Универзитет у Бањој Луци I Архитектонско-грађевинско-геодетски факултет
University of Banja Luka I Faculty of architecture, civil engineering and geodesy
ISSN 2303-6036 **UDK** I UDC 72

АГГ+

[7] 2019 7[1]

АГГ+ часопис за архитектуру, грађевинарство, геодезију и сродне научне области
ACEG+ Journal for Architecture, Civil Engineering, Geodesy and other related scientific fields

074-082 **Прегледни научни рад** I Review scientific paper
UDK I UDC 624.073.2+624.012.45
DOI 10.7251/AGGPLUS1907074N
Рад примљен I Paper received 06/06/2019
Рад прихваћен I Paper accepted 18/10/2019

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ПРОЦЕНА ПОЛОЖАЈА И ПРЕЧНИКА ШИПКИ АРМАТУРЕ ПРИМЕНОМ САВРЕМЕНИХ МЕТОДА БЕЗ РАЗАРАЊА

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ESTIMATION POSITION AND DIAMETER OF REBAR BY MODERN NON-DESTRUCTIVE TECHNIQUES

ABSTRACT

Ultrasonic testing of concrete by modern equipment has grown in importance in recent years in non-destructive testing. Measuring concrete cover thickness and estimating steel rebar position and diameter is main focus for assessment of existing reinforcement concrete facilities. Voids, entrained air and potential delamination are important to detect in order to evaluate the quality of the executed concrete members. This paper presents the latest two modern non-destructive techniques – ultrasonic tomography and electromagnetic pulse induction – suitable for testing reinforcement concrete members. The capabilities of these techniques for locating defects, reinforcement bars and determining their size in unilaterally accessible concrete members are described.

Key words: *non-destructive methods, ultrasound tomography, electromagnetic pulse induction*

ПРОЦЕНА ПОЛОЖАЈА И ПРЕЧНИКА ШИПКИ АРМАТУРЕ ПРИМЕНОМ САВРЕМЕНИХ МЕТОДА БЕЗ РАЗАРАЊА

РЕЗИМЕ

Ултразвучно испитивање бетона у последњих неколико година је добило на значају у односу на примену осталих метода без разарања. Мерење дебљине заштитног слоја бетона до арматуре и процена положаја и пречника шипки су основни фактори за процену стања постојећих армиранобетонских објеката. Веома је важно детектовати шупљине, заробљени ваздух и постојање потенцијалне деламинације како би се могао проценити квалитет изведених бетонских елемената. У раду је приказана примена две недеструктивне методе са најмодернијом опремом – ултразвучна томографија и електромагнетна импулсна индукција – погодне су за испитивање армиранобетонских елемената. Приказане су могућности лоцирања дефеката, положаја шипки арматуре и одређивања њихове величине у елементима чија је само једна страна доступна за испитивање.

Кључне ријечи: *методе без разарања, ултразвучна томографија, електромагнетна импулсна индукција*

1. INTRODUCTION

The widespread use of concrete in construction in recent decades has shown that concrete is not durable and superior material as claimed in the early 1970s. Continuous deterioration of reinforced concrete structures exposed to aggressive environment in industrial plants is one of the main problems in the modernization of industrial production facilities. The application of modern non-destructive technique during testing of RC (reinforced concrete) structure plays an important role in assessment of RC structures before considering future repair methods [1,2].

In addition to dead and live loads, RC structures are also exposed to action of aggressive environment. In the middle and at the end of the last century, it is evident now that concrete properties in hardened state and cover thickness of RC member is not designed properly, but it should be noted that it wasn't the subject of technical regulations at that time. Also, it was not pointed out in professional and scientific circles. Experimental data affecting the concrete durability was not available. In the early 1980s, it was still considered that concrete was significantly more durable material and its strength development over time is implied.

A realistic cost estimation of maintaining or repairing reinforced concrete structures should be based on a detailed scope of testing within assessment report. Certainly, destructive testing methods cannot be left out, but greater importance should be given to modern, non-destructive testing by which types of damage, their extent, and the probable cause can be determined.

