A COMPREHENSIVE SYNOPSIS OF ADVANCED NDT TECHNIQUES FOR THE INSPECTION OF CONCRETE ASSETS

REUBEN BARNES, MD: PCTE-INDUSTRIAL

PCTE
PAPWORTHS CONSTRUCTION TESTING EQUIPMENT

INTRODUCTION

- Objectives for Concrete Investigation
- How Construction and Industrial NDT differ
- Overview of applications:
    - 1. Strength
    - 2. Reinforcing location
    - 3. Corrosion
    - 4. Defect analysis
    - 5. Geometry
- Conclusion

OBJECTIVES OF A CONCRETE INVESTIGATION

NEW CONSTRUCTION

- Quality Control and Assurance
- Inform construction decisions
- Investigate defective construction

EXISTING STRUCTURES

- Estimate life expectancy
- Investigate damage
- Inform fit-out or repair decisions

CONCRETE TESTING VS METAL TESTING

CONCRETE TESTING

- Concrete is a metal/non-metal composite
- Concrete is heterogenous
- Concrete is an insulator
- Concrete is porous
- Concrete is generally formed on site
- Concrete is made from locally available materials

METAL TESTING

- Metal is relatively homogenous
- Metals are conductive
- Metals are non-porous
- Metal working is generally completed in more sterile environments
- Metals whilst variable in quality are generally sourced for specific characteristics with controlled assay

CONCRETE TESTING VS METAL TESTING

Concrete is a metal/non-metal composite

This makes concretes mechanical behaviour complex and ensures corrosion is extremely difficult to predict.

Concrete is heterogenous

So whilst ultrasonics is possible it must be low frequency hence low resolution

Concrete is an insulator

The concrete itself can not be testing using eddy current or magnetic flux testing for defects, but is excellent for techniques such as Ground Penetrating Radar

Concrete is porous

Its behaviour can be extremely variable dependent on ambient conditions. Even simple testing like resistivity is difficult to interpret.

Concrete is generally formed on site

Quality can be highly variable between types of construction and from one element to another

Concrete is made from locally available materials

There are no standards that can be called upon for pre-calibration, everything must be determined on site using the concrete elements in question.

OVERVIEW OF APPLICATIONS

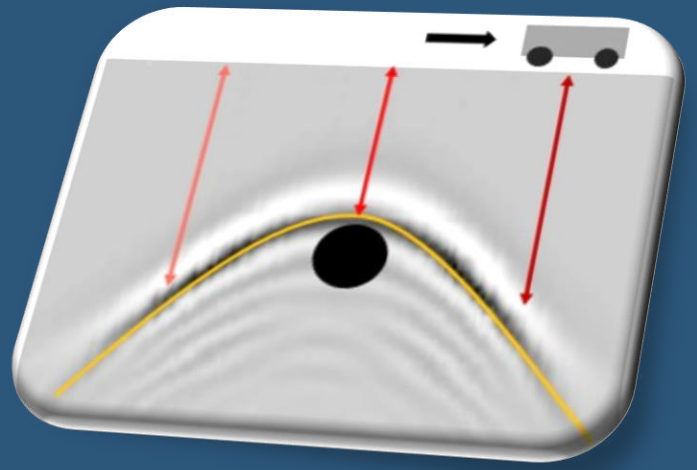
Attribute	Option 1	Option 2	Option 3	Option 4	Option 5
Strength	Rebound Hammer	Ultrasonic Pulse Velocity (UPV)	Windsor Probe	Combined Methods	
Reinforcing	Covermeter	Ground Penetrating Radar (GPR)	Covermeter Array		
Corrosion	Half Cell Potentials	Corrosion Rate (LPR)	Corrosion Monitoring	Resisitivity	
Defects	UPV	Impact Echo	Ultrasonic Pulse Echo		
Geometry	GPR	Covermeter	Impact Echo	UPE	Sonic Echo

1. SPECIFIC APPLICATIONS – STRENGTH

- Concrete strength generally refers to compressive strength
- Concrete strength is determined by the “mix” of the concrete with more cement and less water being the biggest factors
- As well as a structural requirement, is also generally used to designate quality or ability to withstand environmental factors
- During construction, strength is tested at regular intervals using cylinders
- Once hardened, samples (cores) must be used for destructive testing
- NDTs are limited in terms of accuracy when not used in concert with some destructive testing
- Rebound Hammers and UPV correlate surface hardness or pulse velocity to compressive strength using lab generated empirical relationship

