Imaging of Concrete Structures Using Ultrasonic Shear Waves Instuments

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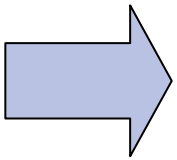
Content:

1. General information on ultrasonic NDT for concrete evaluations
2. Description and distinctive features of shear wave instruments

Concrete as a material for inspection

- **Heterogeneous material** with inherent ultrasonic background noise
- **Complex structure** (cement matrix, reinforcing steel type)
- **Large test areas**
- Most tested structures currently are **under service**



- **Strong dependence on the skills and experience of the testing engineer**
- **Unique structural characteristics and features for each structure**

Ultrasound as a testing method

Advantages:

+ Real-time results and imaging of the internal characteristic of the structure

+ Less sensitive to dense layers of steel reinforcement

+ Different testing techniques possible (pulse echo method, through transmission, surface sounding)

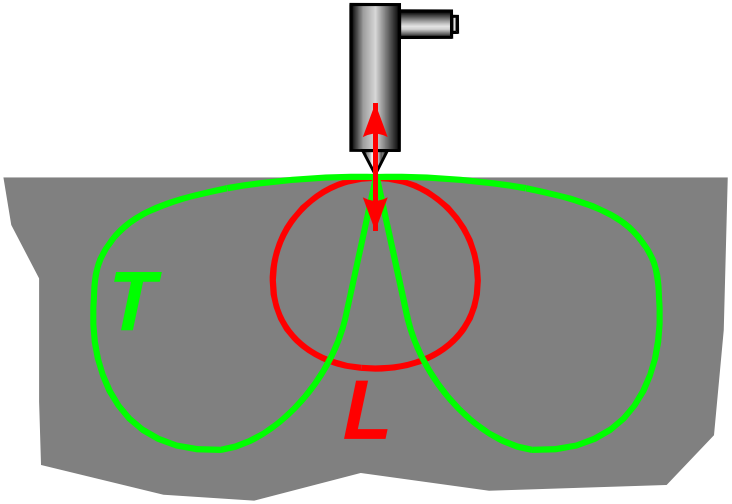
Ultrasound as a testing method

Features:

- Frequency range for concrete testing
  20 – 150kHz (λ ~ 2 – 25 cm)
- Strong dependence of attenuation on frequency
- High level of background noise
- Sizes of defects and distances are comparable with λ
- Unreliable acoustic contact through coupling

DPC Transducers

Transducers with Dry Point Contact (DPC)



On diagrams:

L – Longitudinal wave

T – Shear wave

DPC Transducers

CHARACTERISTICS AND SPECIAL FEATURES:

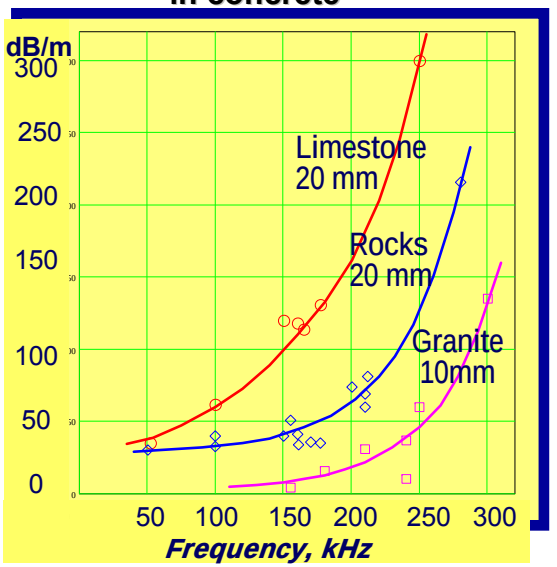
- **Point acoustic contact**:
  reliable acoustic connection without coupling material
- **Short signals:** 1,5 – 2 periods of oscillations
- **Fast-falling self-reverberation noise:**
  more 10 dB for one period of oscillations
- **All main types of acoustic waves:**
  Longitudinal waves, Shear waves, and Rayleigh waves

