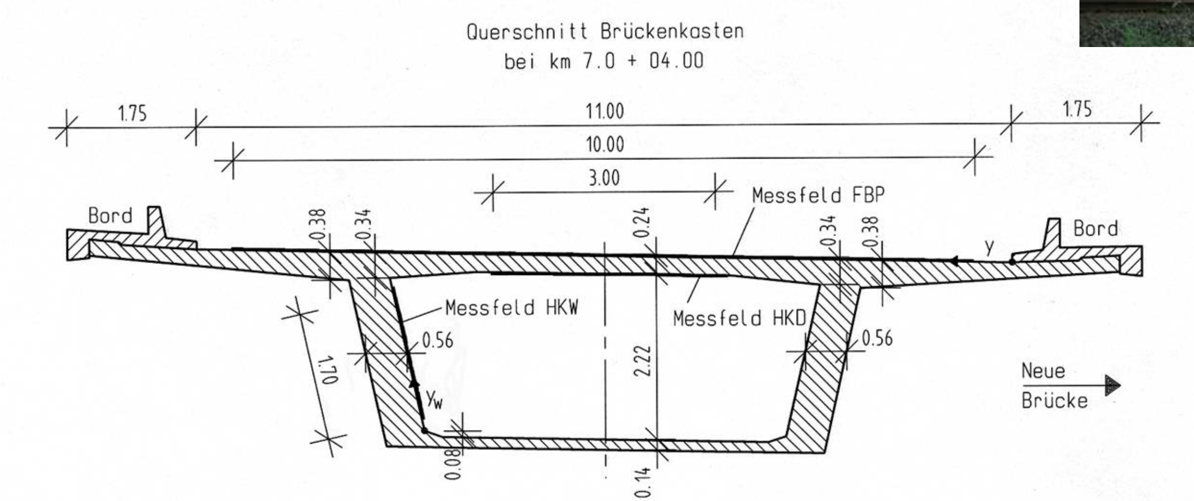
Bridge investigations applying NDT-CE

Bridge deck: Full field investigation
8 Measured areas for detailed investigation with Radar, Ultrasonic echo, impact-echo, (magnetic stray field) (1999)

Girder and Bridge deck:
Scanning echo methods for tendon ducts and honeycombing (2001)

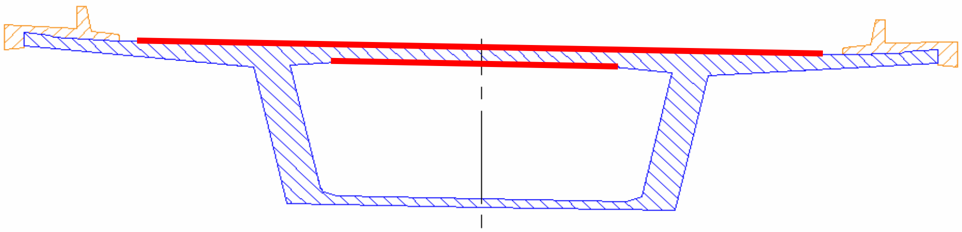
Bridge Eichenzell

Construction
Cantilever unicellular box bridge
Length: 480 m
Prestressed in longitudinal and transversal direction
Constructed 1966, deconstruction 2004



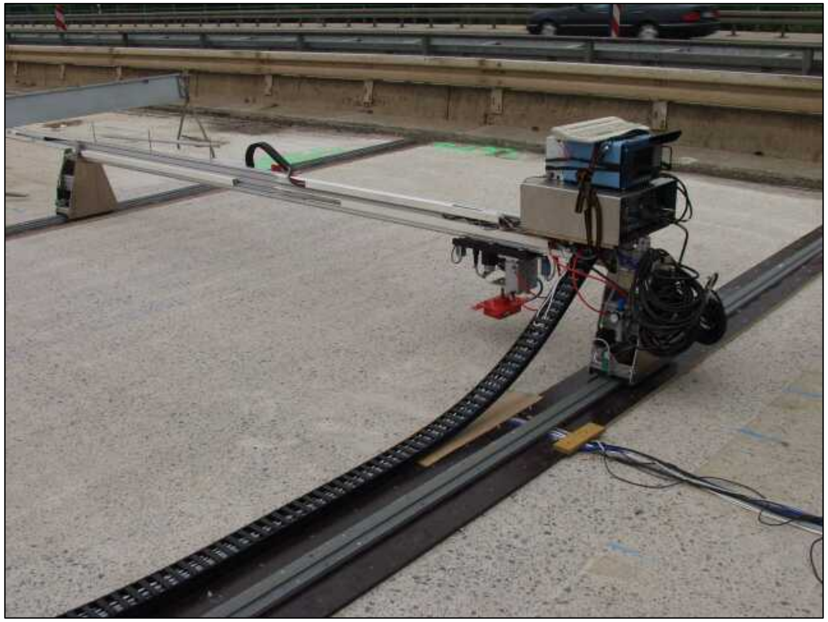
- Radar
- Impact-Echo
- Ultrasonic Echo

Bridge Eichenzell: Investigated Areas



Test Area on the top: 4.0 m x 10.0 m
Test Area on the bottom: 3.0 m x 10.0 m

- tendon ducts with diameters of 45 mm, each with 6 wires
- thickness of the deck 23 - 38 cm



Bridge Eichenzell: Radar – Datafusion

Radar-Visualization of the Results as 3D-Animation

2 Data Sets

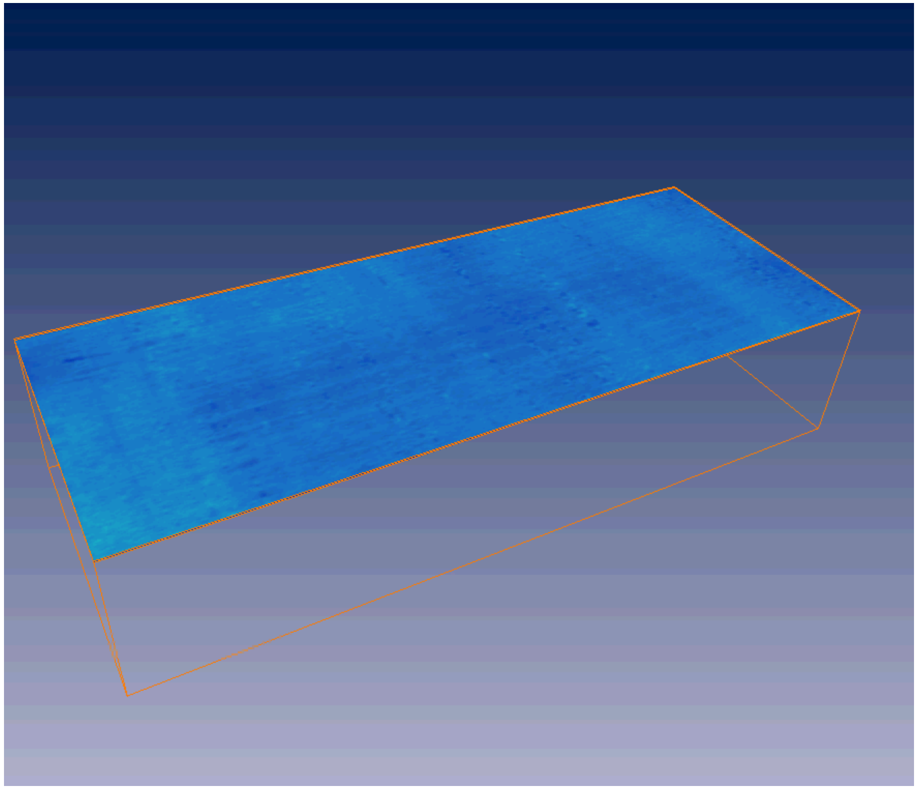
recorded with the 1.5 GHz-antenna

with polarization in x and y-direction

3D-Reconstruction with SAFT

(Synthetic Aperture Focusing Technique)

