Infrastructure & Asset Inspection

Concrete Structures – Version 2.2.1

by Marcel Poser, CEO Screening Eagle Technologies

www.linkedin.com/in/**ProtectTheBuiltWorld**

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Infrastructure & Asset Inspection – Concrete Structures

ABOUT US

Screening Eagle Technologies

Protect the Built World

Swiss Engineering

SCREENING EAGLE

proceq

Leading NDT sensors since 1954

dreamlab

Software & Robotics since 2015

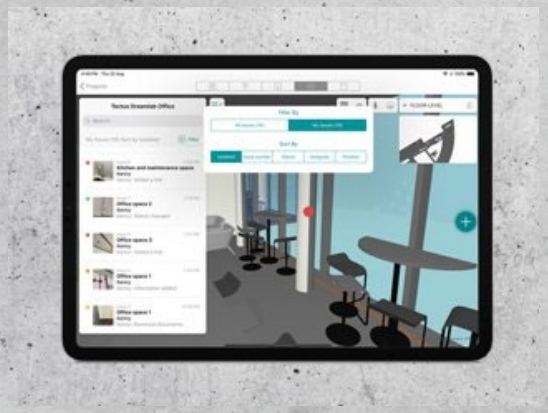
Global Network

>200 Employees	8 Country offices	3 R&D sites	>200 Distributors	>100 Countries

Screening Eagle Technologies

Full-stack Intelligent Inspection Ecosystem

+



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ADVANCED SENSORS

- Inspection
- Data Collection
- Defect Detection

INTELLIGENT SOFTWARE

- Data Visualization
- Efficient Workflows
- Holistic Assessment

PREDICTIVE MAINTENANCE

- Digital Twins
- Artificial Intelligence
- Asset Lifecycle Management

Infrastructure & Asset Inspection – Concrete Structures

WHY Infrastructure & Asset Inspection?

WHY Infrastructure and Asset Inspection

Birth Defects & Aging Infrastructure


US $210,000,000,000,000
value of all buildings lacking a proper quality rating

Crumbling Bridge Infrastructure

10%

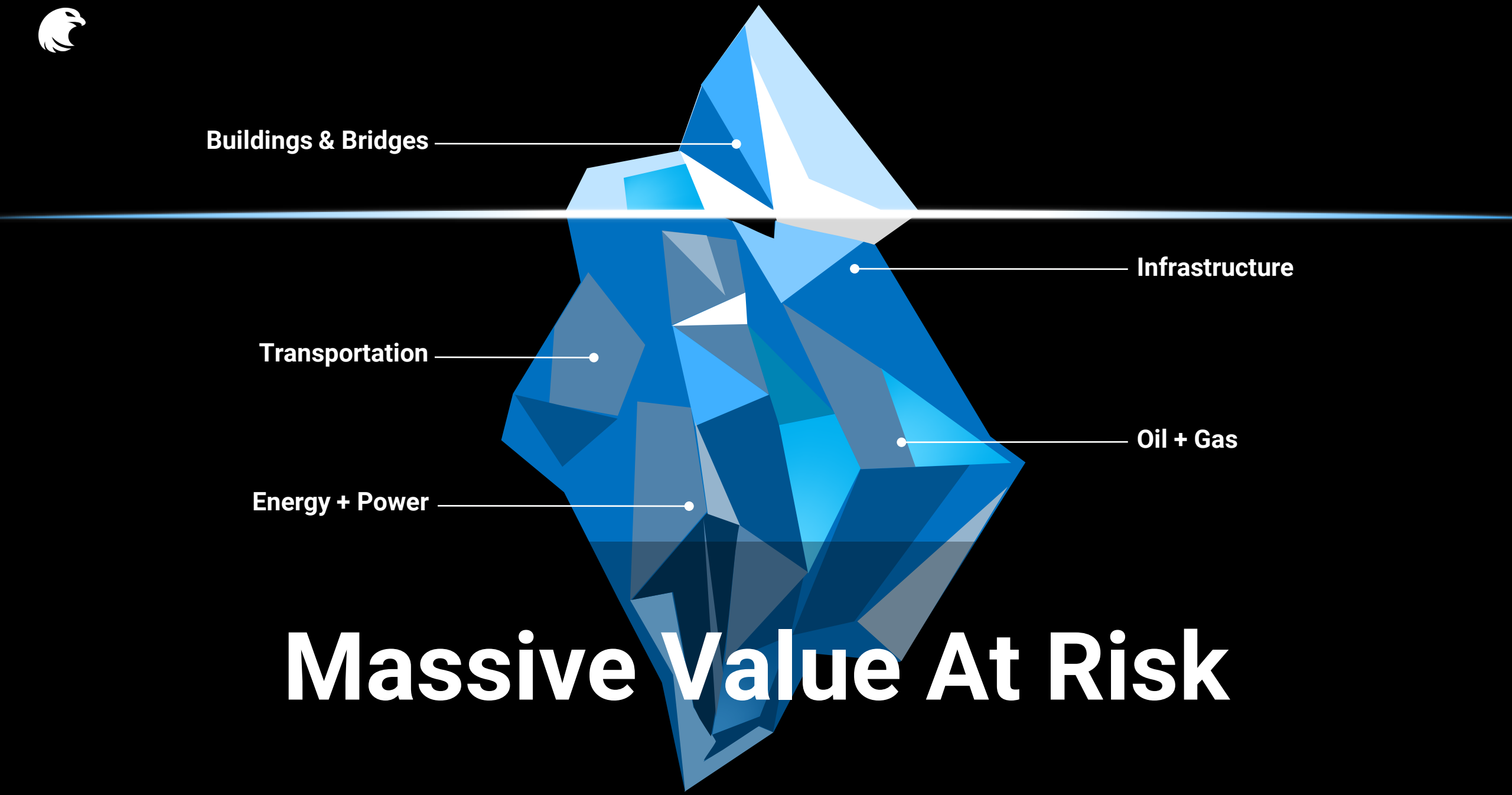
Structurally Deficient

12%

Severe Damages

28.5%

Worsening or Deficient



Massive Value At Risk

WHY Infrastructure and Asset Inspection

Challenges

Birth defects

of new infrastructure due to lack of quality control

Aging infrastructure

due to poor inspection and maintenance

Data lost

in analog style black box inspection devices

Paper records

and highly fragmented reporting tools

Shortage of inspectors

and few young people entering the industry

Infrastructure & Asset Inspection – Concrete Structures

WHAT is Concrete?

New Concrete per Year

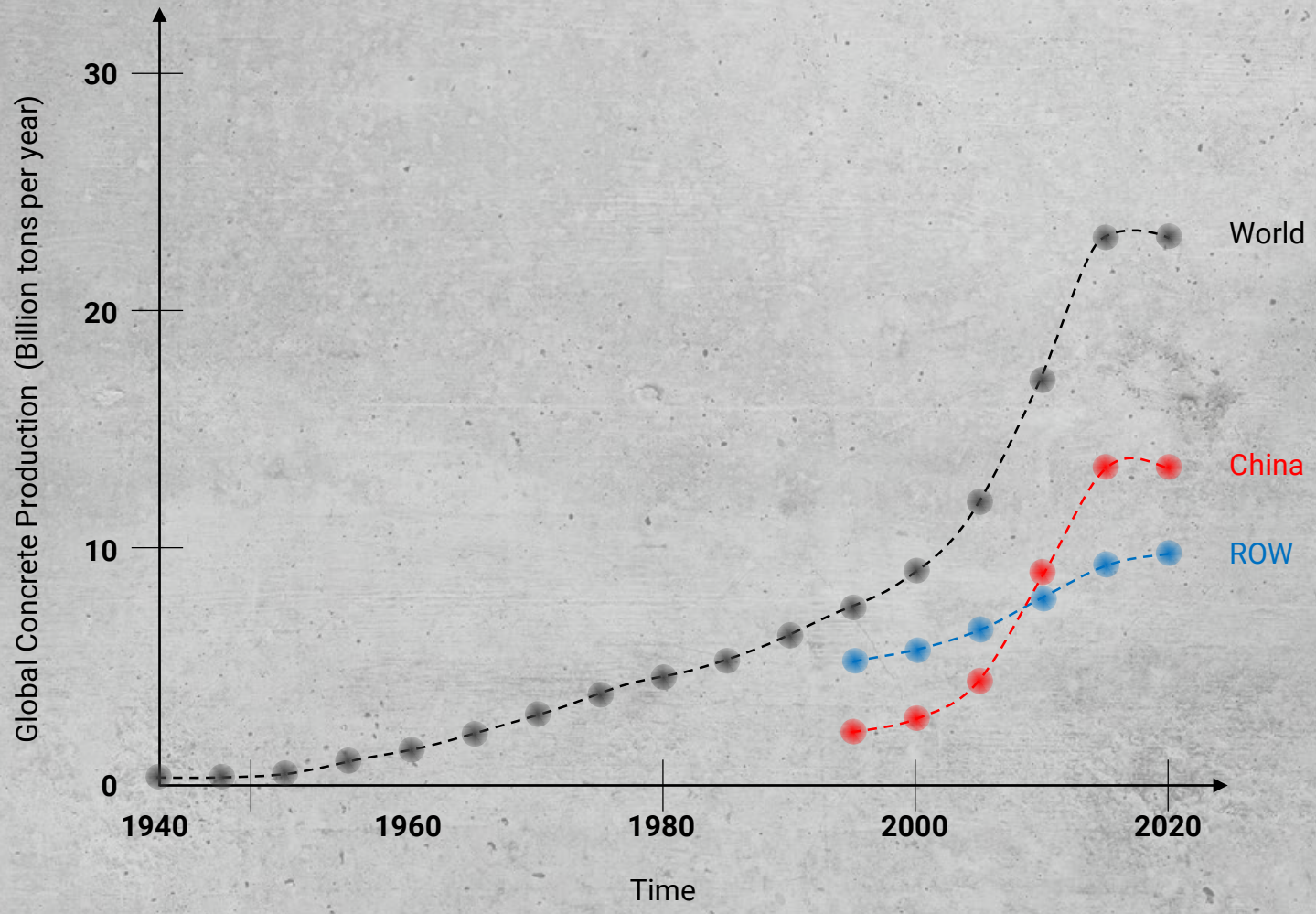
22,000,000,000,000 kg

1 m^3 per global capita per year..
…really lots of concrete!

"Can the building industry break its addiction to concrete?"
CNN | May 2018

WHAT is Concrete?

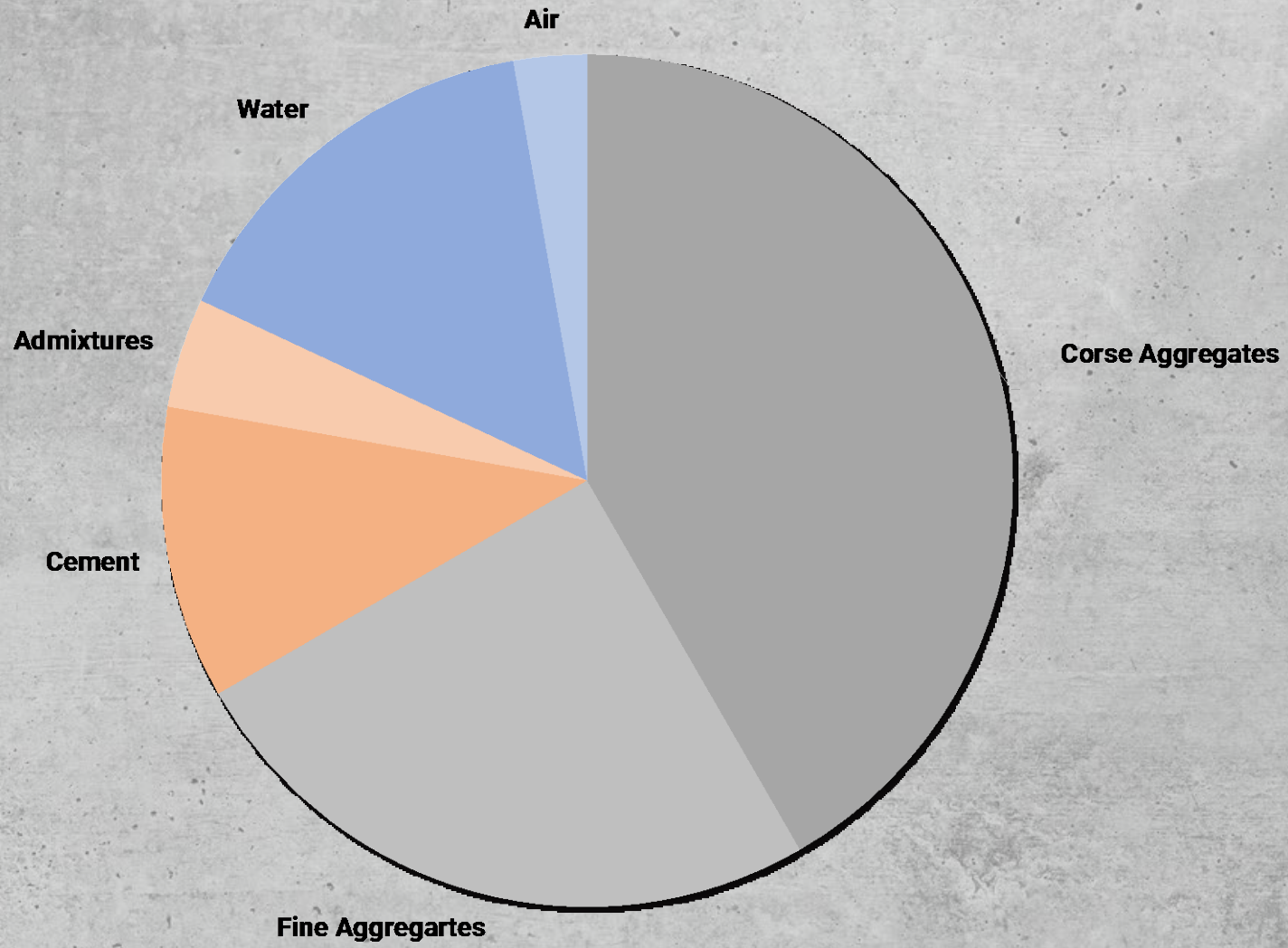
Concrete Production



- estimation -

WHAT is Concrete?

Composition



WHAT is Concrete?

Compressive Strength

WHAT is Concrete?

Compressive Strength

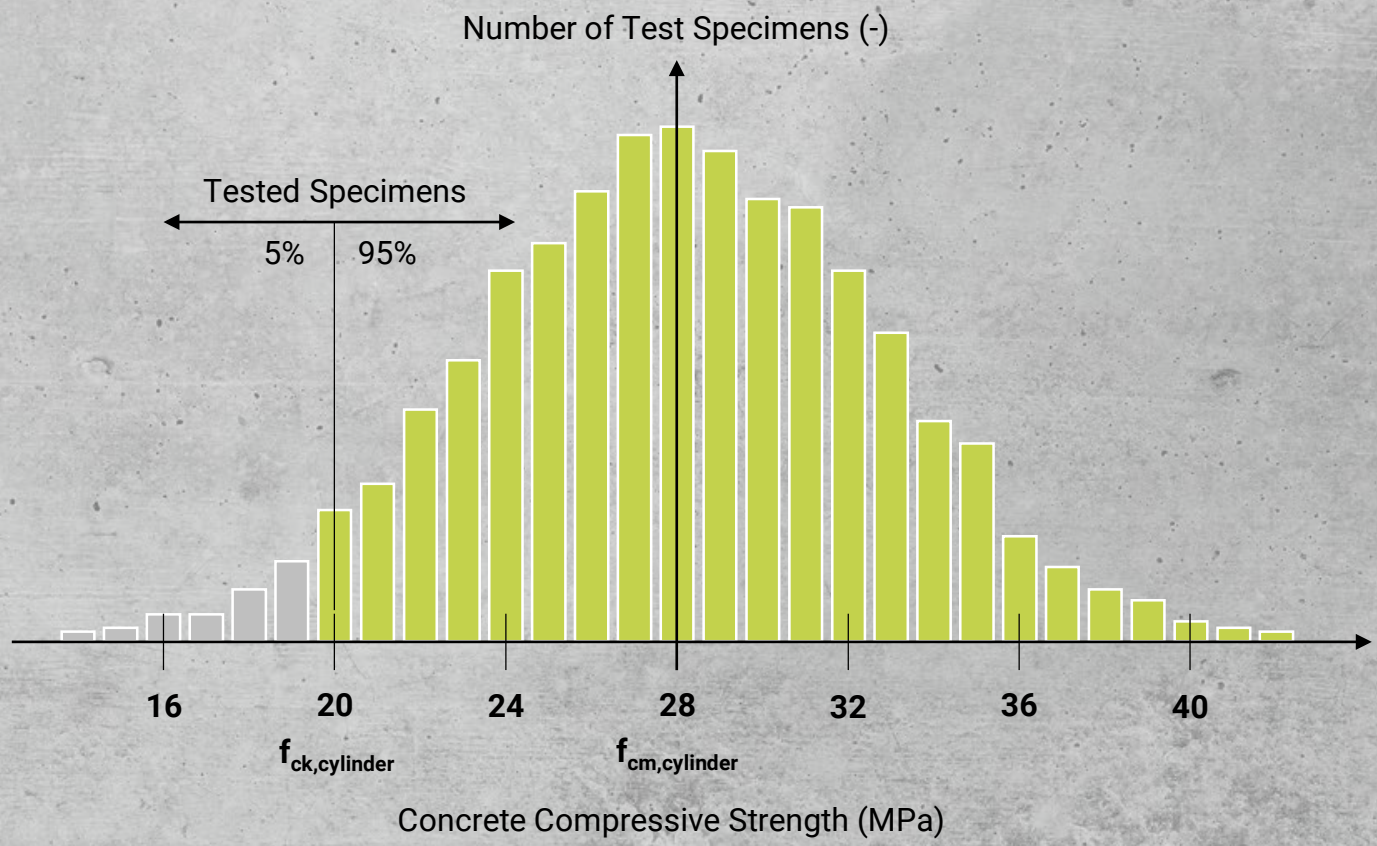
Compressive strength of concrete in accordance with EN 206 “Concrete. Specification, performance, production and conformity” is defined by the **characteristic value f_{ck}** (5% fractile of normal distribution) obtained in **destructive compressive** tests executed at 28 days after casting of cylindrical or cubic specimens.

Compressive strength classes are denoted by the letter C followed by two numbers that indicate the **cylinder and cube characteristic strength**, expressed in MPa, for example **C20/25**.

The curve peak coincides with the average of the compressive strength and is normally known as the **mean compressive strength f_{cm}**.

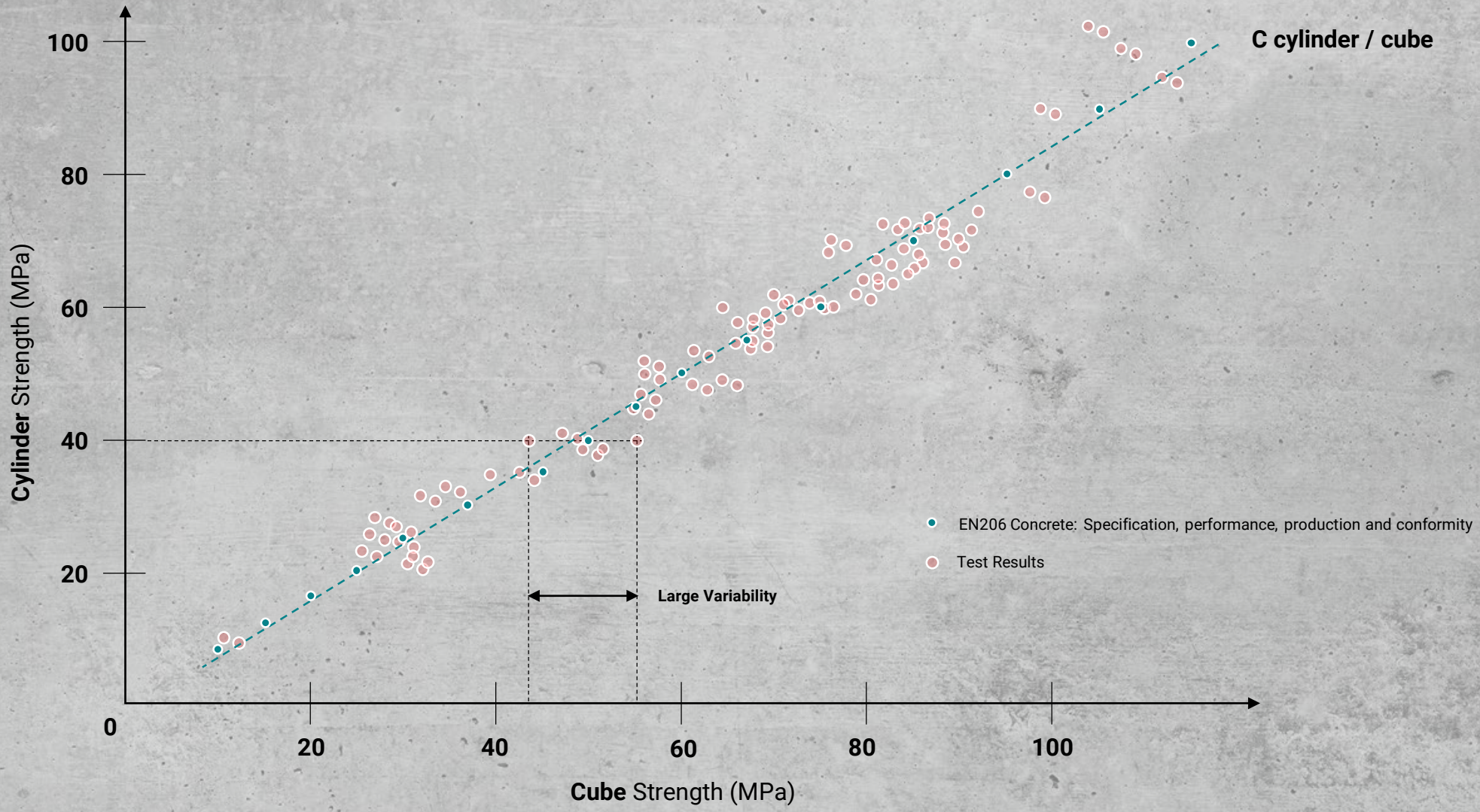
The characteristic compressive strength is lower than the mean compressive strength and both may typically be related with the following expression:

fck,cylinder ≈ fcm.cylinder – 8 MPa



WHAT is Concrete?

Compressive Strength



Compressive Strength

Compressive Strength of Concrete is **NOT** an **Exact Science** with a single value of truth, but a **Statistical Evaluation** where one determines a safe lower bound value, or **Characteristic Compressive Strength!**

WHAT is Concrete?

The Human Analogy

Concrete = **Muscle** and **Skin** of the Structure

- **inhomogeneous** mix of aggregates, cement, admixtures & water

Steel Rebar = Skeleton of **Reinforced Concrete**

- alkaline concrete **protects the rebars** from corrosion

Post-tensioning = **Tendons** that keep the Structure in shape

- allows longer spans, **reduce the amount of concrete** and reduce cracking

Electrical **Cables**, Pipes etc. = **Neural Network** of a Structure

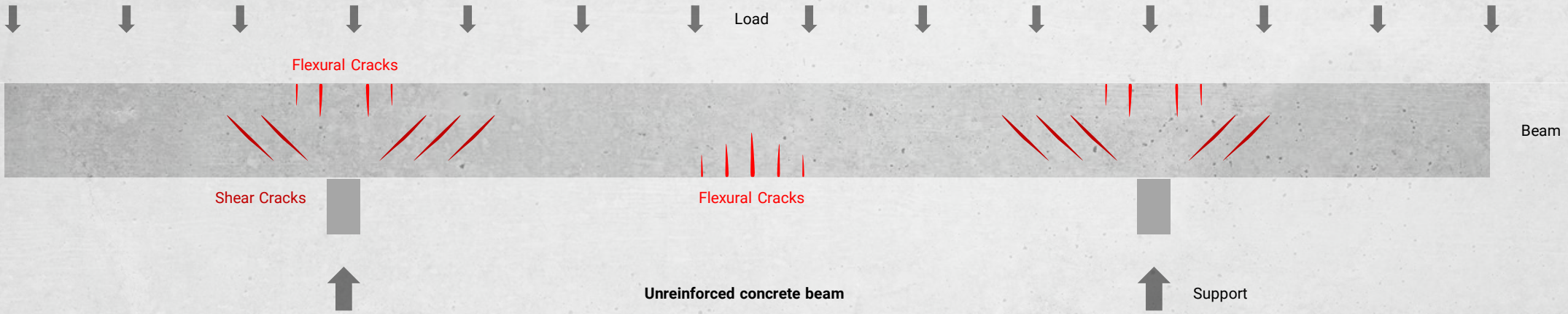
- are **not structural** but support the operation of the structural asset

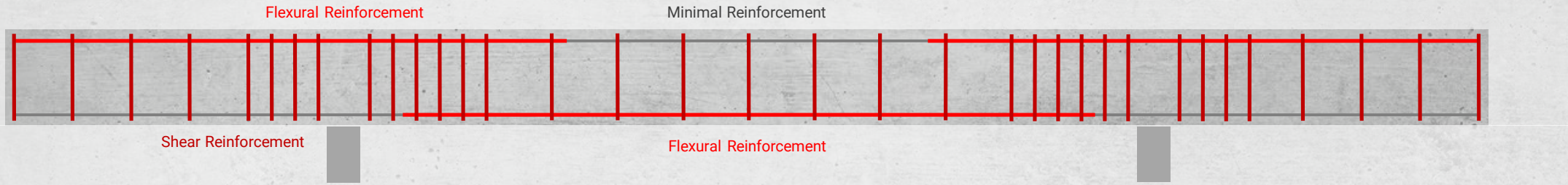
WHAT is Concrete?

Strong in Compression & Weak in Tension

WHAT is Concrete?

Strong in Compression & Weak in Tension





Reinforcement to provide strength and to control cracks

WHAT is Concrete?

Durability of Concrete

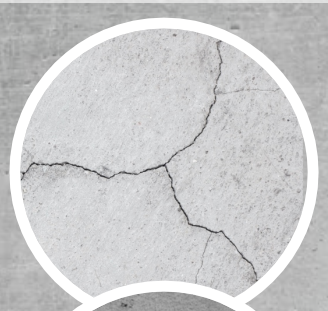
Durability of Concrete

In the early 20th century engineers thought that reinforced concrete structures would last perhaps for **1000 years**.

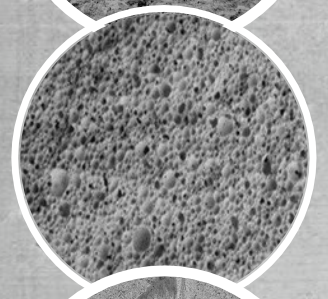
In reality, the lifespan is more like **50 years** or less.

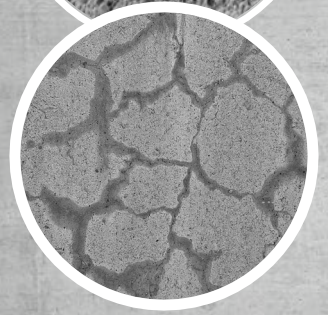
Deterioration can begin in as little as **5 years**.

Cracks and Surface Defects


Crack


Scaling


Disintegration


Crazing

Cracks and Surface Defects occurring **during the hardening** of the concrete

- Early frost damage
- Plastic: shrinkage or settlement
- Construction movement: formwork or subgrade

Cracks and Surface Defects occurring **after the hardening** of the concrete

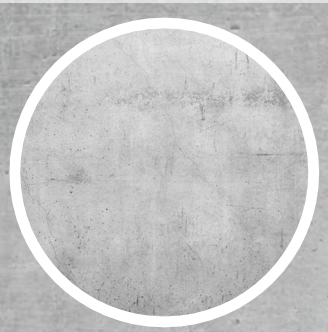
- Structural: overload, creep
- Chemical: disintegration, corrosion of reinforcement, alkali-aggregate reaction
- Physical: drying shrinkage, crazing, shrinkable aggregates
- Thermal: external variations, scaling (freeze/thaw), contraction (external or internal)

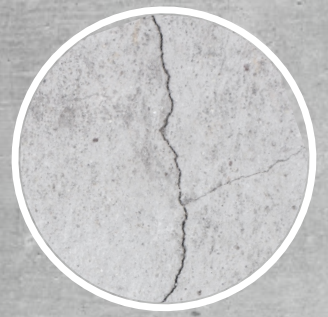
Cracks can be:

- **Cosmetic** (crazing)
- Structural **weak-spots** ► risk of structural **failure**
- Attack points for **concrete cancer**

WHAT is Concrete?

Concrete Cancer





Concrete Cancer results from a volume expansion due to **I. Rebar Corrosion**, leading to **Cracks**, **II. Delamination** and **III. Spalling** of the concrete.

I. **Rebar Corrosion**
   i. **Chlorides** from marine environments (sea), de-icing salts, poor aggregates or mixing water, and **air-pollution** penetrate the concrete and **corrode the rebar**
   ii. **Carbonation**: CO^2 (environment or **air-pollution**) reacts with the concrete, resulting in shrinkage cracks and reduced pH, leading to **rebar corrosion**
   iii. Loss of rebar cross-section weakens the structure and can result in a **failure**

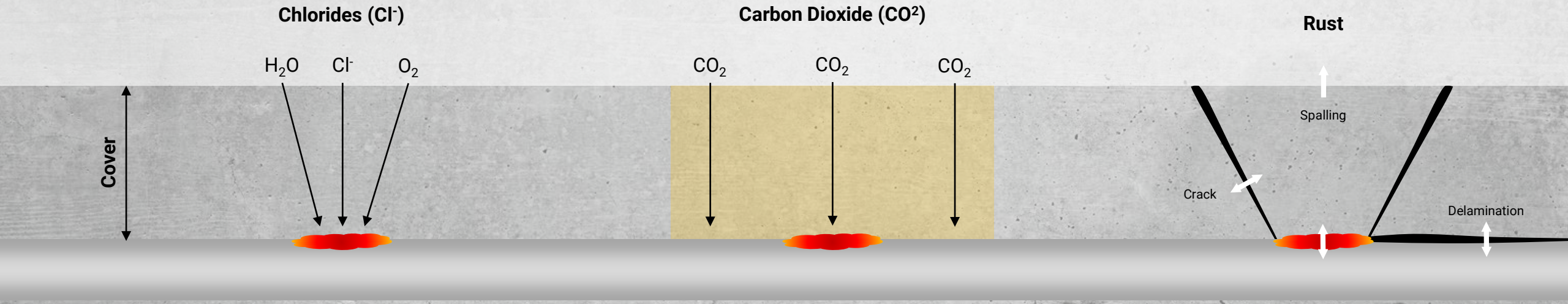
II. **Delamination:** separation of the surface from the concrete below

III. **Spalling:** fragments of the surface **detach** from the concrete below

Concrete cancer in an advanced stage is **deadly, hard to stop** and **expensive to fix**.

WHAT is Concrete?

Chlorides & Carbonation (Aging of Concrete)



Chloride ions in the cement paste react to form hydrochloric acid (HCl), which destroys the passive protective layer of the steel. In this situation the surface of the **steel acts as anode** and the **passive surface coating acts as cathode**.

$Fe^{++} + 2\ Cl^- \rightarrow FeCl_2$
$FeCl_2 + 2\ H_2O \rightarrow Fe(OH)_2 + 2\ HCl$

Carbonatation is a chemical reaction in which calcium hydroxide (water+ cement) reacts with carbon dioxide and forms insoluble calcium carbonate which is lower in pH and once it reaches the steel, the steels can **start to corrode**.

$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$
pH > 12 → pH < 9

Corroded steel (rust) **expands** in volume and the expansive force (oxide jacking or rust burst) will cause cracking and damage to surrounding concrete.

$Fe \rightarrow Fe{+}{+}\ 2\ e^-$
$Fe{+}{+} + 2(OH) \rightarrow Fe(OH)_2$
$Fe(OH)2 + 2\ H_2O + 0_2 \rightarrow Fe(OH)_3$

WHAT is Concrete?

Carbonation (Aging of Concrete)

50% < **Humidity** < 85%
Higher **Temperature**
Higher **CO^2**

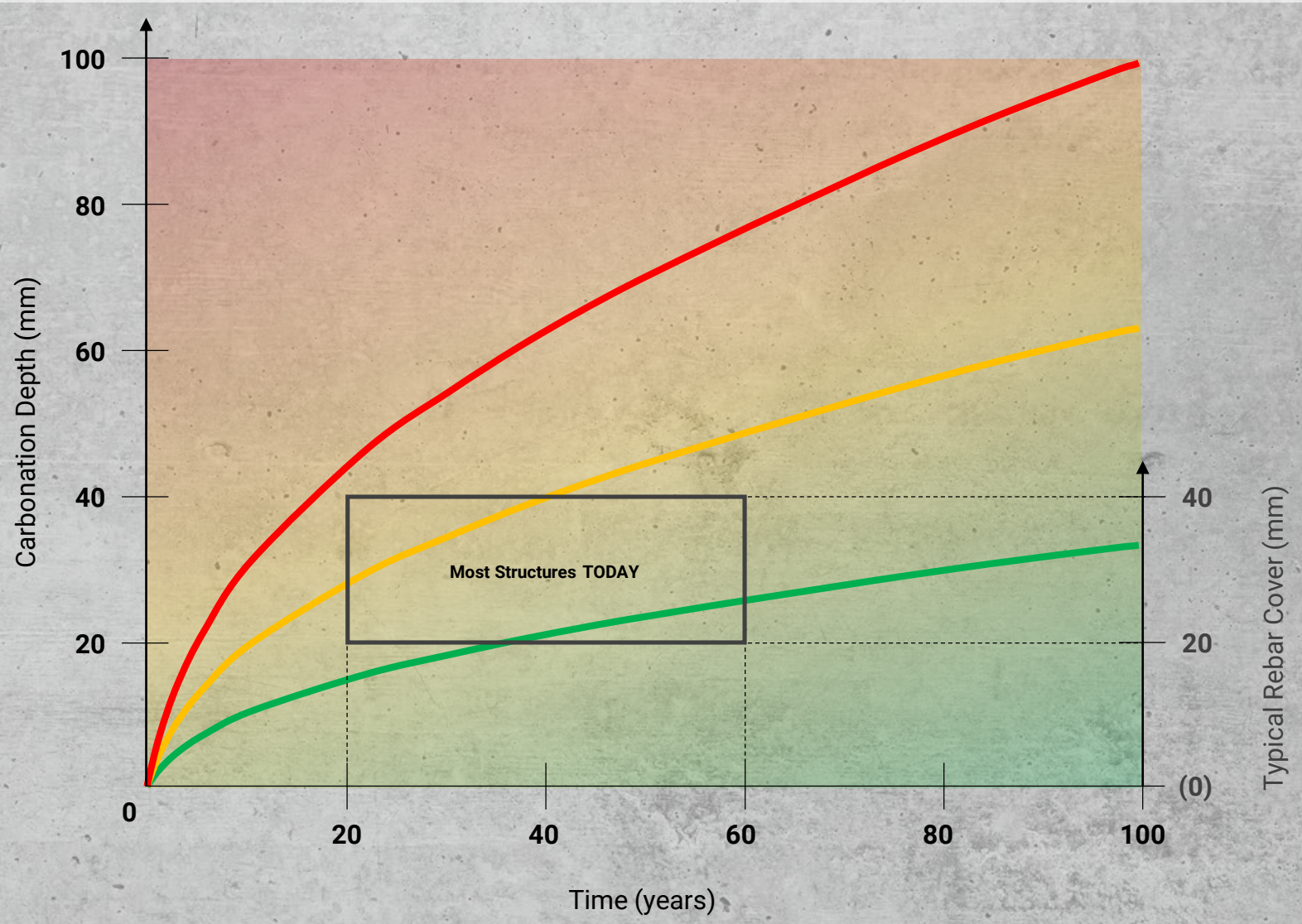
Many **Cracks**
Rough **Surface**

Cement Type CEM III/b
Low Strength Concrete
High **Water/Cement** Ration (0.6)

40% > **Humidity** > 95%
Lower **Temperature**
Lower **CO2**

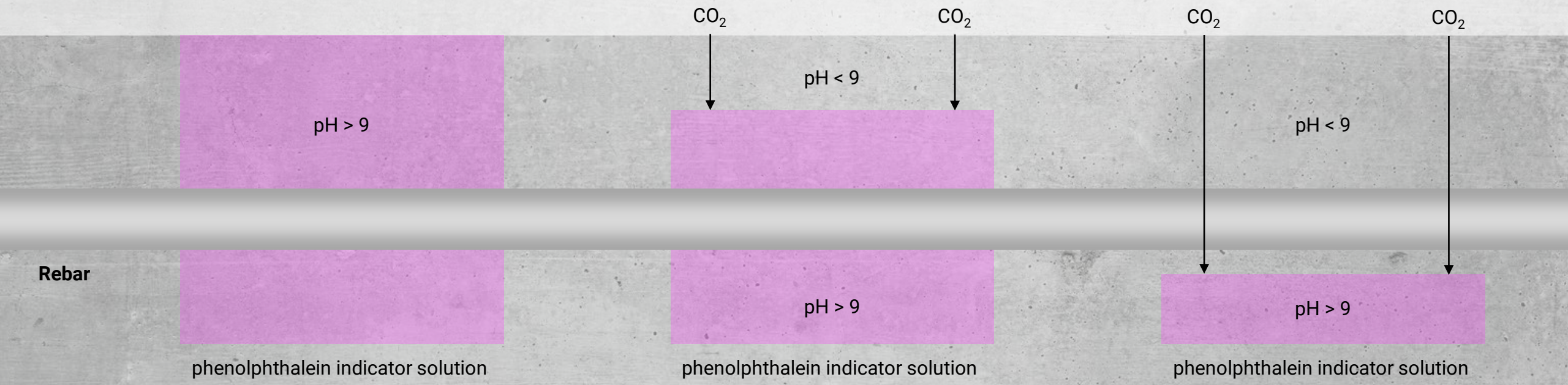
Few **Cracks**
Smooth **Surface**

Cement Type CEM I
High **Strength** Concrete
Low **Water/Cement** Ration (0.4)



WHAT is Concrete?

Carbonation (Aging of Concrete)

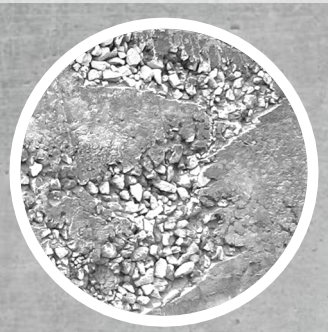


The affected carbonation depth of a concrete surface (coring etc.) can be readily shown by the use of **phenolphthalein indicator solution**. Phenolphthalein crystalline material and for use as an indicator it is dissolved in a suitable solvent such as isopropyl alcohol (isopropanol).

WHAT is Concrete?

It gets really bad and very expensive...

