Testing Techniques

Cover Metre Surveys **BS 181-204;1988**

HTA use 2 models of cover metres to aid with Structural Investigations:

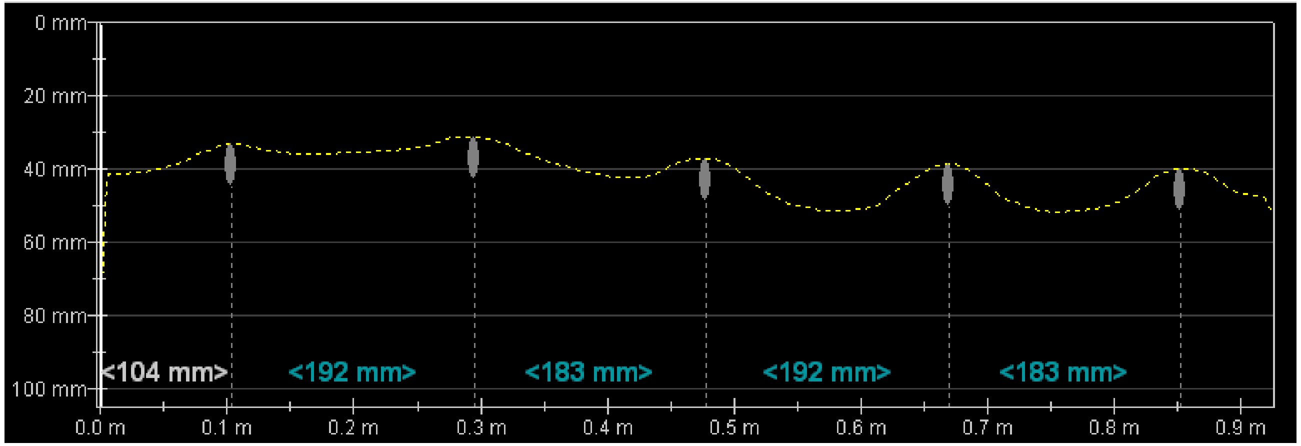
Proceq 650AI:

The Proceq 650AI is a logging cover meter using Eddie current technology. HTA have used this cover meter with good success to undertake accurate results across large areas in reduced time in comparison to traditional cover meters. An extension rod can be added to the unit (Approx 2m) which helps to overcome access issues.

The cover meter can be used in single line mode where centres and depths are recorded in just one direction. To create a full picture of reinforcement in both directions, area mode can create a computer generated image of reinforcement patterns/depths. Excel Data can also be downloaded from the cover meter, which in the past has been useful to our clients.

Proceq 650AI Single Line Mode Data Example

Longitudinal Reinforcement Survey



Reinforcement Details

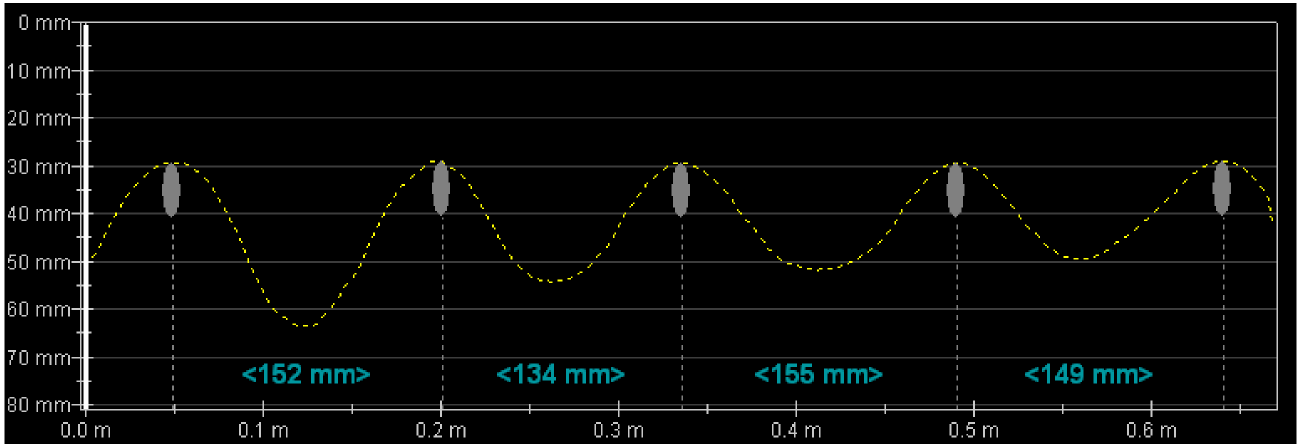
Statistics of Covers [Normal]