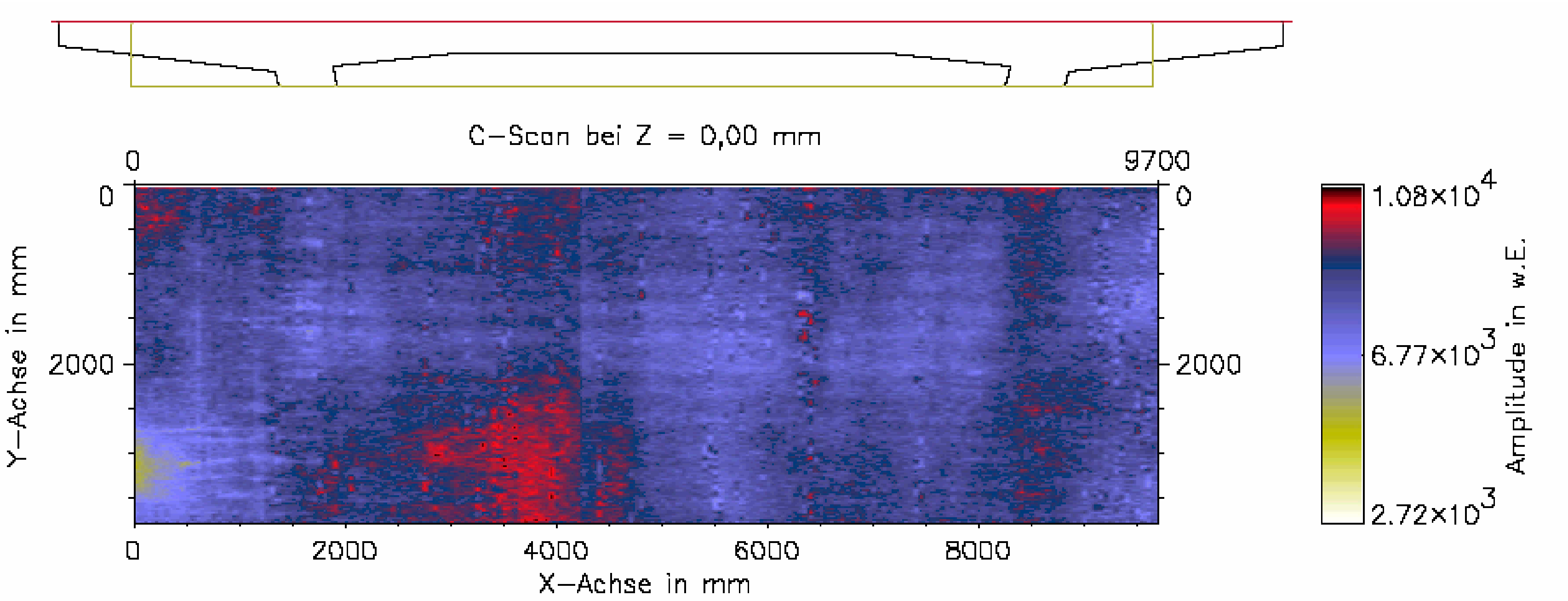
Data Fusion



Test Area 4.0 m x 10.0 m

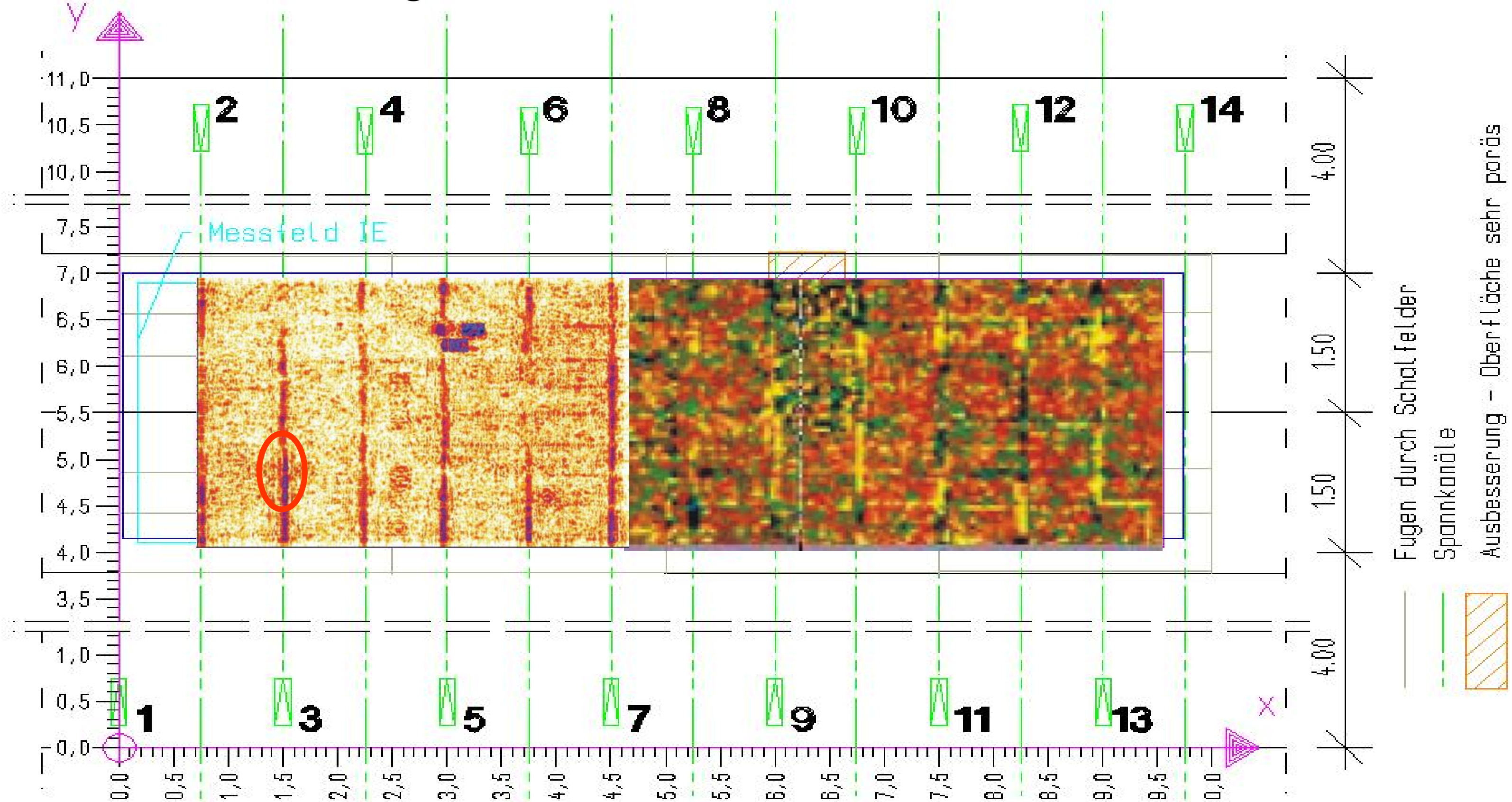
Bridge deck: Superposition of radar data from the top side and bottom side (Polarization in x- und y-direction, maximum of magnitude is represented)

Movie of slices parallel to the surface:



Bridge Eichenzell: Ultrasound: Duct investigation

Bridge deck bottom side



Left:
SAFT-C-Projection
depth 11,7 cm … 12,1 cm
step width 2,5 cm

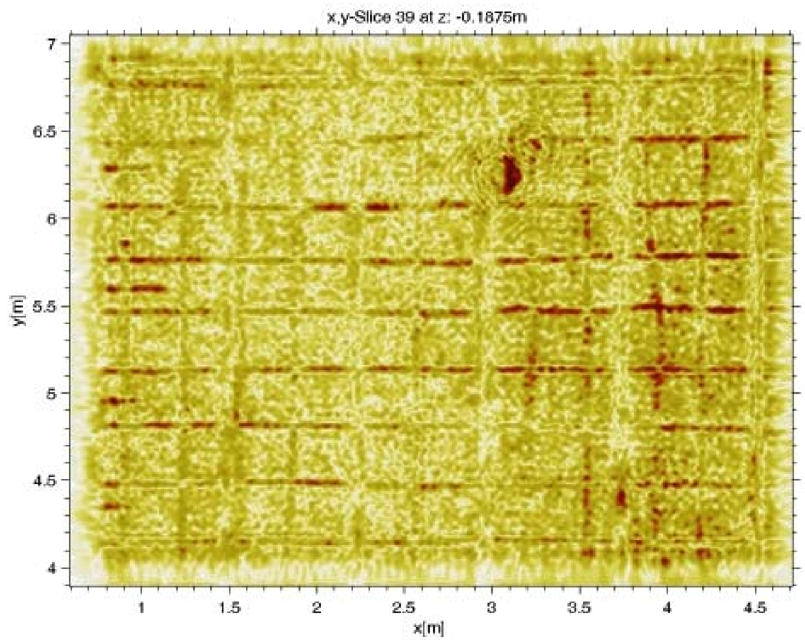
High reflection intensity at both sides

Right:
C-scan depth about 8 cm
step width 5 cm

Bridge Eichenzell: Ultrasound: Duct investigation

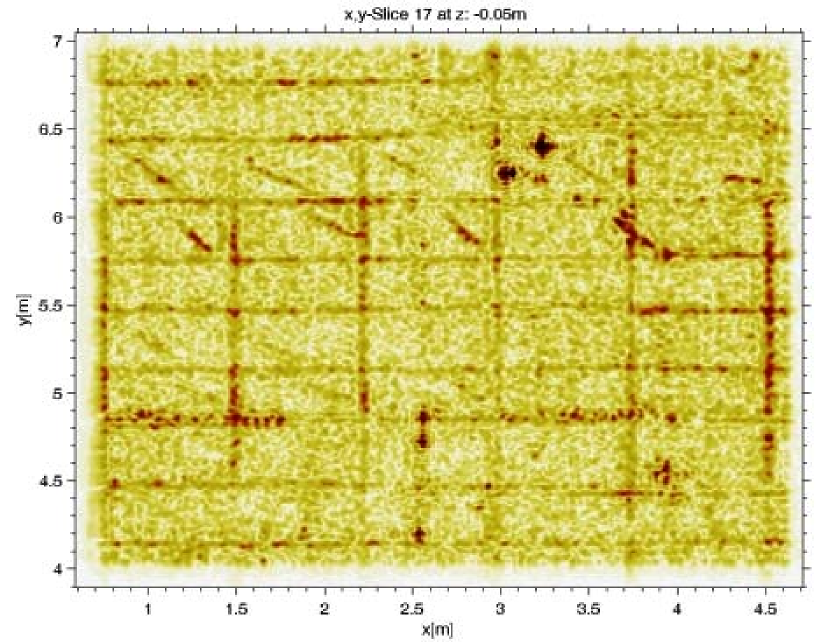
Ultrasonic **Investigation from below bridge deck**

Area ca. 3 m x 4,5 m Spacing 2,5 cm



Slice in depth 18,8 cm

Upper reinforcement layer

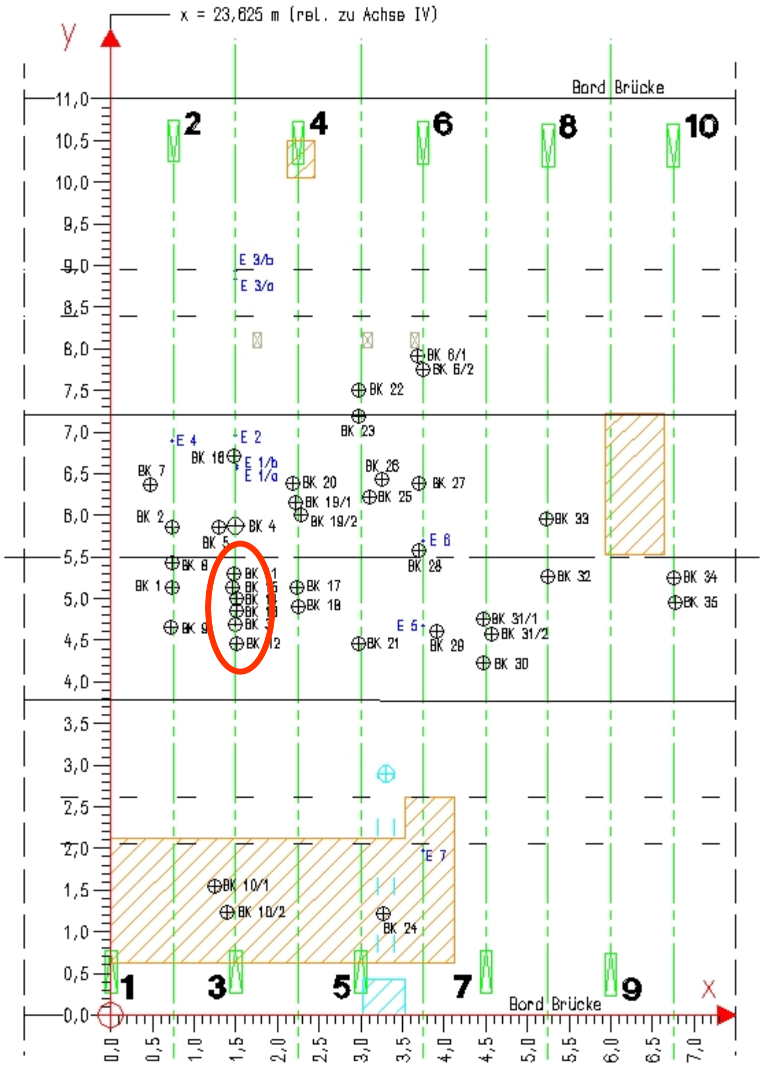


Slice in depth 5 cm

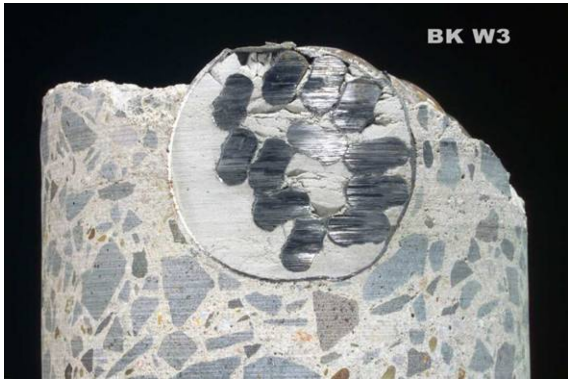
Upper reinforcement layer

Bridge Eichenzell: Verification

Destructive testing: 35 cores, endoscopy



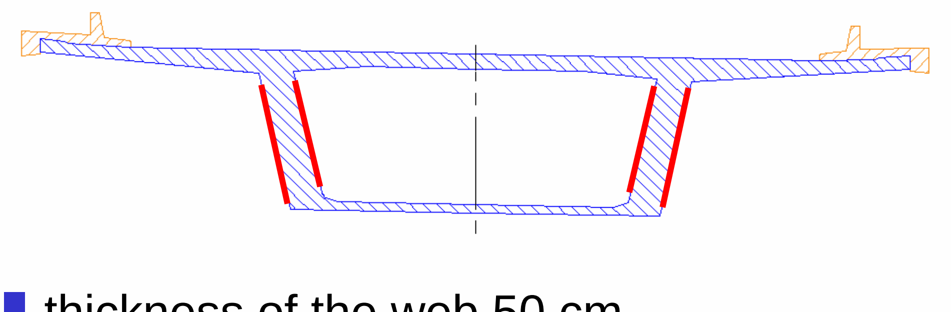
Bridge deck (transverse tendon ducts): Very good grouting condition



Box girder wall (longitudinal tendon ducts)

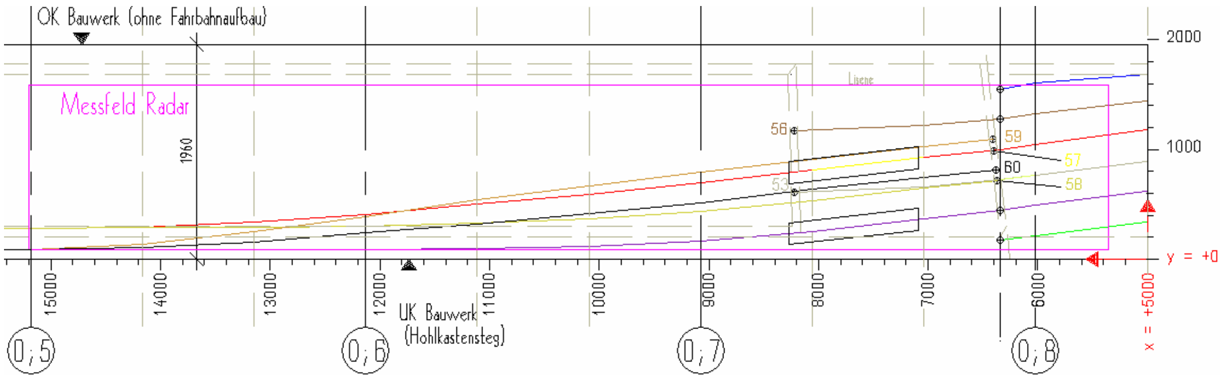
Bridge Vienna

Measurements on webs of box girder bridges



- thickness of the web 50 cm
  (83 cm in the area of anchoring of the pre-stressing)
- bridge under unaffected traffic
- simultaneous mounting of the impact-echo and ultrasonic sensors on the scanner

Test Area: 10 m (length) x 1.5 m (height)



