7èmes journées
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Probabilistic evaluation of impact-echo sources: NDT assessment of void detection within tendon ducts

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14 laboratories, 100 people

Contents

- Context and objective
- Basic concept of probabilistic based assessment of NDT Performance
- Experimental program
- Results and analysis
- Conclusions

General context and objective

Pre-stressed and post-tensioned concrete bridges:

- Sensitive to a void in the duct (corrosion of tendons -> failure)

- Extensive zone to investigate (NDT tools)

- Gamma ray radiography: efficient for detection but costly, demands trained and licensed personnel, and safety risks

- Need for alternative in terms of simplicity and cost to get the first level of measurement (for further investigations)
  Here: Impact echo method

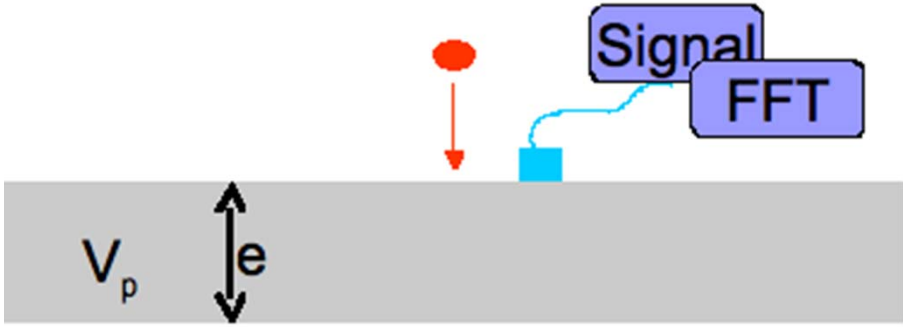
General context and objective

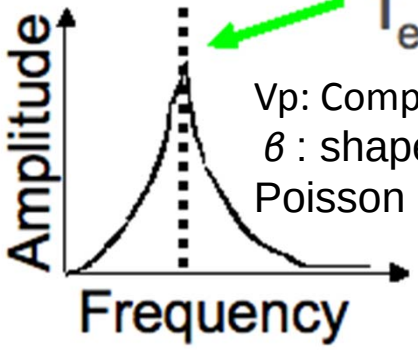
The impact echo method

Source: steel balls 6mm ->12mm

Establish for a slab

Zero Group Velocity Lamb mode





$f_e = \beta V_p / 2e$

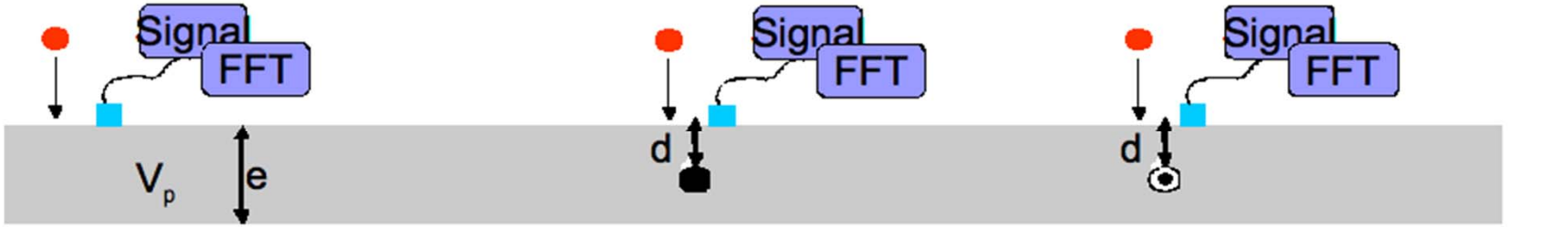
Vp: Compression wave velocity

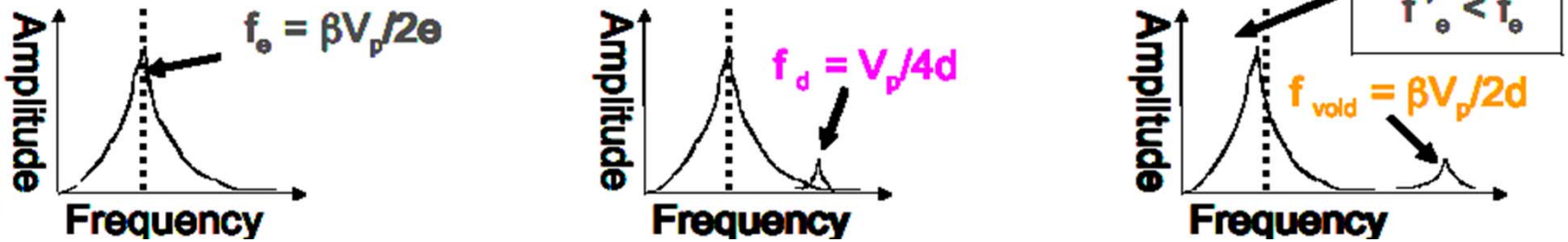
β : shape factor, function of the Poisson ratio ν $\beta = 0.095$ for $\nu = 0.22$