The parameters of steel rebars that need to be inspected in existing facilities include their location, spacing, diameter, cover thickness and the degree of corrosion. Among them, accurate determination of the rebar diameter and cover thickness in a non-destructive way is still challenging. Electromagnetic pulse induction (EMI) is the principle of most of the commercially available rebar locators and cover meters. EMI is sensitive to both the depth and size of metallic buried objects. However, it is difficult to simultaneously and accurately obtain the two unknowns in a direct manner.

Among the available non-destructive testing techniques, including the Ground-penetrating radar (GPR), X-rays, the Ultrasonic Tomographic Imaging based on shear wave pulse-echo technique becomes more and more demanding due to its feasibility to more accurate and effective detection of different defect types, higher resolution of testing and applicability for deeper thicknesses of testing object[3, 4,5].

2. ELECTROMAGNETIC PULSE INDUCTION TECHNIQUES

Profometer 650 AI (Figure 1) of the Swiss company Proceq was used for determination of steel rebar position and estimation of reinforcement bar diameters. The Profometer 6 uses electromagnetic pulse induction technology to detect rebars [6]. Coils in the probe are periodically charged by current pulses and thus generate a magnetic field. On the surface of any electrically conductive material which is in the magnetic field, eddy currents are produced. They induce a magnetic field in the opposite direction. The resulting change in voltage can be utilized for the measurement.

Figure 1. *Proceq Profometer 650 AI [6]*

The Profometer 6 uses different coil arrangements to generate several magnetic fields. Advanced signal processing allows locating a rebar as well as measuring of cover and rebar diameter. This method is unaffected by all non-conductive materials such as concrete, wood, plastics, bricks etc. However any kind of conductive materials within the magnetic field (sphere of approx. 200mm) will have an influence on the measurement (Figure 2).

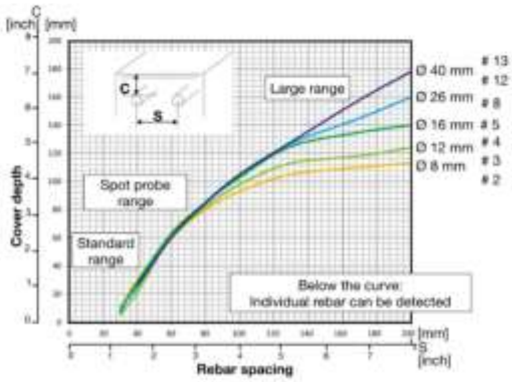

Figure 2. *Measuring resolution of Profometer 6 [6]*

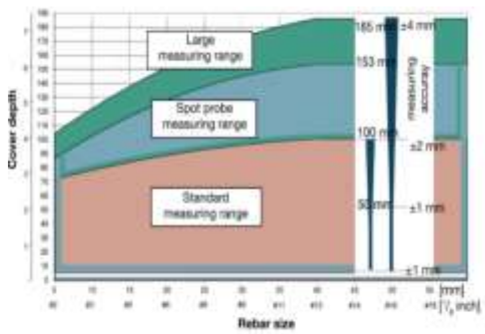

Figure 3. *Measuring ranges and accuracy of Profometer 6 [6]*

The Profometer 6 is calibrated to measure on a normal rebar arrangement which is an arrangement of non-stainless steel rebars fastened with binding wires only. There is a limit to the minimum spacing of bars depending on the cover depth and rebar diameter. It is impossible to distinguish between individual bars above these limits. The measuring range is dependant on the bar size. The expected accuracy of the cover measurement is given in the graphic below (Figure 3).

3. ULTRASONIC TOMOGRAPHY

The tests were conducted with the latest device from a leading Russian-German company in the field of this type of equipment: ACSys Monolith A1220 and Mira Lite A1020 (Figure 4,5).

MIRA Lite is a multifunctional (10-100kHz) phase ultrasonic system for detecting objects, internal defects and anomalies in concrete structures. Ultrasonic testing with transverse waves is one of the most advanced techniques available in non-destructive testing of concrete. Transverse waves are generated by the excitation of piezoelectric materials with short excitation, high-amplitude pulse, which has high voltage and current. One converter sends out the voltage of the wave, the second converter receives the reflected impulse [6].