Shear vs Longitudinal Waves, Operational Frequency

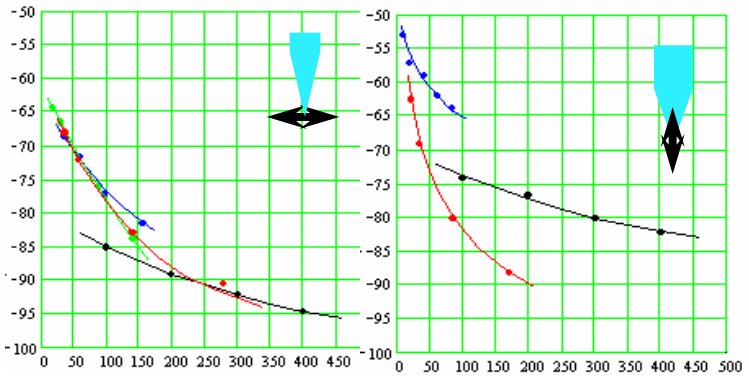
Advantages

1. Smaller dead zone
2. The background noise when testing with shear waves transducers is 12 dB less in comparison to longitudinal waves transducers
3. The wavelength sizes of defects for shear waves are twice bigger then for longitudinal waves at the same frequency
4. The cracks filled with water in concrete reflect shear waves better then the longitudinal waves

Attenuation of longitudinal waves in concrete



Signals-to-Noise Ratios



- Structural noises
- Noises from SH-waves

Backwall signal
Noises from Rayleigh waves

Antenna arrays from DPC transducers

- ✓Use of antenna arrays from DPC transducers provide good signal-to-noise ratio
- ✓Better resolution due to the more narrow directivity diagram with increased aperture of the array
- ✓Good acoustic contact even on rough surface
- ✓Elements of antenna arrays are spring loaded, allowing operation on uneven surfaces

Equipment for concrete inspection

Advantages:

- **Testing at one-side access to the object**
- **Dry acoustic contact (no coupling)**
- **No special preparation of surface necessary**
- **Good Signal-to-noise ratio**
- **Different testing techniques:** Pulse-echo method, surface transmission, through-sounding

Ultrasonic tester SURFER

Features:

- Time / Velocity of ultrasound propagation measurements
- Evaluation of crack depth
- Small size
- Built-in transducers – more comfortable operation

Application:

- Estimation of concrete consolidation
- Estimation of concrete strengthening when building with mess concrete and sliding form
- Estimation of porosity and cracking

Patent RF № 2082163

Flaw detection and imaging of concrete

- ✓ Access only from one side to the test object is needed
- ✓ Data acquisition from several positions giving readable and understandable imaging
- ✓ Can be integrated in automated scanning systems

Flaw detector **EyeCon**

Tomographic instrument **MIRA**

Low-frequency Flaw detector EyeCon

Features:

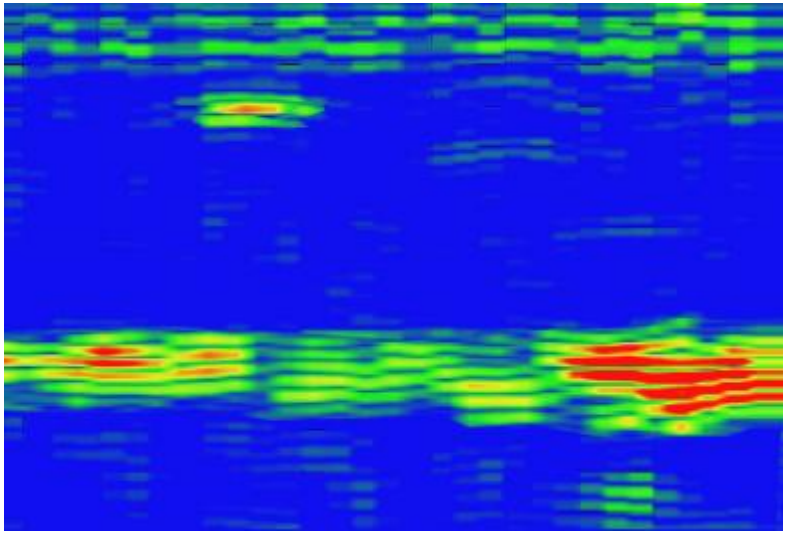
- Dry contact
- One-side access to testing object
- 24-element antenna array
- Pulse-Echo method
- Thickness of concrete up to 60 cm
- Software for data processing with reconstruction of B, C, D-Scans