General context and objective

Generalization to an heterogeneous material

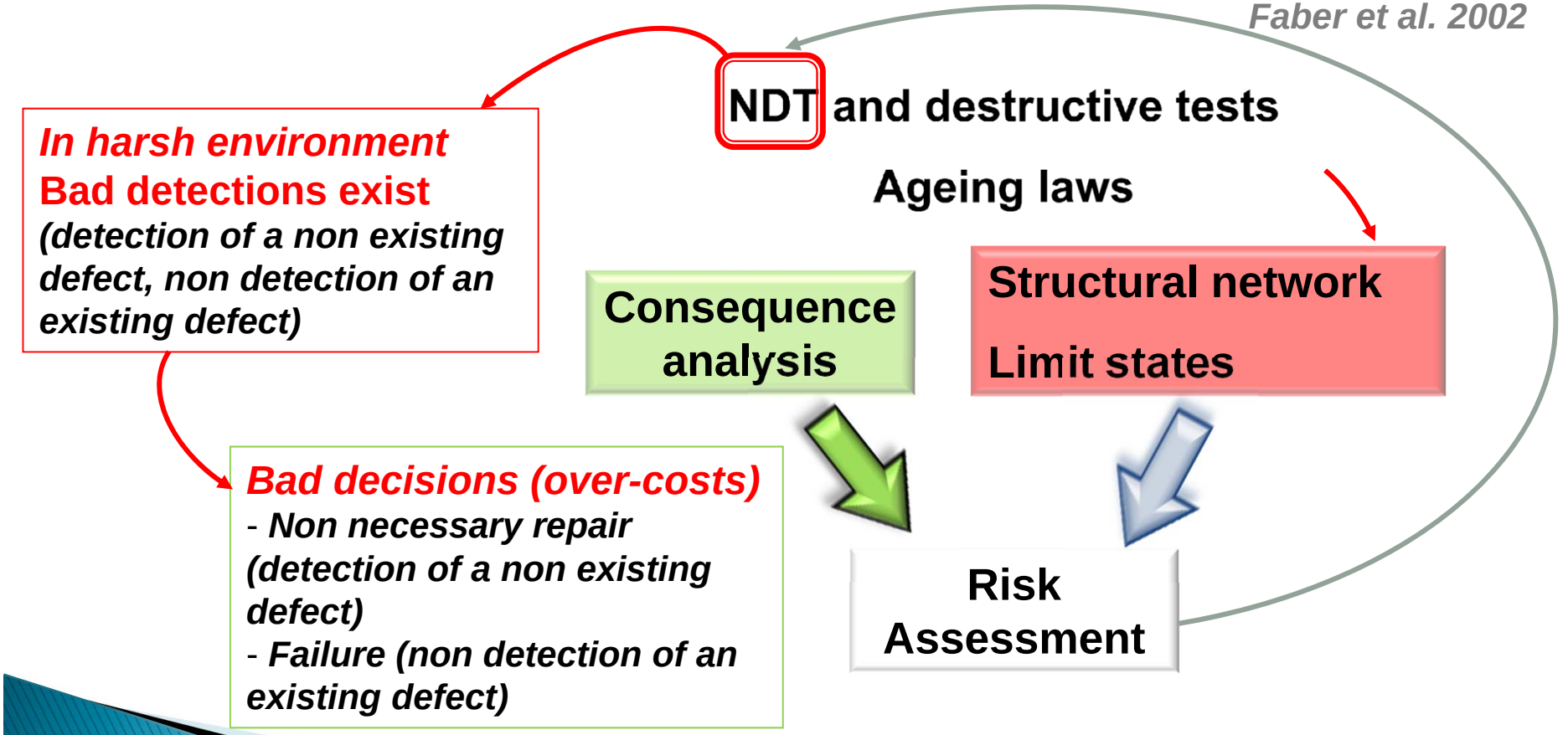
- In case of a void
  - Frequency shift of the thickness frequency (f_e)
    - $f_e \rightarrow f'_e$
    - $f_{void} = \beta V_p / 2d$





