PART 2 / Ultrasonic methods for testing concrete structures

2.1 General principle

2.2 Ultrasonic Pulse Echo (UPE)

2.3 Impact Echo (IE)

2.4 Conclusions and recommendations

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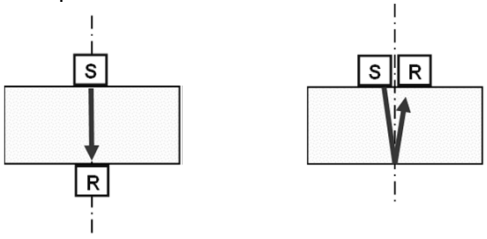
2.1 General principle

Type of waves P, S, R, Lamb

$$C_P = \sqrt{\frac{E(1-\nu)}{\rho(1+\nu)(1-2\nu)}} \qquad C_S = \sqrt{\frac{E}{2\rho(1+\nu)}}$$

- ρ density,
- E dyn. Young modulus
- ν dyn. Poisson coef.

Configuration / position of transducers



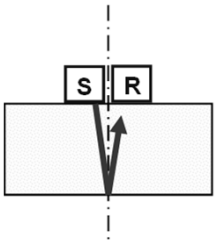
Standard EN 12-504-4 (2005)

IFSTTAR G. Villain & L. Gaillet, 30 may 2012 Investing in our common future

2.2 Ultrasonic Pulse Echo (UPE) 1/3

For detection + localization of flaws
For thickness measurement

US pulse (compression or shear waves)



$$C = \frac{2e}{\Delta t}$$

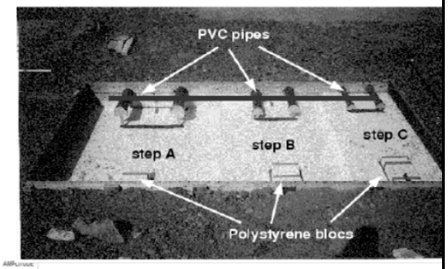
Measurement of Δt
➔ thickness e if the velocity C is known OR
➔ velocity C if the thickness e is known)

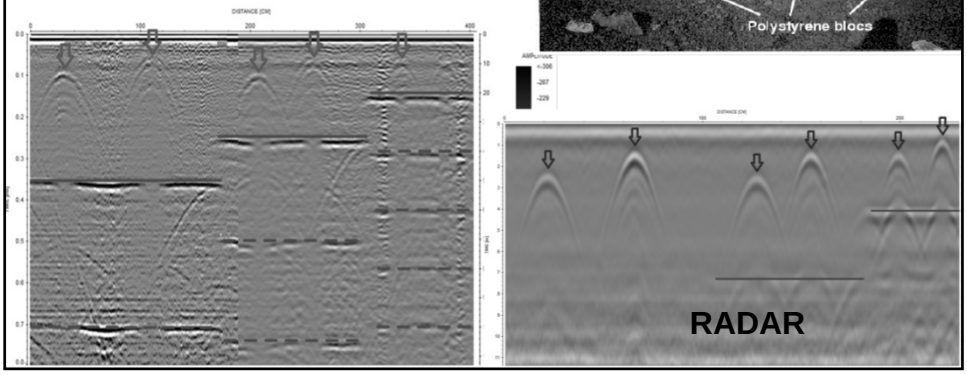
ACSYS material
fc = 55 kHz
Array of 2x12 transducers
S waves

➔ 2 examples

2.2 Ultrasonic Pulse Echo (UPE) 2/3

Longitudinal scan 1 meas. / cm
Concrete slab
3 various thicknesses 50 cm, 35 cm and 20 cm





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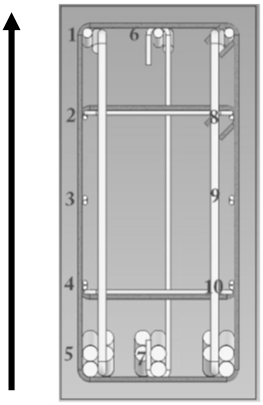
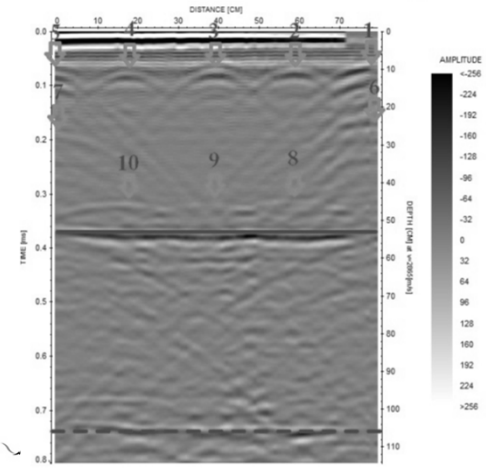
2.2 Ultrasonic Pulse Echo (UPE) 3/3

