Method of estimating the stress-strain state of reinforced concrete structures

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November 21, 2018

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Abstract. The article analyses the modern methods of estimation of stress-strain state of reinforced concrete structures. The result The analysis is a new method for estimating the stress-strain state of reinforced concrete structures. The method is based on extracting a small sample of concrete from the array. The article describes the method of execution of works, the method of calculating the stresses. Previously the method was investigated under laboratory conditions. The results are presented in graphs and tables. Conducted research on assess the stress state on existing concrete structures. As the objects of research is was taken two industrial buildings 1933 and 1941 construction year. Was held assessed stress state for a panel residential building. The measurement results were analyzed. The method recommended for determining the stresses in reinforced concrete buildings and structures.

1 Introduction

At all stages of design, construction and operation must be correct assessment of technical condition of building structures. This allows increasing the reliability and durability of design. During the examination of buildings and structures is often necessary to assess the Stress-Strain State (SSS) of the structure. In this case, it is possible to compare the characteristics of the material with the actual stress. Currently, the actual stresses in the structures, in most cases, be determined analytically. Experimental determination of the SSS of full-scale structures, due to the great complexity and cost, is used in very important cases. Therefore, the development of effective experimental method of assessing SSS is an urgent task

2 Review of methods of measurement of stresses in concrete

Experimental methods for measuring stress and strain can be divided into the following:

a) calculating the stresses from the measured deformations [1,2, 3, 4];

b) associated with changes in the physical properties of materials under the action of mechanical stresses;

c) compensation.

Measurement of deformations is carried out on the surface and inside the material design.

The essence of the method lies in the fact that after removing the initial deformations, the design is partially unloaded, and then take the second readings on the instruments. By difference of readings calculate the difference of the deformations and corresponding stresses that acted at the site of the structure before the removal of the load.

So in the works of Pavlov P. A. [5], Yakubovskiy B.V., Ermolaev N. N., Acridine D. V. [2] the discharge produced by cutting out around the rosette strain gauges annular grooves with a depth of ¾ of the diameter of the circle. The same method used for the evaluation of stresses in massive rocks [6]. Essentially mechanical method in the form of way of the annular recess is found only with one limitation – safety device notches for strength of structures, which in most cases can not serve as an obstacle for measurements in stone and concrete structures. The transition from deformation to stress the most is just the presence of the linear law of discharge. But voltage can be calculated and the deviation from the linear law, if the curves of deformation of a material sufficiently studied. A similar method (Korshunov D. A., Sidorenko M. V., Yalov [7])was used while partial unloading of material by performing one of the slots next to the sensor deformation.

Method of the hole is based on the calculation of stresses in correspondence local deformations caused by drilling holes. Strain gauges are installed before drilling the holes and are usually located relative to the latter radially. The desired voltages are searched according to the measurements of deformations in three directions [8, 9, 10, 11]. The method is designed for plates, but can be used at the surface of the array with sufficient depth of the hole (about 1.5 diameter holes). The method involves the absence of local damage around openings and availability of the elastic properties of the material, for stone and concrete occurs only at low loading. The drawback of this method is that for determining stresses by the measured strains it is necessary to know the deformation modulus of concrete and Poisson's ratio, which in turn depends on the magnitude of the stresses. Therefore, in practice, it is necessary to set the modulus of elasticity according to the known dependency of the strength of the concrete or directly in the design of the test specimens of the same concrete or concrete extracted from the structure.

Offers a number of physical methods for direct measurement of voltages. In this case, be absent the need for determining the modulus of deformation, it simplify the calculations. However, these methods have shown shortcomings. The scope of application of the optical method [3] is limited to the study of models. X-ray method [12, 13, 14] is complicated and dangerous and yet has a low accuracy. The magneto elastic the method of for concrete can enjoy only indirectly. [15, 16, 17]. Method of nuclear magnetic resonance, and also energy measurement of gamma rays [18] is used for precision physical experiments homogeneous materials. It is known to use acoustic emission method [19, 20] together with the local heating of the surface of the concrete. Method is complicated and not precise enough.