Other Defects



Honeycombing: stony spaces on the inside or the surface due to poor workmanship

- structural **weak-spots** ► risk of structural **failure**
- attack points for **concrete cancer** if at the surface

Voids: cavities on the inside or the surface due to poor workmanship

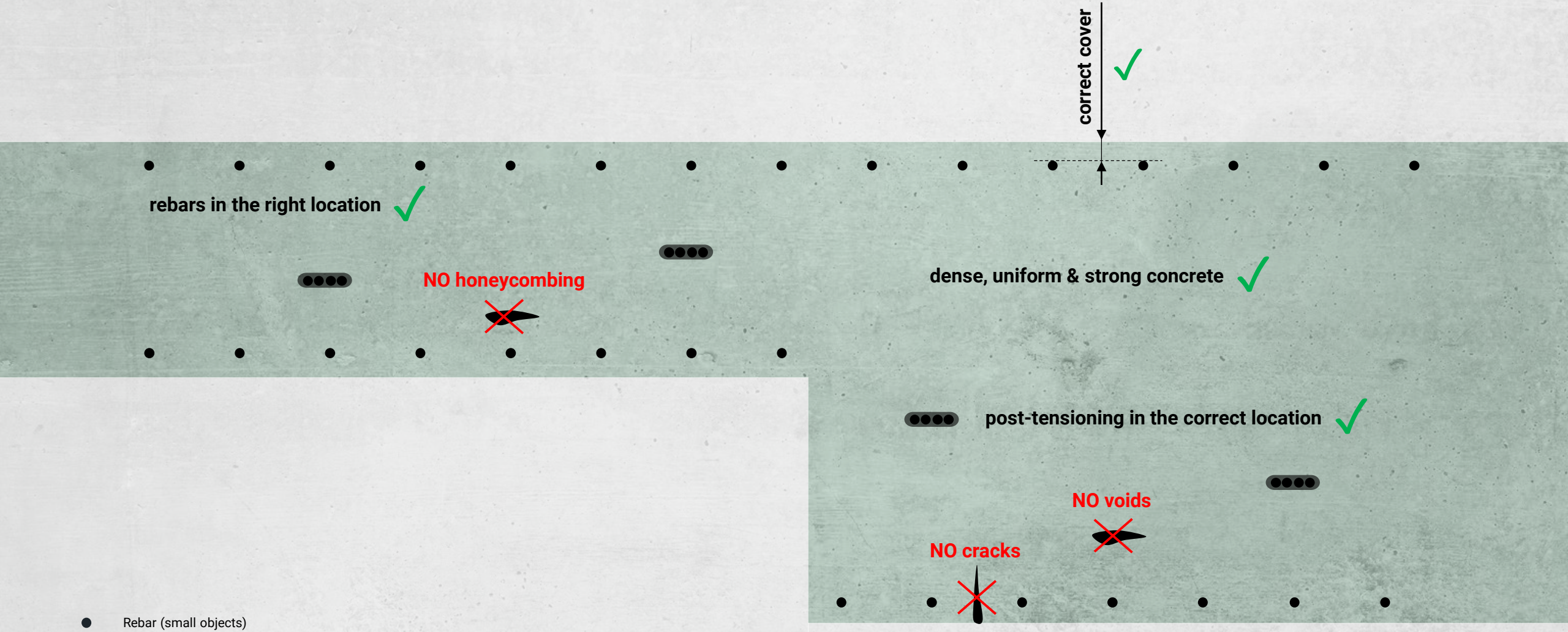
- structural **weak-spots** ► risk of **structural failure**
- attack points for **concrete cancer** if at the surface

Wear / Erosion: mechanical **abrasion** of the surface of the concrete

- structural **weak-spots** ► risk of structural **failure**
- attack points for **concrete cancer**

WHAT is Concrete?

Healthy Concrete



Rebar (small objects)

Post-tensioning, Cables Ducts (larger objects)

Crack, Delamination, Voids, Honeycombing (air)

WHAT is Concrete?

Skilled Workers are a must...

WHAT is Concrete?

Digital Inspections are a MUST...

Infrastructure & Asset Inspection – Concrete Structures

HOW to Inspect Concrete Structures?

HOW to Inspect Concrete Structures?

Relevant Parties

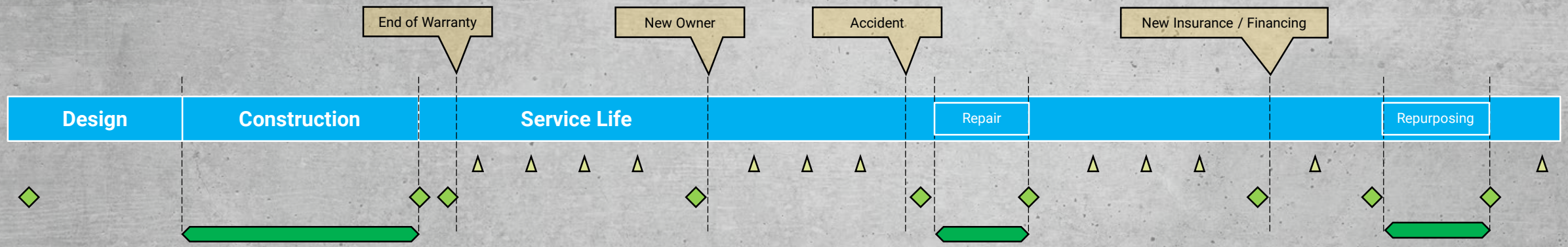
- Owner
- Bank / Insurance
- Government / Authority / Research

- Architect
- Engineer
- Supervisor, Inspector, Surveyor, Locator

- General Contractor / Builder
- Specialist Contractor / Subcontractor
- Material / Component Supplier

HOW to Inspect Concrete Structures?

Lifecycle



Type of Inspections

Quality Control Inspection
When: daily / weekly / monthly
Result: NO Birth Defects

As-Built / Condition Inspection
When: targeted
Result: Birth & Health Status / Record

Periodic Inspection
When: every 1 to 5 years
Result: Healthy Checks / Record

IMPORTANT: All inspection data needs to be recorded & needs to be accessible over time!

HOW to Inspect Concrete Structures?

Visual Inspection | Vital Signs | Locating, Mapping & Imaging

Avoid **birth-defects** on new structures & perform **health-checks** during the service life

Visual Inspection

- surface condition ▶ basic assessment

Vital Signs of Concrete

- strength & uniformity ▶ structural strength
- homogeneity ▶ structural strength & protection of rebars
- permeability ▶ risk of rebar corrosion

Locating, Mapping & Imaging

- rebars, post-tensioning, cables, pipes (objects) ▶ structural elements correctly in place
- delamination, voids, honeycombing (defects) ▶ detect weak-spot & fight concrete cancer
- rebar cover & diameter ▶ protection of rebars & structural strength
- corrosion potential ▶ risk of rebar corrosion

HOW to Inspect Concrete Structures?

Visual Inspection | Vital Signs | Locating, Mapping & Imaging

Avoid **birth-defects** on new structures & perform **health-checks** during the service life

Visual Inspection

- surface condition ▶ **Digital Inspection (Inspect)**

Vital Signs of Concrete

- strength & uniformity ▶ **Rebound (Schmidt) / UPV (Pundit)**
- homogeneity ▶ **Ultrasound Pulse Velocity (Pundit)**
- permeability ▶ **Resistivity (Resipod)**

Locating, Mapping & Imaging

- rebars, post-tensioning, cables, pipes (objects) ▶ **Ground Penetrating Radar (Proceq GPR)**
- delamination, voids, honeycombing (defects) ▶ **Ultrasound Pulse Echo (Pundit Array)**
- rebar cover & diameter ▶ **Eddy Current (Profometer)**
- corrosion potential ▶ **Half-cell Potential (Profometer)**

HOW to Inspect Concrete Structures?

Visual Inspection

HOW to Inspect Concrete Structures?

Visual Inspection | Vital Signs | Locating, Mapping & Imaging

Avoid **birth-defects** on new structures & perform **health-checks** during the service life

Visual Inspection

- surface condition ▶ **Digital Inspection (Inspect)**

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Locating, Mapping & Imaging

- rebars, post-tensioning, cables, pipes (objects) ▶ **Ground Penetrating Radar (Proceq GPR)**
- delamination, voids, honeycombing (defects) ▶ **Ultrasound Pulse Echo (Pundit Array)**
- rebar cover & diameter ▶ **Eddy Current (Profometer)**
- corrosion potential ▶ **Half-cell Potential (Profometer)**

HOW to Inspect Concrete Structures?

Visual Inspection

Surface Condition
Visual Inspection
Inspect

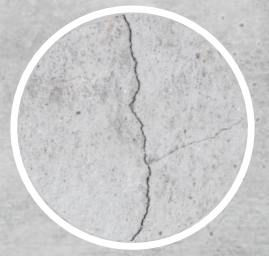
scaling

Surface Condition
Visual Inspection
Inspect

surface defect

Surface Condition
Visual Inspection
Inspect

concrete cancer



crack

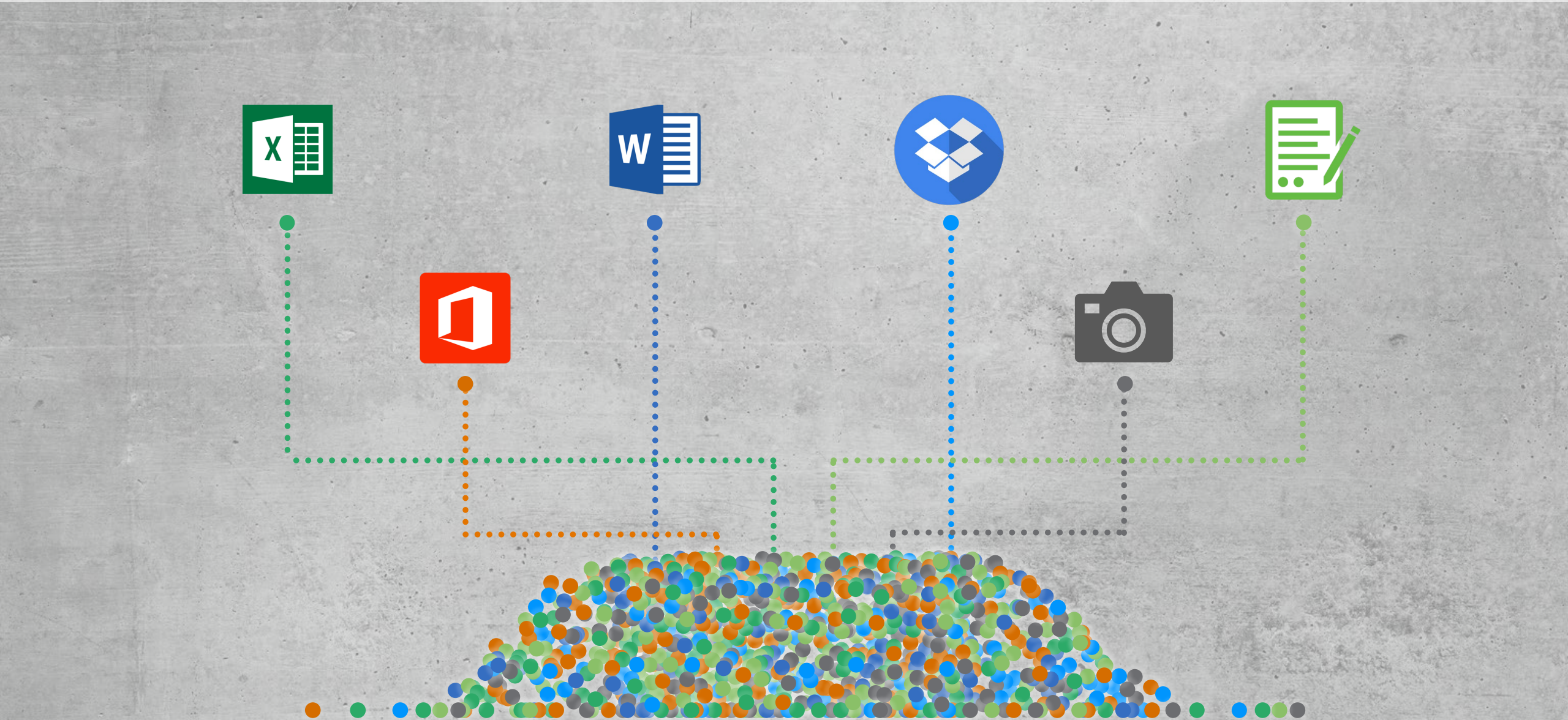
Surface Condition
Visual Inspection
Inspect

HOW to Inspect Concrete Structures?

Outdated Procedures that get lost...

HOW to Inspect Concrete Structures?

Massive Fragmentation of Tool



HOW to Inspect Concrete Structures?

Data Collection & Reporting

Data Collection

Reporting

Up to **65%** of time spent with **writing** the **Inspection Report**

Records & Reports are often **LOST** over time

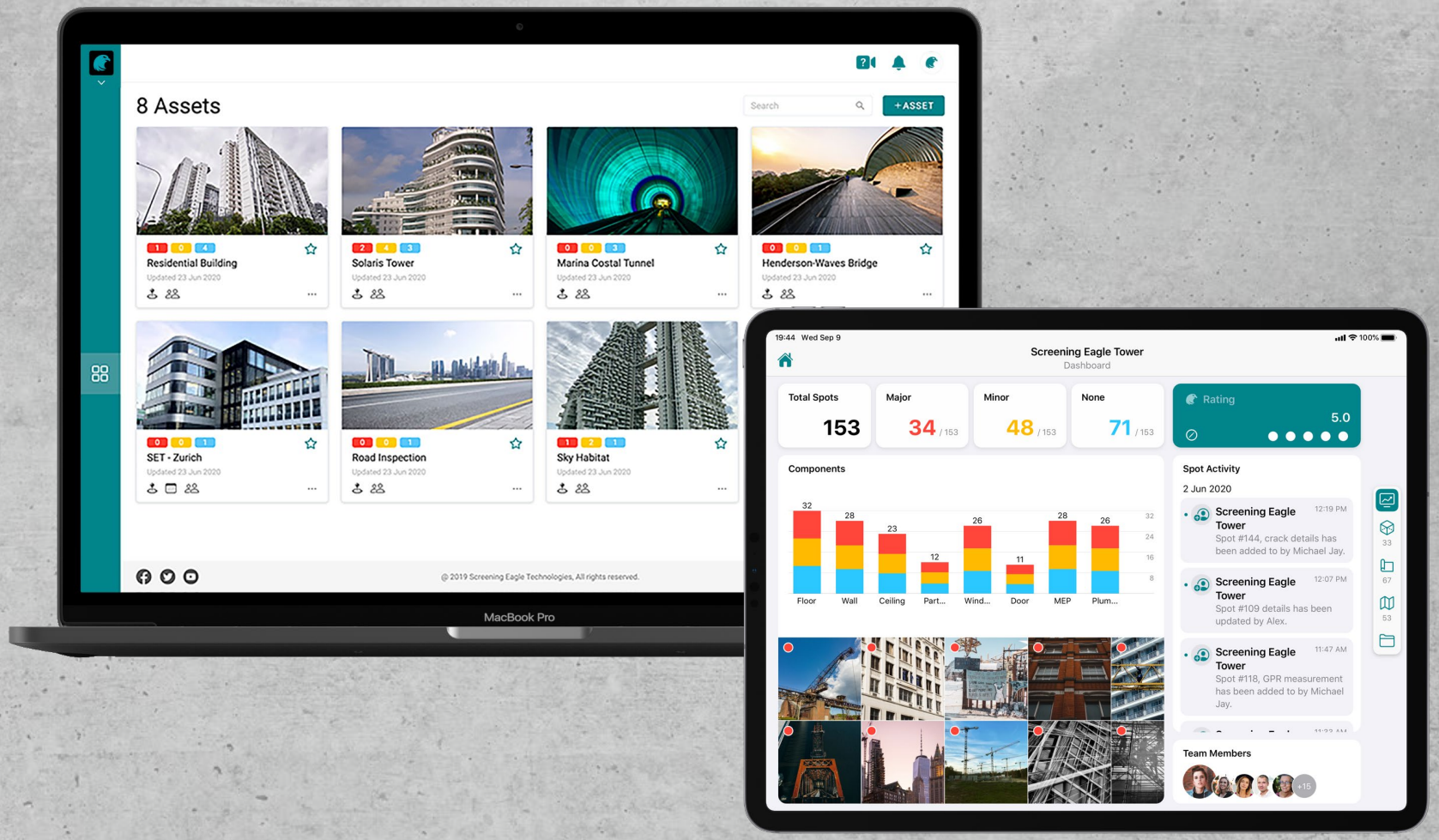
Research by Proceq with representative Inspectors and Asset Owners

HOW to Inspect Concrete Structures?

INSPECT ► Digital Visual Inspection

Download on the App Store

Screening Eagle Inspect



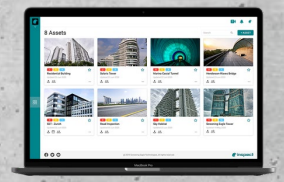
HOW to Inspect Concrete Structures?

INSPECT ► Inspection Software Platform

Inspection Report

- One-click report port
- 24/7 data availability

Asset preparation



- Customize workflow
- Team administration

Repair & Maintenance

Pre-Inspection

inspect

End-to-end inspection software platform

- ✓ Structured and customizable workflow management
- ✓ Encrypted data stored in different cloud-based data centers
- ✓ Data available anytime and anywhere
- ✓ Significantly reduced reporting time

Post-Inspection

Field Inspection

Data Analysis

- Dashboard analytics
- Asset health status

Data Collection

- Create SPOTs
- Define location

HOW to Inspect Concrete Structures?

INSPECT ► Focus on Inspection – Not Paperwork

improve
Quality

3x
more digitral obersvations

field observations for **Inspectors** to support complete assessment

traceable and **reliable data**

increase
Productivity

100x
Faster Reporting

for **Inspectors** on structured data collection and reporting to

save time and **money**

secure
Asset Data

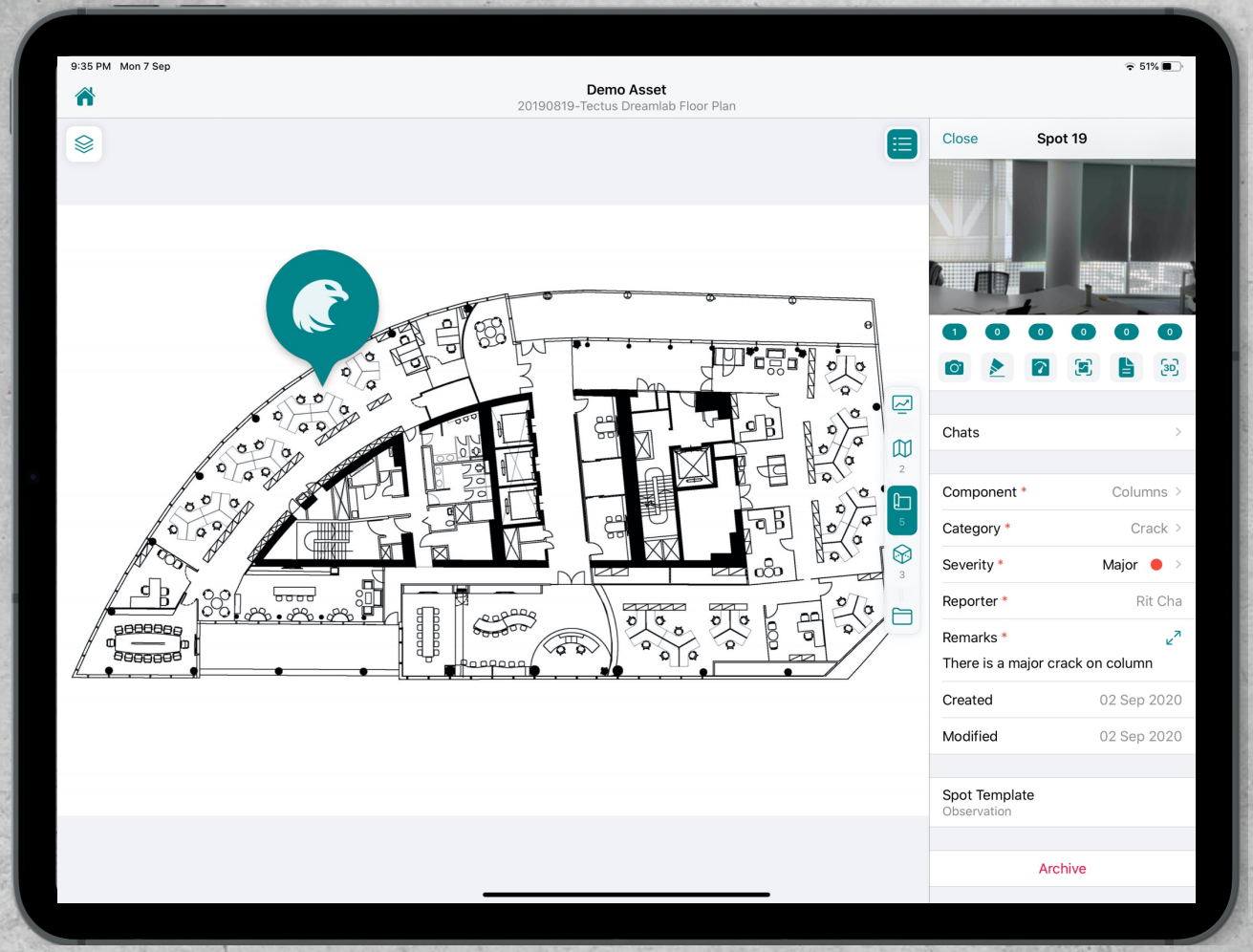
Forever

for recurring inspections and digital health record for **Owners**

24/7 access to analytics

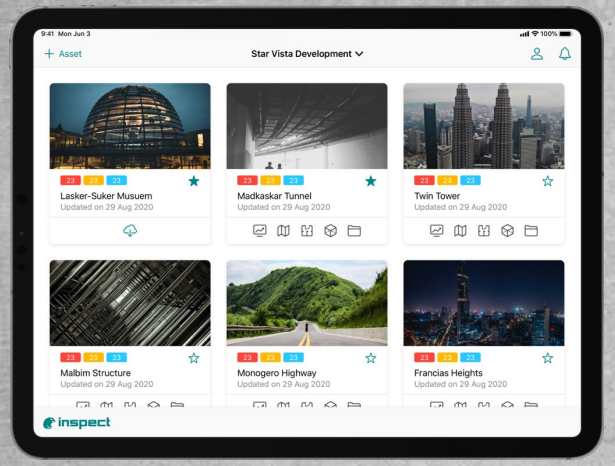
HOW to Inspect Concrete Structures?

INSPECT ► Location (SPOT) is at the Core



HOW to Inspect Concrete Structures?

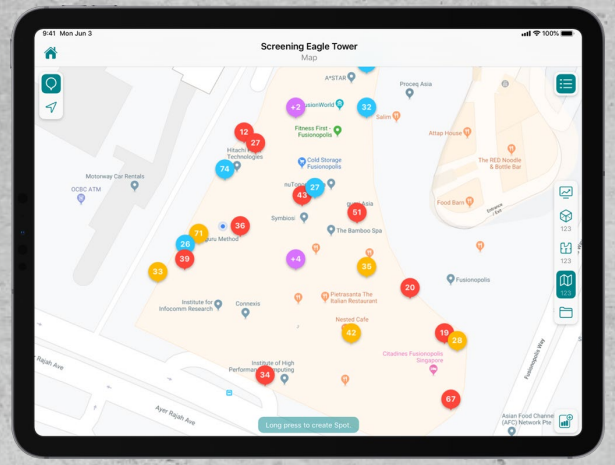
INSPECT ► Digital Twin

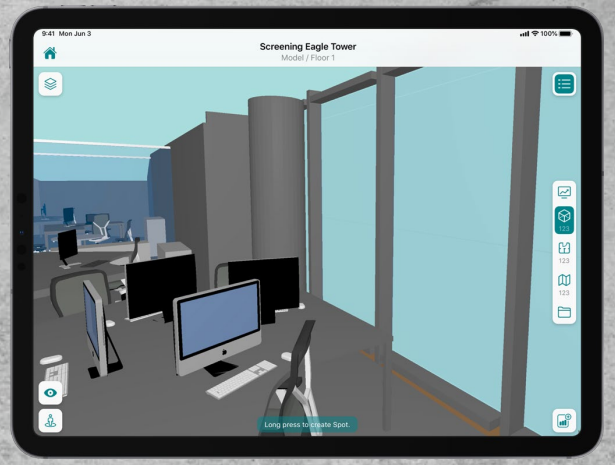


Manage all your Inspection Data

GEOMAP | **2D** (Drawings, Sketches) | **3D** (BIM Model Import)

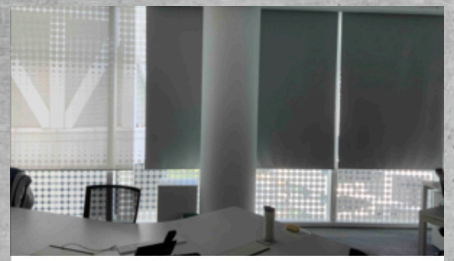
Track automatically **WHAT**, **WHERE**, **WHEN** and **WHO**





HOW to Inspect Concrete Structures?

INSPECT ▶ Swiss Army Knife



1 0 0 0 0 0

Photo Sketch NDT Data AI DEFECT Documents 3D SCAN

Chats

Live CHAT

Component * Columns

Category * Crack

Severity * Major

Reporter * Rit Cha

Remarks *

There is a major crack on column

Created 02 Sep 2020

Modified 02 Sep 2020

Spot Template

Observation

Fully customizable SPOT Templates

HOW to Inspect Concrete Structures?

INSPECT ▶ Dashboard

HOW to Inspect Concrete Structures?

INSPECT ► AI DEFECT Digitalization

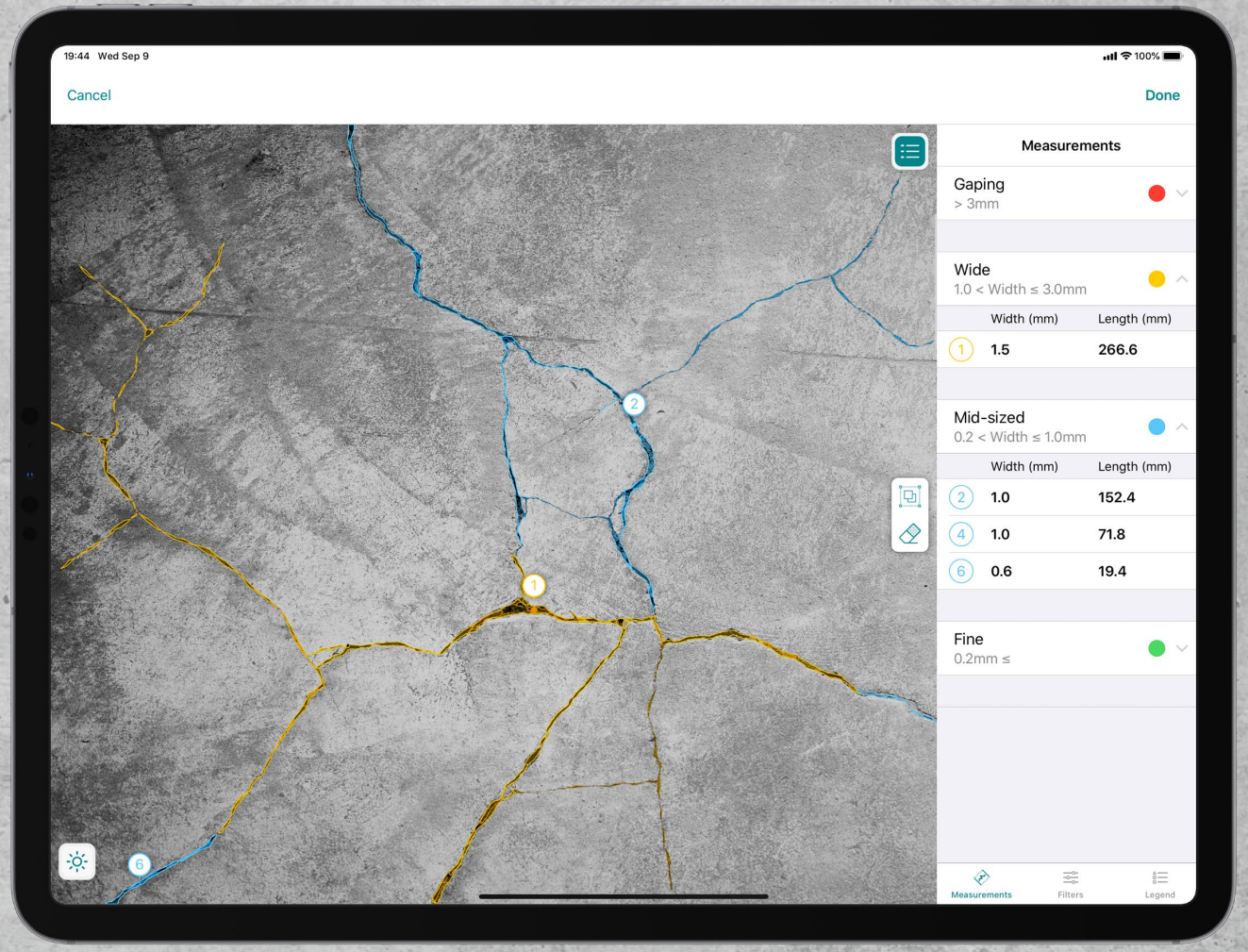
Test pictures for Neural Network

16 Mio

- Digitize crack with CAD export
- Crack dimensioning (future release)
- Edit crack, add/remove parts

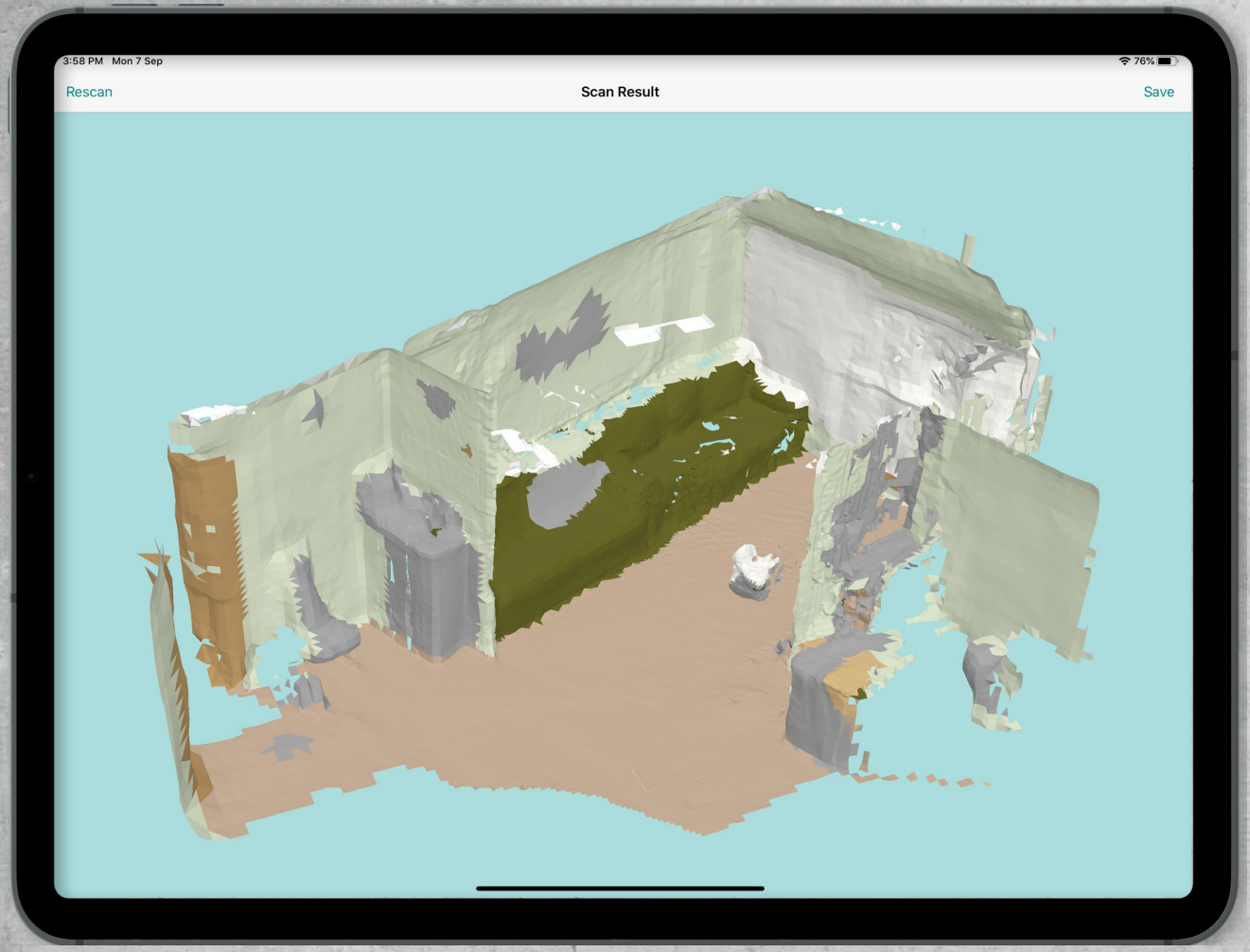
Benefits

- ✓ Reduces guess work
- ✓ Increases productivity
- ✓ Path to predictive maintenance



HOW to Inspect Concrete Structures?

INSPECT ► 3D SCAN reality replica



New Dimension

- 3D Scan using LiDAR
- Point cloud export (future release)
- Use as a 3D model in Inspect (future release)

Benefits

- ✓ Dimensioning of asset
- ✓ Create spots on 3D replica
- ✓ Save money in converting asset to reality

HOW to Inspect Concrete Structures?

INSPECT ► CAPTURE your surroundings

Reduce photo-reporting time

20x

- **Real-time** photo capture with location tagging
- Recording & visualizing the traveled path
- Allowing remote inspection workflows

Benefits

✓ Saves time

✓ Full context

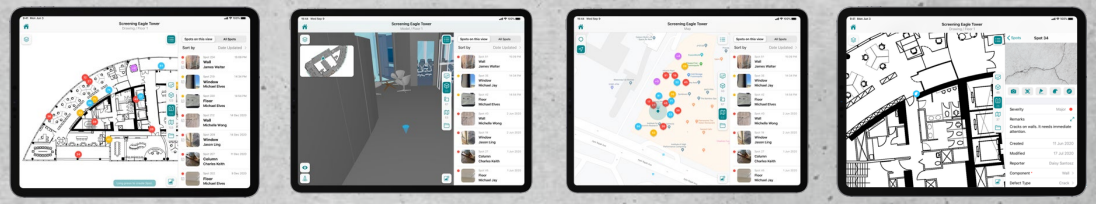
✓ Time comparability

HOW to Inspect Concrete Structures?

INSPECT ► Comprehensive Feature Set for InspectionTech

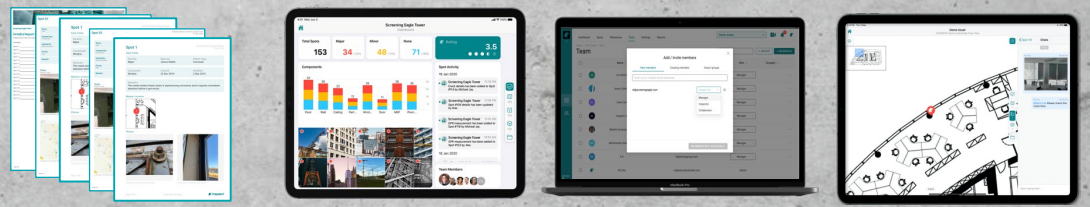
Core Functions

- 2D View
- 3D View
- GeoMap
- Picture Sketch



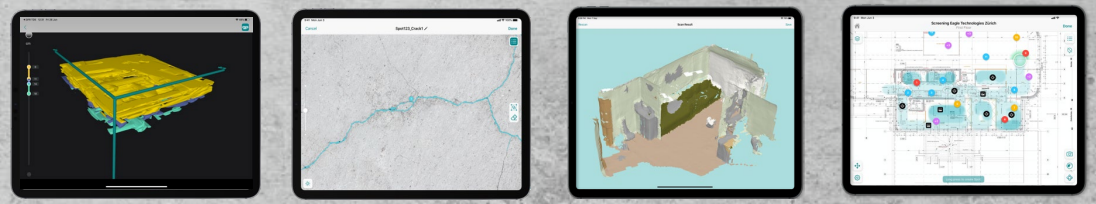
Collaboration

- Report
- Dashboard
- Access Management
- Chat



AI & Data Analysis

- proceq NDT Sensor Data
- AI DEFECT
- 3D SCAN
- CAPTURE



HOW to Inspect Concrete Structures?

INSPECT ► Running on the iPad

iPad – the solution of choice for Visual Inspections

Camera (minimum specifications for Visual Inspections)

- 8MP ƒ/2.4 aperture
- 1080p HD video recording at 30 fps

Camera (high-end specifications)

- Wide Angle:12MP ƒ/1.8 aperture
- Ultra Wide: 10MP ƒ/2.4 aperture, 120° field of view
- 2x optical zoom out & digital zoom up to 5x
- 4K video recording at 60 fps
- True Tone flash
- Lidar

Capacity: 64 GB – 1 TB

iPad with minimum specifications is starting at **UDS 329**

iPad Pro with high-end specifications and cellular starting at **USD 949**

Pad Pro 11-inch
iPad Pro 12.9-inch

HOW to Inspect Concrete Structures?

Vital Signs of Concrete

HOW to Inspect Concrete Structures?

Visual Inspection | Vital Signs | Locating, Mapping & Imaging

Avoid **birth-defects** on new structures & perform **health-checks** during the service life

Visual Inspection

- surface condition ▶ **Digital Inspection (Inspect)**

Vital Signs of Concrete

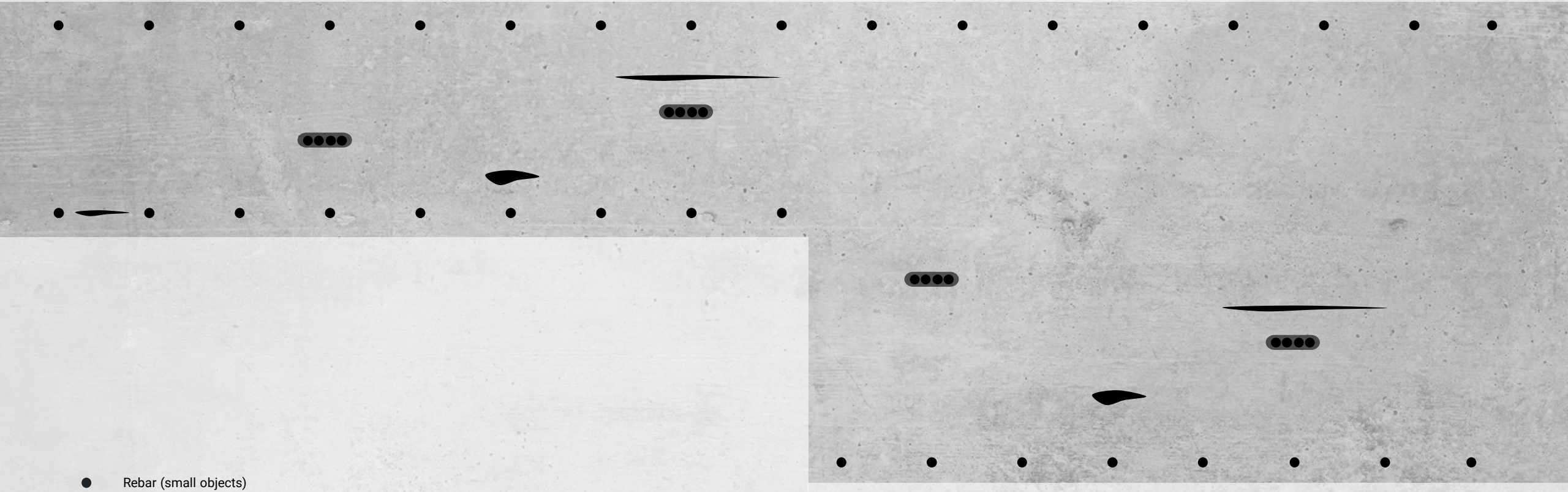
- strength & uniformity ▶ **Rebound (Schmidt) / UPV (Pundit)**
- homogeneity ▶ **Ultrasound Pulse Velocity (Pundit)**
- permeability ▶ **Resistivity (Resipod)**

Locating, Mapping & Imaging

- rebars, post-tensioning, cables, pipes (objects) ▶ **Ground Penetrating Radar (Proceq GPR)**
- delamination, voids, honeycombing (defects) ▶ **Ultrasound Pulse Echo (Pundit Array)**
- rebar cover & diameter ▶ **Eddy Current (Profometer)**
- corrosion potential ▶ **Half-cell Potential (Profometer)**

HOW to Inspect Concrete Structures?