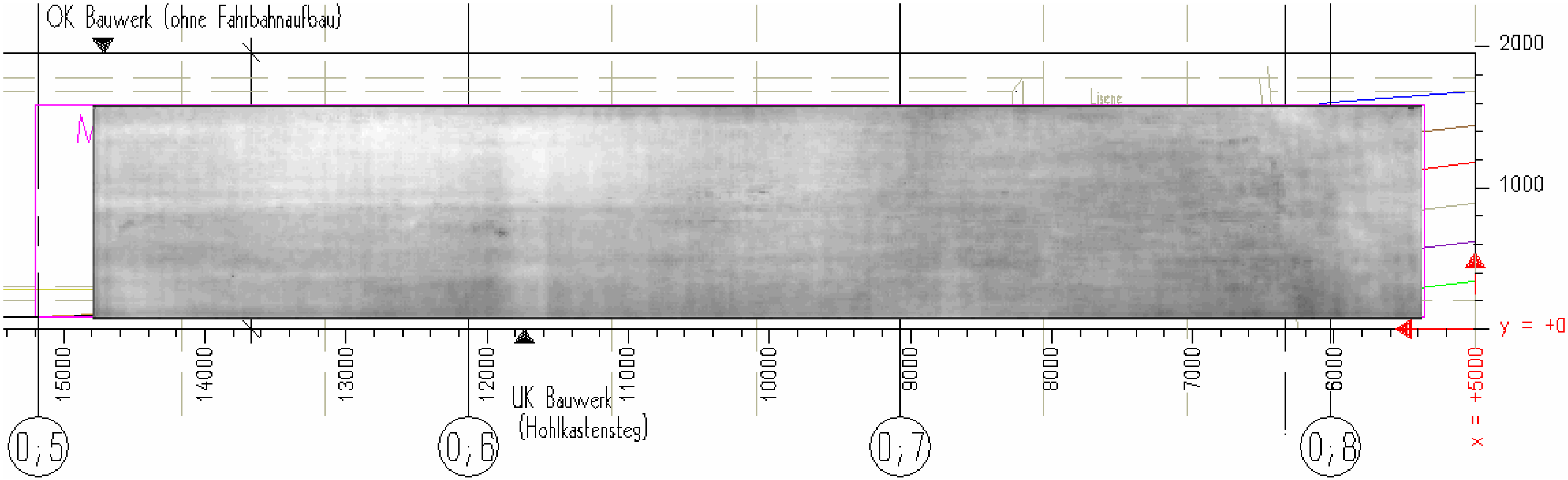
Bridge Vienna

Data Fusion of Radar and Ultrasonic Echo

3D-reconstructed and fused radar data sets (1.5 GHz-antenna)

and

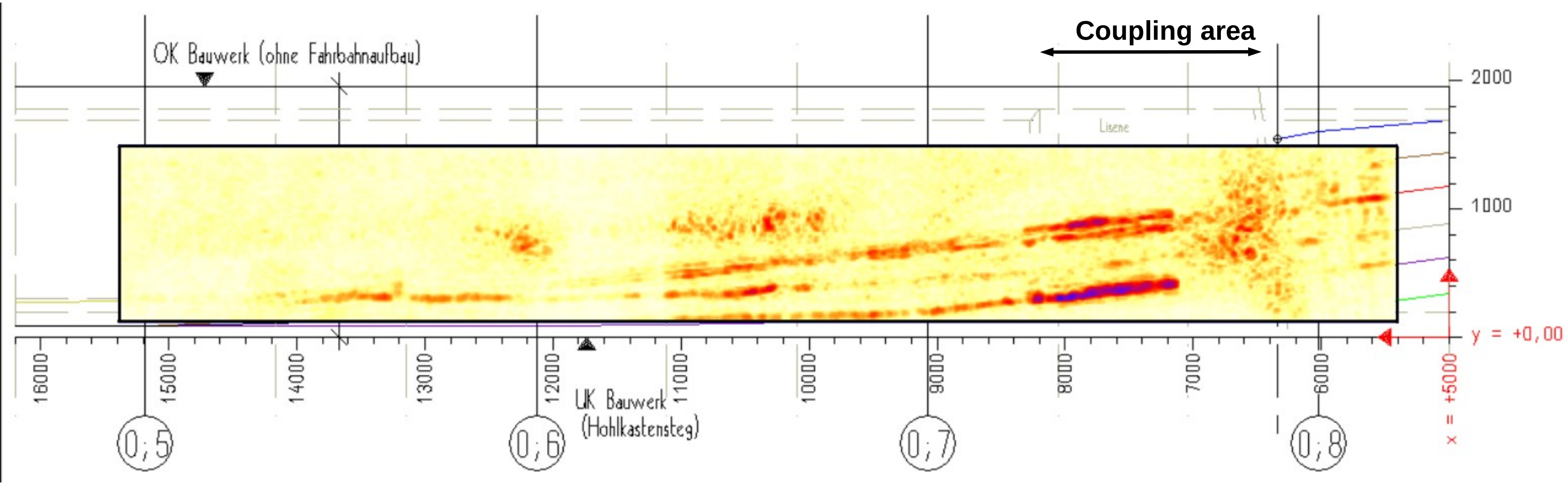
3D-reconstructed ultrasonic echo data set



Animated sections parallel to the surface
through the measurement depths from 0 cm to 60 cm

Bridge Vienna

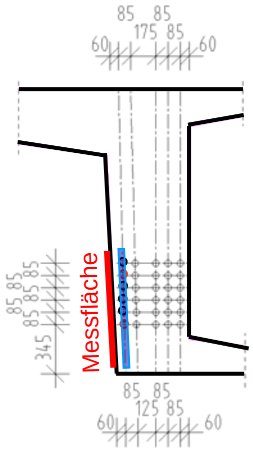
Ultrasonic Echo

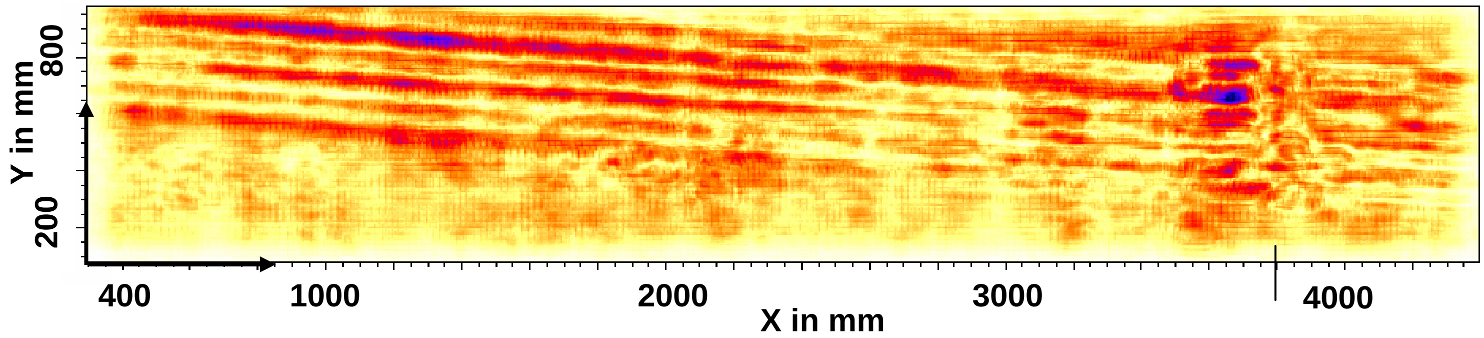


SAFT-C-Projection parallel to the measurement surface at the range of depth from 22 cm to 28 cm

