NDT INVESTIGATION OF PT DUCTS

By
DAVID CORBETT

POST-TENSIONING INSTITUTE ®

Authorized reprint from: December 2018 issue of the PTI Journal

NDT INVESTIGATION OF PT DUCTS

BY DAVID CORBETT

Nondestructive investigation of PT ducts is a challenging task, but modern technology is making it possible. Both ground-penetrating radar (GPR) and ultrasonic pulse echo (UPE) technology can be used for this purpose.

There are two major tasks that need to be addressed. The first is the location of the PT duct. This is the easier of the two and both GPR and UPE can be used for this purpose. The second is to detect grouting defects within the duct that can lead to corrosion and eventually failure of the PT cable. This is not so straightforward, but we will see that UPE can be used for this purpose successfully.

DETECTION OF OBJECTS IN CONCRETE

It is possible to detect objects in concrete through the reflections that occur at the boundary between two materials with different properties (Fig. 1).

In the case of GPR, reflections occur when the two materials have different dielectric (ε) properties. In the case of UPE, reflections occur when the two materials have a differing acoustic impedance (Z). The size of the reflection can be easily calculated (Table 1). If we look at the typical acoustic impedances of the materials that are encountered in reinforced concrete, we can get a good idea of the size of the echoes we can expect.

PTI JOURNAL, V. 14, No. 2, December 2018. Received and reviewed under Institute journal publication policies. Pertinent discussion will be published in the next issue of *PTI JOURNAL* if received within 3 months of the publication.

The response is very different. GPR waves are totally reflected at a concrete-steel boundary and partially reflected at an air boundary or a plastic boundary.

UPE waves, on the other hand, are totally reflected at a concrete-air boundary but partially reflected at a steel or plastic boundary.

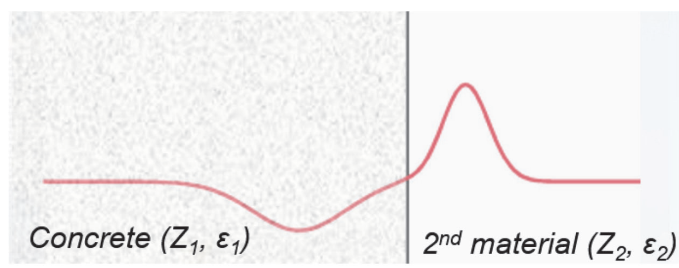

Fig. 1—GPR reflections through two materials.

Table 1—Calculated size of reflection

Interface	ε_1	ε_2	$R = \dfrac{\sqrt{\varepsilon_1} - \sqrt{\varepsilon_2}}{\sqrt{\varepsilon_1} + \sqrt{\varepsilon_2}}$
Concrete-air	5	1	38%
Concrete-steel	5	∞	100%
Concrete-plastic	5	2.4	18%

(a) GPR echo strength

Interface	Z_1	Z_2	$R = \dfrac{(Z_2 - Z_1)^2}{(Z_2 + Z_1)^2}$
Concrete-air	9.6	0.000429	99%
Concrete-steel	9.6	46.5	43%
Concrete-plastic	9.6	2.33	37%