2. SPECIFIC APPLICATIONS – REBAR

- Rebar offers the main tensile strength in the concrete composite
- Rebar are also important for crack control whilst concrete hardens
- NDT and rebar generally falls into four application types:
  - Cover checks for durability
  - Rebar location for penetrations
  - Rebar placement and existence
  - Structural investigations
- The two main technologies employed are Covermeters and Ground Penetrating Radar



GROUND PENETRATING RADAR

- GPR uses EM waves to locate embedments
- EM waves reflect where a dielectric contrast occurs between two materials (concrete/steel)
- Depth is given by time of flight and EM wave velocity estimate (heavily affected by moisture)
- Low frequency antennas penetrate deeply whilst high frequency give better resolution
- Newer SFCW systems move away from this traditional pulsed technology offering wide frequency bands, whilst solving in frequency domain

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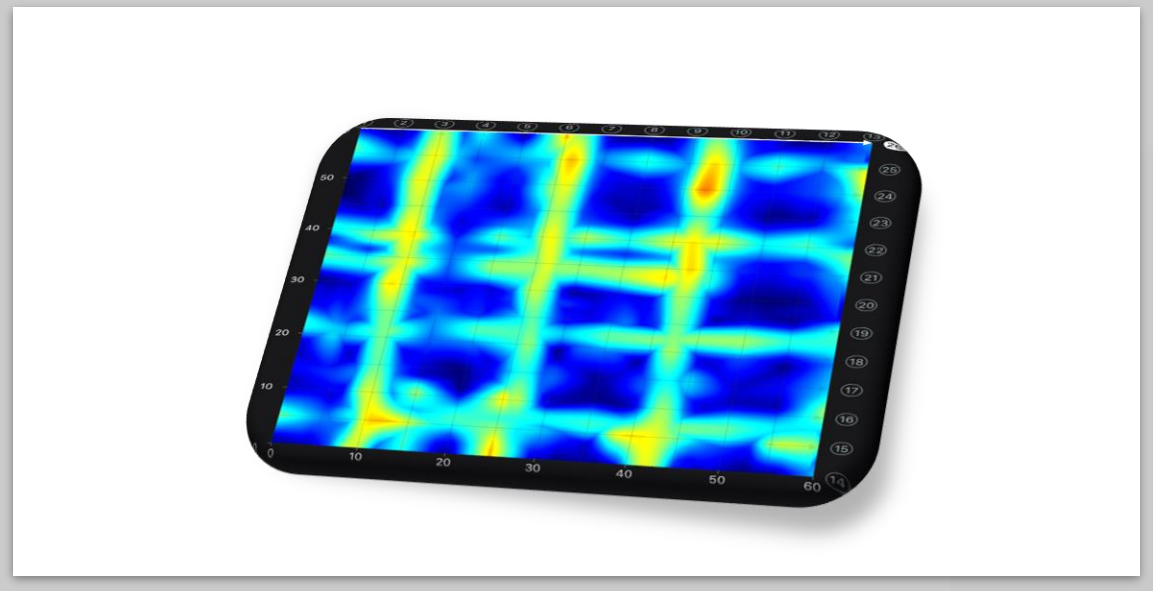
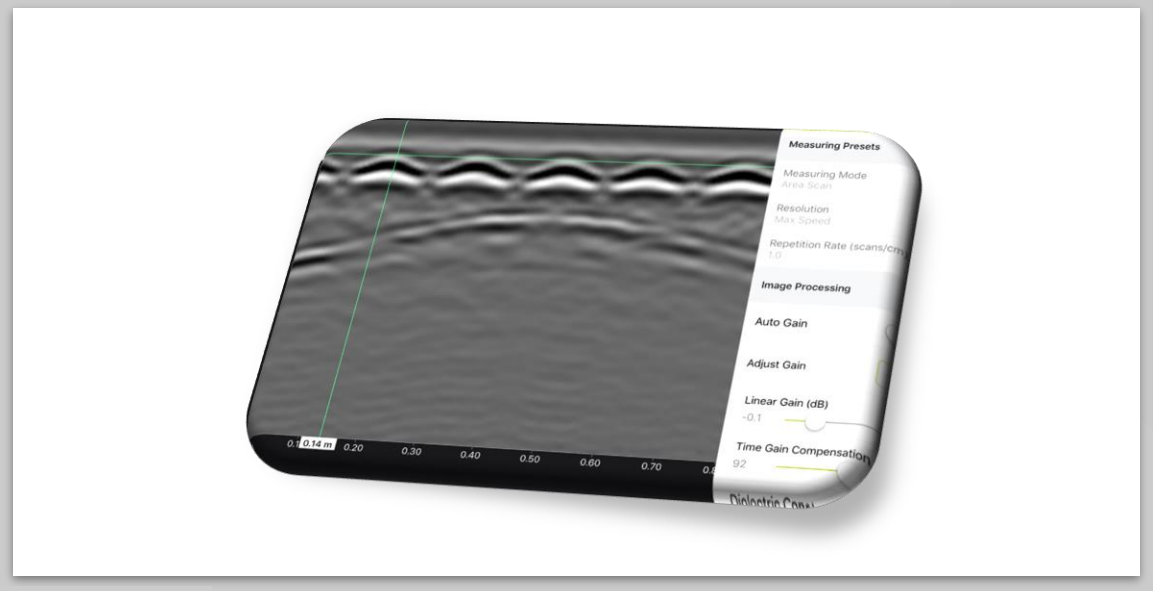
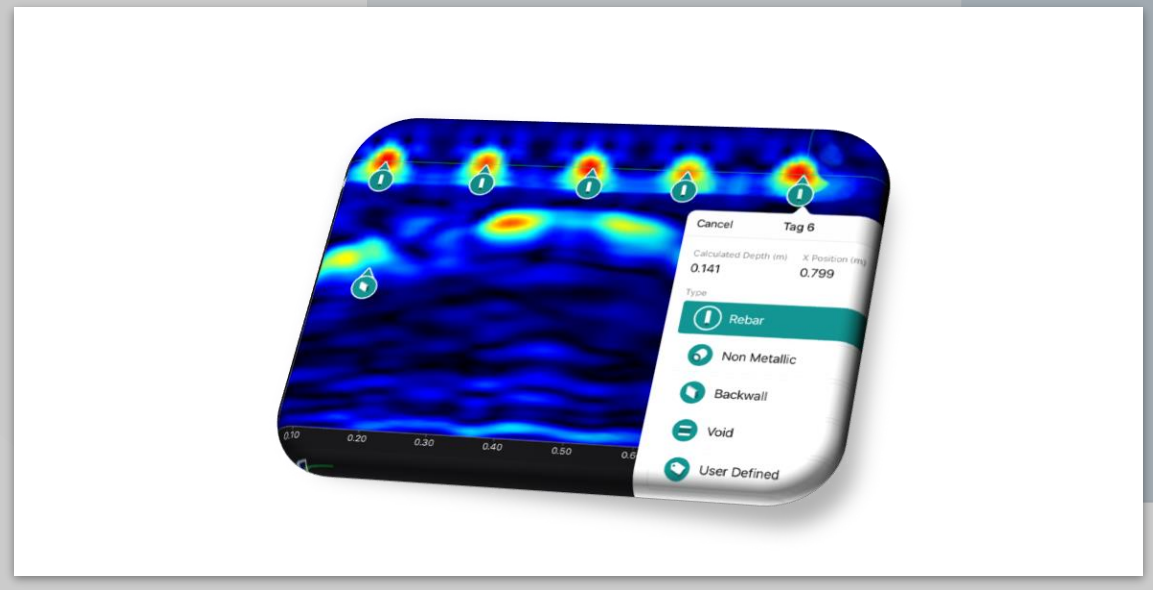
B-Scan (Line Scan)



