MONITORING AND DIAGNOSIS OF THE PROCESS OF SHRINKAGE AND CRACK FORMATION IN CONCRETE DAMS USING A HOLOGRAPHIC INTERFEROMETRY

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Abstract. ***Experimental studies in hydro technical construction are discussed, in particular such long-term processes in concrete dams, as are shrinkage and crack formation. The study was conducted using a coherent measurement technique –holographic interferometry. This method enables monitoring and diagnostics in the construction of dams. The relevant research literature has been reviewed, as well as experimental data is given.***

Key words: ***holography, interferometry, deformation, crack resistance, shrinkage, swelling, creeping.***

Introduction

Concrete is the main building material for the construction ofconcrete dams. Therefore, it is very important to study the long-term processes such as shrinkage, creeping,swelling, temperature impacts and crack resistancethat affect its strength. Familiar methods and relevant laboratory studies incompletely describe the process of complex composition of materials such as concrete and reinforced concrete. The method of holographic interferometry is the best possible way to observe the early stage of the formation of concrete structure and study the processes ongoing in the course ofstrengthening, which are not visually observed.

Main part

Structural features of concrete structures in conjunction with environmental and load conditions accelerate the development of cracking processes, on the regulation of which directly dependthe durability of concrete and reinforced concrete [1].

In recent years, hard efforts were applied for the development of reliable methods of calculation of the long-term impacts of concrete structures and the accumulation of relevant experimental data in large quantities. But, at the same time, more attention was paid to the study of the issues on concrete shrinkage and crack resistance.

Since the researchers are dealing with the materials of the most difficult structure, as well as many factors affecting its tense-deformed conditions while studyingthe nature of these matters, there has been no scientific consensus reached yet.

In-depth study of the nature of concrete shrinkage and crack resistance using the latest advances in physics and physical chemistry is considered to be one of the topical tasks in concrete studies [2].

The analysis of the works related to the study of structural voltage in concrete carried out by various researchers has showed that theyconsidered too simplified mathematical models, enabling them to conduct their analytical description, or they studied physical models, where one of the concrete components wasreplaced by a model (fiber-sensitive) material. With this replacement,

some parts of the complex pattern of the interaction between the cement stones and granules of filling material were lost. The process of temperature crack formationshould also be noted, which is a complex multi-factor process in concrete structures, and its intensity depends both on the properties of concrete structure and environmental conditions. According to our own and world experience, despite significant improvements in the methods of thermo-regulation of concrete pavements, the cracks of various trajectories, depths and opening widths, as well as temperature-settling stitches (organized cracks) are still observed in many massive concrete buildings that have been already constructed or are under construction, in particular in concrete dams. Therefore, it is of utmost importance to observe various stages of the process of crack formation in concrete buildings which areconstructed or under construction with modern, improved methods.

Therefore, it is important to investigate the nature of the development of shrinkagedeformation and identify the role of certain factors (the nature and quality of creeping limitation, the quality of cement, water-cement ratio, etc.) in the development of these deformations, as well as to investigate the process of formation and development of the cracks and the impact of cement quality (mineral composition) on this process. A tense-deformed condition, on the other hand, is a possible source of filtration, which in its turn causes corrosion of reinforcement and eventually has a negative impact on the durability of the building.

These issues are important for Georgia, since the construction of Khudoni HPP with a 200-meter concrete arched dam on the Enguri River is plannedin the nearest future.

Intensification of concrete works has got an important role in the construction of dams, whichcreates additional requirements for designers to increase the parameters(volume) of structural elements (sections, blocks). Massive blocks complicate the process of thermo regulation of bulk concrete and increase the risk of crack formation temperature. That's why thedynamics and factors must be studied at the initial stage of thecrack formation process that are to be necessarily taken into account while developingtechnical conditions for concrete works and their practical implementation in the future in order to minimize the process of crack formation.

It is known that due to its tense-deformed condition in arch dams (a volumetric compression of the structures with the impact of arched voltages), filtration is less expensive compared to the other concrete dams. This peculiarity can be used for concrete casing using dam wide blocks (alongside the arch). That's why the concept of track formation management becomes topical, in particular, predictionand preliminary initiation of radial direction cracks, including anti-filtration measures, which occurs with a vertical mark placed in the concrete layer. Such practices and methods were tested and introduced in the construction of relatively thin ($h = 0{,}3 \div 0{,}5$ m) structures (concrete paved roads, marine ports, airfields). In addition, it is important to set stitch parameters for such bulk concrete that are characteristic for concrete dams ($h_{gl} = 0.75 \div 1{,}5$ m and more) [3].