Context of RBI

RBI (optimize the planning)
Faber et al. 2002



Harsh conditions of inspection

NDT tool

Propagation of uncertainty

Natural hazard

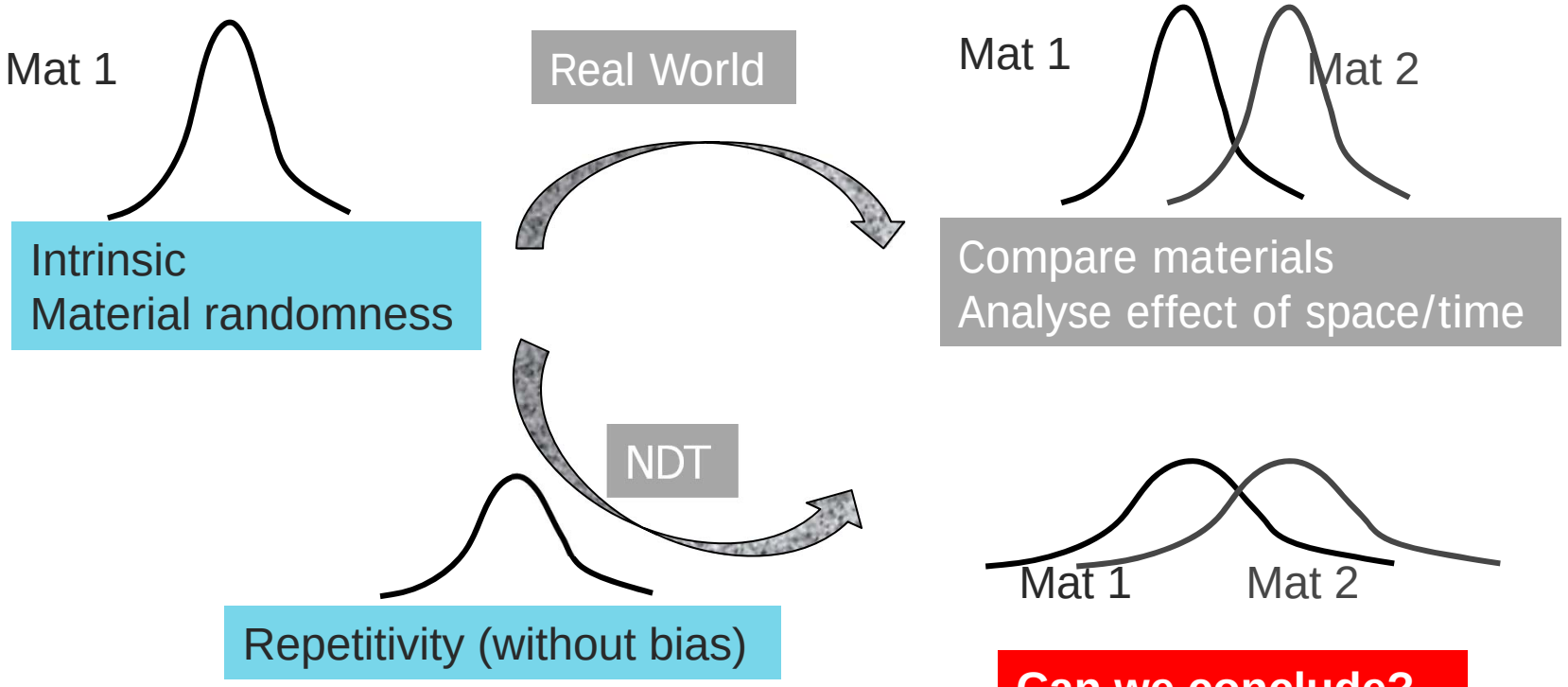
Measured property

+ Statistical uncertainty (limited number of measurements)

Marginal distribution assessment

Physical indicator (frequency)
Condition of measurement
Calibration ...

Characterization of the uncertainty after measurement



General scope of using NDT tools results in RBI context

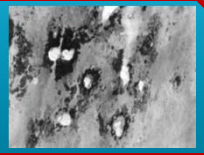
STAKES:

- Model the uncertainty

- Take into account expert judgement and model its choice

The real world

Natural Hazard



SELECTED APPROACH:

- Probabilistic modelling of inspection based on detection theory

The accessible world

PFA, PoD

Technical performance Human Factor

- Bayesian modelling of inspection results

- Introduce the expert judgement

The needs for decision

$P_i = f(PoD, PFA, \gamma)$

γ

Expert Judgment

Probabilistic modelling of inspection based on detection theory

Definitions

Probability of Detection (PoD) : Probability to detect (event d(X)=1) an existing defect (X=1)

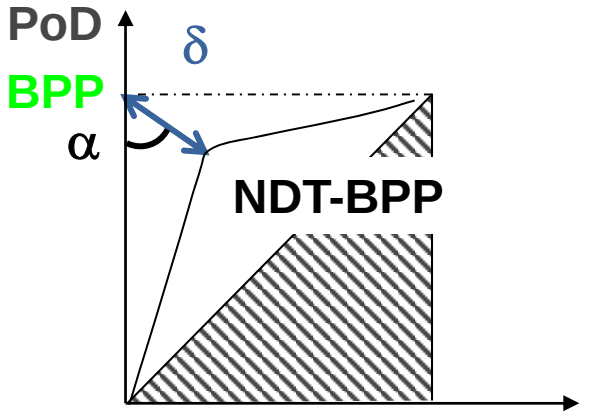
Probability of False Alarm (PFA) : Probability to detect (d(X)=1) a non-existing defect (X=0)

Bayesian definition of the PoD and the PFA:

PoD(X) = P(d(X)=1 | X=1)

PFA(X) = P(d(X)=1 | X=0)

