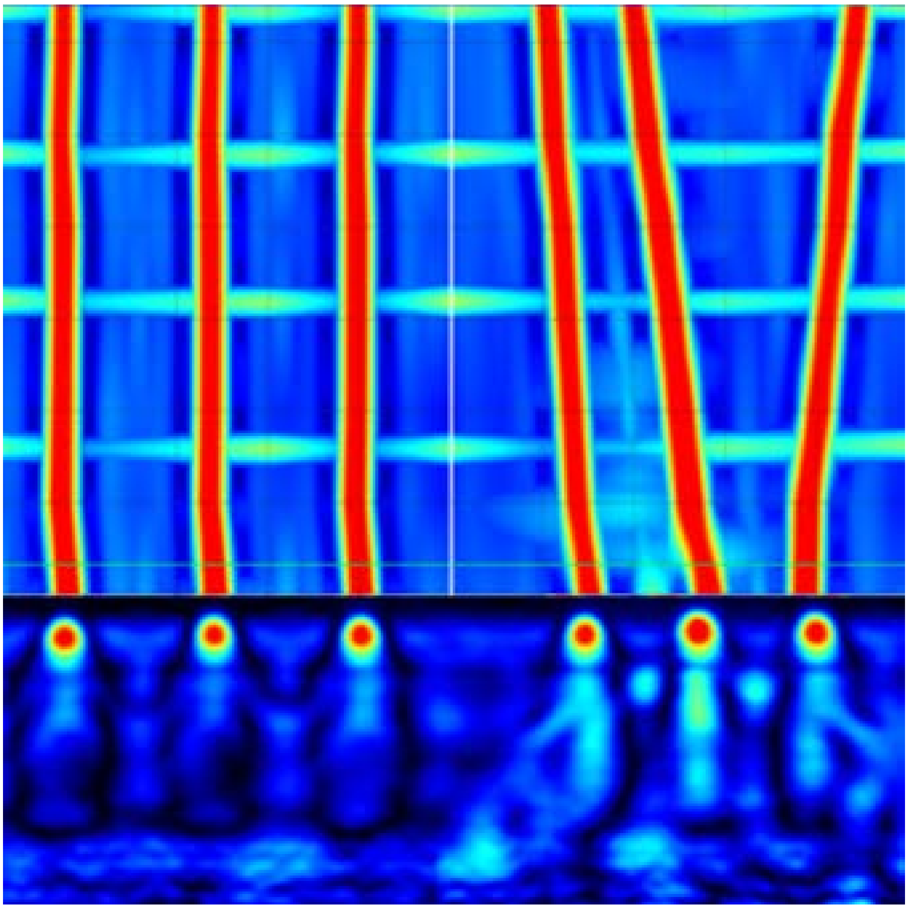
METHODS FOR DETECTION OF REBAR IN NUCLEAR CONCRETE STRUCTURES

REPORT 2026:1182

NUCLEAR POWER CONCRETE TECHNOLOGY



Energiforsk

Methods for detection of rebar in nuclear concrete structures

Non-destructive testing methods

MAGNUS NILSON

ISBN 978-91-89917-25-5 | © Energiforsk april 2026

Energiforsk AB | Phone: 08-677 25 30 | E-mail: kontakt@energiforsk.se | www.energiforsk.se

Foreword

This report forms the results of a project performed within the Energiforsk Nuclear Power Concrete Program. The Concrete Program aims to increase the knowledge of aspects affecting safety, maintenance and development of concrete structures in the Nordic nuclear power plants. A part of this is to investigate possibilities to facilitate and simplify the work that is performed in the nuclear business.

Being able to accurately detect and map rebar in concrete constructions is important for safe and efficient performance of investment and maintenance projects in the nuclear power plants.

There are many methods and instruments available, and this study aims to evaluate non-destructive methods for rebar detection, clarifying which tasks can be performed by in-house technical staff and when specialist expertise is required. The focus is on practical applicability and method selection.

The results show that no single method is sufficient for all scenarios. Combining ground-penetrating radar and ultrasound provides the most reliable mapping, while cover meters offer a useful first step for near-surface rebar.

The study was carried out by Magnus Nilson, Inspekt AB. The study was performed within the Energiforsk Concrete Program, which is financed by Vattenfall, Uniper, Fortum, TVO, Skellefteå Kraft, Karlstads Energi, the Swedish Radiation Safety Authority and SKB.

Summary

This project has reviewed non-destructive methods for detecting reinforcement in concrete structures and clarified which tasks can be performed by technically skilled in-house personnel and when specialist support is required.

The study is based on technical documentation provided by suppliers, practical experience from applying these techniques in field assignments, and comparative testing of equipment at supplier facilities, where Inspekt also used its own instruments to obtain comparable data. The results show that cover meters are a low-cost first step that can be used to quickly indicate the presence and position of reinforcement near the surface. The method works well when the concrete cover is relatively thin, and when information on deeper reinforcement is required, ground penetrating radar is a natural next step. GPR can, in most cases, be operated by technically competent personnel, but specialist expertise may be needed, particularly when misinterpretation of the data could have serious consequences.

If information is needed for additional reinforcement layers, or if the objective is to identify reinforcement-free zones, the measurements should be complemented with ultrasonic testing. This type of measurement should not be carried out without prior experience. There are also techniques such as radiography, magnetometry and impact echo. These methods have their specific purposes, but they are not recommended for the primary task of detecting reinforcement in concrete structures.

Keywords

Non-destructive testing, Concrete, Rebar, Ground penetrating radar, Georadar, Cover meter, Ultrasound, Eddy current, Impact echo, Magnetometry, Radiography, X-ray.

Oförstörande provning, Concrete, Rebar, Georadar, Täckskiktsmätare, Ultraljud, Eddy Current, Impact Echo, Magnetometri, Röntgen.

Sammanfattning

Detta projekt har kartlagt oförstörande metoder för att detektera armering i betongkonstruktioner och klargjort vad som kan göras med egen tekniskt kunnig personal och när specialiststöd behövs.

Studien har utgått ifrån tekniskt underlag tillhandahållet av leverantörer, erfarenheter av tillämpning av teknikerna för detektering av armering i betongkonstruktioner inom uppdrag, och jämförande tester av utrustning hos leverantörer, där Inspekt även använder egen utrustning för att få jämförbar data. Resultatet visar att täckskiktsmätare är ett billigt första steg som kan nyttjas för att få en snabb indikation av var armering finns inom betongen. Mätningen fungerar vid tunnare täckskikt och om information av djupare belägen armering behövs, är georadar ett naturligt nästa steg. Även georadar kan till stor del användas av tekniskt kunnig personal, men man bör vara beredd på att specialistkompetens kan behövas, särskilt om en feltolkning av data kan få allvarliga konsekvenser. Om information behövs för fler lager av armering, eller om man vill se var betongen är fri från armering, bör mätning kompletteras med ultraljudsmätning. Denna typ av mätning rekommenderas inte att man utför själv utan erfarenhet. Det finns även tekniker som röntgen, magnetometri och impact echo. Dessa tekniker har sina syften men rekommenderas inte inom syftet att detektera armering inom betongkonstruktioner.

List of content

1 Introduction

There is currently a wide range of commercially available measurement systems for non-destructive detection of rebar, but their operating principles, limitations, and competence requirements differ significantly. To use these systems effectively, an overview is required of which techniques are suitable for different types of inspection tasks, and under what conditions they can be applied by in-house technically qualified personnel, as opposed to when specialist support needs to be involved.

The purpose of this project is to compile the most relevant commercially available systems for rebar detection in nuclear concrete structures and to assess their practical applicability. The assessment is based on technical documentation provided by suppliers, experience from field applications where the methods have been used in practice, and comparative testing conducted at supplier facilities, where in-house equipment has also been used to obtain comparable measurement results. The results provide a basis for method selection in condition assessments and form recommendations for how the different systems can be applied in practical investigations.

2 Method

2.1 OBJECTIVE

The purpose of this report is to provide project managers, engineers, and technicians with an impartial and practically applicable basis, including a concise technical background of the different techniques, their advantages, and their limitations, to support the selection of an appropriate method or combination of methods for rebar detection in concrete structures.
The focus is on which tasks can be performed using commercially available measurement instruments, whether these can be carried out by in-house technically competent personnel, and when specialist expertise needs to be involved.

2.2 SCOPE

The report addresses rebar detection only, together with closely related aspects such as concrete cover, spacing (c/c distance), and indications of multiple rebar layers. Damage diagnostics, material degradation, and sensor-based long-term monitoring are outside the scope of this report. X-ray methods are discussed at a conceptual level but are not included in practical testing due to safety considerations.

3 Non-destructive methods for detecting rebar in concrete

3.1 AVAILABLE TECHNOLOGIES ON THE MARKET

The review of available methods for detecting rebar in concrete structures shows that several techniques are currently used within the construction sector. The non-destructive testing (NDT) methods are based on different physical principles and therefore highlight different types of information. This entails both advantages and limitations, meaning that the methods are suited for different inspection objectives. In order to obtain a comprehensive assessment of a structure, it may be necessary to combine several methods.

Cover meter (Eddy current)
A cover meter is used to determine concrete cover and locate the first layer of rebar. The method is based on eddy currents induced in the steel. When the probe generates a varying magnetic field, currents are induced in the conductive material, and changes in the probe response are used to estimate cover depth and rebar position. For moderate cover depths and even surfaces, these instruments can provide direct readings of cover depth and rebar diameter without additional signal processing.

The achievable accuracy is influenced by cover depth, surface roughness, nearby metallic objects, and edge effects. A homogeneous cover zone and a flat surface are therefore important prerequisites for obtaining usable results. The method is well suited for rapid checks of the top rebar layer, but the detection depth is limited and reliable separation of multiple rebar layers is not possible. When rebar diameter estimates are needed, or when results require verification, cover meter measurements can be combined with GPR to confirm that the probe is positioned directly above the correct bar.[1]

Ground-penetrating radar (GPR)

Unlike cover meters, GPR produces a dataset (a radargram) that must be interpreted, and a depth assessment cannot be made without some data processing. The analysis is, however, relatively straightforward compared with ultrasonic testing, and a technically competent person can typically locate the top rebar layer with technical support from the equipment supplier.

GPR is based on transmitting short electromagnetic pulses into the concrete and recording reflections at interfaces where the material's dielectric properties change. Such interfaces can arise, for example, at rebar, cracks, air voids, or transitions between different concrete pours. By measuring the travel time and amplitude of the returned pulses, the rebar's lateral position can be detected and the depth can be estimated.

[1] Iowa State University, Eddy Current Testing, Nondestructive Evaluation Techniques : Eddy Current Testing (n.d), https://www.nde-ed.org/NDETechniques/EddyCurrent/eddycurrenttesting.xhtml (Accessed 2025-11-04)

Under normal conditions, the method provides a good overview of the internal structure of the concrete. Accuracy is however dependent on the concrete's dielectric properties. Moist or electrically conductive concrete can attenuate the signal and reduce detection depth, while densely reinforced sections can generate multiple reflectors that complicate interpretation. To achieve reliable depth estimates, the wave velocity must be correctly calibrated.

GPR can be used on walls, ceilings, and floors and is particularly well suited for large areas. A wide range of GPR systems is available today, from units designed for single line scans to systems intended for mapping areas on the order of multiple hectares.[2]

Ultrasound

Ultrasonic testing is a non-destructive method that uses high-frequency sound pulses to identify discontinuities, measure dimensions, and assess material properties. The method is typically based on the pulse-echo principle, where the system transmits a sound pulse into the material. When the pulse encounters a discontinuity, for example a crack or an interface between layers, part of the energy is reflected back to the receiver, which converts the echo into an electrical signal for display. By analysing the echo arrival time and signal amplitude, the position, extent, and orientation of internal indications can be determined.

The technique can detect both near-surface and deeper indications with high accuracy, and measurements can often be performed from one side only. At the same time, there are limitations. The method is more sensitive to surface conditions than both GPR and cover meters. A rough or uneven surface, or insufficient coupling between the equipment and the concrete, prevents the pulse from entering the material and results in missing or difficult-to-interpret echoes. For certain systems, coupling media must therefore be applied, the transducer must be held with consistent pressure against the surface, and the operator must maintain a stable scanning speed when using rolling ultrasound equipment. Overall, this means ultrasound places higher demands on operator experience and on consistent execution than the other techniques addressed in the study.[3]

Impact Echo

Impact Echo is based on applying a short mechanical impact to the concrete surface, generating elastic waves that propagate through the structure. When the waves encounter internal interfaces, such as delaminations, cracks, or the back surface, they are reflected and recorded by an accelerometer. By analysing the frequency spectrum and travel times, concrete thickness can be estimated and internal defects can be detected.

[2] J.Daniels, Ground Penetrating Radar Fundamentals, Department of Geological Sciences, The Ohio State University (2000).
https://www.researchgate.net/publication/237508286_Ground_Penetrating_Radar_Fundamentals (Accessed 2025-11-04).

[3] Iowa State University, Basic Principles of Ultrasonic Testing (u.å.),, https://www.nde-ed.org/NDETechniques/Ultrasonics/index.xhtml (Accessed 2025-11-04)

The method is well suited for locating delamination and estimating thickness, but it does not provide a clear mapping of rebar layout in planar view. Impact Echo is therefore primarily used for point-based condition assessments rather than for determining rebar geometry.[4] [5]

Passive magnetic induction (Magnetometry)

Passive magnetometry is based on the principle that corrosion and other material changes in rebar affect the magnetic flux around the steel, which can be detected from the surface without applying an external magnetic field. The method enables mapping of variations through covering layers such as concrete or other non-magnetic materials, and results are presented as a plan-view map showing percentage deviation. The technique does not provide depth information, but according to the supplier it can provide accurate rebar positioning in planar view.

