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Results of experimental tests of building samples

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Abstract. The purpose of the experimental study presented in the work is to generate new knowledge about the quality of concrete samples in a new information field that consolidates information about the results of full-scale tests and video streams that were obtained during active laboratory experiments-studies. When conducting experimental studies, the traditional technology of testing concrete samples for central compression was used. This was accompanied by continuous monitoring and the formation of a video stream for each sample. A distinctive feature of the study is the formation of an information field of experiments, which contains three levels: the level of initial data, the level of analysis of initial data and the level of generation of new knowledge. The level of analysis of the source data using the video stream allows you to obtain information at the end of the experiment that cannot be recorded in real time. For the samples under study, time intervals with different rates of defect development were obtained. The results obtained made it possible to identify new possibilities for the formation of the information field during traditional experimental studies of the quality of concrete images and, based on the information obtained, to identify patterns of development of surface continuity disorders in dynamics. New opportunities for the formation of the information field allow in real time to obtain and process information on the state of concrete and reinforced concrete structures of construction projects by quality indicators and, on the basis of the data obtained, predicting the risk of accidents, including at hazardous production facilities.

1. Introduction

To decide on the applicability of materials and structures in the construction industry, to date, it remains most expedient to perform experimental studies, the results of which require subsequent analysis of the information obtained using new information technologies and artificial intelligence. The current level of development of computer technology and software allows connecting computer vision and intellectual analysis tools to such research [1-5]. From the point of view of the methodology of scientific research set out in the widely cited book "Methodology" by authors A.M. Novikov and D.A. Novikov, empirical methods-operations and methods-actions form the basis for studying the object and subject of research. The empirical stage of scientific research is an integral part of the technological phase of design and the basis for assessing the compliance of the results obtained with the behavior of the real processes under study [6-9].

Analysis of theoretical and practical developments in the field of testing concrete samples showed that the greatest attention is paid to:

1) calculation of stress-strain state of samples on the basis of theoretical calculations [10-13];



- 2) forecasting the service life of reinforced concrete structures operated in conditions of climatic influences and aggressive environment [14,15];
- 3) development of methods and devices for laboratory tests in the study of the properties of concrete images [16-18];
- 4) selection of additives in the composition of concrete to change its structure and strength properties [19, 20];
- 5) development of methods of destructive and non-destructive testing in the study of samples [21-26].

Despite the large number of theoretical and practical studies on the testing of concrete samples, the question of conducting their experimental study to identify new knowledge about the characteristics for further forecasting the behavior of finished products and structures in conditions of operational and over operational load remains relevant.

In this regard, the purpose of the experimental study given in the work is *to* generate new knowledge about the quality of concrete *samples* in a new information field that consolidates information about the results of full-scale tests and video streams that are obtained during active laboratory experiments-study.

2. Methods

For testing, prototypes were made, which included:

- Portland cement (cement grade PC 500-D0, manufactured at the Magnitogorsk Cement and Refractory Plant);
- cube-shaped crushed stone of M1400 grade and fractions of 5-20 mm (mining site Gumbey granite quarry);
- washed sand, 40-5 mm edged (Narovchatsky sand quarry);
- concrete modifier "Embelit" 0-100;
- plasticizer "Zika viscokrit" SP 5-600;
- drinking tap water according to GOST R 51232-98 at a temperature of 20-22 °C (Figure 1).



Figure 1. Type of materials and manufactured samples: 1, 2 – concrete modifier "Embelit"; 3 – crushed stone; 4 – washed sand; 5, 6 – Portland cement; 7 – drinking water with plasticizer

For the selection of the composition of high-strength, self-compacting, straining concrete, four varying indicators were chosen: the mass of cement, the water-cement ratio, the ratio of the mass of the plasticizer to the mass of cement, the ratio of the mass of the modifier to the mass of cement. Two immutable materials are also defined: the mass of sand; mass of crushed stone. The levels of variation of indicators are presented in Table. 1.

Table 1. Levels of variation of indicators

Name of varying indicator	Designation	Indicator level		
		Maximal	Zero	Minimal
Cement weight, kg per 1000 l	C	490	460	430
Water cemental attitude	B/C	0.40	0.35	0.30
Ratio of plasticizer to cement mass	P/C	0.030	0.022	0.014
Ratio of modifier to cement mass	M/C	0.25	0.2	0.15

Laboratory samples are represented by two types: a sample cube with dimensions of 100×100×100 mm according to GOST 10180-2012; sample-prism with dimensions of 100×100×400 mm according to GOST 10180-2012. Three series were made for each type of samples. In each series there were 12 sample cubes and 3 samples-prisms.

