Acoustic Emission Monitoring to Evaluate the Detection of Adhesion of Reinforcing Rebar in the Concrete Beams

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Abstract. Acoustic Emission is a Non-destructive Testing method, widely used for monitoring the mechanical behaviour of steel and concrete structures. In particular, the method can be characterized and evaluate cracks or other defects under the stress of the structures. The present research aims to investigate the feasibility to evaluate the adhesion of the rebar to concrete using the Acoustic Emission Technique. For this purpose, the Active Acoustic Emission technique has been used for rebar-reinforced concrete beams. An acoustic Emission test has been made on both conditions of rebars, with/without adhesion. The fundamental parameter to distinguish adhesion and non-adhesion rebar has been the attenuation of acoustic energy, generated by the acoustic sensors, activated as ultrasonic transducers. The results have been very promising; the difference of attenuation between adhesion and non-adhesion rebar showed high enough to evaluate the condition of rebars.

Keywords: Acoustic emission · Reinforced concrete · Rebar · Adhesion

1 Introduction

The evaluation of rebar-concrete adhesion is based on the iron-cement transmission/attenuation of acoustic energy sent by the main tie-rod to the concrete. A good rebar adhesion allows a sufficient transmission of mechanical energy to the concrete. A corroded, poorly adherent iron drastically reduces transmission. Laboratory tests have simulated this phenomenon. The method chosen to satisfy the purpose of evaluating the corrosion of the rods understood as detachment and/or loosening of adhesion to the concrete is the acoustic emission (AE). Acoustic Emission is used to detect acoustic vibrations in the frequencies of 100–200 kHz in components and structures under stress conditions.

Wang et al. [1] showed that replacing the transient acoustic emission source can be improved for the pipeline by two AE sensors with broadband. Kobayashi et al. [2] investigated the reinforcing bar in a reinforced-concrete block through cyclic tension-compression loading. Their results showed that the AE signals can detect the debonding regions and those disconnected by dye injected within the cracked concrete. Sharma

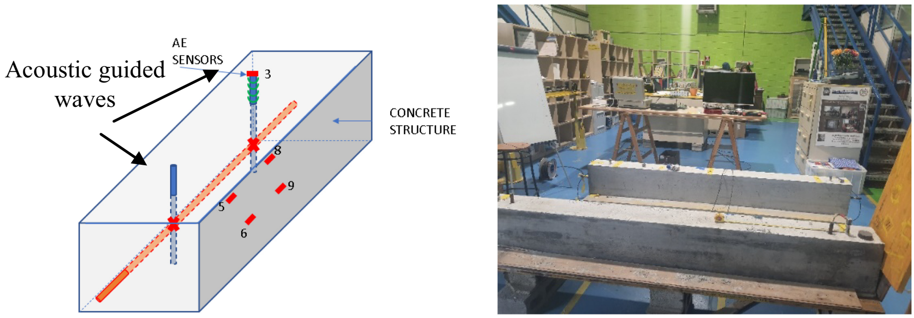
C. Pellegrino et al. (Eds.): EUROSTRUCT 2021, LNCE 200, pp. 1301–1307, 2022.
https://doi.org/10.1007/978-3-030-91877-4_148

et al. [3] investigated the passive and active wave propagation for both ultrasonic guided waves and acoustic emission for corrosion monitoring of reinforced concrete under the chloride and oxide exposure.

The AE was created to capture the dynamic reactions, as vibrating energy, that can be generated within a stressed structure in presence of the defects and/or other anomalies. In these cases, the AE is applied with the **Passive Technique**. The **Active technique**, which was chosen for the specific application of the analysis of the adhesion of the bars to the concrete, uses the sensors both in transmission and reception conditions, in other words, it can become a radar that transmits and receives [4, 5]. An initial experimentation has already been presented by the same author at an AICAP (Associazione Itlaiana Calcestruzzo Armato e Precompresso) conference in Verona.

2 Experimental Models

The model on which the experimental tests have been carried out are represented in Fig. 1; The concrete strength was in the range of 350–400 kg/cm^2. Two acoustic guided waves in steel, with 20 mm diameter, have been connected with the central rebar with wires as the normal steel structures are assembled. The dimension of the beams is 300 × 200 × 2500 mm.



(a) (b)

Fig. 1. (a) Schematic presentation of the beam with the central bar; the position of the two acoustic guided waves (blue bars) where the AE sensors have been placed to transfer pulses to the rebar. (b) General view of the two beams in the laboratory where the test has been carried out.

For evaluation of the concrete quality, an echography is made with the same principle of phased array and full matrix capture (FMC) with MIRA equipment, see Fig. 2. As it is shown in Fig. 2, the velocity of shear waves was 2230 m/s.

