Applications 2

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History: Imaging Ultrasound (Pulse-Echo)

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

Visualization of the US wave propagation

Amplitude in a. u.
BAM NDT Stepper with A1220 and Impact-Echo
US Device with Dry Coupling

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)

Controller with 10 transducer units

Controlling Linear Arrays over TCP/IP

unit with 55 kHz shear wave transducers
Imaging Ultrasound on Concrete

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

www.acsys.ru/eng/
BAM Scanner Systems

- Ultrasonic Echo/Impact Echo
  - 1m²/h, 0.02 m point grid
- Radar
  - 15m²/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:
2D Scanning and 3D-SAFT
(Synthetic Aperture Focusing Technique)

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

Workshop: Ultrasonic Imaging of Concrete
Oakland, CA September 12, 2008
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

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Oakland, CA September 12, 2008
Bridge Eichenzell: Verification

Destructive testing: 35 cores, endoscopy

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

Box girder wall (longitudinal tendon ducts)
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)
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
Ultrasonic Echo

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

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

SAFT-B-Scan

SAFT-B-Projection
Depth of test area: 1.20 m

Inside of the web
Outside of the web
Bridge Somewhere

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

Right: SAFT-B-Projection about the whole length of 18.40 m
Evaluation of the Intensity of Ultrasonic Echo-Signals

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

Reinforcement bars
Tendon duct
Back wall of the structure in a depth of 1.75 m
Evaluation of the Intensity of Ultrasonic Echo-Signals

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

- Reinforcement bars
- Tendon duct
- Back wall of the structure in a depth of 1.75 m
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
Reflection on the back wall of the structures (topside in a depth of 1.75 m): **transfer of phase** (red-green-red)

Reflection on the upper side of a tendon duct: **no transfer of phase** (green-red-green)

SAFT-B-Projection (Phase)

Top: about y=1940-2100 mm, Down: about y=1828-1926 mm (tendon duct 2)
Linear Array – First Measurements

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

3D-Scan along duct

D-Scan in 751 mm

C-Scan at 267 mm to 307 mm

C-scan at 307 mm to 407 mm

Single B-scan at 400 mm to 600 mm

Workshop: Ultrasonic Imaging of Concrete
Oakland, CA September 12, 2008
Thanks You!

DFG funded group

And many, many others …