

# Non-Destructive Testing of Steel Fibre Reinforced Concrete

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**Abstract.** For standard reinforced concrete, there are several non-destructive test (NDT) methods available for measuring the concrete cover and for locating subsurface objects and defects. Whether or not these methods may also be applied to fibre reinforced concrete has been the subject of a recent study. The results and a recommendation for the most suitable technology for use with fibre reinforced concrete is the topic of this paper.

## 1. Introduction

One of the major design parameters for ensuring a minimum service life of a structure is the concrete cover. Together with the concrete quality this determines how long it will take for aggressive agents such as chlorides and carbonation layers to reach the steel reinforcement. All major standards bodies have recommendations for the concrete cover based on the environmental exposure class to which the structure is subjected. The concrete quality is typically specified prescriptively in terms of compressive strength class, minimum cement content and water / cement ratio. The concrete cover can be checked at the time of construction by non-destructive methods.

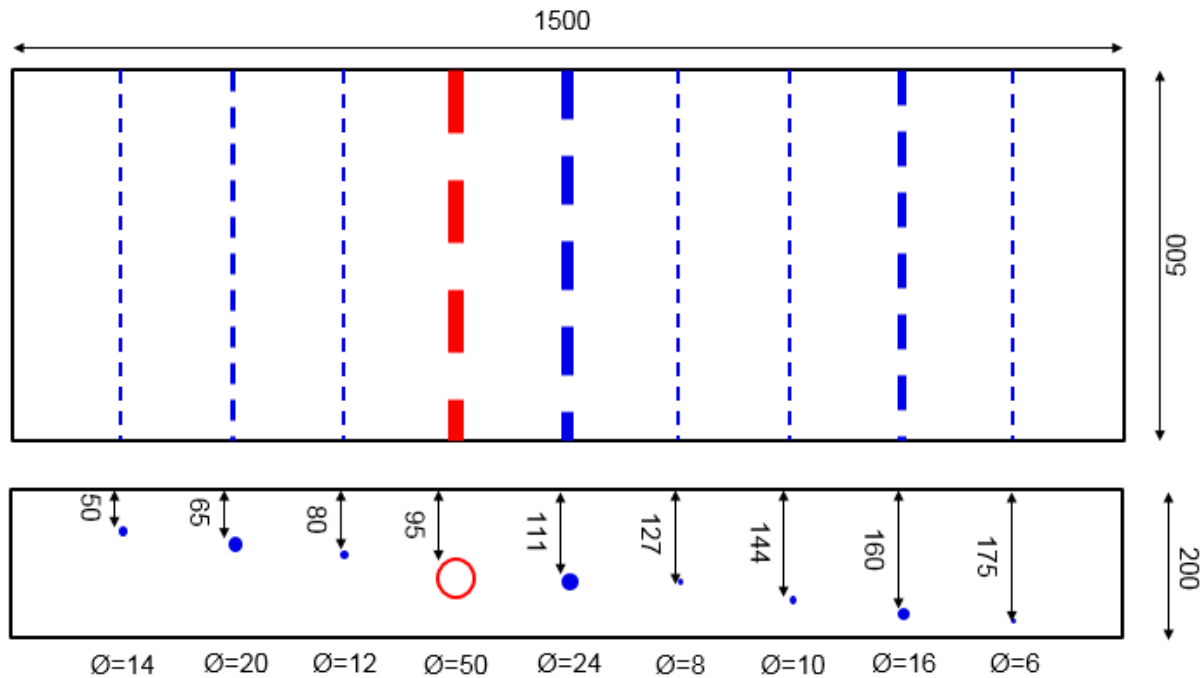
The two most common technologies used for measuring concrete cover are magnetic eddy current and ground penetrating radar. A study [1] has recently been carried out at HSR “Hochschule für Technik” Rapperswil in Switzerland to investigate whether or not these technologies along with several others could be applied to fibre reinforced concrete.

As developers and manufacturers of NDT equipment, Proceq were invited to carry out their own tests on the specially dedicated test blocks to reach their own conclusions independently. This paper presents the results of that testing.

## 2. The Test Objects

Three test objects were made available by HSR. Each test object was a 150x50x20cm concrete prism with eight different rebars and a plastic tube embedded at different depths (Figures 1 and 2).



