საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 17, №3, 2023
BULLETIN OF THE GEORGIAN NATIONAL ACADEMY OF SCIENCES, vol. 17, no. 3, 2023

Geophysics

Investigation of the Depth of Visible Cracks on the Concrete Surface Using the Ultrasonic Method

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The task of the research is to determine the depths of the cracks formed on the concrete surface. Study of the depths of the cracks formed on the concrete cover was carried out by means of ultrasonic waves. Several tens of cracks were studied on the research surface, corresponding waveforms were recorded and the data were processed. The crack consists of two parts, opened and closed. The depth of the open part of the crack was determined according to the British standard algorithm BS-1881-203 as well as the depth of the unopened part of the crack, according to the shape of the incoming waves and their first arrivals. The corresponding first arrival waves of the opened and unopened parts of the crack have different shapes: in particular, the first incoming wave in the case of an open crack has a rather disturbed (jagged) shape, which, in our opinion, is due to its passage through the closed crack. In the case of the closed part of the crack, the first incoming wave has an undisturbed (smooth) shape, which seems to be due to its passage through an undisturbed medium. Determining the depth of the closed part of the crack is important, because under certain loads it can open and play a significant role in the stability of the structure. *© 2023 Bull. Georg. Natl. Acad. Sci.*

ultrasonic, P-wave, nondestructive testing

As a result of the progress in the development of technology, the accuracy and capabilities of geophysical equipment are increasing. Ultrasound tomography is a technique that can inspect the internal characteristics of materials using nondestructive methods [1, 2]. Due to this, in developed countries, ultrasonic methods are increasingly used to solve various geophysical and geotechnical tasks, as well as engineering and household tasks [1-3]. For surveying concrete, stone, wood, etc. buildings and structures [4-6], were used for purposeful implementation of construction and restoration works.

Field Research

Our goal was to conduct geophysical studies in the project area in order to determine the depths of the cracks formed on 1m thick concrete cover. It should be noted here that these cracks were completely filled with dust material. For this purpose a study of the depths of the cracks formed on the concrete cover was carried out by means of longitudinal

ultrasonic waves. On the research surface 44 cracks were studied, corresponding waveforms were recorded and information was processed. Crack depths were determined according to the British BS-1881-203 standard algorithm.

The studies were conducted using a 50 kHz piezo-transducer. The specified standard procedure for determining crack depth (BS-1881-203) is as follows:

1. The piezo transmitter (emitter and receiver) is placed at an equal distance from the crack (150 mm in our case), on different sides. The first arrival time is measured and the waveform is recorded.

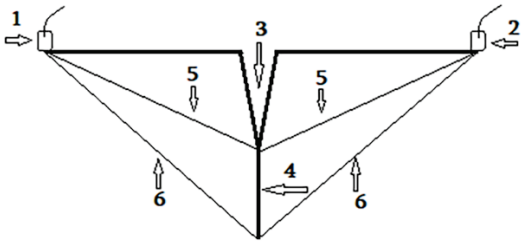

Fig. 1. Ultrasonic measurement scheme: 1 – transmitter, 2 – receiver, 3 – open part of the crack, 4 – unopened part of the crack, 5 – bypass wave of the open crack, 6 – bypass wave of the unopened part of the crack (respectively, full crack).

2. The piezoelectric transducer is moved twice as far (in our case, by 300 mm), again the first arrival time is measured and the waveform is recorded.

3. Crack depth is calculated based on the existing theoretical formula (6)

$$C = 150\sqrt{\frac{4t_1^2 - t_2^2}{t_2^2 - t_1^2}},$$

where t_1 is the time of the first arrival of the wave when the distance of the piezo transducer from the crack is 150 mm, t_2 is the time of the first arrival of the wave when the distance of the piezo transducer from the crack is 300 mm.

4. An analysis of the features of the configuration of the registered waveform image is done.

Research Results

The work of determining the depth of cracks using the ultrasonic method was carried out in the research area, in Tbilisi.

In order to analyze the obtained results, control measurements were carried out in the uncracked concrete in all parts of the study area to determine the velocity of ultrasonic waves in the uncracked concrete.