The study of power crack developmentregularities was initiated in the 20s of the last century. For the purpose of determining a criterion of fracture, A. Griffiths introduced an energy approach, which was further followed by a power approachintroduced by G. Irvin. Later, the attitude towards energy and power values used by A. Griffiths and G. Irvin was established, which confirmed their identity. The development of the new science is well illustrated in the encyclopedic work on the fracture mechanics, which was published under the editorship of G.Libovitz.

For successful application of fracture mechanics to compose materials, it is necessary to carry out a study in two directions[4]:

First of all, the process of fracture must be studied in detail. Existing simplified models for the development of cracks do not accurately describe the process.

On the other hand, the selection of experimental methods is quite important. We may select several basic methods:

1. Photo elasticity, moiré patterns, optical holography, X-ray and electronic microscope, radiation, etc.

2. Methods based on application of elastic waves: acoustic emission, an impulsive ultrasound method, acoustic holography.

3. Tensometer method, method of mercury phorometry.

4. Computational methods based on the study of different mathematical models.

All these methods have both positive and negative aspects from the scientific, practical and economic point of view. Therefore, the use of the method depends largely on the task facing a researcher and the means (intellectual, technical, material) employed by the researcher.

In 1948 Denis Gabor,an English scientistinvented a "holography, three-dimensional photography" that was not common because there was no source of light.

In 1962 Russian scientists Basov and Prokhorov invented "Laser", which means "forced exposure to light source". From 1962 begins an intensive application of holography.

In 1967 an American scientist Leight invented a "Holographic interferometry", which was used in almost all fields of science, technology and industry.For this invention Gabor, Basov and Prokhorov were awarded the Nobel Prize.

It is used for scientific research to measure the deformations, as well as for monitoring and diagnostics of merchandizemade of different materials, as well as concrete and reinforced concrete structures.

This modern, perfect method is of utmost importance for monitoring of crack formation, shrinkagein the early and different stages of observation without contact [5].

Through this method it is possible to evaluate a deformedcondition of solid body qualitatively and quantitatively and the processes of concrete shrinkage and crack formation of different composition, as well as their development processes. Helium-neon ЛГИ-215 laser with a capacity of 60 MVT is used in the course of experiment.

One of the first scientists who used holography in the fracture mechanics and conducted appropriate experiments was T. Duderal.

In 1977 one of the first experiments [6-10] was conducted in the "Research Laboratory of Optical Methods for Construction Materials" in the K. Zavryev Institute of Construction Mechanics and Seismic Stability of the Academy of Sciences of Georgia.

Through the method of holographic interferometry, we can simultaneously observe a crack birth, its development and deformation field near its top atthe early stages of the structural formation. The accuracy of the measurement is higher by this method (632,8 nm), rather than by the method of placing a photo-elastic layer.

Unlike the tensometer, it does not require preliminary surface treatment and its placement on the surface. In addition,a moist surface may be studied without contactduring the mixing of cement stones and concrete, as well as visualization of the entire process.

We are interested in the method of holographic interferometry as far asit enables us toevaluate qualitatively and quantitatively the deformation of a solid body and the processes of shrinkage, crack formation and development of concretes of different compositions. This method is only a tool or a weapon to achieve the desired goals, andthe main point is that a holographic plate exposes twice before photographic processing –for the first time when the surface of the test sample is in the initial condition, and the second time when it is deformed or undergoes any other impact.

This is a unique way to simultaneously observe a unified picture of deformation on the whole registered surface of the object of study and at the same time to measure all three components of the displacement vector at any chosen point.

As we have noted,a spatial perception of the processes ongoing in concrete structures and a photographic reflection of the dynamics of the tense-deformed condition of constructive elements (Figure 1-5) enable us to observe the concrete at the early stage of its structure formation through the method of holographic interferometry. The research aims to develop measures that will

neutralize the process, on the one hand; On the other hand, it will specify the parameters of stitches and marks that providethe process of organized crack formation, taking into account the minimization of its negative consequences.