**Figure 1.** Test blocks**Figure 2.** Test Block Dimensions and Layout

Although identical in size and layout the difference between the test objects was in the fibre content of the concrete used. Test block 1 was constructed with standard concrete with no fibre content. Test block 2 had a fibre content of  $30 \text{ kg/m}^3$  and test block 3 had a content of  $60 \text{ kg/m}^3$ . Dramix steel fibres  $1 \times 50\text{mm}$  were used. The concrete used had a concrete compressive strength class of C25/30 with a maximum aggregate size of 32mm.

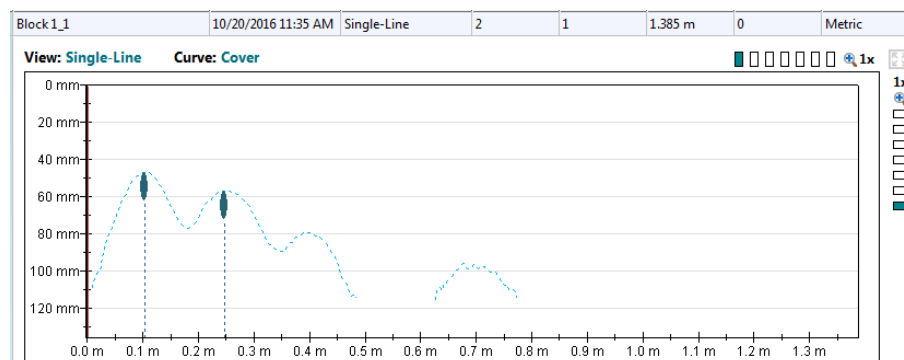
### 3. Pulse Eddy Current Testing

The instrument used for this test was the Proceq Profometer 650 AI (pulsed eddy current), Figure 3. This is a typical cover meter working on magnetic eddy current principles. This technology is generally recognized as providing the most accurate assessment of cover on site.



**Figure 3.** Profometer 650 AI Cover Meter

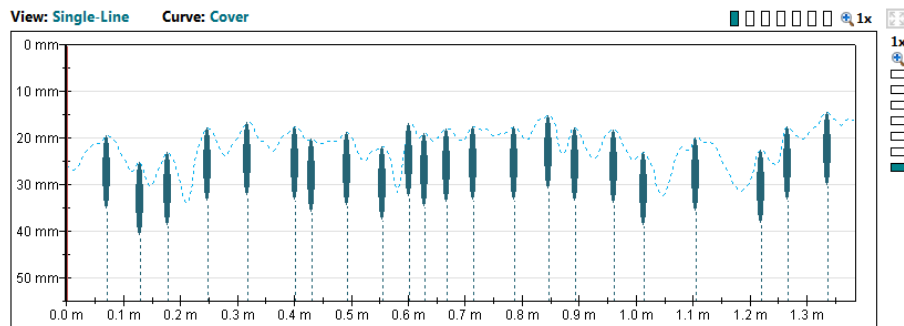
Longitudinal single line scans were made on all three blocks. Such scans record the signal strength as the scan cart is moved along the block and also detects the location of rebars automatically. The signal strength is converted into concrete cover based on the rebar size. Figure 4 shows the result from test block one which acts as the reference block.



**Figure 4.** Block 1 Eddy Current Single-Line Scan

The first two rebars can be easily detected as they lie within the standard measuring range. After that the signal strength becomes too small for automatic detection, although from the cover single line it is easy to see the location of the 3<sup>rd</sup> rebar and the 5<sup>th</sup> rebar. The 4<sup>th</sup> object is a hollow plastic pipe which cannot be detected by magnetic eddy current instruments.

Now compare this with the scan of block 2 containing 30 kg/m<sup>3</sup> of steel fibres.