In 1949 proposed a method for direct measurement of stresses in concrete. [21]. The method involves the formation of hollow in the concrete, with subsequent placement in a cavity of the Jack and recovery of the deformation. However, the accuracy of the measurement of stresses in concrete this method is not high. The method to was used in the measurement of stresses of the masonry of the piers of St. Isaac's Cathedral in Leningrad (1963). The method allows to determine only compressive stresses only in one direction. When sensor inside the material , there is the question of the relationship between the stiffness of the sensor and material. The above-described methods of testing structures of operated buildings and structures do not allow to identify the actual safety margins of constructions. To improve the reliability assessment of the bearing capacity of the test structures when exposed to loads higher than the exploitational, it is recommended to re-determine the stresses.

Analysis of the known methods showed that with a slight modification of the method of local removal of the load can get rid of many of the shortcomings of this method and to expand the scope of its application. To do this, on the surface of the concrete structure necessary to put strain gauges. Around each sensor perform cuts with the formation of the prismatic sample for extract the sample with glued on he sensor. From the results of conducted tests it was obtained that, even slit be if a deep enough remains the impact of the array on the sample. And only a complete extraction of the sample with the sensor gives a guarantee on the withdrawal of the influence of array structure on deformation of the specimen. Extraction of the sample from the array allows to obtain other advantages. To sample not only do we get direct the magnitudes the stresses in the fiber, but also a complete diagram of the behavior of the extracted fiber. Unable to results of direct measurements of corrosion, material density, etc. Can appreciate the history of working fiber (using a memory effect) in the studied point and to predict its future behavior.

Currently, the cutting of the samples is performed to determine the strength of concrete [22]. Therefore, it was proposed to develop a method of determining the stresses in concrete reinforced concrete structures using the method of extraction of sample from the array.

3 The methodology of the tests

It was found that the best way of getting information about status of material design is a method of extracting a sample from the operated constructs, and then testing the extracted sample. It is connected with the fact that modern theories of strength are based on tests of standard samples of the material. The information obtained in the test sample, allows to construct a diagram of the concrete in the period under study. The diagram is integrally detects all design changes that have occurred in the material during its operation. Using models of theory of degradation [23] it is possible to assess the overall picture of the changes in concrete and to predict its behavior. The initial diagram of the behavior of concrete can be obtained and the results of tests of concrete in the project age or along the diagram available in standards.

We recommend the following sequence of actions

1. In the studied point in the design is marked with rectangular rosette Strain gauges on which the strain gauges are glued

2. In accordance with Rosette Strain to make cuts to the depth of two diameters of the filler.

3. The educated prismatic elements retrieved from array along

The difference between the deformations of the prismatic specimens define the elastic (ε_{el}) fiber strain of the concrete [6]. From the measured linear elastic deformations of the strain gauges calculate the main strain $\varepsilon_{1,2}$ and their direction according to the formulas for rectangular rosette:

$$\varepsilon_{1,2} = \frac{\varepsilon_0+\varepsilon_{90}}{2} \mp \frac{\sqrt{2}}{2} \cdot \sqrt{(\varepsilon_0 - \varepsilon_{45})^2 + (\varepsilon_{45} - \varepsilon_{90})^2}, \tag{1}$$

where $\varepsilon_{1,2}$ - strains along the main axes, ε_0 ,ε_{45} ,ε_{90} - the readings of strain gauges located at angles of 0,45 ,90 degree.

Educated prismatic elements scroll saw for the formation of prisms with a size of, for example, 25x25x100 mm. At the lateral saw cuts for each prism define the structure of the concrete and the volumetric content of filler φ. Conduct a testing of the prism taking into account [24]. For testing prisms it is proposed to use a special installation piston which makes possible to test samples small dimensions. The resulting voltage in the point test receives on the basis tests of small prisms and from the difference of deformations of the prismatic specimens before and after retrieved from array. The modulus of elasticity of the concrete is leveled on the basis of volumetric two-component model [Казань]:

$$\frac{E_F}{E_M} = 1 + \frac{V_F}{V_F}\left(\frac{E_F}{E_M} - 1\right), \tag{2}$$

where E_M -the elastic modulus of the matrix, V_F and E_F - volume and elastic modulus of aggregate, V_P and E_P - volume and elastic modulus of the prism.

