Journal of the Georgian Geophysical Society, ISSN: 1512-1127
Physics of Solid Earth, Atmosphere, Ocean and Space Plasma, v. 23(2), 2020, pp. 14-20

Ultrasonic Tomography and Pulse Velocity for Nondestructive Testing of Concrete Structures

[1]Nodar D. Varamashvili, [2]Bezhan Z. Asanidze, [3]Mamuka N. Jakhutashvili

[1] Ivane Javakhishvili Tbilisi State University, Mikheil Nodia Institute of Geophysics,
[2] British Petroleum Company (BP),
[3] Georgian Technical University

ABSTRACT

The purpose of these research was to study the current state of the Tsageri catchment by geophysical methods. One such method is the ultrasound method. This method can measure and calculate the elastic parameters of the object of study without damaging it. We measured the propagation velocities of ultrasonic longitudinal (P) and shear waves (S) at the studied object. Then, material density (ρ), Poisson's ratio (ν) and Young's modulus (E) were calculated based on the measured speed. Ultrasonic devices, availability in our laboratory, can be used for the so-called tomography, "coverage" from the one side with the help of reflected waves. In this case, it is possible to identify voids of certain sizes, inhomogeneous regions in the body under study, and to distinguish regions of different densities (weakened).

Key words: *tomography, ultrasonic, P-wave, S-wave, nondestructive testing*

Introduction

Tomography is an emerging technique for non-destructive evaluation of concrete. The objective of tomography is to provide visualization, either by cross section or three dimensional structure of the structure interior, so that better identification of anomalous regions and determination of physical properties of the measured region can be achieved [7].
In analogy to visible and ultraviolet light, the terms sound and ultrasound are used to describe the propagation of a mechanical perturbation in different frequency ranges. Ultrasound corresponds to a mechanical wave propagating at frequencies above the range of human hearing (conventionally 20 kHz). Ultrasound and sound waves propagate in fluids (gases and liquids) and solids. In particular, the wave propagation depends on the intrinsic elastic properties of the medium as well as on its mass density [10]. Ultrasonic testing uses high-frequency sound waves to conduct examinations and measurements. In addition to its widespread use in engineering applications (e.g., defect detection / evaluation, material characteristics, etc.), ultrasounds are also used in the medical field. In general, ultrasound testing is based on the recording and quantification of reflected waves (pulse-echo) or transmitting waves.

A ultrasonic pulse-echo test concentrates on measuring the transit time of ultrasonic waves traveling through a material and being reflected to the surface of the tested medium. Based on the transit time or velocity, this technique can also be used to indirectly detect the presence of internal flaws, such as cracking, voids, delamination or horizontal cracking, or other damages [9].

Each of the two types is used under certain conditions [4,5]. In our scientific research, we use acoustics for geophysical and geotechnical research [1,3,5]. In this paper we present scientific-applied studies in the field of geomechanics using acoustic methods [6].

Equipment and software for ultrasound examination

We used ultrasound equipment produced by the Swiss company (PROCEQ, https://www.proceq.com/) for geophysical work, called Pundit PL-200 and Pundit PL-200PE. Ultrasonic testers (Pundit PL-200 and Pundit PL-200PE) are used to study concrete, wood and stone materials and structures using non-damaging acoustic control methods. Equipment and methods can be used: to study internal defects and cracks, heterogeneities and voids in materials, to calculate material modulus, stiffness and Poisson's ratio.