Sample cubes and prism samples were poured from a single batch of concrete. Their tests were carried out on the same day. Under these conditions, the age of concrete and its strength indicators are conditionally the same for assessing the mechanism of destruction of control samples under load.

For testing, samples were installed on the lower base plate of the press in the center of the longitudinal axis. After the specimen was installed on the lower base plate of the test machine, the top plate of the test machine was aligned with the upper reference face of the sample so that their planes were completely adjacent to one another. Compensating gaskets were used to eliminate the effect of stress concentrations at the contact boundaries of the samples with the upper and lower plates of the test machine (Figure 2). The sample was loaded to destruction at a constant load rate (0.6 ± 0.2) MPa/s.

In Figure 2a, the designations are introduced: 1 - the upper plate of the test machine; 2 - the lower plate of the test machine; 3 - compensating gaskets; 4 - sample; 5 - camera; 6 - the surface of the sample included in the video stream; 7 - the background included in the frames of the video stream; 8 - the forces acting on the sample during central compression.

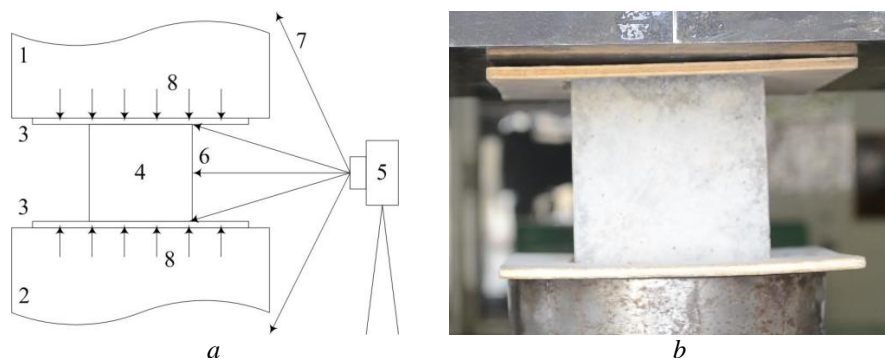


Figure 2. Installation of the sample for testing: a – scheme; b – full-scale sample

During the tests, two types of data were obtained: data characterizing the axial compression strength of the control samples; video stream, which allowed to fix the moment of origin of cracks, the dynamics of their development up to the destruction of control samples.

3. Results and Discussion

3.1 Structure of the information field of experimental research

The use of video recording tools in the course of experiments to study the strength of concrete images made it possible to form a new structure of the information field of tests (Figure 3).

The structure of the new test information field includes three main levels (1, 2, 4) and one functional unit (3).

The first level is designed to organize the storage of data obtained during the experiment, and their structuring. The level of data analysis involves the extraction of the necessary primary information, the implementation of data analysis based on simple calculations or calculation using traditional methods and using new information technologies. The third level involves the generation of new knowledge based on consolidated data that has not previously been considered in traditional regulatory documents. For example, estimating the time of development of defects before reaching their critical development.

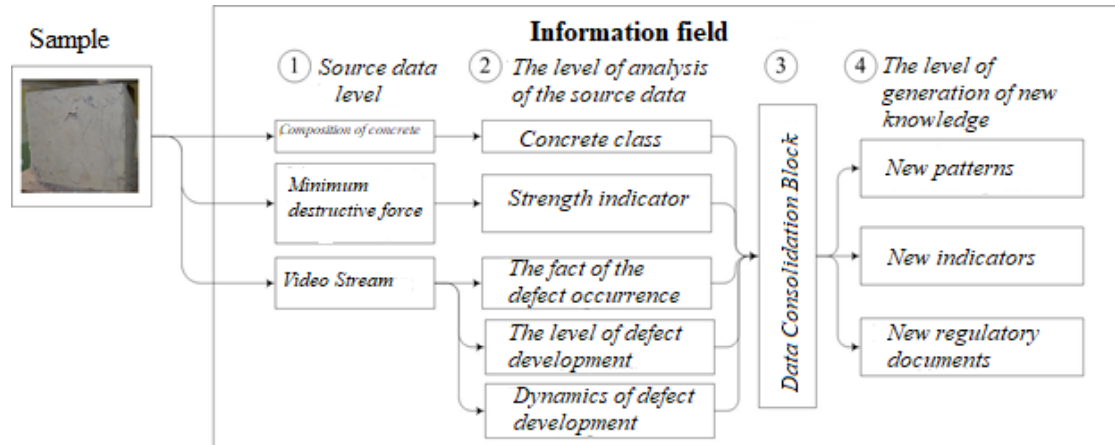


Figure 3. Structure of the information field of concrete samples testing

3.2 Methodica and results of strength assessment of concrete samples

According to the results of the planning of the experiment, the composition of concrete was selected, which is given in Table. 2.