Vital Signs of Concrete



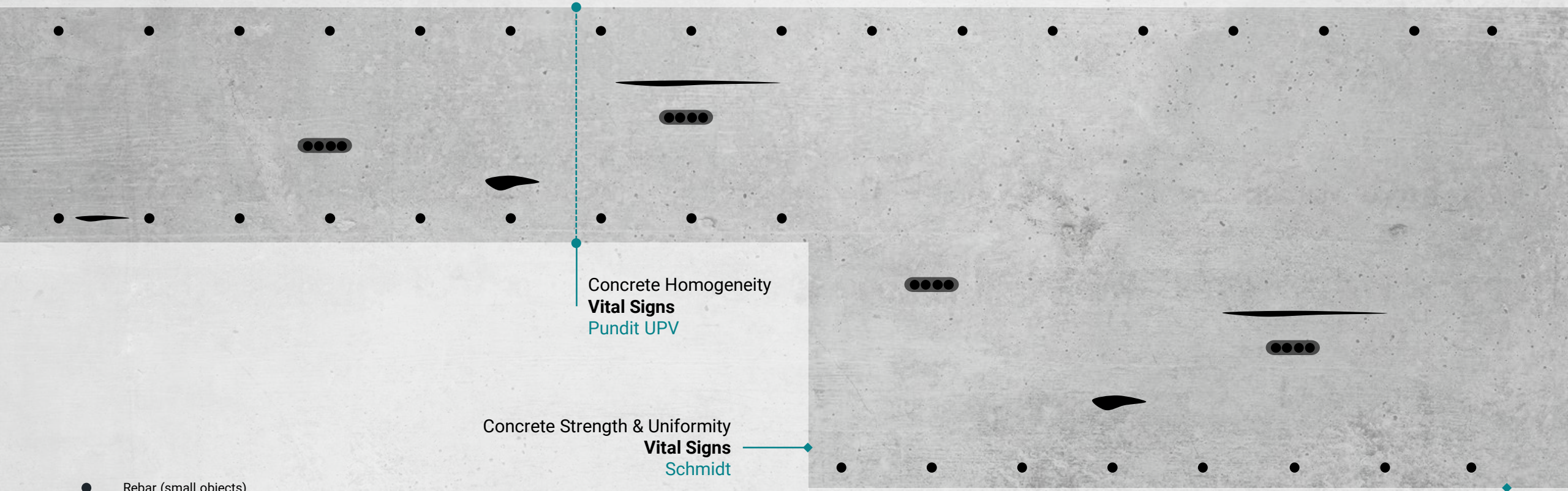
Rebar (small objects)

Post-tensioning, Cables, Pipes (larger objects)

Cracks, Delamination, Voids, Honeycombing (air)

HOW to Inspect Concrete Structures?

Vital Signs of Concrete



Vital Signs of Concrete

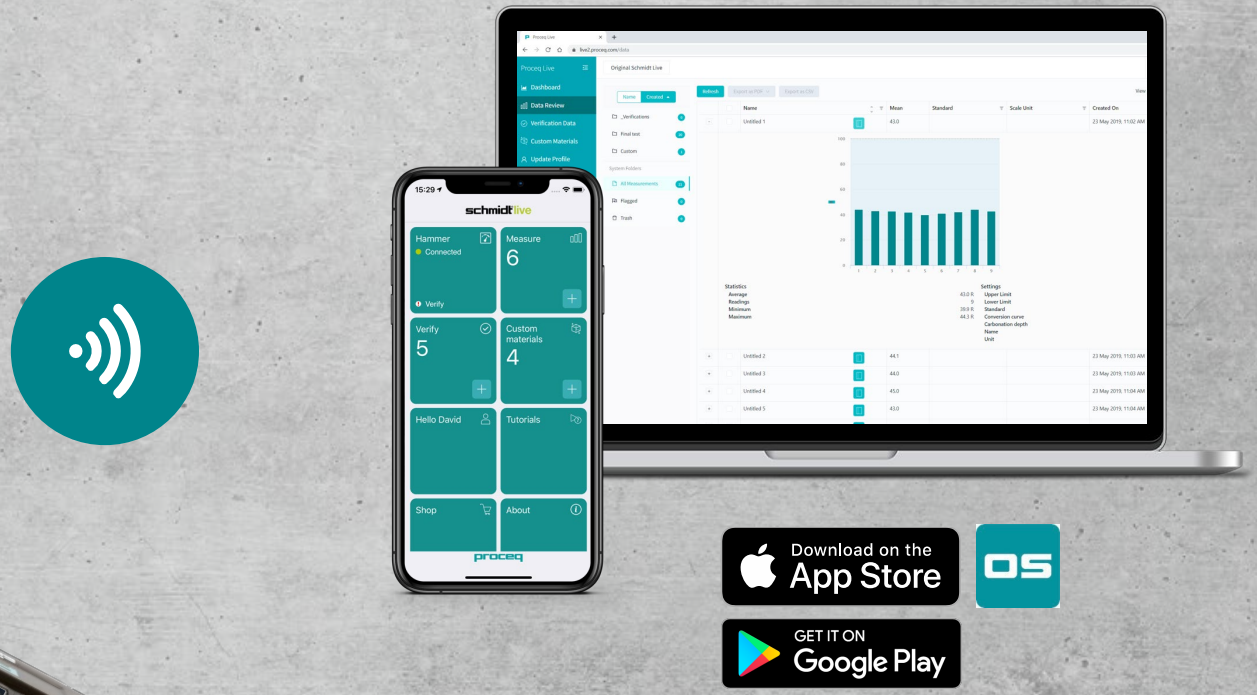
Rebound (Schmidt)

Vital Signs of Concrete

Strength & Uniformity ► Rebound (Schmidt)

Silver Schmidt **OS8200**

Original Schmidt **OS8000**

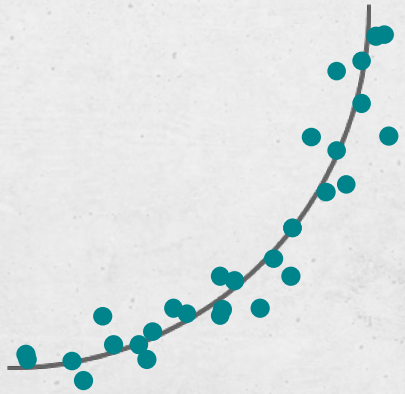


Download on the App Store

GET IT ON Google Play

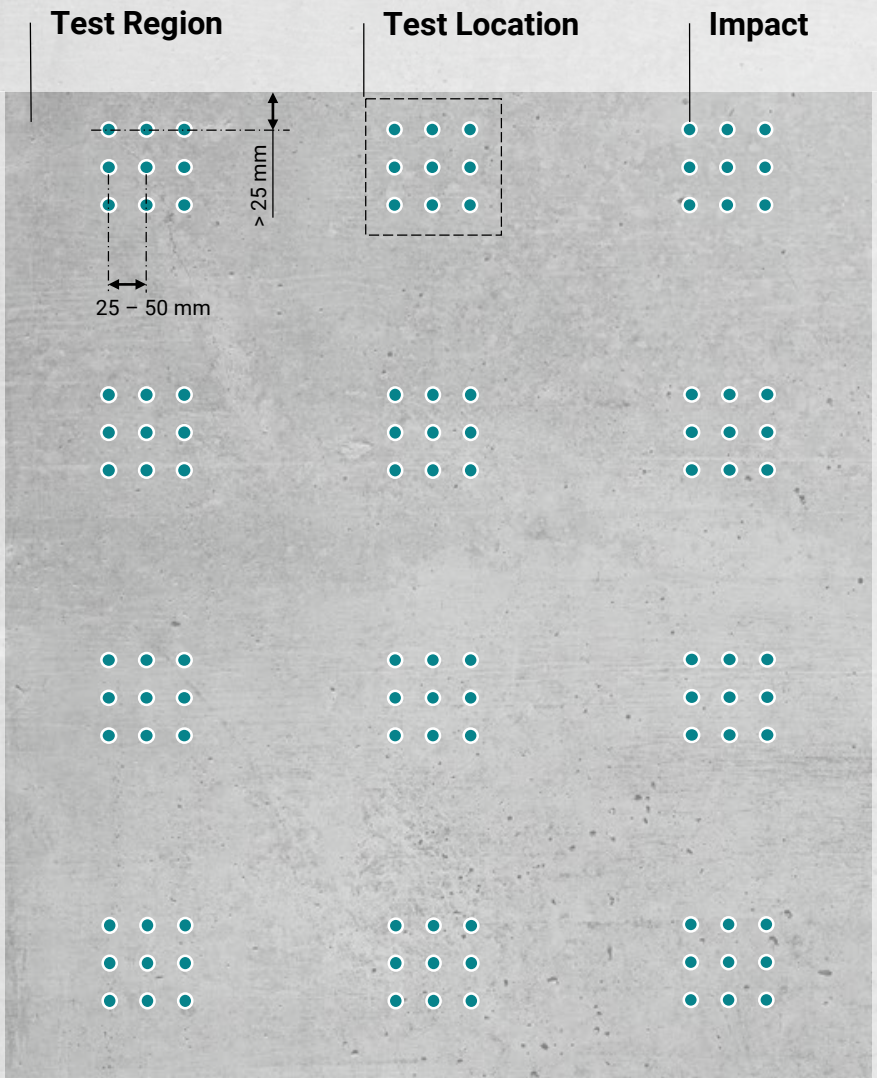
Vital Signs of Concrete

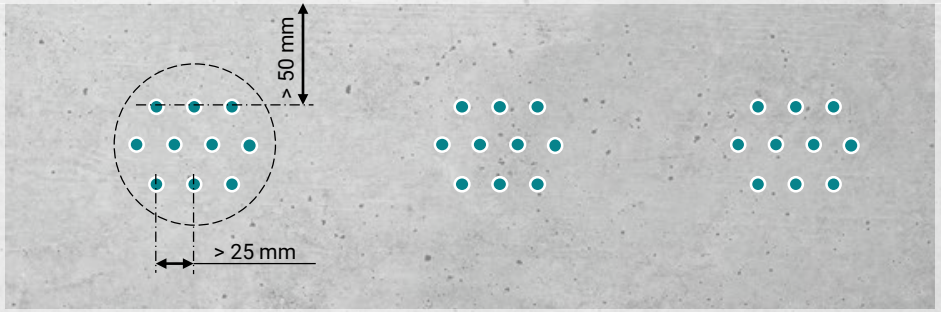
Strength & Uniformity ► Rebound (Schmidt)

	Measure	Convert to Strength	Result
			MPa
Original Schmidt	mechanical	**R** historic reference	10 – 70
Silver Schmidt	optical	**Q** higher accuarcy	5* 10 – 100

* with Mushroom Head

Strength & Uniformity ► Rebound (Schmidt)





ASTM C805 “Standard Test Method for Rebound Number of Hardened Concrete”

Example with 12 Test Locations

EN 12504-2 “Testing concrete in structures. Non-destructive testing. Determination of rebound number”
EN 13791 “Assessment of in-situ compressive strength in structures and precast concrete components”

Strength & Uniformity ► Rebound (Schmidt)

Inspection Procedure - Original Schmidt OS8000 & Silver Schmidt OS8200

- EN 12504-2 “Testing concrete in structures. Non-destructive testing. Determination of rebound number”
- EN 13791 “Assessment of in-situ compressive strength in structures and precast concrete components”

1. Smoothen the concrete surface in the Test Location with a grinding stone
2. Perform a minimum 9 Impacts in a Test Location
3. Determine mean Q or R value (if > 20% of Impact values differ from median > 30%, discard test series)
4. Perform steps 1 to 3 for multiple (minimum 9) Test Locations within a Test Region
5. Review **Uniformity** of the Mean Values of the Test Location across the Test Region ► **Weak Spots in the Test Region?**
6. Determine **Concrete Strength Class** (EN13791) ► **Characteristic Compressive Strength f_{ck}**

7. If the value determined by the rebound test alone is deemed insufficient, then a combination with core data can be used for verification
8. Use the data collected from the rebound testing to determine the ideal location for cores
9. Create custom curve correlating rebound and data from coring to determine the compressive strength at any location in the test region

Steps 3 to 6 and 9 are fully automated with the Original Schmidt App

Strength & Uniformity ► Rebound (Schmidt)

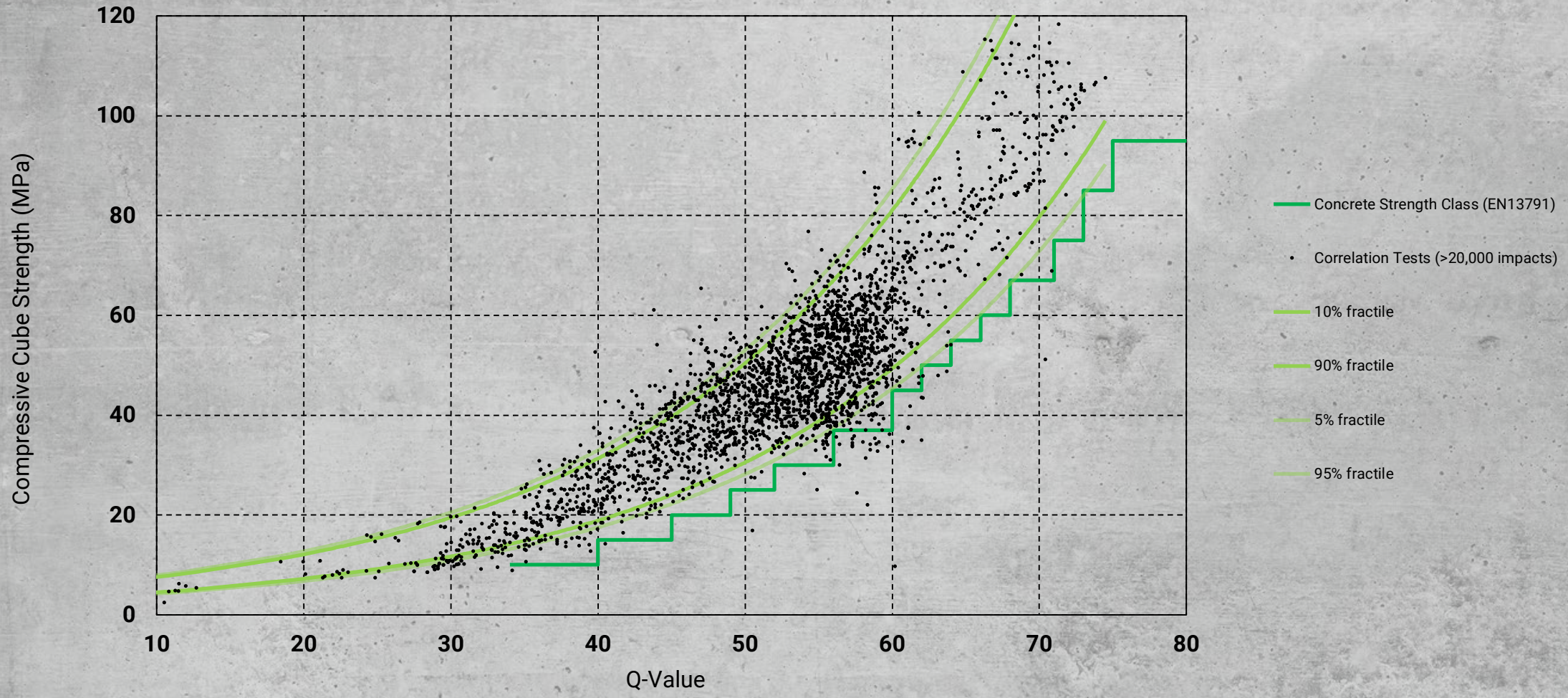
Determine Concrete Strength Class according EN13791

Q		$f_{ck,cylinder}$ / $f_{ck,cube}$	R	
min. Median for Test Location	min. Median for each Test Region	**Compressive Strength Class EN206**	min. Median for Test Location	min. Median for each Test Region
25	34	**C8/10**	26	30
29	40	**C12/15**	30	33
36	45	**C16/20**	32	35
42	49	**C20/25**	35	38
46	52	**C25/30**	37	40
51	56	**C30/37**	40	43
56	60	**C35/45**	44	47
59	62	**C40/50**	46	49
60	64	**C45/55**	48	51
62	66	**C50/60**	50	53
64	68	**C55/67**		
66	71	**C60/75**		
69	73	**C70/85**		
71	75	**C80/95**		

EN 13791 “Assessment of in-situ compressive strength in structures and precast concrete components”

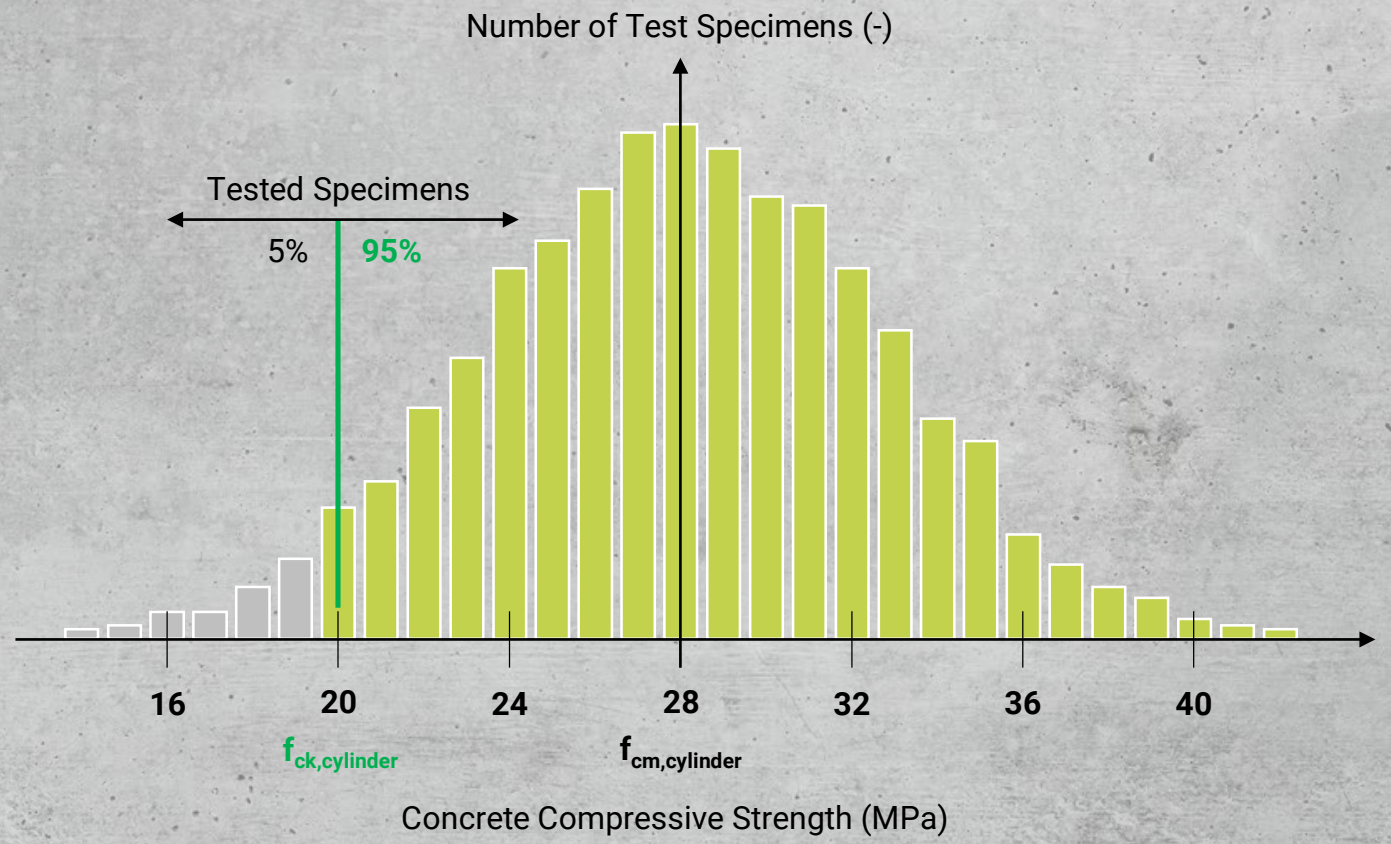
Vital Signs of Concrete

Strength & Uniformity ► Rebound (Schmidt)



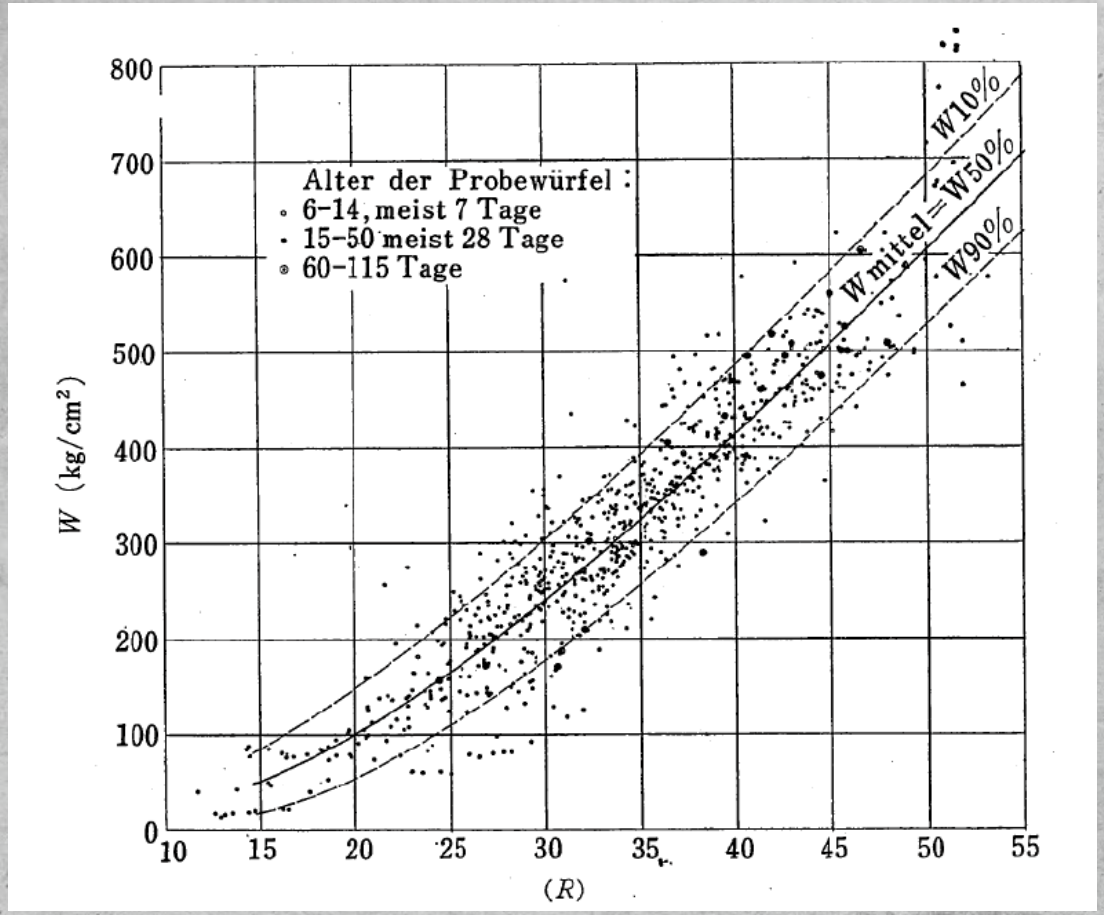
Silver Schmidt Data correlating Q and Compressive Strength

Strength & Uniformity ► Rebound (Schmidt)



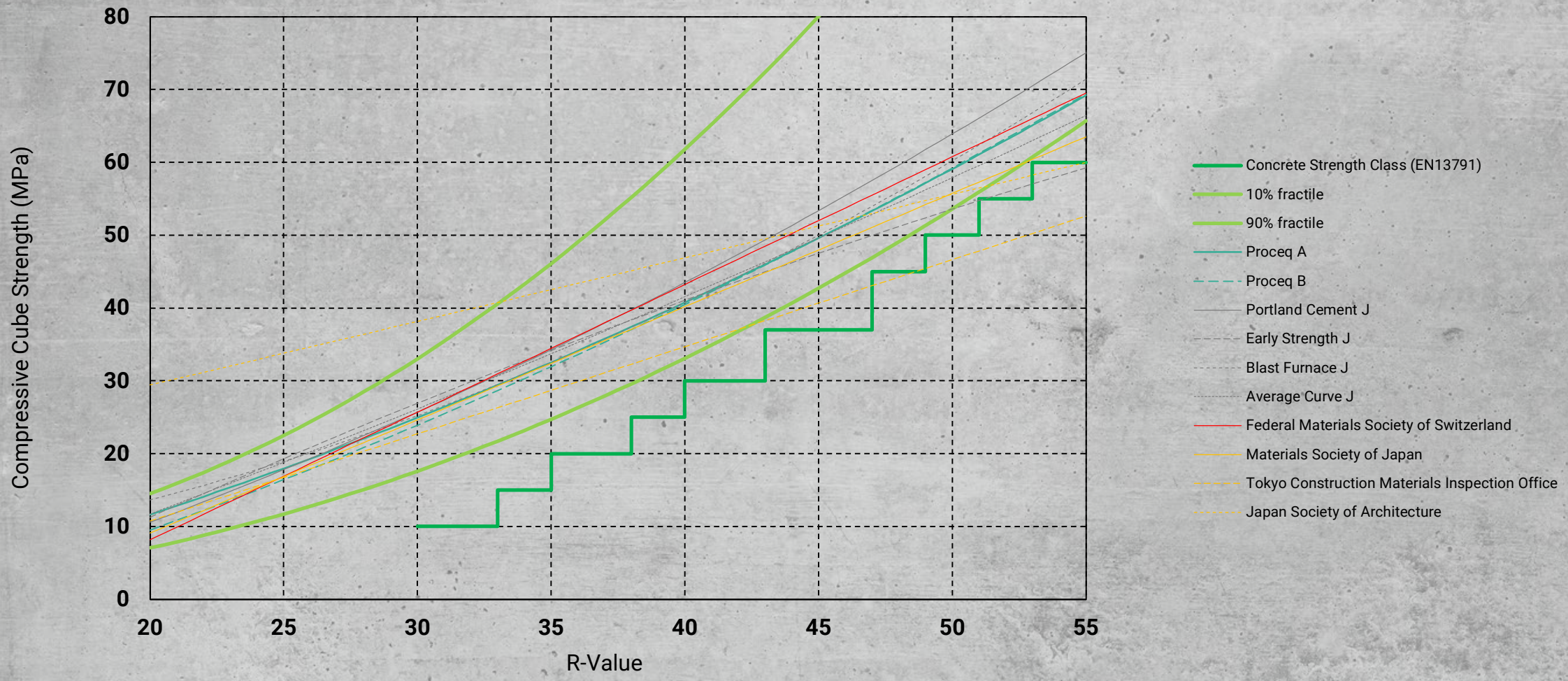
Compressive strength of concrete in accordance with EN 206 “Concrete. Specification, performance, production and conformity”

Strength & Uniformity ► Rebound (Schmidt)



Original Schmidt N data collected in 1960 by Dr. A. Gaede
(German Committee for Reinforced Concrete)

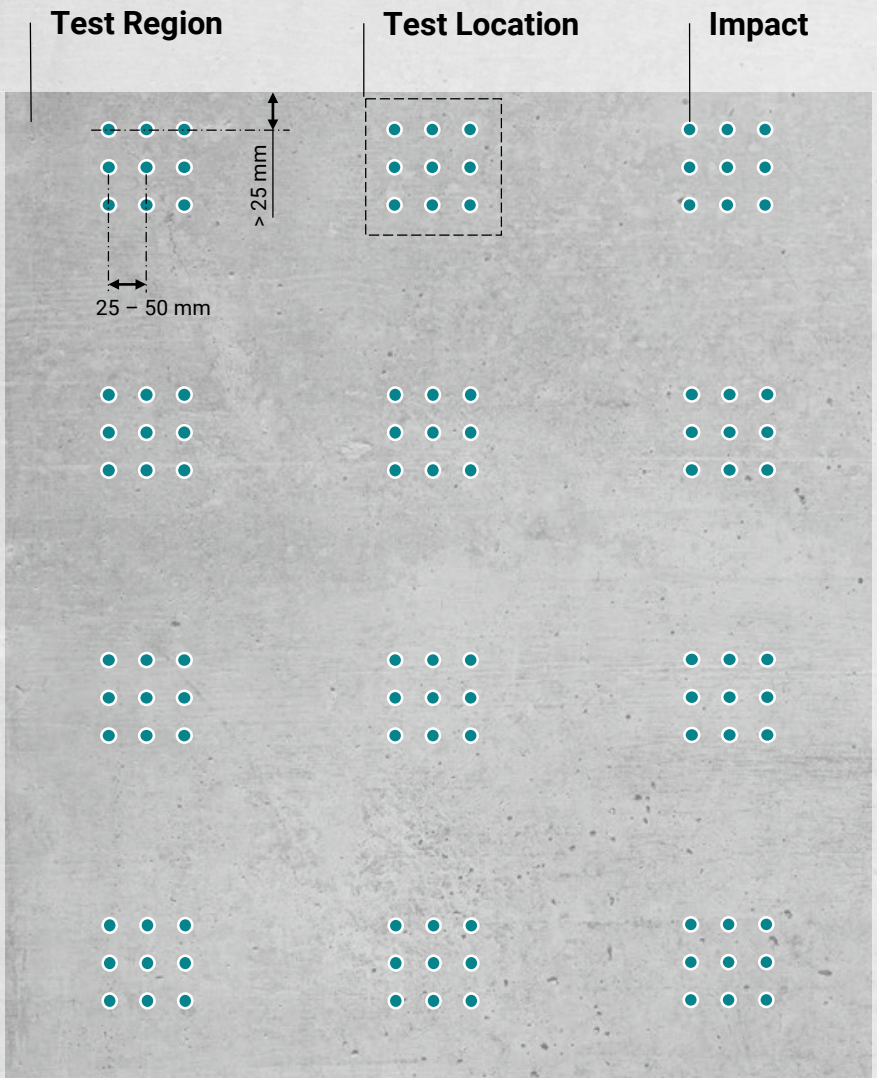
Strength & Uniformity ► Rebound (Schmidt)



Original Schmidt Curves correlating R and Compressive Strength

Vital Signs of Concrete

Strength & Uniformity ► Rebound (Schmidt)



Test Region with 12 Test Locations

Prepare ► Measure ► Characteristic Compressive Strength ► Report

Silver Schmidt (Digital) ► 6 minutes

Productivity 15x

Original Schmidt (Analogue) ► 90 minutes

Strength & Uniformity ► Rebound (Schmidt)

Cores for structural assessment according to EN13791 with and without Schmidt testing

Purpose	Test region	Minimum Number of	
		Test Locations with Schmidt	Cores
Conforming compressive strength class		**9**	**0**
Doubtful compressive strength class	30 m^3	**9**	**2** at locations with lowest NDT result
	60 – 120 m^3	**12**	**3** 1 at lowest NDT test location 2 at median NDT test location
	150 – 180 m^3	**20**	
Compressive strength with Cores only		not required but recommended	**10**

EN 13791 “Assessment of in-situ compressive strength in structures and precast concrete components”

Strength & Uniformity ► Rebound (Schmidt)

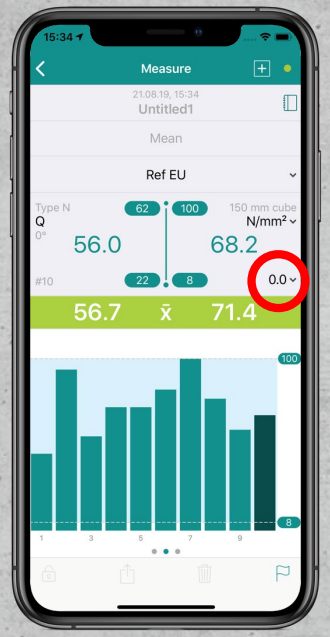
Important

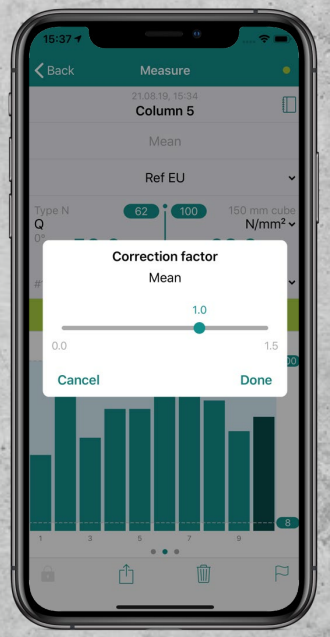
1. Silver Schmidt or Original Schmidt Hammer	► **Silver Schmidt**, for higher accuracy, Concrete Strength 5 - 100 MPa ► **Original Schmidt**, if compared to historic R value records, Concrete Strength 10 - 70 MPa
2. Type N or Type L	► **Type N** for Concrete Thickness > 10cm ► **Type L** for Concrete Thickness < 10cm
3. Measure over Rebar with low cover	► as for cores, rebars in the test region can influence the strength measurement ► use **Profometer** to secure that impacts are not performed over rebar
4. Carbonated Concrete	► increases the hardness of the concrete surface to give higher Q and R values ► EN13791 recommends a correction for carbonation > 5mm ► carbonation values can be corrected directly in the Schmidt app for the Q (Silver Schmidt)
5. Regional Concrete Mix or Local Conditions	► **custom correlation curve** between destructive cylinder or cube test vs. Q or R values

Strength & Uniformity ► Rebound (Schmidt)

Carbonation Correction

1. Measure on the carbonated concrete
2. Remove the carbonated layer and measure directly on the non-carbonated concrete
3. Calculate the correction factor = measurement on non-carbonated concrete surface / measurement on carbonated surface
4. Enter correction factor directly in the Schmidt app (Q value and **Silver Schmidt** only)





Vital Signs of Concrete

Strength & Uniformity ► Rebound (Schmidt)

EN 12504-2 “Testing concrete in structures. Non-destructive testing. Determination of rebound number”
EN 13791 “Assessment of in-situ compressive strength in structures and precast concrete components”
(Europe)

ASTM C805 “Standard Test Method for Rebound Number of Hardened Concrete”
(USA)

ACI 228.1R “In-Place Methods to Estimate Concrete Strength”
(USA)

ISO 1920-7 “Testing of concrete — Part 7: Non-destructive tests on hardened concrete”
(International)

JGJ/T 23 “Technical specification for inspecting of concrete compressive strength by rebound method”
(China)

JSCE-G504 “Hardened concrete test hammer strength test method”
(Japan)

JIS A1155 “Method of measurement for rebound number on surface of concrete”
(Japan)

ГОСТ 22690 “Determination of strength by mechanical methods of nondestructive testing”
(Russia)

Vital Signs of Concrete

Ultrasound Pulse Velocity (Pundit)

Vital Signs of Concrete

Ultrasound Pulse Velocity (Pundit)

Pundit 200

Ultrasound Probes

pundit

Ultrasound Pulse Velocity (Pundit)

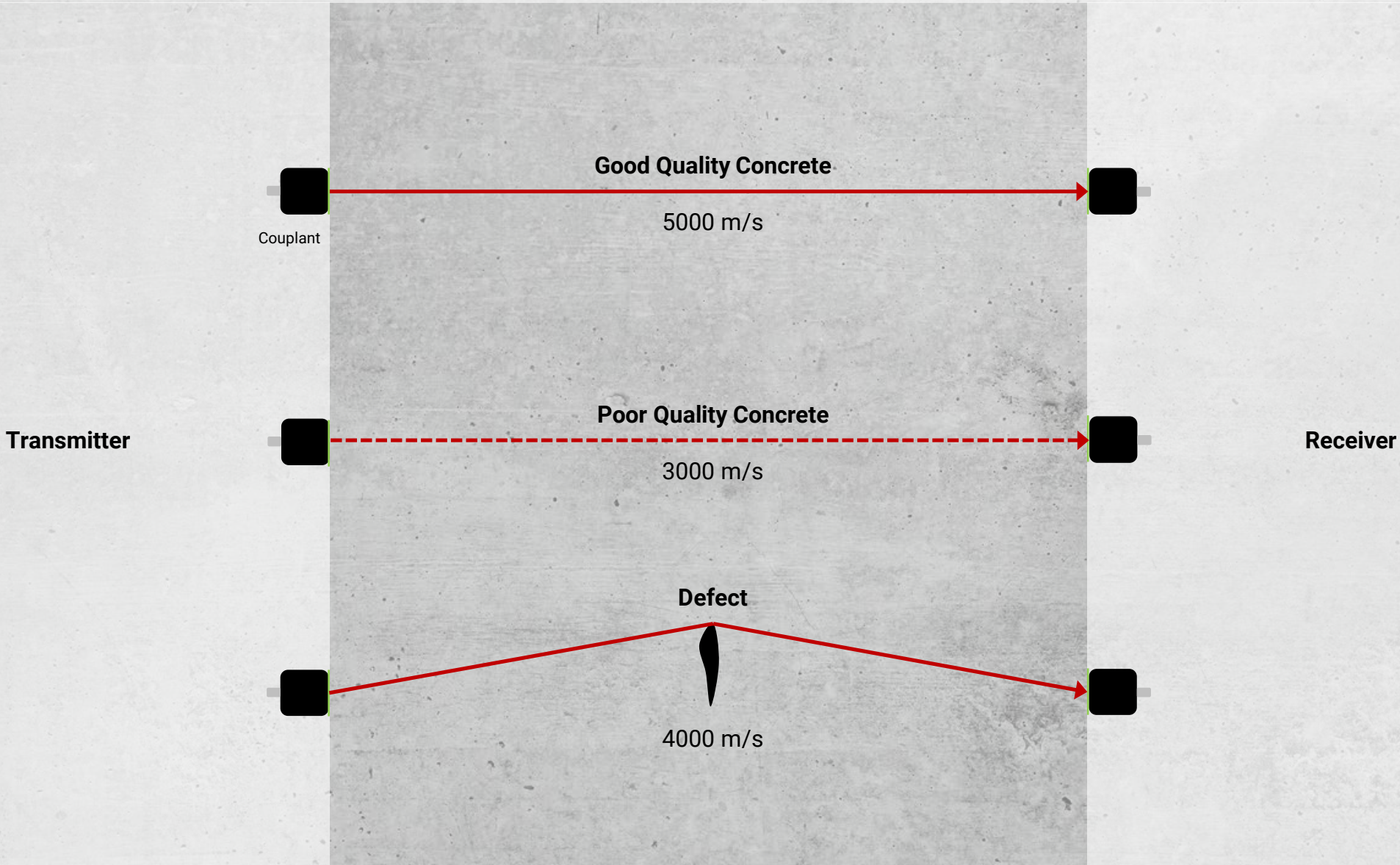
Primary Objectives

- Evaluate the Homogeneity and quality of the Concrete
- Detect internal defects (flaws, cracks, honeycombing, poor patches)

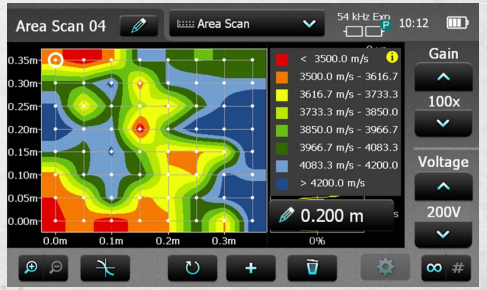
Secondary Objectives

- Predict the Strength of the Concrete
- Estimate the Depth of Cracks in Concrete
- Estimate Dynamic Modulus of Elasticity of the Concrete