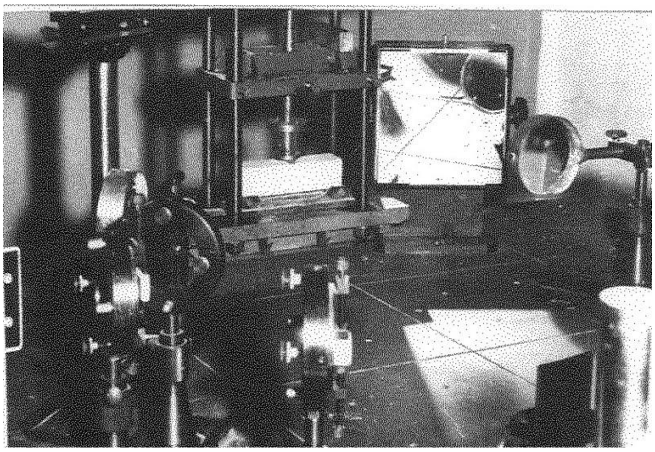
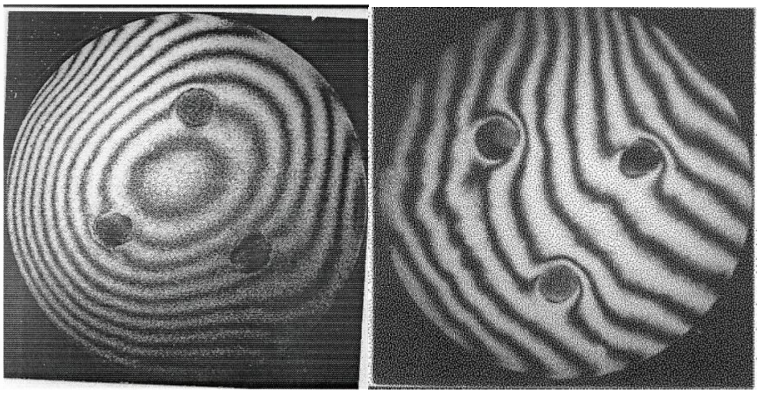
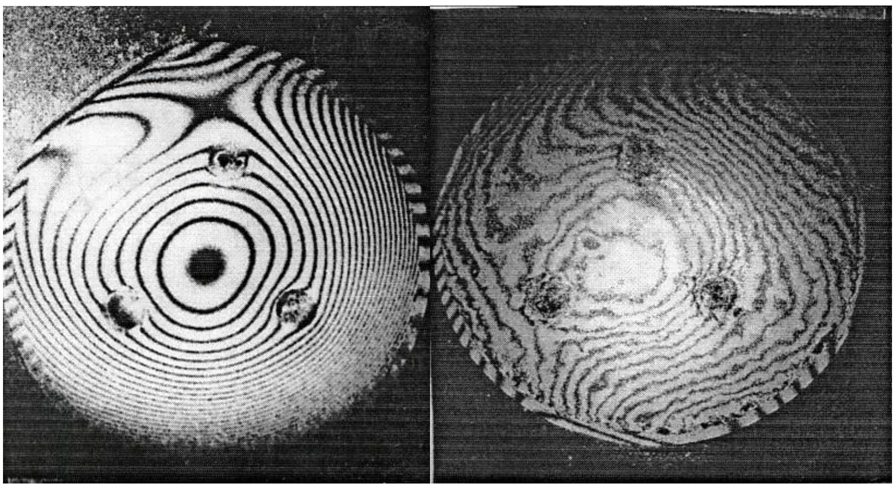