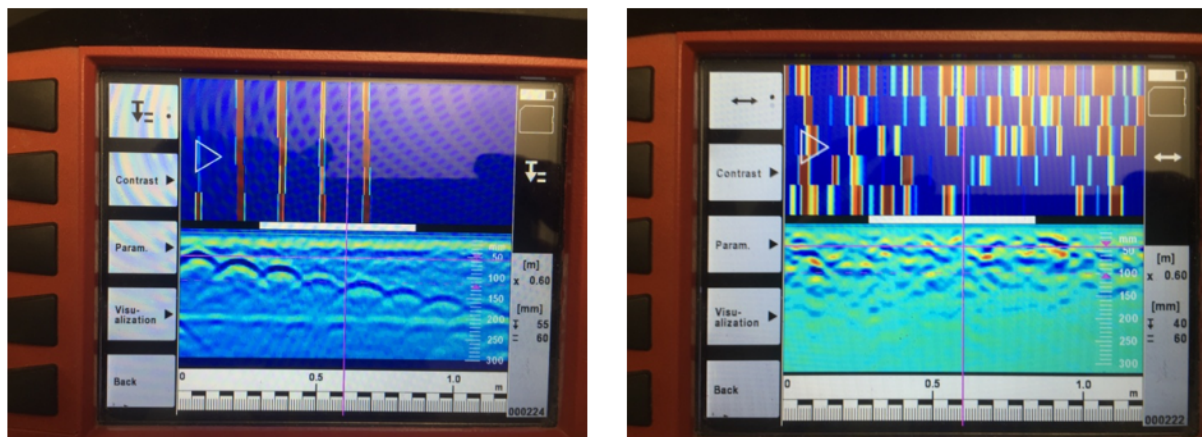


**Figure 5.** Block 2 Eddy Current Single Line Scan

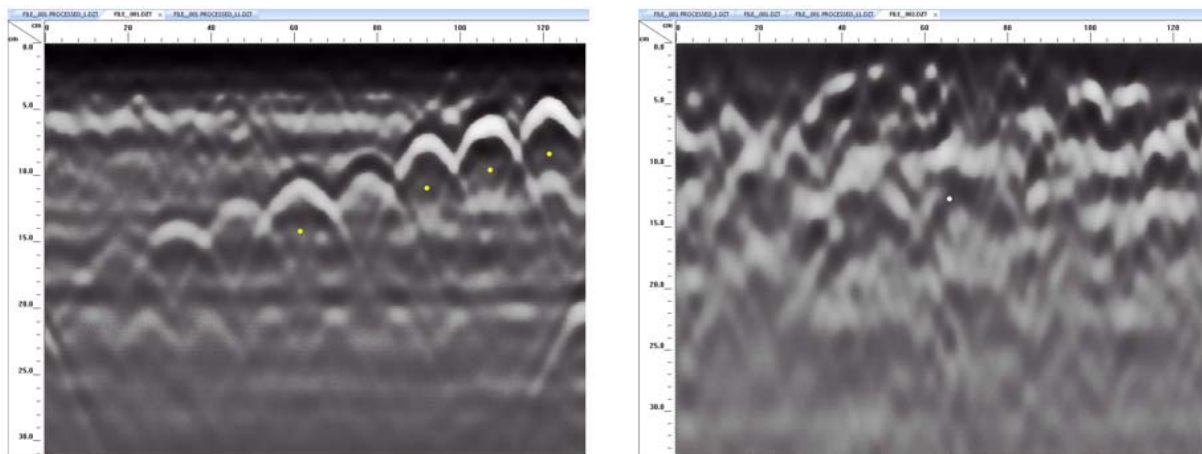
No rebar can be clearly detected. The signal curve was always affected by large numbers of local peaks, completely masking the actual position of the rebars. The same occurred when testing on block 3 with the higher steel fibre content.

#### 4. Ground Penetrating Radar (GPR) Testing

Two instruments were used for this test, the Hilti PS-100 and the GSSI Mini Structure Scan XT. Once again scans were carried out on the reference block and then on the blocks containing fibres. The results from each instrument can be seen in Figures 6 and 7.



**Figure 6.** Hilti GPR scan of block 1 (left) and block 2 (right)



**Figure 7.** GSSI GPR scan of block 1 (left) and block 2 (right)

In both examples, it can be seen that the rebars and also the hollow pipe can be clearly detected on block 1. The back wall is also clearly identifiable. However, on block 2 the results are meaningless. It is impossible to detect the objects.