Application:

- Thickness measurement of concrete objects
- Assessment of voids, cracks, honeycombs, foreign inclusions inside concrete
- Through transmission testing using corresponding transducers

Patent RF
№ 2080592

SAMPLE: 800 × 400 × 400 mm (filling – granite, 20 mm)



EyeCon + Software PlaneVisor

(30 positions of Array with step 20 mm along the block)

Drilled holes:

diameter 30 mm,
depth 130 mm;

diameter 13 mm,
depth 55 and 160mm

Shear Wave Tomography Instrument MIRA

Inspection of plain or reinforced concrete,

Maximum thickness 2,5 m

Imaging of the structure

Antenna array A1040 MIRA for manual application

10 Modules by 4 elements

Step between elements:

- horizontal 40 mm
- vertical 20 mm

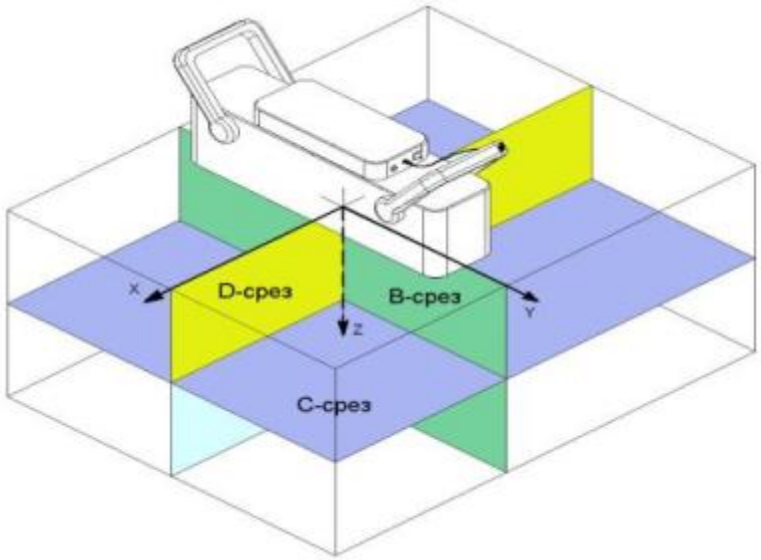
MIRA: Antenna Operation

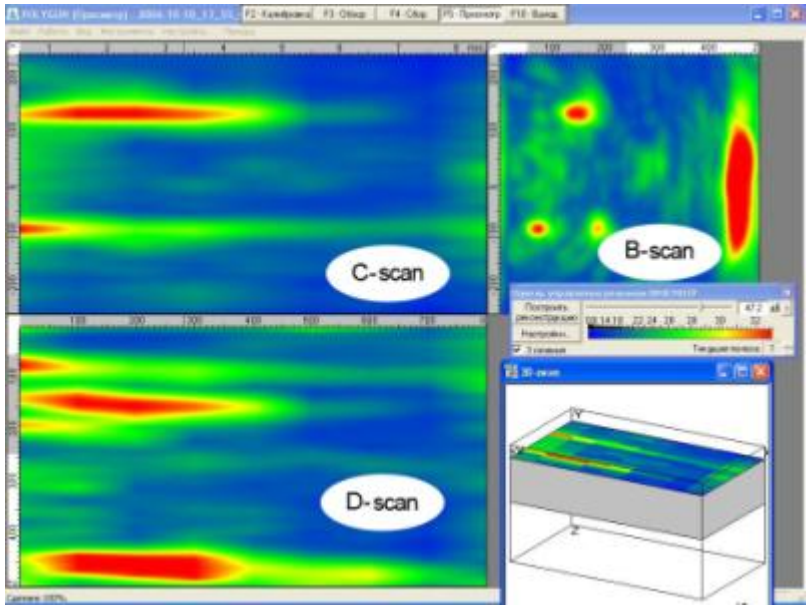
Process – acquisition of signal outputs from all possible pairs of measuring elements, working as senders and receivers

