



Comparison of NDT techniques on a post-tensioned beam before its autopsy

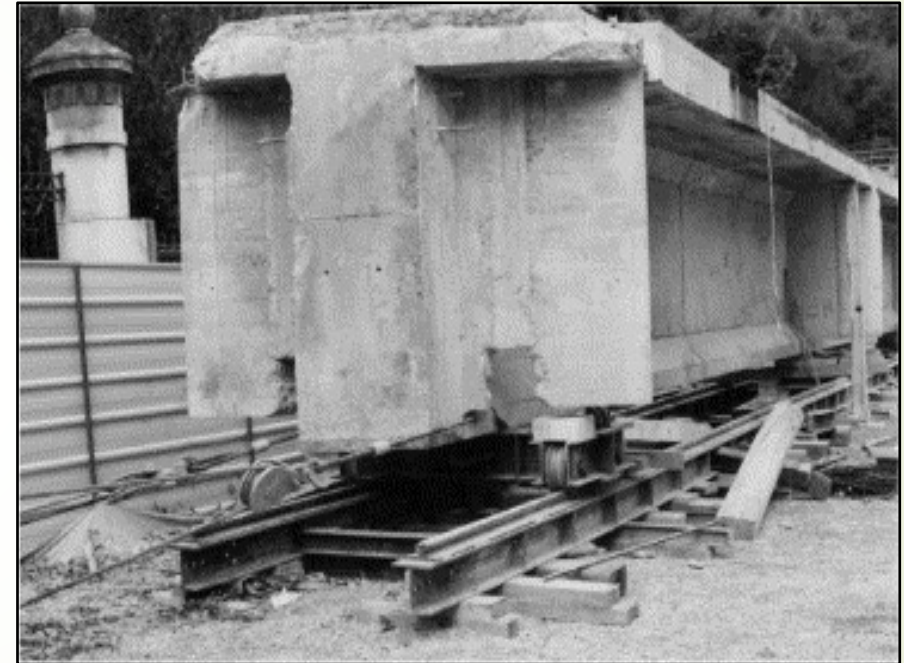
By : X. Dérobert^a, C. Aubagnac^b, O. Abraham^a

Introduction

- Demolition of a post tension pre-stressed concrete bridge in southern France is taken as a case study.
- Element of a post-tensioned beam for autopsy is preserved by the Regional Transport Research Laboratory (LRPC), Toulouse to validate the method of acoustic monitoring.
- Detailed inspection led to the conclusion that the primary problem of the bridge was,
 1. Poor Filling of the post tensioned ducts.
 2. Tendon corrosion due to water and potential infiltration of corrosive agents.
- French Transport Research Laboratory installed passive acoustic monitoring devices for the intensive monitoring.
- Output results were compared with the highest affected portion of the beam after demolition to find the accuracy in NDT techniques.

Specifications of test beam

- Height : 2.10 m
- Length : 9.50 m
- Height of the web : 1.10 m
- Thickness of the web : 0.20 m
- 11 post tensioned tendons
- 5 anchorage at the end stringers & 6 in the top.



Post Tensioned test beam before autopsy

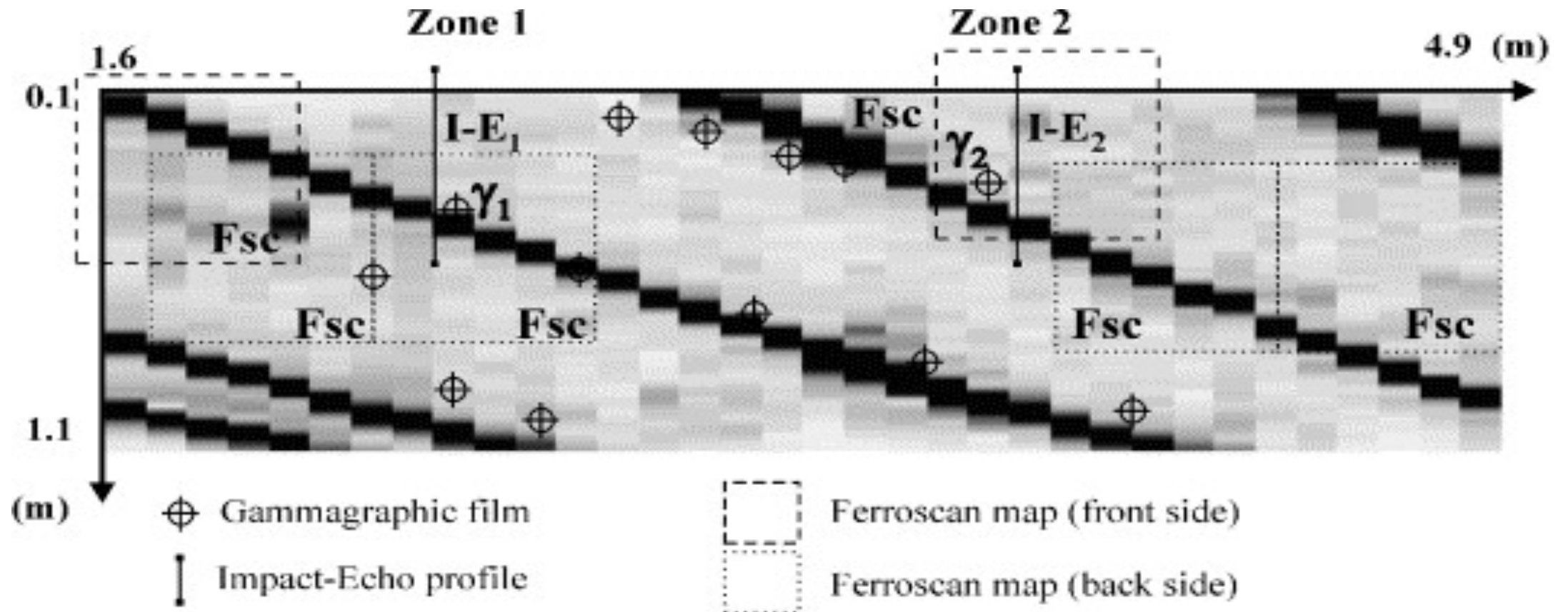
Why NDT?

