Detection of Defects in Massive Concrete Blocks by Impact-Echo

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Example of Massive Concrete Blocks

Foundation of huge engines, dams, nuclear powerplants
Certain Massive Concrete Blocks

Reference block
Certain Massive Concrete Blocks

Reference block
Certain Massive Concrete Blocks

Block with artificially inserted “defects”
Certain Massive Concrete Blocks

Block with artificially inserted “defects”
Certain Massive Concrete Blocks
Certain Massive Concrete Blocks
Principle of Impact-Echo

- \( L_{\text{min}} > \lambda \)
- \( d_{\text{min}} > 0.5 \lambda \)
- \( d_{\text{max}} < 4 \lambda \)

**Fast Fourier Transform**

- Amplitude
- Time [\( \mu \text{s} \)]
- Frequency [kHz]

\( f_T \) and \( f_D \) labels.
Principle of Impact-Echo

- Impact wave travels through air and hits the concrete.
- Concrete acts as a material of high acoustic impedance, e.g., steel.
- Compressive and tensile waves are generated.

Mathematical Formulas:

\[ f_T = \frac{c_p}{2T} \]

\[ f_z = \frac{c_p}{4d} \]

\[ f_v = \frac{c_p}{2d} \]
Starting Measurement

• Estimation of P-wave velocity (can be used ultrasonic instrument)

• Assumption of “defects depths” (by the project, by direct measuring)

• Calculation of expected frequencies

• Preliminary detection of “bad” places

• Verification of correct velocity and depths
Starting Measurement

Block with artificially inserted "defects"
Starting Measurement

Measuring of cover depths
## Starting Measurement

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| A | B | C | D | E | F | G | H | I | J | K | L | M | N | O | P | Q | R |

**Bold = steel reinforcement**

**Assumed cover depths in mm**
Starting Measurement

Measuring with ultrasonic instrument TICO
Starting Measurement

Measuring with ultrasonic instrument TICO
Starting Measurement

Pulse velocity distribution - front wall
Frequency Assumption

• Having certain pulse velocity $c$ (can vary)
• Knowing “interesting” places (low velocity) where can be defects, their cover depth $d$
• Expected fundamental frequencies can be calculated by relationships

\[ f = \frac{0.5c}{d} \text{ (air)} \]
\[ f = \frac{0.25c}{d} \text{ (steel)} \]
Frequency Assumption

Expected frequencies in raw 3 in kHz

Expected frequencies in raws 5 and 7 in kHz
Frequency Assumption

Expected frequencies in raw 9 in kHz

Expected frequencies in raws 11 or 13 in kHz
Impact-Echo Measurement
Impact-Echo Measurement

Measuring and evaluation system DOCter
Impact-Echo Measurement

Measuring and evaluation system DOCter
Impact-Echo Measurement

Measuring and **evaluation** system DOCter
Impact-Echo Measurement Conclusion

• Strong echo (peak in frequency spectra) with natural oscillation \( f \) are determined by measuring device DOCter.

• Cover depth of anomalies \( d \) can be calculated by relationships:

\[
d = 0.5c/f \quad \text{(air)}
\]
\[
d = 0.25c/f \quad \text{(steel)}
\]
Article Conclusion

• Previous knowledge about the structure is necessary

• It is preferable combining more methods

• Fundamental frequencies analysis shows anomalies in concrete as honeycombing, plastic duct without concrete, rarely also thicker steel reinforcing bars

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