Result – Stored and SAFT-C processing of the signals from each pair in a resulting image

(at 10 units – totally 45 signal outputs)

MIRA: Data processing





Data imaging as B, C, D-scans

Determination of actual depth of the flaw and signal amplitude in any point of reconstructed image

Additional instruments for better imaging

Storing data files with inspection parameters

MIRA: Special features

Additional advantages for easier operation

- **Automatic calibration from 8 positions:**

- the average ultrasound velocity is measured
- surface SH-wave compensation is made, providing better imaging in near surface area

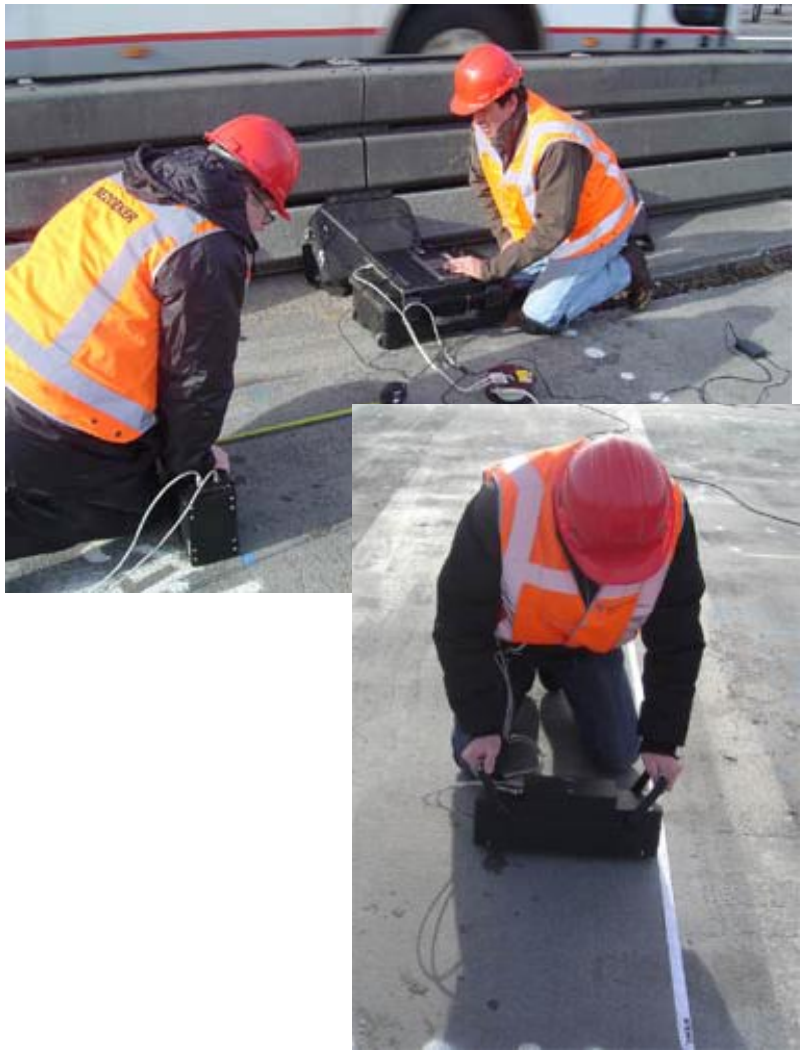
- **Wireless connection between the array and PC**