Table 2. Composition of high-strength self-compacting straining concrete of class B80

Component name	Bulk density of material, kg/m ³	Weight, kg per 1000 l
Cement	3100	520
Embelite	2200	104
Zika viscokrit SP 5-600	1100	8,32
Sand	2600	678,20
Macadam	2600	910,46
Water	1000	166,4

After testing the control samples-cubes, the composition of concrete was obtained, providing with a probability of 0.95 the class of concrete in terms of axial compressive strength not lower than B80. The strength index of concrete as a quantitative characteristic was determined according to the methodology given in GOST 10180-2012 [13].

The results of tests of one of the series of samples suitable for visual and measuring control with a size of 100x100x100 mm at a scale coefficient of 0.95 are given in Table. 3.

During the experiment, a video stream was formed, which recorded the dynamics of changes in the continuity of samples on its surface.

Table 3. Test results of control samples-cubes on axial compressive strength

Index	Sample number					
	1	2	3	4	5	6
Minimum destructive force, kN	888.1	891.3	860.0	864.2	845.2	864.6
Compressive strength of concrete, MPa	84.4	84.7	81.7	82.1	80.3	82.1
Average compressive strength of concrete, MPa	82.5					
Concrete class by axial compression strength according to GOST 18105-2018	Q80					

3.3 Results of visual analysis of video flow of loading and destruction of concrete samples

Video recording of experiments on loading samples allowed performing the study of changes in the continuity of the surface after the completion of the stage of active full-scale experiment. Figure 4 shows fragments of the video stream, which display the key transition points in the dynamics of the destruction of the concrete sample.

Figure 4 highlights the states of destruction of the sample according to the expert assessment are selected and given:

- (a) The specimen is defect-free at the time of commencement of the central compression test;
- b) a sample in the initial stage of the destruction mechanism: 1, 2 - chipping of small areas of the surface of the concrete sample due to the rupture of concrete in the transverse direction; 3 - the appearance of microscopic and visible cracks of separation, directed in parallel or with a slight inclination to the direction of action of the compressive forces;
- c) a sample at the stage of a progressive mechanism of destruction: 4 - chipping of large areas of the surface of the concrete sample due to the rupture of concrete in the transverse direction;
- d) a sample in the further stage of progression of the destruction mechanism: 5, 6 - growing, opening and connecting cracks;
- e) the sample in the state preceding the complete destruction and maximum opening of cracks: 7 - new emerging visible cracks; 8, 9 – progressive cracks; 9 – crack with maximum opening;
- (e) A sample after destruction.

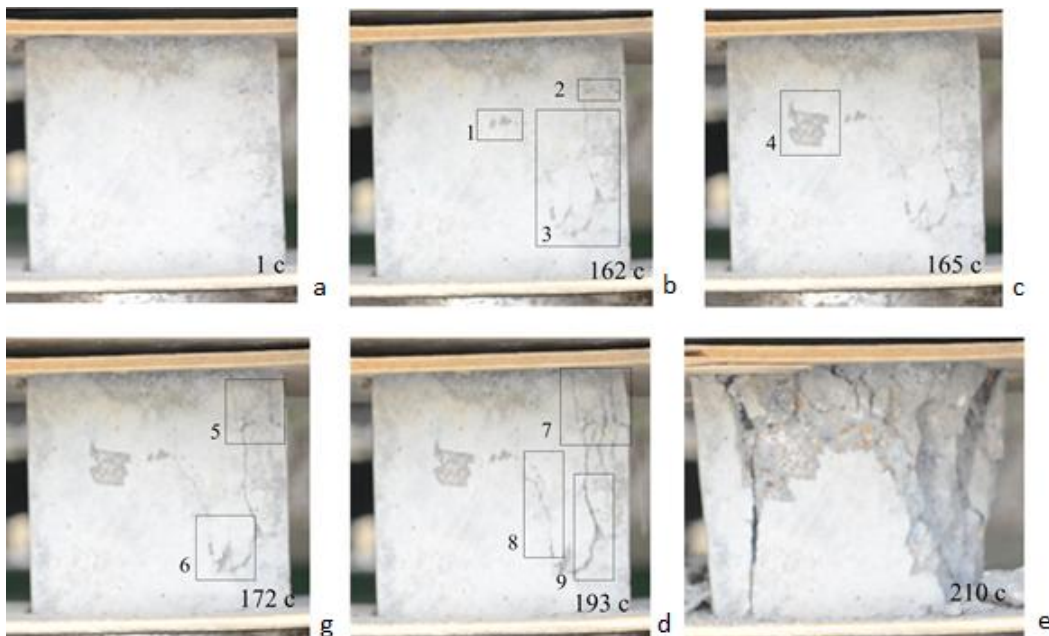


Figure 4. Fragments of the video stream with key fracture transitions

Multiple cracks in the sample on the right side are prerequisites for destruction. However, before destruction, there is a noticeable redistribution of stresses in the sample, resulting in the appearance of a crack on the left side of the sample.