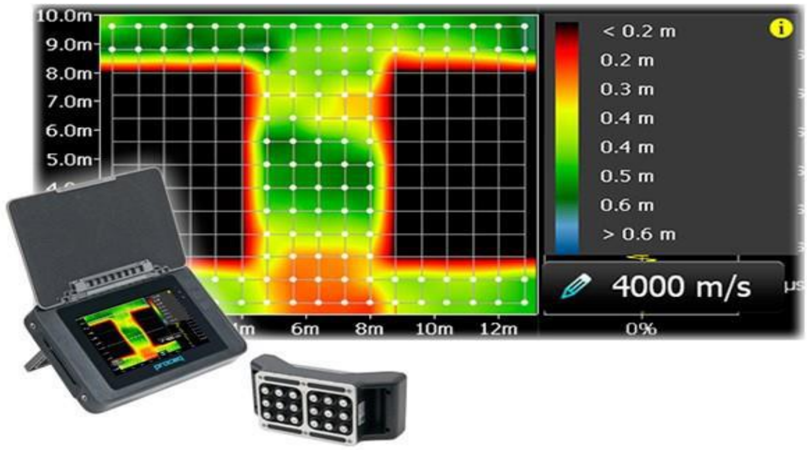
Pulse Echo Transducer - Pundit PL-200PE

The Pulse Echo transducer is a shear wave transducer designed for single-handed and two-handed operation. It is particularly suited to testing where access is limited to a single side. It can be used to perform several types of testing (scanning):

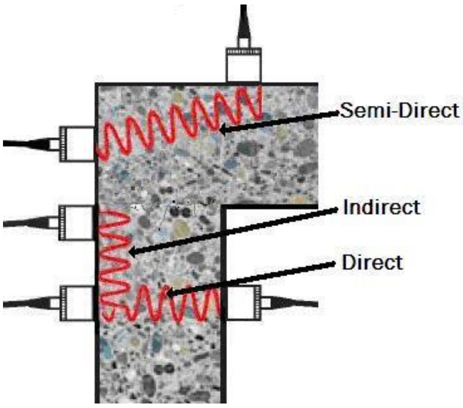
B-Scan
A cross-sectional view perpendicular to the scanning surface is provided. It facilitates the search for pipes, cracks, voids, etc.
State-of-the-art image processing for improved image quality.
Cursor placement allows a direct readout of the slab thickness and the location of hidden objects or defects.

A-Scan
A-Scan allows direct analysis of the raw signal. Digital filters for better echo visibility and noise suppression.
Automatic readout of slab thickness (Echo tracker).

Area Scan
Contour map of results over a concrete surface, either Velocity or thickness values can be mapped.



The Pundit PL-200 offers three methods of transmission. These can be seen in the image below.



Direct transmission: Optimal configuration with maximum signal amplitude. The most accurate method for determining pulse velocity.

Indirect transmission: The signal amplitude is about 3% of the direct transmission signal amplitude.

Indirect (semi-direct) transmission: Sensitivity is somewhere between the first two methods. The length of the road is measured from center to center.

Ultrasonic research methods
In our case, we used ultrasonic sounding with piezoelectric 54 kHz sensors. Piezoelectric transverse wave sensors with a frequency of 250 kHz were also used, and piezoelectric sensors with a frequency of 50 kHz were used for ultrasound tomography. With the help of sensors in such frequency ranges, it is possible to study the structure of a solid and concrete at a depth of 50-60 cm, and in some cases even up to 1 m.

Performing ultrasound examinations
Ultrasound examinations were performed on the load-bearing piers and walls of the Tsageri catchment (Fig. 1). Approximately 100 sites were selected in the vertical direction on the walls of the building where the mechanical properties of the concrete were studied.

a.

b.

Fig. 1. a) Tsageri catchment. 1 - East wall, 2 - First (east) pier, 3 - Second (central) pier, 4 - Third (west) pier and 5 - West wall. b) A picture of the ultrasound work on the load-bearing piers and walls of the catchment dam.

Data processing

Ultrasound waveform and tomographic (B-scan) recordings (Fig. 2) were processed using (PL-Link) standard software.