- ▀ Localization of a prestressed tendons
 - ✓ Layout & Cover thickness
- ▀ Reinforcement bars details
- ▀ Prestressing Quality :
 - ✓ Injection state
 - ✓ Severity of rebar corrosion
 - ✓ Tendon fractures
- ▀ Concrete Quality :
 - ✓ Physical pathologies : Lack of concrete, heterogeneities, and cracks
 - ✓ Chemical pathologies : Carbonation, presence of chlorides and alkali-reactions

NDT Methods used for validation :

- 1 Ferroskan (Coverometer)
- 2 Ground Penetrating Radar (GPR) Technique
- 3 Gammagraphy
- 4 Impact-Echo Technique

1.5 GHz GPR map in the Central part of the beam, with the layout of the other NDT measurements





Ferroskan :

- Scanners are produced by the HILTI Company.
- Uses the Electromagnetic Technique.

Pros :

- Reconstructs a 60 cm² image with the horizontal positioning of rebar and ducts in the first 9 – 10 cm of concrete. (Accurate to within +/- 0.5 cm)
- Up to 6 cm 2 level precision can be determine.
- Cover measurement precision is within 5% for simple reinforcement configuration.
- Numerical data of vertical reinforcement position and up to 30° inclined ducts can be easily obtained on the field immediately.



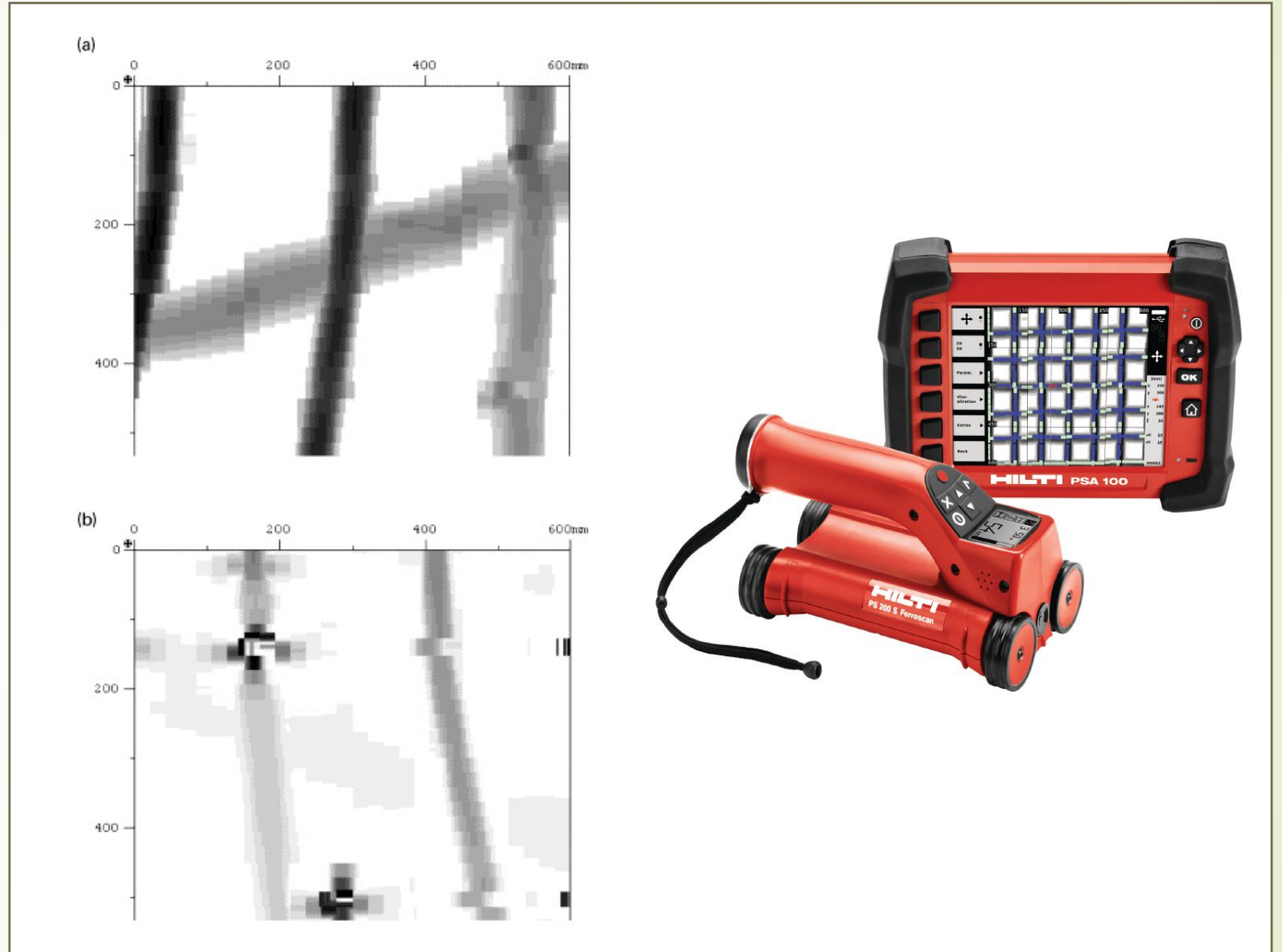
Ferrosan :