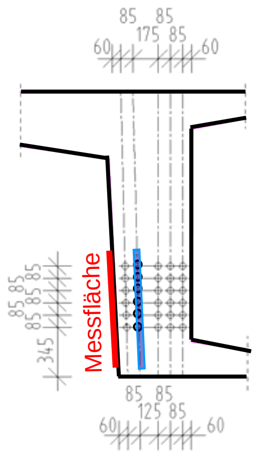
Bridge Vienna 2

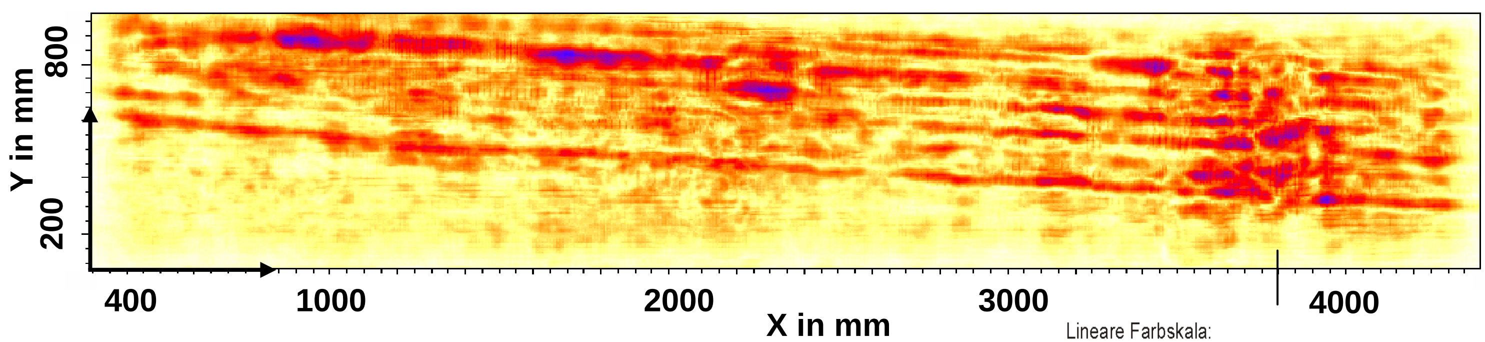
1. Layer of tendon ducts

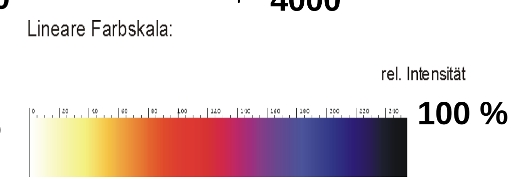




2. Layer of tendon ducts





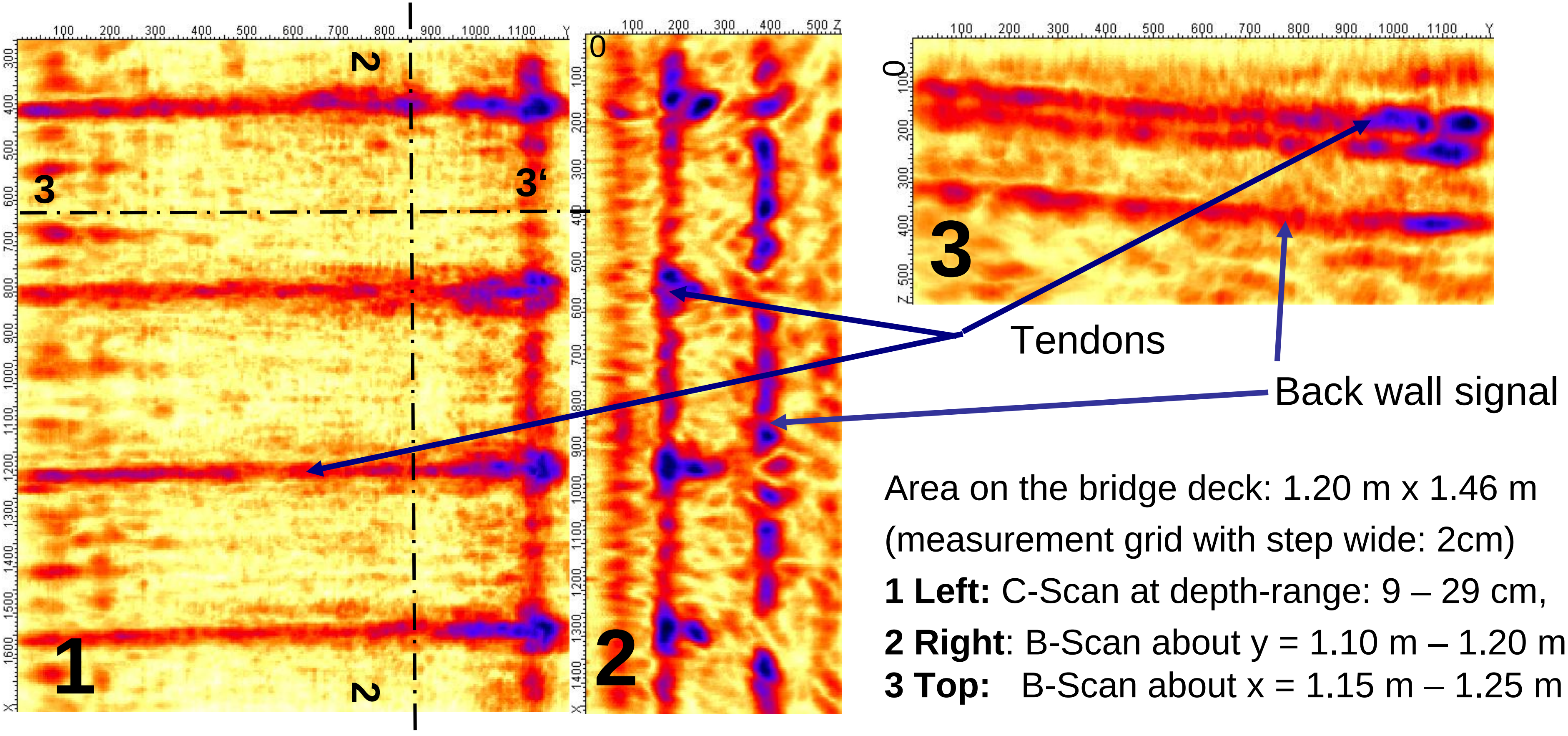


SAFT-C-Projektions of parallel Slices
top: **5,2 – 9,5 cm** depth range, bottom: **12,5 – 17,5 cm** depth range

Bridge Duisburg

3-D-SAFT Reconstruction

Location of transverse prestressing in Railway Bridge RC-Track-Slab



Area on the bridge deck: 1.20 m x 1.46 m (measurement grid with step wide: 2cm)

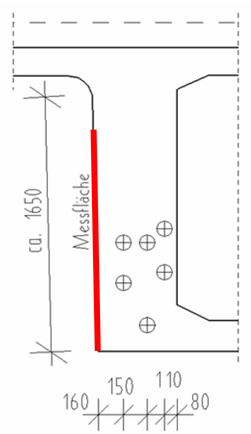
1 Left: C-Scan at depth-range: 9 – 29 cm,

2 Right: B-Scan about y = 1.10 m – 1.20 m,

3 Top: B-Scan about x = 1.15 m – 1.25 m

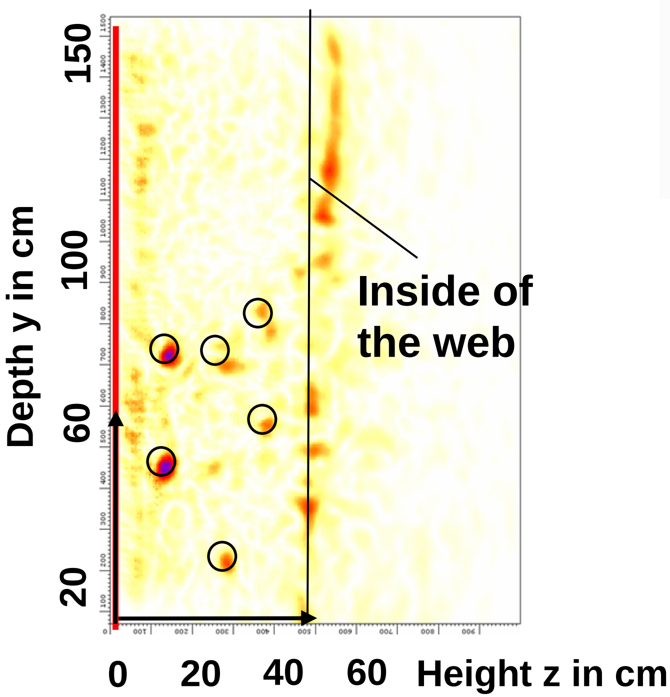
Bridge Duisburg

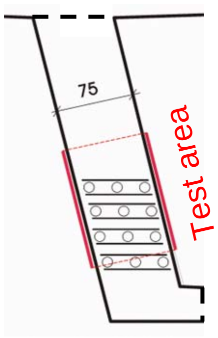
Ultrasonic Echo



Box girder web
Thickness: 50 cm
Height of test area: 1.40 m

SAFT-B-Scan

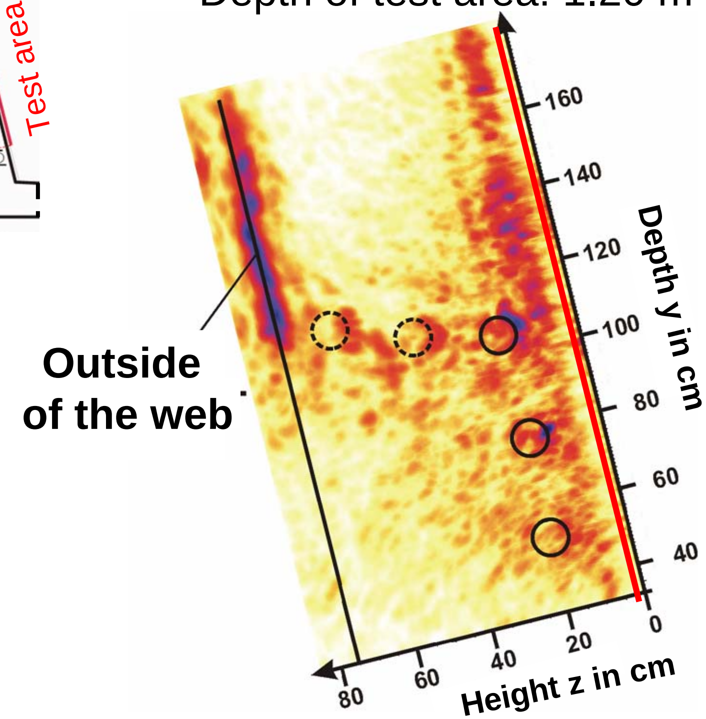




Box girder web
Thickness: 75 cm
Height of test area: 1.60 m

SAFT-B-Projection

Depth of test area: 1.20 m



Measurements on a bridge deck, pre-stressed in longitudinal direction

Test Area on the bottom side of the deck, 0.96 m x 18.40 m:

ultrasonic echo measurements were done in 23 scanning areas length of 2 m x 0.40 m