Homogeneity ▶ Ultrasound Pulse Velocity (Pundit)



Homogeneity ▶ Ultrasound Pulse Velocity (Pundit)



Couplant

Good Quality Concrete

5000 m/s

Transmitter

Poor Quality Concrete

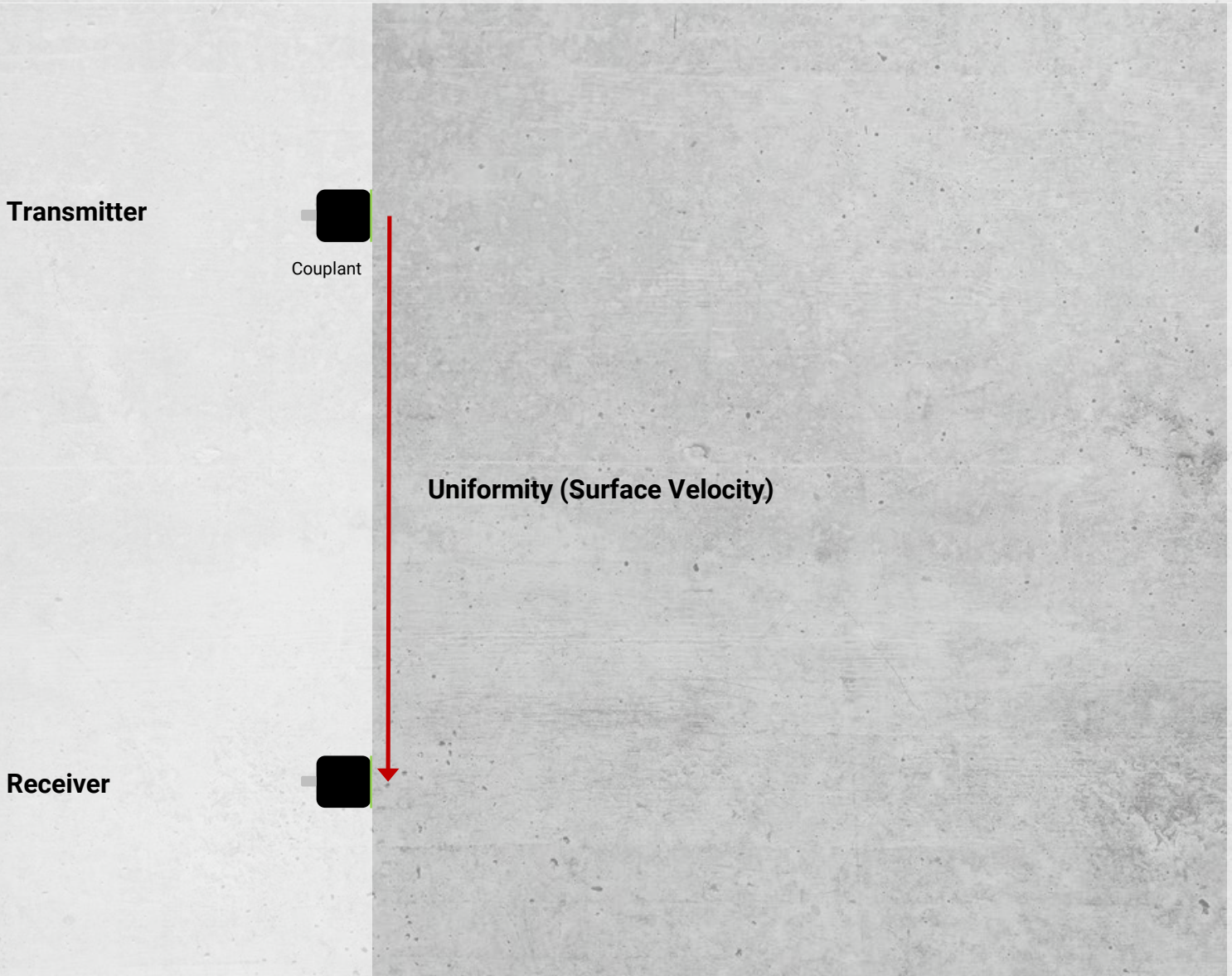
3000 m/s

Receiver

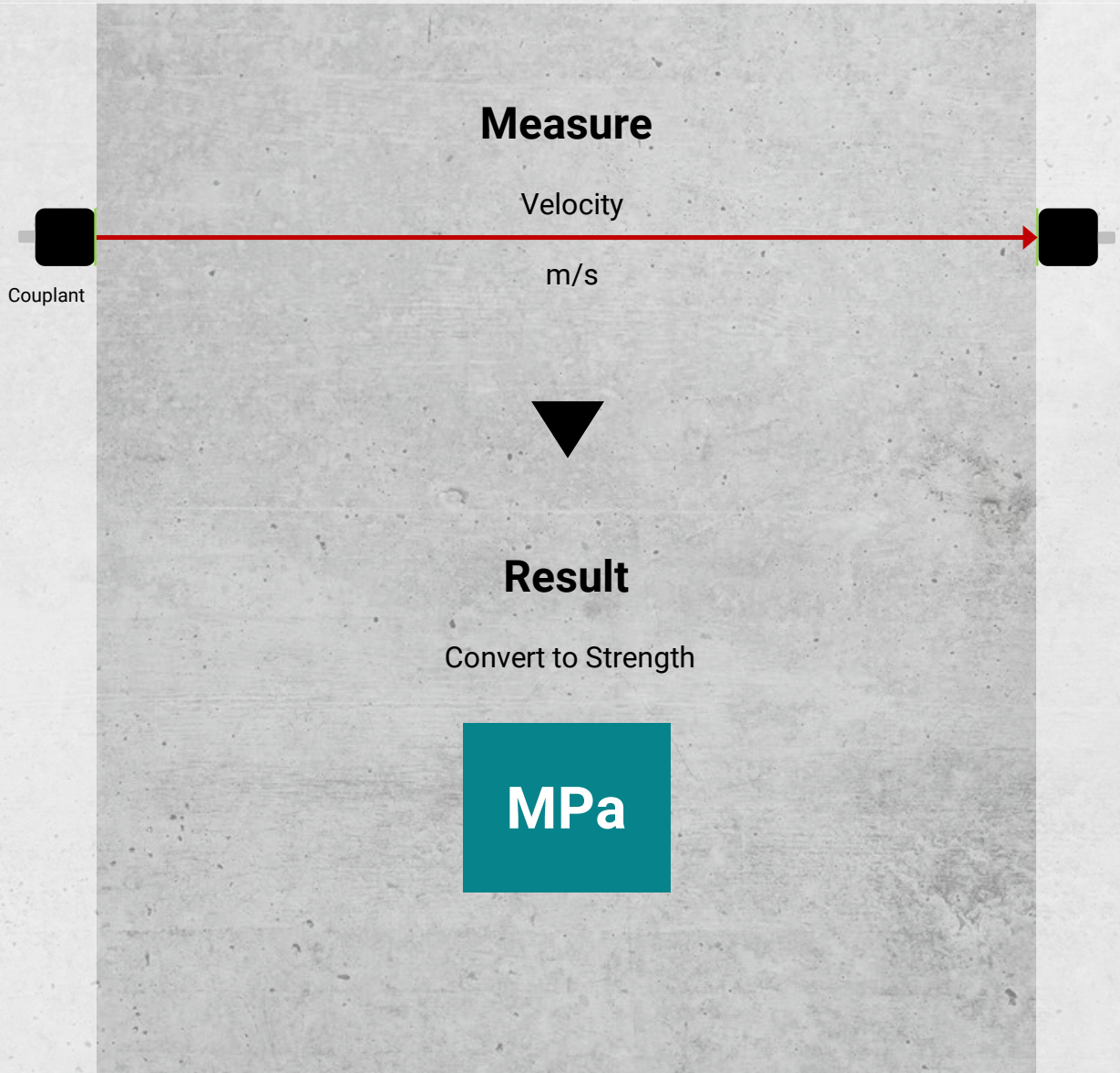
Good Quality Concrete

5000 m/s

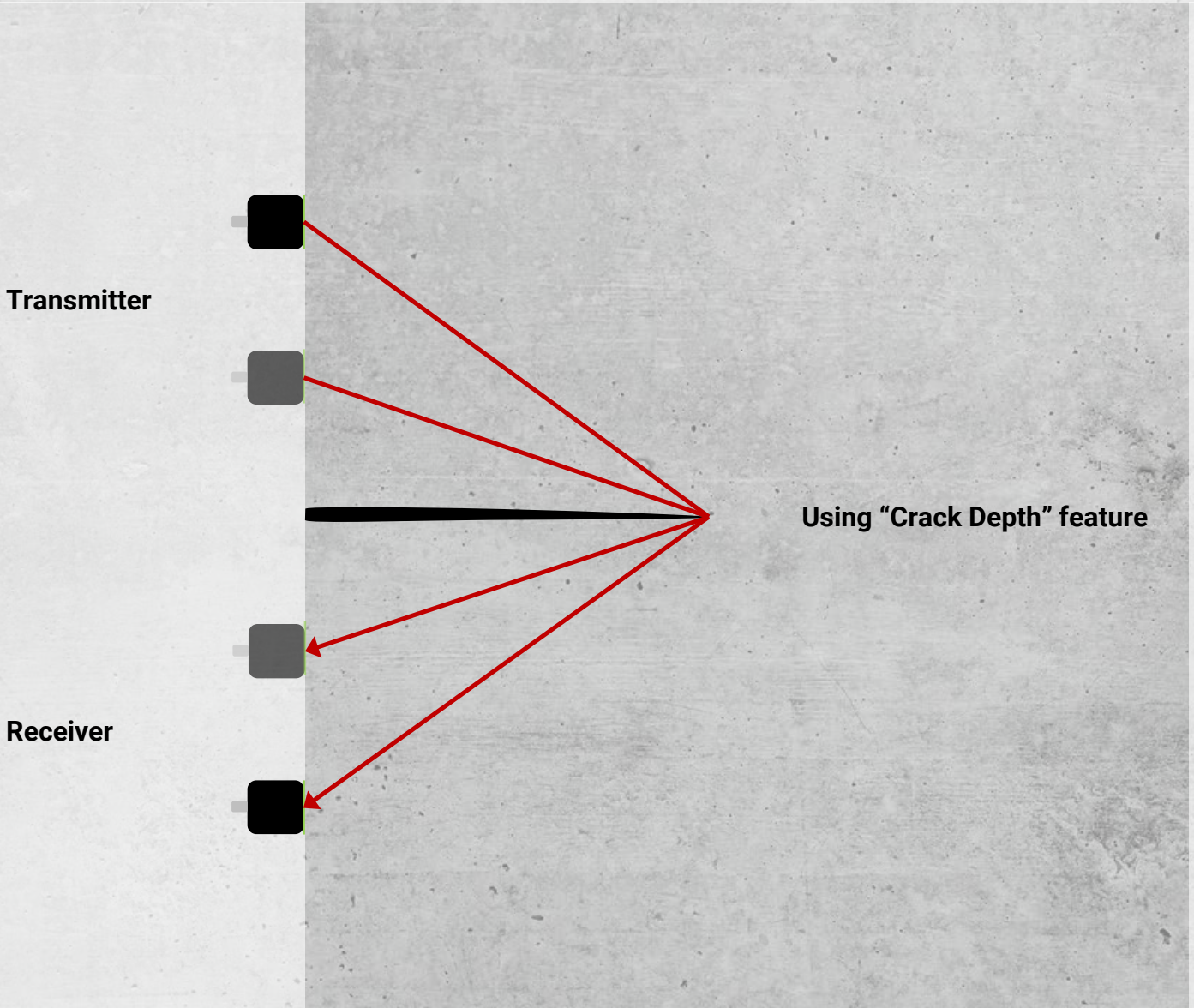
Uniformity ▶ Ultrasound Pulse Velocity (Pundit)



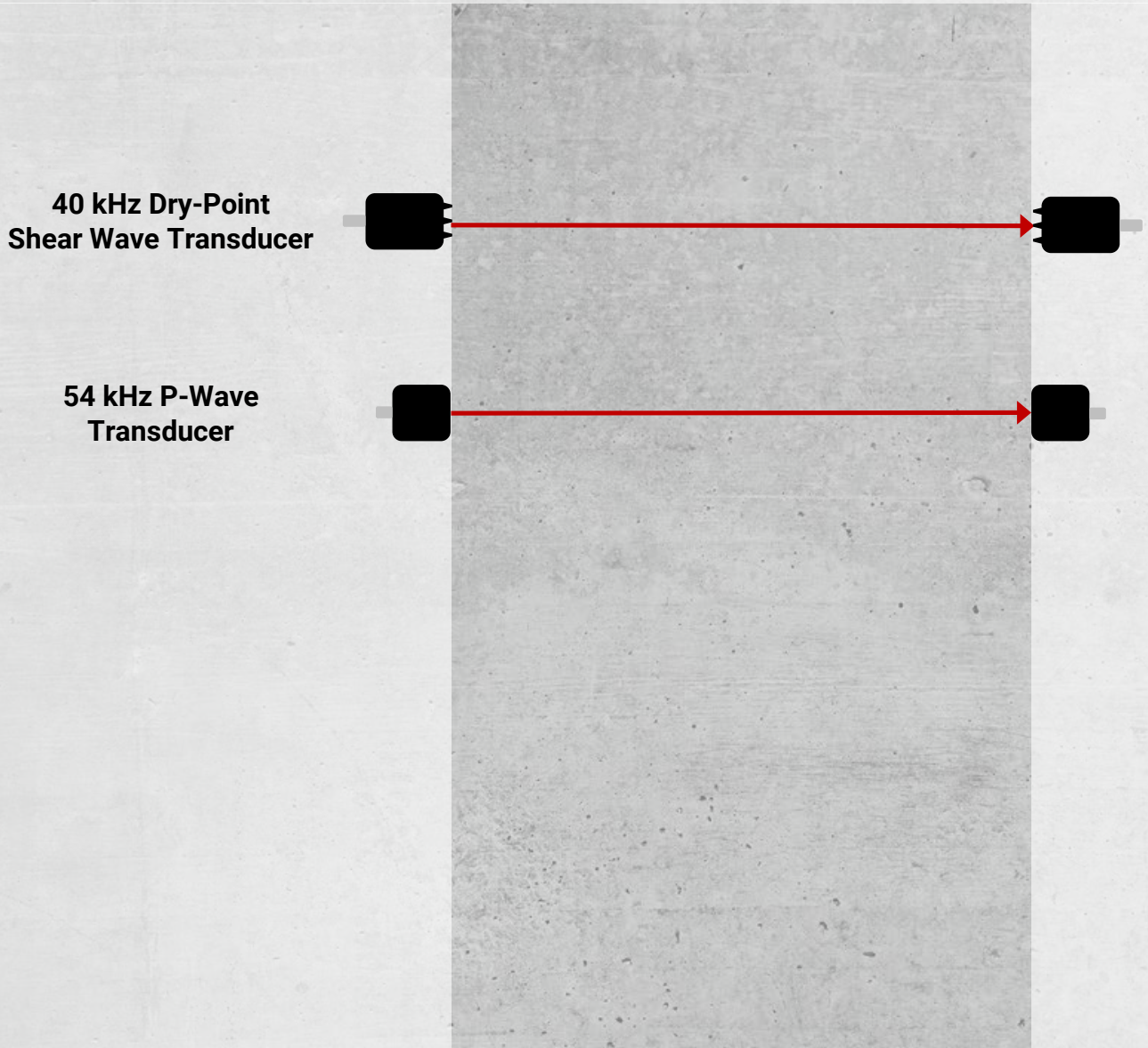
Concrete Strength ▶ Ultrasound Pulse Velocity (Pundit)



Crack Depth ► Ultrasound Pulse Velocity (Pundit)



Dynamic Modulus of Elasticity ► Ultrasound Pulse Velocity (Pundit)



1. Measure shear wave velocity
2. Measure P-wave velocity
3. Input density
4. Calculate dynamic modulus of elasticity
5. Convert to static modulus of elasticity

Empirical relationship between static and dynamic modulus of elasticity and the pulse velocity

Pulse velocity km/s	Modulus of Elasticity MN/m²	
	Dynamic	Static
3.6	24‘000	13’000
3.8	26‘000	15‘000
4.0	29‘000	18‘000
4.2	32‘000	22‘000
4.4	36‘000	27‘000
4.6	42‘000	34‘000
4.8	49‘000	43‘000
5.0	58‘000	52‘000

Ultrasound Pulse Velocity (Pundit)

Important

1. Transducer selection
   - ► **54 kHz** for Concrete Thickness 0.5 – 7 m
   - ► **24 kHz** for mass concrete < 15m
   - ► **40 kHz DPC** combine with P-wave measurements for elastic modulus
   - ► **54 kHz Exponential** for rough or curved surfaces (possible use without couplant)
1. Measure over Rebar
   - ► use **Profometer** to avoid measuring over rebars
2. Direct / Indirect measurement
   - ► best results obtained with direct measurements
   - ► indirect measurements provide no information about the interior of the concrete
3. Compressive strength testing
   - ► **custom correlation curve** between destructive cylinder/cube test vs. pulse velocity
   - ► SONREB combine with **Schmdit** measurements to improve strength estimations

Vital Signs of Concrete

Homogeneity ► Ultrasound Pulse Velocity (Pundit)

EN 12504-4 “Testing concrete. Determination of ultrasonic pulse velocity.”
EN 13791 “Assessment of in-situ compressive strength in structures and precast concrete components”
(Europe)

ASTM C597 “Standard Test Method For Pulse Velocity Through Concrete”
(USA)

ACI 228.1R “In-Place Methods to Estimate Concrete Strength”
(USA)

ISO 1920-7 “Testing of concrete — Part 7: Non-destructive tests on hardened concrete”
(International)

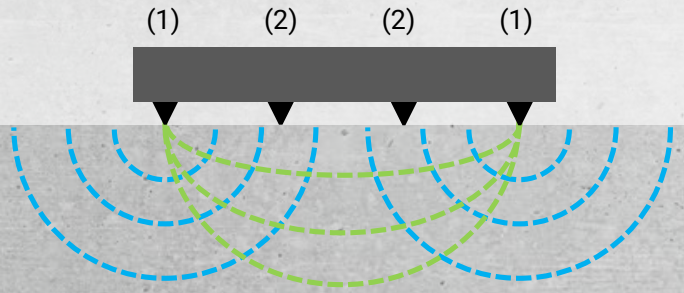
CECS 21 “Technical Specification for Inspection of Concrete Defects by Ultrasonic Method”
(China)

ГОСТ 17624 “Concrete. Ultrasonic Method of Strength Determination”
(Russia)

Vital Signs of Concrete

Resistivity (Resipod)

Permeability ► Resistivity (Resipod)



(1) current applied

(2) potential measures

Resipod

A current is applied to the two outer probes and the potential difference is measured between the two inner probes. The current is carried by ions in the pore liquid. The calculated resistivity depends on the spacing of the probes.

Resistivity $\rho = 2\pi aV/I$ [kΩcm]

Resistivity is directly linked to both the **likelihood of corrosion** due to **chloride diffusion** and to the **corrosion rate** once depassivation of the steel has taken place. A low **electrical resistivity** of the concrete means that the **likelihood of corrosion is high**, while a high resistivity equates to a low **corrosion risk.**

Permeability ► Resistivity (Resipod)

Important

1. Resipod 50 mm or Resipod 38 mm

► **Resipod 50 mm** industry standard. Probe spacing greater than typical maximum aggregate size

► **Resipod 38 mm** if 1.5” probe spacing as specified by AASHTO TP95 “Standard Method of Test for Surface Resistivity Indication of Concrete’s Ability to Resist Chloride Ion Penetration”

2. Measure over Rebar

► use **Profometer** to avoid measuring over rebar.

3. Moisture content

If the concrete composition is homogeneous, mapping resistivity shows wet and dry areas.
If concrete is uniformly wet, variations in resistivity can indicate local variations in water-to-cement ratio.

4. Interpretation

ρ ≥ 100 kΩcm	corrosion is unlikey	► > 20 kΩcm Low corrosion rate
ρ = 50 to 100 kΩcm	risk of corrosion is low	► 10-20 kΩcm Low to moderate corrosion rate
ρ = 10 to 50 kΩcm	modest risk of corrosion	► 5-10 kΩcm High corrosion rate
ρ ≤ 10 kΩcm	risk of corrosion is high	► < 5 kΩcm Very high corrosion rate

Vital Signs of Concrete

Permeability ► Resisitivity (Resipod)

AASHTO TP 95-14
(USA)

"Standard Method of Test for Surface Resistivity Indication of concrete's Ability to Resist Chloride Ion Penetration Testing concrete in structures."

RILEM TC-154
(International)

"Test methods for on site measurement of resistivity of concrete"

HOW to Inspect Concrete Structures?

Vital Signs of Concrete

Strength & Uniformity
near surface property

Schmidt

Rebound

Homogeneity
through thickness property

Pundit UPV

Ultrasound Pulse Velocity

Permeability
near surface (rebar cover) property

Resipod

Resistivity

- Complimentary: **Profometer**
  avoid measuring over rebars

HOW to Inspect Concrete Structures?

Locating, Mapping & Imaging

HOW to Inspect Concrete Structures?

Locating, Mapping & Imaging

Avoid **birth-defects** on new structures & perform **health-checks** during the service life

Visual Inspection

- surface condition ▶ **Digital Inspection (Inspect)**

Vital Signs of Concrete

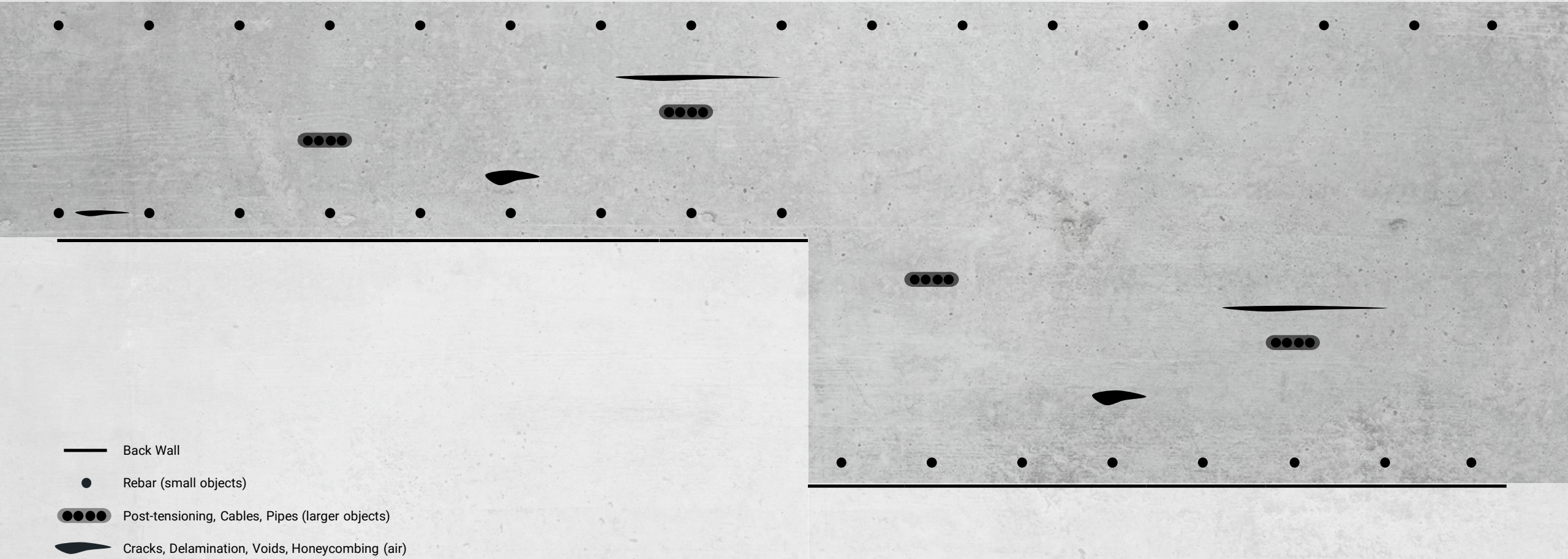
- strength & uniformity ▶ **Rebound (Schmidt) / UPV (Pundit)**
- homogeneity ▶ **Ultrasound Pulse Velocity (Pundit)**
- permeability ▶ **Resistivity (Resipod)**

Locating, Mapping & Imaging

- rebars, post-tensioning, cables, pipes (objects) ▶ **Ground Penetrating Radar (Proceq GPR)**
- delamination, voids, honeycombing (defects) ▶ **Ultrasound Pulse Echo (Pundit Array)**
- rebar cover & diameter ▶ **Eddy Current (Profometer)**
- corrosion potential ▶ **Half-cell Potential (Profometer)**

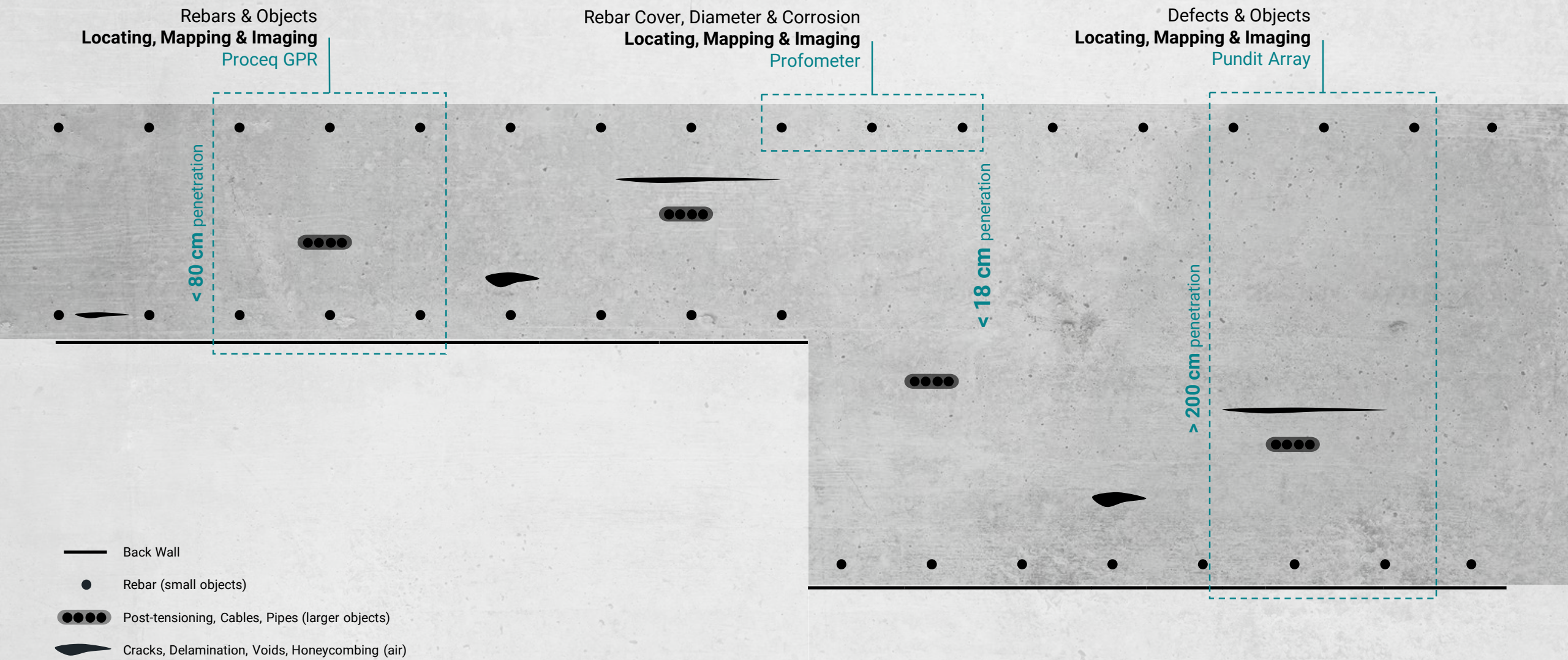
HOW to Inspect Concrete Structures?

Locating, Mapping & Imaging



HOW to Inspect Concrete Structures?

Locating, Mapping & Imaging

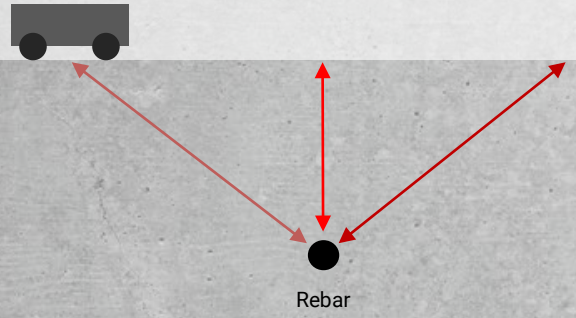


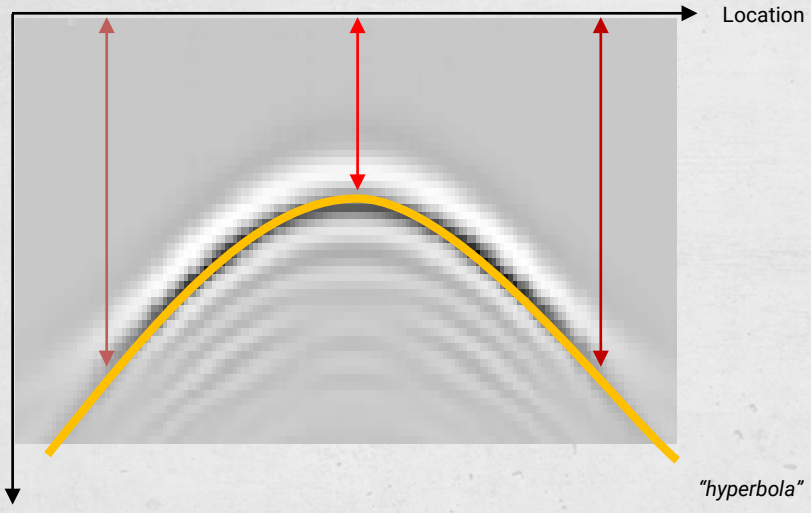
Locating, Mapping & Imaging

Ground Penetrating Radar (Proceq GPR)
Ultrasound Pulse Echo (Pundit Array)

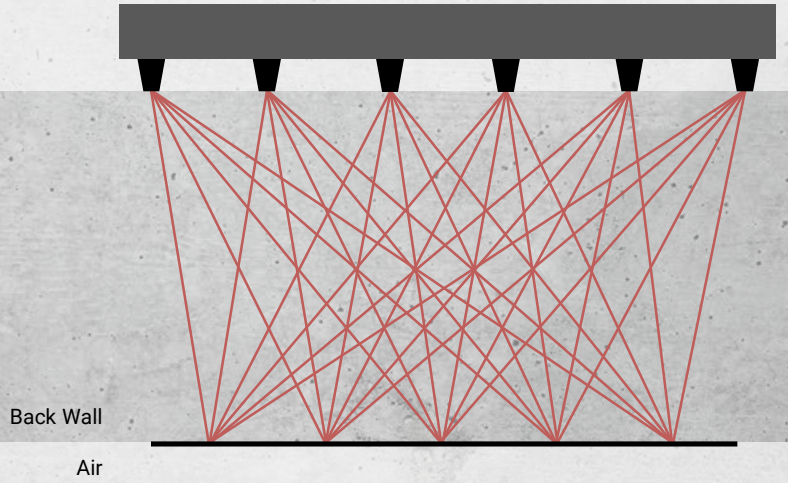
Ground Penetrating Radar & Ultrasound Pulse Echo

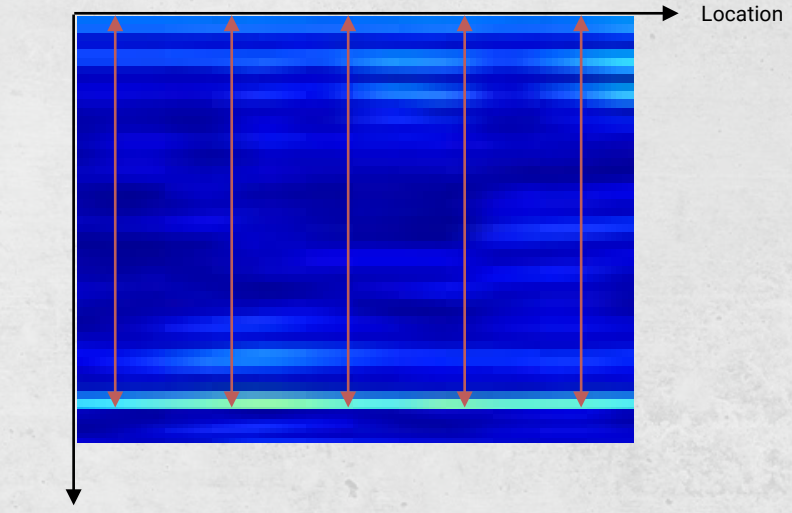
GPR (Radio Wave)





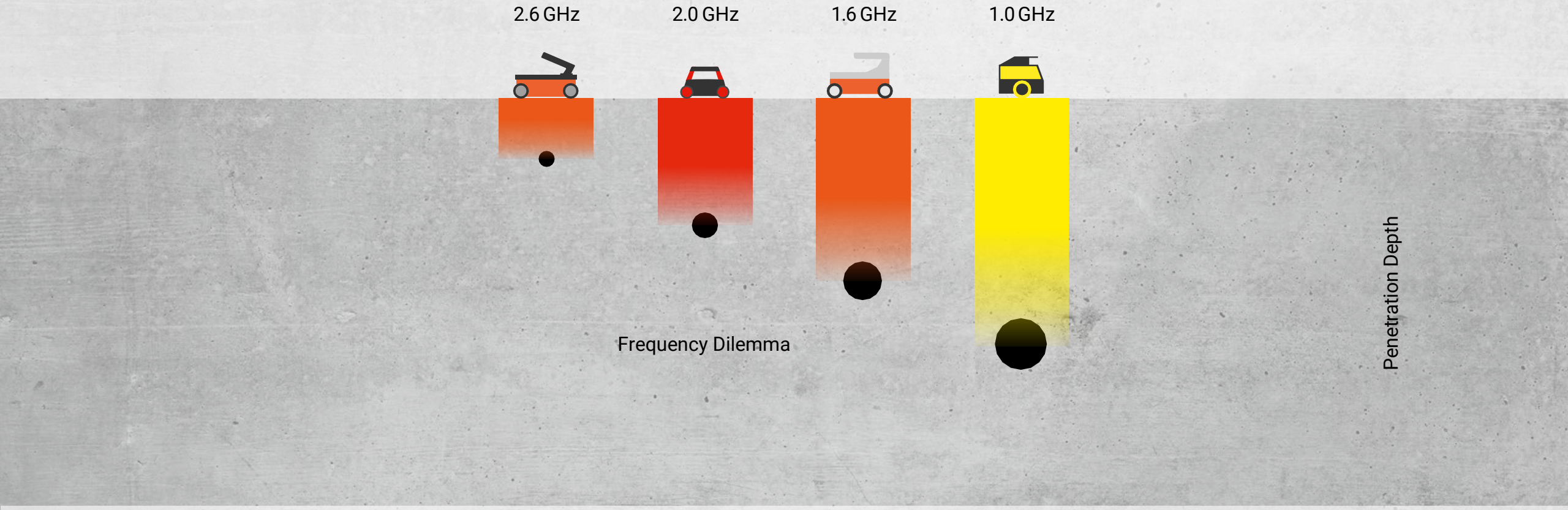
Ultrasound Pulse Echo





The Archaic Principle

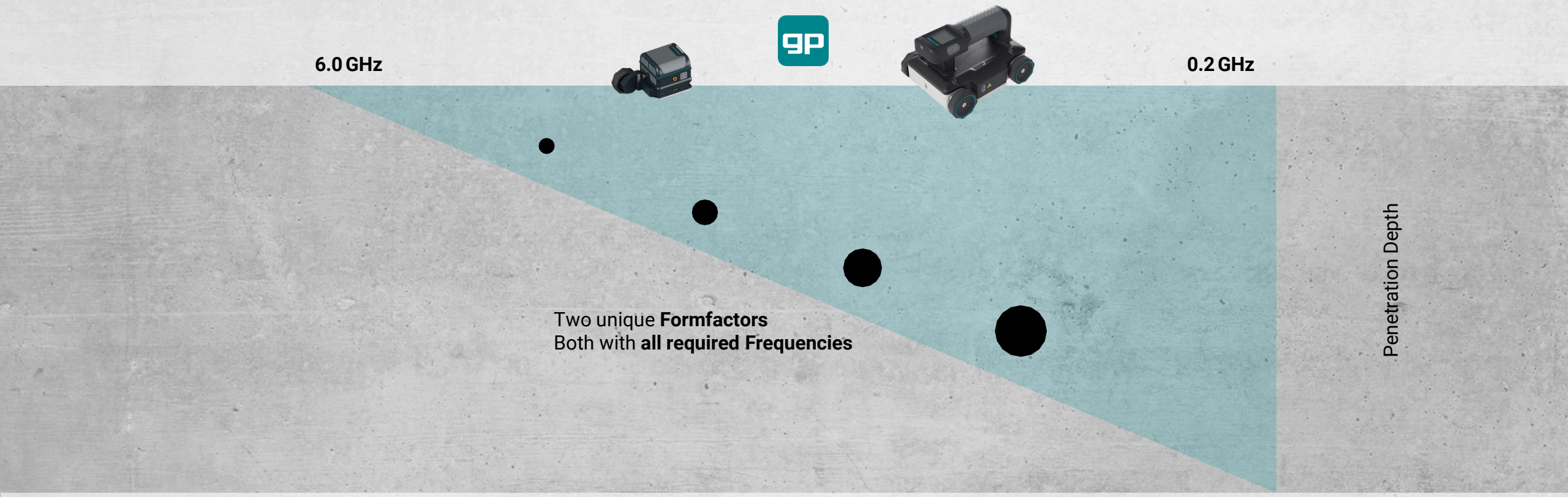
Pulsed GPR



small — Detectable Objects — large

The Technology Benchmark

Stepped Frequency Continuous Wave – SFCW (Proceq GPR)



small — Detectable Objects — large

Stepped Frequency Continuous Wave – SFCW (Proceq GPR)

Proceq GPR

GP8000 **GP8800**

Download on the App Store

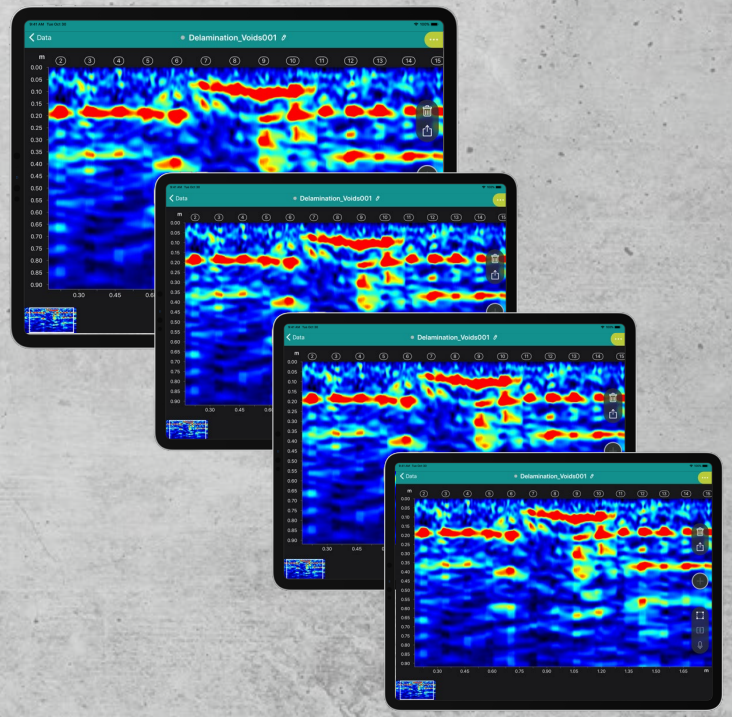
Stepped Frequency Continuous Wave (SFCW) GPR

Wireless wheel, instant cross-polarization

Proceq GPR: Technology...