Cons :

- Low depth penetration.
- Impossible to determine cover in the areas of high reinforcement density.
- Produced unprocessed false color scale can introduce field errors.
- Non-detection of elements.
- Corresponding software may not be accurate.
- Relying on field imaging results alone becomes dangerous without any laboratory processing.

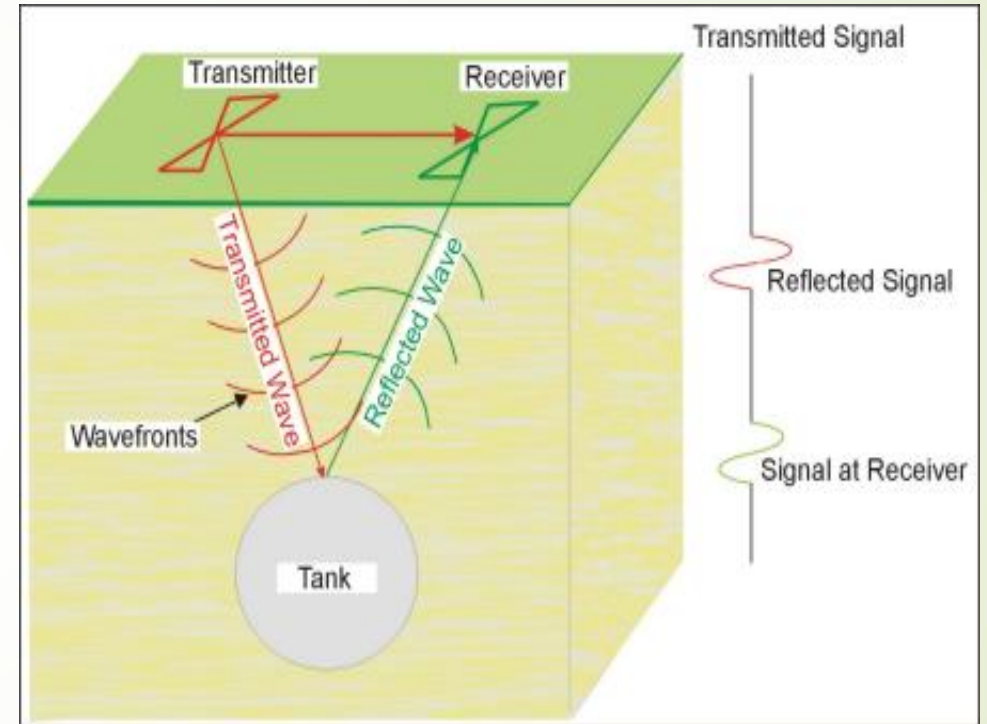
Ferroskan device by HILTI

- Ferroskan maps acquired from the two opposite sides of the same zone of the beam web.
- Difference in the duct detection reveals the limitation.



Ground Penetrating Radar (GPR) :

- It will also work on the Electromagnetic Technique.
- Electromagnetic pulse will be transmitted to the structure, at a very high frequency ,with 1.5 GHz central frequency antenna.
- Receiving antenna will record GPR impulse signals which contains echoes from the reflections generated by metallic heterogeneities in the concrete.