Figure 1. Laboratory of holographic interferometry

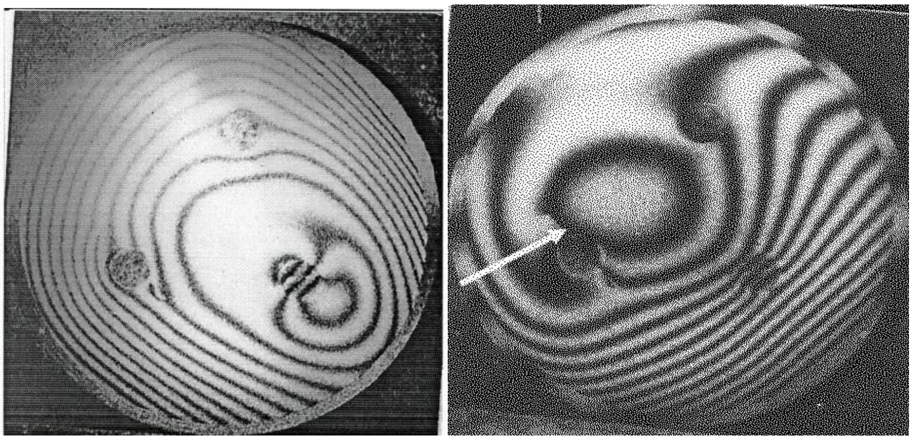


After 40 hrs **After 62 hrs**

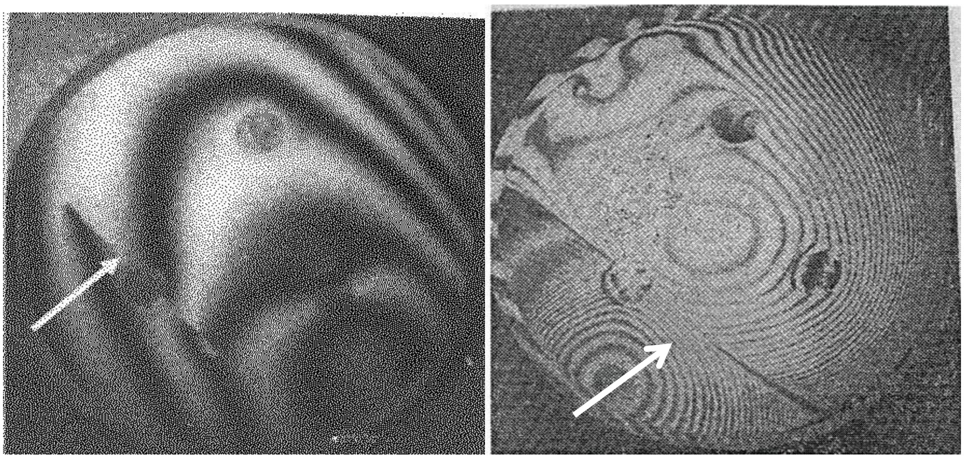


After 89 hrs **After 114 hrs**

Figure 2. Interferogram, a cement matrix and a granite stone composed in it with d = 2 cm fillers in the free condition



After 60 hrs   **After 62 hrs**



After 120 hrs   **After 489 hrs**

Figure3. Interferogram, a cement matrix and a granite stone fixed rigidly in it with d = 2 cm fillers

A tense-deformed process is increasedin this matrix. As observed in the interferogram, there was a crack in the contact zone of the matrix and the granite fillernot visible on the sample. After 120 hrs the crack was intensely developed, the tension-deformed process on the sample decreased.

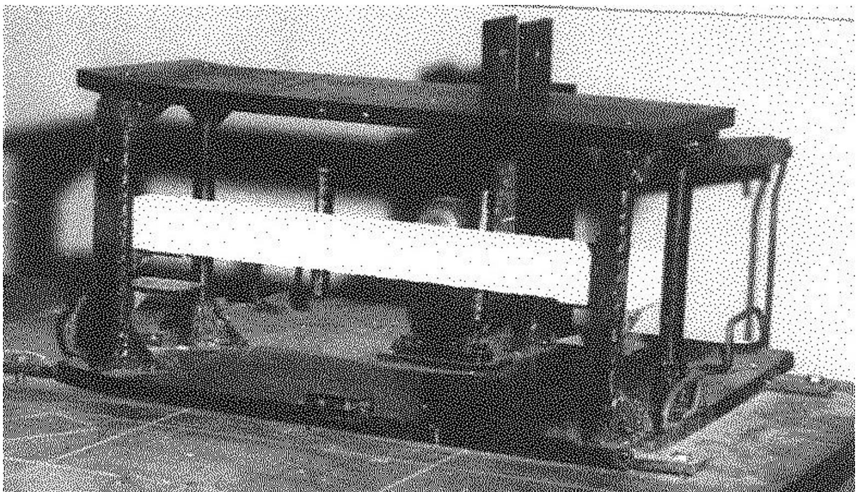


Figure 4. Equipment testing concrete samplesfor flexure

Figure 5. Interferogram during flexure

Here are the cracks that are not visualized on the sample until its complete rapture.

Conclusion

The new phase begins with the development of this methodthat implies the improvement and development of research methods, as well as a broad introduction of its results in practice, which will further facilitate the reliability and durability ofconcrete and reinforced concrete structures, one of the major building materialsin construction, in particular in hydro-technical construction.This will create a solid foundation for engineering-technical personnel working in this field.

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