Figure 4. *Acsys Monolith A1220 [7]*

Figure 5. *Mira lite A1020 [7]*

The ultrasonic probe on the ACSys A1020 MIRA Lite does not require the application of grease or other gel to transmit waves into concrete, and the probe can be moved from place to place without extensive position preparation. Therefore, the test time is significantly reduced compared to conventional ultrasound tests. The probe for the MIRA Lite is composed of 4 transmitter units in 8 rows. Transmitters operate as transmitters and receivers in sequential mode. Transmitters are very damped so that a short duration pulse is obtained (Figure 6). Differences in the speed of passage of the ultrasonic wave through different environments (in the case of anomalies, reinforcement or other defects) are detected as changes in the structure of concrete [7].

One of the most significant features of the ACSys A1020 MIRA Lite device is its ability to reconstruct the image of concrete in three dimensions, which allows engineers to evaluate the integrity within the concrete. In order to obtain a three-dimensional analysis of concrete, it is necessary to make series of scans of ACSys A1020 MIRA Liten at a given distance, all on the test surface. The probe is oriented directly in the scan direction and data is recorded at predefined steps along each scan line. When the scan line is complete, the final test layout is inserted into the computer and both scan and layout are analyzed during signal processing to establish a three-dimensional picture of the concrete state in the element. The distance of the transmitted transmitters in the probe of the ACSys A1020 MIRA Lite is 30x30mm so that a single shot can cover an area of 210x90mm [7].

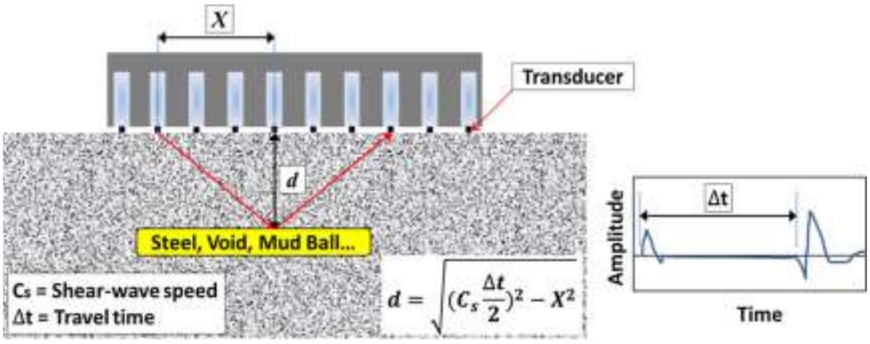

Figure 6. *Ultrasonic wave reflection [7]*

4. APPLICATION EXAMPLES

Our non-destructive testing procedure begins with the use of a EMI device (Proceq Profometer 650 AI). The following example will show estimation of rebar number, position and diameter of longitudinal bars in the lower zone of middle cross-section of beam (Figure 7).

Figure 7. *RC beam on which tests were carried out*

Two consecutive measurements were performed and diagram of concrete cover thickness and electromagnetic signal strength are shown on Figure 8. Six signals can be clearly observed. Three positions were used to estimate the rebar diameter. The obtained values indicated that the steel bars diameter was 20 or 22mm. The presence of a large number of steel tubes made the measurement process difficult. Based on these measurements, it could not be said if there was single row or exists second row of reinforcement.

As can be seen in Figure 2 and 3, there are limitations in the application of this method. At a depth of 7cm, it was significantly more difficult to detect the individual rods. In this case, it is very useful to apply ultrasonic tomography [8].