The results of the tests of small prisms showed that their strength does not exceed the strength of the prisms of standard dimensions. Diagrams the small prisms are processed according to the theory of degradation [23] with identification of the highest level of stress reached in the considered point. Then we find the expected value of concrete creep, modulus of elasticity of the original and old of concrete [24].

3.1 Testing methods

Validation of the method was carried out on concrete prisms of size 150x150x600 mm, and blocks 600x600x600 mm. The Samples were made of concrete classes B7.5; B15; B20; B30 (tab. 1,2). Prism strength of concrete samples was in the range of 12 to 42 MPa. For the manufacture of concrete be used: slag-cement Magnitogorsk cement plant M300 and M400, river sand 0-5 (MK=2.9) from Agapovskiy career of JSC "Magnitostroy", gravel 10-20 career of JSC "Magnitostroy".

Table 1. Characteristics of the concrete mix

Composition	Class concrete	Volumetric weight of the mixture kg/m3	Mobility of the mixture, cm
1	B7.5	2410	6.0
2	B15	2410	5.0
3	B20	2358	5.0
4	B30	2440	6.0

The samples were tested under four loading methods (Fig.1). In table 2 it is shown the number of samples for each test.

Table 2. The number of samples tested

<table>
<tr><td rowspan="2">Name</td><td colspan="6">Number of samples on the diagrams Fig.1.5</td></tr>
<tr><td colspan="3">I</td><td>II</td><td>III</td><td>IV</td></tr>
<tr><td>The number of prisms without cutting out</td><td colspan="3">8</td><td>8</td><td>8</td><td>8</td></tr>
<tr><td>The number of prisms by sawing</td><td>8</td><td>8</td><td>8</td><td>4</td><td>4</td><td>4</td></tr>
<tr><td>At levels of load</td><td>0.5</td><td>0.6</td><td>0.8</td><td>0.6</td><td>0.6</td><td>0.6</td></tr>
<tr><td>The number of cubes</td><td colspan="3">12</td><td colspan="2">12</td><td>12</td></tr>
<tr><td>The samples age, days</td><td colspan="3">90</td><td colspan="2">90</td><td>365</td></tr>
</table>

*At the age of 28 days. was tested 12 cubes and three cubes after long-term tests.

**Four prisms to be used to estimate shrinkage during all tests.

3.2 The methodology of the tests

Each mode was tested three prisms of each composition. The expected failure load was determined by the results of the test cubes.

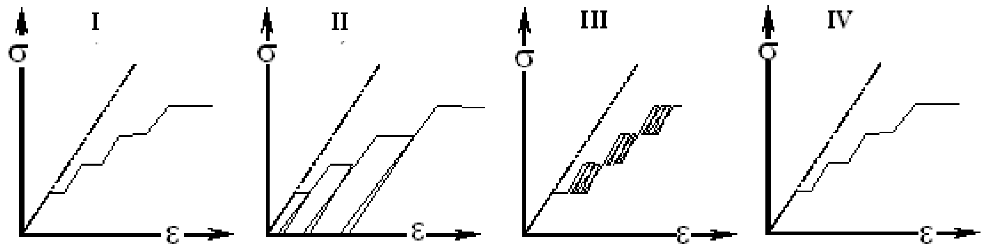

Fig. 1. Scheme of loading of the prisms

Samples of schemes I, II (Fig.1.) was tested according to [25] at the age of 90 days. The timing was determined by the necessity of removing the main part of shrinkage deformations. Scheme III used in step-cyclic loading. At long load case used the scheme IV Fig. 1. The alignment of the samples was carried out according to geometric and then the physical axis at the level of loading of 0.3 the expected failure load. The duration of action of the load at each stage was 10 minutes. After the relative load 0.7 of Deplete duration of exposure was 20 minutes. The step size of load cases was 0.1 of the expected failure load. At every step the burden grew with a speed of 0.6 MPa/s. As a conventional zero is adopted load 2% of the estimated failure loads. Under cyclic loading as the criterion stopping to be accepted the complete cessation of inelastic deformations on stage for 60 minutes or after triple loading. Samples test according to schemes II, III and IV was carried out out on a hydraulic stand with using a flat steel hydraulic jacks. The stand allowed you to simultaneously load from one to six samples load up to 2000 kN. The force on the sample was controlled using the exemplary pressure gauge and dynamometer 5000 kN.