No. of Readings	5
Median (mm)	37.2
Mean (mm)	36.0
Standard Deviation (mm)	3.3
Lowest (mm)	31
Highest (mm)	40

Statistics of Rebar Spacing

No. of Readings	4
Median (mm)	187
Mean (mm)	187
Standard Deviation (mm)	5
Lowest (mm)	183
Highest (mm)	192

Transverse Reinforcement Survey



Reinforcement Details

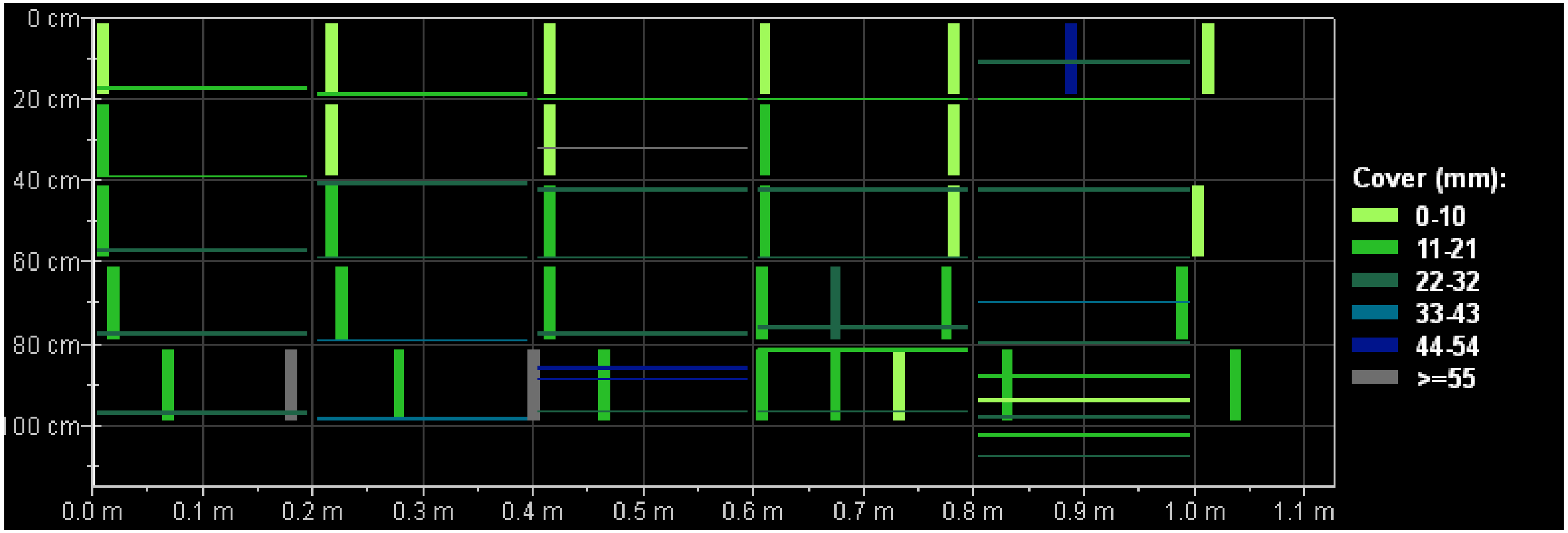
Statistics of Covers [Normal]

No. of Readings	5
Median (mm)	29.3
Mean (mm)	29.2
Standard Deviation (mm)	0.1
Lowest (mm)	29
Highest (mm)	29

Statistics of Rebar Spacing

No. of Readings	4
Median (mm)	151
Mean (mm)	148
Standard Deviation (mm)	8
Lowest (mm)	134
Highest (mm)	155