At present, commercially available systems for this type of corrosion mapping are tied to a single supplier, where raw data is transferred to servers outside the EU for analysis. The user does not have access to the processing chain or the ability to perform an independent interpretation, which limits transparency in data handling and raises data security considerations.[6]

X-ray

Radiography-based non-destructive testing is based on placing an ionizing radiation source on one side of the object while a detector film, digital panel, or electronic receiver is placed on the opposite side. The radiation is attenuated as it passes through the concrete, and variations in attenuation are used to visualize internal structures. The method therefore requires unobstructed access to both sides of the structure, which in many practical situations constitutes its main limitation.

When inspecting thinner concrete sections, roughly in the range of 20–30 cm and with a limited amount of rebar, radiography can provide very high geometric resolution and clearly visualize the rebar positions in plan. In such cases, the method can be used to confirm rebar placement or to check whether the rebar deviates from the designed location. Determining the rebar position in depth, however, is considerably more challenging and requires either multiple exposures from different directions or very high precision in geometric calculations. Even then, uncertainties remain, especially where multiple rebar layers are present.

For thicker structures (>30 cm), the required radiation energy increases. Concrete is a relatively radiation-attenuating material, and the greater the section thickness, the more powerful sources are needed to achieve sufficient penetration.

---

[4] Iowa State University, Acoustic Emission Testing, https://www.nde-ed.org/NDETechniques/AcousticEmission/AE_Intro.xhtml (Accessed 2025-11-05)

[5] N.J.Carino, THE IMPACT-ECHO METHOD: AN OVERVIEW. Building and Fire Research Laboratory National Institute of Standards and Technology Gaithersburg (2001). https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=860355 (Accessed 2025-11-04).

[6] InspecTerra, 'Quantitative Corrosion Mapping Solution', InspecTerra, (n.d), https://www.inspecterra.com/ (Accessed 2025-12-04).

Commercially available mobile systems quickly reach their limits, and practical field use often becomes unrealistic due to requirements for:

- High radiation energy
- Large exclusion zones
- Long exposure times
- Extensive radiation protection measures

The amount and geometry of rebar also strongly affect the method. Even a single layer of coarse rebar can cause significant absorption and scattering. With two or more layers, these effects increase to the point that it becomes difficult to distinguish deeper rebar or determine its dimensions. The risk of image uncertainty increases, as does the risk of misinterpreting overlapping structures.

In nuclear environments, substantial occupational and organizational challenges are added. Radiographic work requires cordoning off large areas, approved radiation protection plans, specialist personnel, and often a production stoppage. These factors make the method logistically and economically demanding. In many facilities, establishing the required exclusion zones is in practice not possible, particularly in confined spaces or in operation-critical parts of the plant.

In summary, radiography is considered to have very limited applicability for broad mapping of rebar in concrete structures. The method can be relevant in certain specific cases, primarily for thin sections, limited rebar content, and good access, but it is not well suited for assessing rebar depth positioning or sizing in structures with greater thickness and complex rebar geometry. The requirements regarding work environment, radiation protection, and access also mean that other techniques are normally preferable for this purpose.[7]

[7] Jinnestrand, J. Chief Technical Officer, Inspekt Sweden AB, D, Karosas. Regional manager, Inspekt Sweden AB [Interview] (2025-11-24).

4 Available equipment on the market

The table below lists a selection of equipment of practical interest for detecting reinforcement in concrete.

Where equipment datasheets specify both spatial resolution and positional accuracy (margin of error), the less favourable of the two values is reported. This approach is intentionally conservative, as a high operating frequency may suggest a theoretical resolution that exceeds what the manufacturer actually guarantees in practice. In such cases, the stated positional accuracy/margin of error is used, since it reflects the manufacturer's own bounds on detection reliability rather than a theoretical optimum.

In cases where resolution and positional accuracy data are unavailable for GPR, estimated values based on the theoretical limits for vertical and lateral resolution have been used. These values should be regarded solely as an indication of the relative level of detail between different units, and are intended to assist in equipment selection. The distance shown represents the theoretical minimum separation required between objects within the concrete for them to be resolved as two distinct objects.

The following equations are used to estimate theoretical resolution values for GPR equipment where manufacturers do not provide complete specifications. These estimates are not exact and should be regarded as indicative only, intended to allow comparison between units on a common basis.

Equation 1 gives the propagation velocity of the GPR signal through concrete, derived from the speed of light and the dielectric value of the material. A dielectric value of 9 is assumed, representative of dense, well-compacted concrete. In practice this value can range from approximately 4 to 10 depending on concrete composition, air- and moisture content.

$$\text{Propagation velocity through the material (concrete)}, \qquad v = \frac{c}{\sqrt{\varepsilon_r}}$$

Equation 1 - Velocity through the material.

Where c is $3 \cdot 10^8$ m/s and ε_r (the relative permittivity of concrete) is assumed to be 9.

Equation 2 calculates the wavelength of the signal as it travels through the material, using the propagation velocity from Equation (1) and the frequency of the equipment.

$$\text{Wavelength in the material}, \qquad \lambda = v/f$$

Equation 2 - Wavelength in the material.

Where f is set to the instrument’s maximum frequency.

Equation 3 gives the theoretical vertical resolution, meaning the minimum size an object must be in the depth direction to be detected as a distinct object rather than lost in the surrounding signal.

$$Vertical\ resolution = \frac{\lambda}{4}$$

Equation 3 - Vertical resolution.

Where λ is the wavelength of the central frequency of the transmitted signal. In the table, however, the maximum frequency of each unit has been used, as the equipment employs stepped frequency sweeping and information on the optimised central frequency, at which signal strength is greatest, is not available.

Equation 4 gives the theoretical lateral resolution, meaning the minimum separation required between two objects in the horizontal plane for them to be resolved as separate objects. This value is also depth-dependent, as the signal beam widens with increasing depth.

$$Lateral\ resolution = \frac{\lambda}{4} + \frac{D}{\sqrt{\varepsilon_r + 1}}$$

Equation 4 - Lateral resolution.

Where f_0 is the central frequency of the signal. D is the depth to the reflecting object; in this example, 6 cm is used. ε_r is the dielectric value of the material through which the signal propagates; in this example, it is set to 9 for concrete.[8]

[8] G.Leucci, S.Negri, Ground Penetrating Radar (GPR): An application for evaluating the state of maintenance of the building coating (2003), Annals of Geophysics. https://www.researchgate.net/publication/27772009_Ground_Penetrating_Radar_GPR_An_application_for_evaluating_the_state_of_maintenance_of_the_building_coating (Accessed 2025-11-05).

4.1 TABLE VALUES

The tables in sections 4.1 to 4.4 use a consistent set of parameters across all equipment types. The parameters used in the tables are defined as following:

Resolution

Horizontal and Vertical refer to the spatial resolution of the equipment in the horizontal and vertical direction respectively, meaning the minimum separation at which two objects within the concrete can be distinguished as separate objects. Usage indicates the assessed level of difficulty in operating the equipment. Survey Speed indicates the rate at which an area can be covered.

Rebar

Covers the equipment's capability for rebar detection. Detection of rebar indicates whether the equipment is capable of locating rebar at all. Est. rebar diameter indicates whether the equipment can provide an estimate of bar diameter. Depth indicates the maximum detection depth. Multiple rebar layers indicates whether the equipment is capable of detecting rebar below the uppermost layer. Corrosion indicates whether the equipment can provide an estimate of how corroded the rebar is.

Suitable for survey of

Indicates which surface types and orientations the equipment can be used on, including floors, walls, ceilings, and coated surfaces. Suitable for corners and openings indicates whether the equipment can be used in confined geometries such as wall junctions or around penetrations. Confined Spaces indicates whether the equipment is suitable for use in physically restricted environments, as some units require significant clearance from edges or are too bulky for restricted access. Survey Size indicates the maximum or recommended area that can be scanned in a single continuous dataset.

Known sources of interference

Lists factors that are known to affect measurement reliability. Moisture refers to the presence of water or high humidity in the concrete. Rough surface indicates whether surface irregularities affect the measurement. Temp. Limits indicates the operating temperature range of the equipment. Vibrations indicates whether the equipment is sensitive to mechanical vibration during measurement. Cables/Pipes indicates whether nearby installations can interfere with the signal. Close metal indicates whether adjacent metallic objects affect the result.

User Friendliness

Covers the practical aspects of operating and reporting. Handling Equipment and Surveying indicate the assessed level of difficulty in setting up and carrying out a survey. In-situ results indicates whether results are available immediately on site. Analysis by layperson indicates whether results can be interpreted without extensive prior experience. Locally stored data indicates whether measurement data can be stored directly on the unit without being uploaded to an external cloud service, which is a requirement in certain operating environments. Easily reported data indicates whether results can be presented to a client without significant post-processing, as some equipment requires considerable additional work before the output is interpretable. Reproducibility reflects an overall assessment of how consistently the equipment produces comparable results under similar conditions.

Concrete

Indicates whether the equipment can provide information beyond rebar detection. Quality indicates whether the equipment can provide an assessment of concrete quality. Thickness indicates whether concrete thickness can be estimated. Chlorides indicates whether chloride content can be detected. Cracks, Delamination, Spalling, and Honeycombing indicate whether the respective defect types can be identified.

4.2 TABLE - ULTRASOUND

	Ultrasound							
System:	Insight Scanner	PD8050	Pundit 200	Pundit Lab	A1040 MIRA 3D	A1040 MIRA 3D PRO	Surfer	Pulsar
Supplier	Elop Techn-ology	Proceq/Screening Eagle			ACS		Germann Instruments	
Origin	Norway	Schweiz			Germany		Denmark	
Resolution								
Horisontal (mm)	<10	~0,2	~0,2	~0,2	×	×	~0,2	~0,2
Vertical (mm)	<10	~0,2	~0,2	~0,2	×	×	~0,2	~0,2
Usage	Hard	Easy	Easy	Easy	Easy	Easy	Easy	Easy
Survey Speed (m/s)	0,5	Point	Point	Point	Point	Point	Point	Point
Rebar								
Detection of rebar	10 mm<	×	No	No	×	×	No	No
Est. rebar diameter	No	No	No	No	No	No	No	No
Depth (cm)	200	200	1500	1500	300	300	-	-
Multiple rebar layers	Yes	Yes	No	No	Yes	Yes	No	No
Corrosion	No	No	No	No	No	No	No	No
Suitable for survey of								
Floor	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Walls	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ceiling	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Coated surfaces	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Suitable for corners and openings	No	No	No	No	No	No	No	No
Confined Spaces	No	No	No	No	No	No	No	No
Survey Size(m x m)	5x5	5x5	Point	Point	1x1	1x1	Point	Point
Known sources of interence								
Moisture	Partially	Part-ially	Part-ially	Part-ially	Partially	Partially	Part-ially	Part-ially
Rough surface	Partially	Part-ially	Part-ially	Part-ially	Partially	Partially	Part-ially	Part-ially
Temp. Limits (+/-)	(-10)-50	×	×	×	×	×	(-20)-50	(-10)-50
Vibrations	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cables/Pipes	Part-ially	Part-ially	Part-ially	Part-ially	Part-ially	Part-ially	Part-ially	Part-ially

Close metall	No	No	No	No	No	No	No	No
User Friendliness								
Handling Equipmenten	Hard	Easy	Easy	Easy	Easy	Easy	Easy	Easy
Surveying	Hard	Easy	Easy	Easy	Easy	Easy	Easy	Easy
In-situ results	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Analysis by layperson	No	No	No	No	No	No	No	No
Locally stored data	Yes	×	×	×	×	×	×	-E39
Easily reported data	No	No	No	No	No	No	No	No
Reproducibility	Medium	Medi um	Medi um	Mediu m	Medium	Medium	Mediu m	Mediu m
Concrete								
Quality	Yes	×	Yes	Yes	×	×	Yes	Yes
Thickness	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Chlorides	No	No	No	No	No	No	No	No
Cracks	Yes	Yes	part-ially	part-ially	Yes	Yes	part-ially	part-ially
Delamination	Yes	Yes	part-ially	part-ially	Yes	Yes	part-ially	part-ially
Spalling	Yes	Yes	part-ially	part-ially	Yes	Yes	part-ially	part-ially
Honeycombing	Yes	Yes	part-ially	part-ially	Yes	Yes	part-ially	part-ially
Price (1000 SEK)	1500	400	×	×	700	1400	×	×[9]

[9] The ultrasound table is based on the equipment suppliers' technical specifications, datasheets, and marketing materials. A complete list of sources is provided in the Reference List.