The criterion for termination of exposure on the steps of scheme IV Fig.1 served as the stabilization of the deformations after a fifteen-day exposure of the sample under load. The samples were tested in a climatic chamber. Automatically regulated temperature in the range of 20 ± 2 0C and the relative humidity in the range of – 55 ± 4%. Measurement of deformations was performed with dial indicators, strain gauges Aistova with a scale division of 0.001 mm and load cells on the base of 50 mm

3.3 Techniques for cutting out test samples

In places the stickers of sensors the surface is thoroughly primed and dried. Sensors were mounted on a template, and aligned on the risks. Sockets with sensors at an angle of 45^0. Prior to measurements, the sensors were dried for three days, then was heated with a dryer for 20-30 minutes at t =40 - 500C. First measurements were performed in a day.

For the estimation of SSS used two methods:

- gluing of the sensor, loading samples , cutting the prism with the sensor under load;
- loading the sample, the gluing of the sensor, cutting the prism with the sensor under load.

On a concrete sample under load pasted the vertical Strain gauge which after drying was sawed and removed from the array. Simultaneously sawed and removed adjacent strain gauges which was pasted before loading of the sample.

The cuts performed in separate steps. At each steps, carried out measurements of deformations. Produced two longitudinal cutting depth of 3 mm; the transverse cutting depths of 3 mm; the slits bring to 5 mm. Then in steps of 5 mm cuts were deepened to 30 mm and the sample break out from the array. After each step was made break 15 to 20 minutes. The temperature of the concrete was controlled with a thermocouple. Heating of the strain gages in the filing did not exceed 400C.

On the laboratory samples 300x100x100 mm was studied the influence on the readings of the strain gages: distance cut slits from the sensor, depth of cut, the time of cutting and restoring deformation, the heating temperature of the concrete, power and speed of rotation of the disk cutting, thickness of the disk. Longitudinal the cut performed at 100 mm from the load cell. Then closer in increments of 10 mm (Fig.2). All was done 36 samples (24 of concrete of known composition, six from the solution 1:3 and six 1:1).

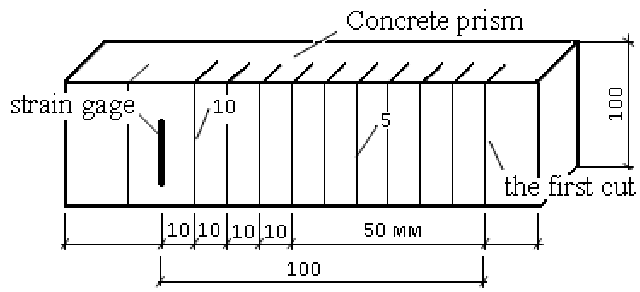

Fig. 2. Methods run for longitudinal cuts

On the basis of the conducted experiments suggested the following recommendations for extract of strain gauge from the array:

1. The distance from the axis of the load cell prior to cutting has to be at least 10 mm in each direction due to the destruction of the superficial zone around the disk at the initial moment of cutting;

2. The cut deeper than 10 mm should be done in a few stages (no more than 5 mm for each propyl) to prevent excessive heating of the cut down sample. The time interval between the sawing must ensure the cooling of the sample to the temperature differ no more than +10 from initial;

3. For accounting for changes in the ambient temperature in the process of cutting out mandatory sticker of a compensation sensor for this design outside of the zone of cutting; recommended to sticker the sensor compensation on the plot previously cropped on all sides;

4. The recovery of deformation after cutting to a depth of 5 mm is 20 - 25 minutes, more deep to a few hours. So after cutting out the sensor on all sides to a depth of 45 mm his to extract it is recommended not earlier than in a day; size of the sample for cutting is not less than 25x25x30 for aggregate size of 20 mm and 40x40x160 mm for aggregate size of 40 mm;

5. For isolation of sensors on the surface of building structures were selected paraffin-Vaseline mixture, made from petroleum jelly and paraffin oil by mixing in a heated state (+70...80^0 C). Waterproofing composition protects the strain gauges and connecting wires into sections 10-15 mm;

6. The most expedient way to evaluate the impact of temperature - install temperature sensors on the surface of the structure.