Proceq 650AI Area Scan Data Example



Snapshots	[Distance(m) Cover(mm)]			
(mm mm mm)	**LX:1**	[0.801 10.4]	[0.829 16.1]	[0.609 28.7]
	[0.012 9.9]	[1.024 10.1]	[1.036 16.6]	[0.795 30.6]
	[0.219 5.7]	**LX:4**	**LY:1**	[0.881 49.4]
	[0.417 5.5]	[0.043 17.7]	[0.177 17.4]	[0.908 47.2]
	[0.613 6.3]	[0.250 16.9]	[0.393 21.7]	[0.987 31.9]
	[0.783 6.7]	[0.439 19.6]	[0.576 26.2]	**LY:4**
	[0.890 54.6]	[0.631 16.7]	[0.780 29.4]	[0.210 21.0]
	[1.015 7.7]	[0.698 23.3]	[0.975 29.5]	[0.433 25.1]
	LX:2	[0.798 14.7]	**LY:2**	[0.600 27.3]
	[0.024 13.4]	[1.012 14.2]	[0.189 20.8]	[0.771 25.3]
	[0.232 9.6]	**LX:5**	[0.408 24.1]	[0.826 19.9]
	[0.430 8.8]	[0.067 19.6]	[0.591 28.1]	[0.978 32.5]
	[0.625 12.1]	[0.180 61.3]	[0.795 33.0]	**LY:5**
	[0.795 9.1]	[0.277 18.6]	[0.987 34.3]	[0.049 32.7]
	LX:3	[0.399 60.5]	**LY:3**	[0.140 20.8]
	[0.030 14.8]	[0.463 20.9]	[0.015 16.2]	[0.363 22.7]
	[0.238 13.3]	[0.606 19.8]	[0.219 19.6]	[0.530 23.0]
	[0.436 12.0]	[0.673 14.8]	[0.338 60.8]	[0.640 33.6]
	[0.631 13.3]	[0.731 8.0]	[0.442 23.8]	[0.737 25.9]

Comment

[Add]

Device Info

Statistics of Covers [Normal]

Scan Direction	[X, Y]
No. of Readings	[35, 36]
Median (mm)	[14.2, 25.2]
Mean (mm)	[17.2, 27.0]
Standard Deviation (mm)	[13.6, 9.7]
Lowest (mm)	[6, 9]
Highest (mm)	[61, 61]

Settings

Measuring Range	Standard (None)
Rebar Diameter Ø1 Scan-X (mm)	12
Rebar Diameter Ø2 Scan-Y (mm)	12
Artificial Intelligence / Neighboring Rebar Correction	☐
Cover Calibration	☐
Minimum Cover	☐
Minimum Cover Value (mm)	-
Maximum Cover	☐
Maximum Cover Value (mm)	-
Cover Offset	☐
Cover Offset Value (mm)	-
Align Rebar Positions	☑
Line Height (cm)	20
Grid Width (cm)	20
Probe Position	—
Scan Cart	Ruggedized

Profoscope:

The profoscope is a singular unit cover meter which HTA use to locally determine locations of reinforcement without the need to log the information. Both the Profometer 650AI and the Profoscope have bar diameter detection technologies, however through our experience the Profoscope is superior in terms of accuracy for this particular application.

To determine approximate bar diameters non-destructively the bar under investigation must be over around 80mm away from any neighbouring steel i.e. would not be possible to detect twin bar diameters. For an assessment of a structure we would only advise using diameter detection as a guide and could reduce the number of intrusive breakouts required depending on accuracy of calibration results.

Please note that the only way to determine the type of reinforcement within a structure is to breakout and expose the reinforcement.

<u>Intrusive Breakouts to Expose Reinforcement</u> **HTA IN HOUSE PROCEDURES**

To determine the bar type and diameter of embedded reinforcement a breakout to expose the steel is required. The following techniques are used:

- Locate reinforcement using either a Cover Meter or Ground Penetrating Radar. Mark on the locations with chalk.
- At the intersection where 2 bars cross a square cut (approx. 100mmx100mm) using a Hilti angle grinder is made into the concrete.
- Using a Hilti TE-60 hammer action drill, the concrete is locally removed using a chisel until the reinforcement is exposed. Experienced operatives will ensure that no damage is caused to the reinforcement.
- Details are obtained using depth gauges and callipers to determine cover and bar diameters.
- Photographs are taken on site at each intrusive location.