Principle of GPR Technique



Ground Penetrating Radar (GPR) :

Pros :

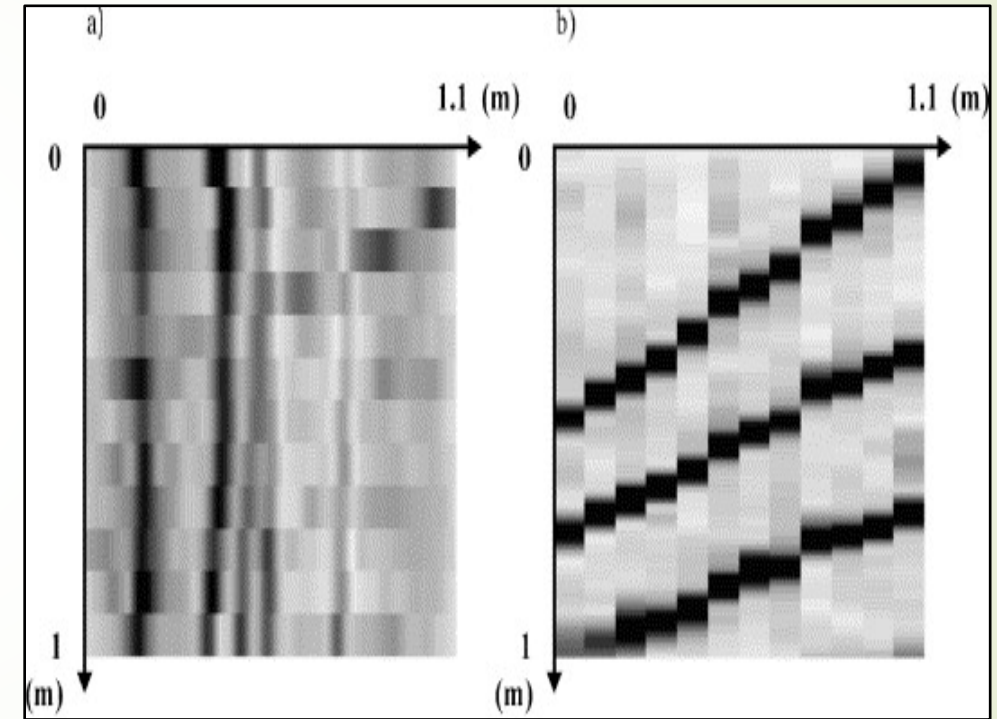
- High speed NDT of structures.
- It can measure rebar covers at depths over 30 cm.
- Possible to investigate concrete elements with complex geometry.

Cons :

- Frequency is not enough to obtain rebar diameter.
- It is not possible to investigate interior portion of the metallic ducts with such waves.
- Anchorages and overlapping geometry detection is difficult with two-dimensional GPR acquisition principle.

Ground Penetrating Radar (GPR) :

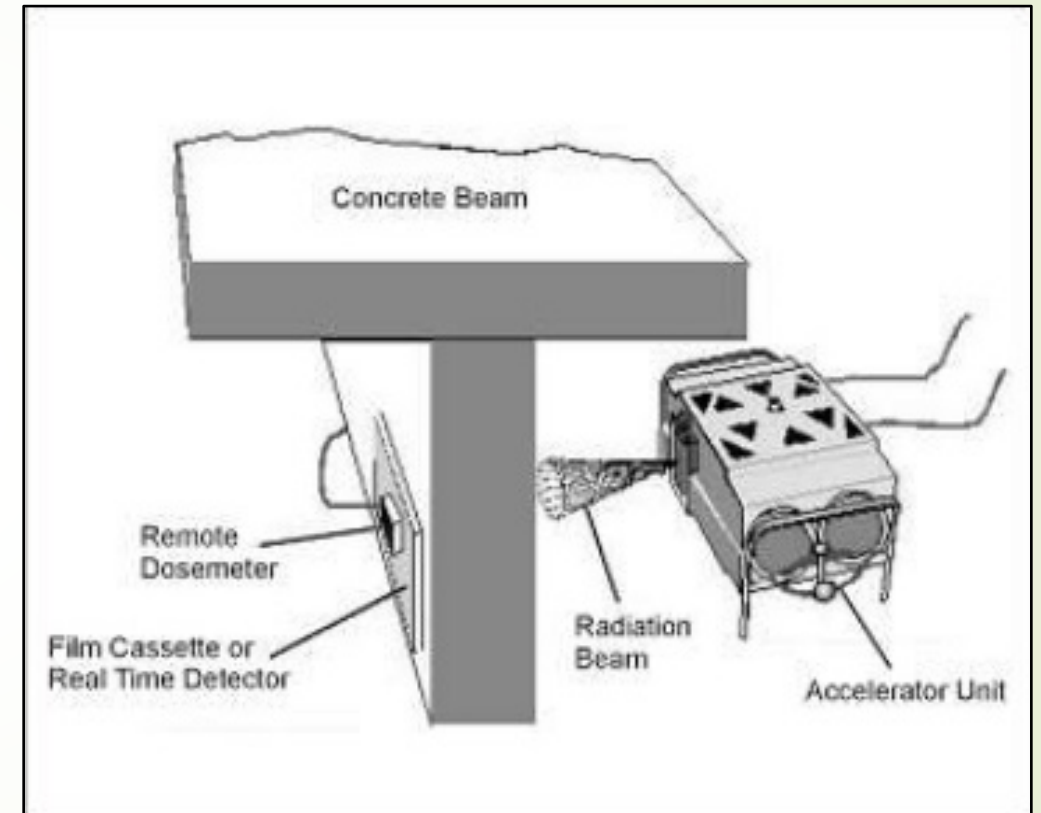
- Fig A and B shows the 1.5 GHz maps on the same area of the bridge.
- Either embedded rebar data or position of the duct can be achieved at a time.
- Position of the vertical rebar can be obtained with the horizontal GPR profile. (electrical field is perpendicular to the profile position) **(Fig-a)**
- Vertical GPR profile will perfectly localize the ducts without any interference of reinforcement mesh. **(Fig-b)**