4.3 TABLE - GEORADAR

	Georadar 1/2						
Unit/System	GP8000	GP8100	GP8800	C-thrue	C-thrue XS	Conquest 100	PS 1000 X-Scan
Supplier	Proceq/Screening Eagle	Proceq/Screening Eagle	Proceq/Screening Eagle	IDS Georadar	IDS Georadar	Sensors & Software	Hilti
Origin	Schweiz	Schweiz	Schweiz	Italien	Italien	USA	Lichte-nstein
Resolution	LPOL	LPOL	CPOL	CPOL	CPOL	LPOL	LPOL
Lateral (z=6 cm) (mm)	*6,3*	*6,3*	*4,2*	*12,5*	*12,5*	40	10
Vertical (z=6 cm) (mm)	*25,2*	*25,2*	*23,1*	*44*	*44*	40	10
Usage	Easy	Easy	Easy	Easy	Easy	Easy	Easy
Survey Speed (m/s)	0,2	0,2	0,2	×	×	×	×
Rebar							
Detection of rebar	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Est. rebar diameter	No	No	No	No	No	No	No
Depth (cm)	150	80	65	100	100	91	30
Multiple rebar layers	partially	partially	partially	part-ially	part-ially	partially	part-ially
Corrosion	Partially	Partially	Yes	Part-ially	Part-ially	Partially	Part-ially
Suitable for survey of							
Floor	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Walls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ceiling	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Coated surfaces	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Suitable for corners and openings	No	No	Yes	No	No	No	No
Confined Spaces	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Survey Size(m x m)	4x4	10x10	4x4	×	×	1,2x1,2	×
Known sources of interence							
Moisture	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rough surface	No	No	No	No	No	No	No

Temp. Limits	×	×	×	×	×	(-40)-50	×
Vibrations	No	No	No	No	No	No	No
Cables/Pipes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Close metall	partially	partially	partially	part-ially	part-ially	partially	part-ially
User Friendliness							
Handling Equipmenten	Easy	Easy	Easy	Easy	Easy	Easy	Easy
Surveying	Easy	Easy	Easy	Easy	Easy	Easy	Easy
In-situ results	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Analysis by layperson	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Locally stored data	No	No	No	×	×	×	×
Easily reported data	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reproducibility	High	High	High	High	High	High	High
Concrete							
Quality	No	No	No	No	No	No	No
Thickness	partially	partially	partially	part-ially	part-ially	partially	part-ially
Chlorides	No	No	No	No	No	No	No
Cracks	partially	partially	partially	part-ially	part-ially	partially	part-ially
Delamination	No	No	No	No	No	No	No
Spalling	partially	partially	partially	part-ially	part-ially	partially	part-ially
Honeycombing	partially	par-ially	par-ially	part-ially	part-ially	partially	part-ially
Price (1000 SEK)	200	300	260	×	×	×	100

	Georadar 2/2						
Unit/System	FLEX NX	FLEX LT	NX15	NX25	D-TECT 200C	DWD18 1ZJ	M12 Sub-scanner
Supplier	GSSI	GSSI	GSSI	GSSI	Bosch	Makita	Milwaukee
Origin	USA	USA	USA	USA	Tysk-land	Japan	USA
Resolution	CPOL	CPOL	CPOL	CPOL	LPOL	LPOL	LPOL
Lateral (z=6 cm) (mm)	*4,2*	*4,2*	×	*4,2*	5	5	×
Vertical (z=6 cm) (mm)	*22,4*	*22,4*	×	*22,4*	5	5	×
Usage	Easy	Easy	Easy	Easy	Easy	Easy	Easy
Survey Speed (m/s)	0,2	0,2	0,2	0,2	×	×	×
Rebar							
Detection of rebar	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Est. rebar diameter	No	No	No	No	No	No	No
Depth (cm)	75	75	150	75	20	17,8	15,2
Multiple rebar layers	part-ially	part-ially	part-ially	part-ially	part-ially	part-ially	partially
Corrosion	Yes	Yes	Yes	Part-ially	No	No	No
Suitable for survey of							
Floor	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Walls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ceiling	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Coated surfaces	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Suitable for corners and openings	No	No	Yes	Yes	No	No	No
Confined Spaces	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Survey Size(m x m)	1,2x0,6	1,2x0,6	1,2x0,6	1,2x0,6	×	×	×
Known sources of interence							
Moisture	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rough surface	No	No	No	No	No	No	No
Temp. Limits	(-20)-50	(-20)-50	(-20)-50	(-20)-50		(-10)-40	(-5)-40
Vibrations	No	No	No	No	No	No	No
Cables/Pipes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Close metall	part-ially	part-ially	part-ially	part-ially	part-ially	part-ially	partially

User Friendliness							
Handling Equipmenten	Easy	Easy	Easy	Easy	Easy	Easy	Easy
Surveying	Easy	Easy	Easy	Easy	Easy	Easy	Easy
In-situ results	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Analysis by layperson	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Locally stored data	Yes	Yes	Yes	Yes	×	×	×
Easily reported data	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reproducibility	High	High	High	High	High	High	High
Concrete							
Quality	No	No	No	No	No	No	No
Thickness	part-ially	part-ially	part-ially	part-ially	part-ially	part-ially	partially
Chlorides	No	No	No	No	No	No	No
Cracks	part-ially	part-ially	part-ially	part-ially	part-ially	part-ially	partially
Delamination	No	No	No	No	No	No	No
Spalling	part-ially	part-ially	part-ially	part-ially	part-ially	part-ially	partially
Honeycombing	part-ially	part-ially	part-ially	part-ially	part-ially	part-ially	partially
Price (1000 SEK)	300	×	400	400	7	×	×[10]

[10] The georadar table is based on the equipment suppliers' technical specifications, datasheets, and marketing materials. A complete list of sources is provided in the Reference List

4.4 TABLE – COVER METER

	Täckskiktsmätare						
Unit/System	Elco-meter 331	PM8000 Pro	PM8000	PM8000 Lite	PS 300 Ferro-scan	PS 85 Ferro-scan	MC8 022+
Supplier	Elcometer	Proceq/Screening Eagle	Proceq/Screening Eagle	Proceq/Screening Eagle	Hilti	Hilti	Kolectric
Origin	UK	Schweiz	Schweiz	Schweiz	Licht-enstein	Licht-enstein	UK
Resolution							
Lateral (mm)	1-4	1-4	1-4	1-4	3	5-10	1-4
Vertical (mm)	1-4	1-4	1-4	1-4	3	5-10	1-4
Usage	Easy	Easy	Easy	Easy	Easy	Easy	Easy
Survey Speed (m/s)	×	0,5	0,5	0,5	×	×	×
Rebar							
Detection of rebar	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Est. rebar diameter	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Depth (cm)	6,5	6,3	6,3	6,3	20	20	16
Multiple rebar layers	No	No	No	No	No	No	No
Corrosion	Yes****	No	No	No	No	No	No
Suitable for survey of							
Floor	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Walls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Ceiling	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Coated surfaces	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Suitable for corners and openings	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Confined Spaces	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Survey Size(m)	×	1000	×	×	×	×	×
Known sources of interence							
Moisture	No	No	No	No	No	No	No
Rough surface	No	No	No	No	No	No	No

Temp. Limits (+/-)	0-50	✕	✕	✕	✕	(-10)-50	(-10)-50
Vibrations	No	No	No	No	No	No	No
Cables/Pipes	No	No	No	No	No	No	No
Close metall	part-ially	part-ially	part-ially	part-ially	part-ially	part-ially	part-ially
User Friendliness							
Handling Equipmenten	Easy	Easy	Easy	Easy	Easy	Easy	Easy
Surveying	Easy	Easy	Easy	Easy	Easy	Easy	Easy
In-situ results	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Analysis by layperson	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Locally stored data	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Easily reported data	No	Yes	Yes	Yes	Yes	Yes	Yes
Reproducibility	Medium	Medium	Medium	Medium	Medium	Medium	Medium
Concrete							
Quality	No	No	No	No	No	No	No
Thickness	No	No	No	No	No	No	No
Chlorides	No	No	No	No	No	No	No
Cracks	No	No	No	No	No	No	No
Delamination	No	No	No	No	No	No	No
Spalling	No	No	No	No	No	No	No
Honeycombing	No	No	No	No	No	No	No
Price (1000 SEK)	30	80	40	30	18	15	✕[11]

[11] The cover meter table is based on the equipment suppliers' technical specifications, datasheets, and marketing materials. A complete list of sources is provided in the Reference List.

s

4.5 TABLE – IMPACT ECHO AND MAGNETOMETRY

	Impact Echo		Magnet-ometry
Unit/System	PI8000	Mirador	iCAMM
Supplier	Proceq/Screening Eagle	Germann instruments	InspecTerra
Origin	Schweiz	Germany	Canada
Resolution			
Lateral (mm)	×	×	1 - 4
Vertical (mm)	×	×	No
Usage	Easy	Easy	×
Survey Speed (m/s)	Point	Point	1 / 8
Rebar			
Detection of rebar	Partially	Partially	Yes
Est. rebar diameter	No	No	×
Depth (cm)	×	×	Ø x 10
Multiple rebar layers	Partially	Partially	No
Corrosion	No	No	Yes
Suitable for survey of			
Floor	Yes	Yes	Yes
Walls	Yes	Yes	Yes
Ceiling	Yes	Yes	Yes
Coated surfaces	Yes	Yes	Yes
Suitable for corners and openings	No	No	Yes
Confined Spaces	Yes	Yes	Yes
Survey Size(m x m)	Point	Point	X
Known sources of interence			
Moisture	No	No	No
Rough surface	No	No	No
Temp. Limits (+/-)	×	(-10)-50	No
Vibrations	partially	partially	No
Cables/Pipes	partially	partially	No

Close metall	partially	partially	×
User Friendliness			
Handling Equipmenten	Easy	Easy	×
Surveying	Easy	Easy	×
In-situ results	Yes	Yes	×
Analysis by layperson	No	No	×
Locally stored data	×	×	No
Easily reported data	No	No	×
Reproducibility	×	×	High
Concrete			
Quality	Yes	Yes	No
Thickness	Yes	Yes	No
Chlorides	No	No	No
Cracks	Yes	Yes	No
Delamination	Yes	Yes	No
Spalling	Yes	Yes	No
Honeycombing	Yes	Yes	No
Price (1000 SEK)	×	×	×[12]

[12] The Impact Echo and Magnetometry table is based on the equipment suppliers' technical specifications, datasheets, and marketing materials. A complete list of sources is provided in the Reference List.

4.6 DEMO EQUIPMENT

Efforts were made within the project to obtain access to demonstration equipment. Unfortunately, suppliers either did not respond to enquiries or requested fees that exceeded expectations in order to provide access to demo units. Several systems were identified as relevant based on the market survey, but within this project it has not been possible to verify the suitability of those systems or the suppliers' claims regarding reliability.

The equipment supplied by Inspekt for the project comprised the Elop Insight Scanner (ultrasound), the Proceq GP8000 (GPR) and the Elcometer 331 (cover meter). In addition, four external systems were assessed as being of particular interest to test. The ACS MIRA M1040 is an ultrasound system with a detection depth of up to 300 cm and support for area scanning, which distinguishes it from the point-measurement systems in the ultrasound table and makes it a candidate for mapping deeper rebar layers. The Proceq PD8050, also an ultrasound system, shows comparable specifications to the Elop Insight Scanner used in the field studies, with a similar detection depth and area scanning capability, but was not available in time to be included in the practical testing. The GSSI Flex NX, a GPR system, is of interest due to its camera-based positioning system, which removes the need for pre-marked grids and can be an advantage in environments where surface marking is undesirable or time-consuming. The GP8800, also a GPR system, uses cross-polarised antenna technology, which reduces the dominance of reflections from the uppermost rebar layer and may improve the ability to detect objects at greater depth. Both GPR systems have shown promising capability to detect a second rebar layer. The reseller for the ACS MIRA M1040 3D was open to arranging a demonstration, but at a cost that could not be accommodated within the project budget.

Among the GPR systems, the GP8800 and the GSSI Flex NX and NX25 are of particular interest due to their cross-polarised antenna technology, which reduces the dominance of reflections from the uppermost rebar layer and improves the ability to measure between rebars in that layer, making it more feasible to detect underlying layers. Among the ultrasound systems, the Elop Insight Scanner, Proceq PD8050 and ACS MIRA M1040 are the most relevant candidates due to their capability for tomographic measurement, which provides a three-dimensional view of the concrete's internal structure and improves the ability to locate rebar beyond the first layer.

InspecTerra’s solution, “iCamm”, passive magnetometry equipment, was presented in a PowerPoint presentation during a Teams meeting. However, the analysis is performed exclusively by InspecTerra, which means that collected data must be transferred abroad for processing and interpretation. A paid demonstration was proposed by InspecTerra, but the cost exceeded what could be covered within the budget for this project.[13]

[13] Teams meeting between Inspekt and InspecTerra regarding Icamm, 2025 februari 13.

No practical testing with radiography has been carried out due to safety requirements and cost level. The assessment of this type of equipment is instead based on internal experience from personnel within Nordic Inspekt Group who have experience of radiography in nuclear environments. Field studies and equipment testing

As the measurement equipment was tested on different surfaces at each supplier, the measurement conditions vary somewhat between the examples. When interpreting the results, the reader should note that the examples presented in this report are therefore not necessarily directly comparable.

4.7 FIELD STUDIES

4.7.1 Rebar survey in a concrete block using ultrasound, GPR and a cover meter

A concrete block with four rebar layers arranged in two grids was produced within the project to evaluate which methods could be used to identify rebar-free zones ahead of possible future changes to the concrete structure. Concrete quality and mix design are not documented, and it was noted that the blocks may not be fully representative of the concrete conditions found in the structures of interest. GPR measurements were carried out using a Proceq GP8000, a linearly polarised GPR system fitted with wheels that provide ground clearance, scanning in a grid pattern with 10 cm spacing in two perpendicular directions across the full extent of the block. Ultrasound measurements were carried out using an Elop Insight Scanner, a rolling ultrasound system that generates real-time 3D visualisations of the concrete's internal structure, scanning in parallel lines with 10 cm spacing. The reinforcement was arranged both in its intended orientation and with deliberately skewed bars, as shown in Figure 1, to illustrate how the methods handle deviations that may occur in the field. The purpose of the specimen was to identify rebar-free areas ahead of a theoretical drilling operation, rather than to map every bar precisely. The finished test block, surveyed with GPR and ultrasound, is shown in Figure 2. In this case, the approach was to determine where rebar is not present, since the goal was to avoid cutting rebar during the theoretical drilling. Here, the techniques can be combined effectively. GPR is used first to collect as much data as possible and to assess whether the rebar is sufficiently sparse to make the lower layer visible already at an early stage, or whether the rebar is too large and too closely spaced for any underlying layers to be detected. In this case, the rebar was both too large and too closely spaced to detect the lower rebar grid (layers 3 and 4, numbered from the top). The skewed bars also produced converging reflectors that can be misinterpreted as additional rebar, as illustrated in Figure 4.

Figure 1 - Overview of the rebar layers before casting the test block.