Square Cutting Breakout

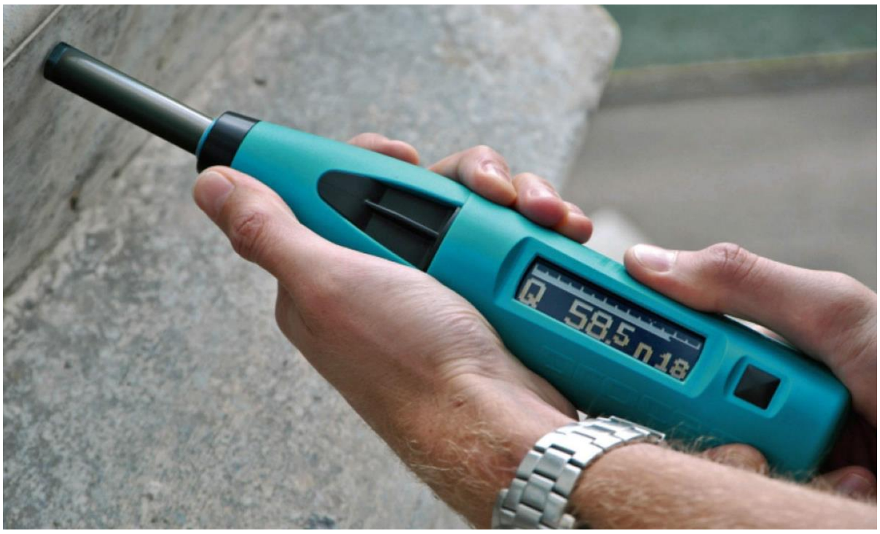

Chiselling to expose re-bar


Exposure of reinforcement

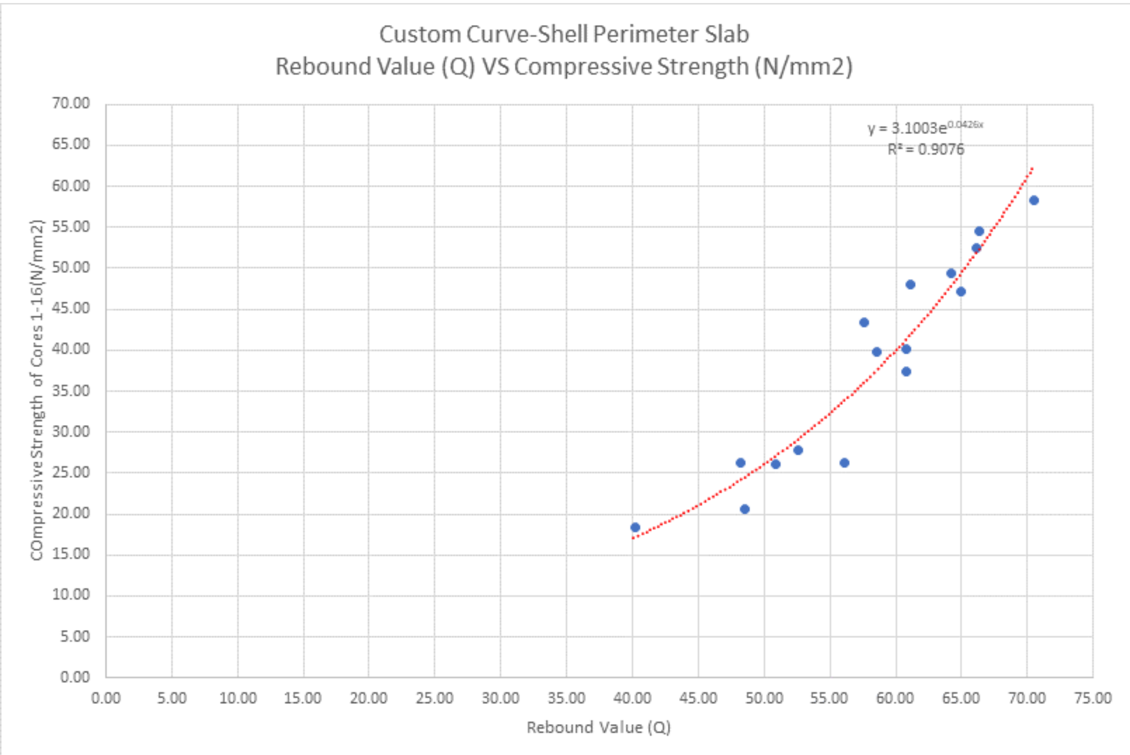
Determine Concrete Strength: **SCHMIDT = EN 12504-2-2012**