Processing of the results of the experiments showed that the accuracy of voltages measurement was 6±1.2%.

3.4 Methods of test for full-scale structures

On operated building we marked out a rectangular rosette. On the surface, in accordance with the layout, attach sensors base 50 mm. For labels of strain gages used glue BF-2 with subsequent waterproofing. The process of gluing the strain gages was the same as in the laboratory. Compensation sensor located on the plot previously cropped on all sides; Drying was carried out according to the method described above. Observation of stability was carried out for one week. Then removed samples 25x25x100 mm and 160x40x40 mm with sensors by the above procedure and their subsequent breaking.

Samples were taken of reinforced concrete columns of solid section of industrial plants, and load-bearing vertical panels at the nine-story building at a height of 1.5 m from the floor level (Fig.3). Columns were chosen in the axes where there is the most intense mode of operation of the bridge crane.

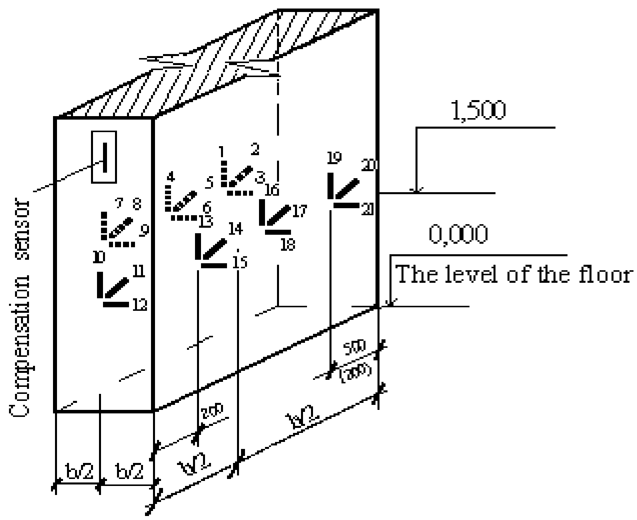

Fig. 3. Diagram labels of strain gages on columns

After cutting out the rosette strain gage, formed recesses plastered high-strength rapid-hardening compositions. Subsequent the rosette strain gage were cut with exposure in one day. Trials of small prisms was carried out with help of piston installation (Fig. 4)
The modulus of elasticity was determined by testing specimens 25x25x25 and 160x40x40 mm in a specially made piston setup on a scale of 100 kN on the hydraulic press. Longitudinal strain measurements were made with dial indicators with a scale division of 0.001 mm and the strain gages. The design of the installation due to its rigidity and manufacturing precision has provided central load case samples. The prism is mounted on gypsum from high precision and pressed the piston. Tests were carried out one day after installation.

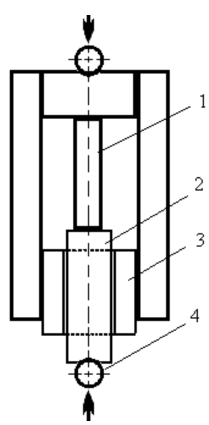

Fig. 4. Setup piston
1 – tested sample; 2 – piston; 3 – frame installation; 4 – hinge

On sawn samples set the volume of coarse aggregate and mortar part from the ratio of the squares aggregate and mortar on the sides. A comparison of this method with the known actual composition of the experimental prisms showed that measurement accuracy was 11 % when the reliability level 0.95.

3.5 The results of the determination of the stresses in full-scale structures

Practical test of a method happened in shaped-foundry of ZAO "Mehanoremontny complex", JSC "Magnitogorsk metallurgical combines" (department of casting of steel and department of cast iron casting), as well as in residential nine-story panel houses a series of 121 city of Magnitogorsk.