Figure 2 - The same test block after casting, surveyed with GPR and ultrasound.

A cross-section (B-scan) from the GPR measurement near the front edge of the test block, shown in Figure 3, shows that the first rebar layer is clearly detected at the correct positions (red color). The outermost rebars are only faintly visible because they are located at the edge of the scanner's accessible area. The second rebar layer is not visible, as it is masked by the strong reflection from the upper rebar layer.

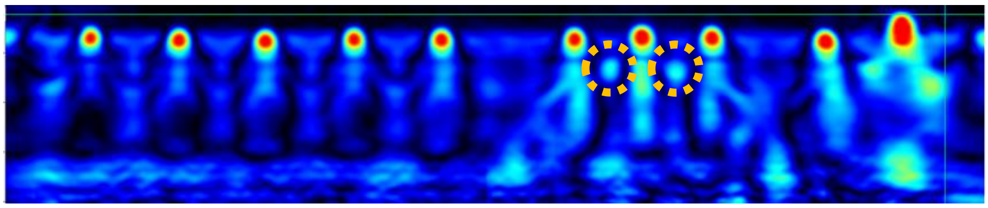


Figure 3 - Side view through the concrete. The upper rebar layer produces a converging echo that indicates rebars that do not exist (orange marking).

A planar view (C-scan) directly above the surface shows the rebar grid in the first layer clearly, as shown in Figure 5. The vertical rebars appear red because they are closer to the surface and therefore produce a higher amplitude (red marking), which illustrates why GPR is generally not reliable for estimating rebar diameter. The horizontal rebar is slightly deeper and appears in a different color due to lower amplitude. The blue areas indicate locations that are safe to drill based on the first layer, but they do not guarantee that the concrete is free of rebar below the upper layer.

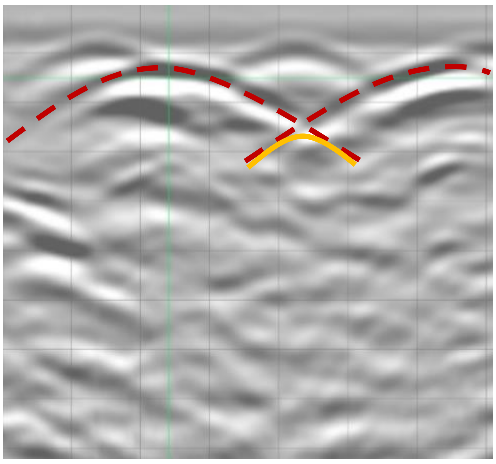


Figure 4 - Example of two hyperbolas (red marking) converging and forming a third hyperbola (yellow marking) that can be misinterpreted.

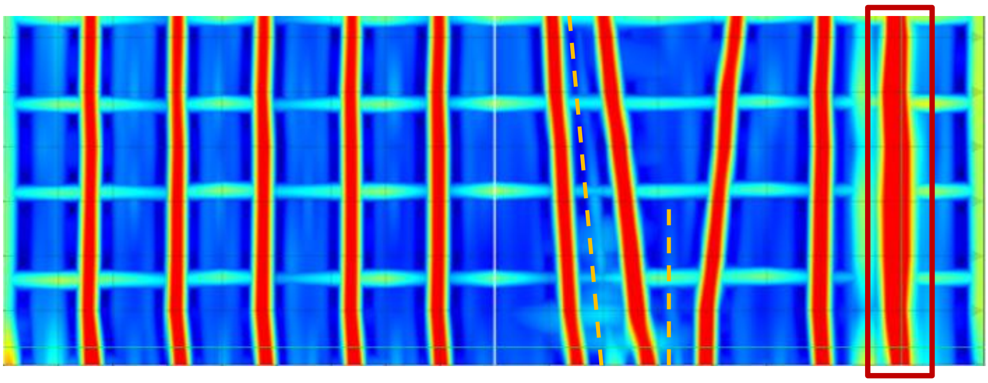


Figure 5 - GPR results from the test block above. The image shows a planar view through the concrete from above. The upper rebar layer produces a converging echo that indicates rebars that do not exist (orange marking). One rebar appears much wider because of it being located closer to the surface than the other rebar (red marking).

As shown in Figure 5, the upper rebar grid produces a converging echo that indicates rebars that do not exist (orange marking), and one rebar appears much wider due to being located closer to the surface than the others (red marking). An alternative representation of the same dataset, shown in Figure 6, uses different colours to distinguish depth levels, with vertical rebar shown in yellow and horizontal rebar in gray.

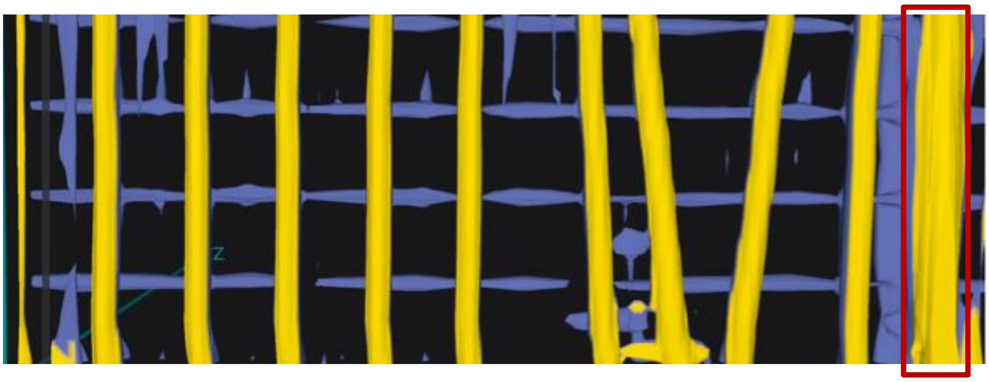


Figure 6 – Alternative view of the same GPR dataset where different depth levels are shown in different colors. Vertical rebar is shown in yellow and horizontal rebar is shown in gray.

As shown in Figure 7, the ultrasound result is more fragmented and the rebar appears with less uniform amplitude than in the GPR results, for several reasons. GPR is, in practice, almost fully reflected at metal interfaces, and no signal penetrates through, whereas ultrasound has a lower reflection coefficient at steel and part of the signal passes through the metal without being reflected. At the same time, ultrasound has a high reflection coefficient at air and can, in many cases, also penetrate deeper into the concrete. This can be an advantage when detecting deeper rebar layers.

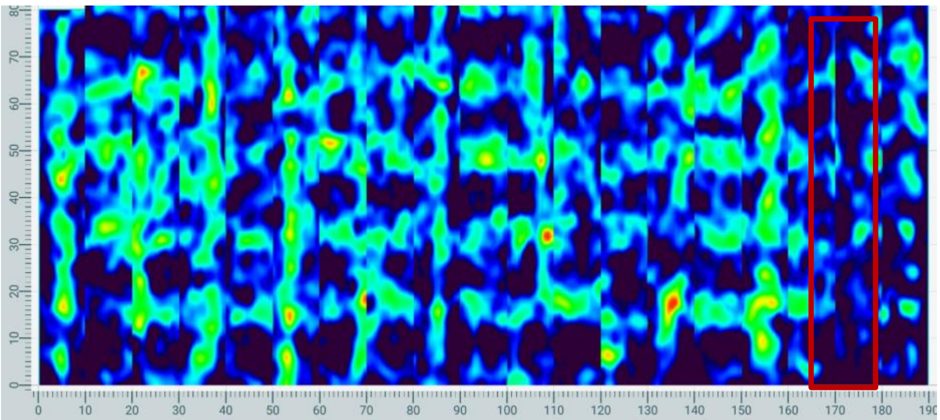


Figure 7 – Ultrasound result processed only to visualize the data. All reflections within the test block are visible and a large part of the rebar can be distinguished in planar view. One rebar is missing (red marking) because it is too shallow for the equipment to produce a reflection.

Although the image is fragmented and significantly more difficult to interpret than the GPR data, the position of the rebar grid can in most cases be identified or inferred from the context in the image, with help of from the GPR C-scan as a complement. There are, however, exceptions, and in practice the rebar layout is rarely known in detail in the way it is for a test block where the rebars are visible at the sides. The shallowest rebar, with a cover of approximately 2 cm (second from the right), lies above the ultrasound equipment's specified minimum detection depth of 5 cm and is therefore not detected. Another exception is the left part of the vertical angled rebar, where the amplitude is very weak and only short segments are visible.

The equipment detects most of the rebar in the upper rebar grid (layers 1 and 2), as shown in Figure 8. The lower rebar grid (layers 3 and 4) is also partially detected, as shown in Figure 9, though not consistently across all rebar. The rebar diameter is sufficiently large that part of the wave passes through the rebar and part is reflected back to the sensor, but the response is inconsistent.

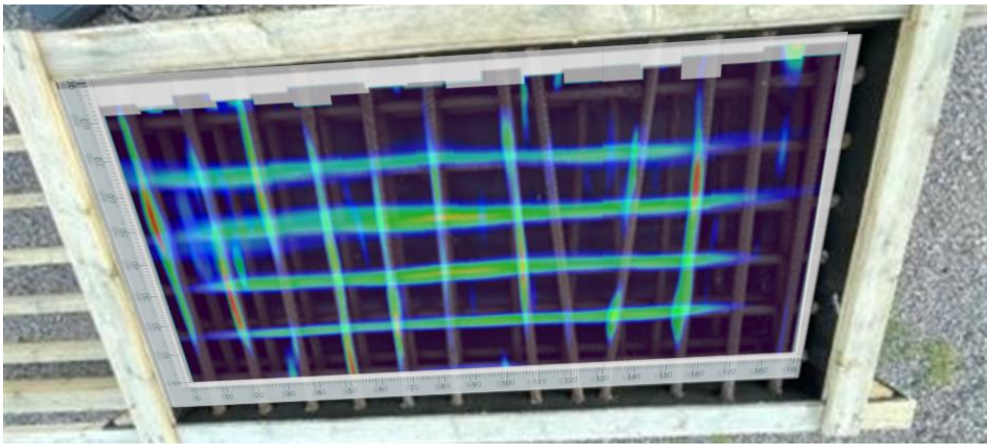


Figure 8 - Ultrasound result, upper rebar layer. A large portion of the rebar is detected in planar view.

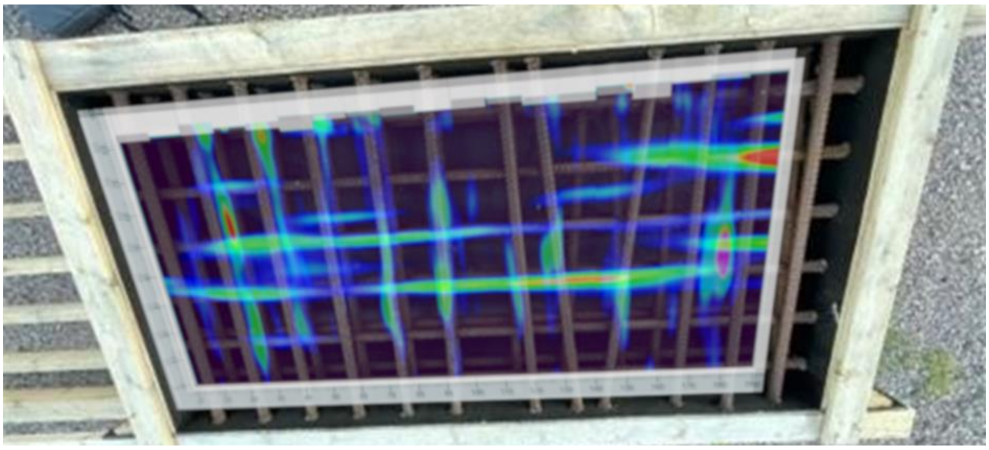


Figure 9 - Ultrasound result, lower rebar layer. A considerably smaller portion of the rebar is detected in planar view.

In this case, the primary aim is not to detect the entire extent of the rebar, but to ensure where drilling can be performed without drilling into rebar. This means that ultrasound can be used to evaluate where a backwall echo is received from the rear surface of the concrete. Areas with a strong and clear reflection (larger red regions) from the backwall indicate that there are no obstructions in the shallow layers, such as rebar layers, as shown in Figure 10.

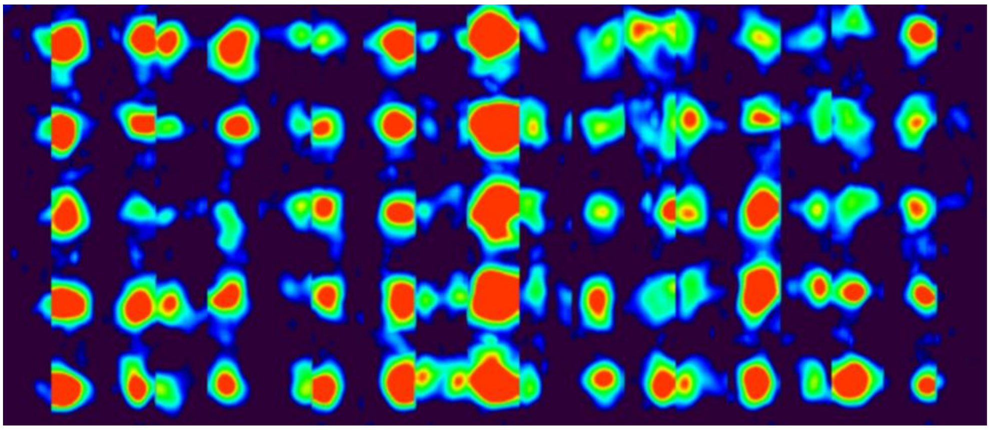


Figure 10 - Ultrasound result, reflections from the concrete backwall.

By combining the reflections from the rebar layers with the reflections from the concrete backwall, a map can be established showing where rebar is present and where it is not, as shown in Figure 11.