(b) UPE echo strength

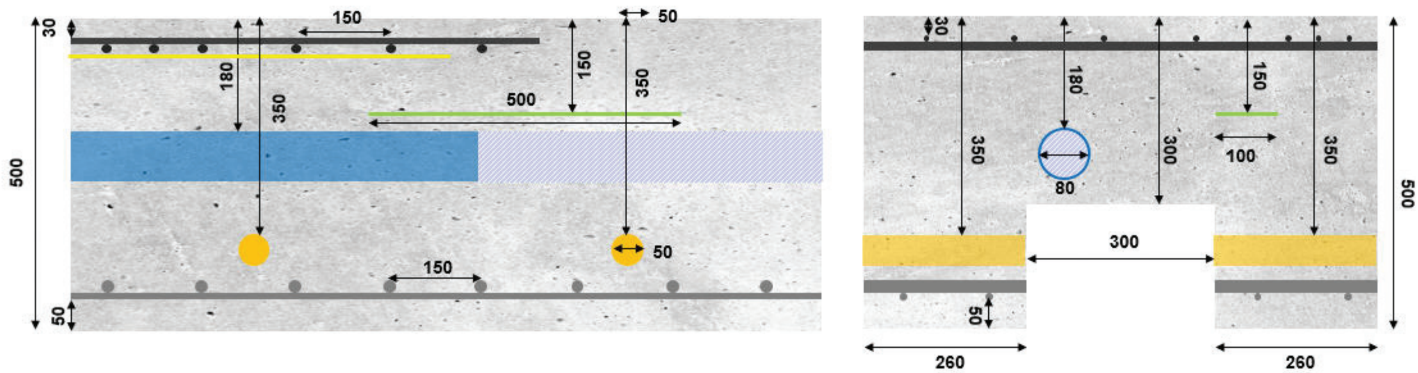

Fig. 2—Test block demonstrating amplitude variations. (Note: Dimensions in mm; 1 mm = 0.0394 in.)

(a) Transducer and indicating device *(b) Transducer directly above duct*

Fig. 3—Pulse echo instrument.

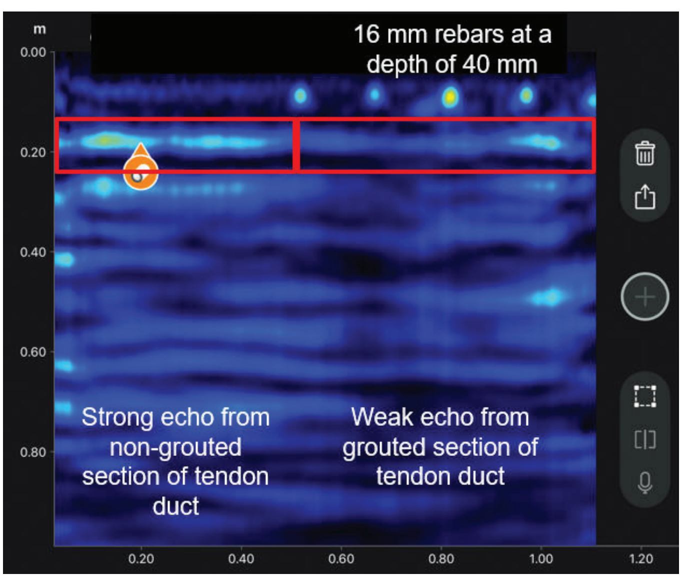

Fig. 4—Resulting scan from test block.

So what are the implications of this as far as PT duct investigation is concerned?

The total reflection at a concrete-steel boundary means that GPR is well suited for mapping out the reinforcing bar structure and locating steel-sheathed PT ducts, but it makes it impossible to detect voids beyond the sheath.

The partial reflection at a concrete-steel boundary means that UPE technology enables PT-duct detection through reinforcing bar configurations that would severely limit GPR penetration. More importantly, the total reflection from air means it is possible to detect the presence of voids beyond the steel sheath.

DETECTION OF GROUTING DEFECTS IN PT DUCTS

There are two parameters that can be used to detect grouting defects in ducts: amplitude and phase.

To demonstrate the use of amplitude variations, we will look at an example on a test block containing an 80 mm (3.1 in.) steel sheathed tendon duct at a depth of 180 mm (7.1 in.) (Fig. 2). One section of the duct is fully grouted. The other section of the duct is not grouted.

A B-scan was made directly over the tendon duct using a Pundit Live Array Pro 8 channel pulse echo instrument from Proceq (Fig. 3). Figure 3 shows the transducer and indicating device on the left and the transducer placed directly above the tendon duct on the right.

The resulting B-scan (Fig. 4) is a cross section through the block perpendicular to the scanning surface.

The analysis of this B-scan shows a strong echo from the non-grouted section of the tendon duct on the left-hand side of the image and a much weaker echo from the grouted section on the right-hand side of the image.

With pulse echo technology, it is also possible to create C-scans and three-dimensional (3-D) images. To do this, it is necessary to scan with the transducer perpendicular to the probe, as shown in Fig. 5.