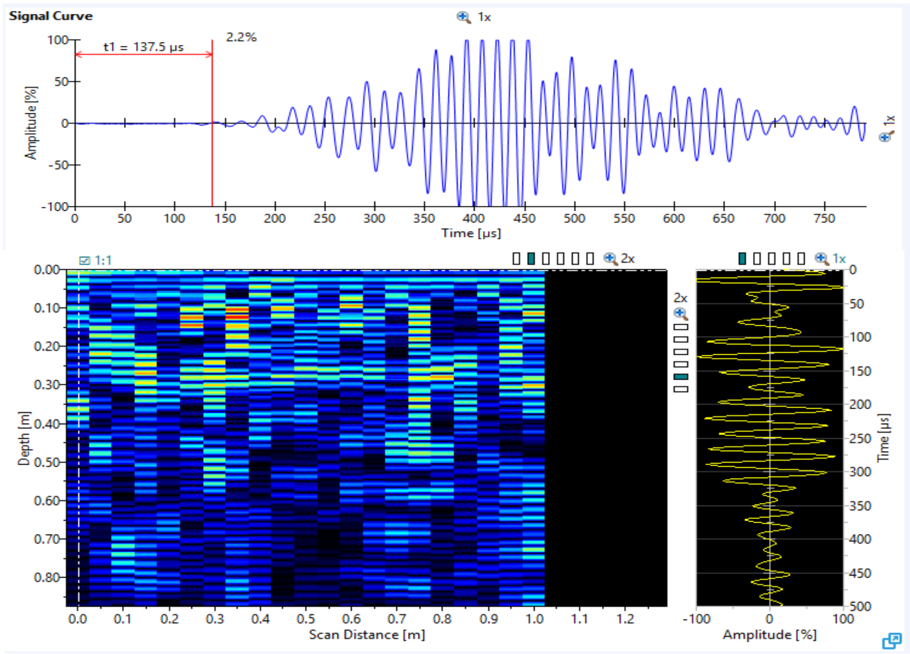


Fig.2. Ultrasound waveform (upper) and tomographic (lower) recordings.

On the records of oscillograms, the separation of longitudinal and transverse waves took place, their velocities were determined and various elastic parameters were calculated on the corresponding profiles. T On the processing and analysis of tomographic recordings (B-scans) took place us to identify possible voids, heterogeneous and weakened areas in the concrete.

Results of ultrasound examinations

About 100 precincts were processed. The image presented for each precinct is indicated by brown lines indicating the relevance of the tomographic images to the profiles. The yellow lines indicate the correspondence of the longitudinal velocities and the Poisson ratio with the profiles. The probable damaged areas localized by the velocity measurement are highlighted in blue, while the probable damage and weakening localized at different depths in the concrete pavement are marked in red by scanning. Here we present two of the location.

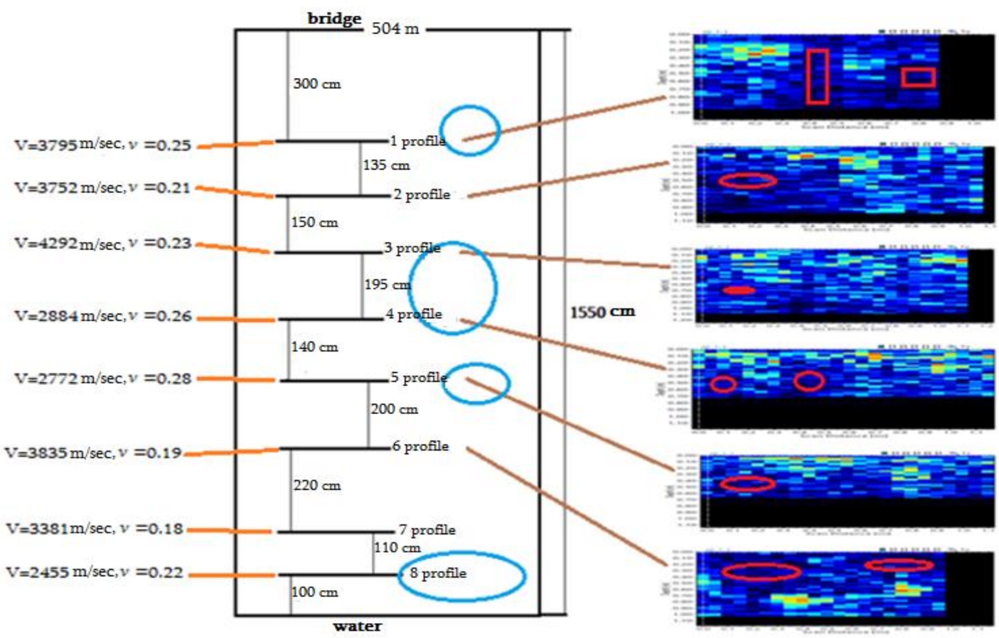


Fig.4. Profiles and tomographic records of one areas of the catchment.