The department of casting of steel - building rectangular in plan with dimensions 85,64×299 m consists of four spans in one direction. Commissioned in 1941, the frame of the building is made mainly in the form of monolithic reinforced concrete frames with a pitch of 6.5 m (within the melting Department). All the spans are equipped with bridge cranes.

The building department of cast iron casting is a complex shape in plan with overall dimensions of 162.5×91,08 m and consists of five longitudinal and two transverse bays. Commissioned in 1933. The building Frame is made mostly in the form of monolithic reinforced concrete frames with a pitch of 6.5 m; All spans, except for D-E, equipped with bridge cranes with capacity from 50 up to 400 kN.

Operating voltage was determined under constant load (cranes were deleted). Determined the proportion of added stress when hitting the overhead cranes in the column: this deviation of the readings of the load cells during operation a crane in spans with different loads and modes of operation during a work shift

The extracted samples from structures smaller than the standard. So we compared the test of the extracted samples and standards. When sawing of standard samples under laboratory conditions, the variation of strength and deformation characteristics of small samples and standard wedges did not exceed 14%. In panel homes were selected prisms 120x120x480 mm at the future site of the aperture and made his test in the laboratory. The strength of the prisms was less than the average strength obtained from testing specimens 40x40x160 mm 8%. Little difference in the results of tests of standard prisms and samples of small size can be attributed to weakening of concrete prisms that appear when sawing and breaking, and the eccentricities, which arise when testing small samples.

The test results of samples selected from the reinforced concrete columns and panel nine-floor houses shown in the figures 5-6 , where the following abbreviations are used:

DCS-K21-A-1 – department of casting of steel, column №21 on axis "A", sensor №1;

DCIC-K23-A-3 – department of cast iron casting, column №23 on axis "A", sensor № 3.

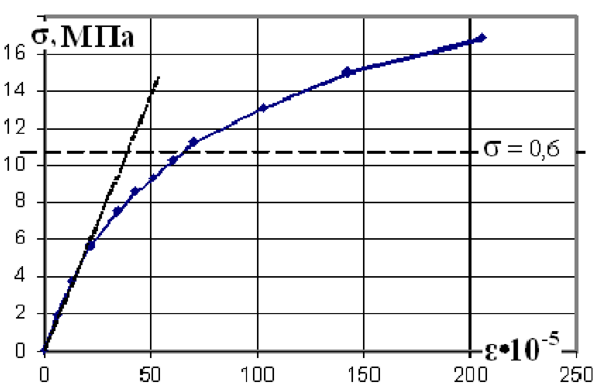

Fig. 5. The dependence of relative deformations from stress sensors 1 and 3, a nine-floor house

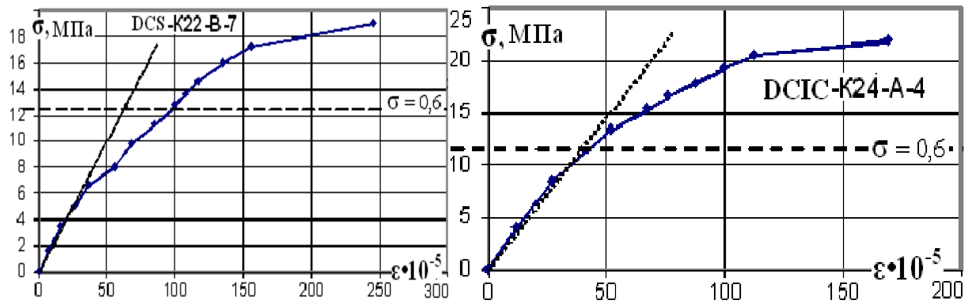

Fig.6. The dependence of the relative deformation from stress

On The results of the tests of the samples and available data, obtained in the process of cutting, were identified stress in the designs. The main results of determination of stresses in the designs are summarized in table.3…11.