CORE TESTING: BS EN 12504-1: 2009

To identify the true compressive strength of hardened concrete, cores must be extracted from the structure and tested in a UKAS accredited laboratory. Schmidt Hammer Testing can also be carried out to Non-Destructively determine an approximation of concrete Strength. HTA use a Proceq Silver Schmidt hammer where 10 No readings are taken at each location and an average is calculated.



From our experience we recommend extracting cores along side Schmidt hammer hardness readings in order to create a custom curve for the concrete under investigation. This allows strength determinations throughout large areas and able to reduce the number of cores extracted. See below an example of a curve created on a previous project:



See below the methodologies used to extract concrete cores for compressive strength:

- Using either a cover meter or GPR device the location of reinforcement is marked on the concrete. This is to avoid cutting any steel during the coring process.
- Using a Hilti DD120 or similar rig, a hilti nugget is drilled into the concrete (15mm diameter) which anchors the coring rig.
- The diameter of core will vary dependant upon reinforcement centres, however usually 100mm or 75mm diameter is standard.
- Once cutting, the core requires a water flush system. HTA now use a Hilti water management system which recirculates the water and produces no ‘mess’, so ideal for working within buildings. This system can be used vertically up/down and horizontally.
- The required length of core required is 1.0 ratio from length to diameter, therefore on site we extract approximately 20mm longer than the diameter of the core barrel. This ensures that the laboratory can cap the core at a length:diameter ratio of 1:1.

See below a picture of a core being extracted using Hilti Water Management1:

<u>Ground Penetrating Radar (GPR) Techniques</u> EN 302066 - ETSI

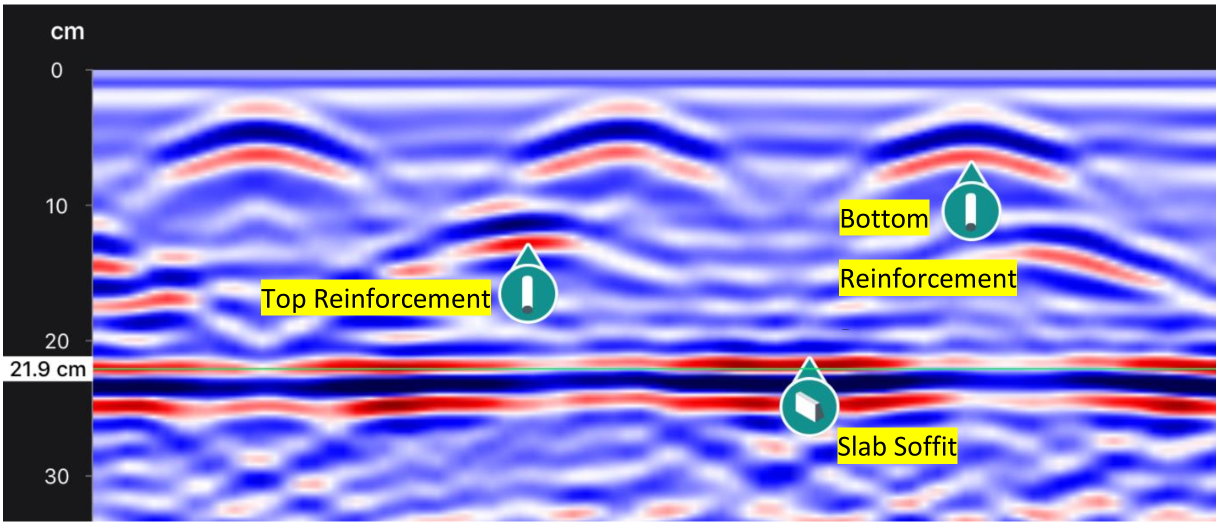
HTA use 2 No types of Ground Penetrating Radar units specifically designed for concrete structures:

GSSI Structure Scan Mini XT

Proceq GPR Live

HTA have regularly been using GPR to locate embedded elements within concrete i.e. reinforcement, Post Tensioning Ducts, Plastic Pipes etc. The GPR can detect any material that has a different density to concrete with accurate results.