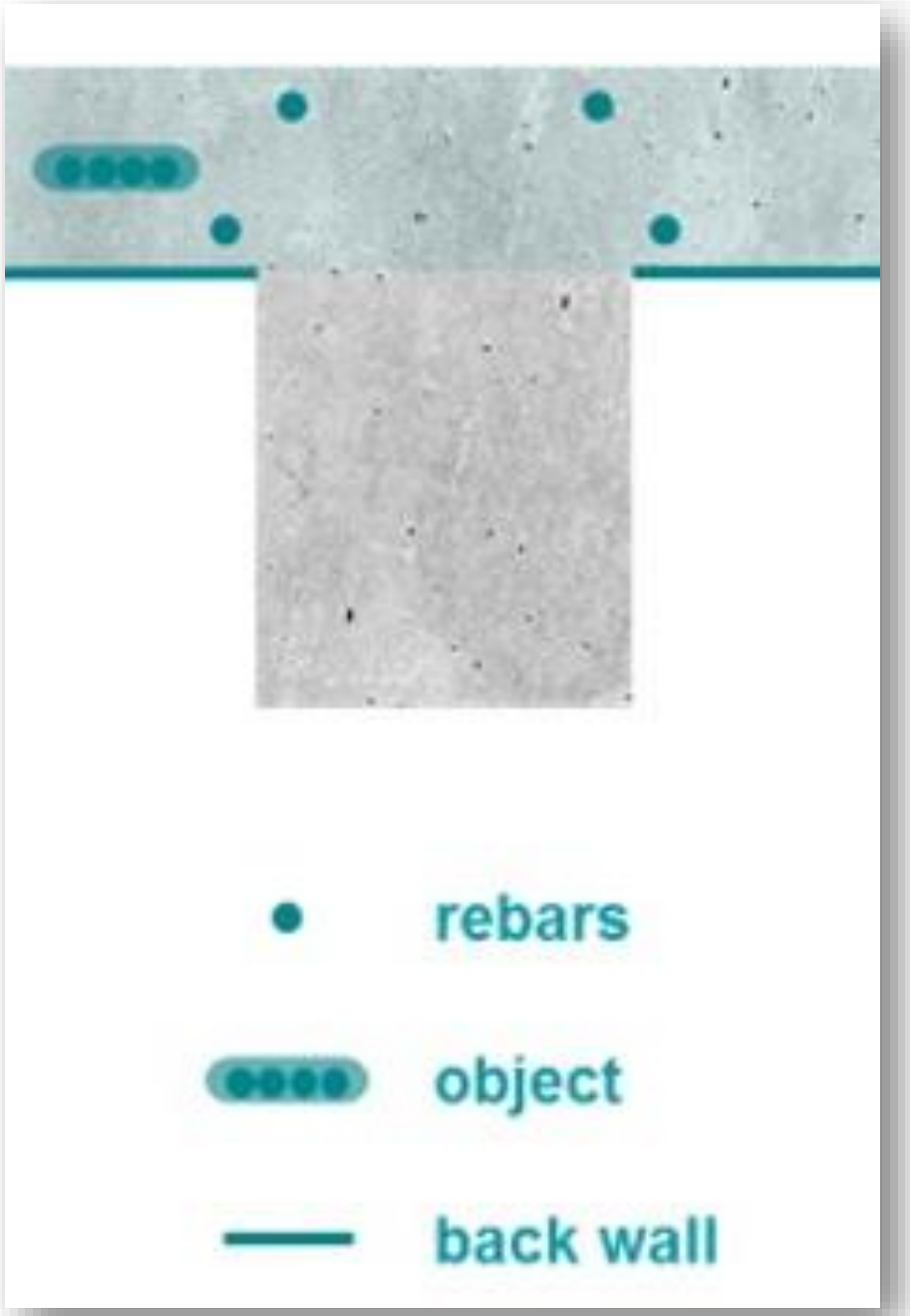
3D Images



C-Scan (Area Scan)

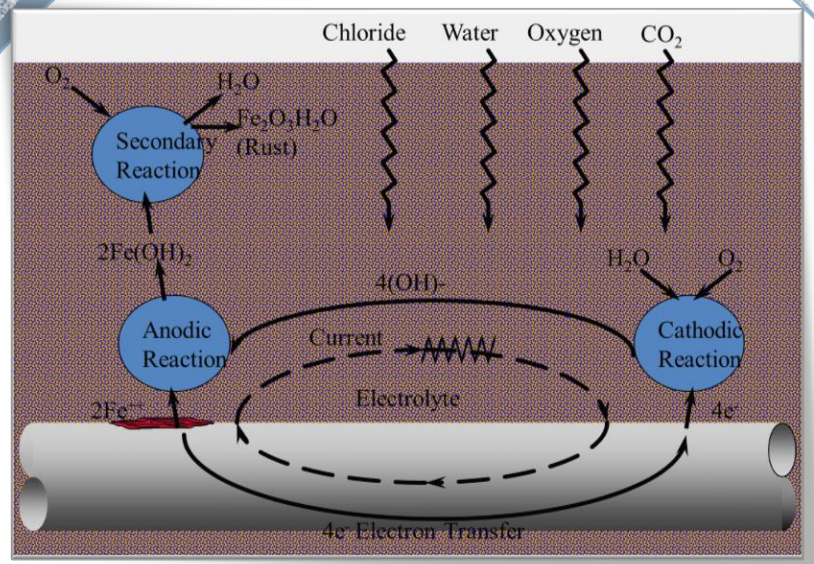


Migrated B-Scan (Heat Map)