Table .3. Working table Cutting slits DCS-K23

Note	1 Sensor Vertic.	2 Sensor Vertic.	3 Sensor Vertic.	4 Sensor Vertic.	5 Sensor Vertic.	6 Sensor Horiz.	7 Sensor Under 45^0	Date	T, ^{0}C
23.08. Sticker sensors	1080	- -	1000	960	1040	1010	990	28.08	15
24.08. waterproofing	1060	-	850	880	945	1170	930	29.08	17
28.08. Sticker sensors	1050	970	840	920	1010	1010	940	30.08	19.8
29.08 waterproofing	1090	1000	950	940	1010	990	970	31.08	17
Before performing the cuts	1180	1100	920	1040	1110	1110	1060	3.09	15
Through one day	1410	1010	890	905	1055	1030	1000	4.09	18
Befor to extract	1510	1050	910	950	1100	1040	1010	5.09	18
After extraction	1550	1270	1010	1260	1600	-	1035	5.09	18
After one hour	1510	1230	900	920	1410	-	1130	10.09	20

Note: the second sensor is pasted in advance on the sawn surface

Table 4. The nine-floor house series 121

№ sensor	Module E, MPa	ε_{el}, 10^{-5}	$\sigma_{exp.}$, MPa	R_b, MPa	Theoretical voltage from full load, $\sigma_{th.}$, MPa	σ^{max}_{exp}, MPa
1	29800	4	1.19	18.7	1.32	6
2	32100	5	1.61	18.2	1.32	-
3	31000	-	-	18.4	-	5.7
4	29500	1	0.29	21.7	-	5
5	30100	4.5	1.35	18.2	1.32	4
7	27500	-	-	19.2	1.32	5

Table 5. Samples DCS-K22-B

№ sensor	Module E, MPa	ε_{el}, 10^{-5}	$\sigma_{exp.}$, MPa	R_b, MPa	σ_{th} constant load, MPa	σ_{th} full load, MPa	σ^{max}_{exp}, MPa
1	25600	18.0	4.6	35.3	3.07	11.43	5.0
4	25100	6.5	1.6	-	2.53	9.58	-
7	22000	3.4	0.7	21.9	1.56	6.27	7.5
13	23000	3.4	0.8	-	1.59	6.40	-
16	24700	6.8	1.7	20.6	2.58	9.78	10.5
17	24000	0.3	0.1	-	-	-	-

Table 6. Samples DCS-K23-A

№ sensor	Module E, MPa	ε_{el}, 10^{-5}	$\sigma_{exp.}$, MPa	R_b, MPa	σ_{th} constant load, MPa	σ_{th} full load, MPa	σ_{exp}^{max},MPa
1	29700	2.3	0.7	11.5	0.94	3.08	-
4	34300	12.4	4.3	10.1	1.12	3.92	4.0
7	25700	15.0	3.9	13.9	1.32	4.82	5.8
10	29000	3.4	1.0	12.5	1.43	5.30	-
16	28400	9.0	2.6	9.8	1.08	3.74	4.0
18	29100	0.3	0.1	11.0	-	-	-

Table 7. Samples DCS-K20-A

№ sensor	Module E, MPa	ε_{el}, 10^{-5}	$\sigma_{exp.}$, MPa	R_b, MPa	σ_{th} constant load, MPa	σ_{th} full load, MPa	σ_{exp}^{max},MPa
1	23700	18.0	1,63	21.2	0.92	2.99	5.0
7	26800	10.5	2,8	18.4	1.33	4.88	10.0
10	25000	6.5	4,19	19.2	1.43	5.30	-
16	33200	10.1	3,3	17.3	1.01	3.38	-
17	28900	-	-	18.1	-	-	-

Table 8. Samples DCS-K22-A

№ sensor	Module E, MPa	ε_{el}, 10^{-5}	$\sigma_{exp.}$, MPa	R_b, MPa	σ_{th} constant load, MPa	σ_{th} full load, MPa	σ_{exp}^{max},MPa
4	29300	9.8	1.76	16.6	1.0	3.35	4.6
5	17200	2.0	0.34	21.7	-	-	1.0
10	21900	12.0	2.80	22.3	1.43	5.30	6.2
11	23600	1.4	0.31	31.0	-	-	0.9
16	18700	2.4	0.45	28.2	0.9	2.93	3.3