- one person operation is possible

MIRA: Application

- Concrete quality control
- Determining the integrity of concrete
- Determining the presence of cracks, honeycomb delaminations
- Thickness measurements
- Assessment of thick concrete (about 2,5 m)

MIRA: Inspection procedure



Step-by-step scanning

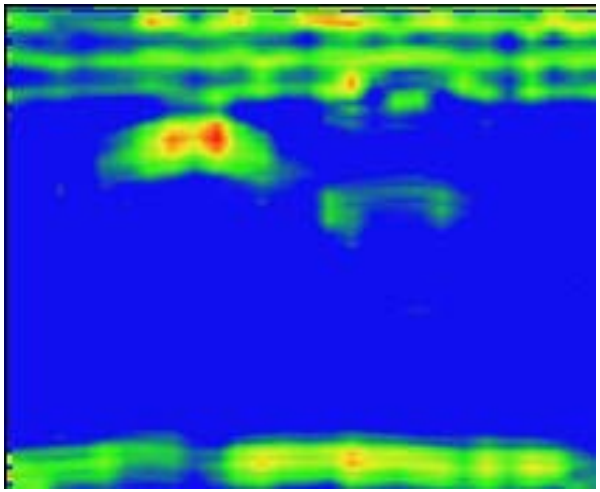
Real-time imaging (reconstruction of section in 3 sec)

Data accumulation from several positions and **reconstruction of image of the entire scanned line**

SAMPLE BLOCK
800 × 400 × 400 mm
(filling – granite, 20 mm)