Ultrasound testing works were performed on eight profiles at this site. Longitudinal (P) wave velocities in different profile ranges vary from 4292 m / s to 2455 m / s, transverse 2541 m / s to 1483 m / s, Poisson's ratio (ν) from 0,26 to 0 , At 18 intervals, and the Ju ng modulus (E) - (11639-39857) in the MPa interval.

One and more measurements of ultrasonic wave velocities were performed on all profiles in this area. They are made on concrete slab, on "poured concrete" and in the area of transition from concrete to tile. As the transition from the upper profiles of the precinct to the lower profiles, a gradual change in the speed of the ultrasonic wave will be observed. The velocity values are reduced in the vicinity of the third and fourth profiles. The values of the Poisson's ratio change in the range of 0.21-0.28 in the areas of the top five profiles, which probably indicates a weakening of the concrete structure in these areas. The velocity decreases particularly in the vicinity of the eighth (bottom) profile, which probably means damage to the concrete at this site or deterioration of its structure in this part of the pier [8].

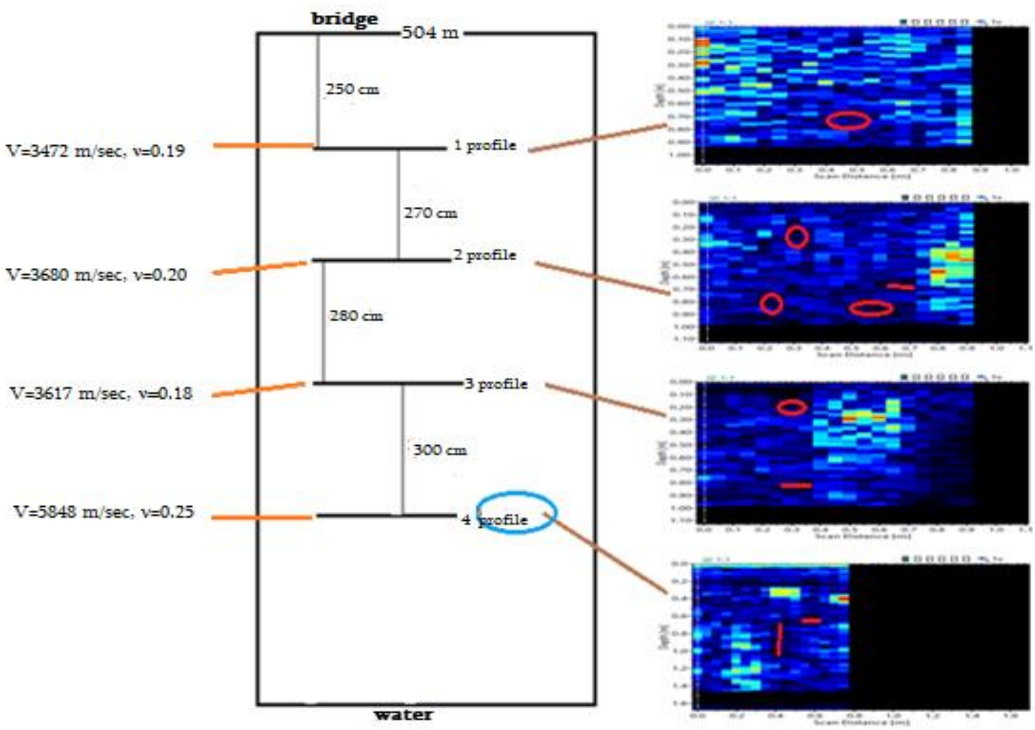


Fig.5. East wall (on the side of the dam) profiles of the first catchment tower and tomographic record of some profiles.