Bridge Somewhere

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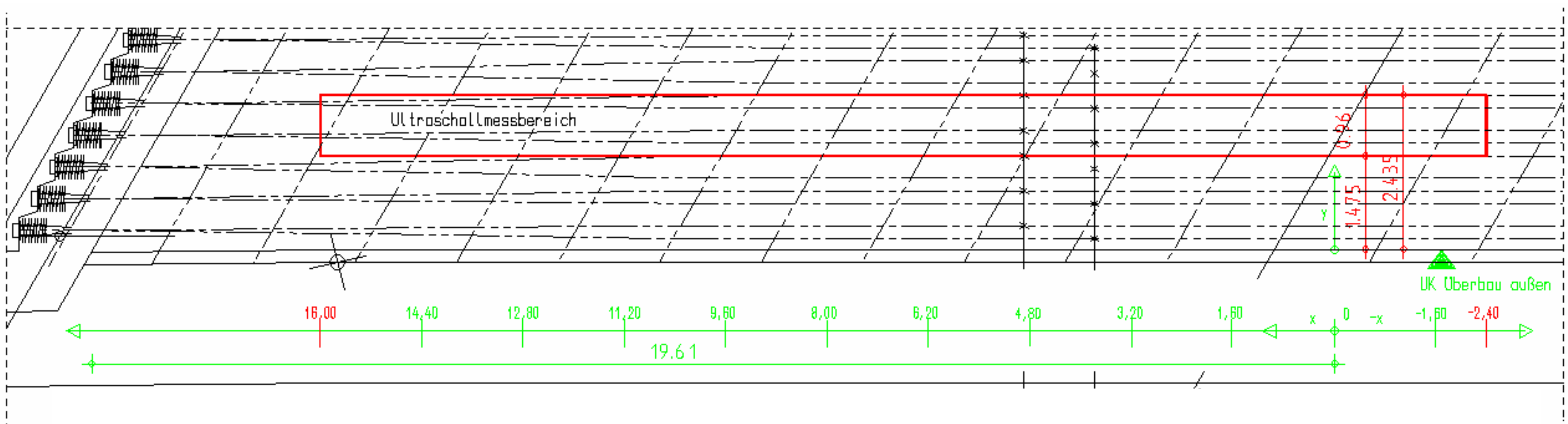
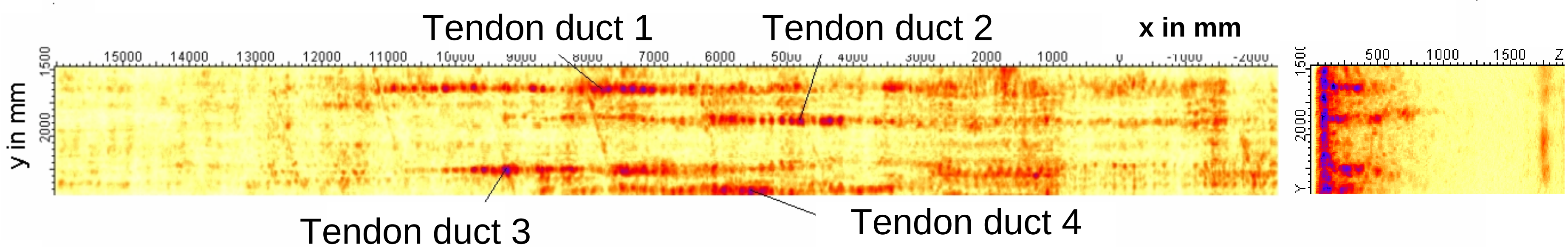
Zerstörungsfreie Schadensdiagnose und Umweltmessverfahren
VIII.2

Ultrasonic Echo



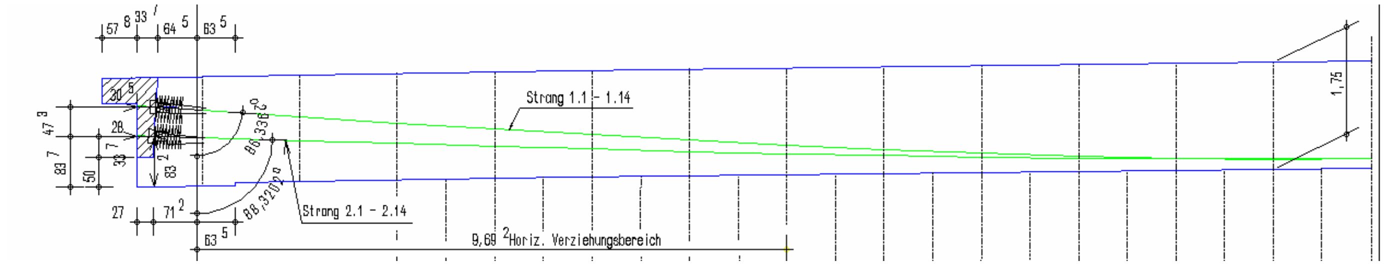


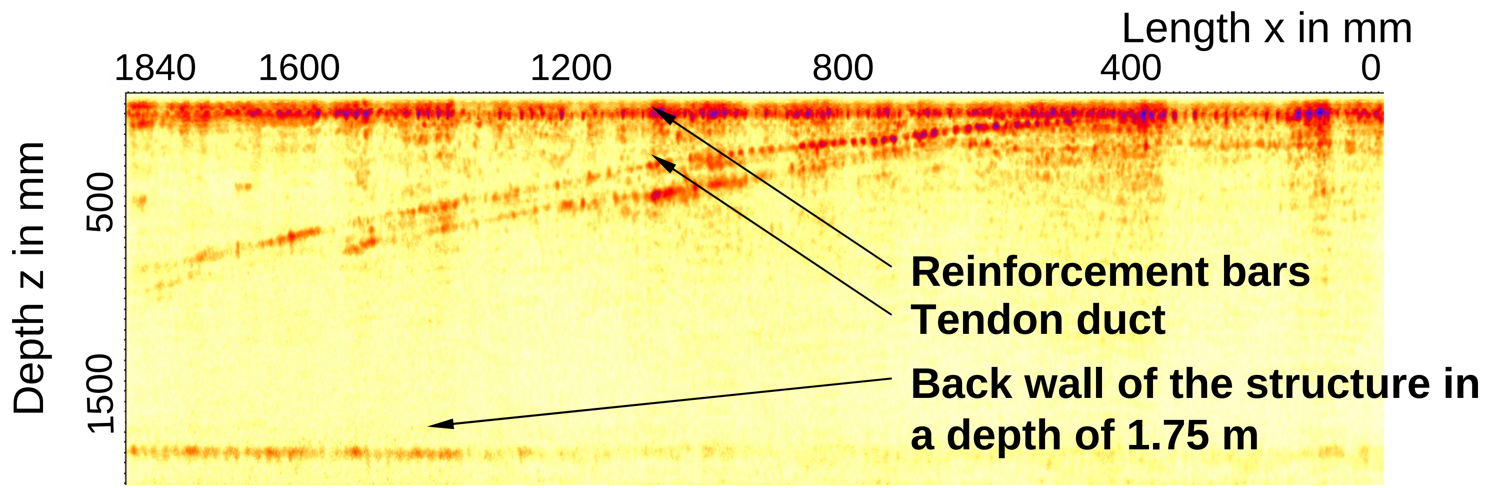
SAFT-C-Projection in the depth range of z = 200 – 400 mm