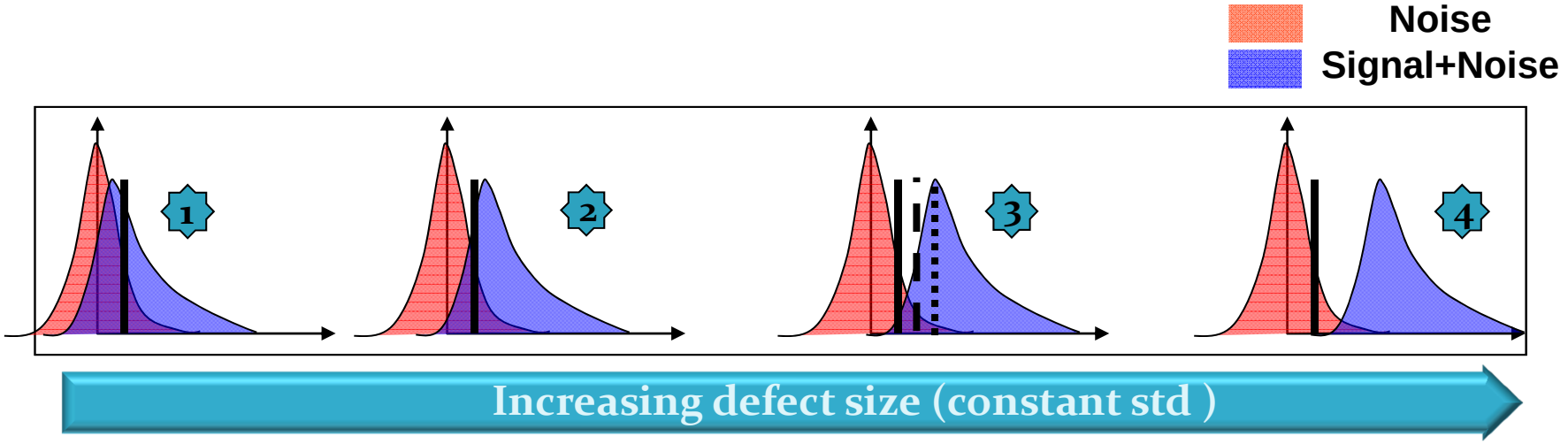
Rouhan & Schoefs, 2003



Schoefs & Boéro, 2010

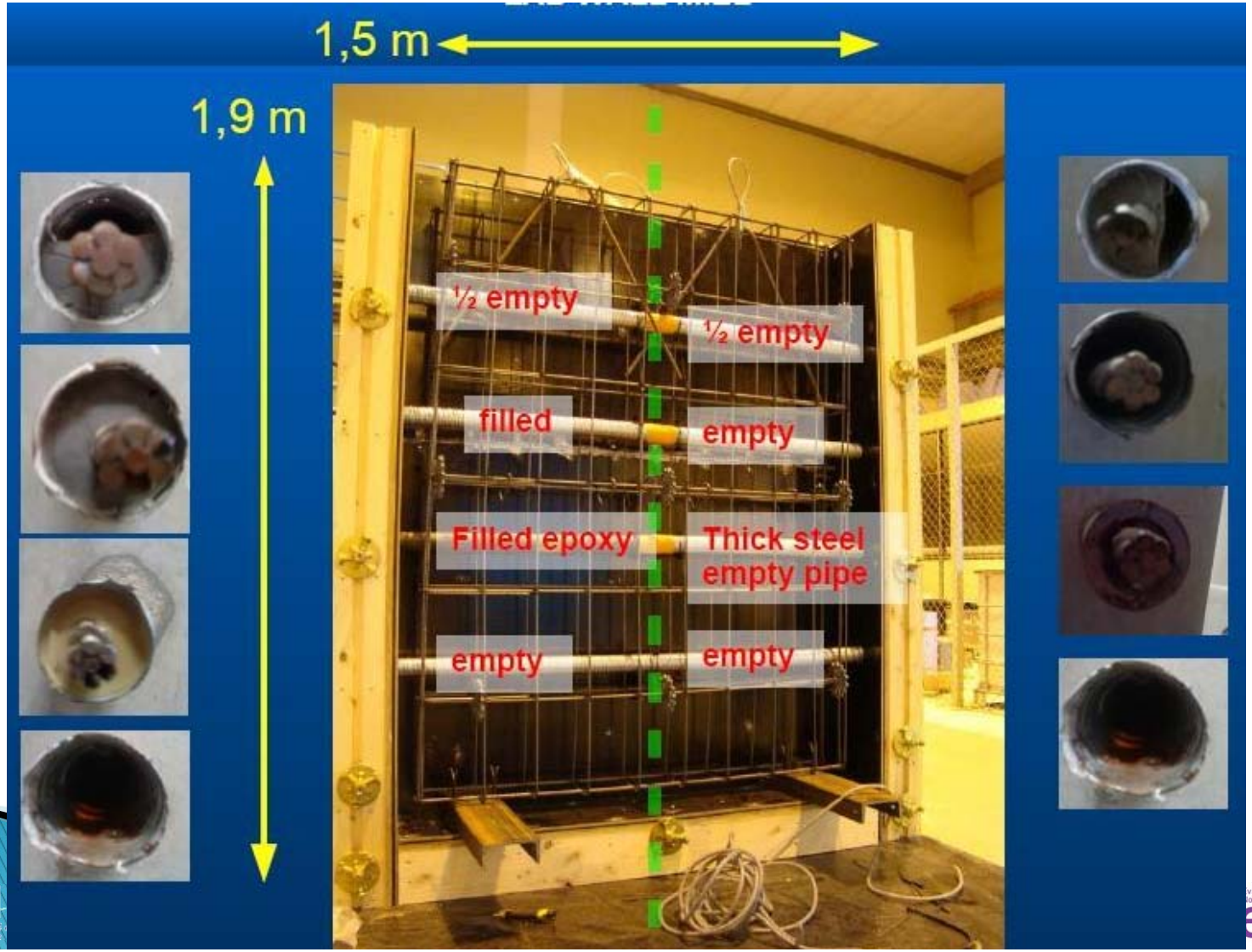
Receiver Operating Characteristic (ROC) curve

Receiver Operating Characteristic Curve (ROC)



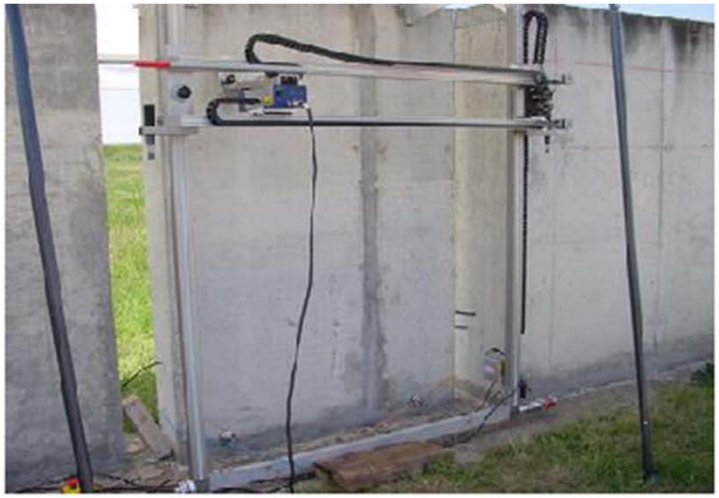
Full scale wall (IFSTTAR)