Ultrasound Pulse Echo (Pundit Array)

Pundit Array **PD8000**



Download on the App Store

pundit

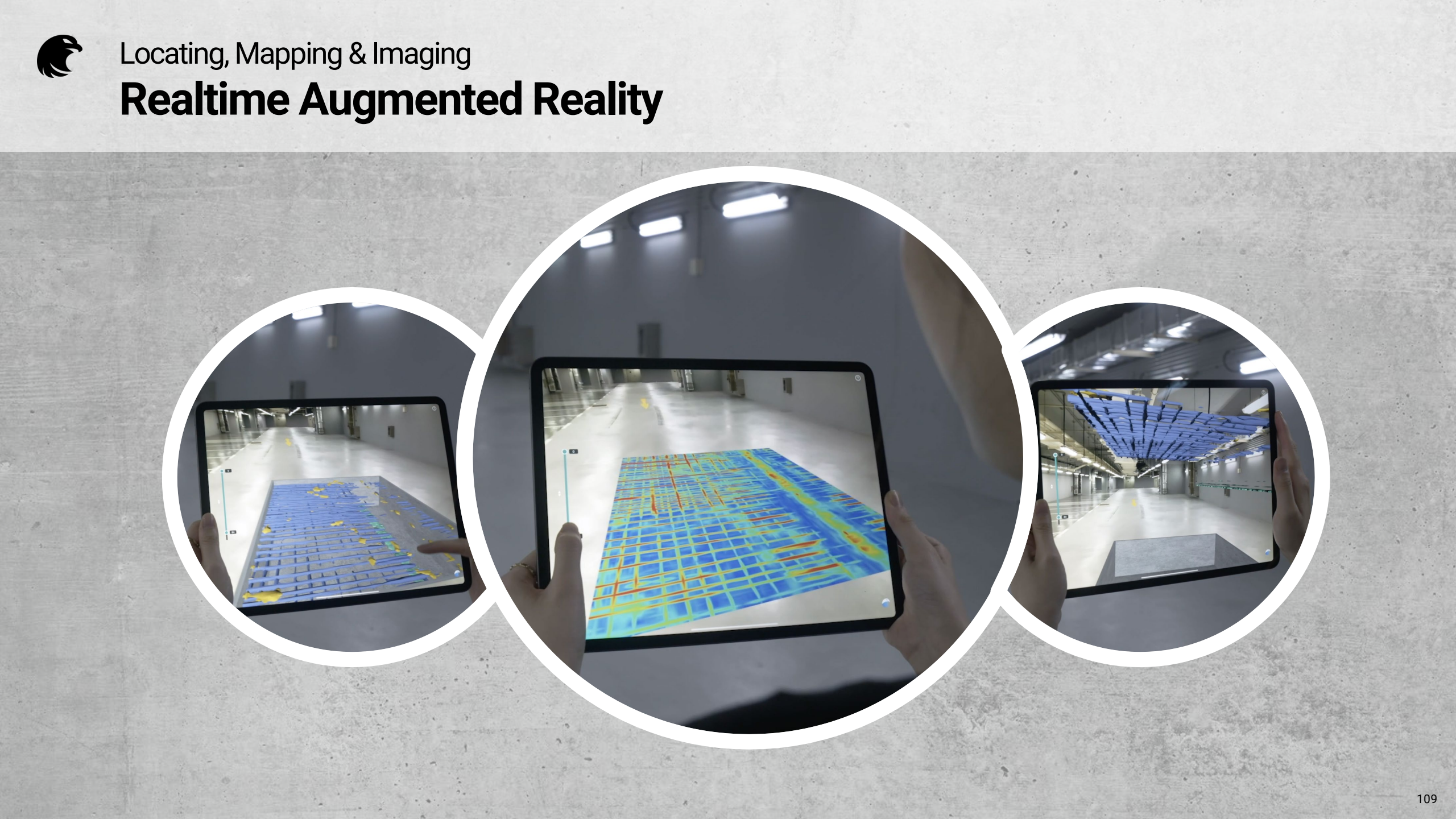
Ultrasound Pulse Echo (Pundit Array)

A.I. positing system

Modularity for 2x Productivity

Locating, Mapping & Imaging

Intuitive Software



Locating, Mapping & Imaging

Realtime Augmented Reality

Realtime Augmented Reality

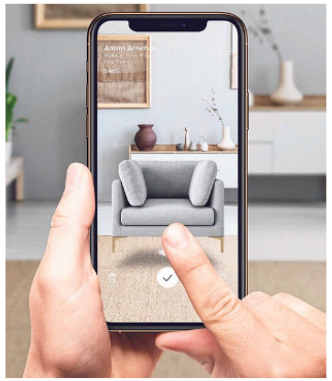
THE STRAITS TIMES

June 6, 2020

Furniture stores turn to AR to survive pandemic

Stores remain shut, but some retailers are leveraging augmented reality, which lets customers see how that couch looks in their homes before they buy it

Chantal Sajan
Senior Correspondent



Furniture retailer Castlery's augmented reality app (left) helps users to visualise furniture pieces in their homes before they buy.
PHOTO: CASTLERY SINGAPORE

At an augmented reality (AR) presentation in August last year, Mr Marcel Poser, chief executive officer of Singapore-based inspection technology firm Screening Eagle Dreamlab, recited the famous words of the late novelist William S. Burroughs: "When you stop growing, you start dying."

He was making the point that businesses need to be constantly on their toes and leverage cutting-edge technology to stay ahead of the game.

A few months later, the world was pummelled by Covid-19.

Today, Burroughs' words resonate with a newfound urgency, especially for businesses struggling with stagnation.

However, tech-savvy furniture retailers Ikea and Castlery were able to draw visitors to their online stores despite the havoc Covid-19 was wreaking.

Ikea's online presence enabled it to continue serving customers even as its physical stores were closed due to Covid-19. Meanwhile, Castlery moved quickly to create a digital replica of its collection just before the circuit breaker measures were put in place from April 7 to June 1.

Both companies leveraged AR, a technology they started exploring a few years ago.

Augmented reality differs from virtual reality (VR) in that it functions in real time. VR obscures one's vision and replaces it with an alternate reality and is usually enabled only with bulky headgear. AR, on the other hand, enables transparency of the immediate surroundings and adds to it. The mobile game Pokemon Go is one example.

Unlike VR, the technology fuelling AR can be easily downloaded on smartphones.

Currently, Apple has the world's largest platform of AR-enabled devices, as well as an exhaustive range of AR apps on its App Store, according to its website. Apple's hardware and software are also designed from the ground up for a more immersive AR experience.

The burgeoning popularity of AR is boosted by its affordability.

Swedish retailer Ikea – one of the first furniture brands to use AR – launched its Ikea Place AR app in 2017. Designed in Sweden using Apple's ARKit framework, it is constantly updated with Ikea's new product lines.

The app instantly scales products, based on the user's room dimensions, with 98 per cent accuracy and also simulates the texture of fabric used, as well as how light and shadows appear on Ikea's upholstery.

In the light of Covid-19, Castlery's new normal entails maintaining both a physical 11,000 sq ft showroom in Jit Poh Building in Keppel Road as well as its new AR-enabled online store.

Co-founder Declan Ee says that during the circuit breaker, Castlery launched a "Stay Home With Us" online campaign aimed at bringing the showroom to its customers. The campaign included a virtual tour, an AR-enabled styling of living spaces through its app and a 14-day home trial of the furniture pieces.

"The original timing for our AR app release was for the second half of 2020, but when the circuit breaker was announced, we accelerated development for a late-April launch," says Mr Ee.

"It took us almost 18 hours to capture our entire physical showroom digitally before the lockdown.

"Our tech team then had to spend the next two days mapping out the website and linking to the app while tagging every single item.

"The do-or-die mentality triggered by the circuit breaker definitely created an adrenaline rush for our team to power through."

During the first three weeks of the circuit breaker, the Castlery team finalised the AR development, fixed numerous glitches arising from 3D scaling and launched more than 250 products for AR styling in its app.

Mr Ee says that by late April, the app's AR function was ready.

The design of the app addressed a key issue that plagued online shopping – the lack of a tactile quality only possible in a physical store.

He says: "The design of our AR app not only helps our customers visualise how items will look, but is also embedded with the crucial 'touch and feel' element when shopping for furniture."

The app design replicates textures, hues and dimensions to take the guesswork out of an online purchase.

Castlery's team used Apple's ARKit 2 framework and the iPad Pro to develop the app quickly and affordably.

"Business has been significantly impacted by Covid-19 so we had to adapt and not simply sit back," says Mr Ee. "The AR launch is us fighting back and we are hopeful it will improve our retail business over the long term."

Regular Castlery customer Nelson Yap, 38, who is the founder of menswear label Benjamin Barker, likes the app. He says: "I appreciate the functionality and seamless experience of the AR tool, which is especially useful in visualising how different products look in specific spaces. This not only saves time, but also helps ensure we buy the right products for the look we want."

The next stage for Castlery, established in 2014, is when 5G networks are in place. "AR will get a big boost and, for Castlery, it will increase the digital experience for our customers exponentially."

ABILITY TO HAVE X-RAY VISION

For Singapore-based Dreamlab, AR has helped the inspection technology company develop "X-ray vision".

It sells this feature to governments, property owners and engineers to save millions of dollars in disruptions from decaying infrastructure such as concrete buildings and mass rapid transit systems.

Its range of new AR apps is the first to dispense with clunky inspection hardware and conventional engineering tools that move at a glacial pace to print reports of defects.

AR is combined with sensors equipped with artificial intelligence as well as radar- and ultrasonic-wave technology in its products, such as the Screening Eagle Inspect and Proceq GPR Live, to "see through" concrete and instantly create a 3D digital model of the defective site.

The Proceq GPR Live was used during a recent inspection of the Central Expressway road tunnels.

Says Mr Craig Rice, executive director of Dreamlab Singapore: "A very typical use for the AR app is during renovations of existing structures."

"Architects or engineers might want to cut a hole into an existing concrete wall or drill into the wall to attach a new building element," he says.

"In this case, they need to make sure they do not hit anything in the wall when they are cutting or drilling into the concrete. This is what we call the 'hitprevention' use case."

Mr Rice says that even with original detailed construction drawings, it is difficult to determine the exact location of steel reinforcing bars, water pipes or electrical cables which are concealed by concrete.

Before Dreamlab's AR-powered technology, the typical work flow was to use rudimentary scans, transfer these to a USB stick and then into a PC for processing.

"Today, what would take several days is now done in minutes, and at almost 50 per cent shaved off the total project cost," says Mr Rice.

chantal@sph.com.sg

MORE STORIES on C2

Singapore-based inspection technology firm Screening Eagle Dreamlab's apps combine augmented reality with radar- and ultrasonic-wave technology to "see through" concrete and create 3D digital models of the site (left).
PHOTO: SCREENING EAGLE DREAMLAB

*"At an augmented reality (AR) presentation in August last year, Mr Marcel Poser, chief executive officer of Singapore-based inspection technology firm Screening Eagle Dreamlab, recited the famous words of the late novelist William S. Burroughs: "**When you stop growing, you start dying**."*

*He was making the point that businesses need to be **constantly on their toes and leverage cutting-edge technology** to stay a head of the game. A few months later, the world was pummelled by Covid-19. Today, Burroughs' words resonate with a newfound urgency, especially for businesses struggling with stagnation…*

ABILITY TO HAVE X-RAY VISION

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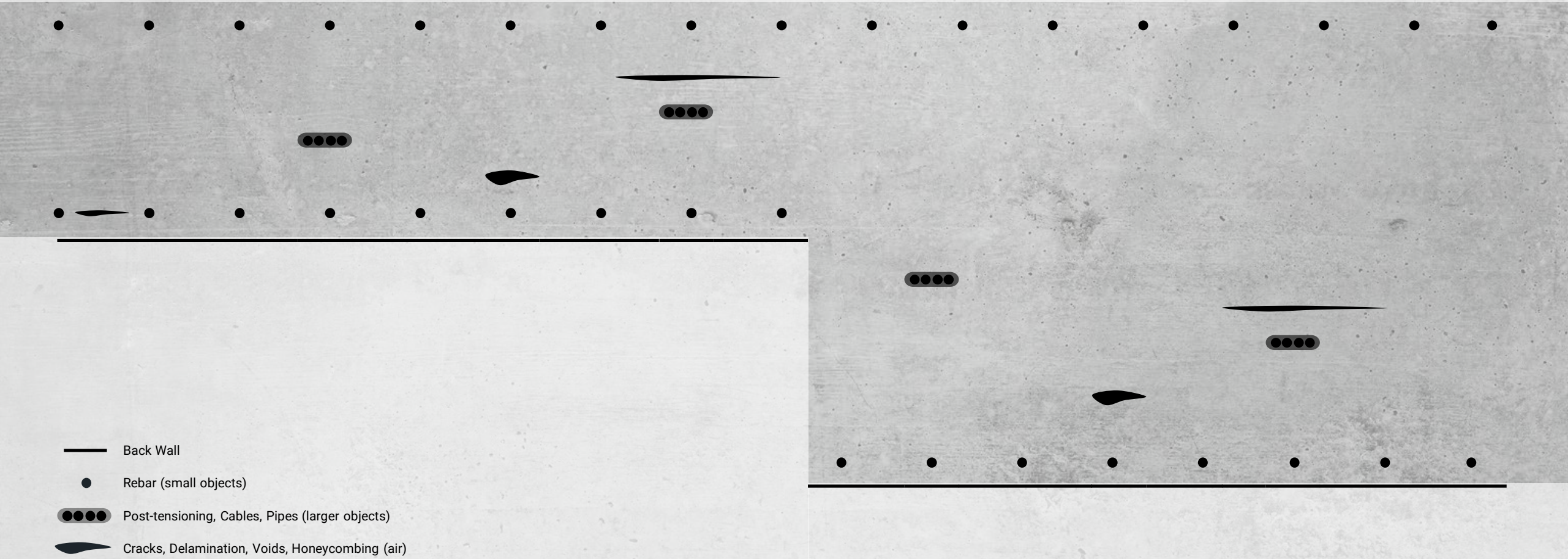
Locating, Mapping & Imaging

Rebars | Objects | Thickness | Defects

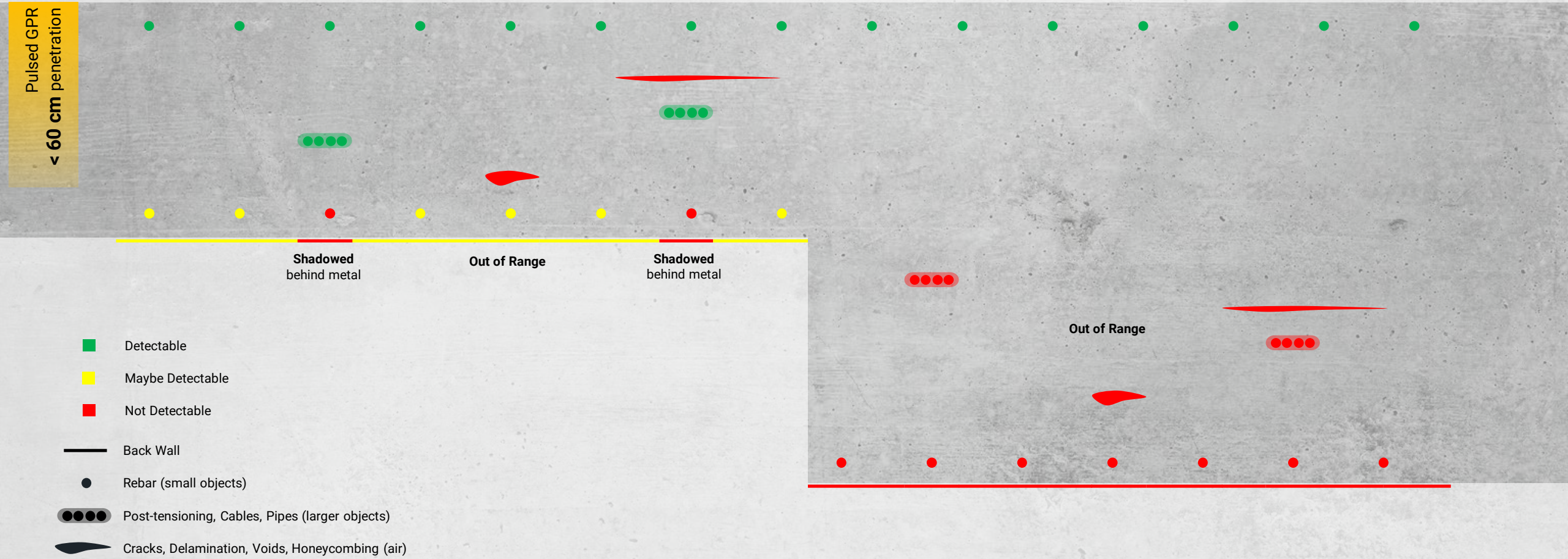
Benchmarking



Pulsed GPR

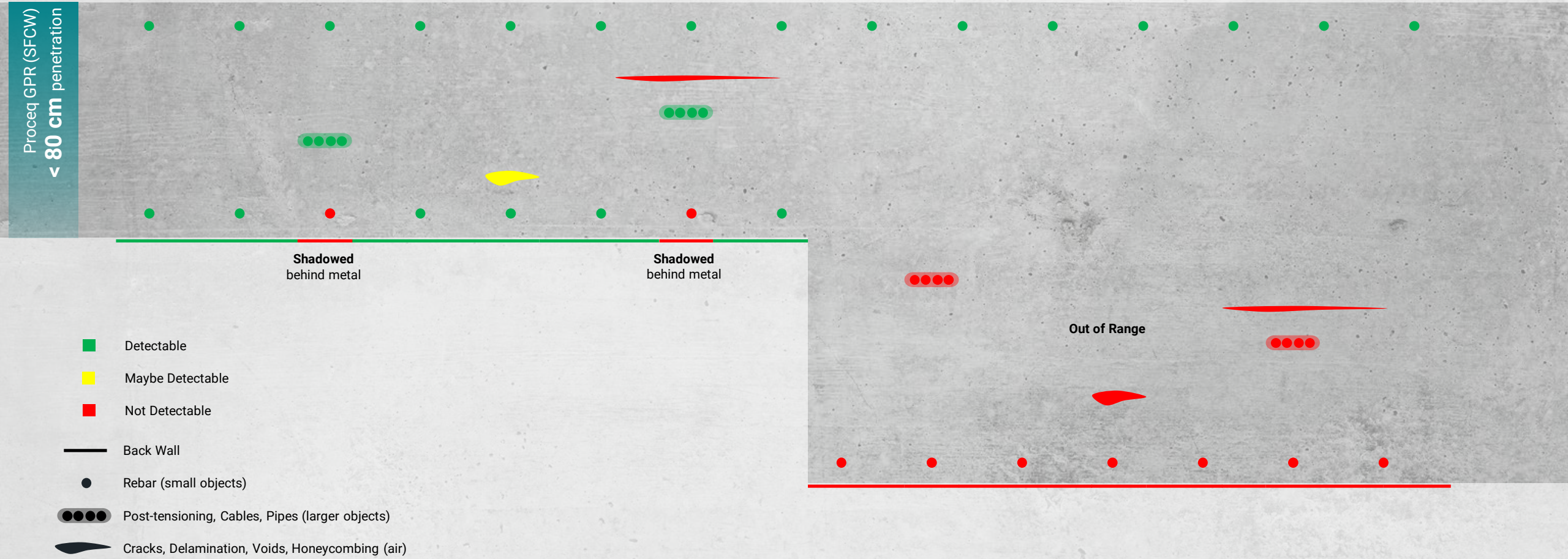

Pulsed GPR
< 60 cm penetration
Detectable
Maybe Detectable
Not Detectable
Back Wall
Rebar (small objects)
Post-tensioning, Cables, Pipes (larger objects)
Cracks, Delamination, Voids, Honeycombing (air)

Pulsed GPR


Pulsed GPR
< 60 cm penetration
Shadowed
behind metal
Out of Range
Shadowed
behind metal
Out of Range
Detectable
Maybe Detectable
Not Detectable
Back Wall
Rebar (small objects)
Post-tensioning, Cables, Pipes (larger objects)
Cracks, Delamination, Voids, Honeycombing (air)

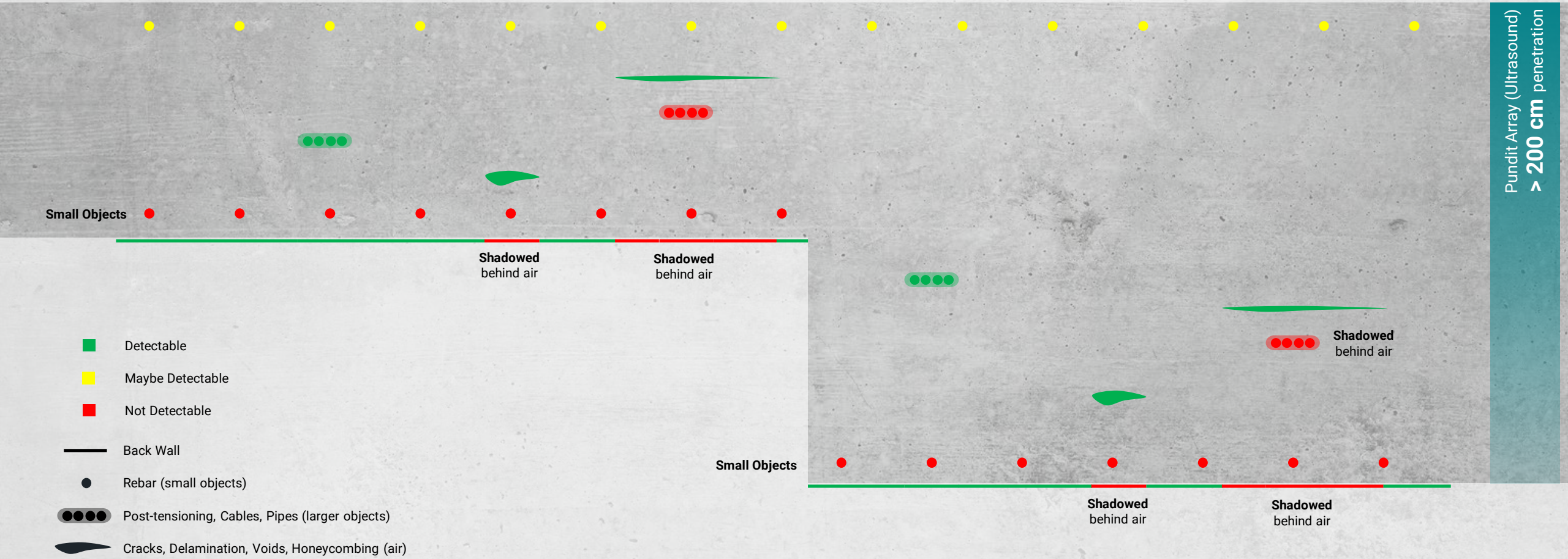
Stepped Frequency Continuous Wave – SFCW (GPR)

Proceq GPR (SFCW)
< 80 cm penetration

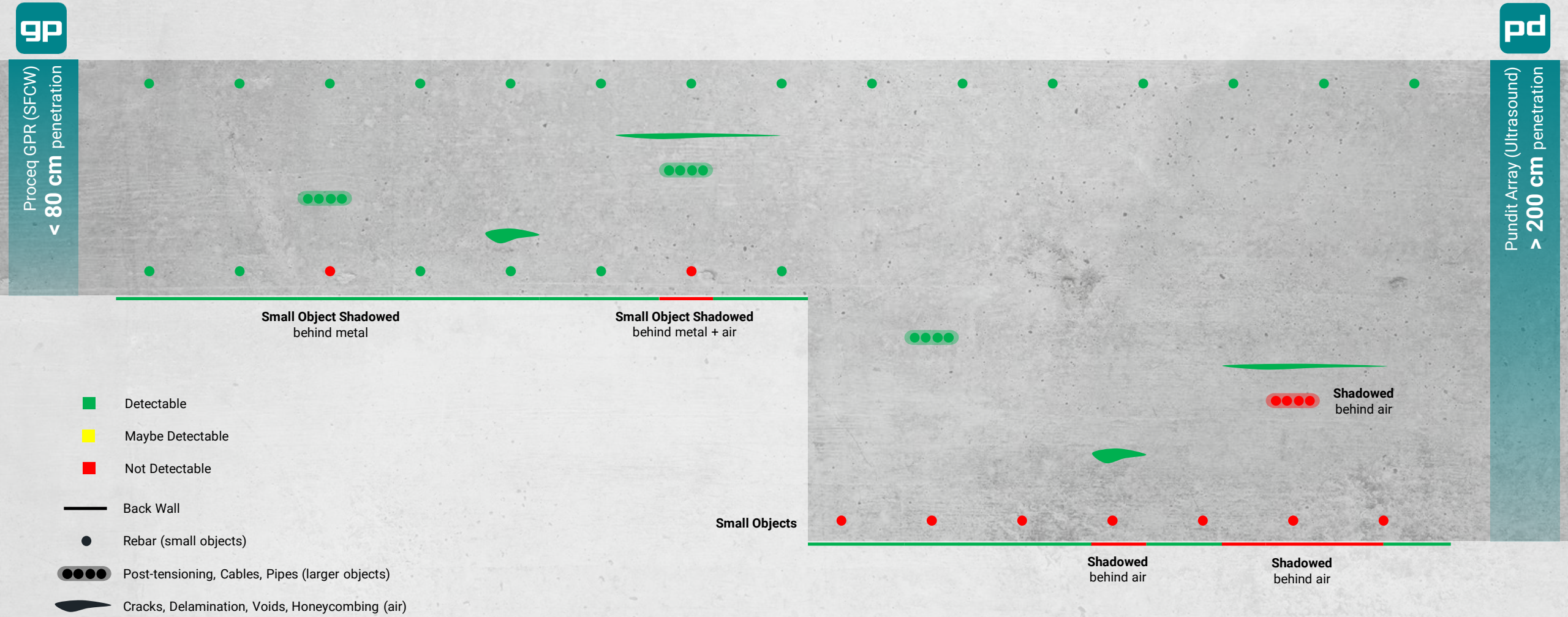


Locating, Mapping & Imaging

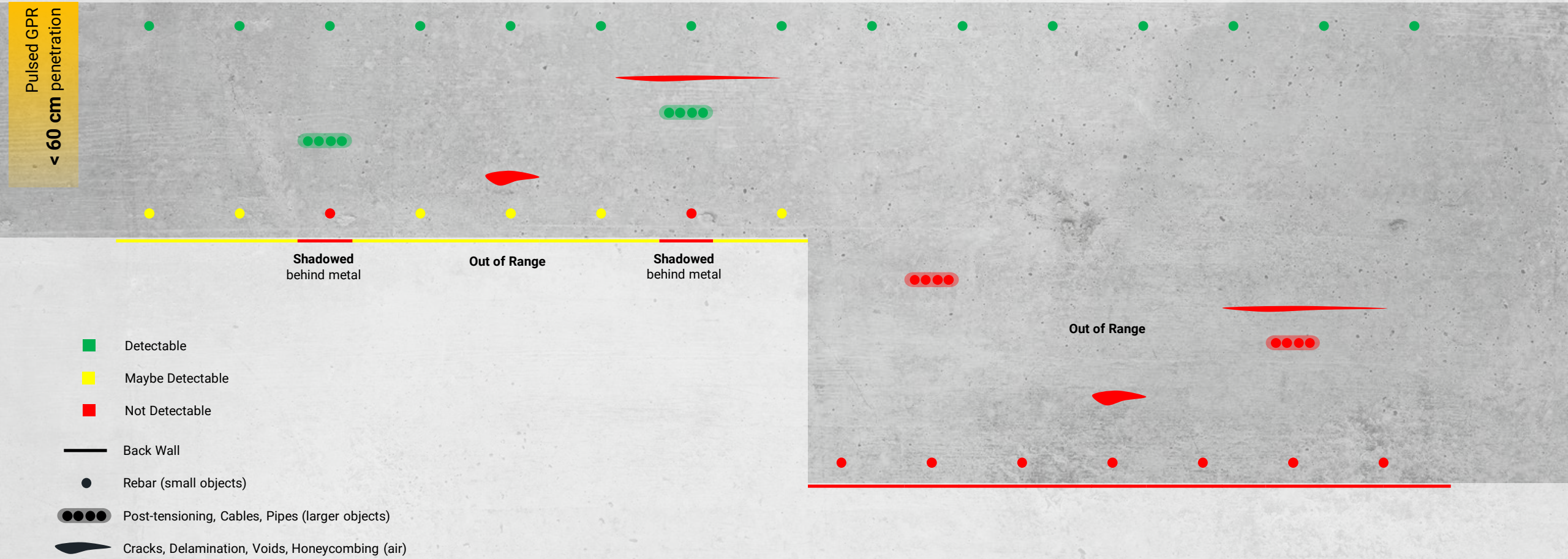
Ultrasound Pulse Echo (Pundit Array)



Combined Results

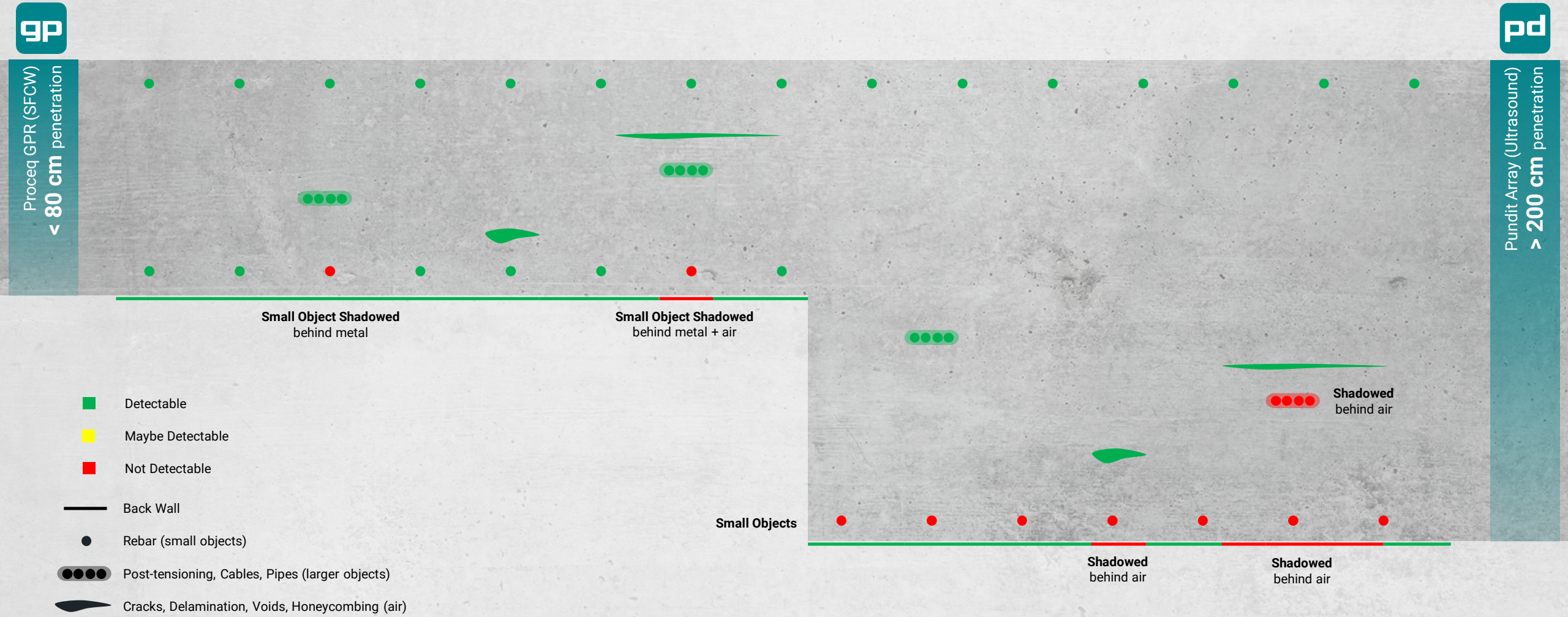


Pulsed GPR


Pulsed GPR
< 60 cm penetration
Shadowed
behind metal
Out of Range
Shadowed
behind metal
Out of Range
Detectable
Maybe Detectable
Not Detectable
Back Wall
Rebar (small objects)
Post-tensioning, Cables, Pipes (larger objects)
Cracks, Delamination, Voids, Honeycombing (air)

Locating, Mapping & Imaging

Combined Results



Ground Penetrating Radar (GPR) & Ultrasound Pulse Echo

Reflection

GPR			
Interface	ε_1	ε_2	R
Concrete - Metal	7	∞	**100%**
Concrete - Air	7	1	**45%**

Ultrasonic Pulse Echo			
Interface	Z_1	Z_2	R
Concrete - Metal	9.6	46.5	**43%**
Concrete - Air	9.6	.000429	**99%**

$$R = \frac{\sqrt{\varepsilon_1} - \sqrt{\varepsilon_2}}{\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2}}$$

R = energy reflected

ε_1 = permittivity of concrete

ε_2 = permittivity of 2nd material

$$R = \frac{(z_2 - z_1)^2}{(z_2 + z_1)^2}$$

R = energy reflected

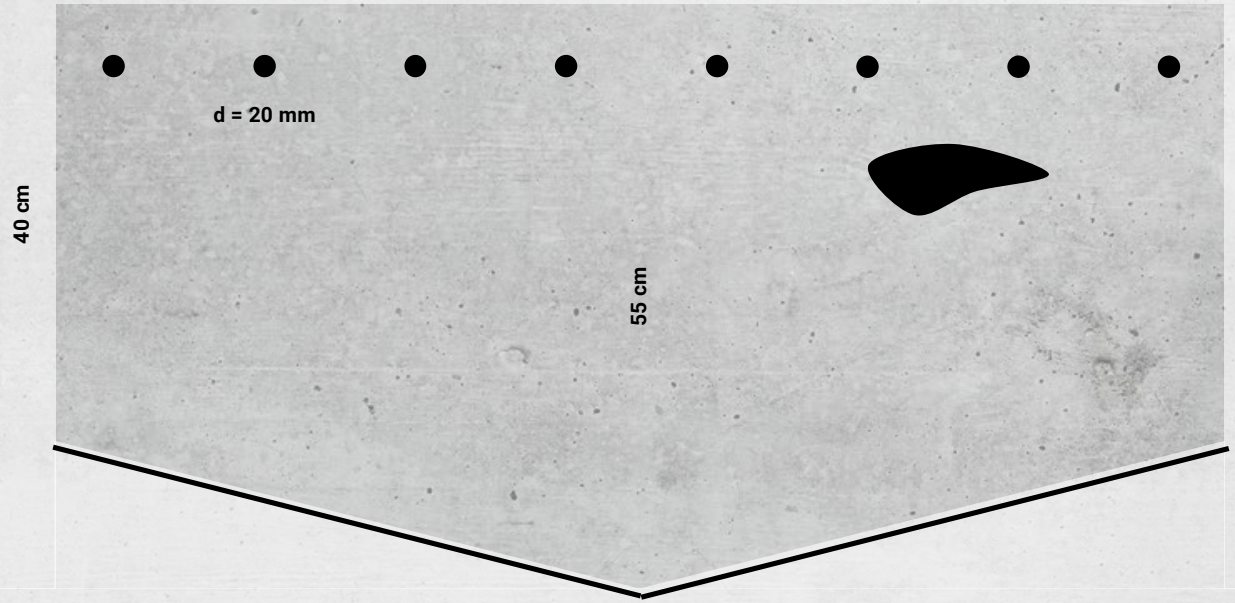
Z_1 = acoustic impedance concrete

Z_2 = acoustic impedance 2nd material

Ground Penetrating Radar (GPR) & Ultrasound Pulse Echo

GPR	Ultrasonic Pulse Echo
• **100%** reflection of **metal objects**	• **99%** reflection of **air gaps**
• **cannot see** objects **behind metal**	• **cannot** see objects **behind air gaps**
• travels (55%) **through air gaps**	• travels (57%) **through metal objects**
• **45%** reflection of **larger air gap**	• **43%** reflection of **larger metal objects**
• can **see** objects **behind an air gap**	• can **see** other objects **behind metal objects**