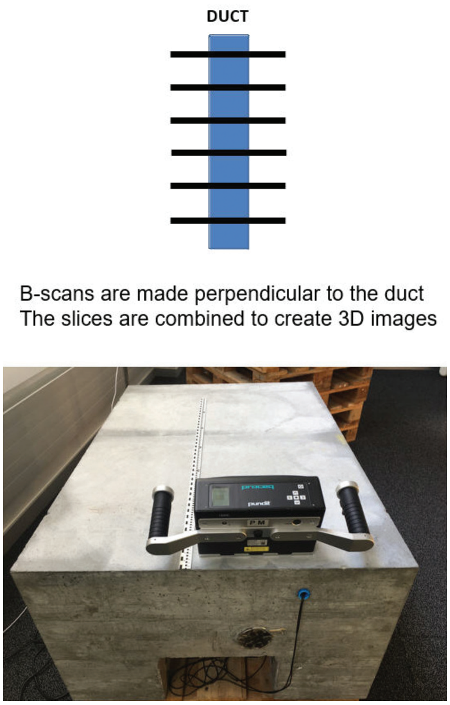

Fig. 5—Scanning with transducer perpendicular to the probe to create 3-D images.

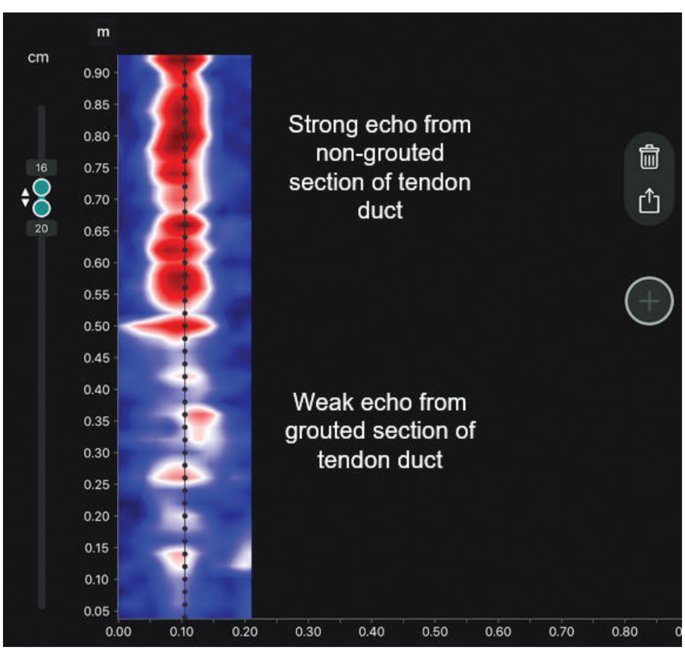

Fig. 6—Analysis of grouting defects.

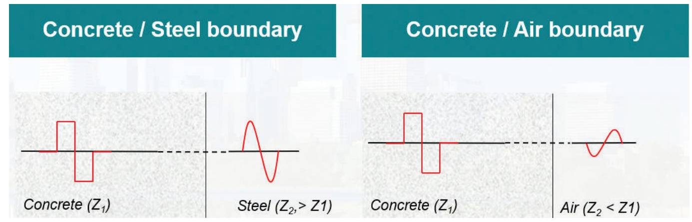

Fig. 7—Phase change at boundary of two materials.

The resulting data is used to generate C-scans, which is a slice parallel to the scanning surface at any depth showing the amplitude at that depth. To analyze grouting defects, a thin slice (4 cm [1.6 in.]) is selected and then moved down to a depth covering the top of the tendon duct (Fig. 6).

The difference between grouted and non-grouted sections of the duct become much clearer using this technique.

To increase the confidence of the assessment, a second parameter can be used. This is the phase change that can occur at the boundary between two materials (Fig. 7).

There is no phase change when the second material has a higher acoustic impedance, but there is a phase change