HTA also use GPR to determine slab thickness and void detection. The GSSI Structure Scan Mini XT penetrates to a maximum depth of 500mm and the Proceq GPR Live penetrates to a maximum depth of 700mm. See below an example of GPR determining slab thickness' and reinforcement details:



The above scan was carried out to the soffit of a reinforced concrete slab.

Determine Tensile Strength/Grade of Steel **BS EN ISO 6892**

To determine the true tensile strength of reinforcement a sample will need to be extracted, and to completely apply to the above standard the length of re-bar required should be 600mm or 20x diameter of bar. However due to constraints within structures this is very rarely applied and it is standard to remove a sample of approximately 100-200mm in length. These lengths of reinforcement can still be tested in a UKAS lab to give accurate tensile/grade and ductility results as required.

Site conditions may dictate when the larger samples would be required (should exposed reinforcement be found to be cold worked i.e. square twisted), larger samples will need to be extracted as a 10-15% increase in tensile strength could be reported than if the sample was 100-200mm in length.

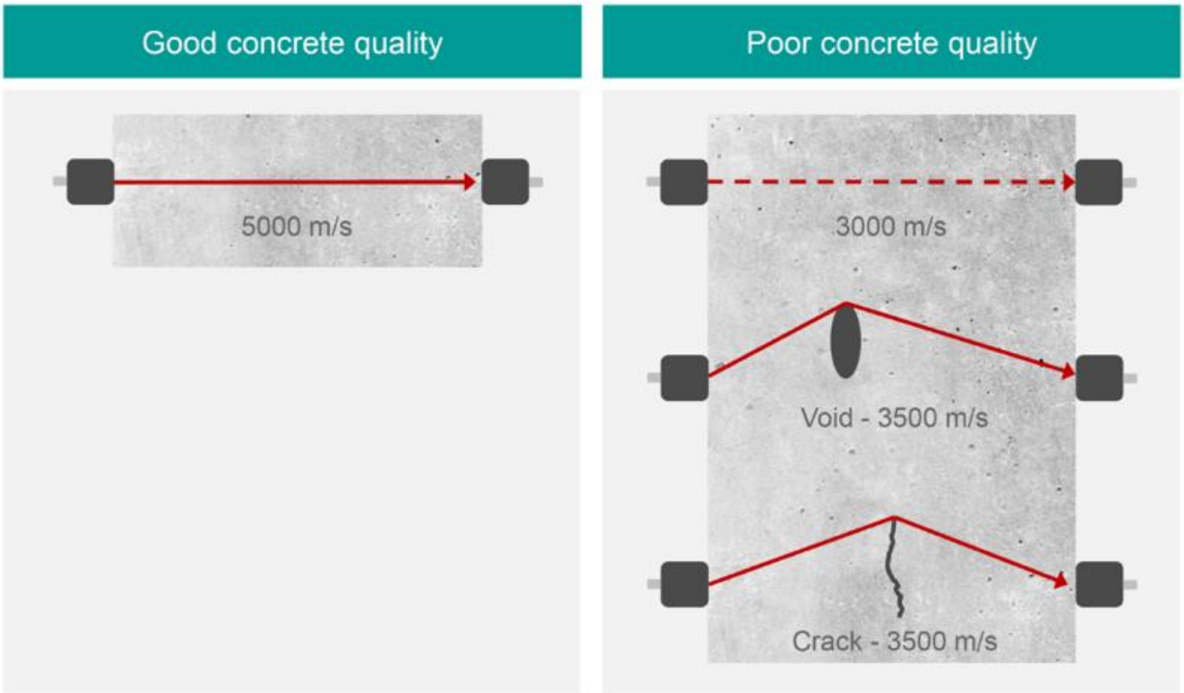
The 2 No methods of extracting the steel samples are to either cut a core directly through the reinforcement or locally break out the concrete and cut the bar out using an angle grinder. Should the reinforcement need to be repaired this can be carried out.