GROUND PENETRATING RADAR

- Advantages of GPR over other Technologies:
  - See deeper to additional layers
  - See metallic and non-metallic targets. So many more applications than just rebar
  - Scanning technology making it cheap and easy to deploy
  - Images easily viewed in 2D and 3D
  - Best technology when dealing with Post Tensioning
- Other applications include:
  - Defect location
  - Find defects under a slab
  - Measuring hidden dimensions (ie thickness)



3. SPECIFIC APPLICATIONS – CORROSION

- Rebar in concrete is protected from corrosion due to the alkali nature of the concrete
- Passivation can be diminished when environmental factors such as the ingress of Chlorides or Carbonation occur
- The cover depth and quality of the cover concrete controls the pace at which this occurs
- Once corrosion occurs the volume increase (due to oxidation) of steel means cracking, and spalling will occur
- Corrosion is a chaotic process with many factors affecting each step in the mechanism
- A variety of tests are used to measure a range of these factors to find the root cause and severity (ie Cover depth, Concrete Quality, Risk Of Corrosion etc)

4. SPECIFIC APPLICATIONS – DEFECTS

- Concrete defects include cracking, delamination, voids and honeycombing
- Voids, honeycombing and some cracking is caused by poor concrete placement (i.e. lack of vibration, concrete temp etc) and are therefore caused during construction
- Cracking and delamination can occur due to structural damage (i.e. impact, poor design) or corrosion
- Techniques reserved for these applications are generally UT due to the contrast in density between concrete and air
- GPR can be used but is generally used as a scanning tool due to its sensitivity to the rebar
- Cracking into the concrete surface are the most difficult to investigate.