Right: SAFT-B-Projection about the whole length of 18.40 m

Bridge Somewhere

Evaluation of the Intensity of Ultrasonic Echo-Signals

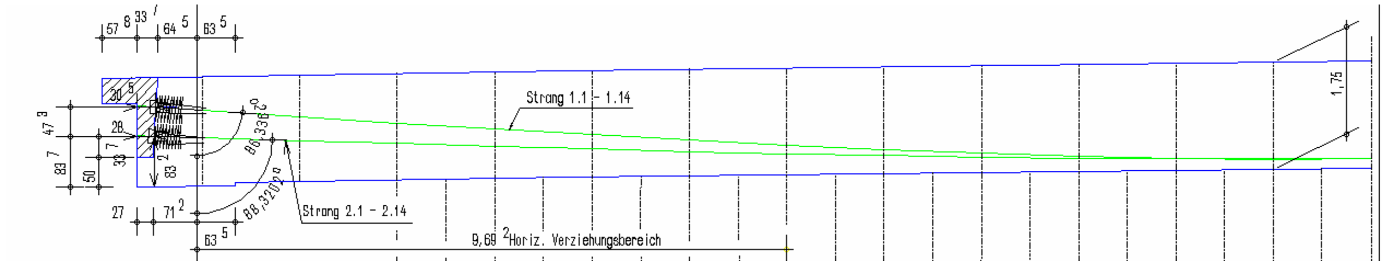


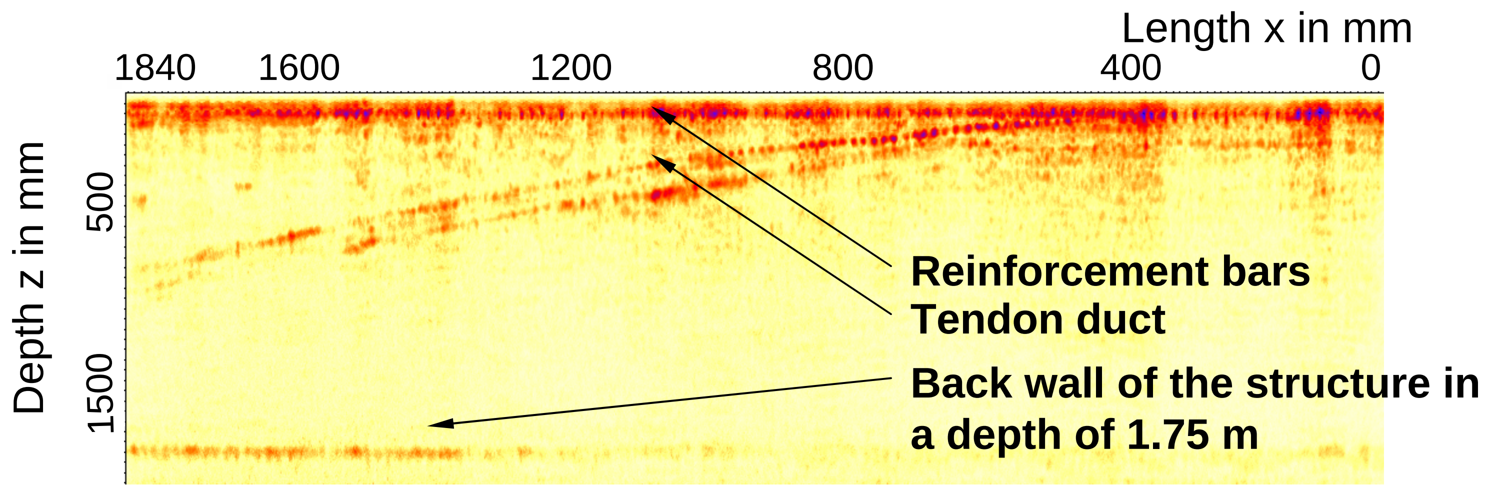


SAFT-B-Projection about the range with the tendon duct 2

Bridge Somewhere

Evaluation of the Intensity of Ultrasonic Echo-Signals

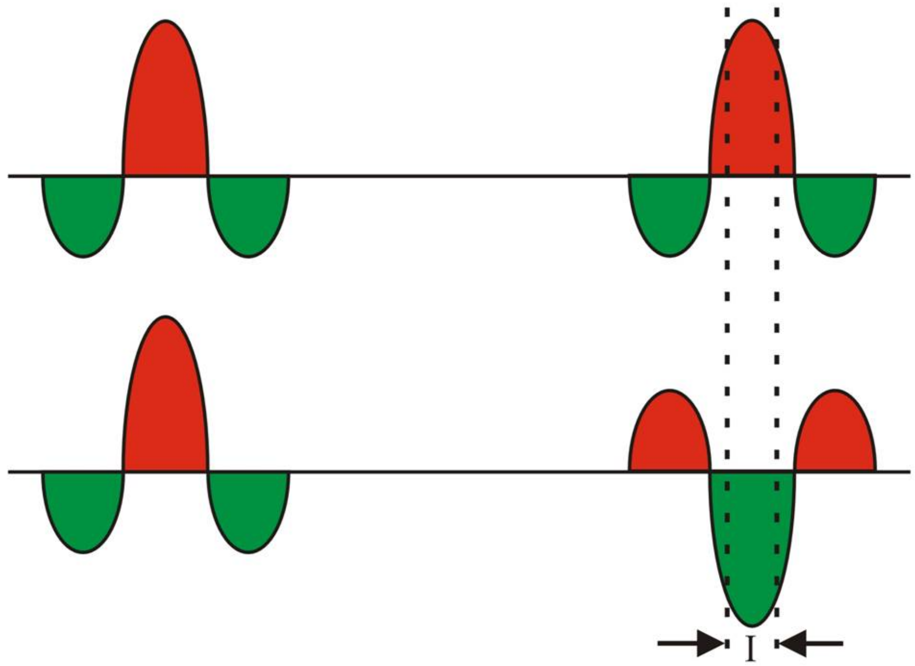




SAFT-B-Projection about the range with the tendon duct 2

Phase Evaluation

Pulse Behaviour of Ultrasonic Echo-Signals



Transmitted pulse

Reflected pulse

Reflections on steel in concrete

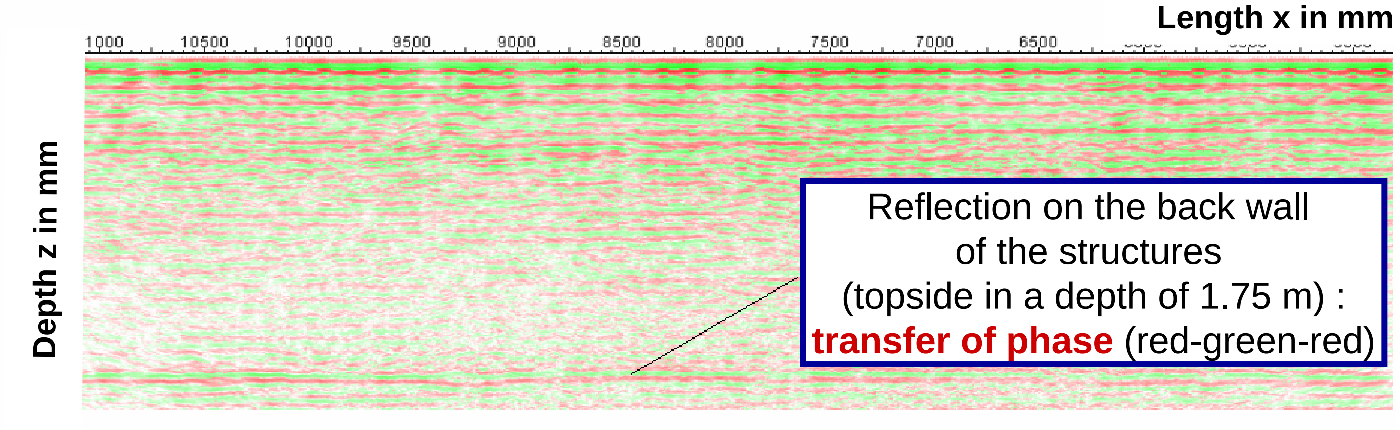
→ **No transfers of phase**

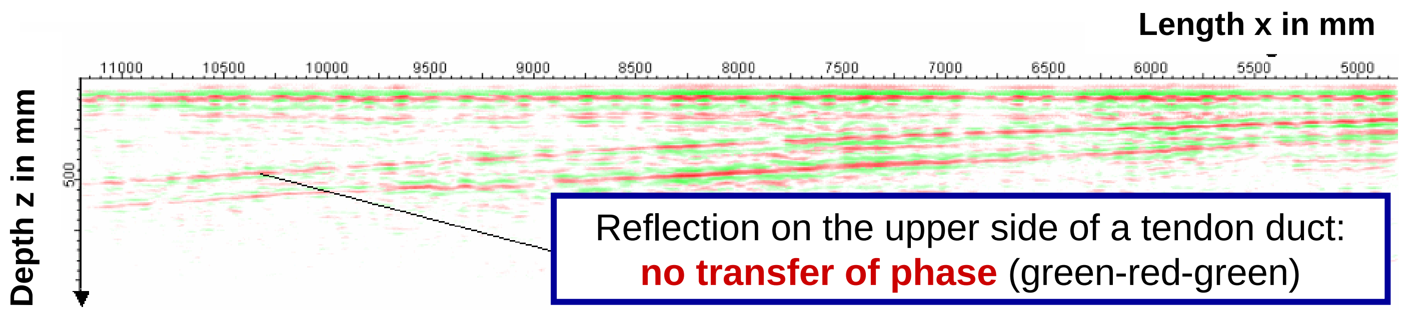
Reflection on air-inclusions in concrete