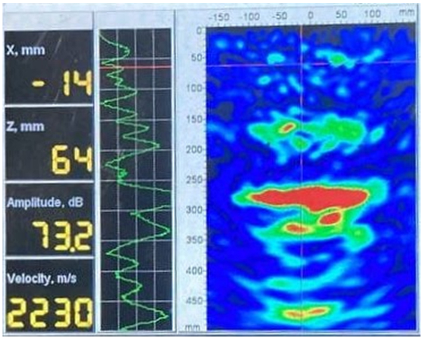


Fig. 2. Echography of the beam section with the central rebar.

2.1 Beam A and Beam B

Two different types of beams have been prepared for the test. In beam A, the steel rebar and acoustic guided waves have been cast to guarantee full adhesion to concrete. In beams B, the central steel rebar and the acoustic guided waves have been isolated with adherent plastic tape. For more details, see Fig. 3.

Fig. 3. Detail of the guided waves insulation during the casting in the framework of the concrete beam.

2.2 Integrity/Homogenous Evaluation of Concrete Through Ultrasonic Velocity

Based on the international well known C diagram, the correlation between the concrete strength and ultrasonic velocity, in addition to the attenuation measurement of the ultrasonic waves which corresponded to the data on its homogeneity. The frequency is used has been 100–150 kHz. The mean value of velocity from longitudinal waves measured in this study was in the range of 4080 m/s and it showed the reliability of the concrete structures.

For this aim one acoustic sensor has been placed as the acoustic guided waves (Sensor number 3); the other sensors, number 5,6,8,9 have been placed on the surface of the beam and the side middle of the beams as shown in the Fig. 4.

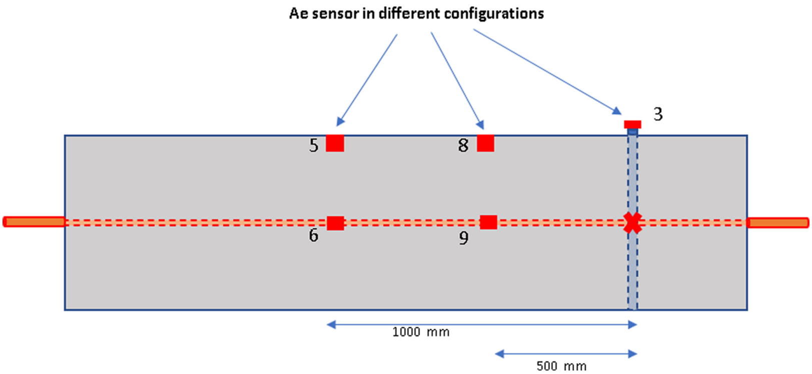


Fig. 4. Schematic of the arrangement of the acoustic emission sensors during the tests on beam A.

3 Results and Discussion

In this study, both beam A and B were evaluated based on their amplitude and attenuation. The acoustic guided wave sensor is installed, and the pre-amplitude has been fixed on 94 dB. Then the value of amplitude and attenuation is measured.

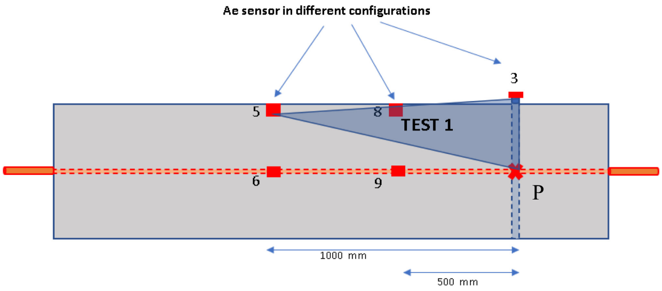
$$\text{Attenuation} = \text{Pre-amplitude} - \text{received amplitude}$$

As mentioned before, one sensor is fixed on the guided wave (sensor 3), and the other sensors are placed on a different level of structures. Figure 5 showed different configuration of the sensors and the results are brought in Table 1.

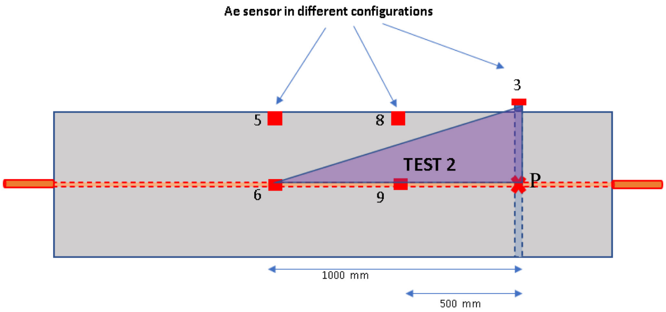
From the values shown in Table 1, the distance and position of the sensor on the concrete was estimated to obtain the lowest attenuation value (16 dB), see Fig. 6.