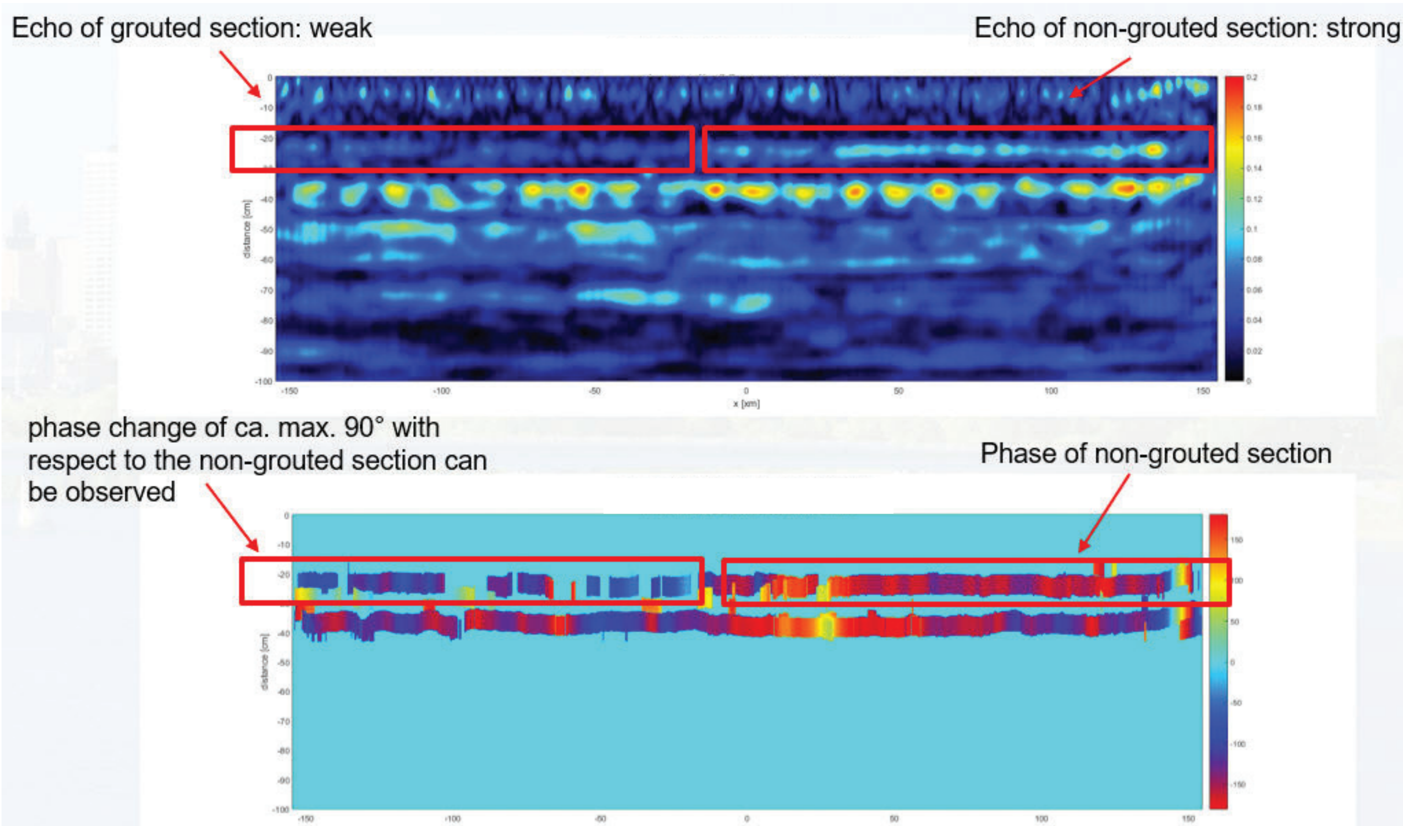

Fig. 8—Amplitude scan of tendon duct.

when the second material has a lower acoustic impedance. If this can be detected, it enables the user to state with confidence if the echo is from steel or from air, confirming the presence of voids.

Figure 8 shows an amplitude scan of a tendon duct section 4 m (13 ft) long with the associated phase information directly below it. The phase information clearly backs up the presence of voids. It should be stated that such phase analysis is not yet possible on commercially available instruments and must be carried out with specialized post-processing software.

These methods are not new. Much research has been carried out in Germany by the Federal Materials Testing Institute (BAM) and a recent study carried out in the United States confirmed that these techniques were able to identify grouting defects.

NCHRP Research Report 848, "Inspection Guidelines for Bridge Post-Tensioning and Stay Cable Systems Using NDE Methods," concluded that "Automated scanning USE together with phase evaluation algorithm is capable of identifying grout defects in internal tendons for both plastic and metal ducts."

CONCLUSIONS

- Pulse echo technology is capable of detecting grouting defects in tendon ducts using amplitude and phase analysis techniques
- 3-D imaging onsite is now available in commercial equipment. At the time of writing, phase analysis is only possible using post-processing.
- The benefits are that a comprehensive evaluation is possible. The test is no longer limited to research institutes.

David Corbett *has been a Product Manager for Concrete NDT Products at Proceq, Switzerland since 2007. He is the Swiss representative on CEN/TC 104/SC 1/TG 8 dealing with the standardization of specifications for concrete and concrete-related products, a member of RILEM TC 249-ISC (Non destructive in situ strength assessment of concrete), and ACI Committee 228, Nondestructive Testing of Concrete.*