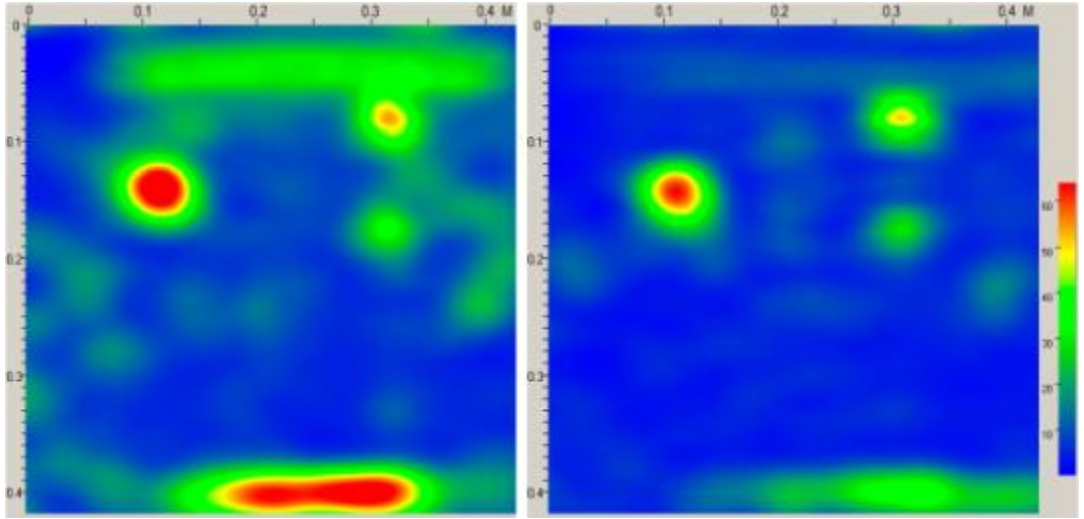
EyeCon

30 positions of Array with step 20 mm along the block

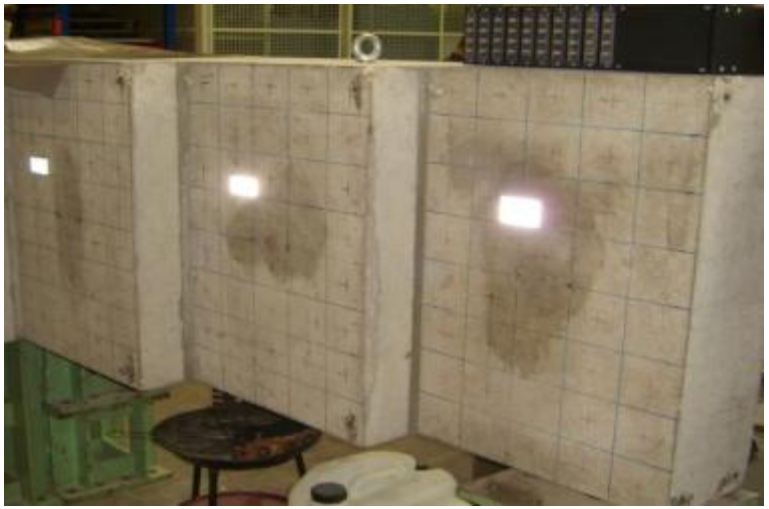


Mira

1 position of A1040 (left), 4 positions of MIRA with step 80 mm along block (right)

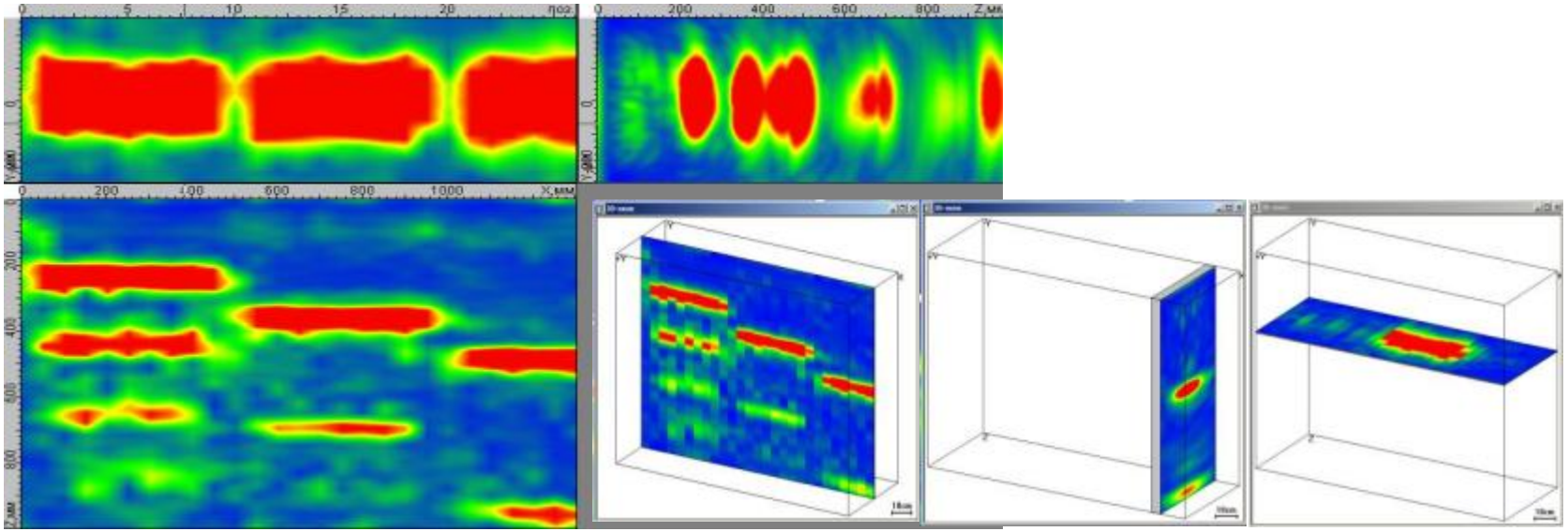


MIRA: Application examples



Concrete plate with variable thickness:

Length of each step - 500 mm
Total plate length – 1500 mm
Thickness of steps – 250, 350, 450 mm



Conclusions:

Different instruments for different kinds of concrete inspection

Imaging of internal structure based on shear wave pulse-echo technique: from simple side-view presentation to SAFT-C tomographic imaging

Easier understanding and analysis