Horizontal & Vertical GPR profile

Gammagraphy :

- This technique is mostly used to diagnose the grouting quality.
- It is operated in the transmission mode between two opposite side of any structure thinner than 60 cm.
- Examination is carried out within specific points. (30 cm x 40 cm)
- Gamma-ray exposure duration depends on the thickness of the investigated structure.



Process of Gammagraphy

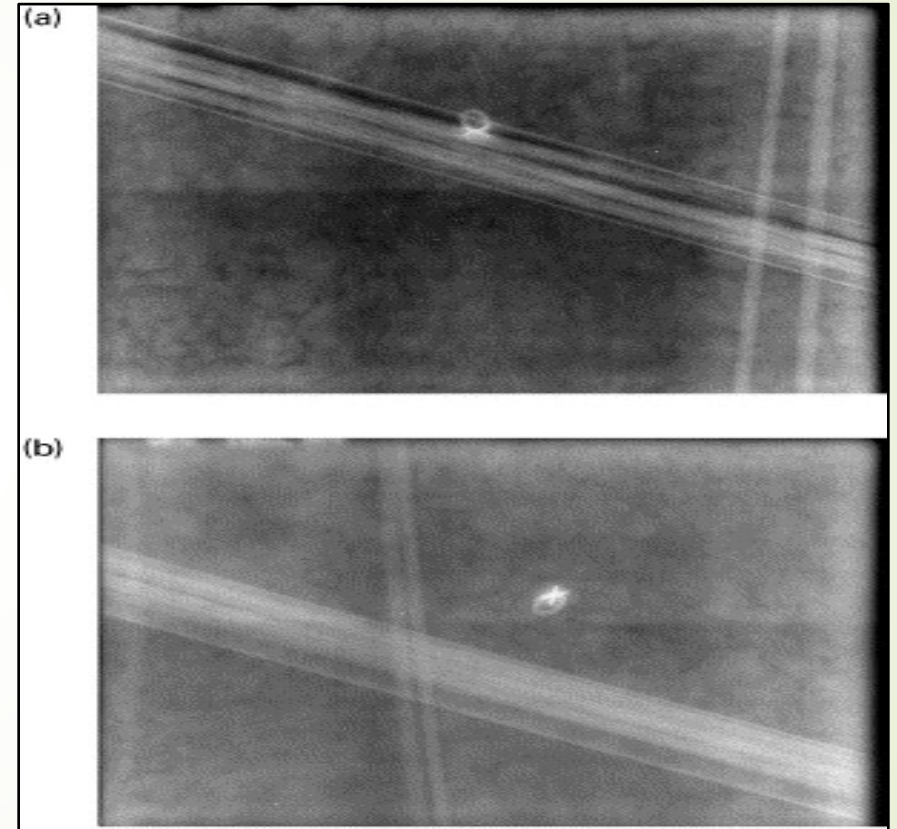


Gammagraphy :

- Two major disadvantage of Gammagraphy,
 1. Expensive technique.
 2. Strict radio-protection constraints for both operator and the environment.
- LRPC found the alternative to overcome the above drawbacks.
- They tested a new technique called “**Digital Phosphor System (DPS)**”, which scans into a numerical film.
- Advantage of DPS over conventional method,
 1. Accurate position of the prestressed ducts and tendons as well as the reinforcement bars can be obtain.
 2. Better Radio-protective conditions for same quality of mapping.
 3. Lower radio activity and exposure duration.