Table 9. Samples DCS-K21-A

№ sensor	Module E, MPa	ε_{el}, 10^{-5}	$\sigma_{exp.}$, MPa	R_b, MPa	σ_{th} constant load, MPa	σ_{th} full load, MPa	σ_{exp}^{max},MPa
1	24100	3.5	0.84	22.6	0.88	2.84	5.0
2	22800	1.7	0.38	24.1	-	-	2.2
12	20600	2.8	0.57	17.7	-	-	4.0
10	25600	3.9	0.99	19.6	1.43	5.30	5.9

Table 10. Samples DCIC -K23-A

№ sensor	Module E, MPa	ε_{el}, 10^{-5}	$\sigma_{exp.}$, MPa	R_b, MPa	σ_{th} constant load,MPa	σ_{exp}^{max},MPa
10	30000	4.8	1.44	18.5	-	4.5
19	35800	2.5	0.89	20.0	-	4.0

Table 11. Samples DCIC -K24-A

№ sensor	Module E, MPa	ε_{el}, 10^{-5}	$\sigma_{exp.}$, MPa	R_b, MPa	σ_{th} constant load,MPa	σ_{exp}^{max},MPa
4	33800	6.4	2.2	22.2	-	9.0
7	36200	4.6	1.7	16.0	-	5.5
10	27600	6.1	1.7	19.6	-	6.0

From the analysis of the theoretical and actual diagrams were made the following conclusions:

1. On the experimental charts, you can determine the maximum tension force in the operation (manifestation of memory effect). This point of deflection diagrams from the straight

line characterizing the initial modulus of elasticity of concrete (straight dotted line in the graphs). For example, for the nine-story building deviation from the modulus of elasticity occurred at voltages of 4–6 MPa at working voltages of 1.3 – 1.6 MPa;

For DCS-K22-B of this point is corresponds to 5 to 10.5 MPa; operating voltage from on most downloaded faces from the constant stress of 4.6 MPa, the maximum equivalent stress of 12.8 MPa. From this we can conclude that in General the concrete structures are studied worked in the field of small stresses. Therefore, plastic deformation was not selected, and the experimental chart was well described by the theoretical curves.

2. As can be seen the values of the obtained stresses for nine-floor house different from the theoretical 2 – 20%. Voltage defined in reinforced concrete columns exceeds the theoretical values. The actual eccentricity of load application in the columns more compared with the theoretical one. For example, DCS-K22-B of theoretical value of e/h in the longitudinal direction was 0.06. After sawing the samples, the ratio e/h = 0,128 in the longitudinal direction, but were identified and the presence of eccentricity in the transverse direction and e / b = 0.07. The value of the current eccentricity exceeded the theoretical value two times in a longitudinal direction, and the magnitude of the eccentricity in the transverse direction was equal to the theoretical value in the longitudinal direction. Because of the eccentricities in both directions of the cross section of columns loaded unequally.

3. The variation of strength of samples selected in the nine-floor house s was 13.8%, for workshops 15.9% of the average. A large scatter (up to 36 %) in the columns DCS-K22-A and DCS-K22-B due to significant structural defects in the concrete in sawn samples (pore size of from 1 to 5 mm, the inclusion of the filler section over 30 mm) educated in solid construction. In all the examined elements voltage to the horizontal sensors were tensile 0.1 – 0.3 MPa.

Conclusions

The developed method allowed determining the operating voltage of existing reinforced concrete structures. It was found that the actual magnitude of stresses and eccentricities of load application in the study of structures larger than the theoretical one. The results of the experiments showed that the investigated structures work mainly at the level of voltages not exceeding the value of 0.5 of the prism strength. The obtained model is concrete with enough for practical purposes accuracy (discrepancy of the order of 15%) describes the behavior of concrete.

Application of the proposed methodology of constructing a model of concrete and the model itself, together with the developed method of determination of stresses in concrete allows to obtain information about changes during the overtime operation of the deformation and strength characteristics of concrete and more adequately assess the condition of structures in the conduct of examinations and determination of residual resource. The method allows determining the highest level of stresses acting in the structure during its exploitation.

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