Example I



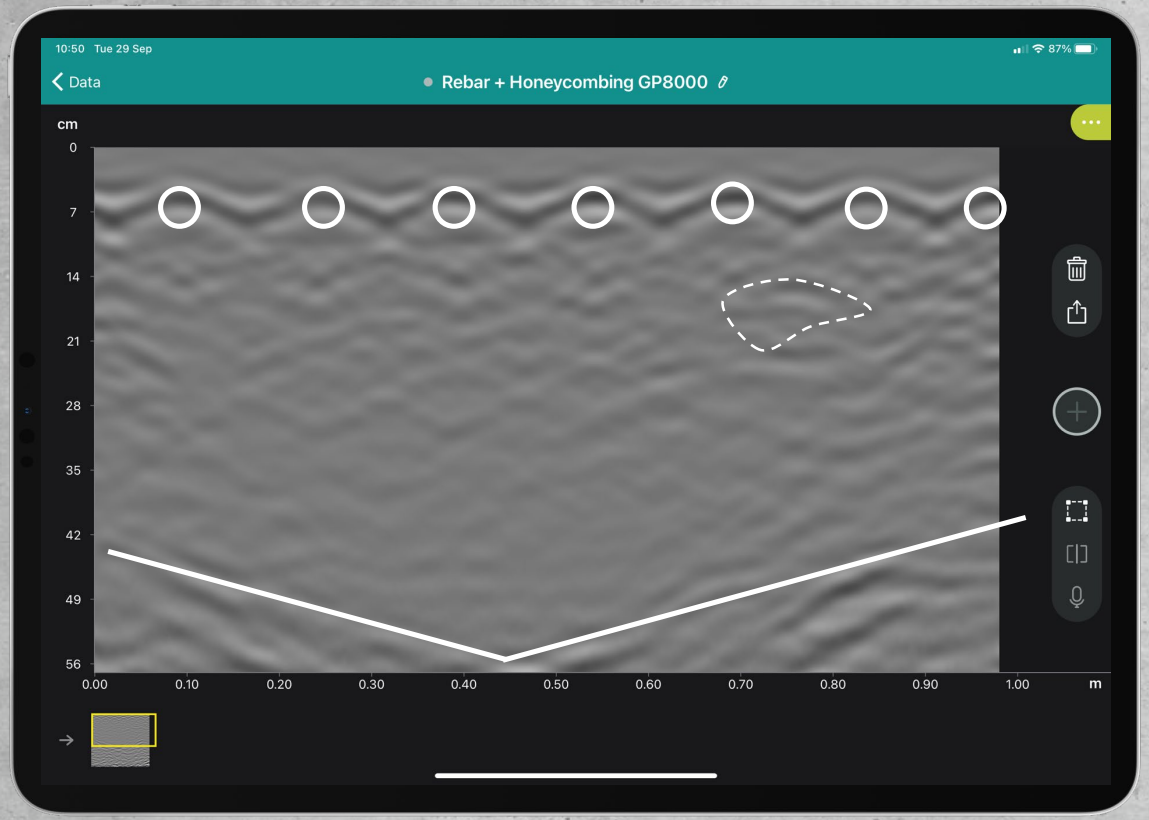
Back Wall

Rebar

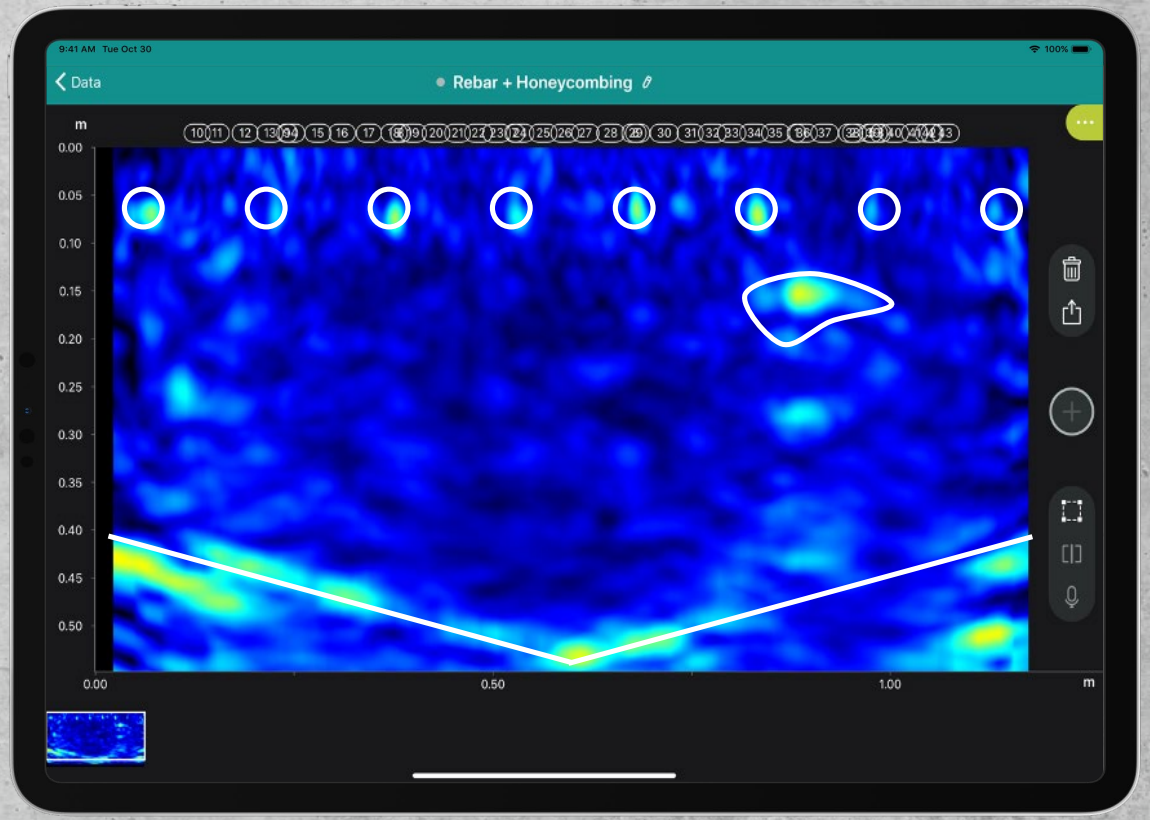
Honeycombing

Example I

Ground Penetrating Radar (Proceq GPR)



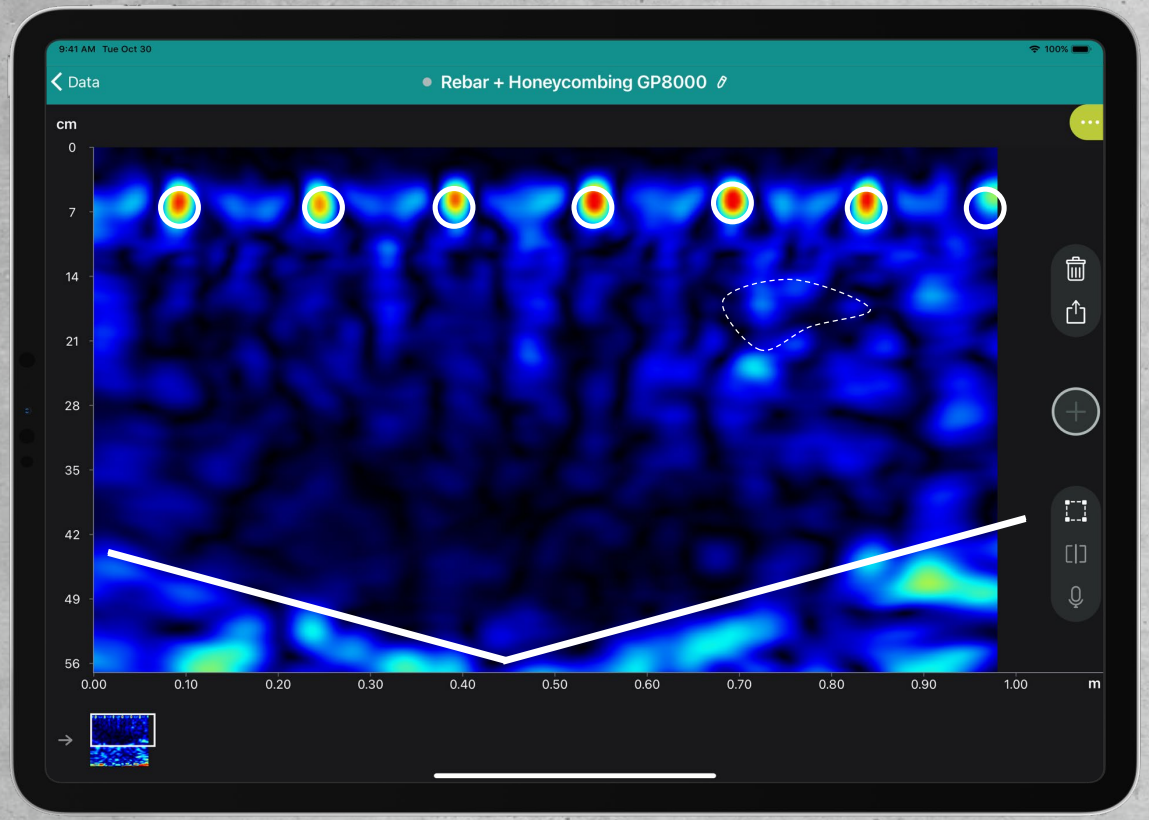
Ultrasound Pulse Echo (Pundit Array)



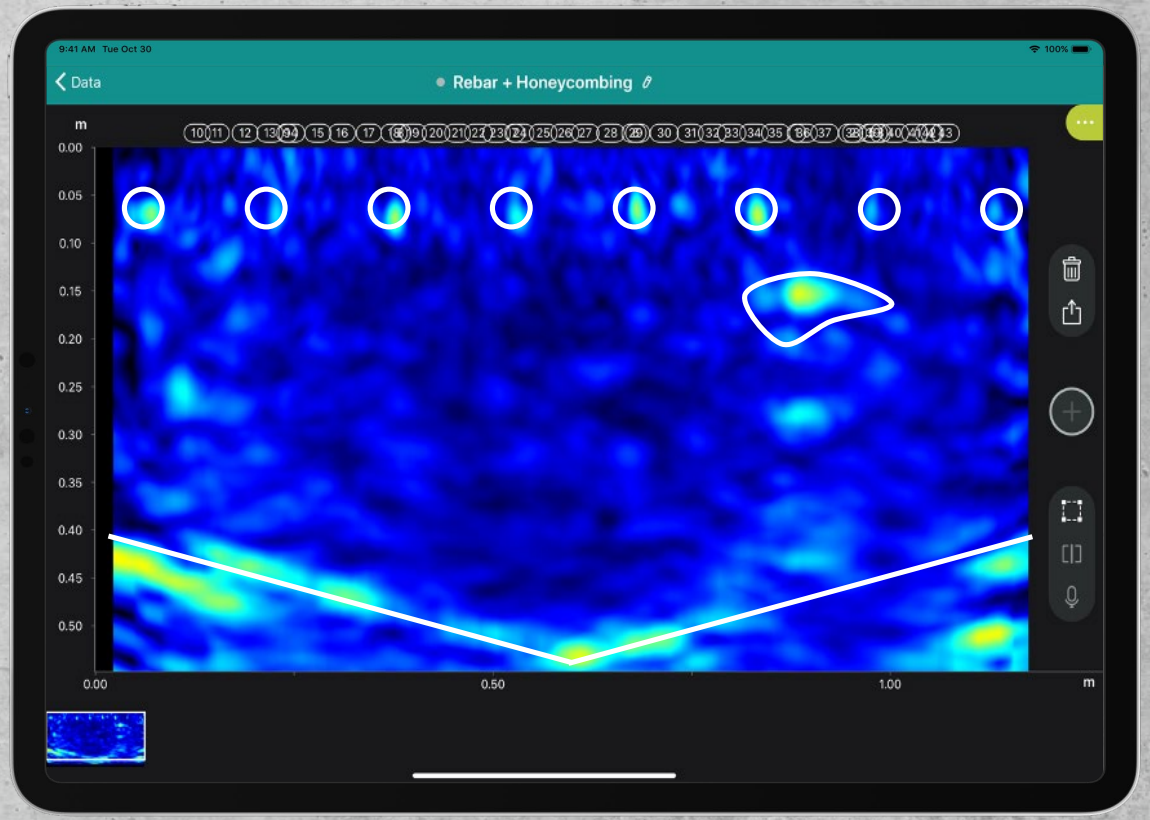
Locating, Mapping & Imaging

Example I

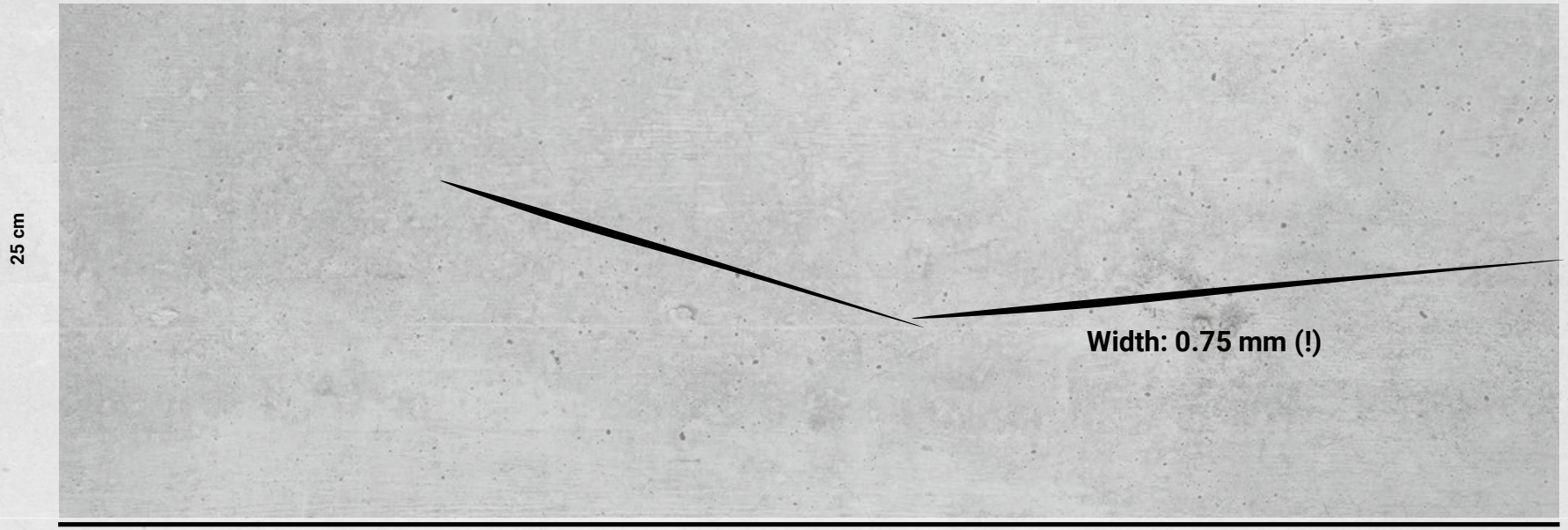
Ground Penetrating Radar (Proceq GPR)



Ultrasound Pulse Echo (Pundit Array)



Example II



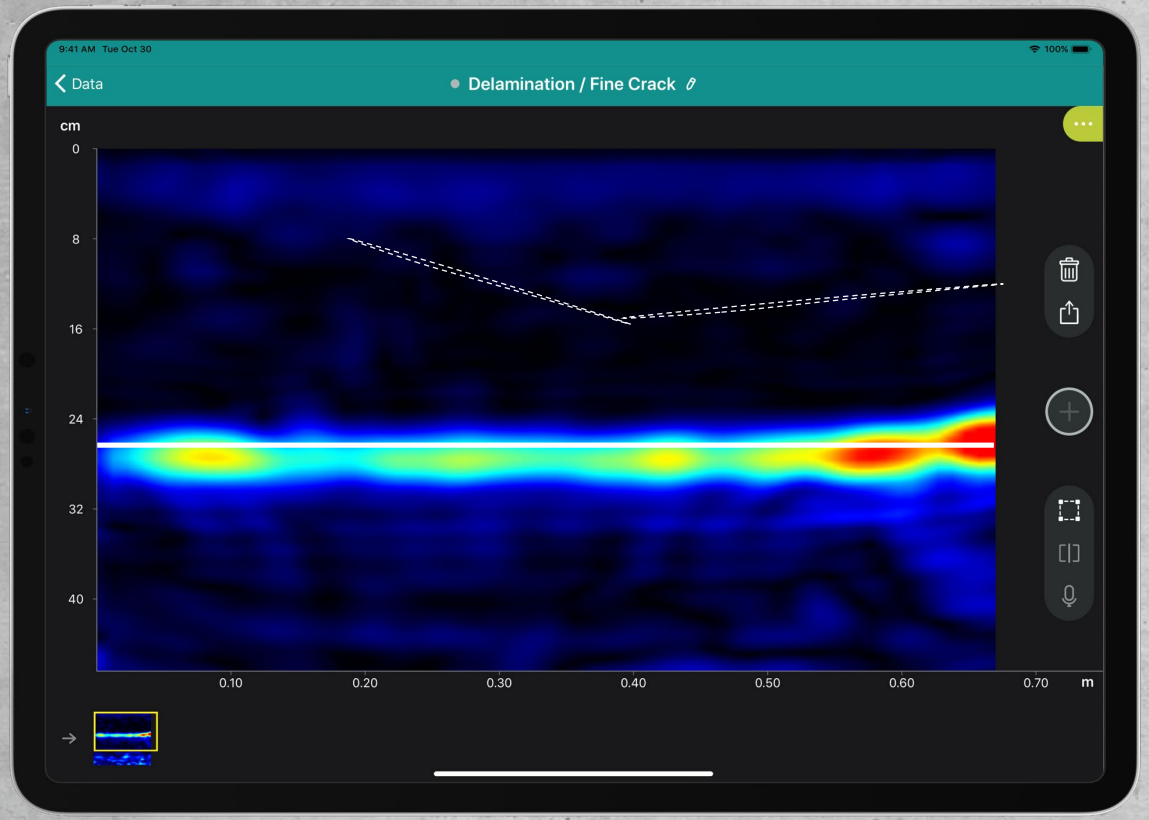
Back Wall

Delamination / Fine Crack (0.75mm)

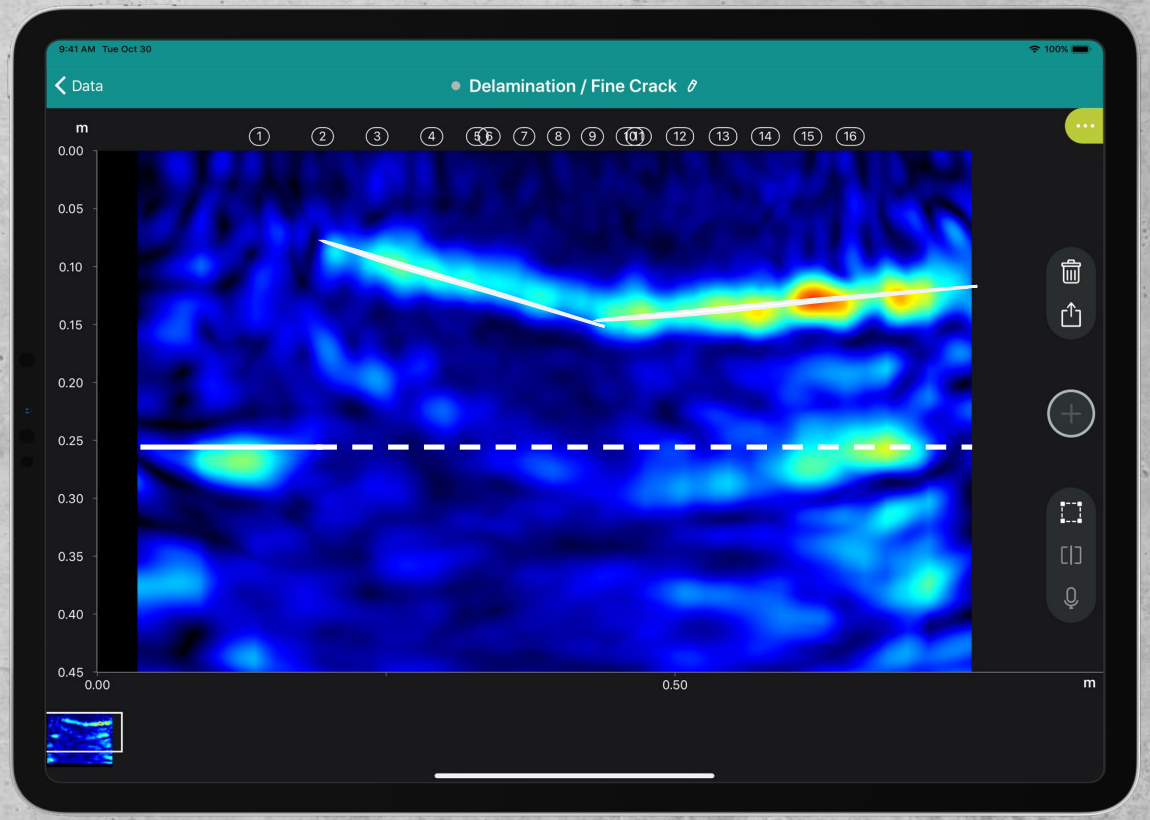
Locating, Mapping & Imaging

Example II

Ground Penetrating Radar (Proceq GPR)



Ultrasound Pulse Echo (Pundit Array)



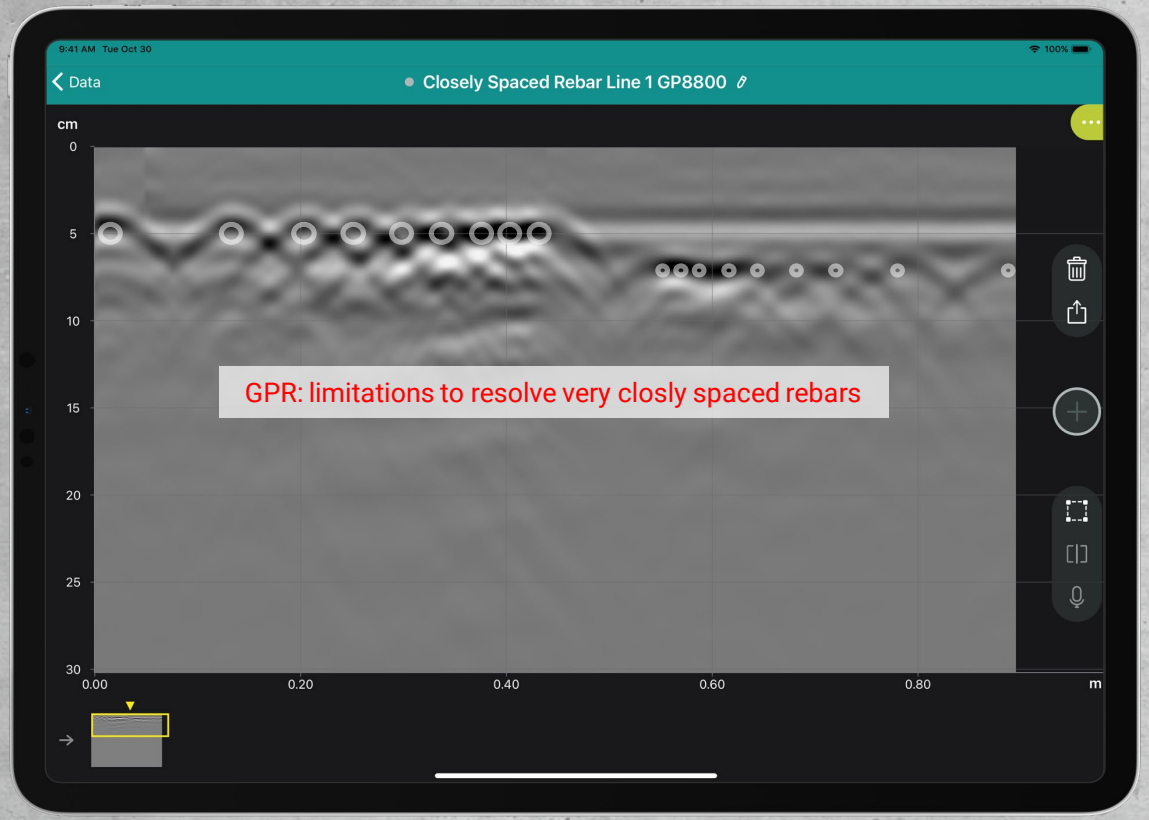
Example III


20 20 20 20 20 20 20 20 20 10 10 10 10 10 10 10 10 10
100 50 32 32 16 16 8 8 100 8 8 16 16 32 32 50 100
Line Scan
20 40 20 120 20 50 20 30
60 10 100 10 90 10 20

Locating, Mapping & Imaging

Example III – Line Scan

Ground Penetrating Radar (Proceq GPR)

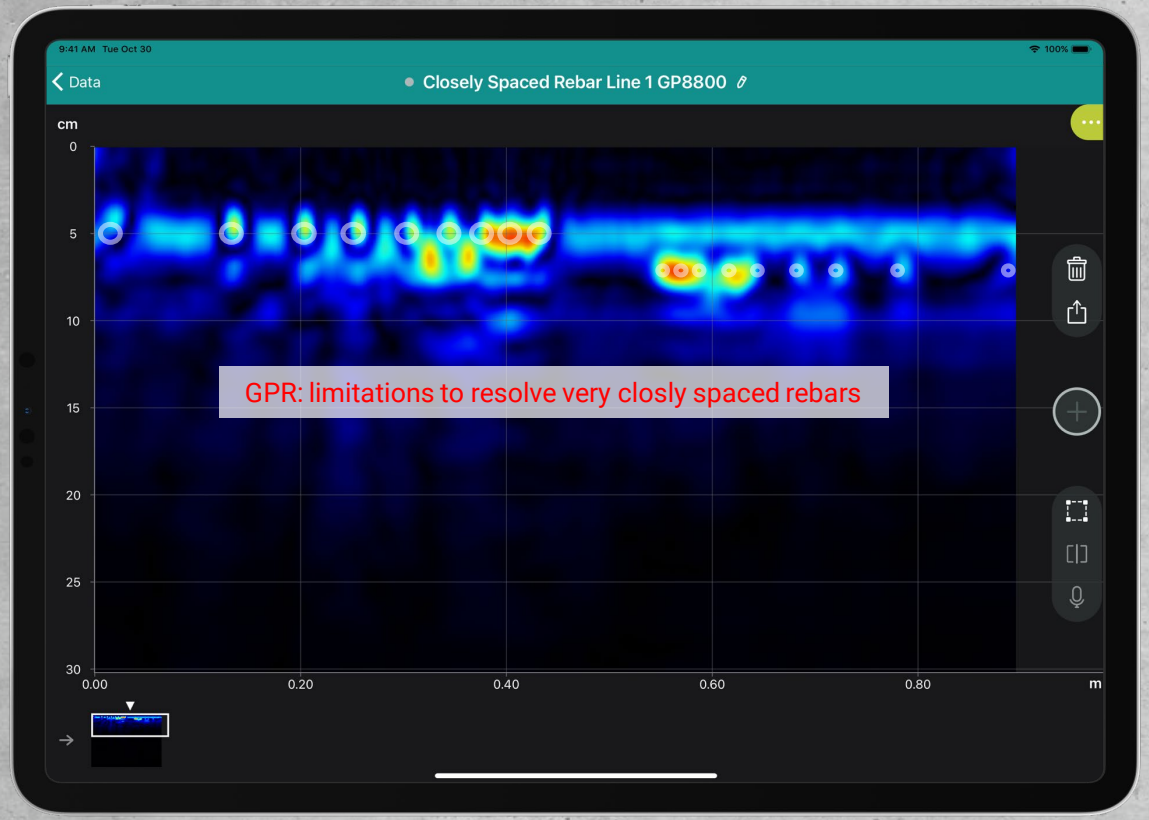


Pulsed GPR

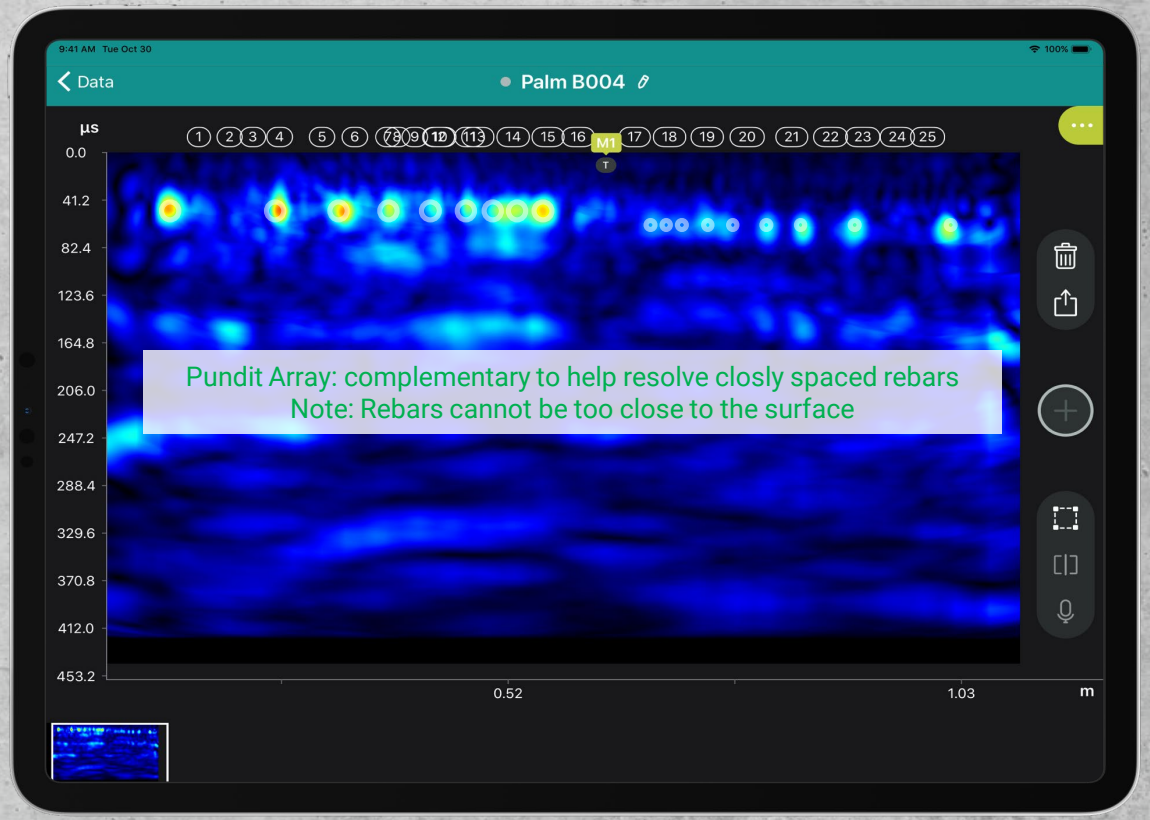
Locating, Mapping & Imaging

Example III – Line Scan

Ground Penetrating Radar (Proceq GPR)



Ultrasound Pulse Echo (Pundit Array)



Locating, Mapping & Imaging

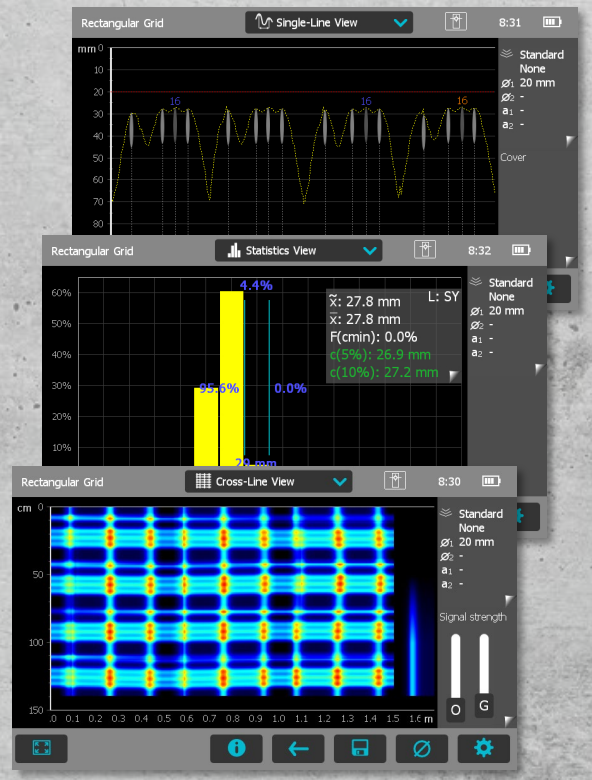
Eddy Current / Half-Cell (Profometer)

Locating, Mapping & Imaging

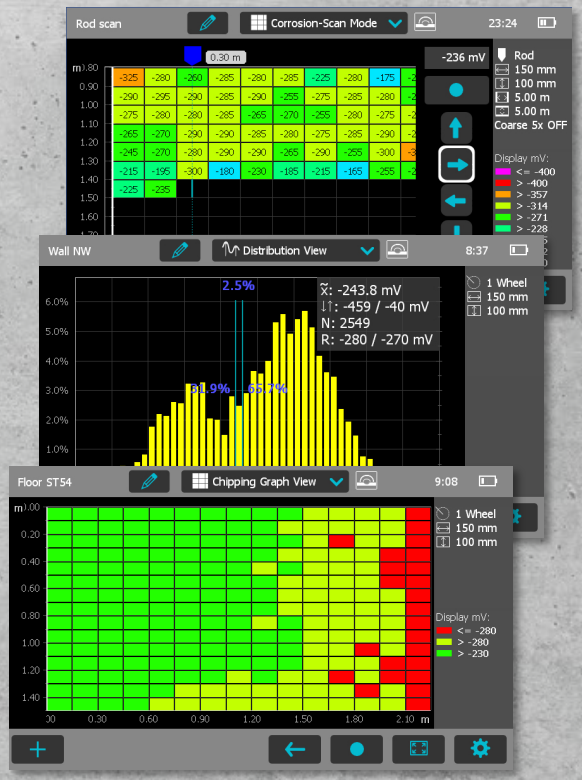
Eddy Current / Half-Cell Potential (Profometer)

Profometer 650

A.I.



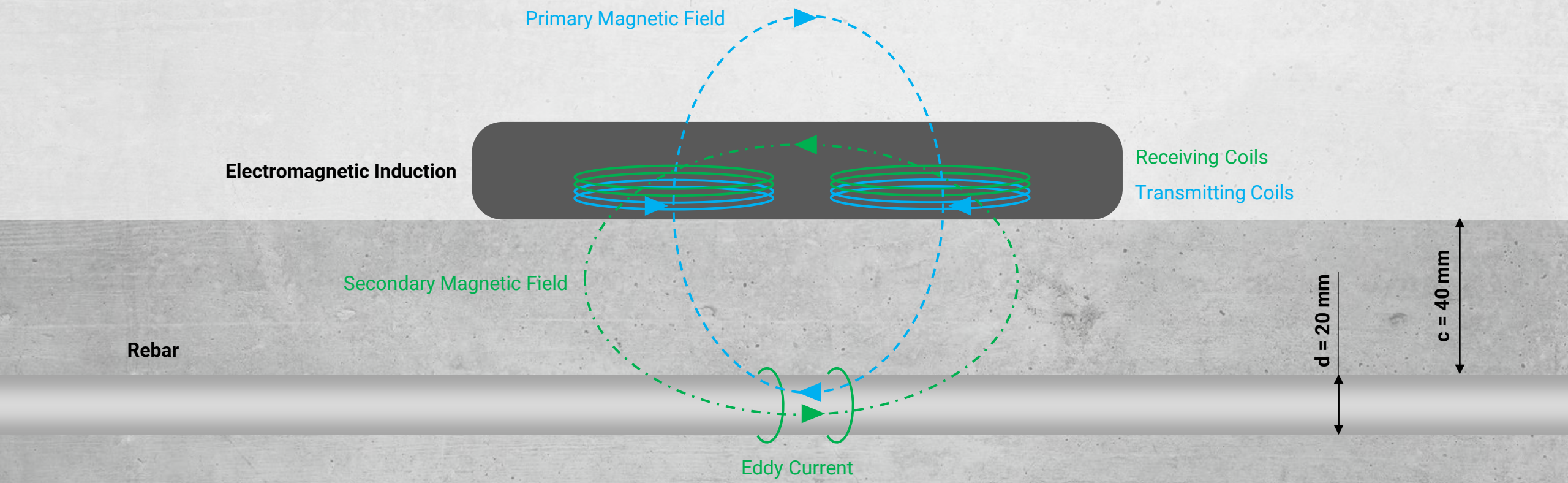
Eddy Current
Rebar Cover, Diameter & Spacing
Line Scan – Cover Statistics – Mapping



Half-Cell
Corrosion Potential
Hotspot Mapping

profometer

Eddy Current (Profometer)



Transmitting coils in the probe are **charged by current** and thus generate a **primary magnetic field**. On the surface of rebars within the magnetic field, **eddy currents** are induced, which produce a **secondary magnetic field** in the opposite direction. The resulting **change of voltage** in the receiving coils can be utilized for measurement.

Eddy Current (Profometer)

Inspection Procedure – Profometer

- DGZfP B2 “Guide for non-destructive concrete cover measurement and reinforcement location on reinforced and prestressed concrete structures”
- BS 1881-204 “Recommendations on the use of electromagnetic covermeters”

1. Ensure there is no conductive material within the magnetic field (sphere of approx. 200 mm / 8 inch radius from the measuring center) which influences the measurement.
2. Select the correct measuring range : standard range for most use cases; spot range to select for small areas corners and small distance between rebars; large range to select when the concrete cover is deeper.
3. Map out the rebars grid on the surface of the element using the Locating Mode or Single-Line Mode. First layer for rebars is normally horizontal for columns and walls but vertical for beams. Second layer for rebars is normally vertical for columns and walls, but horizontal for beams.
4. Move the probe cart crosswise over the rebars for measuring the concrete cover of the first layer reinforcement along a measurement line perpendicular to the first layer reinforcement and in the center of two of the second layer rebars.
5. Above each rebar, whenever the rebar spacing is compatible with the minimum spacings stated in the Operating Instructions, rebar diameter can be measured.
6. An increased accuracy in cover and rebar diameter measurement can be achieved by means of the corrections based on the rebar geometry (Neighbor Rebar Correction, Artificial Intelligence)
7. Analyse the collected data to identify the insufficient concrete cover areas and/or rebar diameter values.
8. Create a chipping graph to identify low cover areas where remedial actions must be taken
9. Use the Area-Scan Mode to show the first layer rebar covers on large areas, e.g. of concrete slabs in car parks. Ideal for a combination with half-cell potential measurements - Profometer Corrosion measurements.

The tools to analyse the data in steps 7 and 8 are included in the Profometer and Profometer Link software

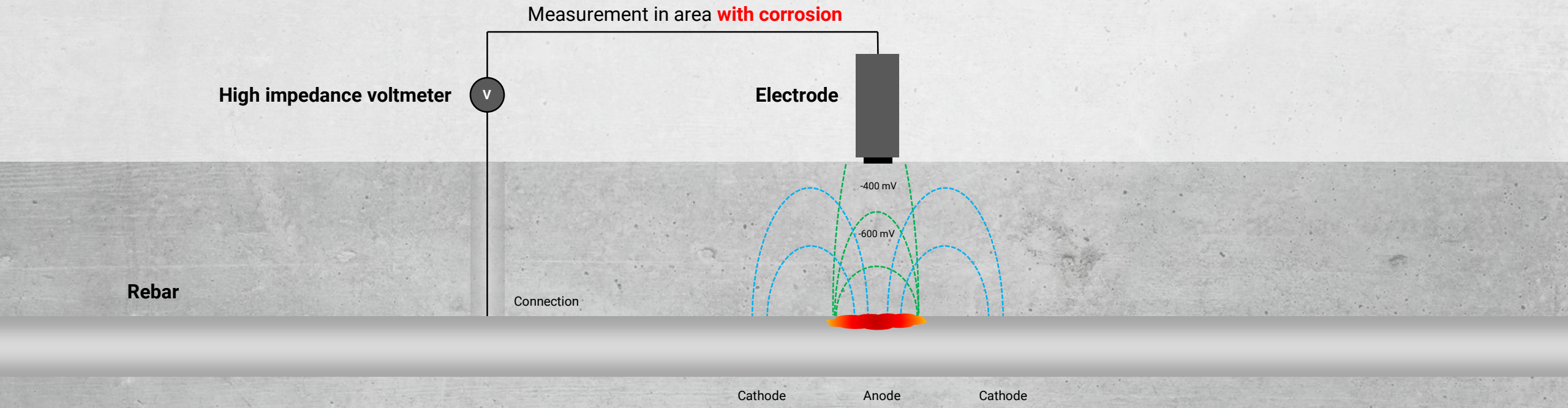
Eddy Current (Profometer)

Important

1. Profometer	► Electromagnetic pulse induction technology with advanced signal processing allowing location of rebar, measuring of cover and rebar diameter. Integrated software for on site data interpretation.
2. Measuring range	► **Standard range** for most use cases. ► **Spot range** for small areas corners and when there is small distance between rebars. ► **Large range** when the concrete cover is deeper.
3. Combination with corrosion measurements	► Integrated with **Profometer corrosion** for half-cell potential measurements using the same instrument ► Corrosion potential is measured by **localizing negative values of the half-cell potential**
4. Combination with concrete resistivity	► resistivity variations increase or decrease corrosion potential measured at the surface and also the area where corrosion hotspots can be detected. ► resistivity spot checks can be measured with **Resipod**

Locating, Mapping & Imaging

Half-Cell Potential (Profometer)



The half-cell method is used to identify **active corrosion of rebars** based on the **electro chemical properties** of reinforced concrete. The detection of the hot spots where active corrosion begins, involves the measuring of the **localized negative values of the half-cell potential** (i.e. corrosion potential).