Vertical scan 1 meas. / cm
VIPP: Reinforced, post-stressed concrete beam
e = 53 cm
Detection of reinforcement





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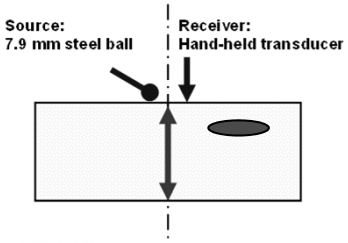
2.3 Impact Echo (IE) 1/3

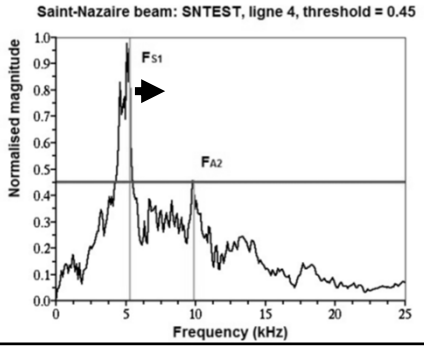
For detection + localization of flaws
For thickness measurement

$$f_{S1} = \beta \frac{C_p}{2e}$$

frequential analysis of mechanical vibrations of a concrete structure
main frequency f_{S1} 1st symmetric Lamb mode (S1 mode)

Measurement of f_{S1}
➔ thickness e if the velocity C is known OR
➔ velocity C if the thickness e is known)





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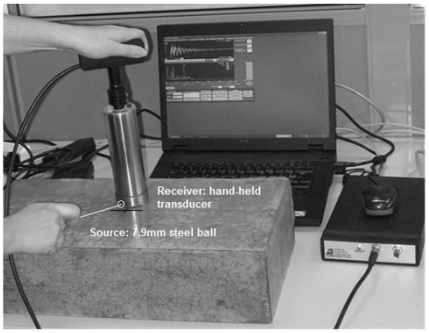
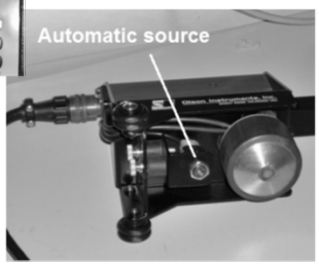
2.3 Impact Echo (IE) 1/3

Several different devices are available on the market

Germann Instrument material
Sansalone device, better software



Olson Engineering material
Easier portable device



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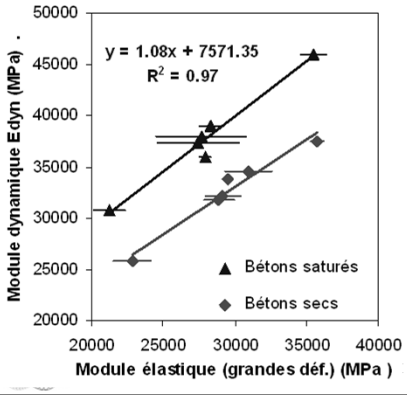
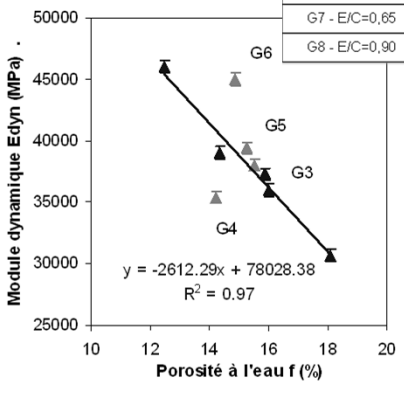
2.3 Impact Echo (IE) 1/3

For the evaluation of concrete mechanical characteristics + durability indicators

Research project ANR-SENSO
Small slabs of 9 concrete mixes
IE frequency fS1 + resonance modes of small slabs
➔Dynamic Young modulus and dynamic Poisson coefficient

Coef. de Poisson ν	SEC	SAT.
G1 - E/C=0,30	0.16	0.16
G2 - E/C=0,45	0.17	0.2
G3 - E/C=0,55	0.18	0.18
G3a - E/C=0,55	0.18	0.22
G7 - E/C=0,65	0.17	0.18
G8 - E/C=0,90	0.20	0.2





2.4 Conclusions and recommendations

Be careful

- **Concrete heterogeneous material (gradients, aggregates, rebars)**
- **So hypothesis of constant velocity in material not always verified**

- **Experienced, qualified operator to analyse the results**

- **Possible determination of dynamic moduli: still under development for both methods UPE and IE**

- **For a correct evaluation of concrete properties (mechanical characteristics + durability indicators):**
  - **Necessary to combine ND methods**
  - **Necessary to calibrate the result on cores from the structure**