Gammagraphy :

- Results on post tensioned test beam shows two types of grouting,
 1. Complete lack of grouting (white area) around the tendons (black area) in the central duct of zone 1. **(Fig-a)**
 2. Correct Injection in the central duct of zone 2. **(Fig-b)**

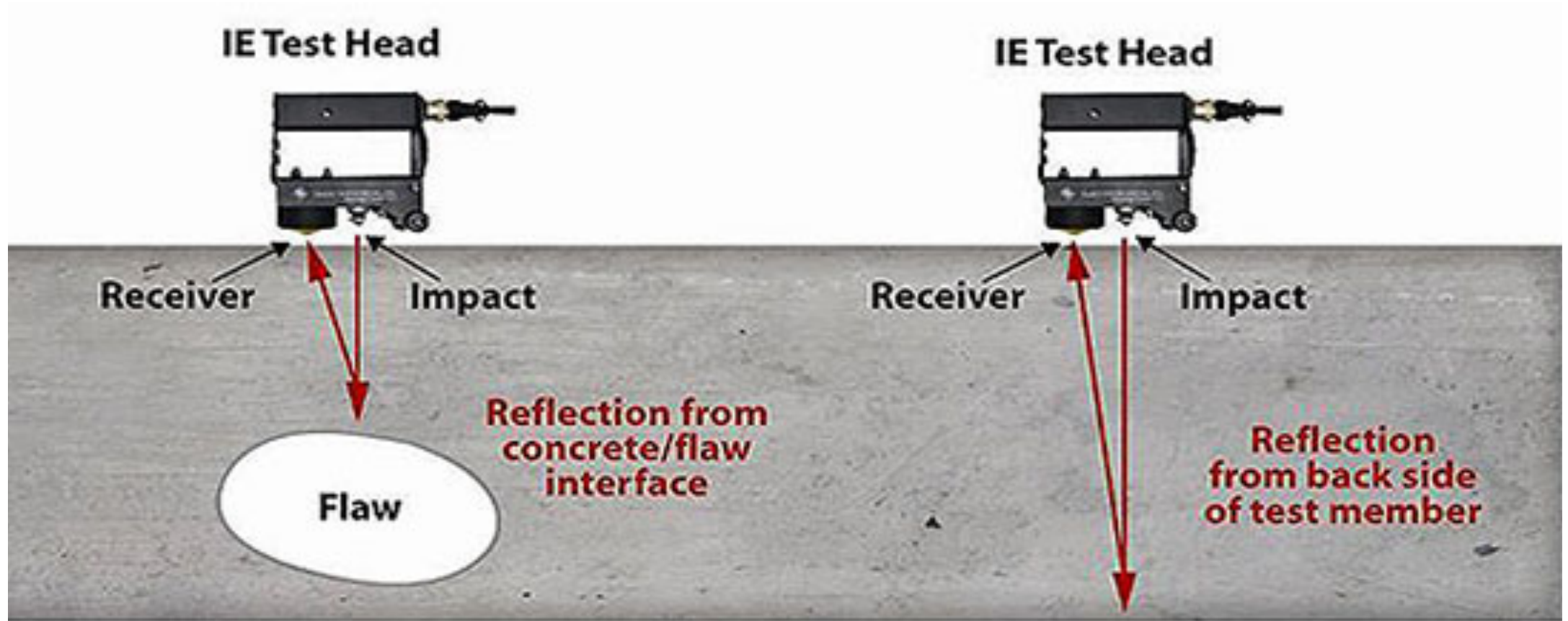


Results of Gammagraphy on test beam

Impact-echo Technique :

- This technique is based on a frequency analysis of the time response of a structure excited by a mere shock.
- Also known as the Sonar concrete testing,
- Generally used for,
 1. Thickness measurement
 2. Void detection
 3. To find delamination. (Mode of failure for composite materials)
 4. Interface detection between materials with contrasting mechanical impedance. (Material compatibility)
- Ultrasonic Testing methods (50-250 kHz) are also under study to detect voids in ducts.

Impact-echo test





Impact-echo Technique :

