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Acoustics in Geophysics and Geomechanics

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ABSTRACT

Acoustic radiation can be initiated during various processes (landslides, mudslides, avalanches, ...). By recording and analyzing the acoustic waves that have arisen in the process of various processes, one can make important conclusions about events of interest to us. Passive and often active methods can be used to study the environment, buildings, living organisms, without damaging them. The paper presents experiments of laboratory modeling arising of acoustic impulses during landslide processes and their results. In paper is reviewed possibility using acoustic methods for monitoring and predicting landslide processes. This method allows you to create landslide monitoring and early private systems with low costs. The paper also presents the results of the study of the mechanical properties of walls of two ancient church and the degree of they damage by measurement of velocity of ultrasound waves, and tomography methods.

Key words**:** acoustic, landslide, Lamb waves, P-wave, S-wave, tomography

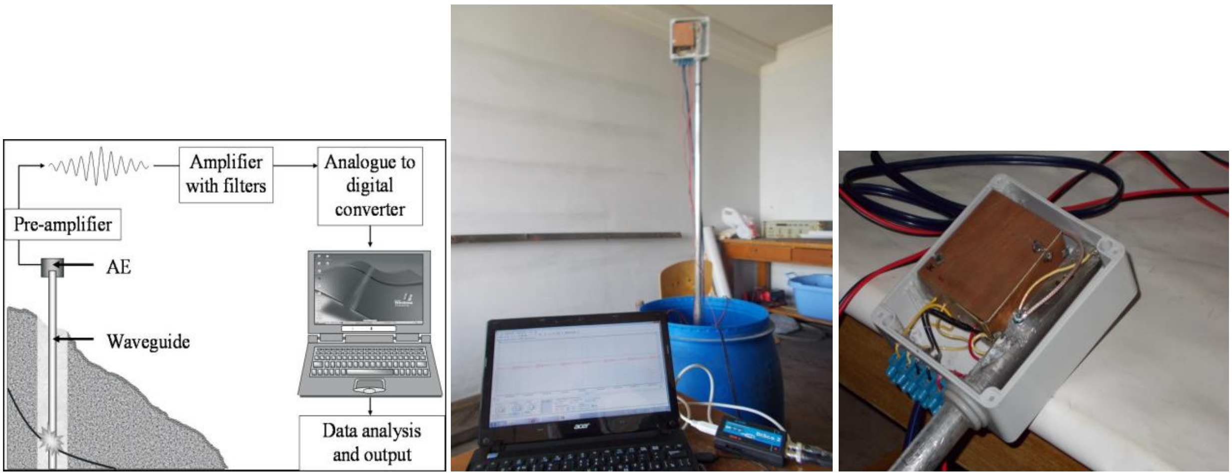
Introduction

Acoustic methods are a very powerful tool in geophysical search, engineering and medical research. Acoustic waves in the seas and oceans can transmit and receive information over long distances, with little loss [5]. In our scientific research we use acoustics in several areas. In this paper we present scientific-applied researches in the fields of geodynamics and geomechanics using acoustic methods [1].

Acoustic in geodynamics

Traditionally, landslides can occur on very steep slopes in mountainous regions, such as Georgia, which do not accurately reflect the nature of this problem. Landslides can occur virtually anywhere in the world. The mountainous regions are, of course, in greater danger. Studies have been conducted for decades to monitor soil movement using acoustic emission (EE).

Detecting AE generated by a developing shear surface within a slope is not an easy task. As AE propagates through soil, it suffers from a loss of signal amplitude: attenuation is high in soil because it is a particulate (granular) medium and energy is lost as AE travels across boundaries from one particle to another. The use of a waveguide to provide a path of low attenuation from the source of the AE (within a soil slope) to the sensor (usually situated above ground surface) has become a standard practice in AE research [1,3,4]. The presence of a waveguide, typically a metal pipe inserted within an unstable slope, also greatly increases the monitoring ability of the AE sensor.



a. b. c.

Fig.1. (a) components of acoustic monitoring system (Dixon et al., 2003), (b) Landslide creep modeling and associated acoustic emission recording using USB oscilloscope and (c) acoustic sensor

Figure 2 shows a schematic representation of a typical AE instrumentation system. AE originating from the deformation of a backfill within the active waveguide propagates along a steel waveguide to a piezoelectric sensor secured to the top of the metal waveguide [2]. The AE signal is then amplified by a preamplifier and an amplifier to enable the signal to travel down the lengths of cable without being subsequently affected by background or electrical noise. Finally the AE is converted to a digital signal for subsequent analysis and manipulation using real time data acquisition software.