ULTRASONIC PULSE ECHO

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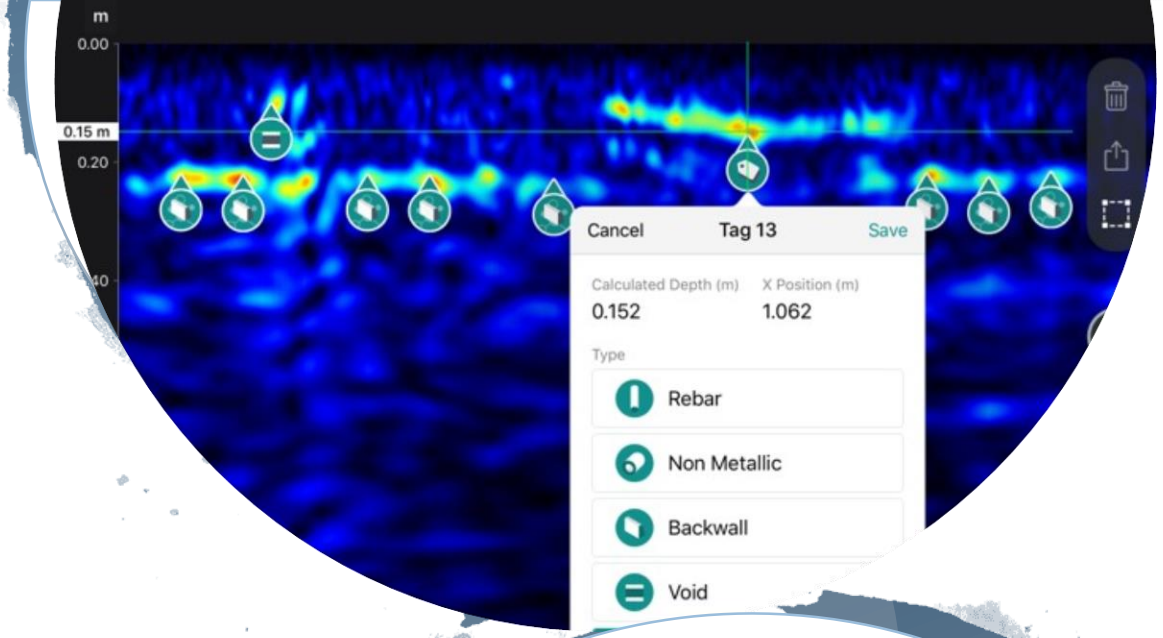