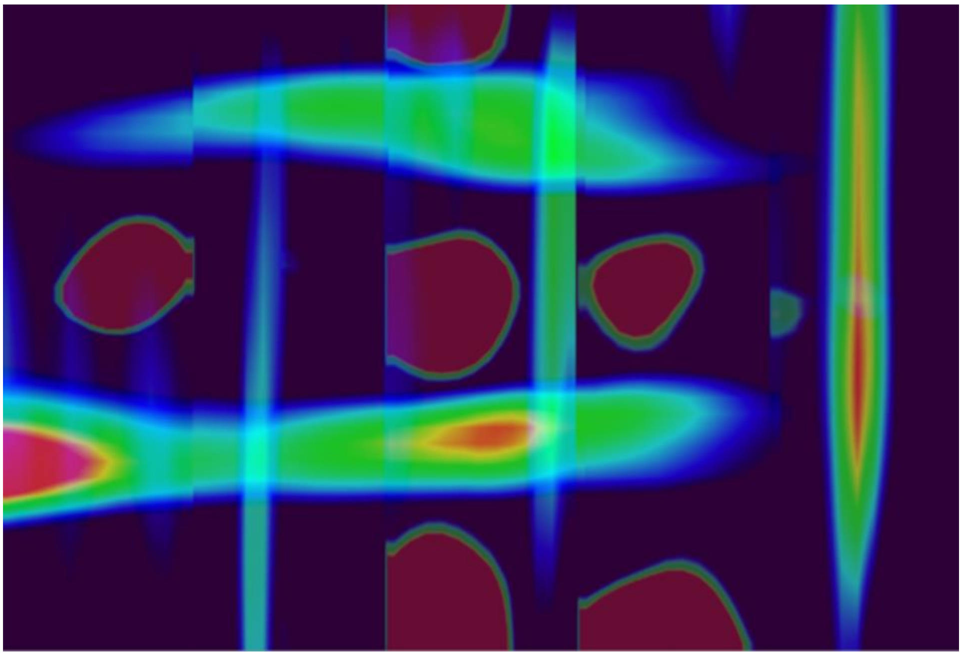


Figure 11 - Ultrasound result, combined presentation of rebar layers and concrete backwall.

For drilling, holes can be pre-drilled with a smaller diameter and checked using a cover meter with a borehole probe (eddy current). Cover meters are available on the market with probes shaped as slender rods, which makes it possible to assess the distance to the nearest metallic object from within the pre-drilled hole. In this way, it is possible to confirm that it is safe to enlarge the hole without drilling into existing rebar.

4.7.2 Basic function of a cover meter

The test was performed using an Elcometer 331 cover meter, an eddy current-based instrument. A Ø16 bar was placed beneath wooden boards to demonstrate the disadvantages of a cover meter in a quick way. Wooden boards were used as a practical means of quickly varying the distance between the sensor and the rebar without the need for cast concrete test blocks, allowing the cover depth to be adjusted repeatedly between tests. The test was performed in field, after a difference in cover thickness and rebar diameter depending on who had performed the survey, was noted. The test was carried out by two operators, and it was noted that results varied depending on who performed the measurement.

Wooden boards were placed over the rebar until the distance between the sensor and the bar reached 40 mm. The cover meter was calibrated and configured with the expected bar diameter set to Ø16, with the sensor positioned as shown in Figure 12. The instrument then indicated exactly 40 mm to the bar when the sensor was positioned directly above the bar location and aligned in the same direction as the bar. However, a small lateral offset or change in orientation produced a significantly different result. The technique is therefore highly operator-dependent, and even an experienced operator can obtain incorrect values if an optimal measurement position is not identified. In real conditions, the measurement is affected by uneven concrete surfaces, which can change the sensor angle relative to the bar, and by corrosion, which can weaken the bar's response.

Figure 12 - Sensor placed directly above the rebar and aligned in the same direction as the bar.

A key advantage of cover meters is that they can estimate rebar diameter with an accuracy of approximately ±2 mm under optimal conditions. This is possible because the instrument uses a low-frequency electromagnetic field to induce eddy currents in the surface of the rebar. The eddy currents form perpendicular to the rebar's longitudinal direction and change the coil impedance in a way that differs depending on whether the sensor is oriented along the bar or across it. By measuring the impedance change in both orientations, the instrument obtains two values that together can be used to estimate the bar's cross-sectional area and thereby its diameter, provided the cover is reasonably homogeneous and the distance is short.

In practical field conditions, accuracy is limited by several factors. Small variations in sensor angle relative to the rebar, variations in the electrical resistivity of the concrete, and corrosion on the steel surface affect the signal response. This makes the technique sensitive to probe placement and local conditions at the measurement point. An example of this variation is shown in Figure 13. Marking the rebar using GPR first can make it easier to position the sensor with a consistent orientation relative to the bar. Even then, a high variance in recorded rebar diameters can be expected.[14] [15]

Figure 13 - Example of the instrument's estimated rebar diameter function. In this example, the instrument detected 38 mm to a Ø18 bar instead of the actual 40 mm to a Ø16 bar.

[14] L. Drobiec, R. Jasinski, W. Mazur, Accuracy of Eddy-Current and Radar Methods Used in Reinforcement Detection (2019), Department of Building Structures, Silesian University of Technology. https://www.mdpi.com/1996-1944/12/7/1168 (Accessed 2025-11-07).

[15] Proceq, Tech Specs PDF – PM8000. https://www.screeningeagle.com/en/products/profometer-pm8000 (Accessed 2025-11-07).

4.8 EQUIPMENT TESTING

4.8.1 GSSI Flex NX & GSSI Flex NX25

Practical tests were carried out with the GSSI Flex NX and NX25 during a demonstration at the supplier's premises in Karlstad on 29 October 2025. The measurements were performed on a concrete floor within the supplier's facility. For the GSSI Flex NX, a square area was marked out with tape to define the survey boundary, though the system itself does not require a pre-marked grid for positioning. For the Proceq GP8000, a printed grid was taped to the surface, as the system requires a defined grid to ensure correct geometry in the output. The Flex NX is a linearly polarised GPR system fitted with wheels and a camera-based positioning system. The NX25 is also linearly polarised but uses direct surface coupling via a wear plate, which provides closer contact with the concrete. To enable a comparative assessment, the same area was also scanned with Inspekt's own Proceq GP8000, a linearly polarised wheeled system. The test included both line scans (B-scan) and area scans (C-scan) in order to evaluate differences in function, handling, and data quality between the systems. The test area is shown in Figure 15.

Flex NX and NX25 correspond to the Proceq GP8000 and GP8800 to some extent in terms of intended use. Flex NX and GP8000 are fitted with wheels that provide ground clearance, which facilitates scanning on rougher surfaces and across unevenness. NX25 and GP8800 are placed directly against the concrete surface and use only a wear plate that is dragged over the concrete, providing closer coupling between the antenna and the material. This direct contact resulted in a clearer signal and greater detection depth, which was evident when comparing the results.

A key difference between the systems is how positioning is handled. Flex NX uses two cameras that continuously register the unit's movement and orientation relative to the surface, as illustrated by the scan passes shown in Figure 14. This means the scan can be performed without the operator first marking out a grid. The solution makes it easy to quickly scan an area and allows a higher measurement point density if the operator passes the same area multiple times. However, positioning can be lost during rapid movements or if the cameras cannot find reference features in the surface. In such cases, the scan must be repeated from the start, since the resolution cannot be improved afterwards.

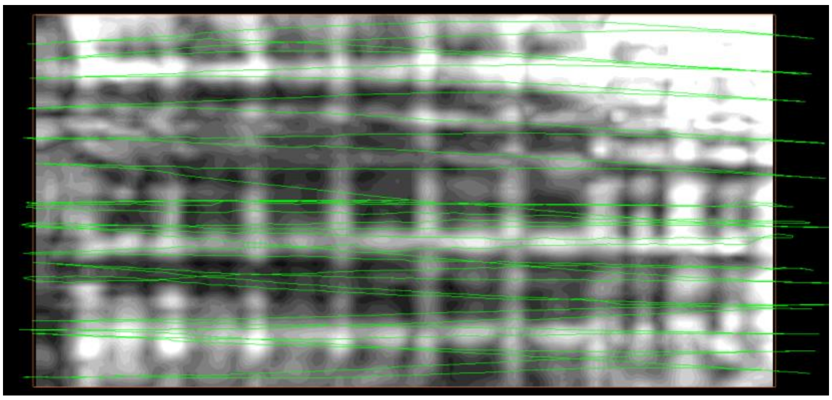


Figure 14 - Survey with Flex NX. The green line indicates scan passes.

Proceq GP8000 requires a marked grid where the survey is performed in two perpendicular directions with a fixed step spacing. Accurate adherence to the grid is essential for the results to be correct. Deviations in direction or sequence affect the geometry of the output. At the same time, the grid-based approach provides a clear advantage for repeated measurements, as it makes it possible to return to the exact same positions at a later stage. Permanent marking of the surface is not always desirable, and it can be time-consuming to apply.

The exact rebar configuration of the scanned structure, including cover depth, bar diameter and c-c spacing, was not verified prior to the test, and the position of the rebar was not known in advance. The focus of the demonstration was on evaluating differences in handling and data quality between the systems rather than on mapping a known rebar layout.

The results from both systems are shown in Figures 19 and 20. Figure 19 shows the Flex NX area scan where an overlap in the reinforcement grid is visible in the upper right corner, and Figure 20 shows the corresponding area from the GP8000, which covers the same section marked in red in Figure 19. Both systems provide comparable information about the upper rebar layer, though the presentation differs. Noise is handled differently between the systems, which is most evident in the C-scans, where the GSSI image tends to appear hazy while the Proceq system introduces straight lines in the background. Which presentation is preferable is largely a matter of personal preference. The NX25 provides additional information beyond the upper rebar layer compared to both Flex NX and GP8000, due to its direct surface coupling.

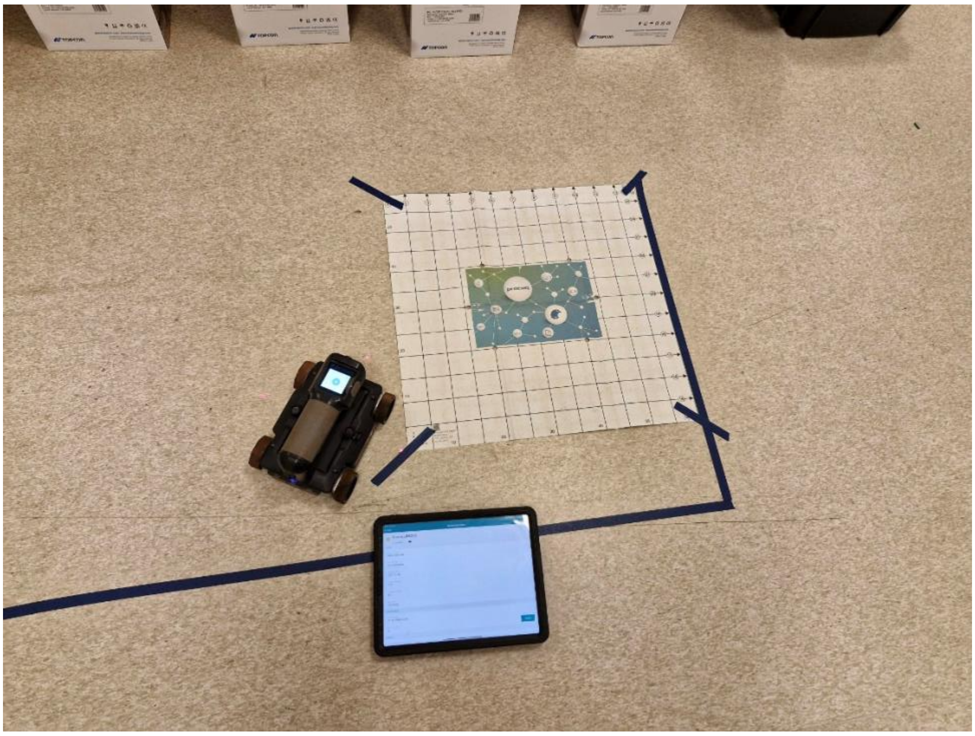


Figure 15 - Test area during the demonstration. The grid shows the survey area for Proceq GP8000, and the outer blue line shows the survey area for GSSI Flex NX.

The differences between the systems are evident in how the data are presented. Proceq provides a more processed visualization where the user has access to a 3D representation of the rebar and a plane slice that can be viewed at different depths. Depth is reported either as signal time or as a converted depth based on a specified dielectric constant. All data are stored automatically in a cloud service, which simplifies sharing and archiving but may impose limitations in environments where storing data outside controlled systems requires specific approvals.

GSSI Flex NX instead provides a less filtered and more direct representation of the acquired signal. This presentation reflects the raw data to a greater extent and reduces the risk that built-in filters or interpretation algorithms influence the results. At the same time, it places higher demands on the operator's experience. Flex NX provides a C-scan for a quick overview of rebar location, but accurate measurements require complementary line scans (B-scan).

In the comparison between Flex NX and GP8000 on the measurement surface in question, no significant difference in detection capability for the first rebar layer was observed. Both systems identified the rebar layout in a comparable manner. Variations in the shape of the hyperbolas were present but are assessed to primarily be due to differences in antenna design and signal processing rather than an actual difference in detectability.

Comparing Flex NX and NX25, the effect of direct coupling to the measurement surface was clear. NX25 produced a sharper radar response and a greater detection depth than Flex NX, which was evident in the line scans from both units, shown in Figures 16, 17 and 18. The difference is the expected result of an antenna system with direct coupling to the surface.