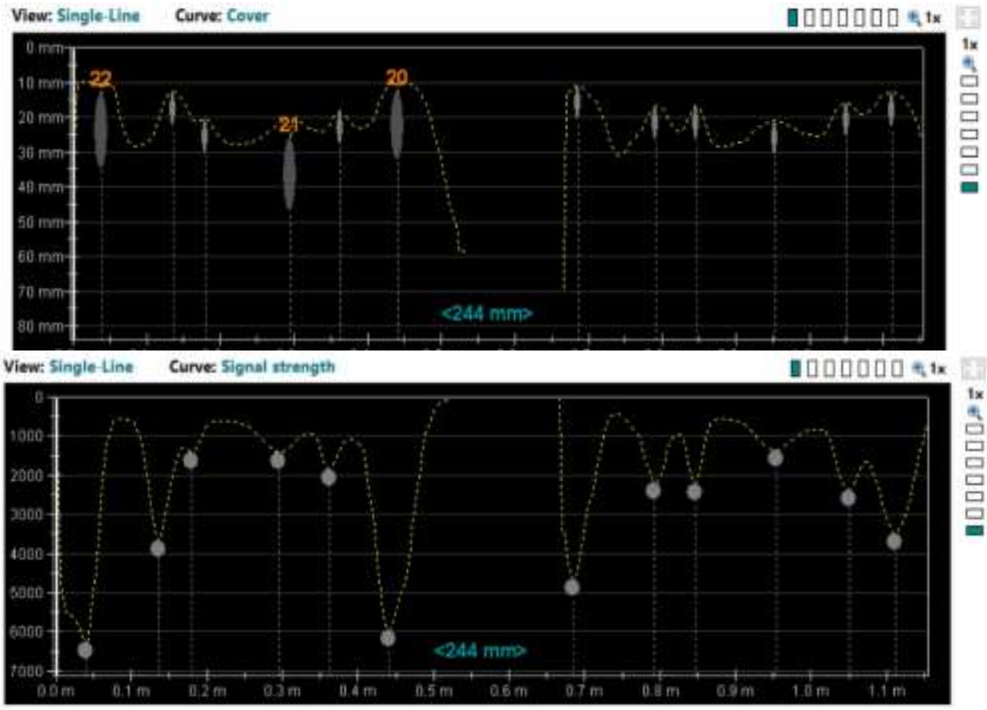

Figure 8. *EMI device output diagram of concrete cover thickness and signal strength*

The first activity in the application of ultrasonic tomography is the calibration device. In order to determine the transit time correctly, the offset should be in advance. This is the time difference between the generation of the signal in the transducer to the actual occurrence in the component. Ultrasonic pulse velocity of the longitudinal and shear waves can be determined by single point sensors (Figure 9).

Figure 9. *Dry point ultrasonic sensors*

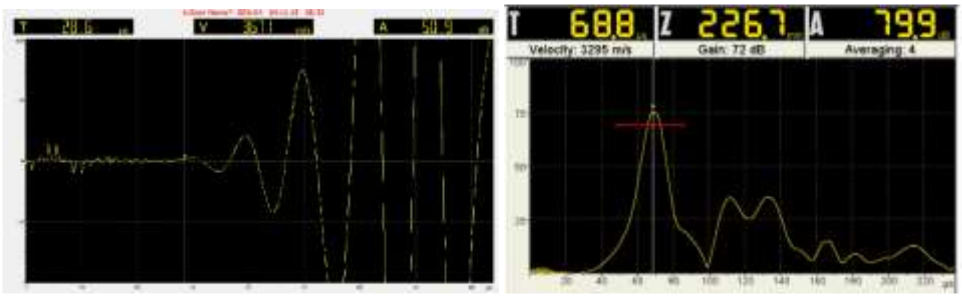

Figure 10. *A-scan of ultrasonic wave*

The ultrasonic tomography image shows a significantly stronger signal in the middle of the cross-section (Figure 11). It can be explained by the fact that the each of the two red areas in centre part of single row reinforcement consists of two closely spaced bars plus two rods at corners (six rebars in total). It is completely clear that there is no second row of reinforcement.