### 5. Ultrasonic Pulse Echo Testing

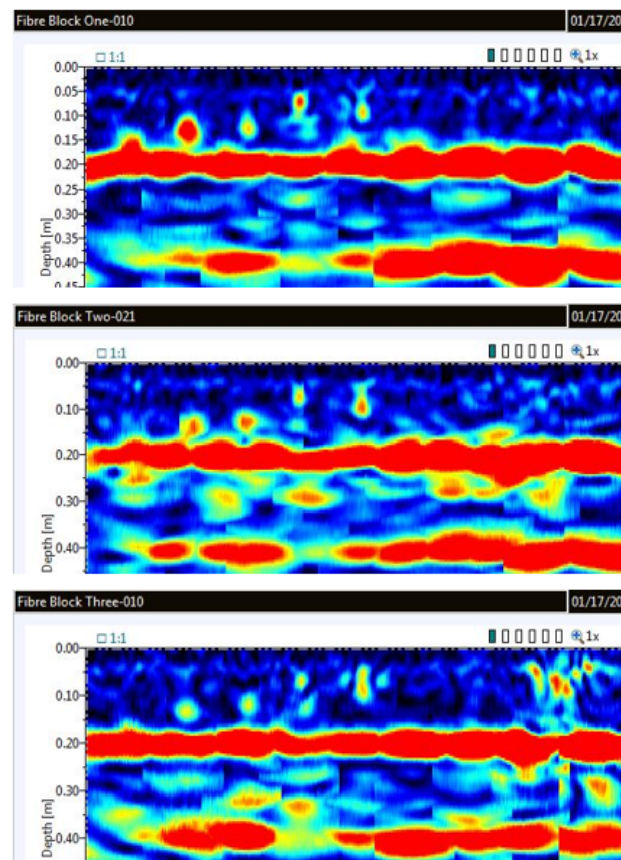
The instrument used for this test was the Proceq Pundit 250 Array.



**Figure 8.** Pundit 250 Array Ultrasonic Pulse Echo Instrument

Panorama B-scans were carried out on all three blocks. The results are shown in Figure 9.



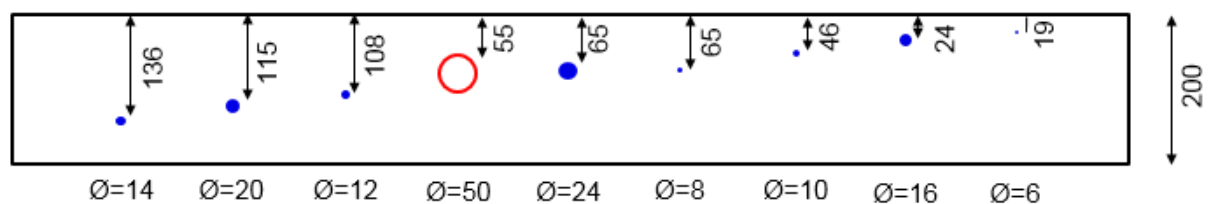


**Figure 9.** Ultrasonic Pulse Echo Scans – Block 1 (top), Block 2 (middle), Block 3 (bottom)

It can be clearly seen here that there is no real difference between the scan on the control block and the scans on blocks 2 and 3 with increasing steel fibre content. This means that it is quite feasible to use this technology for assessing cover in fibre reinforced concrete elements.

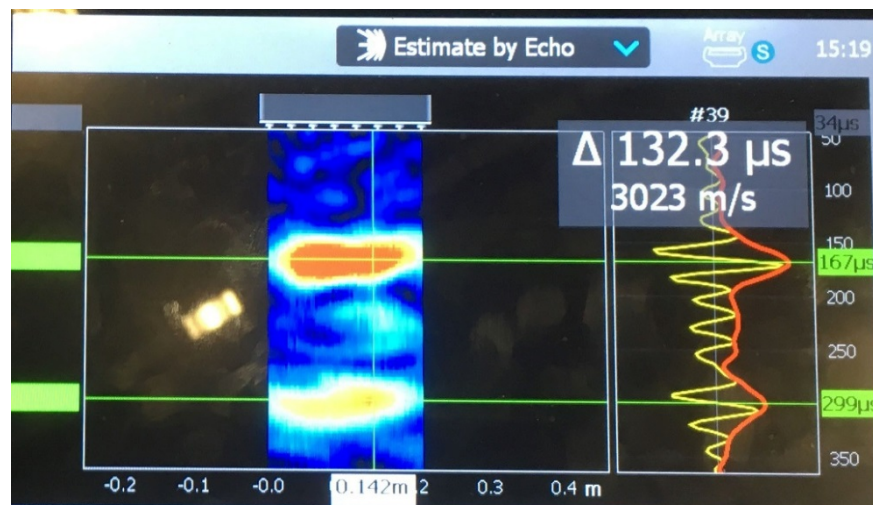
### 5.1. Determination of the Cover

When the ultrasonic pulse echo testing was carried out the test blocks had been flipped over when compared with figure 2. The actual orientation can be seen in Figure 10



**Figure 10.** Test Block Orientation for Pulse Echo Tests

In order to obtain accurate depth information with pulse echo testing, it is necessary to calibrate the pulse velocity. In the Pundit 250 Array instrument this is done by detecting the multiple back wall echoes and calibrating this against the slab thickness information. This can be seen in Figure 11.