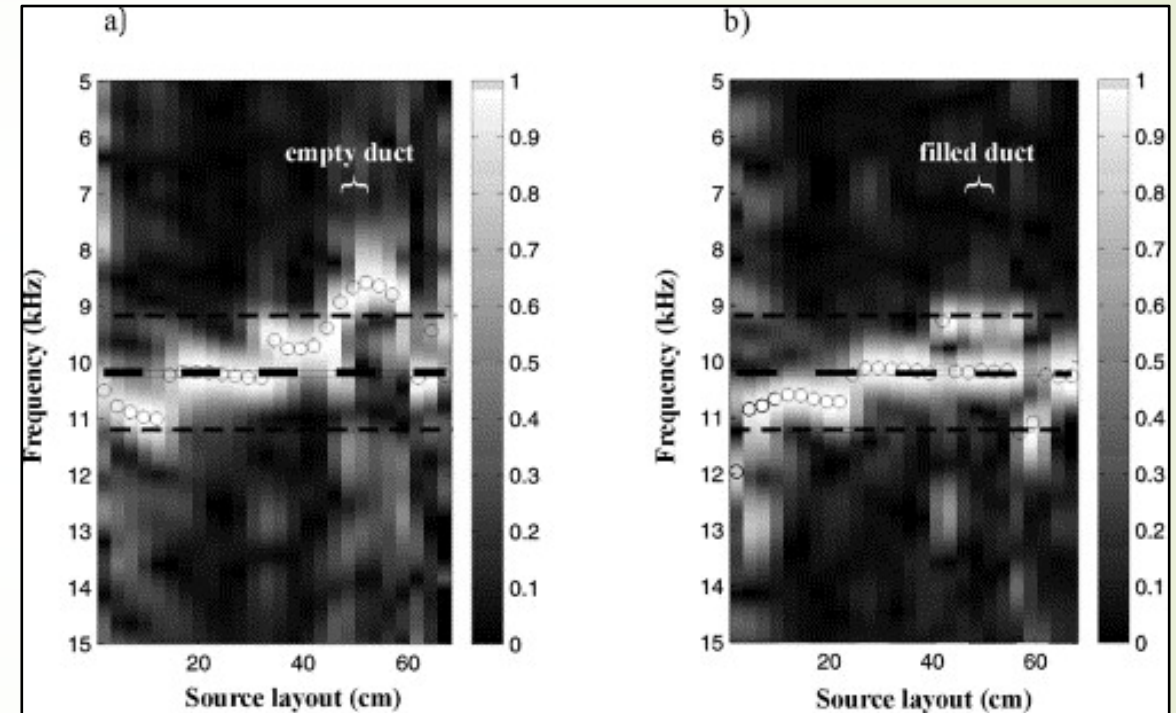
- Sonic pulse reflected on an **empty duct** will generate a high resonance frequency of almost twice that on well injected ducts.
- Frequency to measure slab thickness above an empty duct is lower than that either of the slab solid or when the duct is filled.

Pros :

- Simplicity of the experimental setup because only one side access required.
- Light weight and inexpensive equipments.
- No radio protection constraints compare to Gammagraphy

Impact-echo Technique :

- Results from zones 1 and 2 of the test beam have been shown in figure.
- For filled duct, solid slab thickness frequency is 10.1 KHz. **(Fig-b)**
- For empty duct frequency is shifted from 10.1 KHz to less than 9 kHz. **(Fig-a)**
- No high frequency resonance has been clearly observed above the ducts.



Normalized frequency IE spectrum from zone 1 (a) and zone 2 (b) on vertical measurement lines.

Autopsy Results :

- After completion of NDT campaigns, the beam was hydro demolished with the use of high pressure spouts.
- Concrete destruction was limited to the post tensioned duct areas in order to release them along with anchorages and with the least damage to the tendons.
- Total 11 anchorages and 77m of tendons have been examined.
- Examination includes,
 1. Tendon layout identification.
 2. Opening of each metallic duct.
 3. Grout removing.
 4. Dismounting of each tendon, each strand and each elementary wire to find the corrosion and wire fracture.
 5. Chemical analysis of the grout.