The goal of our study is registration and monitoring of landslide slow motion (creep) by recording the acoustic emission. For this goal we developed the special equipment (Fig.3). Plastic barrel is filled with a soil from the landslide, the in the center of which is a cylinder filled with small stones. The cylinder diameter is approximately 15 cm and a mean diameter of stones about 7 mm. In the center of gravel parcel thick-wall stainless steel tube is placed, through which acoustic pulses arisen in the gravel are transmitted to the acoustic sensor. The deformation of the experimental set up is done with the help of a mechanical jack [3,4].

The similar technique based on the recording of the acoustics generated by displacement in the gravel coating around acoustic sensor was earlier developed by Loughborough University team, but it demands drilling of relatively deep borehole down to the sliding surface. This procedure is quite expensive. Our objective was to develop a cost-effective version of the mentioned method. The idea is to use two sensitive acoustic probes grounded on different depths, one on the depth of several meters and other close to the day surface. The former probe is the basic and the role of latter one is to distinguish signals of surface origin, which in this case are considered as noise.

Registration of acoustic pulses occurring at small shifting of the landslide soil was produced by the acoustic sensor, which was attached to the USB oscilloscope (Fig.1), with which after using special processing software information is sent to computer [3].

Acoustic in geomechanical problems

As approved in the world geophysical community, geophysical methods are increasingly used to solve various engineering and household tasks, to evaluate and investigate the condition of buildings and their infrastructure and to perform restoration work purposefully.

Acoustic (ultrasound) methods are widely used to study the mechanical parameters structures and buildings from stone, wood, reinforced concrete, metal. With ultrasound equipment, without damaging structures and buildings, it is possible to locate and assess the voids, cracks in them and the degree of their damage.

We used ultrasonic equipment from the Swiss company (PROCEQ, https://www.proceq.com/) to perform geophysical work, which is called Pundit PL-200 and Pundit PL-200PE.

Fig.2. PUNDIT PL-200 and PL-200PE Ultrasonic flaw detector

Импульсный эхо тестер (Pulse Echo Transducer) - Pundit PL-200PE

With the help of a pulse tester it is possible to conduct several types of testing (Scanning):

B-Scan

Cross section of the scanned surface. Useful when searching for pipes, cracks, voids, etc.

A-Scan

Gives the possibility of direct signal analysis. It has automatic thickness reading (echo tracker).

Area Scan

Values of the velocity or thickness of the object under study, in the form of a contour map.

The **Pundit PL-200** Ultrasonic Tester gives us oportunity to investigate, follow to three ways, introduced below:

Direct transmission: optimal configuration with a maximum signal amplitude. The most accurate method for determining the speed of a pulse

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

Sideways (semidirect) transmission: sensitivity is somewhere between the first two methods. The distance is measured from the center to the center.

One of our goals was to study the actual situation of the Churchs of Satxe and of Tiseli (Georgia) using the ultrasonic device of the Pundit firm PROSEQ (Fig. 3).

a. b.

Fig.3. a. Works in Satxe Church b. Works in Tiseli Church

The following types of observations was conducted at various sites of church, based on the capabilities of the ultrasound device:

On the walls of the buildings, sites were selected where the mechanical properties of the stones and mortar were studied. In addition, on the south pillar of the main temple and also on the adjacent wall, through the device, a cross-section of profiles was taked 0.1m apart. Since the P and S elastic wave velocities are theoretically and empirically linked to the wall condition parameters, in we may consider the presence of weakened, depleted, and relatively disturbed zones within the study area. Using P and S waves sensors on the visually stored and attenuated areas of the walls of the building resulted in:

With our sensors, we get a good effect at about 0.4 m base (distance between reflector and receiver). It depends on the condition of the stone and the mortar.

The obtained materials determined the propagation velocities of P and S elastic waves, both in the basalt and tuff stone blocks, as well as in the blocks and their filling mortars. On the basis of these velocities the physical-mechanical parameters were determined:

ρ - density; ν-Poisson coefficient; E - Young's dynamic module;

G - shear module; K - compression module;

Based on the results of the work, were carryed out analysis about condition of the Tiseli Church walls rocks, certain areas and exposed areas of the mortar and also were a comprehensive report could be a guide for specialists to undertake future restoration or conservation work.