Ultrasonic Pulse Velocity/Concrete Quality **BS EN 12504-4:2004**

To determine the concrete quality/density of the concrete non-destructively HTA use 2 No instruments:

Pundit Lab:

This technique sends Ultra Sonic Waves through concrete from 1 No Transducer to another. The speed of the waves gives a good indication of the quality of the concrete. Where voids/cracks are encountered the waves will travel around them and therefore takes longer to travel between transducers. See the image below which explains the process:



From our experience the only effective way is to carry out the testing using the 'direct method' which requires access to both faces of the concrete under test. This works well for columns/beams but not for slabs/retaining walls etc. For this application the Pulse Array Live can be utilised. See below a picture of HTA using the Pundit Lab within cells of a Post Tensioned Bridge.

Pulse Array Live:

The pulse array live has only recently come to market and HTA have been assisting Proceq to carry out on site Trials with the technology. HTA have been using this equipment this year on projects to determine concrete quality and detect voids i.e. honeycombing.

The Pulse array only needs to be placed on 1 No face of the concrete under investigation and creates live imaging for the operative visually on site. The Pulse Array is superior to GPR for detecting small voids, whereas GPR detects steel and other objects better, so work well together.

See below an image of HTA using the Pulse Array to detect potential voids within post-tensioned ducts on a project in Ireland:

Concrete Testing

As we understand exposure of reinforcement within various concrete elements is required and HTA would recommend carrying out some condition testing as part of the scope for minimal additional costs. See below the suite of tests that HTA can offer:

Cover Meter Surveys: **BS 181-204;1988**

Using both electromagnetic cover meters and ground penetrating radar technology HTA can carry out cover meter surveys to detect the following:-

Minimum cover readings based upon a designated grid system (normally 500mm or 250mm grid) to ascertain which reinforcing bars within a test area are most likely at risk from corrosion due to reduced levels of concrete cover. Readings require calibration against an actually exposed reinforcing bar which is normally required for other NDT testing.

Spacings of reinforcement and changes in size of reinforcement can also be obtained by the technology discussed above. One major issue is if you require to know the definitive diameter and type of reinforcement this cannot be determined by NDT techniques alone. As discussed above a calibration breakout of the reinforcement in question is required.

Half-Cell Potential Surveys: **ASTM C876-17**

Half-cell potential surveys can identify areas where reinforcement corrosion is most likely to occur without having to remove the cover concrete.

A quick and easy test method to carry out on reinforced concrete. Using the exposed reinforcement as discussed above, the techniques require a high impedence voltmeter (calibrated) a half cell and connections to the reinforcement. Readings are recorded in millivolts (mV). Generally the more negative the reading the higher probability of corrosion occurring at the time of the survey.

However there are certain limitations and possible causes of error, which need to be taken into consideration. In HTA's experience the most common is saturated concrete. Results are normally presented as a contour plot, and the ASTM C876:2017 gives criteria for interpreting results.

Linear Polarisation: **CONCRETE SOCIETY TECHNICAL REPORT 60**

Early detection of corrosion rates can aid client/owners of structures to help produce the correct remedial / reinstatement measures and effectively save expenditure.

Using Linear Polarisation surveys (measurement of the polarisation resistance of reinforcement) is one of the limited surveys that will directly assess corrosion rates. Although well tried and tested the technology is rarely used due to absence of knowledge unlike half-cell potential and resistivity surveys which are used regularly.

Polarisation resistance (corrosion rate) can be measured at locations on concrete structures using either portable equipment or retrofitted probes. With a three electrode system which HTA use, a reference electrode measures the potential changes induced in the reinforcement by a current introduced into the concrete through an auxiliary electrode.

Readings are taken in a very similar manner to half-cell potential surveys with a connection to embedded reinforcement required. The equipment will then record a half-cell reading after which the linear polarisation reading is taken. The later taking 60 seconds.

Corrosion rates are recorded as µm/year and classification of corrosion rates are detailed in Concrete Society Technical Report 60.