→ **Transfer of phase**

Phase Evaluation

Evaluation of Pulse Behaviour of Ultrasonic Echo-Signals

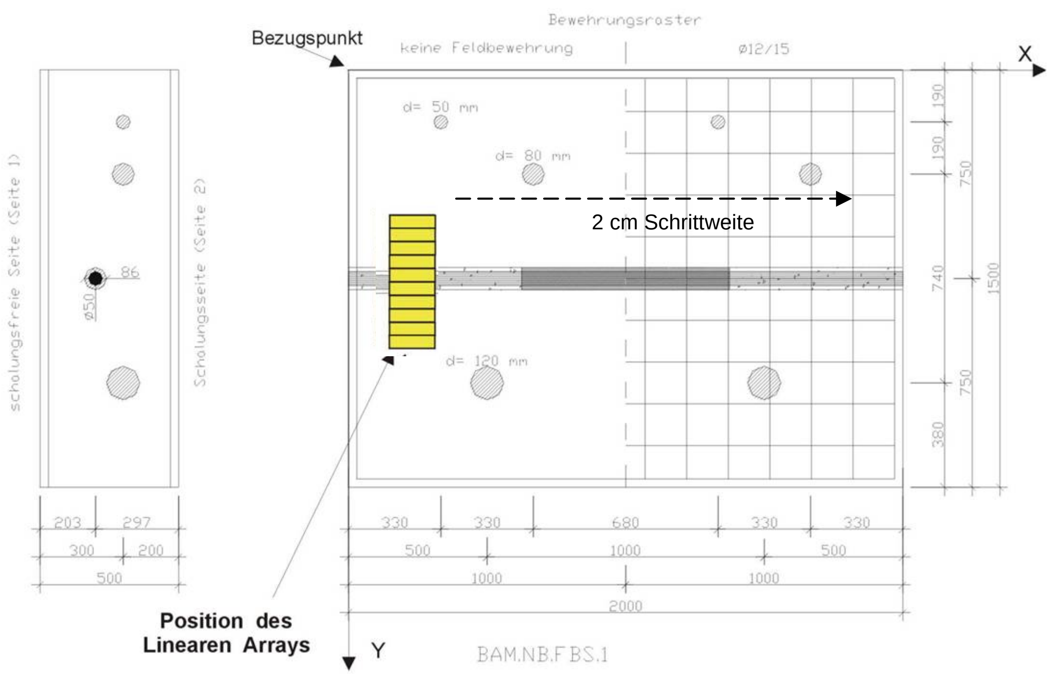




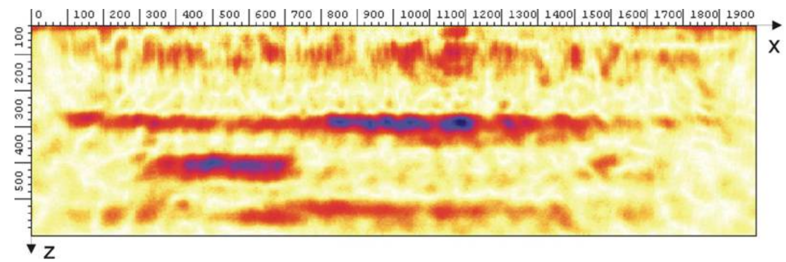
SAFT-B-Projection (Phase)

Top: about y=1940-2100 mm, Down: about y=1828-1926 mm (tendon duct 2)

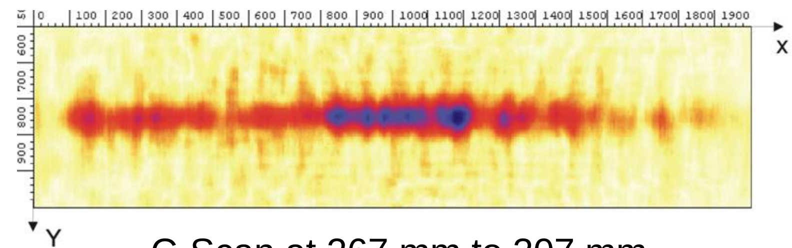
Linear Array – First Measurements



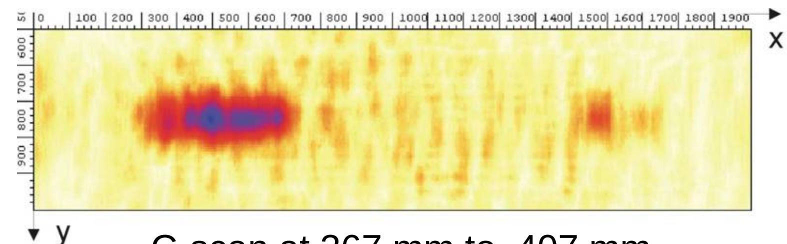
3D-Scan along duct



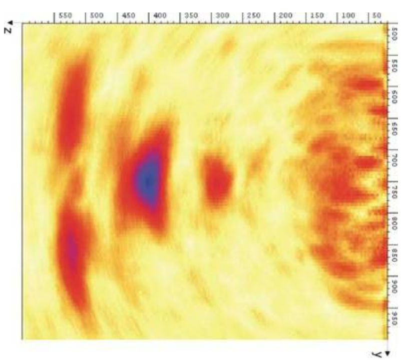
D-Scan in 751 mm



C-Scan at 267 mm to 307 mm



C-scan at 367 mm to 407 mm



Single B-scan at
400 mm to 600 mm

What‘s needed?
Training, Validation,
Software simplification,
Experience

BAM Zerstörungsfreie Schadensdiagnose und Umweltmessverfahren VIII.2

Thanks You!

bast

ASV Fulda

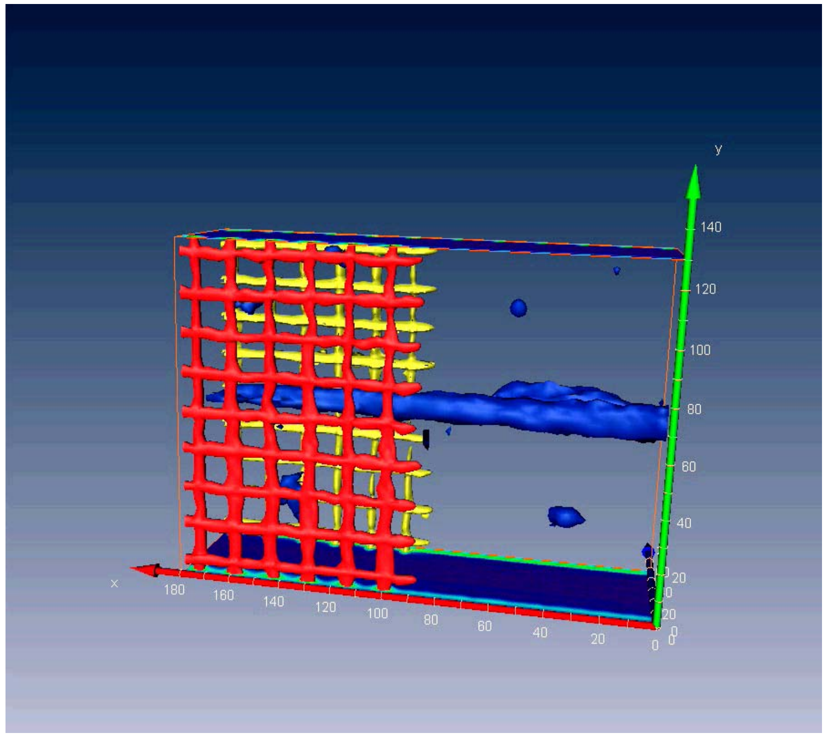
Amt der Wiener Landesregierung

MA 29 BRÜCKENBAU GRUNDBAU

ASFiNAG

Die Bahn DB

Sustainable Bridges



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And many, many others …