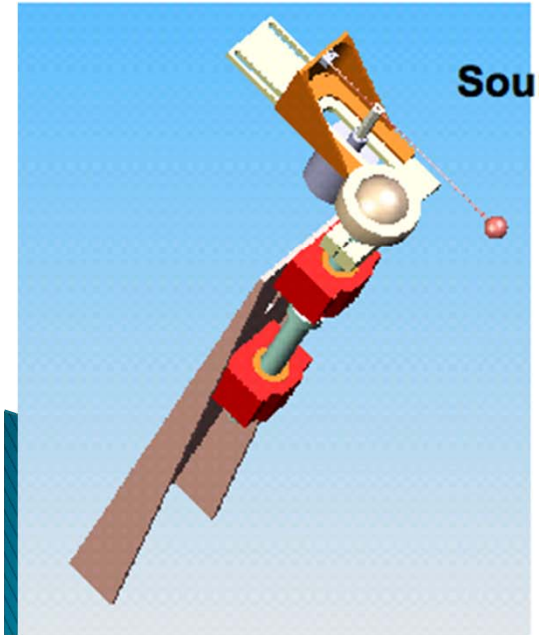
@IFSTTAR



Testing procedure

Contactless Robot @IFSTTAR





Source: steel balls 6mm ->12mm

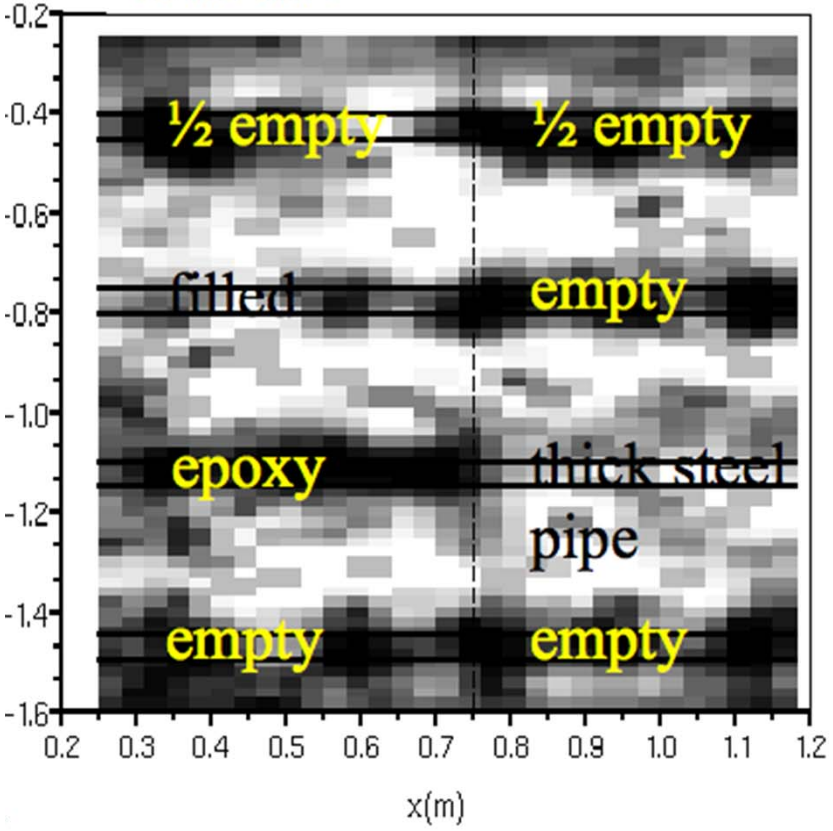
Receiver: Polythec PI
OFV-505 sensor
OFV-5000 controller
VD-02 demodulator
5 $mm.s^{-1}.V^{-1}$
bandwidth 0 → 250 kH