3.1 Test on Beam B

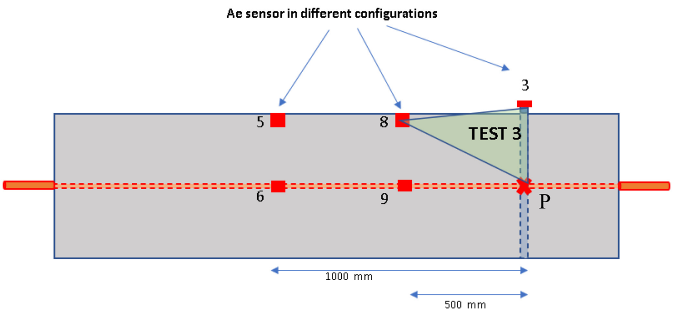
Based on Table 1 for beam A, the conclusion showed that test 4 had the highest rate of attenuation reduction. Therefore, in Table 2, the results for test number 4 given also for beam B. Table 2 it can be seen that the attenuation value with the same position of transducers 3–9 is 40 dB compared to 16 dB for beam A.



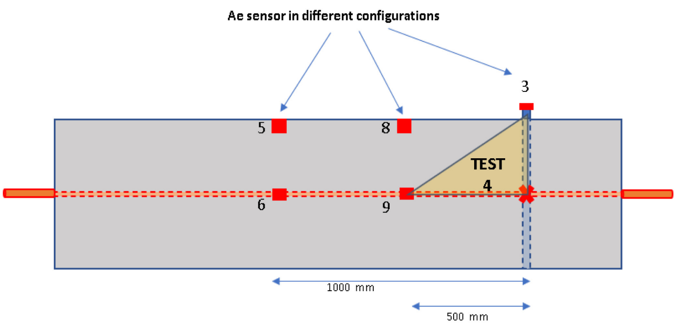
(a). Test number 1



(b). Test number 2



(c). Test number 3



(d). Test number 4

Fig. 5. Schematic of the arrangement of the AE sensors during the four different tests on beam.

Table 1. Detection of attenuation values based on the position of the sensors in beam A.

N. Test	N. Transmitter sensor	Pre-amplitude (dB)	N. Recieving sensors	Recived amplitude (dB)	Attenuation (dB)
1	3	94	5	37	57
2	3	94	6	32	62
3	3	94	8	59	35
4	3	94	9	78	16

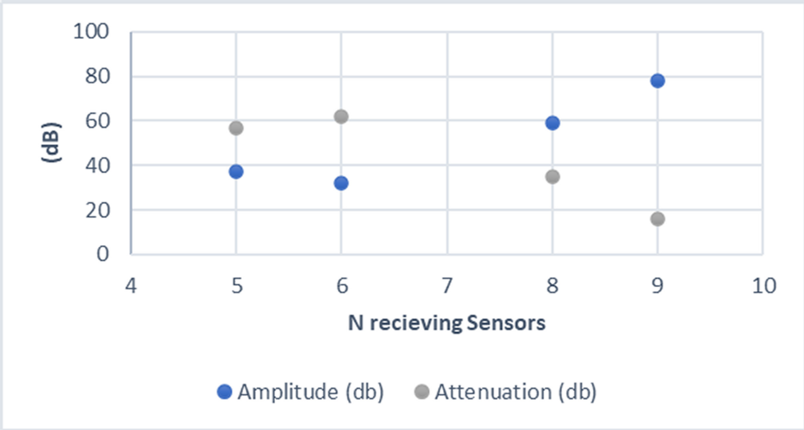


Fig. 6. Diagram of amplitude respect to the attenuation based on each sensor's detection.

Table 2. Values relating to the attenuation of the signal with sensor position 3–9 in Beam B.

N. Test	N. Transmitter sensor	dB	N. Recieving sensors	dB	Attenuation (dB)
1	3 (rode)	94	9 (concrete)	54	40

4 Conclusion

i. Based on the data obtained from experimental tests, the applied technique is highly promised in the direction to establish the state of the adhesion of rebar to concrete.
ii. The high value of an attenuation of 40 dB, measured in the triangled area between sensor 3, sensor 9 and point P gives the significant differences from beam A to beam B.
iii. The technique can be further refined by optimizing frequencies, waveguides and sensors.
iv. These results confirm the possibility during fabrication to set up a simple procedure to prepare the beams for the inspection after installation and during the services across the year without any significant economical increase of costs.

5 Future Research

Phase 2 of this project is already going on and aim to optimize the test parameters, which will be carried out on the different beams by various test configurations, as it has done in previous research field (see [6]).

Also, different adhesion effect on the rebar will be evaluated to simulate the experimental test close to the real industrial structures.

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