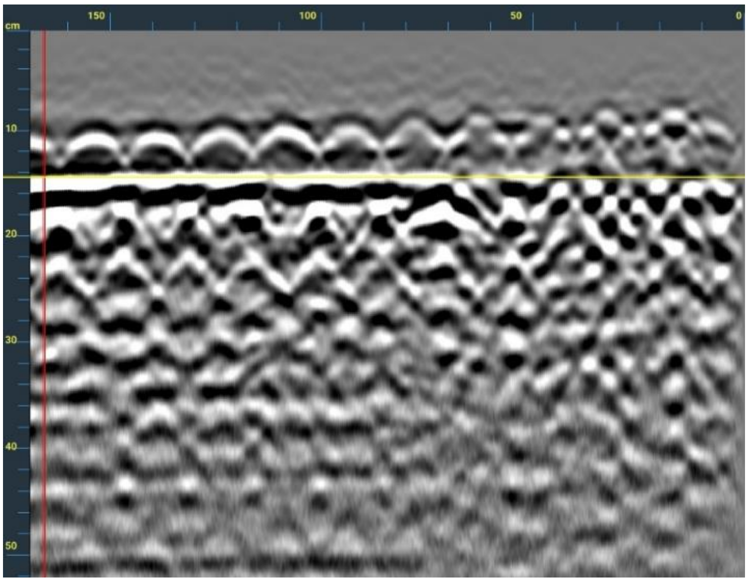


Figure 16 – Line scan (B-scan) from GSSI Flex NX.

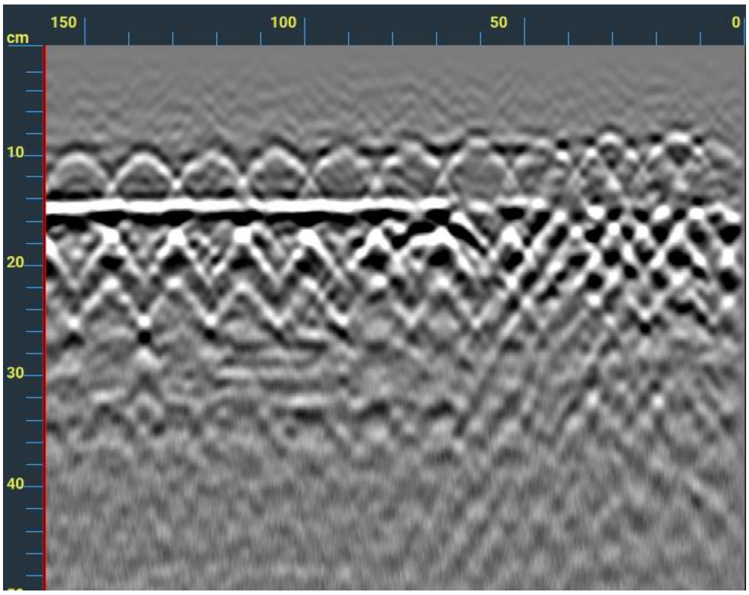


Figure 17 - Line scan (B-scan) from GSSI NX25.

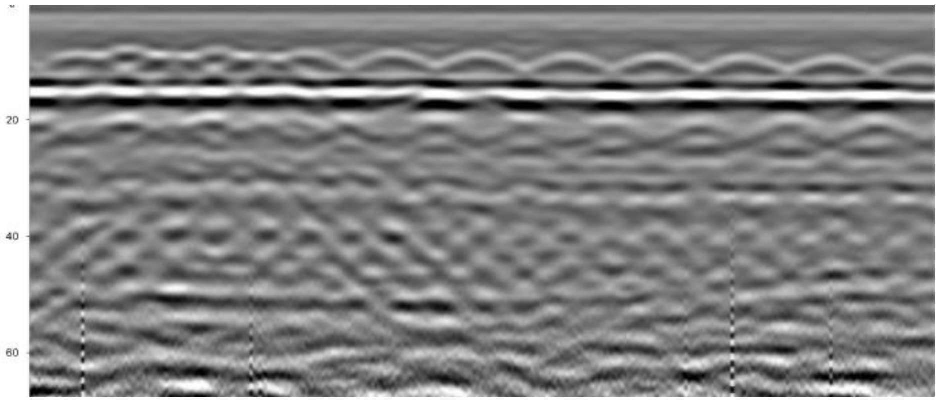


Figure 18 - Line scan (B-scan) from Proceq GP8000.

Area Scan (C-scan)

GSSI FLEX NX

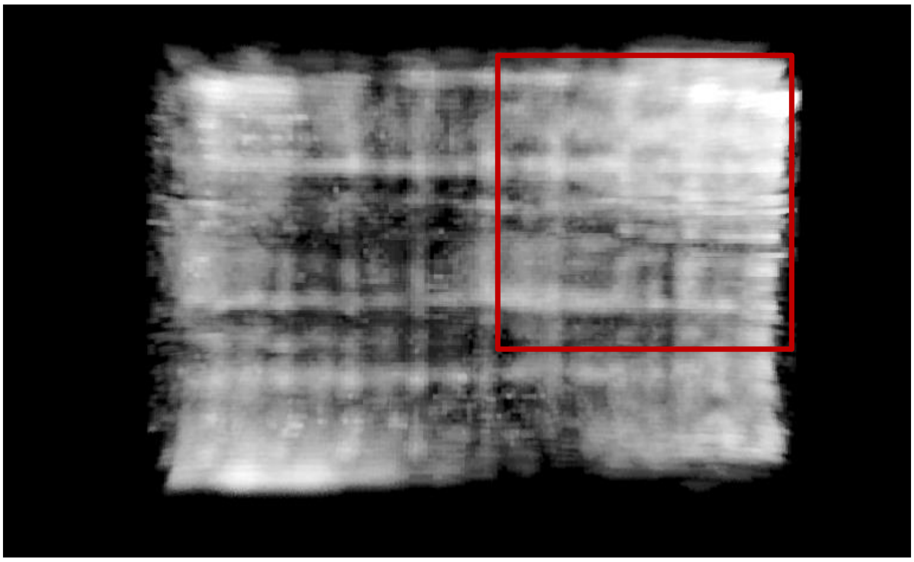


Figure 19 - Area scan (C-scan) from the GSSI Flex NX. An overlap in the reinforcement grid can be seen in the upper right corner (red marking).

Proceq GP8000

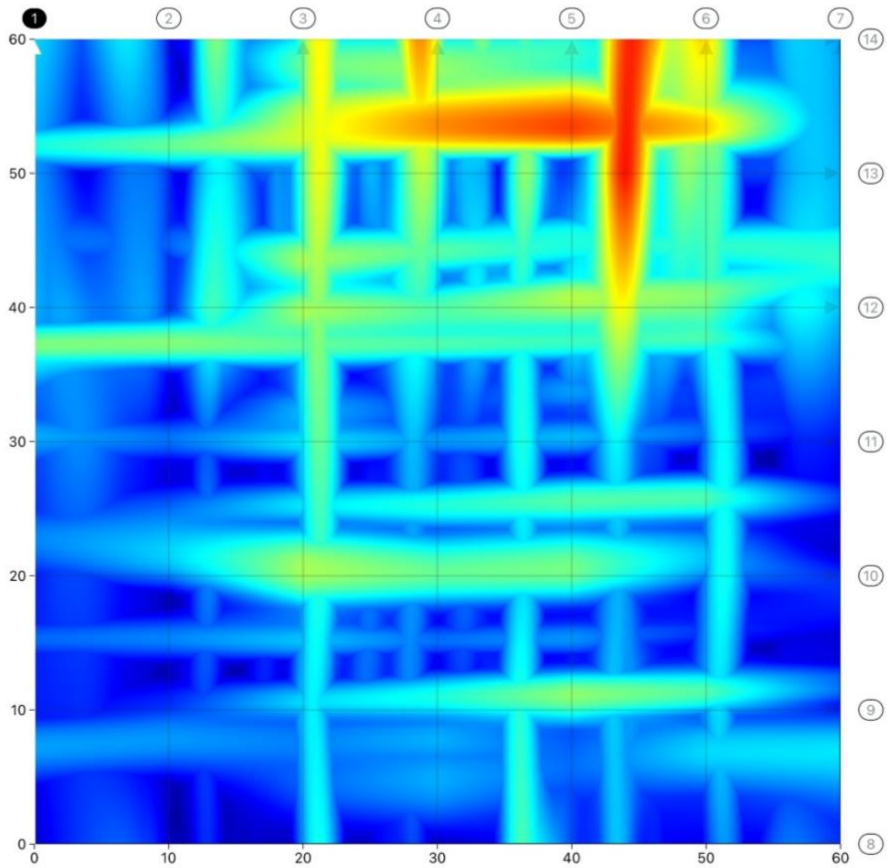


Figure 20 - Area scan (C-scan) from the Proceq GP8000. Corresponds to the upper right corner of the GSSI Flex NX scan (red marking in figure 20).

4.8.2 Proceq / Screening Eagle – GP8000, GP8100 & GP8800

The test was carried out on a test block at KMK Instruments' premises in Västerås using three Proceq GPR systems. The GP8000 is a linearly polarised system fitted with wheels, used here to provide comparable reference data. The GP8800 is a cross-polarised system with direct surface coupling and a slightly higher operating frequency than the GP8000, which produces a clearer image as the stronger reflections from the upper rebar layer are reduced. The GP8100 is a linearly polarised system that acquires six parallel survey lines simultaneously, removing the risk of not being completely parallel between survey swaths. The test block, shown in Figure 21, contains rebar in two layers, and parts of the rebar have been intentionally corroded to demonstrate differences in amplitude. The GP8800 and GP8100 units used in the test are shown in Figures 22 and 23 respectively. The concrete also contains cast-in hoses to enable simulation of a water leak within the concrete. The purpose of the test was primarily to demonstrate differences in image quality between linearly and cross polarised systems rather than to compare technical specifications, which are broadly similar across the three units.

Figure 21 - Test block at the supplier’s site with two layers of rebar.

Figure 22 - Photo of the Proceq GP8800 GPR unit.

Figure 23 - Photo of the Proceq GP8100 GPR unit.

Cross polarization and linear polarization

GPR systems for rebar detection in concrete are fundamentally based on electromagnetic reflections from materials with different dielectric properties. How clearly different objects appear depends, among other factors, on how the antenna's transmitter and receiver are oriented relative to the scan line. Both linearly polarised and cross-polarised antennas are used, and the orientation is suited to different types of surveys.

A standard-oriented antenna (linear polarization) is optimised to capture reflections from metallic objects that are perpendicular to the scanning direction. Rebars, rebar meshes, and metal conduits produce high amplitudes and characteristic hyperbolas. This makes the antenna type very effective when the main purpose is to locate the first layer of rebar. The drawback is that these strong reflections often dominate the signal image. Dense rebar or mesh frequently generates strong hyperbolas that can obscure deeper objects and objects of other materials, such as plastic pipes, cables, or other installations below the first rebar layer.

A cross-polarised antenna is oriented so that the transmitter and receiver are rotated 90 degrees compared with the standard antenna. This makes the antenna significantly less sensitive to metallic objects. Metal is still visible, but with reduced amplitude. The effect is that hyperbolas from the top rebar layer are reduced, making objects deeper in the concrete stand out more clearly in the results. This can include, for example, piping routes or concealed installations.

When both antenna orientations are used together, either in the same pass or integrated in the same unit so that polarization can be selected, the standard-oriented antenna provides clear and rapid localization of metal in the top layer, while the cross-polarised antenna enables interpretation of deeper objects that are often masked by strong reflections from the first rebar layer. The combination therefore provides a more complete picture of the concrete's internal structure and embedded installations than a system with only linear polarization can deliver.

In practical use, this means cross-polarization does not replace linearly polarised systems, which can be considered the standard. Instead, it functions as a filter that may make it possible to see beyond the first rebar layer.[16]

[16] M.Lualdi & F.Lombardi, Significance of GPR polarisation for improving target detection and characterisation (Department of Civil and Environmental Engineering, Politecnico di Milano. 2014) https://re.public.polimi.it/bitstream/11311/880159/3/Significance%20of%20GPR%20polarisation%20for%20improving%20target%20detection_11311-880159_Lualdi.pdf (Accessed 2025-11-04)

In comparative tests between GP8000 and GP8800, the difference between linearly polarised and cross-polarised systems is clear, as shown in Figures 26 and 27. With cross polarisation, the transmitter and receiver are oriented so that signals pass between the rebar rather than through it, which reduces the amplitude of reflections from the upper rebar layer. This makes it possible to distinguish deeper structures, including in some cases the lower rebar layer, that would otherwise be masked.

In the example below, a C-scan shows the concrete measured from above, with results from GP8000 and GP8800 shown in Figures 25 and 26 respectively. The image can be compared to “peeling away” the concrete and displaying only the rebar inside. Within the circle (orange marking), there is also a clear example of how corroded rebar appears in GPR data. This does not provide an absolute corrosion value, but it indicates that the rebar in the area is likely corroded, and corrosion measurement equipment can then be used to obtain a more exact value.

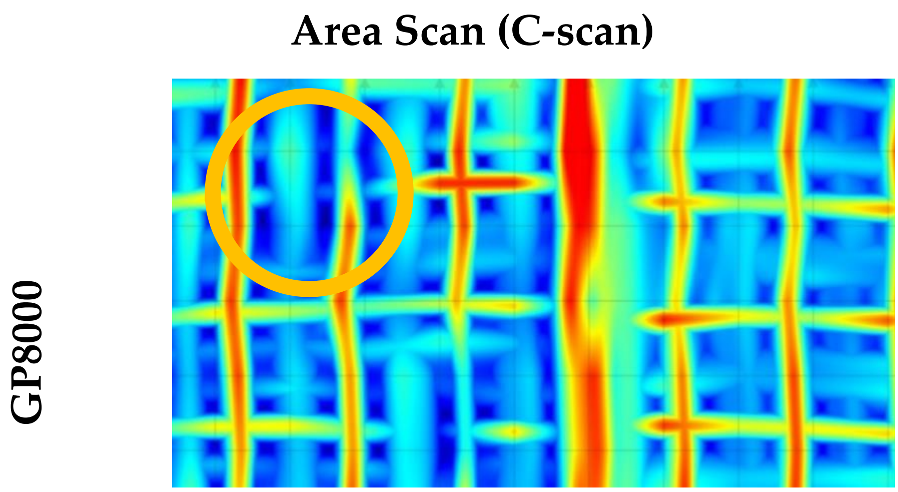


Figure 24 - Area scan (C-scan), GP8000. Corroded rebar is visible in the area marked with a yellow circle.