Release of tendons and anchorages from the beam after hydro-demolition

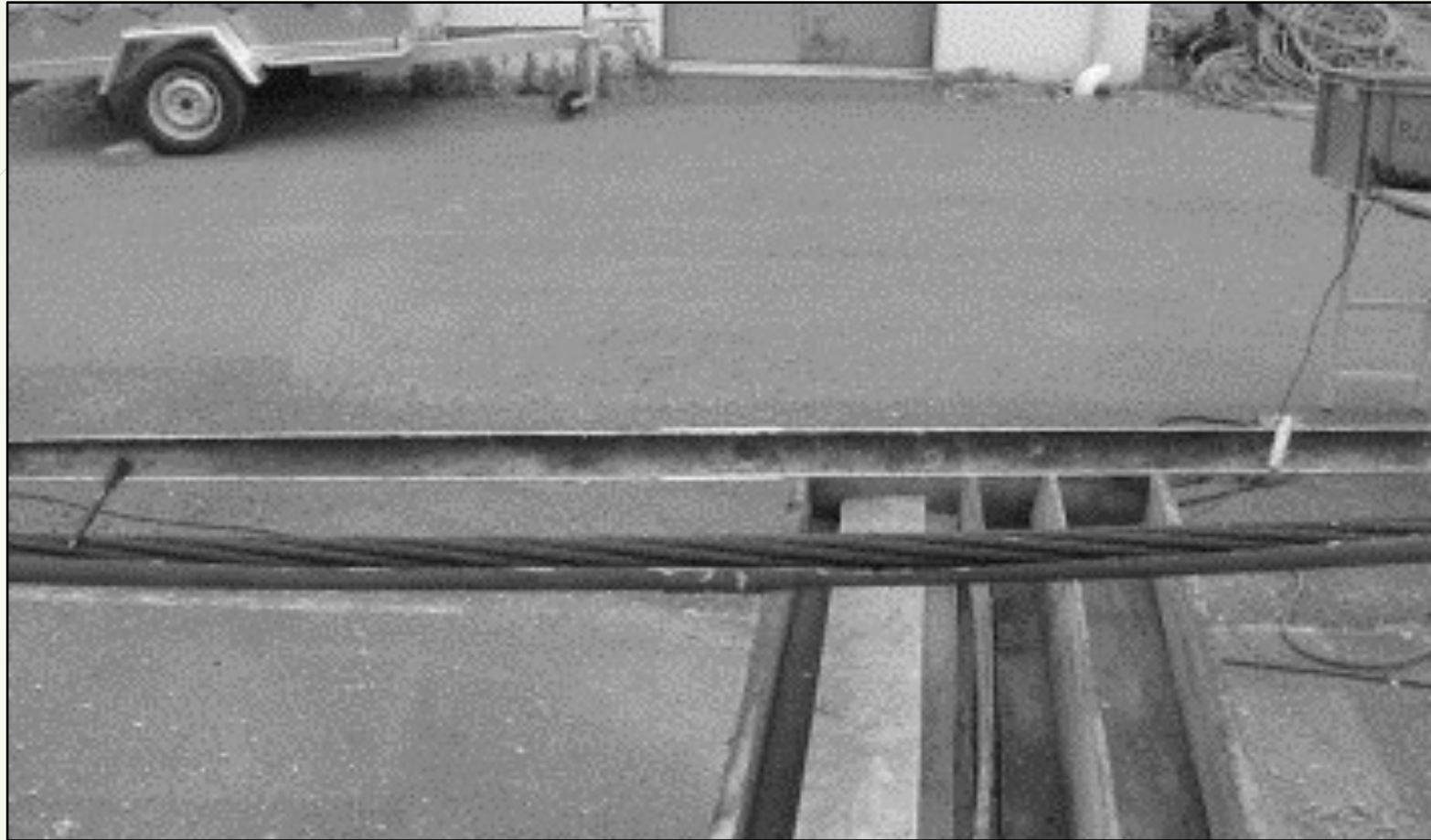


Autopsy result :

- A sizable length of the duct without any grout is observed.
- Tendons have been manually greased to provide protection against corrosion.

Observations,

1. Slight classical electrolytic corrosion is detected on every strand. (Rusting)
 2. Lack of grease reflects distinct stress corrosion with wire fracture and in two cases strand fracture.
 3. Layout of the fracture is exactly same as observed in the test beam during the passive acoustic monitoring.
- Therefore, the observations validate the results obtained by the Passive monitoring acoustic techniques.



Observation Duct without any grout

Evaluation of NDT methods :

- Advantages and limitations of each methods are discussed on three major aspects,

1. Localization of reinforcement bars :

- To locate the reinforcement or to determine concrete cover,
 - For small depths – *Ferrosan* (Up to 10 cm)
 - For larger depth – *Ground Penetrating Radar* (Up to 30 cm)

2. Prestressing quality :

- To know the state of injection in areas,
 - With dual accessibility and radio protection control – *Gammagraphy*
 - With only access to the one side – *Impact-echo*
- Wire and Strand fracture – *Gammagraphy*
- No method can find the extent of tendon corrosion.



Evaluation of NDT methods :

3. Concrete quality evaluation :

- This aspect of NDT method is not within the scope of the the paper I studied.
- Although we can check concrete quality at some extent with sonar and GPR technique.

Conclusion

- NDT methods just provide the partial answers.
- To have the reliable diagnose it is necessary to perform more than one NDT technique to cover all the aspects which is after all a costly affair.
- At the same time, combining various NDT methods can remove ambiguities, localize questionable zones from high speed measurements and can resolve a global problem.
- In this case, it is best to use the best combination according to need.
- For example, to check the grouting quality in the prestressed ducts, best combination is GPR followed by the Gammagraphy or the Impact-echo.

Conclusion

- Apart from that, there is still a missing link between NDT experts and structural managers and because of which a certain number of key points are still unresolved.
- To solve this, more research projections can be shared with the on field structural engineers to have the more accurate imaging while maintaining the practical field driven approach.
- Some very precise topics encompass the work remaining for NDT researchers are,
 1. Rebar Diameter
 2. Prestressed tendon corrosion level
 3. Wire strand fracture estimation.



Thank You..!!