References

[1] Varamashvili N., Chelidze T., Devidze M., Chikhladze V. Laboratory and mathematical modeling of landslides triggered by external factors. Field research. Transactions of Mikheil Nodia Institute of Geophysics of Ivane Javakhishvili Tbilisi State University, vol. LXVIII, Monography, Tbilisi, 2017 (in Georgian).

[2] Dixon, N., Hill, R., Kavanagh, J. Acoustic emission monitoring of slope instability: Development of an active wave guide system. Institution of Civil Engineers Geotechnical Engineering Journal, 156, 2, 2003, 83-95

[3] Varamashvili N., Chelidze T., Chelidze Z., Chikhladze V., Tefnadze D. Acoustic pulses detecting methods in granular media. Journal of Georgian Geophysical Society, v. 16, 2013.

[4] Varamashvili N., Chelidze Z., Chelidze T. Acoustic pulses generated by landslide activation: laboratory modeling. Journal of Georgian Geophysical Society, v. 17, 2014.

[5] Heutschi K. Lecture Notes on Acoustics I. Swiss Federal Institute of Technology, ETH Zurich, 2016.

[6] Varamashvili N., Chelidze T., Chelidze Z., Gigiberia M., Ghlonti N. Acoustical methods in geodynamical and geomechanical problems. International Scientific Conference „Modern Problems of Ecology“, Kutaisi, Georgia, 21-22 September, 2018, (in Georgian)
[7] Chelidze T., Varamashvili N., Chelidze Z., Kiria T., Ghlonti N., Kiria J., Tsamalashvili T. Cost-effective telemetric monitoring and early warning systems for signaling landslide initiation. Mikheil Nodia Institute of Geophysics of Ivane Javakhishvili Tbilisi State University, Monography, Tbilisi, 2018.

აკუსტიკა გეოფიზიკაში და გეომექანიკაში

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რეზიუმე

სხვადასხვა პროცესების (მეწყერი, ღვარცოფი, ზვავი,...) მიმდინარეობისას შეიძლება მოხდეს აკუსტიკური გამოსხივების ინიცირება. აღძრული აკუსტიკური ტალღების რეგისტრაციით და ანალიზის საშუალებით შესაძლებელია ჩვენთვის საინტერესო მოვლენებზე მნიშვნელოვანი დასკვნების გაკეთება. პასიური და ხშირ შემთხვევაში აქტიური მეთოდებით შესაძლებელია გარემოს, შენობა-ნაგებობების, ცოცხალი ორგანიზმების გამოკვლევა მათი დაზიანების გარეშე. ნაშრომში წარმოდგენილია მეწყრული პროცესების მიმდინარეობისას აკუსტიკური იმპულსების აღძვრის ლაბორატორიული მოდელირების ექსპერიმენტები და მისი შედეგები. განხილულია აკუსტიკური მეთოდების გამოყენების შესაძლებლობა მეწყრული პროცესების მონიტორინგისა და პროგნოზისათვის. ეს მეთოდი საშუალებას იძლევა მცირე დანახარჯებით შეიქმნას მეწყრის მონიტორინგისა და ადრეული შეტყობინების სისტემა. ნაშრომში ასევე წარმოდგენილია, ულტრაბგერითი გაშუქების, დრეკადი ტალღების სიჩქარეების გაზომვის და ტომოგრაფიის მეთოდებით, რამდენიმე ეკლესიის კედლების მექანიკური მახასიათებლების, დაზიანების ხარისხის შესწავლის შედეგები.

Акустика в геофизике и геомеханике

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Резюме

Акустическое излучение может инициироваться во время различных процессов (оползни, сели, лавины, ...). Записывая и анализируя акустические волны, возникшие в процессе различных процессов, можно сделать важные выводы о событиях, которые нас интересуют. Пассивные и часто активные методы могут быть использованы для изучения окружающей среды, зданий, живых организмов, не повреждая их. В статье представлены эксперименты лабораторного моделирования возникновения акустических импульсов при оползневых процессах и их результаты. В статье рассматривается возможность использования акустических методов для мониторинга и прогнозирования оползневых процессов. Этот метод позволяет, низкими затратами, создавать экономичные системы мониторинга и раннего оповещения опользневых процессов. В работе также представлены результаты изучения механических свойств стен двух древних храмов и степени их повреждения путем измерения скорости ультразвуковых волн, а также методами ультразвуковой томографии.