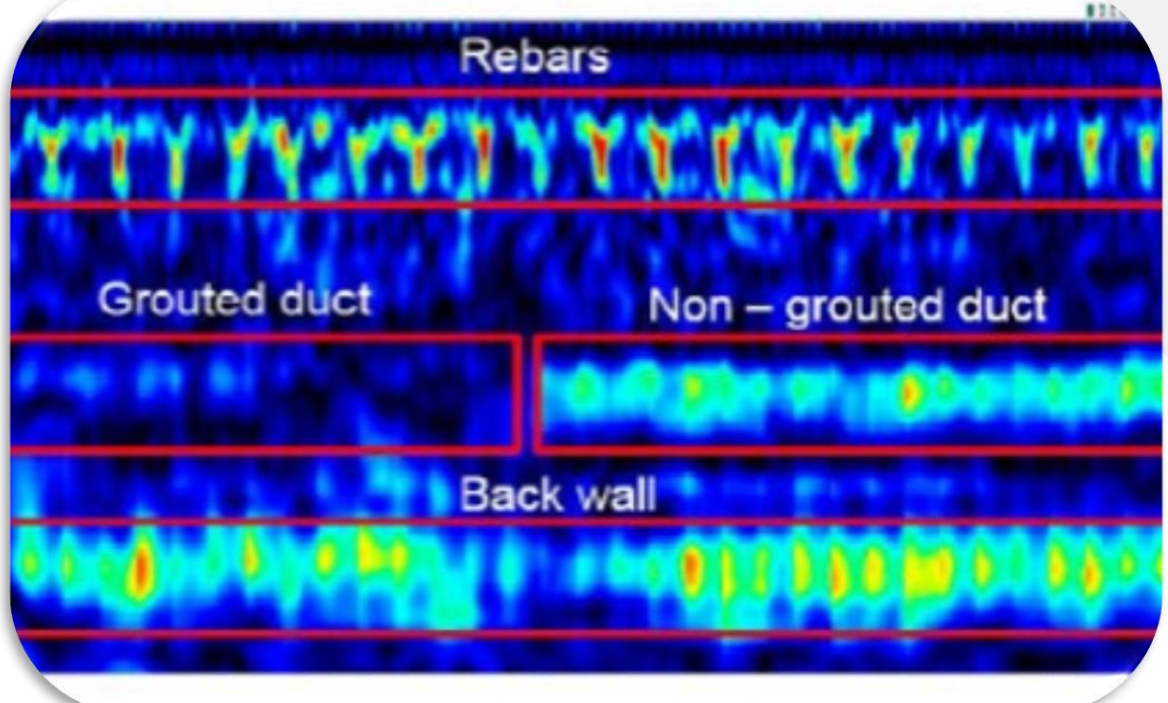
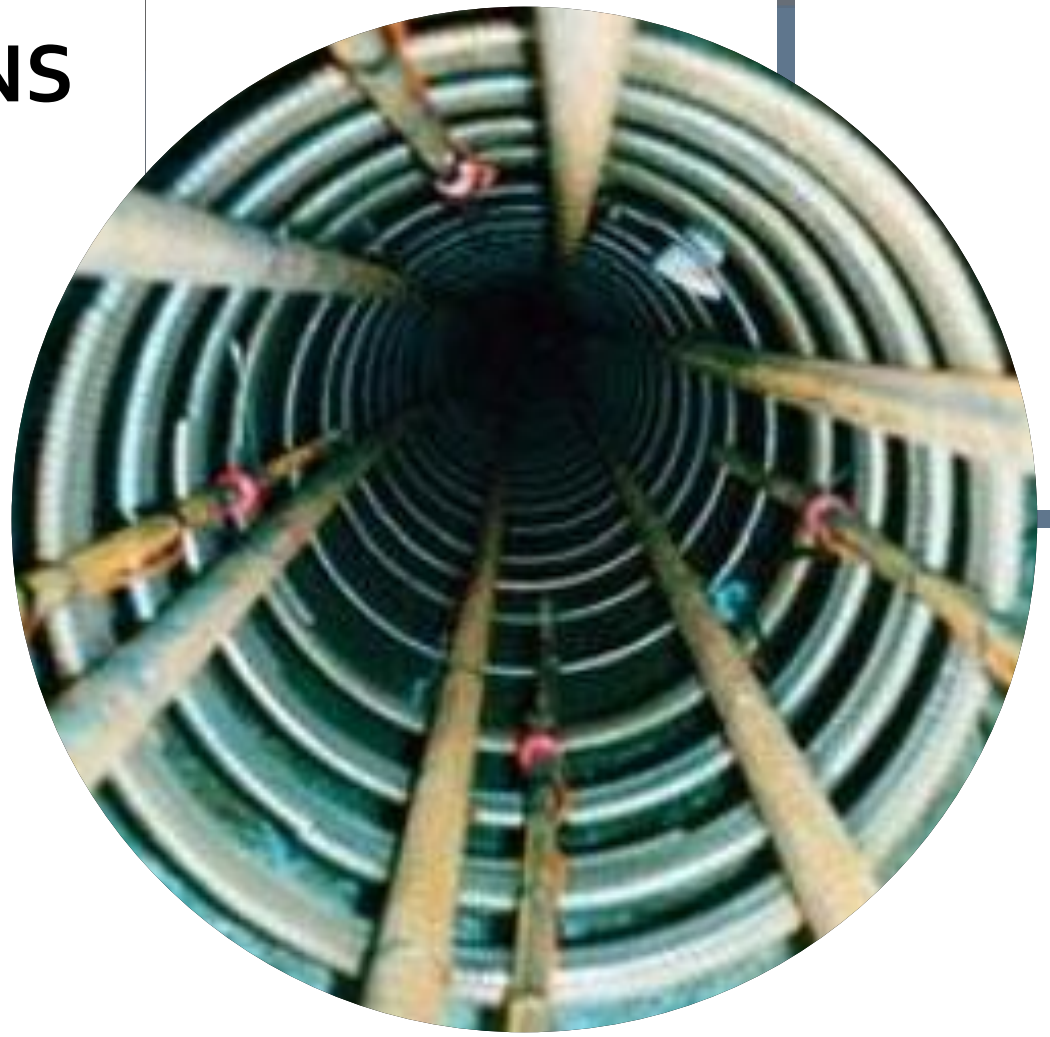