Half-Cell Potential (Profometer)

Inspection Procedure – Profometer Corrosion

- DGZfP B3 “Electrochemical potential measurements for reinforcement steel corrosion detection”
- ASTM C876 “Standard Test Method For Corrosion Potentials Of Uncoated Reinforcing Steel In Concrete”

1. Select the correct electrode for the test. Rod electrode for small areas, columns, etc. Wheel electrode for large areas.
2. Perform a functional check of the half cell instrument
3. Connect to the reinforcement. (if necessary, drill down to reinforcement)
4. Check continuity of the reinforcement using an ohmmeter (A second opening to the reinforcement at the extremity of the test area is necessary.)
5. Prepare the concrete surface. Remove any isolating coatings. Pre-moisten the surface approximately 20 minutes before measuring.
6. Carry out the measurements in a grid pattern over the whole test area. Typically a 15 cm or 25 cm grid is recommended.
7. Ideally carry out a cover meter scan over the same area to remove the influence of cover on the corrosion potential measurements
8. Analyse the collected data to identify the corrosion threshold potential and passive threshold potential.
9. Confirm analysis by opening the concrete at appropriate locations with passive and active potentials to confirm the presence / absence of corrosion
10. Create a chipping graph to identify areas where remedial actions must be taken

The tools to analyse the data in steps 8 and 10 are included in the Profometer Corrosion and Profometer Link software

Half-Cell Potential (Profometer)

Important

1. Profometer corrosion

► Advanced half-cell measuring instrument for on-site mapping of the corrosion potential. Unique combination with rod and wheel electrodes. Integrated software for on site data interpretation.

2. Electrode type

► **Rod electrode** for small areas, difficult to access Concrete Thickness, ca. 50 m^2 / hour
► **Wheel electrode** for horizontal, vertical and overhead surfaces, ca. 450 m^2 / hour
► **4-wheel electrode** for large horizontal areas, ca. 1800 m^2 / hour

3. Combination with cover measurements

► Integrated with **Profometer** for rebar cover measurements using the same instrument
► cover variations increase or decrease the measured corrosion potential

4. Combination with concrete resistivity

► resistivity variations increase or decrease corrosion potential measured at the surface and also the area where corrosion hotspots can be detected.
► resistivity spot checks can be measured with **Resipod**

Locating, Mapping & Imaging

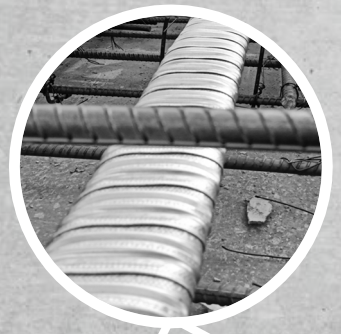
Half-Cell Potential (Profometer)

HOW to Inspect Concrete Structures?

Locating, Mapping & Imaging

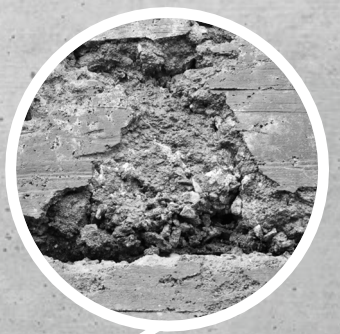
Rebars

Objects



Thickness

Defects



Profometer

1st and 2nd layer rebars
Cover, Diameter & Corrosion

Proceq GPR

Depth: 0 to < 80 cm

Pundit Array

Depth: 0 to > 200 cm

Locating, Mapping & Imaging

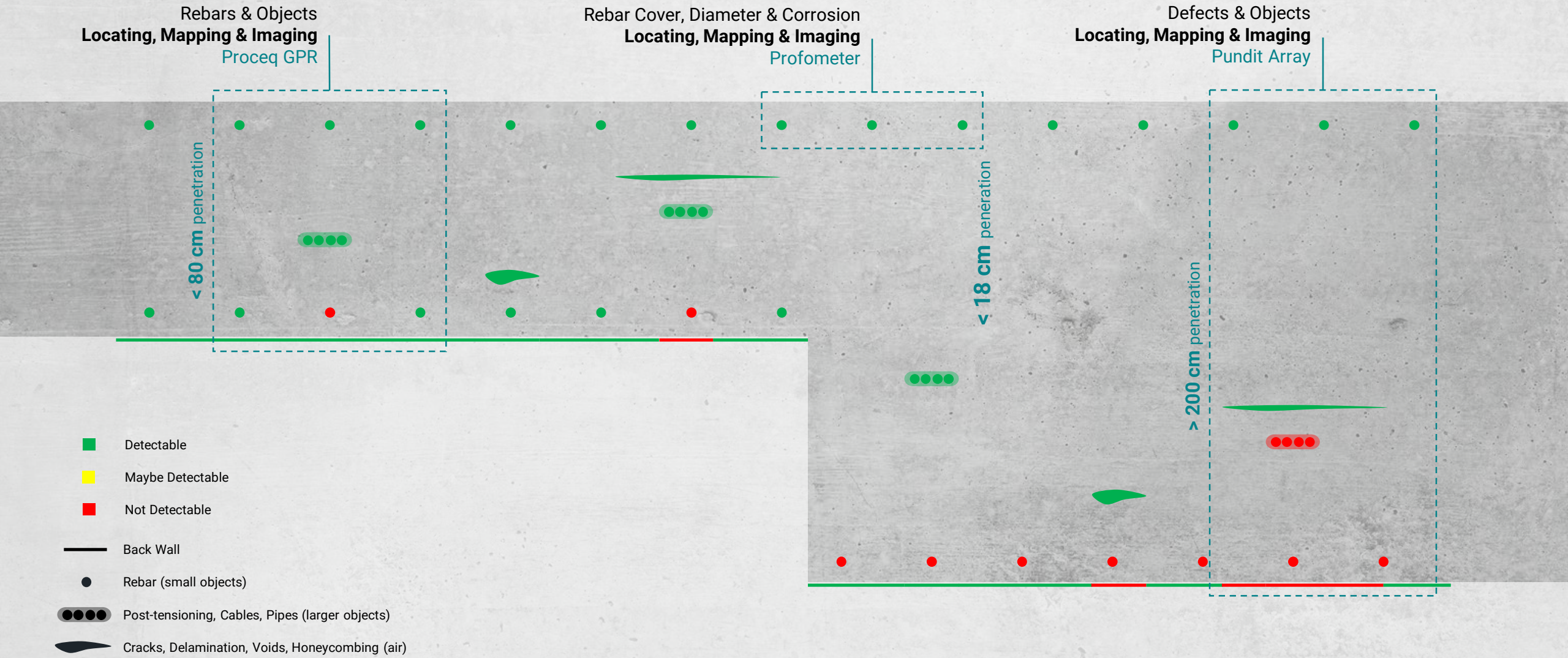
Selected Applications

Locating, Mapping & Imaging

Rebars | Objects | Thickness | Defects

Locating, Mapping & Imaging

Rebars | Objects | Thickness | Defects

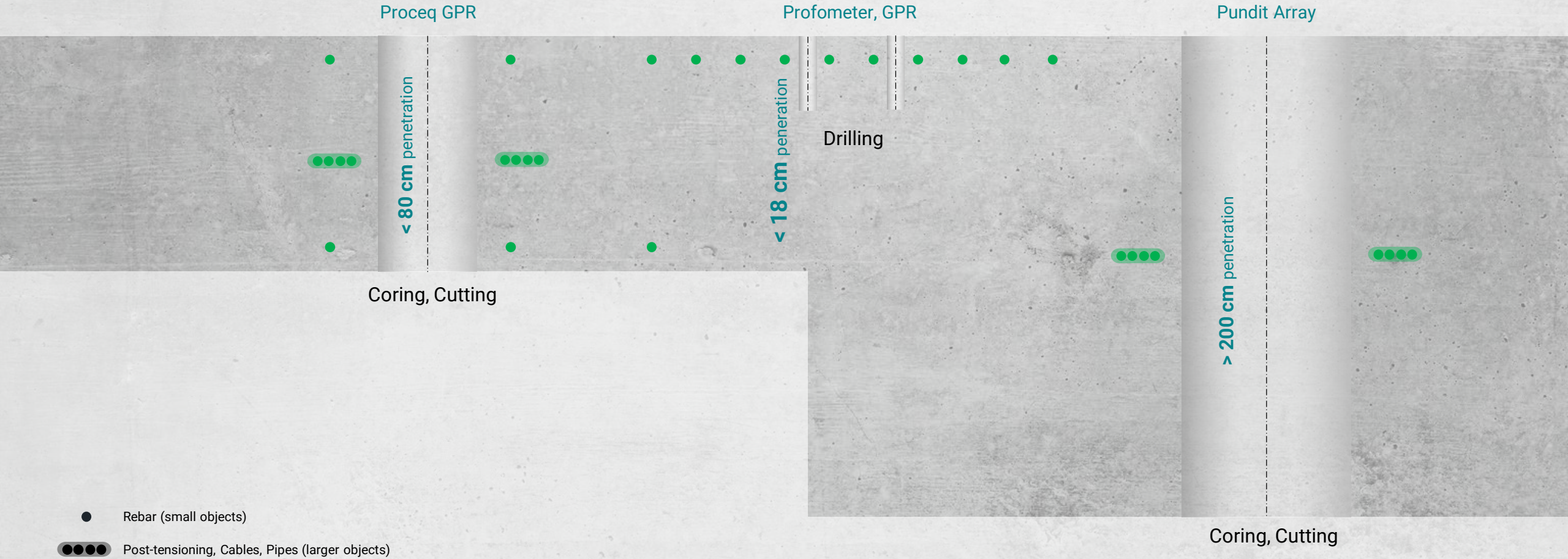


Locating, Mapping & Imaging

Hit Prevention

Locating, Mapping & Imaging

Hit Prevention

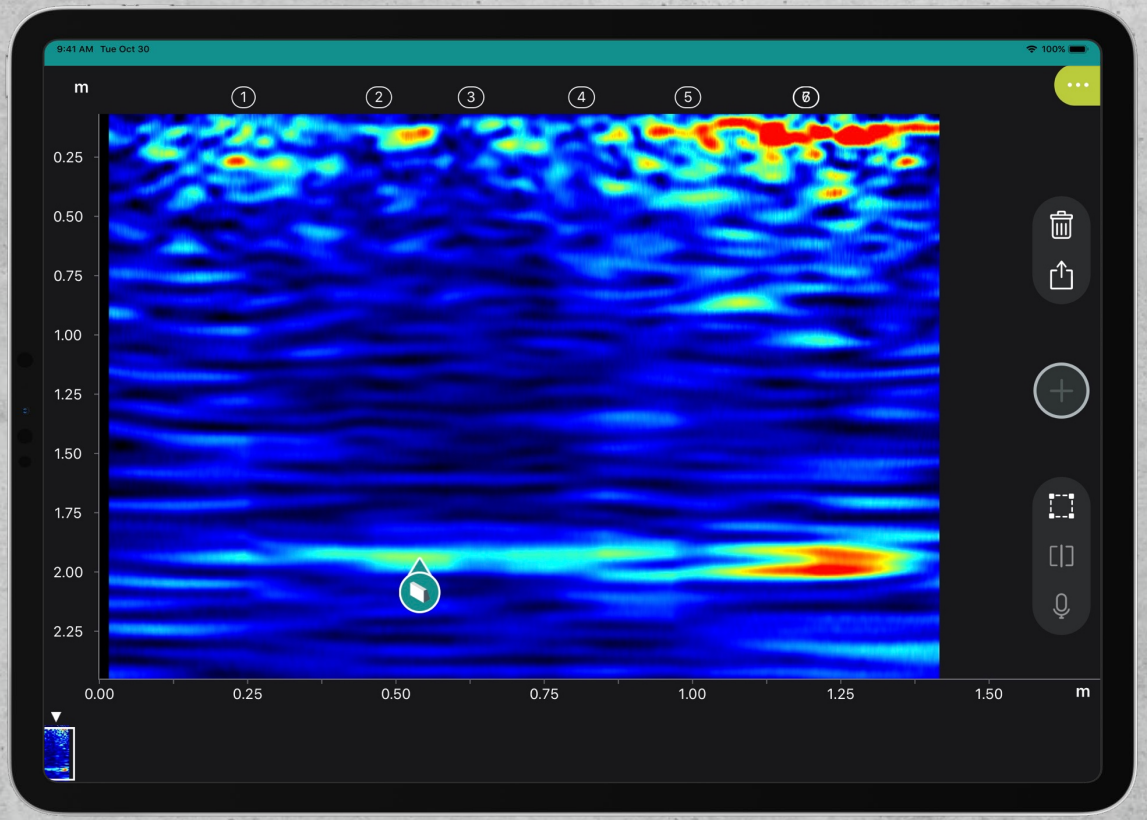


Mass Concrete: Defects + Thickness

Mass Concrete

Ultrasound Pulse Echo (Pundit)

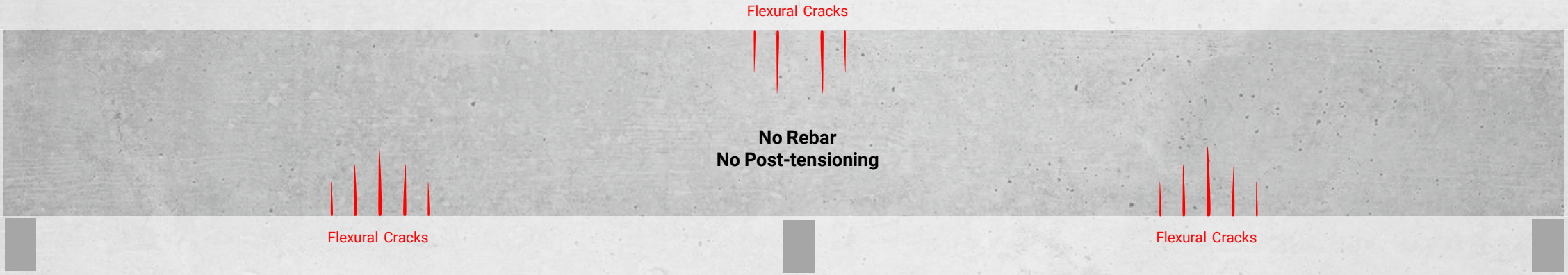
Deep Targets



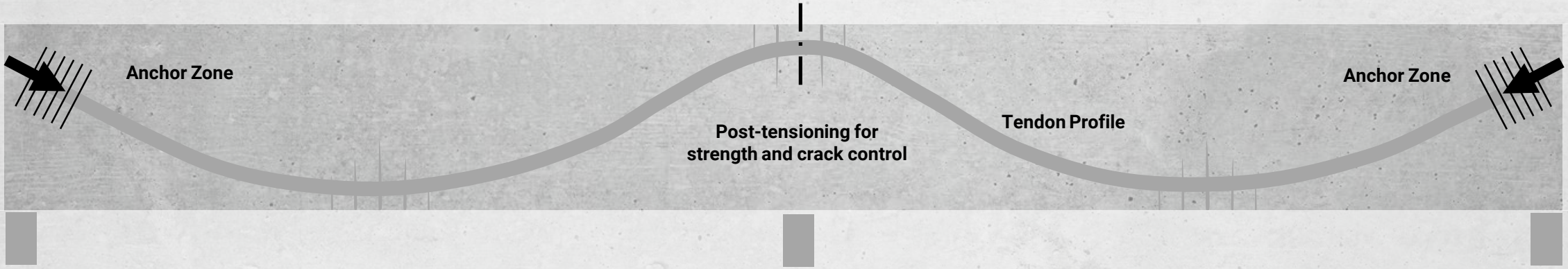
Locating, Mapping & Imaging

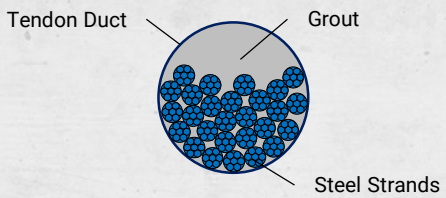
Ungrouted Post-tensioning Ducts

Ungrouted Post-tensioning Ducts



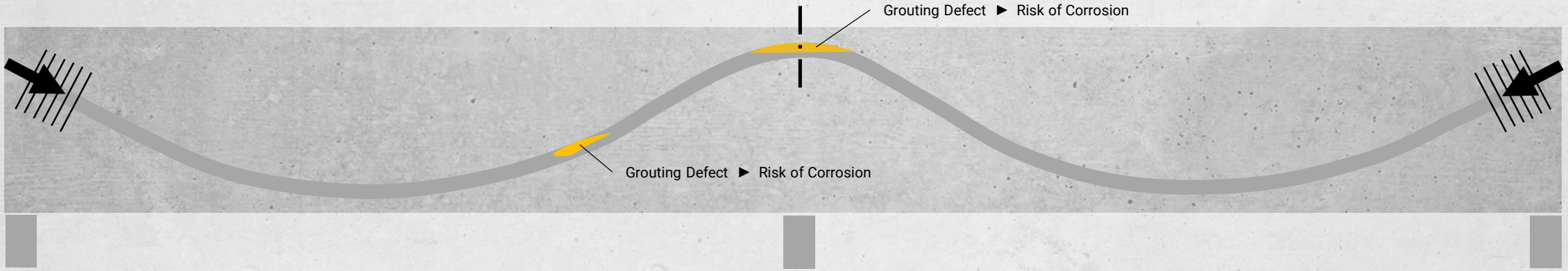
Ungrouted Post-tensioning Ducts

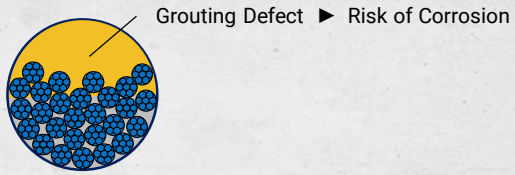




Cross-Section

Ungrouted Post-tensioning Ducts





Cross-Section

Ungrouted Post-tensioning Ducts

NottinghamshireLive

February 11, 2020

Here's what the engineers working on repairing Clifton Bridge had to say

“Engineers have revealed the extent of work being done on Clifton Bridge as experts say they will no doubt be having "many sleepless nights" as they **aim to get the major transport route back open**... Engineers then exposed the condition of the steel tendons - which pull the bridge together and help the bridge withstand tension - and these were found to be corroded...”

ENR Engineering News-Record

June 17, 2020

Structural Cracks, Severe Corrosion Shut Down Florida Bridge

“Detailed inspections of the closed Roosevelt Bridge in Stuart, Fla., have revealed severe corrosion and ruptured steel reinforcing tendons in the southernmost portion of the 23-year old bridge’s southbound span...”

Ungrouted Post-tensioning Ducts

Globally **Millions** of Post-tensioned Structures

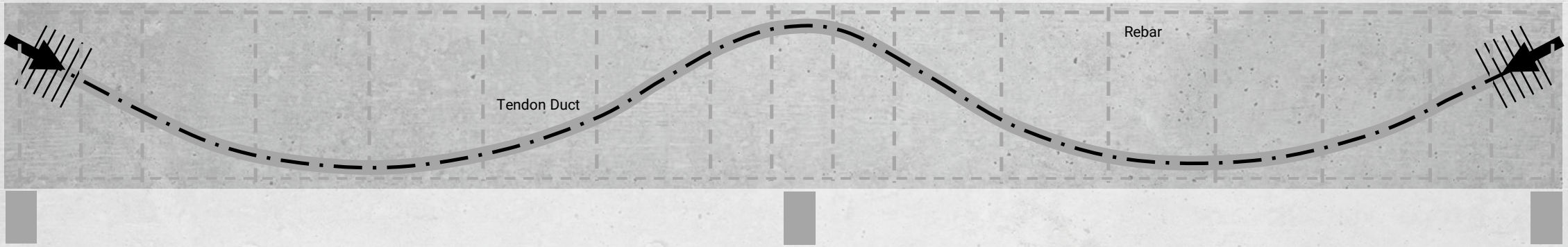
with potentially the same **Problem**!

Periodic Inspections using **Digital Technology**

prevent shut-downs and failures!

Locating, Mapping & Imaging

Ungrouted Post-tensioning Ducts



Inspection Procedure

1… Mapping of Rebar ▶ **Ground-Penetrating Radar (Proceq GPR)**

2… Mapping of Tendon Duct ▶ **Ground-Penetrating Radar (Proceq GPR)**

3… Scan the entire length of the Tendon Duct ▶ **Ultrasound Pulse Echo (Pundit Array)**

Produce **comparable images:** same scan & image processing settings, and a similar line of sight of the Anchor Zone

4… Determine “anomalies” by comparing images

- ▶ fully grouted **= weak reflection**
- ▶ with grouting defect **= strong reflection**

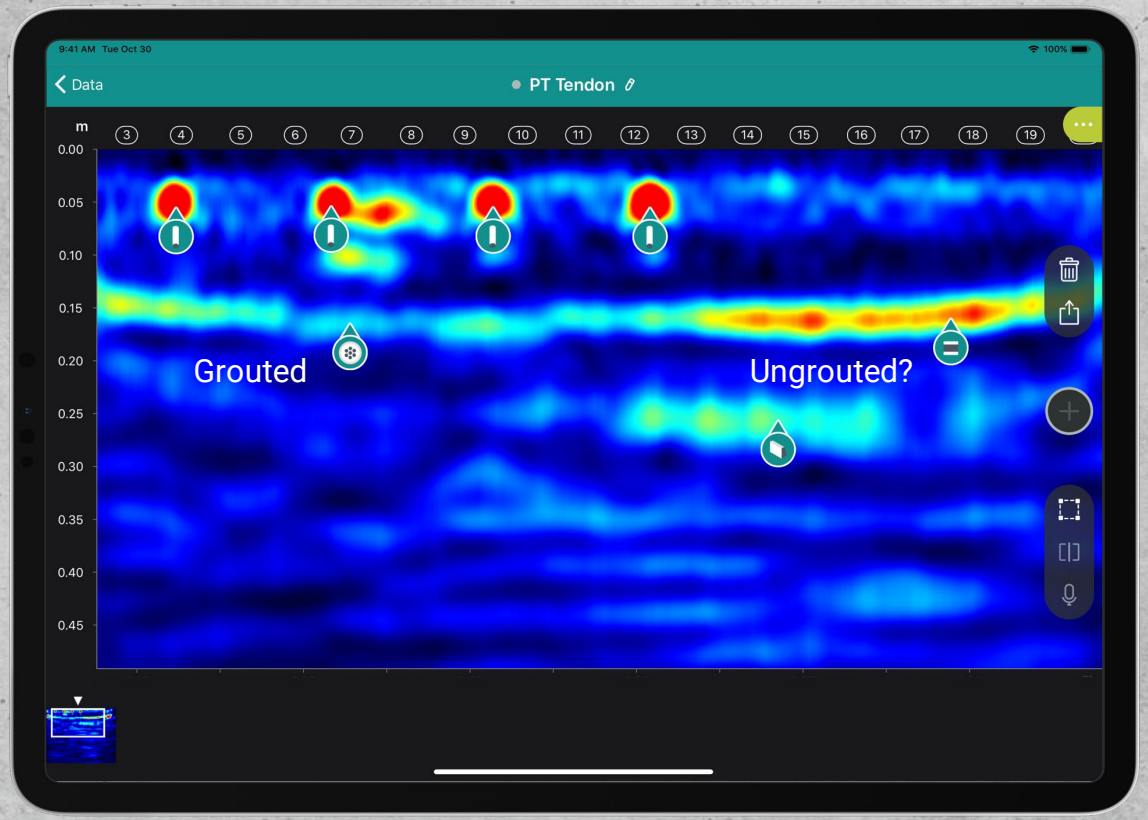
5… Verify “anomalies” ▶ Surgical and targeted Drilling & Borescope verification

Locating, Mapping & Imaging

Ungrouted Post-tensioning Ducts

Ungrouted Post-tensioning Ducts

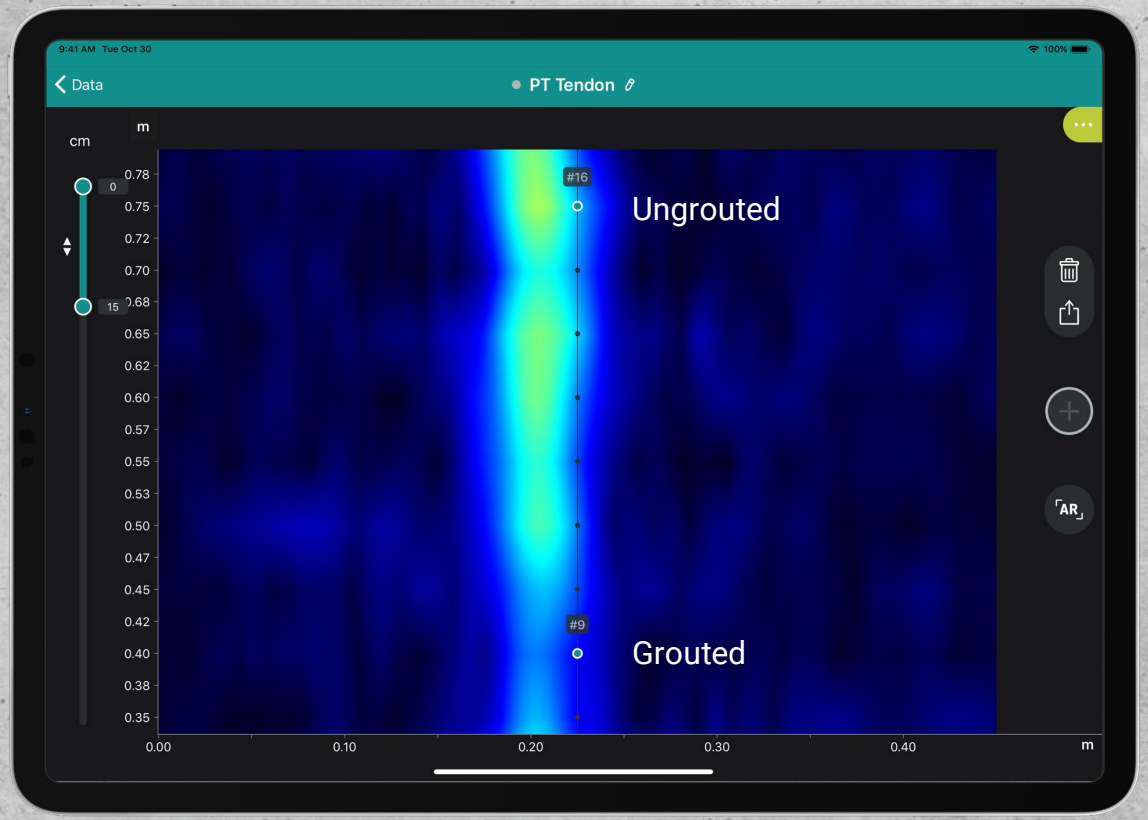
Ultrasound Pulse Echo (Pundit)



Locating, Mapping & Imaging

Ungrouted Post-tensioning Ducts

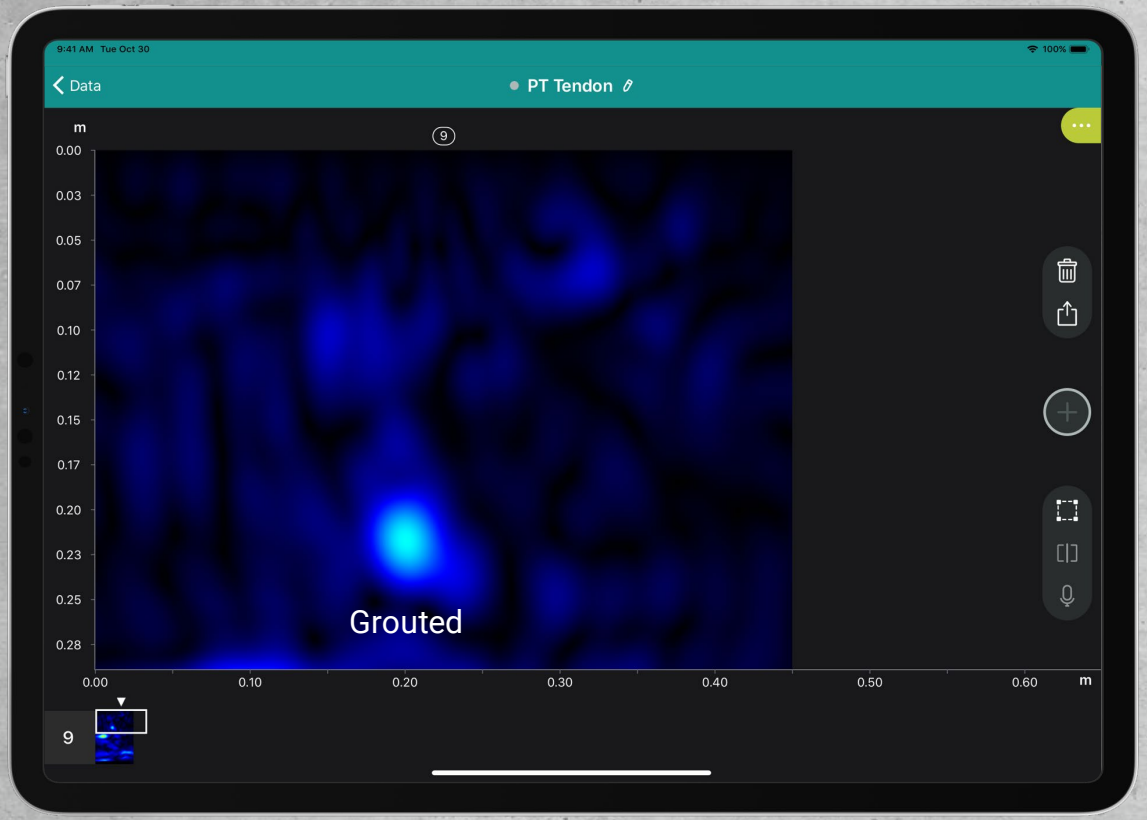
Ultrasound Pulse Echo (Pundit)

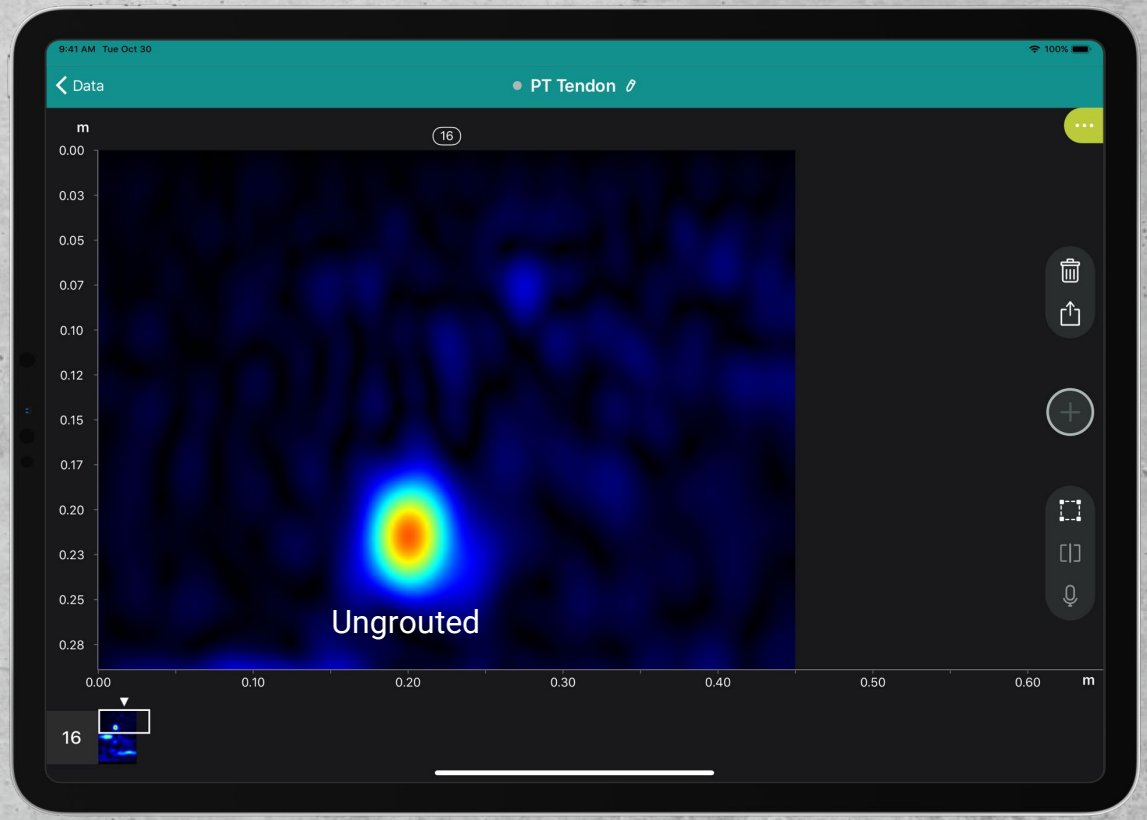


Locating, Mapping & Imaging

Ungrouted Post-tensioning Ducts

Ultrasound Pulse Echo (Pundit)





Locating, Mapping & Imaging

Ungrouted Post-tensioning Ducts

Image source: HTA Over 30 years as the UK's Structural Investigation Experts HENDERSON THOMAS ASSOCIATES LTD

Locating, Mapping & Imaging

Ungrouted Post-tensioning Ducts

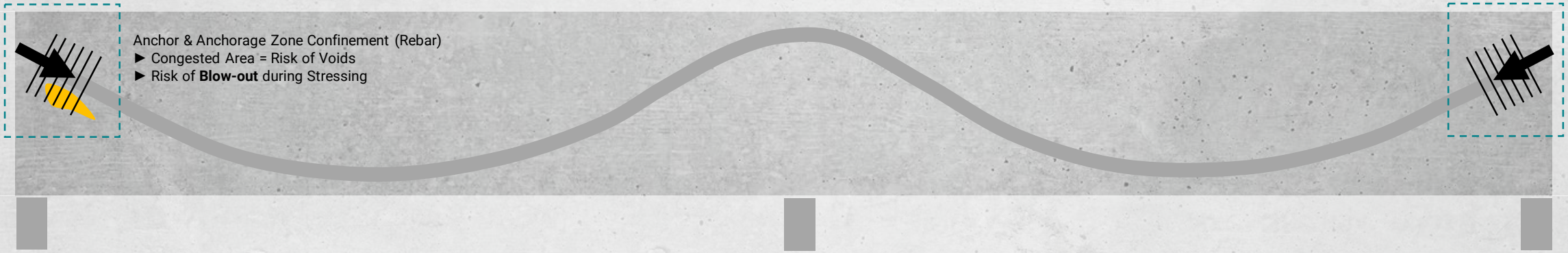
Properly Grouted
No Corrosion

Grouting Defect
Light Corrosion

Grouting Defect
Heavy Corrosion

Tendon failures will result in a full or partial **collapse** of the structure!