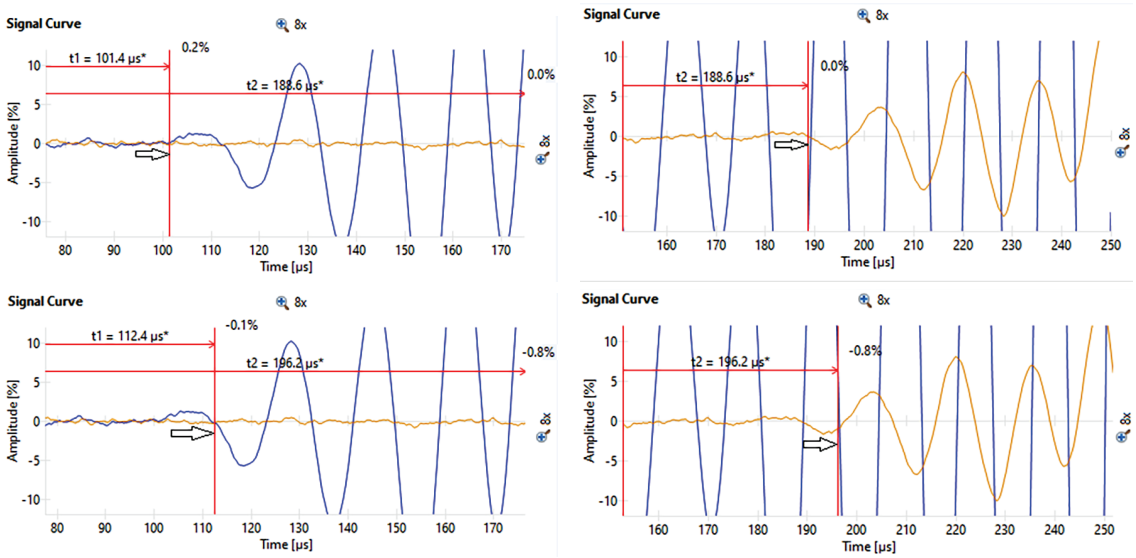

Fig. 2. a) The vertical red line (marked with an arrow) marks the arrival time for an opened crack, from 30 cm (blue wave), b) the arrival time for an opened crack from 60 cm (red wave) is marked in the same way (with an arrow), c) the arrival time for an unopened crack from 30 cm (blue wave) is marked in the same way (with an arrow), d) the arrival time for an unopened crack from 60 cm (red wave) is marked in the same way (with an arrow).

The speed of ultrasound in uncracked concrete ranges from 3260 m/s to 3450 m/s. Accordingly, the time of the first arrival of the wave varies from 87 microseconds to 93 microseconds. When processing the material of the crack depth measurements (Fig. 2), based on these data, the first arrival of the wave is registered in the recording of the cracks.

It is significant that, in almost all recordings, two moments are noted in the incoming first phase. The first one is the direct first entry, and the second one is the transition of the relatively disturbed, (turbulent) part of the first phase of the registered wave to the undisturbed, smooth mode. To identify these moments, we were guided by the following considerations: in general, when the crack is not penetrating (which can be observed visually), it is most opened on the surface and narrows in the depth. From a certain depth, its edges approach each other as much as possible. The crack continues to exist, although it is unopened. At a certain depth, the crack disappears. Thus, the crack consists of two parts, opened and unopened one (Fig. 1). From each record, we identified the depths of the opened and unopened parts of the crack. For this, in the each record, we distinguished the first entry of two wave types. The first arrivals of the waves corresponding to the opened and unopened parts of the crack have different shapes, in particular, the first incoming wave in the case of an open crack has a rather disturbed (jagged) shape, which, in our opinion, is due to the bypassing of the open part, as a result of its passage through the unopened crack (Fig. 1). An unopened crack is a non-uniform inclusion, which obviously has a certain influence on the shape of the wave passing through it. In the case of an unopened crack, the first incoming wave has an undisturbed (smooth) shape, which seems to be due to its passing through a homogeneous, undisturbed environment, i.e., bypassing the entire crack (Fig. 1). The record of Fig. 2 shows the first arrivals of the jagged wave (the blue wave comes from 150 mm, and the red wave from 300 mm). See also the first arrivals of the undisturbed wave. All four of these entries belong to the same crack.

Accordingly, the arrival time corresponding to the opened part of the crack, and the time corresponding to the wave passage of the total crack depth (opened and unopened parts together) are marked in the record.

As we can see, the measured depths do not exceed the thickness of the concrete slab, and therefore no penetrating cracks were observed.

Conclusion

The full depths of cracks range from 6.9 centimeters to 19.6 centimeters, and the depths of the opened part from 4.2 centimeters to 16.2 centimeters.

The bypassing time of the unopened cracks is greater than the bypassing time of the opened cracks, since the latter has to travel a greater distance.

The depth of majority for cracks is between 10 and 16 centimeters.

According to our measurements, none of the cracks are penetrating.

One of the results of our work is the assessment of the depth of unopened cracks using the ultrasonic method.

Estimating the depth of unopened cracks is important because under certain loads and deformations it can become an open crack.

გეოფიზიკა

ბეტონის ზედაპირზე ხილული ბზარების სიღრმის კვლევა ულტრაბგერითი მეთოდით

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კვლევის ამოცანას წარმოადგენს ბეტონის საფარზე წარმოქმნილი ბზარების სიღრმეების დადგენა. კვლევა ჩატარდა ულტრაბგერითი ტალღების საშუალებით. საკვლევ ზედაპირზე შესწავლილ იქნა რამდენიმე ათეული ბზარი. ჩაიწერა შესაბამისი ტალღური ფორმები და დამუშავდა მიღებული ინფორმაცია. ბზარი შედგება ორი, გახსნილი და გაუხსნელი ნაწილისაგან. ბზარის როგორც გახსნილი, ისე გაუხსნელი ნაწილის სიღრმე განისაზღვრა ბრიტანული სტანდარტული ალგორითმის BS-1881-203 შესაბამისად, შემოსული ტალღების ფორმისა და მათი პირველი შემოსვლის მიხედვით. ბზარის გახსნილი და გაუხსნელი ნაწილების შესაბამისი ტალღების პირველ შემოსვლებს აქვს სხვადასხვა ფორმა, კერძოდ, გახსნილი ბზარის შემთხვევაში პირველად შემოსული ტალღა საკმაოდ შეშფოთებული (დაკბილული) ფორმისაა, რაც, ჩვენი აზრით, განპირობებულია მისი, გაუხსნელ ნაწილში გავლის გამო. ბზარის გაუხსნელი ნაწილის სიღრმის განსაზღვრა მნიშვნელოვანია, რადგან გარკვეული დატვირთვის შემთხვევაში ის შეიძლება იქცეს გახსნილ ბზარად და თავისი როლი ითამაშოს კონსტრუქციის მდგრადობაში.

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Received March, 2023