At this site (Fig.5) ultrasonic measurements were performed on three profiles along the wall and on the fourth profile on granite stones. Normal values of the Poisson's ratio (0.18-0.20) were be observed on all profiles and almost all measuring points, indicating the stability of the mechanical parameters of the concrete - its good condition. Ultrasound tomography (B-scan) was also performed on this incision. Deep lesions of different nature were observed in the tomographic images of all profiles, at different depths, as indicated in the images. In the tomographic images, in addition to the marked areas, dark colored areas was observed, which should indicate their weakening [8].

Comparison of the data presented in the two precincts (Fig.4, Fig.5) shows that they are relatively different precincts. The mechanical parameters of the bearing concretes in these areas differ from each other and indicate different mechanical states of the different catchment areas.

Conclusion

1. Modern methods of ultrasound examination and tools used have been found to be effective in assessing the condition of concrete structures constructing piers and walls. To evaluate and investigate visually imperceptible cracks, concrete structure and physical-mechanical properties.

2. The values of the elastic parameters calculated based on the measurement results vary within different values. Ultrasound tomographic scan images are also different. Anomalous areas are clearly visible on them. These anomalous areas should be related to changes in the structure of the concrete.
3. A sharp change in the values of Poisson's ratio should also be associated with a change in the rigidity of the material of the studied objects and its structure.
4. In general, it can be said that the results of the survey of the studied objects confirm that the physical-mechanical parameters are more anomalous in the areas adjacent to the lower, washed-erosion areas than in the areas of concrete slabs above. The concrete structure here should be more modified and characterized by less strength.

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ულტრაბგერითი ტომოგრაფია და იმპულსის სიჩქარე ბეტონის ნაგებობების დაუზიანებელი შეფასებისათვის

ნ. ვარამაშვილი, ბ. ასანიძე, მ. ჯახუტაშვილი

რეზიუმე

კვლევების მიზანი იყო ცაგერის წყალშემკრების თანამედროვე მდგომარეობის გეოფიზიკური მეთოდებით შესწავლა. ამ მეთოდების ერთ-ერთი სახეა ულტრაბგერითი კვლევების მეთოდი. ამ მეთოდით შესაძლებელია საკვლევი ობიექტის დრეკადი პარამეტრების გაზომვა და გამოთვლა, მისი დაზიანების გარეშე. საკვლევ ობიექტზე ხდებოდა ულტრაბგერითი გრძივი (P) და განივი (S) ტალღების გავრცელების სიჩქარეების გაზომვა. შემდეგ გამოთვლილი სიჩქარეების საფუძველზე

მასალის სიმკვრივის (ρ) პუასონის კოეფიციენტის (ν) და იუნგის მოდულის (E) გამოთვლა. ულტრაბგერითი ხელსაწყო-დანადგარების საშუალებით შესაძლებელია საკვლევი გარემოს ე.წ. ტომოგრაფია, მისი „გაშუქება“ ცალი მხრიდან არეკლილი ტალღების საშუალებით. ამ შემთხვევაში შესაძლებელია საკვლევ სხეულში არსებული, გარკვეული ზომის სიცარიელეების, არაერთგვაროვანი უბნების დაფიქსირება და სხვადასხვა სიმკვრივის (შესუსტებული) უბნების გამოყოფა.

Ультразвуковая томография и скорость импульса для оценки без повреждений состояния бетонных конструкций

Н. Д. Варамашвили, Б. З. Асанидзе, М. Н. Джахуташвили

Резюме

Целью исследования было изучение современного состояния водосбора Цагери геофизическими методами. Один из видов этих методов - метод ультразвукового исследования. С помощью этого метода можно измерить и рассчитать упругие параметры объекта исследования, не повредив его. На месте исследования были измерены скорости распространения ультразвуковых продольных (P) и поперечных (S) волн. Затем вычислены коэффициент Пуассона (ν), плотности материала (ρ) и модуль Юнга (E) на основе рассчитанных скоростей. С помощью ультразвуковых аппаратов можно изучать исследуемую среду, сделать томографию, "просвечивать" объект с одной стороны отраженными волнамы. В этом случае можно зафиксировать в исследуемом теле пустоты определенного размера, неоднородные участки и выделить (ослабленные) участки разной плотности.