Contactless Robot

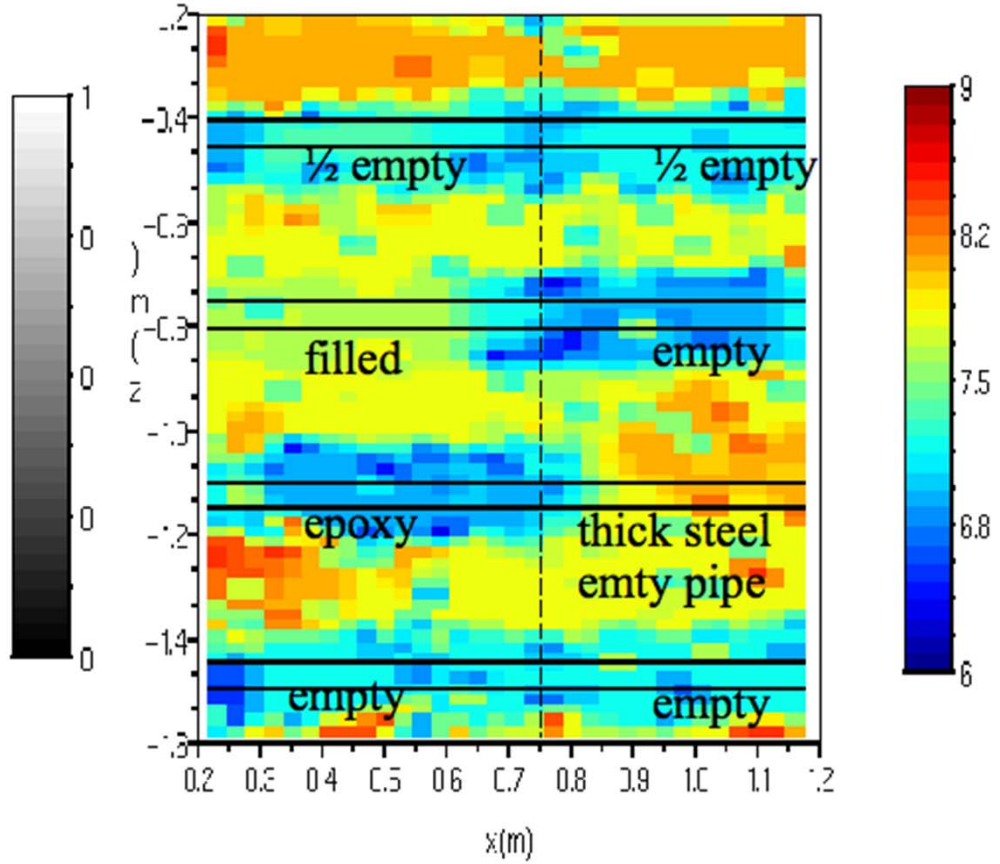
@IFSTTAR

Choice of Fp as quantity of interest

Amplitude of the normalised FFT modulus at **7.8 kHz**



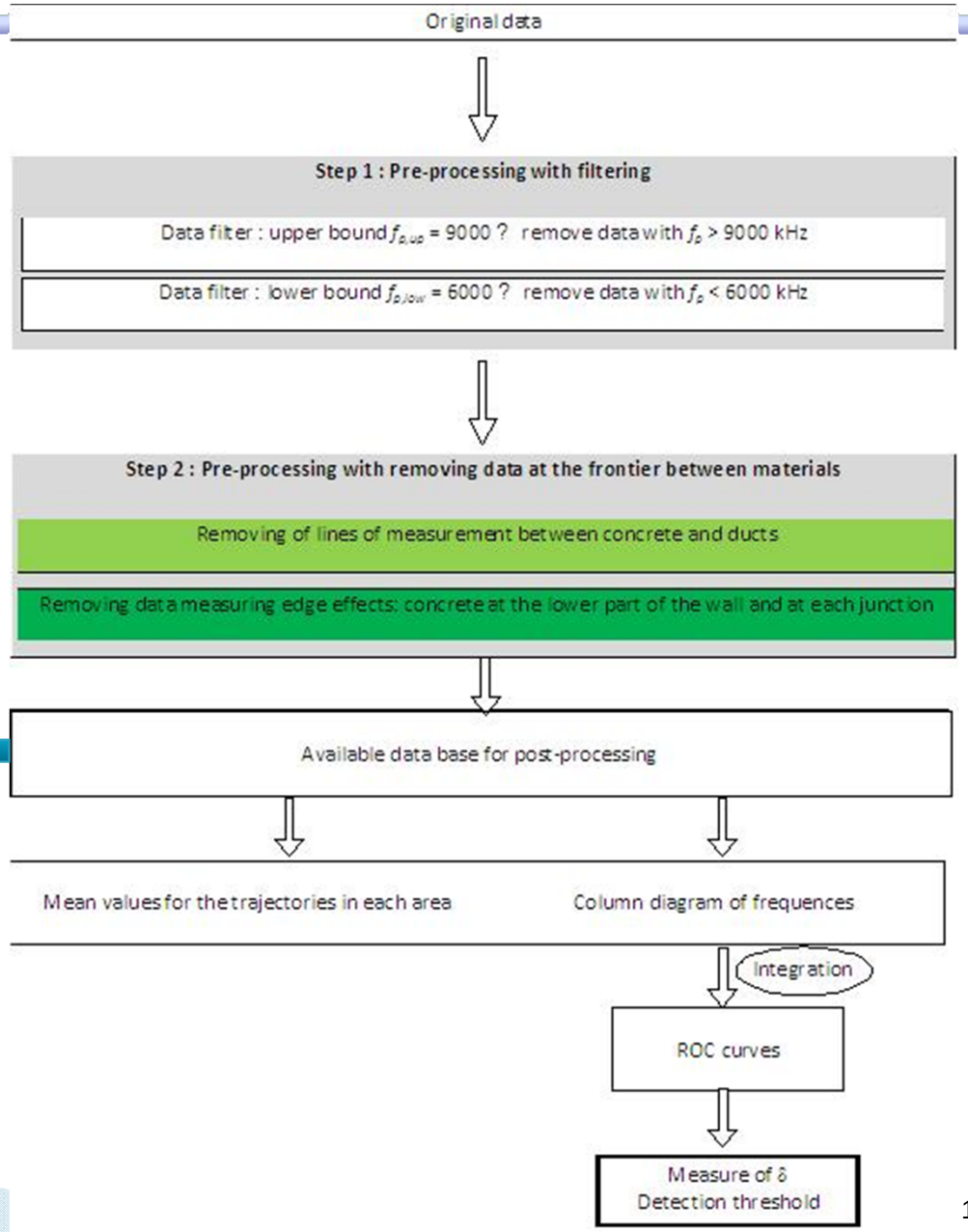
Frequency of the max of FFT modulus



Data treatment

Repetitive test: after each line of measurement a measure is carried out at a given point.