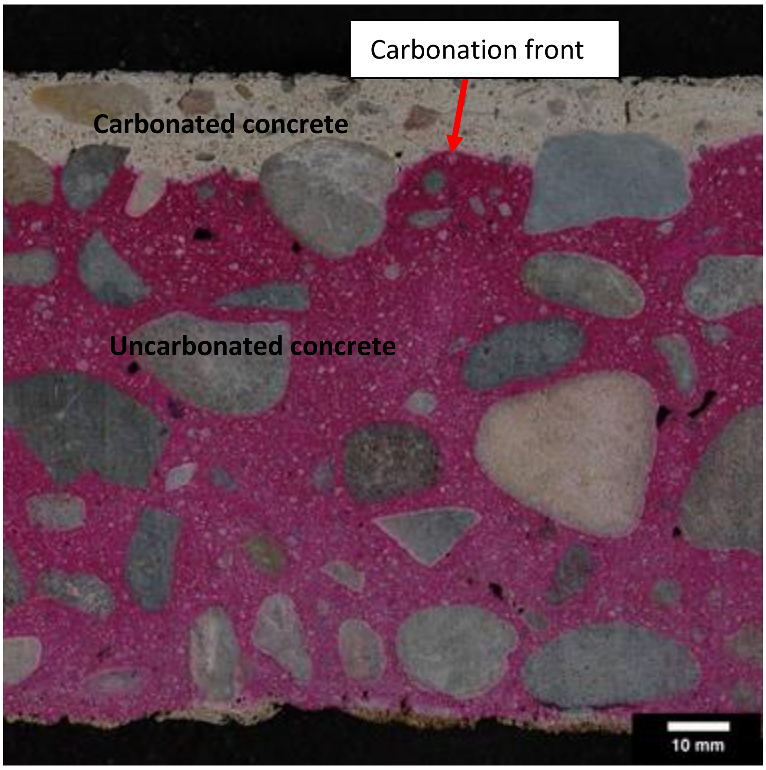
The major advantage of using Linear Polarisation readings is that on a saturated sections of concrete, normally located beneath defective bridge joints / splash zones and/or marine of damp environments (swimming pools, jetties, dams etc) the use of half cell potential surveys will normally record highly negative potentials which will suggest a high rate of corrosion. However this is generally due to a lack of oxygen at the reinforcement level, where corrosion rates will actually be low. Linear polarisation will more accurately determine these corrosion rates and allow the correct repair strategy to be adopted and avoid costly unnecessary repairs.

Depth of Carbonation: **BS EN 14630:2006**

Concrete is an alkaline material. The alkalinity produces a protective film around the embedded reinforcement within, which will protect the reinforcing bar from corrosion.

The protective film surrounding the reinforcement can be broken down by a number of processes. One of them being due to the alkalinity of the concrete being reduced due to the absorption of carbon dioxide gas, known as carbonation. The carbon dioxide gas ingressing into concrete produces a reduction in the protective alkalinity of the concrete, and given the right conditions will allow the bars to actively corrode.

The depth of carbonation can be determined by spraying an indicator solution (1% phenolphthalein solution) on to a freshly fractured face of concrete. The solution will react with an alkaline concrete to form a pink colour, however changes to a low pH will produce a clear result. An example is given in the attached photo.



Chloride Determination: **BS EN 14629:2004**

The highly alkaline conditions at the reinforcement/concrete interface produces a passive film on the surface of the reinforcement. Free chloride ions can locally breakdown this protective film and allow corrosion to occur. It is important to ascertain the source of the chlorides, normally either cast in at the time of construction or ingressed after construction (from de-icing salts or from marine exposure).

Chloride contents are normally expressed as a percentage by mass of concrete. Conversion to percentage by mass of cement can be made by an assumption of cement content or by actual chemical analysis. Determination of chloride levels is carried out by extraction of incremental drillings ensuring no contamination of samples occurs (accreditation by UKAS is a must).

A guide to the risk of corrosion due to chloride content in concrete is given in TRRL Research Report 93 (PR Vassie) and from the Concrete Society TE60, stating the following:-

Chloride % by weight of cement	Risk of Corrosion
>1.0	High
0.4 – 1.0	Moderate
<0.4	Low

Care must be taken when discussing chloride contents if high levels of carbonation occur at the same time.

Cement Determination: **BRE IS 15/74**

Due to the age of the structure in question (1970's) we would recommend carrying out cement type determination as if High Alumina Cement (HAC) is present this may be indicative of a potential for a conversion of the cement which can severely weaken the structure.

This can be determined by extracting small samples of concrete dust (through drilling), and tested in a laboratory.