Voids in the Anchor Zone of Post-tensioning



Inspection Procedure

1… Scan various Anchor Zone locations ► **Ultrasound Pulse Echo (Pundit)**

Produce **comparable images:** same scan & image processing settings, similar line of sight of various Anchor Zones

2… Determine “anomalies” by **comparing images**

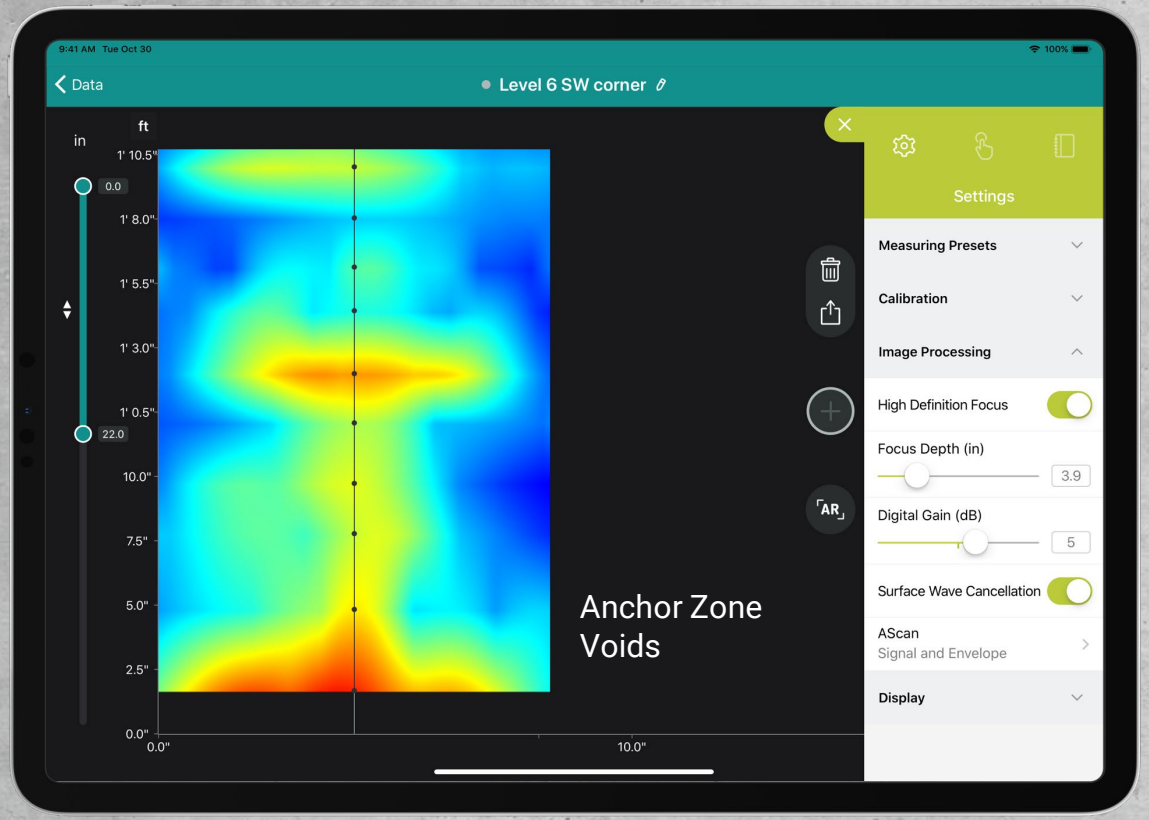
► no voids **= no reflection**

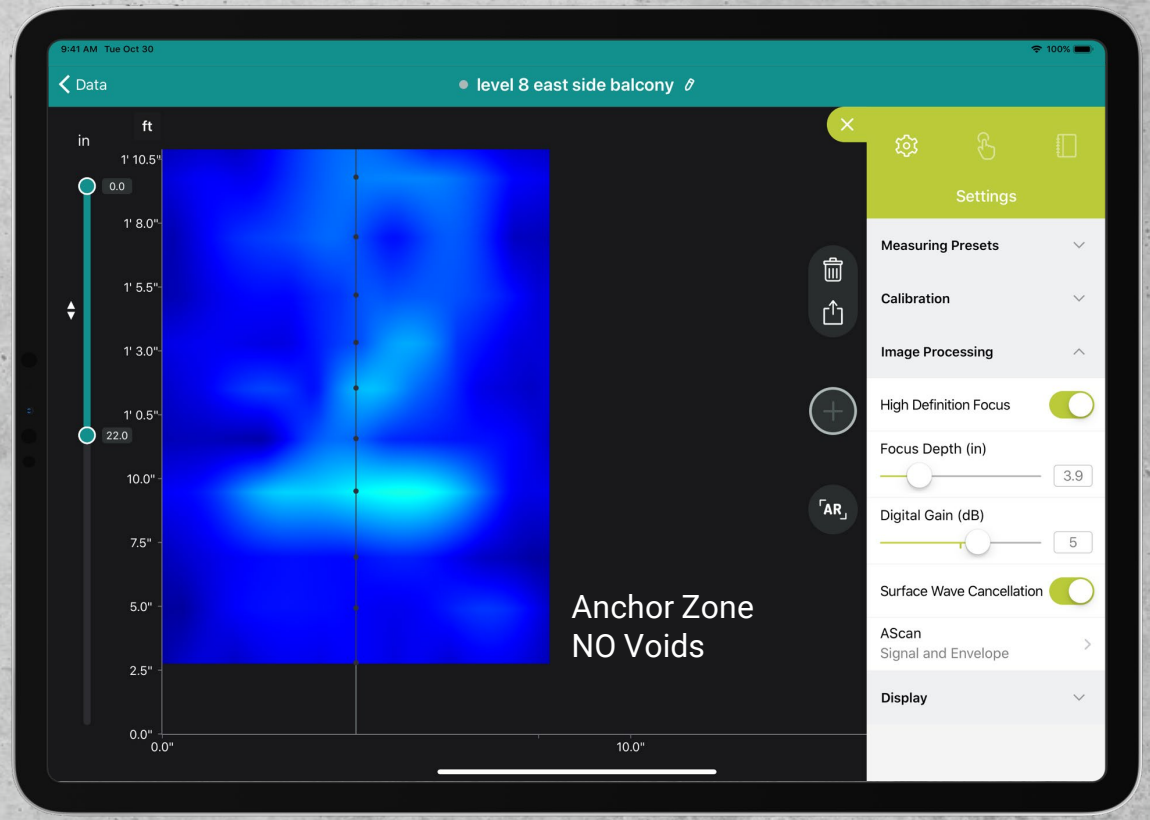
► voids **= strong reflection**

Locating, Mapping & Imaging

Voids in the Anchor Zone of Post-tensioning

Ultrasound Pulse Echo (Pundit)





Locating, Mapping & Imaging

Steel Fiber Concrete

Locating, Mapping & Imaging

Steel Fiber Concrete ► Ultrasound Pulse Echo (Pundit)

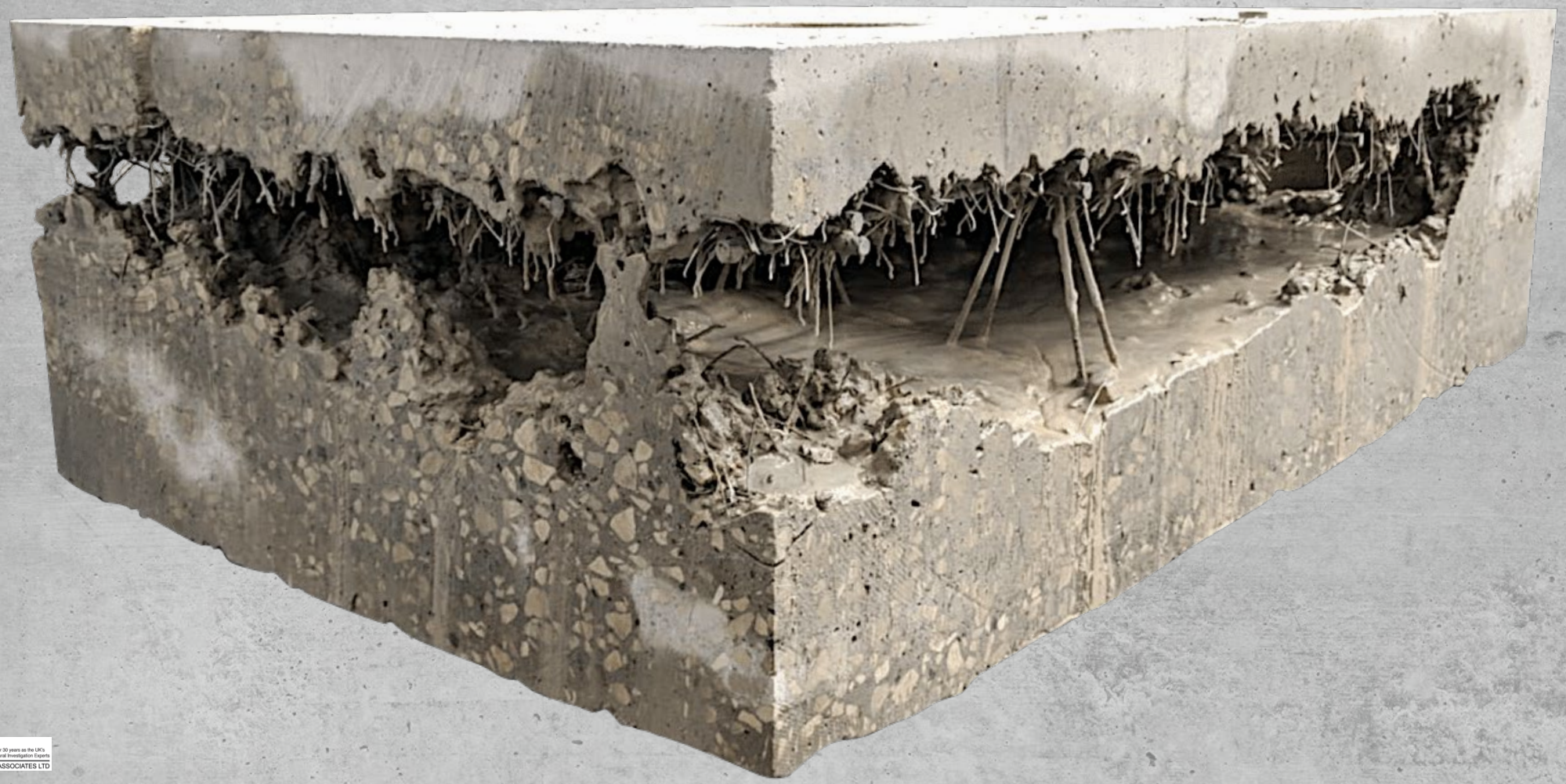
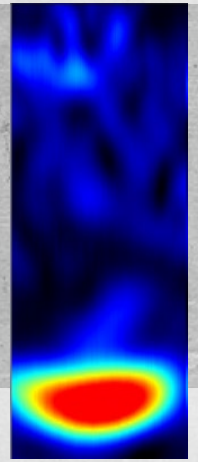
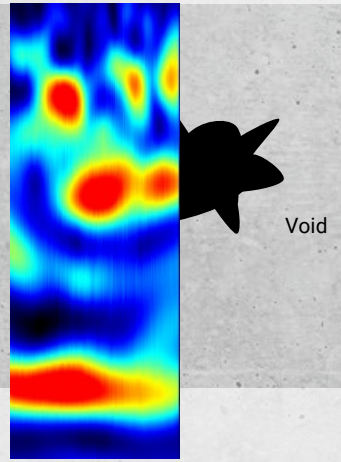


Image source: HTA Over 30 years as the UK's Structural Investigation Experts HENDERSON THOMAS ASSOCIATES LTD

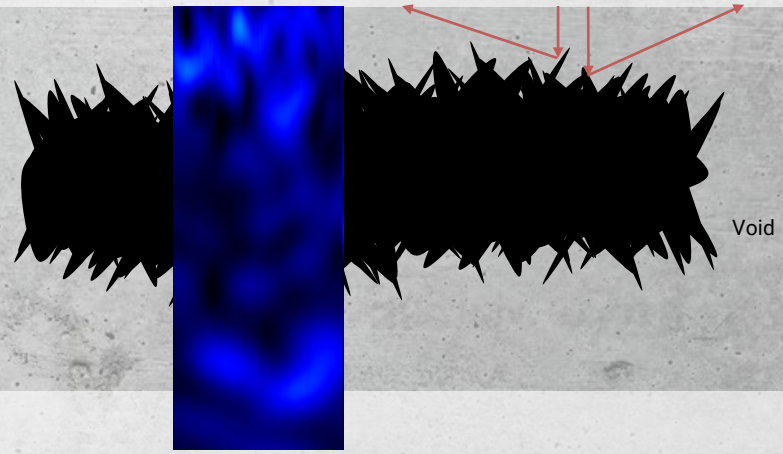
Steel Fiber Concrete



No Voids
Clean Backwall Reflection



Small Voids
Good Reflections



Large Voids
No Reflections!

Due to the rough surface of the voide
"Ultrasound Waves" bounce-off in all directions

Ground-Penetrating Radar (GPR)

- ► **Cannot** be used, because the steel fibres reflect the signal

Ultrasound Pulse Echo (Pundit)

- ► Is to be used, because Ultrasound can slice through the steel fibres
- ► Determine "anomalies" by **comparing images**

HOW to Inspect Concrete Structures?

Summary

HOW to Inspect Concrete Structures?

Visual Inspection | Vital Signs | Locating, Mapping & Imaging

Avoid **birth-defects** on new structures & perform **health-checks** during the service life

Visual Inspection

- surface condition ▶ basic assessment

Vital Signs of Concrete

- strength & uniformity ▶ structural strength
- homogeneity ▶ structural strength & protection of rebars
- permeability ▶ risk of rebar corrosion

Locating, Mapping & Imaging

- rebars, post-tensioning, cables, pipes (objects) ▶ structural elements correctly in place
- delamination, voids, honeycombing (defects) ▶ detect weak-spot & fight concrete cancer
- rebar cover & diameter ▶ protection of rebars & structural strength
- corrosion potential ▶ risk of rebar corrosion

HOW to Inspect Concrete Structures?

Visual Inspection | Vital Signs | Locating, Mapping & Imaging

Avoid **birth-defects** on new structures & perform **health-checks** during the service life

Visual Inspection

- surface condition ▶ **Digital Inspection (Inspect)**

Vital Signs of Concrete

- strength & uniformity ▶ **Rebound (Schmidt) / UPV (Pundit)**
- homogeneity ▶ **Ultrasound Pulse Velocity (Pundit)**
- permeability ▶ **Resistivity (Resipod)**

Locating, Mapping & Imaging

- rebars, post-tensioning, cables, pipes (objects) ▶ **Ground Penetrating Radar (Proceq GPR)**
- delamination, voids, honeycombing (defects) ▶ **Ultrasound Pulse Echo (Pundit Array)**
- rebar cover & diameter ▶ **Eddy Current (Profometer)**
- corrosion potential ▶ **Half-cell Potential (Profometer)**

HOW to Inspect Concrete Structures?

Visual Inspection

Surface Condition
Visual Inspection
Inspect

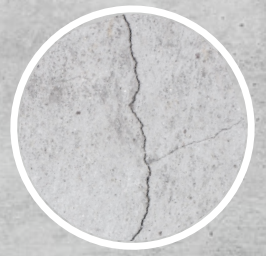
scaling

Surface Condition
Visual Inspection
Inspect

surface defect

Surface Condition
Visual Inspection
Inspect

concrete cancer



crack

Surface Condition
Visual Inspection
Inspect

HOW to Inspect Concrete Structures?

Vital Signs of Concrete

Strength & Uniformity
near surface property

Schmidt

Rebound

Homogeneity
through thickness property

Pundit UPV

Ultrasound Pulse Velocity

Permeability
near surface (rebar cover) property

Resipod

Resistivity

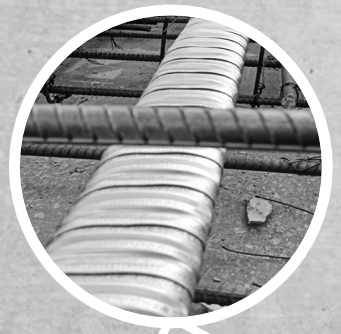
- Complimentary: **Profometer**
  avoid measuring over rebars

HOW to Inspect Concrete Structures?

Locating, Mapping & Imaging

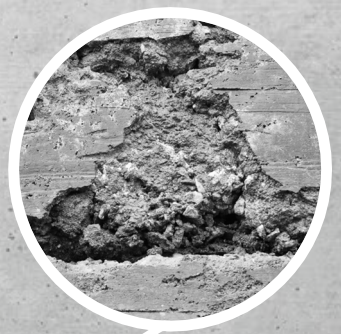
Rebars

Objects



Thickness

Defects



Profometer

1st and 2nd layer rebars
Cover, Diameter & Corrosion

Proceq GPR

Depth: 0 to < 80 cm

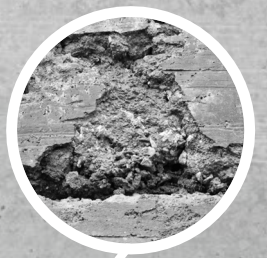
Pundit Array

Depth: 0 to > 200 cm

HOW to Inspect Concrete

Visual Inspection | Vital Signs | Locating, Mapping & Imaging

Surface Condition | Strength & Uniformity | Homogeneity | Permeability | Rebars | Objects | Thickness | Defects



Ungrouted PT Tendons

Steel Fiber Concrete

Inspect
Visual

Schmidt
Rebound

Pundit UPV
Ultrasound Pulse Velocity

Resipod
Resistivity

Profometer
1st and 2nd layer rebars
Cover, Dimeter & Corrosion

Proceq GPR
Depth: 0 to < 80 cm

Pundit Array
Depth: 0 to > 200 cm

HOW to Inspect Concrete Structures?

Multi-Technology Approach

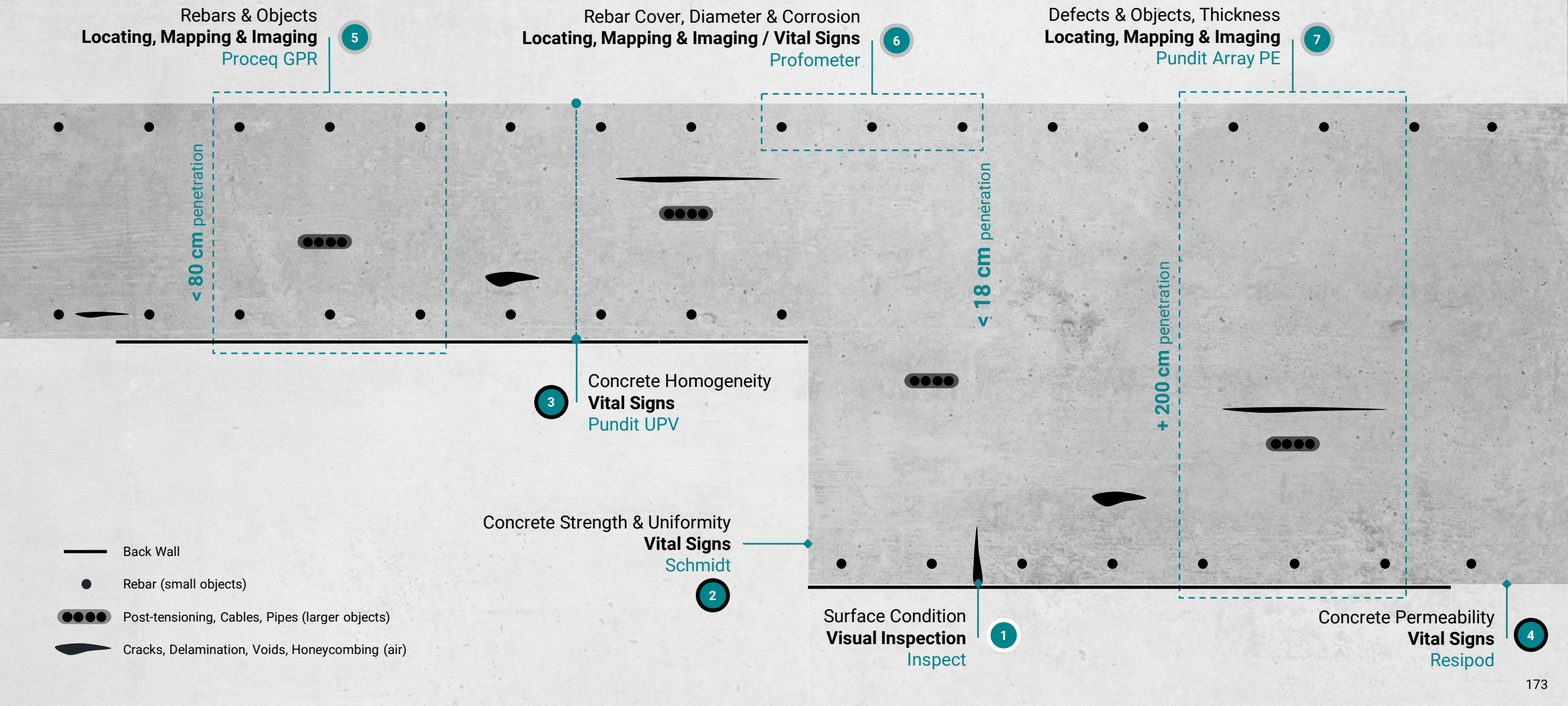
*"…there is **no single technology** that would address it all. The **multi-technology approach** is not an option, it is an **absolute must**."*

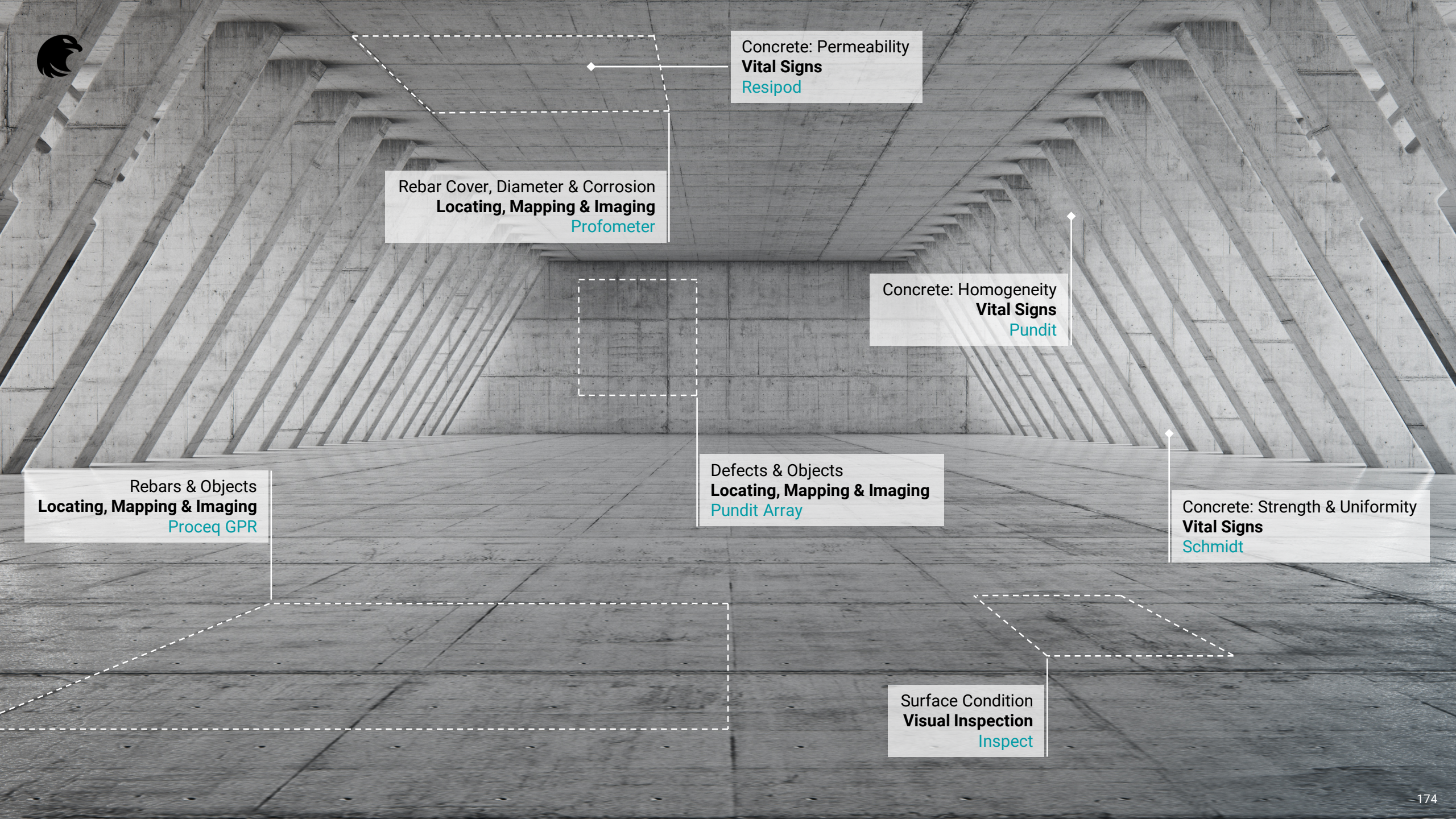
Warren Thomas (Director at HTA)
HTA is a leading Structural Investigation Group operating in England, Scotland and Ireland

HTA Over 30 years as the UK's Structural Investigation Experts
HENDERSON THOMAS ASSOCIATES LTD

HOW to Inspect Concrete Structures?

Multi-Technology Approach



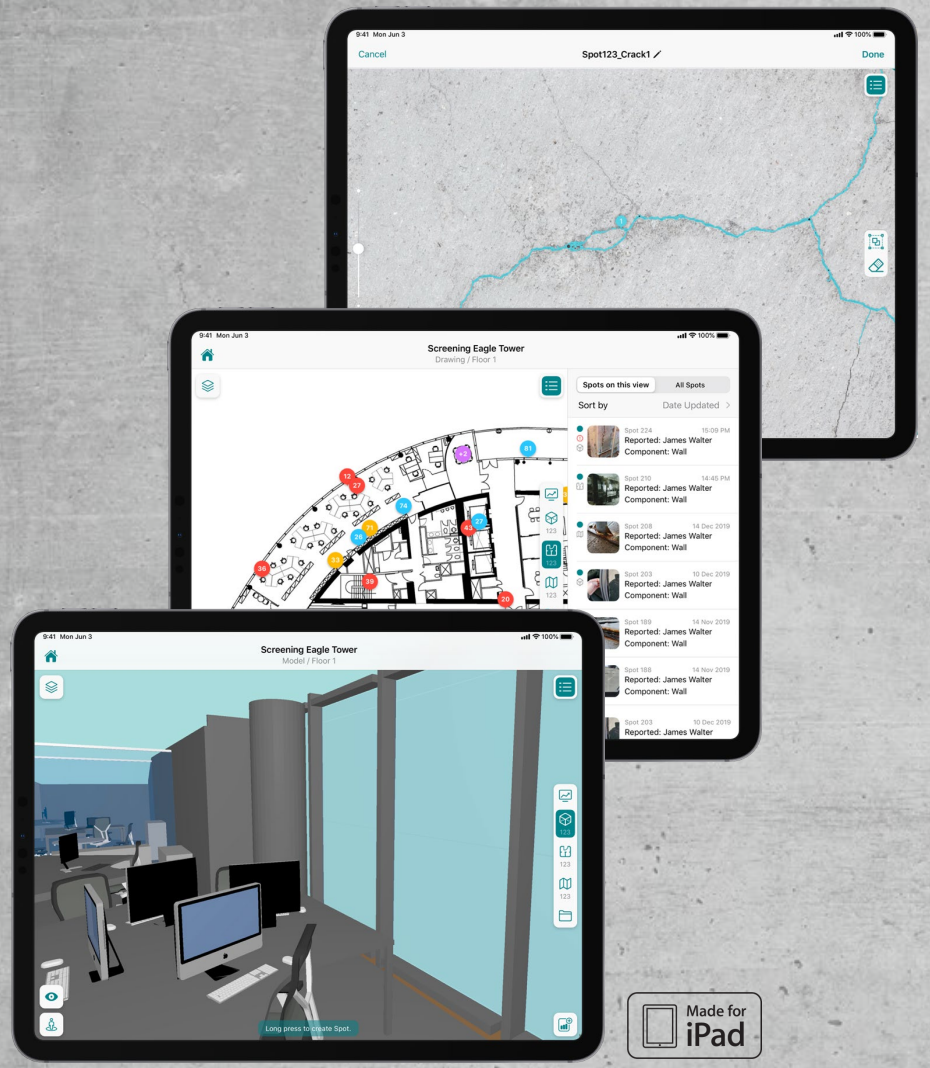

Concrete: Permeability
Vital Signs
Resipod
Rebar Cover, Diameter & Corrosion
Locating, Mapping & Imaging
Profometer
Concrete: Homogeneity
Vital Signs
Pundit
Rebars & Objects
Locating, Mapping & Imaging
Proceq GPR
Defects & Objects
Locating, Mapping & Imaging
Pundit Array
Concrete: Strength & Uniformity
Vital Signs
Schmidt
Surface Condition
Visual Inspection
Inspect

inspect

inspect proceq pundit schmidt profometer

HOW to Inspect Concrete Structures?

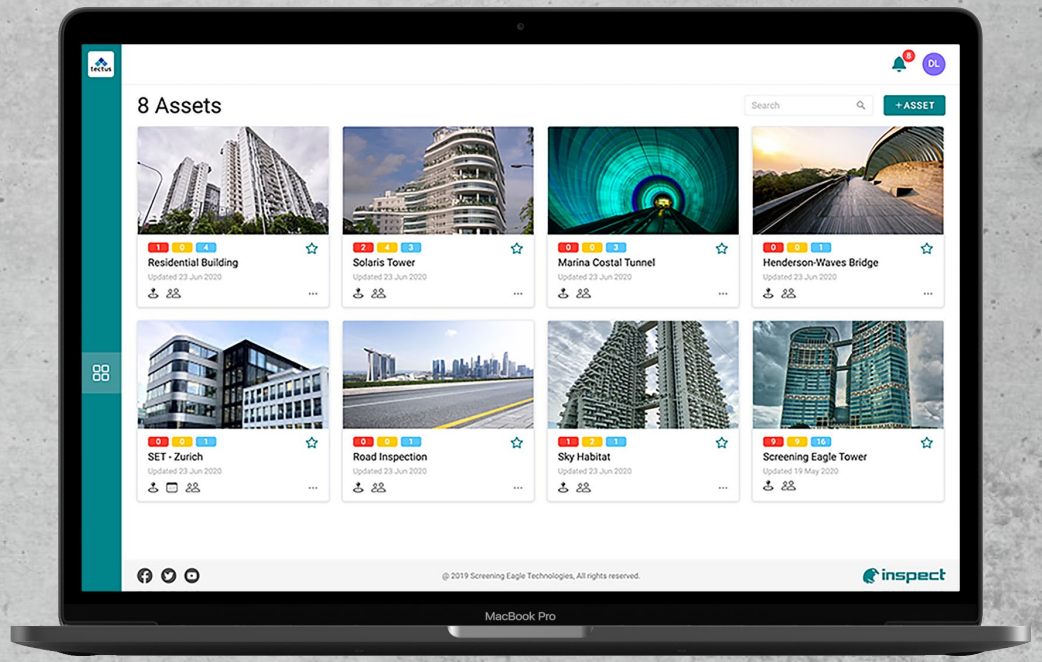
Screening Eagle Inspect is at the Core of ALL Inspections



Made for iPad

Download on the App Store

Screening Eagle Inspect



HOW to Inspect Concrete Structures?

Screening Eagle Inspect is at the Core

In-depth

Imaging

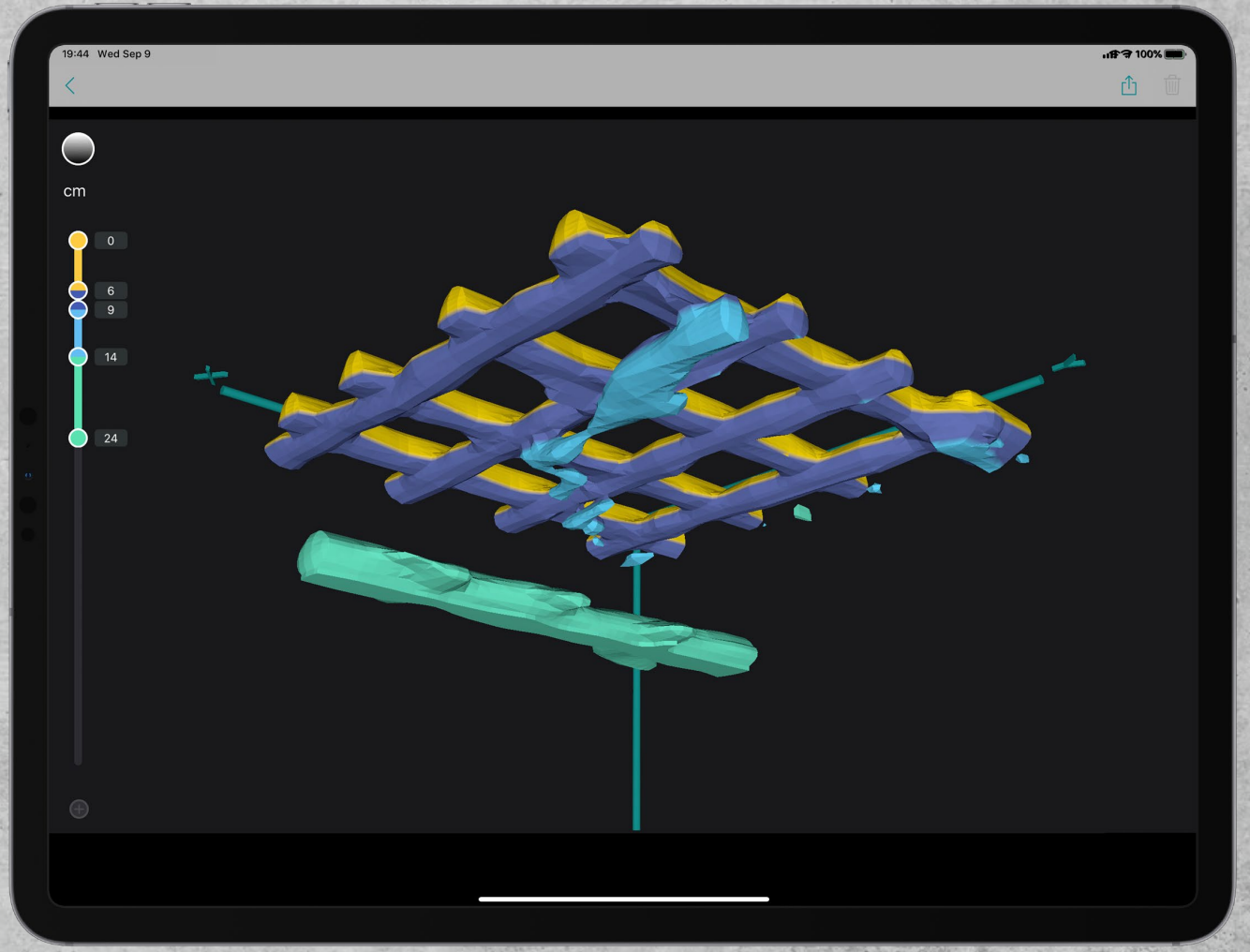
- NDT data
- Quick view of sensor data
- Include valuable information in report

Benefits

✓ Data quality

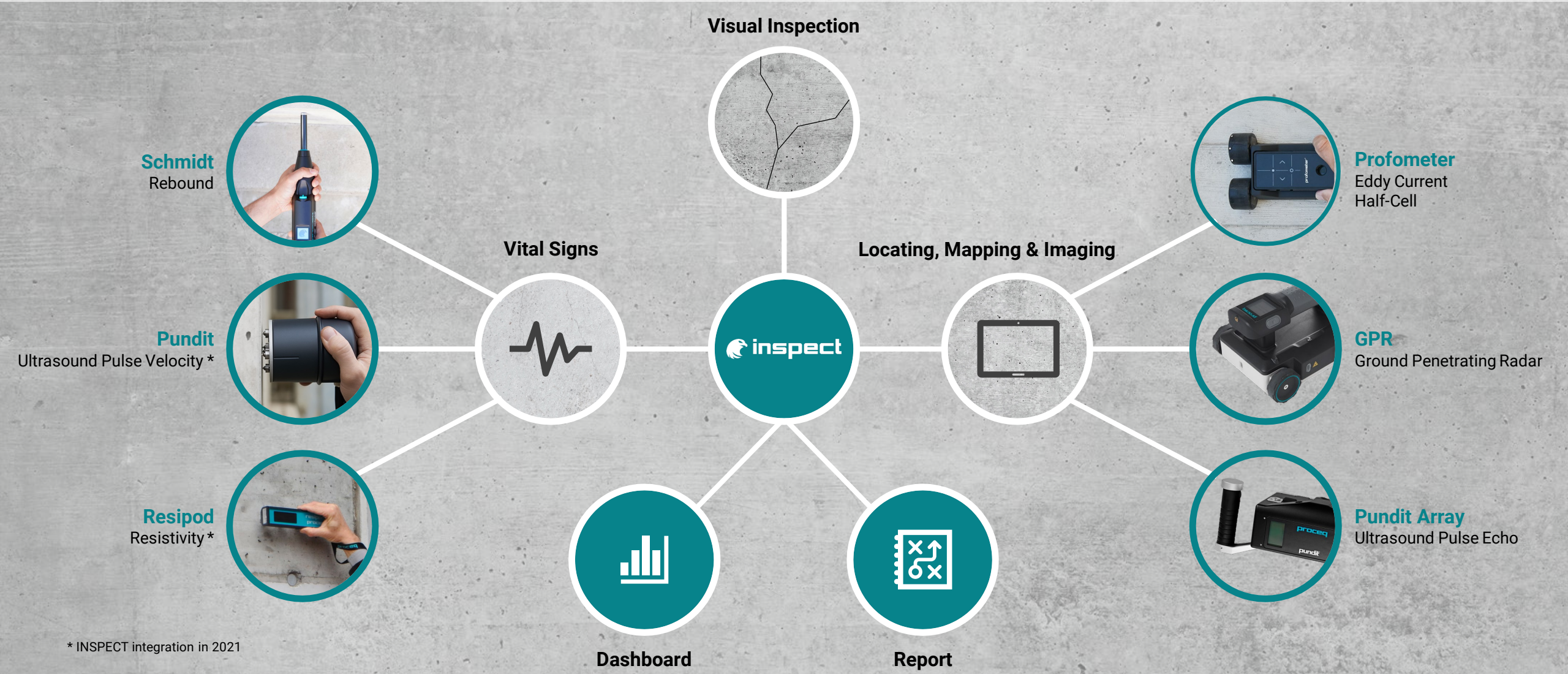
✓ Complete analysis

✓ Better visualization



HOW to Inspect Concrete Structures?

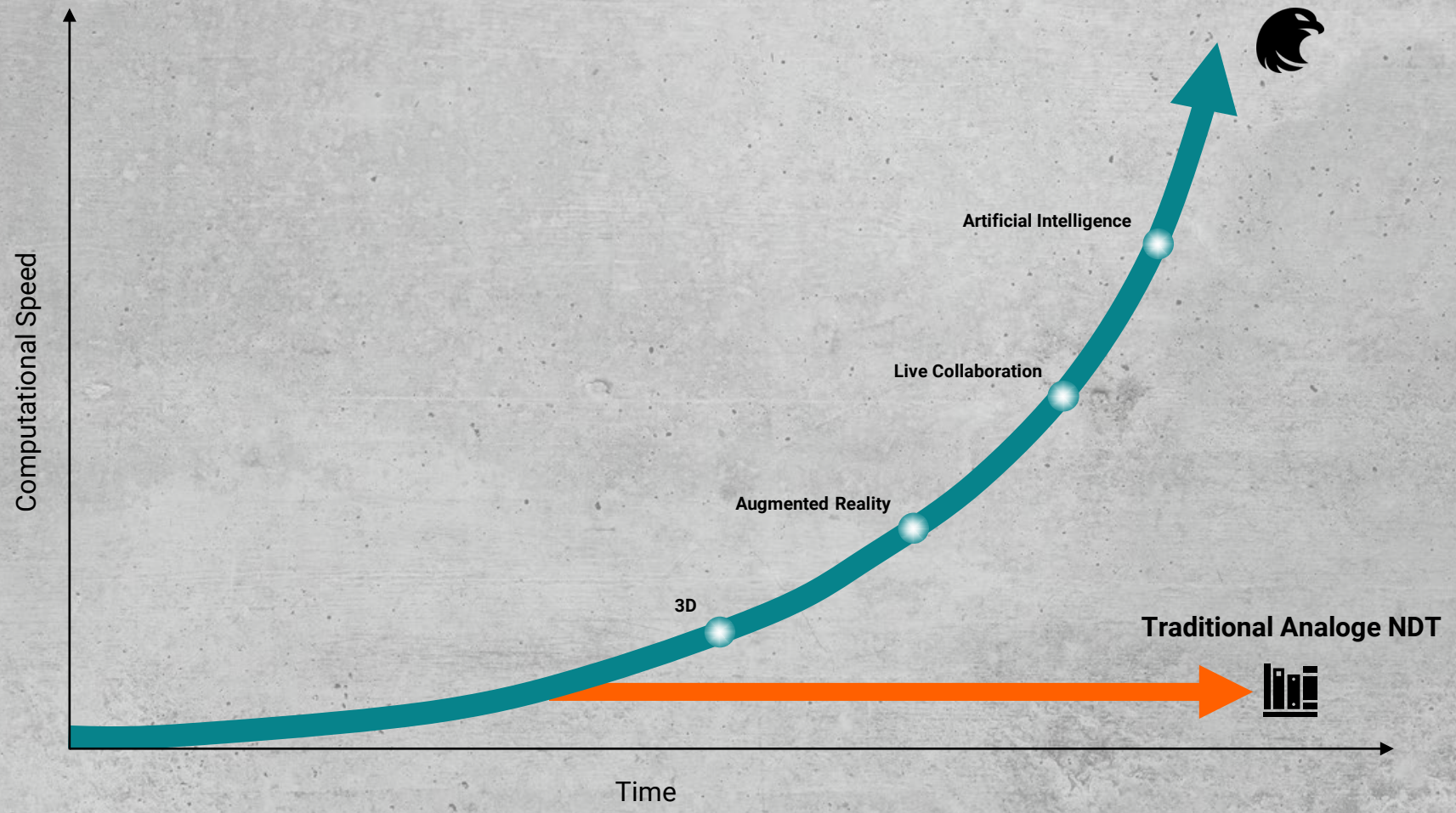
Screening Eagle Inspect is at the Core



* INSPECT integration in 2021

HOW to Inspect Concrete Structures?

Exponential Capabilities



Infrastructure & Asset Inspection – Concrete Structures

WHO are our Customers?

Selected Customers

Construction & Engineering

China State Construction Engineering Corp. (China)
Revenue: $139 billion

China Communications Construction Group (China)
Revenue: $60 billion

VINCI (France)
Revenue: €49 billion

Bouygues (France)
Revenue: €37 billion

ACS Actividades de Construcción y Servicios (Spain)
Revenue: €38 billion

Power Construction Corp. of China (China)
Revenue: $29 billion

Bechtel Group (USA)
Revenue: $26 billion

Hochtief Aktiengesellschaft (Germany)
Revenue: €25 billion

Fluor Corporation (USA)
Revenue: $20 billion

Larsen & Toubro (India)
Revenue: $20 billion

AECOM (USA)
Revenue: $18 billion

Skanska (Sweden)
Revenue: $18 billion

Obayashi (Japan)
Revenue: $17 billion

Strabag (Austria)
Revenue: €15 billion

Hyundai Engineering & Construction (South Korea)
Revenue: $15 billion

Jacobs Engineering Group (USA)
Revenue: $15 billion

TechnipFMC (United Kingdom)
Revenue: $13 billion

Turner Construction (USA)
Revenue: $12 billion

Kiewit Corporation (USA)
Revenue: $8 billion

WSP Global (Canada)
Revenue: $7 billion

Selected Customers

Universities

- National University of Singapore (Singapore)
- Nanyang Technological University (Singapore)
- Hong Kong University of Science and Technology
- The Hong Kong Polytechnic University
- The University of Hong Kong
- University of Tokyo (Japan)
- Shanghai Jiaotong University (China)
- Tongji University (China)
- Korea Advanced Institute of Science & Technology
- Southeast University (China)
- Cambridge (UK)
- Swiss Federal Institute of Technology
- University of Oxford (UK)
- Delft University of Technology (Netherlands)
- Imperial College London (UK)
- Politecnico di Milano (Italy)
- EPFL Lausanne (Switzerland)
- Universitat Politècnica de Catalunya (Spain)
- Politecnico di Torino (Italy)
- Universidad Politécnica de Madrid (Spain)
- University of Texas at Austin (USA)
- Georgia Institute of Technology (USA)
- University of Illinois- Urbana-Champaign (USA)
- Purdue University - West Lafayette (USA)
- University of Michigan - Ann Arbor(USA)
- Pontifical Catholic University of Chile (Chile)
- University of São Paulo (Brazil)
- University of Campinas (Brazil)
- Federal University of Minas Gerais (Brazil)
- University of the Andes (Colombia)

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