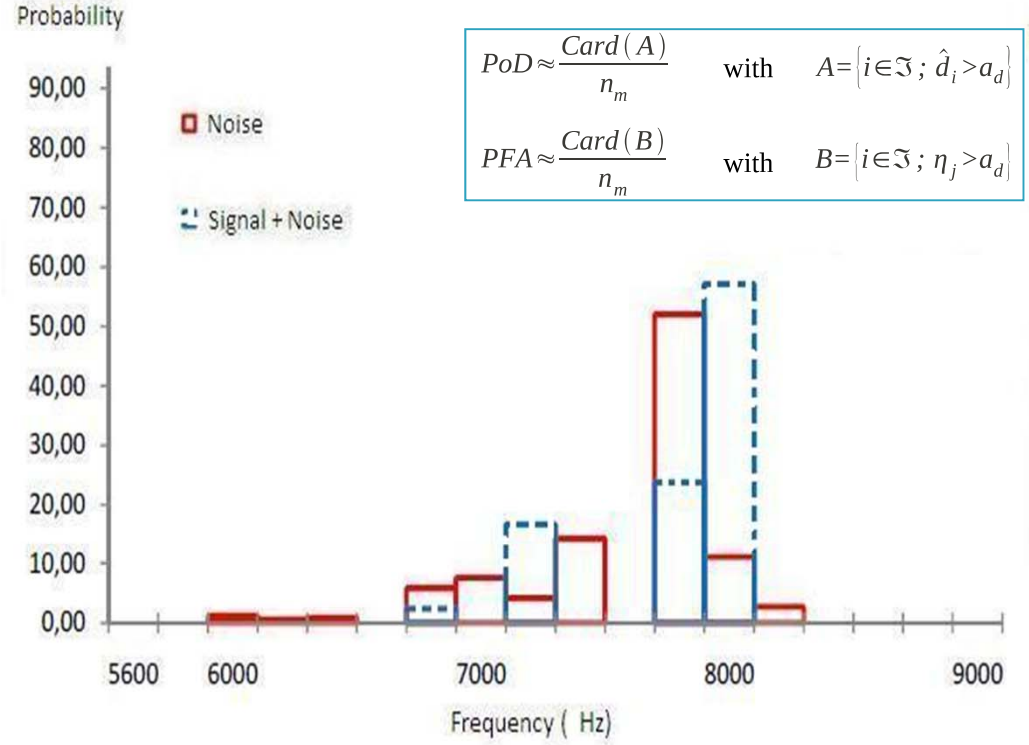
The standard deviation of the data obtained from this repetitive test: 101 Hz (CoV 1.5 %)
// the difference between mean values of peak frequency: 3 kHz



Distribution assessment after filtering

$$PoD \approx \frac{Card(A)}{n_m} \quad \text{with} \quad A = \{ i \in \Im \, ; \, \hat{d}_i > a_d \}$$

$$PFA \approx \frac{Card(B)}{n_m} \quad \text{with} \quad B = \{ i \in \Im \, ; \, \eta_j > a_d \}$$