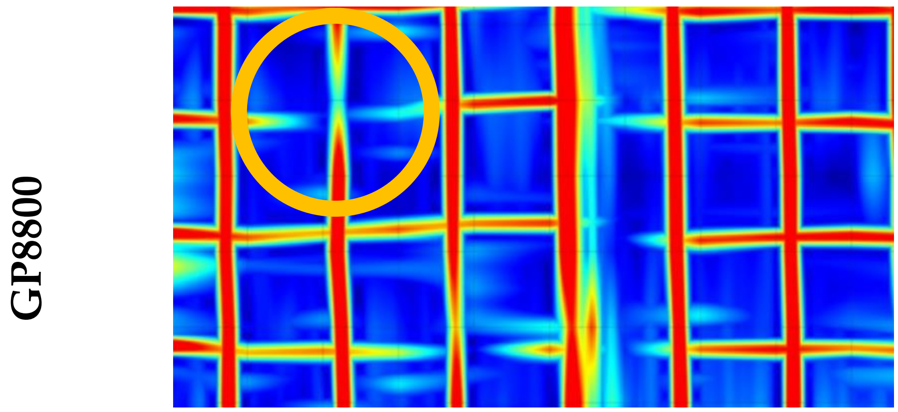


Figure 25 - Area scan (C-scan), GP8800. Corroded rebar is visible in the area marked with a yellow circle.

In the example below, a single measurement line is shown, a B-scan, with results from GP8000 and GP8800 shown in Figures 27 and 28 respectively. The image functions as a cross-section of the concrete, and each hyperbola represents a reflection from an anomalous structure within the concrete. The example shows that even when the gain is adjusted to clearly display the upper rebar layer, subsequent echoes from that upper layer become weaker, making it easier to distinguish weaker structures beneath the upper rebar layer.

In this example, in addition to the upper rebar layer, three reflections from embedded hoses can be seen (orange arrow), as well as a weak reflection that is likely the lower rebar layer (blue arrow). This also illustrates how difficult it can be to distinguish the second rebar layer, even in a controlled environment.

Line Scan (B-scan)

GP8000 (Linjärpolariserat)

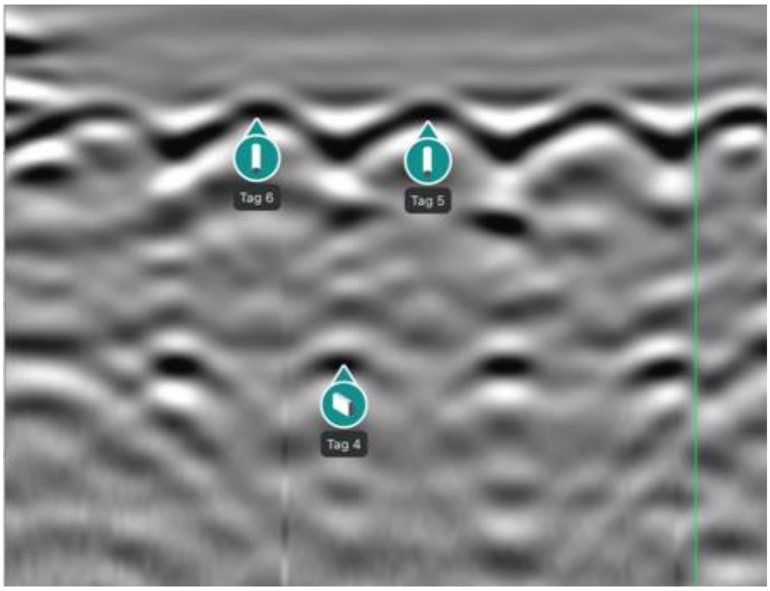


Figure 26 - Radargram (B-scan) measured with linear polarisation. Reflections from the upper layer obscure much of the underlying information.

GP8800 (Korspolariserat)

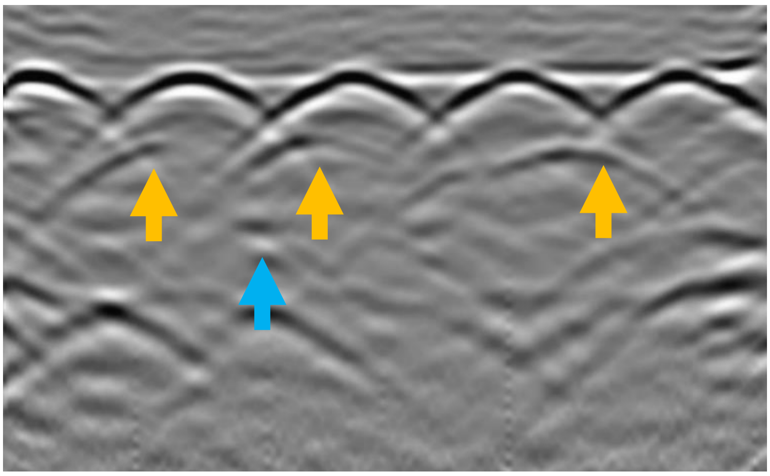


Figure 27 - Radargram measured with cross polarisation. Reflections from the upper layer have less influence, and more information becomes visible.

GP8100 functions like a GP8000, but with six channels across the width, as illustrated in Figure 29. In practice, each pass corresponds to acquiring six perfectly parallel survey lines at the same time. The increased coverage produced a more coherent image of the rebar layout because multiple adjacent lines are recorded simultaneously. This resulted in less geometric distortion of the rebar pattern and a higher capacity to cover larger areas within a single continuous dataset, which can be an advantage when mapping larger structural elements.

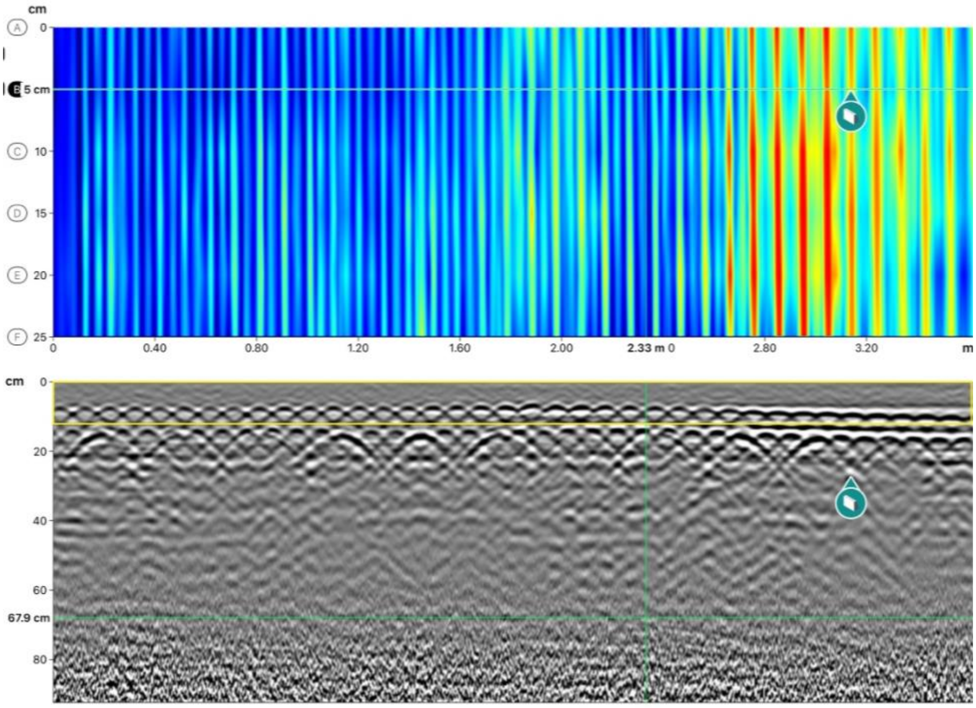


Figure 28 - Example from a measurement with the Proceq GP8100. The unit displays a line scan (B-scan) and a C-scan constructed from one of the six channels in this system.

5 Results and Discussion

Ground-penetrating radar (GPR)

GPR provides a coherent planar view of rebar location and is well suited for mapping larger areas. On dry and homogeneous concrete surfaces, the first rebar layer is clearly resolved, and rebar spacing (c/c) can be established with good repeatability. When measurements are carried out using grid-based profiles, the resulting planar view can be reproduced consistently regardless of operator, as observed in the comparative testing between GP8000 and Flex NX, which makes the method suitable for systematic and repeated investigations. The method is affected by moisture or conductive materials within the concrete, which leads to attenuation and diffuse reflections.[2] In such cases, uncertainty increases, and deeper targets are often masked by hyperbolas from the uppermost rebar layer. On test areas with densely reinforced structures, reflections from the shallow layer dominated the signal response, which limited the ability to distinguish underlying layers.

Ultrasound (UPE & UPV)

The ultrasound measurements showed that the technique can indicate the position of rebar behind the first layer and provide information on the internal structure of the concrete when good coupling and smooth surfaces are available. In several cases, the method produced indications from rebar in both the upper and lower layers and could also be used to identify areas where backwall reflections indicated that no obstructions were present in the near-surface layers.

The field studies also showed that the ultrasound images were more fragmented than the GPR data and that amplitude varied substantially along different parts of the same rebar. The field studies showed that the technique was affected by surface irregularities and variations in rebar diameter, and some rebar produced no clear reflection despite being within the measurement area. Surface roughness is a known factor affecting signal quality, as it influences the amplitude settings required to achieve consistent coupling between the transducer and the concrete surface.[17] Rebar with small cover fell above the detection depth range, which limited the method's ability to show near-surface targets.

Cover meter (Eddy current)

Cover meters are a simpler and less expensive alternative to GPR and can serve as a good starting point if GPR is not available. Because the method responds only to ferromagnetic objects in the concrete, the risk is reduced that an inexperienced operator misinterprets signals from non-metallic objects, such as plastic conduits, as rebar.

[17] S. Wagle, K.R. Chapagain, Seeing beneath the surface – a performance comparison of non-destructive technologies for concrete inspection, Elop Technology AS (2020). https://elop.no (Accessed 2025-11-25).

They are easy to use, but the results were heavily operator dependent, as noted in the equipment tests. The equipment provides a direct indication of rebar position without further analysis and can determine cover thickness, rebar spacing (c/c), and in some cases estimate rebar diameter. For measurements on smooth, dry concrete surfaces with known material properties, a reasonable level of repeatability is achieved, and the uncertainty is ±2 mm for cover up to approximately 50 mm.[15]

Magnetometry

Magnetometry is assessed to provide a clear two-dimensional image of ferromagnetic elements in concrete and can, in principle, be used to detect rebar patterns in planar view. A limitation in the current market is that the commercially available service requires raw data to be transferred to an external supplier for processing, which reduces transparency in the analysis and leaves uncertainty regarding data security.[13] In addition, the method lacks the capability to determine rebar position in depth.

Impact Echo

Based on technical documentation, Impact Echo shows good capability for estimating slab thickness and indicating larger internal defects, particularly in structures where GPR or ultrasound are limited by multiple rebar layers or high moisture. The method cannot separate rebar layers or establish rebar geometry and therefore has limited relevance to the specific question of rebar detection.

Discussion

The overall results show that no single method can provide all the information needed to map rebar position in concrete structures when multiple layers of larger diameter rebar are present. Ultrasonic methods and GPR complement each other well and together constitute the most useful combination when both plan-positioning and detailed depth information are required. GPR can rapidly map the upper rebar layer and provide an initial indication of whether additional layers may be present, but interpretation is limited by moisture, dense rebar patterns, and variations in concrete properties. Ultrasound can, in these situations, provide the required depth control, since acoustic waves can propagate past the upper rebar layer and produce reflections from underlying layers and from the concrete backwall, provided that the surface is sufficiently even and that signal processing is carried out correctly. Using GPR for the planar view and as support for interpreting ultrasound data provides a better decision basis than the methods can deliver individually.

The practical comparisons between techniques show that GPR detects the upper rebar layer and provides an easy-to-interpret image of its position. The underlying rebar layer cannot, however, be detected with sufficient certainty. Ultrasound can in several cases produce indications from rebar in the second layer, but the image is often fragmented and individual bars appear indistinctly or are missing entirely in the raw data. One way to increase reliability is to analyse reflections from the concrete backwall. If an area produces a strong and clear backwall reflection, it is likely free of rebar between the measurement surface and the backwall. Shadowing in these reflections, or weaker reflections, generally coincides with areas where rebar is present in the concrete. For critical point interventions, a cover-meter borehole probe (eddy current) in a small pilot hole can also be used to locally check for nearby rebar before enlarging the hole to the intended diameter.

Among the GPR systems tested, the Flex NX and GP8000 showed comparable detection capability for the upper rebar layer. The NX25 and GP8800, both of which use direct surface coupling, produced sharper radar responses and greater detection depth. This suggests that direct-coupling systems are preferable where maximum detection depth is required. A practical difference between the systems is how data is handled, as Proceq systems store data automatically in a cloud service, though offline operation via a direct USB-C connection is possible. This may be a relevant consideration in environments where data storage outside controlled systems requires specific approvals. Flex NX uses camera-based positioning which removes the need for a pre-marked grid, while GP8000 requires a marked grid but supports more consistent repeatability and the ability to return to exact positions at a later stage. In nuclear environments, the acquisition cost of equipment is also a relevant factor, as equipment that becomes contaminated may need to be left on site. Cover meters is the lowest cost option in this regard, while high end GPR and especially ultrasound systems carry a significantly higher financial consequence in the event of contamination. Both Proceq and GSSI systems are well suited for rebar detection, but directly coupled systems such as the GP8800 and NX25 are preferable where there is a need to survey beyond the first layer of rebar.