Target PT system


Rebars
Grouted duct
Non – grouted duct
Back wall

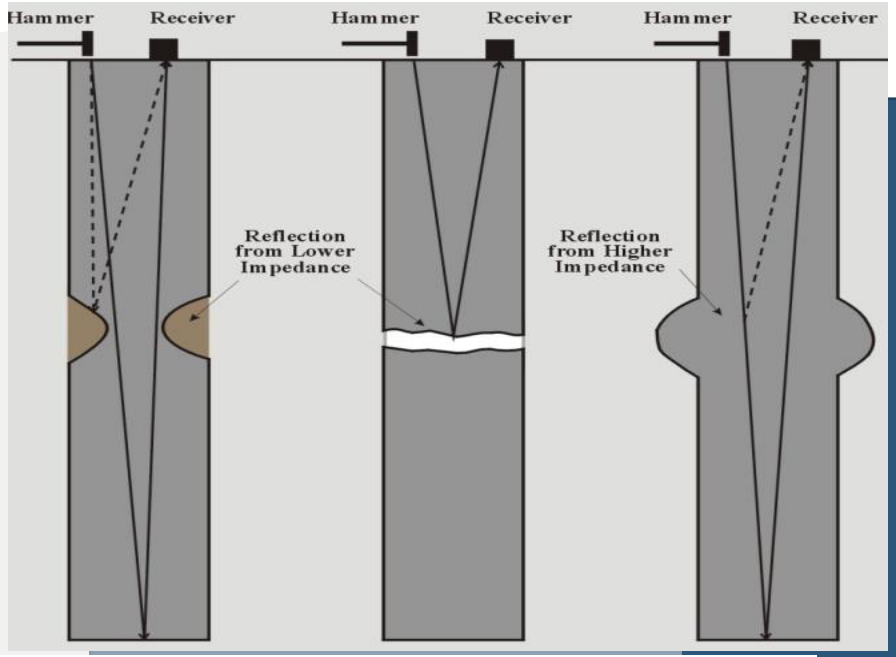
5. SPECIFIC APPLICATIONS – GEOMETRY

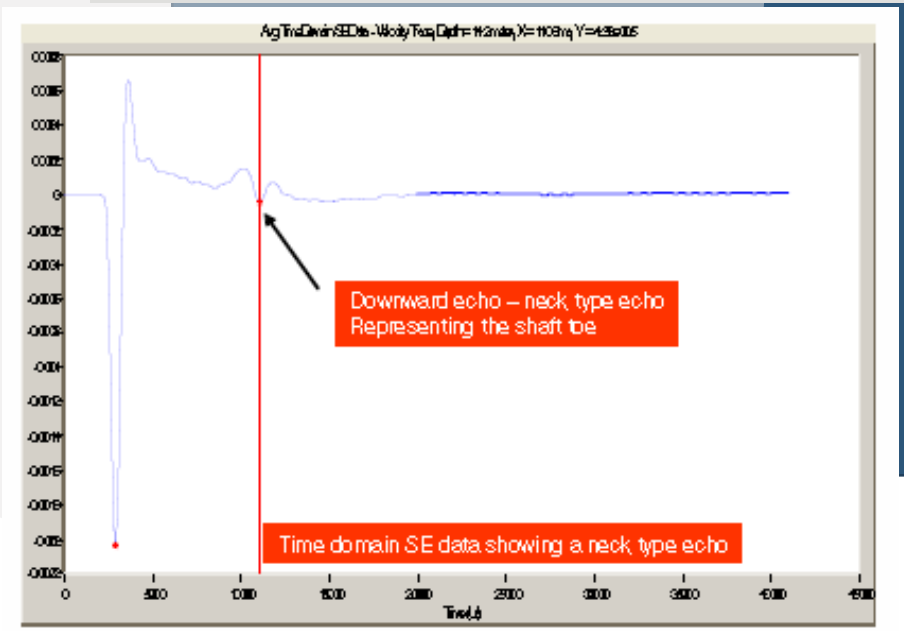
- Applications calling for the thickness or length of elements are generally structural or geotechnical in nature
- There are a number of techniques available including a range of UT techniques and GPR systems
- Access and the required dimension are generally the determining factor in which technique to nominate
- Geotechnical techniques are used where elements are buried in the ground and access is extremely limited form some of the biggest challenges



SONIC ECHO

- This technique is primarily used to determine the length of piles
- An impact is made to the top of the pile, the p-wave follows the generally cylindrical element to the bottom and then reflects back to a receiver
- Sonic Echo and Impulse Response make use of the same equipment
    - Impulse Hammer
    - 1-2 transducers (Geophone and/or Accelerometer)
- Sonic Echo is a time of flight technique L= t/2 x v
- Impulse Response is a related technique that uses the frequency domain





SONIC ECHO

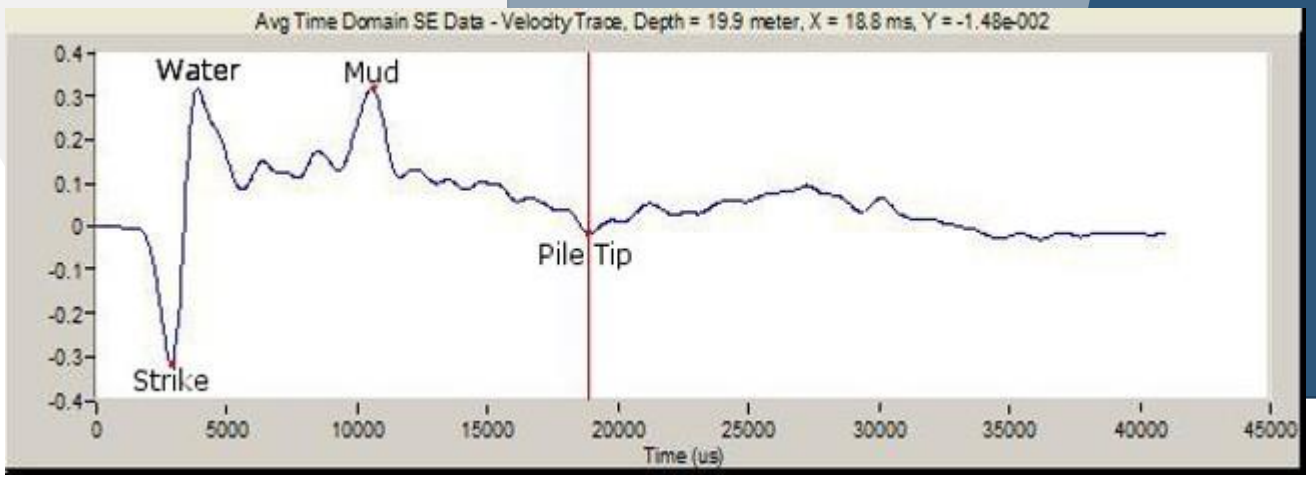
Project Goal: Determine the length of Steel Piles/ Columns

Difficulties:

- Overall length
- Access- strike and sensors
- Layers- air-water-mud

Outcome:

Success- in this instance a 20m pile



CONCLUSION

- There are a variety of reasons concrete structures are tested
- Construction and Industrial NDT vary considerably in terms of the technologies that are employed
- For each application there are a host of technologies available
- Determinations of which to use rely on knowledge of the strengths an weaknesses of each technique

THANK YOU

R.BARNES@PCTE.COM.AU

PCTE.COM.AU : PCTE.CO.NZ : INDUSTRIAL-NDT.COM