Column diagrams for signal and signal + noise (Duct 2L) : filled

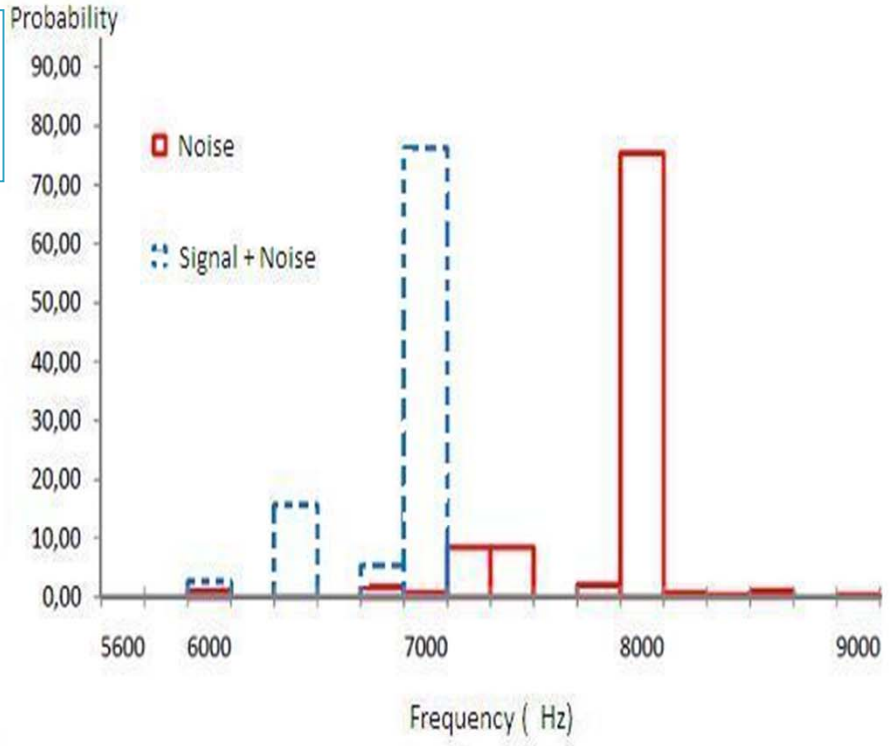
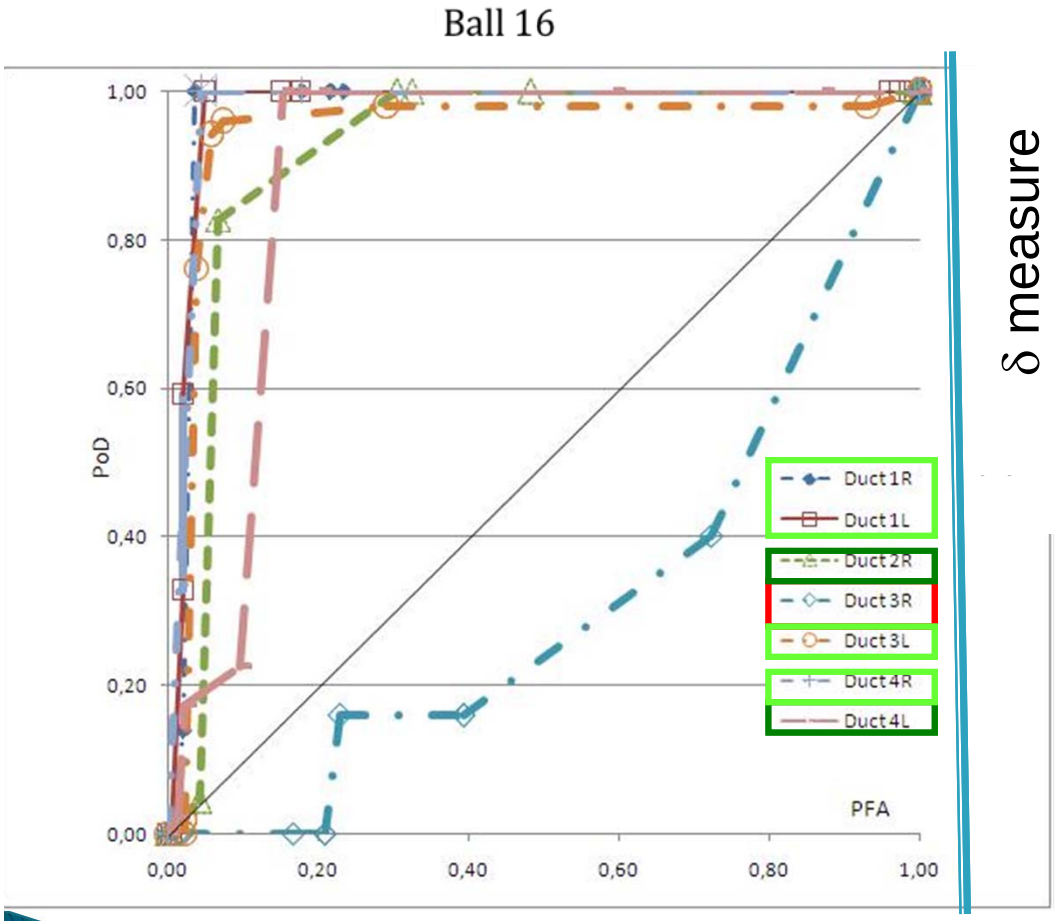
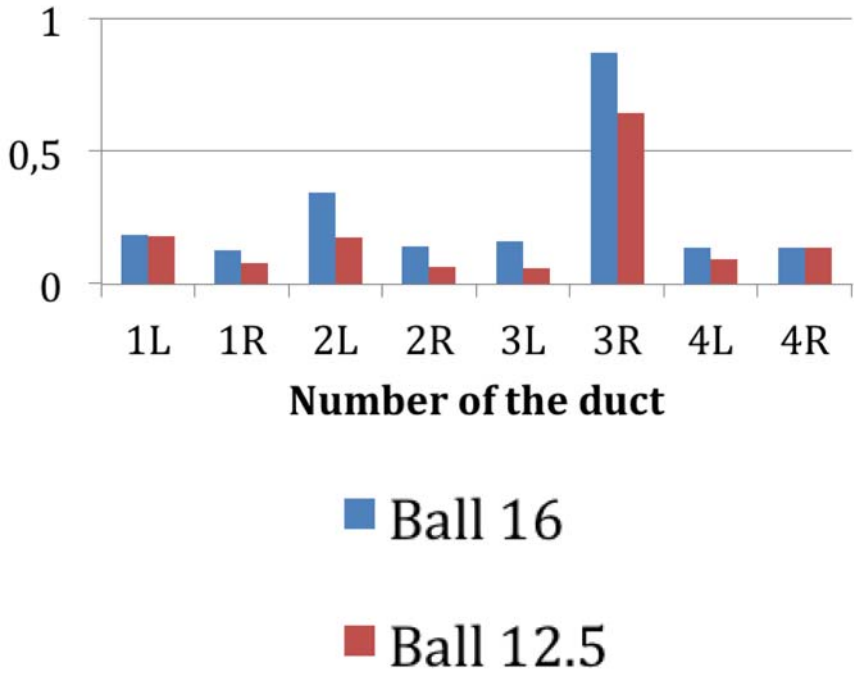


Figure 9. Column diagrams for signal and signal + noise (Duct 4R): empty

Building ROC curves



δ measure



Conclusions

➲ ROC curves are used in order to quantify the performance of NDT tools

➲Process is illustrated for the detection of voids in tendon ducts with impact echo method

Note

➲Effect of the shape of ROC curves (protocol/optimization) on the extra costs can be analyzed through the $\alpha\delta$ method (Schoefs et al. 2009)

➲Easy to implement for the optimisation of inspection and repair (Sheils et al. 2009) including multi-optimization (Bastisdas et al. 2010)

➲ Reliability of the $\alpha\delta$ method can be improved by using projection on polynomial chaos to characterize the 'noise' and 'signal+noise' (Schoefs et al., *Structural Safety*, 2009)

Future works: another quantity of interests (+ data fusion) -> optimization of the design of the robot.

Thank you for your kind attention!

Questions ?

En savoir plus:

Schoefs F., Abraham O., Popovics J., "*Quantitative evaluation of NDT method performance: application example based on contactless impact echo measurements for void detection in tendon duct*", Construction and Building Materials, Available on line March 29th **2012**, in press.

Schoefs F., Abraham O., "Probabilistic evaluation for improvement of design of impact-echo sources", in Transportation Research Record (TRR), Journal of the Transportation Research Board, **2012**