In contexts where the purpose is purely rebar detection, other methods have more limited practical value. Cover meters are useful when only the near-surface rebar layer is to be detected or when rebar diameter needs to be estimated. The method is easy to use, relatively inexpensive, and provides a direct response, but it requires moderate cover depth and that the sensor is positioned exactly over the rebar. Magnetometry can, according to suppliers, provide plan-view images of rebar and indicate magnetic changes that may be related to corrosion, but it lacks depth positioning and does not currently allow in-house analysis. This limits its use in facilities where data handling has national security implications. Impact Echo and radiography serve specific purposes such as thickness estimation or assessment of deep defects, but they have no practical role in routine rebar mapping since other methods provide more practically useful results.

6 Conclusion and recommendations

A practically feasible workflow is to primarily use equipment that technically competent personnel can operate. A cover meter is a suitable first step and provides a quick indication of where rebar is located when the cover depth is moderate. When the cover meter does not provide a response, or when results need to be verified prior to drilling, GPR is a natural next step. In normal cases, GPR can be used by technically competent personnel after a short introduction and with technical support from the equipment supplier, provided that measurements follow the specified procedures and interpretation is limited to the upper rebar layer. Under more complex conditions, such as multiple rebar layers, high moisture, or where incorrect interpretation could have serious consequences, the results should be reviewed and/or supported by a specialist.

Ultrasonic measurements should not be carried out without experience with the method. Reliability depends on operator handling, surface evenness, and signal processing. Ultrasound is best suited as a supplement where GPR cannot provide sufficient information, for example at depths beyond the upper rebar layer. Of the ultrasound systems reviewed, the Elop Insight Scanner is the only one tested in practice within this project, and it demonstrated the ability to detect rebar in both the upper and lower layers as well as identify rebar free zones using backwall reflections. Judging only by technical data sheets for the Proceq PD8050 and MIRA 3D, both options seem suitable as well.

Overall, the most applicable and reliable strategy is to use a cover meter or GPR for the initial mapping, depending on which equipment is available. If additional information is required, the work should continue using a combination of GPR and ultrasound. Based on the results from this project, both Proceq and GSSI GPR systems are well suited for this purpose. For surveys where detection beyond the upper rebar layer is required, directly coupled systems with the option of cross polarisation, such as the GP8800 and NX25 are recommended. For ultrasound, the Elop Insight Scanner performed well in practice, and the Proceq PD8050 and MIRA 3D are assessed as suitable alternatives based on their specifications.

6.1 RECOMMENDATION FOR FURTHER STUDIES

In this project, the original plan was to test all equipment on the same blocks in order to enable a direct comparison between systems. This proved not to be practically feasible, as we are regarded as direct- or indirect competitors by many suppliers. For future studies, it is recommended that this comparative testing be carried out in line with the original plan, since a shared practical trial under controlled conditions provides a clearer basis for method selection and performance comparisons between systems.

7 Reference List

1. Iowa State University, Eddy Current Testing, Nondestructive Evaluation Techniques (n.d). https://www.nde-ed.org/NDETechniques/EddyCurrent/eddycurrenttesting.xhtml (Accessed 2025-11-04)
2. J.Daniels, Ground Penetrating Radar Fundamentals, Department of Geological Sciences, The Ohio State University (2000). https://www.researchgate.net/publication/237508286_Ground_Penetrating_Radar_Fundamentals (Accessed 2025-11-04).
3. Iowa State University, Basic Principles of Ultrasonic Testing (n.d), https://www.nde-ed.org/NDETechniques/Ultrasonics/Introduction/description.xhtml (Accessed 2025-11-04)
4. Iowa State University, Acoustic Emission Testing, https://www.nde-ed.org/NDETechniques/AcousticEmission/AE_Intro.xhtml (Accessed 2025-11-05)
5. InspecTerra, 'Quantitative Corrosion Mapping Solution', InspecTerra, (n.d), https://www.inspecterra.com/ (Accessed 2025-12-04).
6. N.J.Carino, THE IMPACT-ECHO METHOD: AN OVERVIEW. Building and Fire Research Laboratory National Institute of Standards and Technology Gaithersburg (2001). https://tsapps.nist.gov/publication/get_pdf.cfm?pub_id=860355 (Accessed 2025-11-04).
7. Jinnestrand, J. Chief Technical Officer Inspekt Sweden AB, Karosas, D. Regional Manager Inspekt Sweden AB [Interview] (2025-11-24).
8. G.Leucci, S.Negri, Ground Penetrating Radar (GPR): An application for evaluating the state of maintenance of the building coating (2003), Annals of Geophysics. https://www.researchgate.net/publication/27772009_Ground_Penetrating_Radar_GPR_An_application_for_evaluating_the_state_of_maintenance_of_the_building_coating (Accessed 2025-11-05).
9. The Ultrasound table is based on the equipment suppliers' technical specifications, datasheets, and marketing materials, listed below:
    - 9.1. Elop Technology AS, Elop Insight Scanner Brochure and Technical Datasheet. https://elop.no/technical-specifications/ (Accessed 2023-11-29).
    - 9.2. Screening Eagle, Pundit PD8050 Tech Specs. (n.d.). https://www.screeningeagle.com/en/products/pundit-pd8050 (Accessed 2025-10-05).
    - 9.3. Screening Eagle, Pundit 200 Tech Specs.. (n.d.). https://www.screeningeagle.com/en/products/pundit-200 (Accessed 2025-11-05).
    - 9.4. Screening Eagle, Pundit Lab Tech Specs.. (n.d.). https://www.screeningeagle.com/en/products/pundit-lab (Accessed 2025-11-05).

9.5. ACS International, 1040 Mira 3D Product Flyer. (n.d.). https://acs-international.com/instruments/ultrasonic-pulse-echo-tomography-systems-mira/a1040-mira-3d-thickness-measurement-rebar-and-flaw-detection/ (Accessed 2025-11-05).

9.6. ACS International, MIRA 1040 3D PRO Product Flyer. (n.d.). https://acs-international.com/instruments/ultrasonic-pulse-echo-tomography-systems-mira/a1040-mira-3d-pro-thickness-measurement-rebar-and-flaw-detection/ (Accessed 2025-11-05).

9.7. Germann Instruments, Pulsar Technical Data-Sheet. (n.d.). https://www.germanninstruments.com/ultrasonic-velocity-tester-pulsar/ (Accessed 2025-11-05).

9.8. Germann Instruments, Surfer Technical Data-Sheet. (n.d.). https://www.germanninstruments.com/ultrasonic-pulse-velocity-tester-surfer/ (Accessed 2025-11-05).

10. The Georadar table is based on the equipment suppliers' technical specifications, datasheets, and marketing materials, listed below:

10.1. Proceq/Screening Eagle, GP8000 Tech Specs. (n.d.). https://www.screeningeagle.com/en/products/Proceq-GP8000 (Accessed 2025-11-05).

10.2. Proceq/Screening Eagle, GP8100 Tech Specs. (n.d.). https://www.screeningeagle.com/en/products/proceq-gp8100 (Accessed 2025-11-05).

10.3. Proceq/Screening Eagle, GP8800 Tech Specs. (n.d.). https://www.screeningeagle.com/en/products/proceq-gp8800 (Accessed 2025-11-05).

10.4. Hexagon/IDS Georadar, C-thrue Datasheet. (n.d.). https://idsgeoradar.com/products/ground-penetrating-radar/c-thrue (Accessed 2025-11-05).

10.5. Hexagon/IDS Georadar, C-thrue XS Datasheet. (n.d.). https://idsgeoradar.com/products/ground-penetrating-radar/c-thruexs (Accessed 2025-11-05).

10.6. Sensors & Software, Conquest 100 Brochure. (n.d.). https://www.sensoft.ca/products/conquest100/overview/ (Accessed 2025-11-05).

10.7. Hilti, PS 1000 X-SCAN. (n.d.). https://www.hilti.se/c/CLS_MEA_TOOL_INSERT_7127/CLS_CONCRETE_SCANNERS_SENSORS_7127/r6436760 (Accessed 2025-11-05).

10.8. GSSI, GSSI Concrete Scanning Systes – August 2025 (2025). https://www.geophysical.com/products/flex-lt (Accessed 2025-11-05).

10.9. GSSI, Flex LT Advanced Product Specifications. (n.d.). https://www.geophysical.com/products/flex-lt (Accessed 2025-11-05).

10.10. GSSI, Flex NX Advanced Product Specifications. (n.d.). https://www.geophysical.com/products/flex-nx (Accessed 2025-11-05).

10.11. GSSI, NX15 Advanced Product Specifications. (n.d.). https://www.geophysical.com/products/nx15 (Accessed 2025-11-05).

10.12. GSSI, NX25 Advanced Product Specifications. (n.d.). https://www.geophysical.com/products/nx25 (Accessed 2025-11-05).

10.13. Bosch, Wallscanner D-TECT 200 C Professional Technical Specifications. (n.d.). https://www.bosch-professional.com/se/sv/products/wallscanner-d-tect-200-c-0601081601 (Accessed 2025-11-05).

10.14. Makita, DWD181ZJ Technical Specifications. (n.d.). https://makita.com.au/cordless/lxt-18v-36v/measuring/dwd181zj-18v-surface-scanner (Accessed 2025-11-05).

10.15. Milwaukee, M12 Subscanner Operator’s Manual. (n.d.). https://www.milwaukeetool.com/products/details/sub-scanner-m12-detection-tool/2291-20 (Accessed 2025-11-05).

11. The Cover Meter table is based on the equipment suppliers’ technical specifications, datasheets, and marketing materials, listed below:

11.1. Elcometer, Elcometer 331 Covermeter. (n.d.). https://www.elcometer.com/en/elcometer-331-covermeters-half-cell-meters.html (Accessed 2025-11-05).

11.2. Proceq/Screening Eagle, Profometer PM8000 Pro. (n.d.). https://www.screeningeagle.com/en/products/profometer-pm8000 (Accessed 2025-11-05).

11.3. Proceq/Screening Eagle, Profometer PM8000. (n.d.). https://www.screeningeagle.com/en/products/profometer-pm8000 (Accessed 2025-11-05).

11.4. Proceq/Screening Eagle, Profometer PM8000 Lite. (n.d.). https://www.screeningeagle.com/en/products/profometer-pm8000-lite (Accessed 2025-11-05).

11.5. Hilti, PS 300. (n.d.). https://www.hilti.se/c/CLS_MEA_TOOL_INSERT_7127/CLS_CONCRETE_SCANNERS_SENSORS_7127/r9374764 (Accessed 2025-11-05).

11.6. Hilti, PS 85. (n.d.). https://www.hilti.se/c/CLS_MEA_TOOL_INSERT_7127/CLS_CONCRETE_SCANNERS_SENSORS_7127/r13801207 (Accessed 2025-11-05).

11.7. Kolectric, MC8022+. (n.d.). https://www.kolectric.com/mc8022plus-covermeter.php (Accessed 2025-11-05).

12. The Impact Echo and Magnetometry table is based on the equipment suppliers’ technical specifications, datasheets, and marketing materials, listed below:

12.1. Proceq/Screening Eagle, Pundit PI8000. (n.d.). https://www.screeningeagle.com/en/products/pundit-pi8000 (Accessed 2025-11-05).

12.2. Germann Instruments, Mirador Impact Echo. (n.d.). https://www.germanninstruments.com/impact-echo-test-mirador/ (Accessed 2025-11-05).

12.3. Inspekt, Teams Meeting with InspecTerra. (2025). Internal Communcation 2025-02-17.

13. Teams meeting between Inspekt and InspecTerra regarding Icamm, 2025 february 13.

14. L. Drobiec, R. Yessinski, W. Mazur, Accuracy of Eddy-Current and Radar Methods Used in Reinforcement Detection (2019), Department of Building Structures, Silesian University of Technology. https://www.mdpi.com/1996-1944/12/7/1168 (Accessed 2025-11-07).

15. Proceq, Tech Specs PDF – PM8000. https://www.screeningeagle.com/en/products/profometer-pm8000 (Accessed 2025-11-07).

16. M.Lualdi & F.Lombardi, Significance of GPR polarisation for improving target detection and characterisation (Department of Civil and Environmental Engineering, Politecnico di Milano. 2014) https://re.public.polimi.it/bitstream/11311/880159/3/Significance%20of%20GPR%20polarisation%20for%20improving%20target%20detection_11311-880159_Lualdi.pdf (Accessed 2025-11-04

17. S. Wagle, K.R. Chapagain, Seeing beneath the surface – a performance comparison of non-destructive technologies for concrete inspection, Elop Technology AS (2020). https://elop.no (Accessed 2025-11-25).

METHODS FOR DETECTING REBAR IN NUCLEAR CONCRETE STRUCTURES

This project has reviewed non-destructive methods for detecting reinforcement in concrete structures and clarified which tasks can be performed by technically skilled in-house personnel and when specialist support is required.

Being able to accurately detect and map rebar in concrete constructions is important for safe and efficient performance of investment and maintenance projects in the nuclear power plants.

There are many methods and instruments available, and this study aims to evaluate non-destructive methods for rebar detection, clarifying which tasks can be performed by in-house technical staff and when specialist expertise is required. The focus is on practical applicability and method selection.

The results show that no single method is sufficient for all scenarios. Combining ground-penetrating radar and ultrasound provides the most reliable mapping, while cover meters offer a useful first step for near-surface rebar.