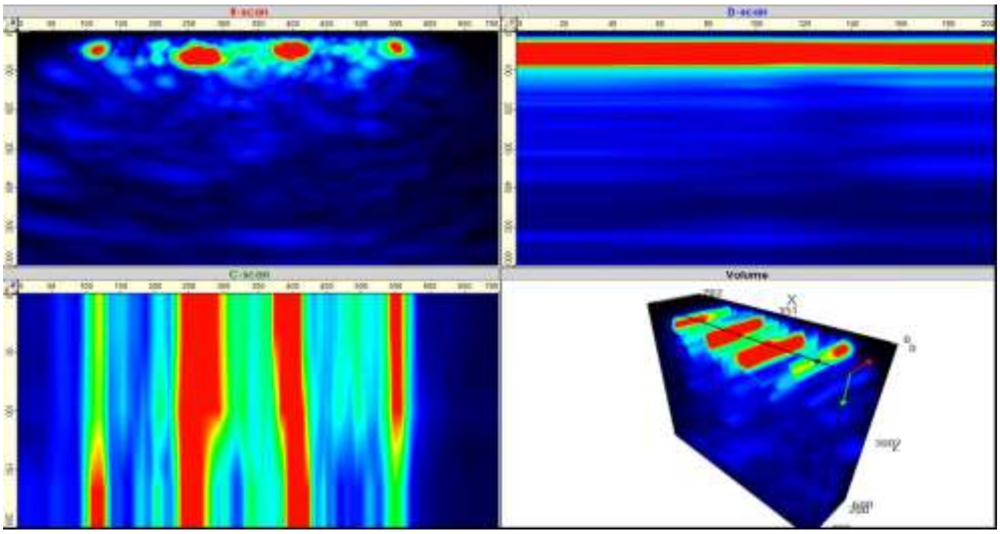

Figure 11. *Ultrasonic tomography image of mid cross-section beam*

The next example shows the applicability of the ultrasonic tomography for thickness measurements on concrete objects and for imaging the internal structure, visualizing the positioning of reinforcement bars inside the panels (Figure 12). The upper left image on Figure 13 is the B-scan – the cross-section view of the tested part of wall area. It can be observed that full reflection of the ultrasonic waves at a depth of 30cm was clearly visible.

Figure 12. *Heavy reinforced shear wall*

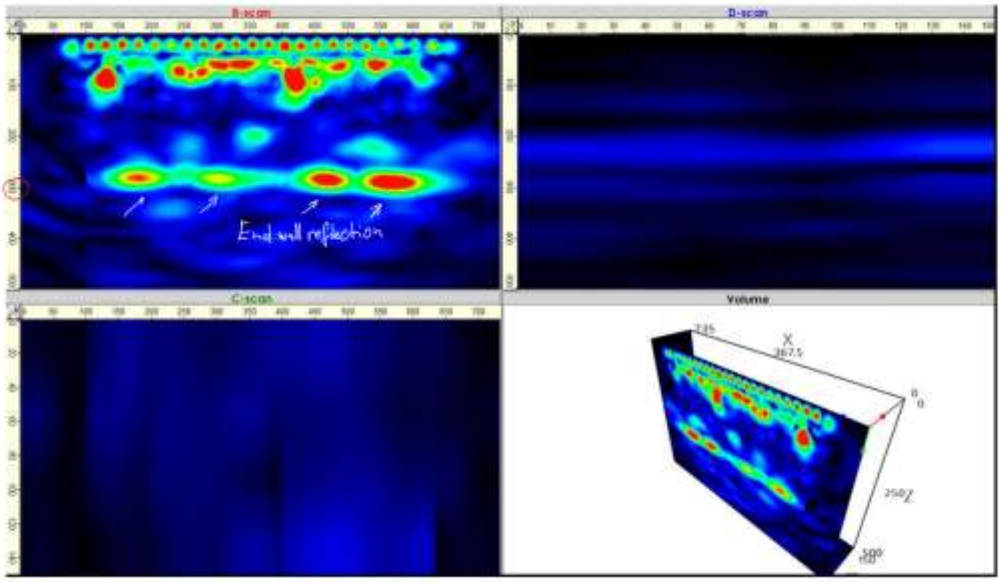

Figure 13. *Ultrasonic tomography image of shear wall*

5. CONCLUSIONS

The aim of this paper was to investigate whether and to what extend electromagnetic pulse induction and ultrasonic tomography are suitable for the detection of near-surface reinforcement.

The given examples for the specified equipment allow concluding its applicability for the following tasks of testing the objects from reinforced concrete and other similar materials:

- Estimation of entrained air or delamination into slab;
- Detection, location coordinates and size estimation of different reflectors inside the concrete objects (reinforcement bars or honeycombing);

- Estimation of structure integrity by the presence or absence of backwall signal and its intensity;
- Thickness measurement (up to 1m) of reinforcement concrete objects at one-side access testing.

The constant development of non-destructive equipment offers improved techniques for investigation of RC structures. Further development in this area is expected, and understanding their compatibilities should remain the imperative for motivated professionals.

ACKNOWLEDGEMENTS

This work was supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia [grant number TR 36017]

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