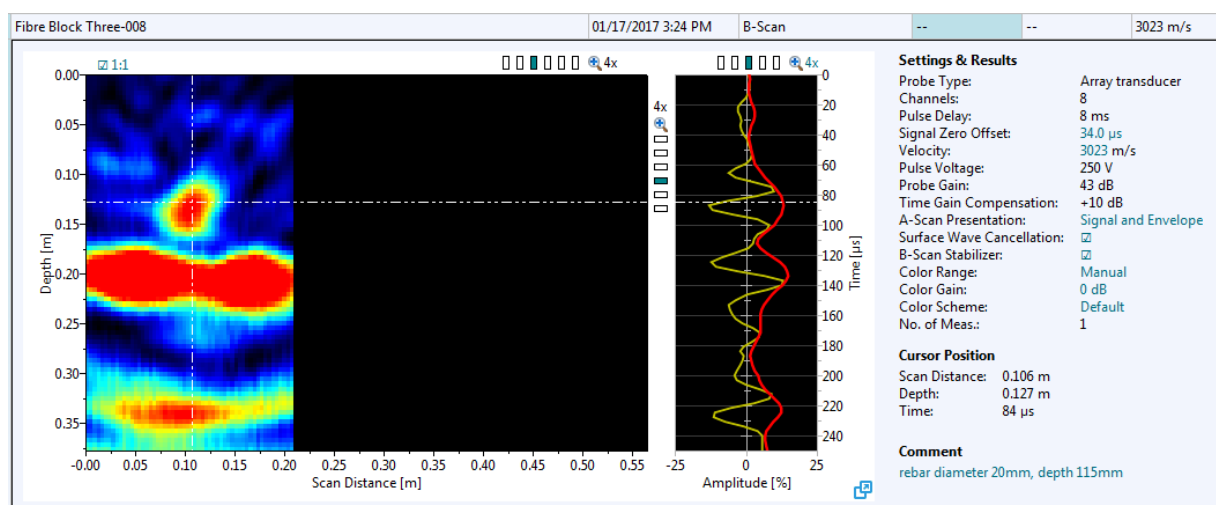
**Figure 11.** Calibration of the Pulse Velocity

The A-scan peaks are used to align the cursor to the first and second back wall echoes. The known thickness of the slab is then used to calculate the pulse velocity. The pulse velocity determined on each of the three slabs was as follows:

- Block one – no fibre content – 2939 m/s
- Block two – 30 kg/m<sup>3</sup> fibre content – 3117 m/s
- Block three – 60 kg/m<sup>3</sup> fibre content – 3023 m/s

It may be expected that with increasing fibre content, the pulse velocity would likewise increase due to the presence of more steel which obviously has a higher pulse velocity than concrete. It was thought that perhaps the pulse velocity determination could also be correlated to steel fibre content. However, as can be seen from the results this is not the case. There is an explanation for this in a study by Gebretsadik published in 2013 [2], who concluded that increased amount of fibre content led to the formation of additional voids in the concrete matrix which has the opposite effect of reducing the pulse velocity.

Once the pulse velocity has been determined the depth of the objects within the structure can be measured. An example is shown in figure 12.



**Figure 12.** Rebar Depth Measurement

Here we can see that the rebar depth is estimated at 12.7 cm. The actual depth is 11.5 cm. This has to do with the measurement technique using the peak of the echo. While easier to detect than the onset

of the received pulse, the effect of ringing of the signal is not always constant and this can lead to some errors. This is clearly something that needs to be refined if accurate depth information is required.

## 6. Conclusions

Traditional measurement techniques used for estimating cover depth use electromagnetic waves. The very nature of these technologies means that they cannot be used on concrete with steel fibre content. Ultrasonic pulse echo testing on the other hand has been shown to be an effective technique on this material. Rebars and pipes can be clearly detected and their relative cover can be determined. Accuracy of the cover measurements depends on accurate pulse velocity estimation which requires knowledge of the slab thickness. The technique to determine the onset of the received echo is in need of some improvement for really accurate cover estimation. Nevertheless, the technique looks very promising for this particular application.

## References

- [1] Bewehrungsüberdeckung in mit Stahlfasern bewehrtem Beton, Technischer Bericht, Projektarbeit FS 2016, Tanja Pfeiffer, 2016.
- [2] Gebretsadik, Belayhun Tesfaye, "Ultrasonic Pulse Velocity Investigation of Steel Fiber Reinforced Self-Compacted Concrete" (2013). UNLV Theses, Dissertations, Professional Papers, and Capstones. 1828.