The study of the video stream made it possible to identify new knowledge on the features of the destruction of the sample:

- the process of destruction of samples in time is not linear and has an avalanche-like character in the 15 percent time interval of the full test;
- the centers of the beginning of destruction on the surface of the sample are located randomly, but subsequently have a directional development along the loading force; there is a significant color difference between the original surface of the sample and fragments of destruction;
- the maximum width of the crack opening is acquired at a time corresponding to the "explosive" destruction of the samples and under organoleptic control can not be directly measured.

Threshold image processing algorithms allow you to determine the boundaries of the sample and cracking even at low contrast of the frames of the video stream, as well as to compare real-world images with post-

processed frames. Figure 5 shows examples of matching video stream frames with low contrast and threshold frame processing results.



Figure 5. Fragment of the video stream when studying the shape of the samples

The authors of the study conducted a series of computational experiments to test the operation of algorithms for selecting significant elements of destruction on images during threshold filtering and allocating boundaries according to Kenny's algorithm. Figure 6 shows one of the examples of images in the comparative analysis and determination of the adequacy of these algorithms.

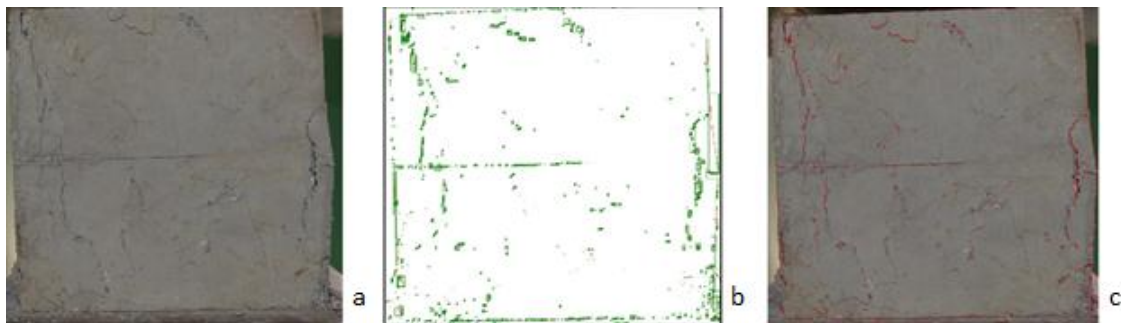


Figure 6. Examples of images in comparative analysis: a – the original frame of the image; b – digital footprint after image processing; in – the result of the comparison of the original frame and the digital footprint

Comparative analysis of the original images and its digital footprint in a visual way did not reveal artifacts that violate the overall picture of the destruction.

4. Conclusions

- a) Analysis of theoretical and practical developments in the field of destructive tests of concrete samples, characterizing their quality, showed a high degree of study from the point of view of calculating the stress-strain state of samples, predicting the service life of reinforced concrete structures operated in climatic conditions and aggressive environments; developing methods and devices for laboratory tests in studying the properties of concrete images in; selection of additives in the composition of concrete to change its structure and strength properties; development of methods of destructive and non-destructive testing in the study of samples. All the works under consideration do not use the capabilities of new information technologies for the systematic extraction of new knowledge about the process of appearance and development of defects in the form of continuity violations on the surface of samples.
- b) Tests of concrete samples of two types (cube and prism) were carried out according to the traditional method to identify strength characteristics characterizing their quality, in conditions of continuous monitoring for their destruction based on the formation of a video stream.
- c) The presence of a video stream based on the results of the experimental study made it possible to form the structure of a new information field, including traditional blocks of information on the quality characteristics of concrete samples and characterized by the presence of an information block with the

results of continuous monitoring of the experiment, which allows generating new knowledge about the dynamics of the formation and development of defects in the form of continuity violations on the surface of the samples.

d) Consolidation of traditional technologies of testing concrete samples and the formation of a new information field is an experimental basis for the synthesis of predicative analytics systems in the creation and analysis of the strength properties of new materials, as well as changes in the regulatory framework for assessing their quality.

e) Promising areas of development of work is the use of the obtained information field for the synthesis of an automated system that allows analyzing consolidated information and forecasting quality indicators of finished products: materials of products and structures.

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