Samples of concrete of small sizes

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Abstract. The article analyzes the sizes of concrete samples. We revealed a possibility to reduce sizes of samples. We simultaneously carried out tests of standard and small (25x25x100 mm) concrete samples. Small samples were obtained by cutting standard samples. In the course of study, the density, strength, and deformation of standard and small specimens were measured. The results are presented in tables and graphs. The strength of small samples was lower than the strength of reference samples. We identified loss of strength of the samples when cutting concrete. The average characteristics of deformation of concrete remained. Small samples are recommended for use in assessing the stress-strain state of reinforced concrete structures.

1 Introduction

Current standard methods to determine the basic physicomechanical characteristics of concrete and stone materials are based on testing standard prismatic samples, the minimum size of which is normalized by the size of the filler grain [1-3] (or heterogeneity):

For rocky soil 30 mm with an inhomogeneity coefficient with a minimum sample size of at least 1:10 (3 mm grain) - (for basic measurements with a minimum size of 15 mm with a grain to base ratio of 1:10 or less). For concrete, the minimum ratio of the maximum aggregate size relative to the smallest prism size (or cylinder diameter) is 1:5; for samples extracted from structures, a 1:2 ratio with a minimum sample size of 44 mm is allowed. The strength of solution is determined on cubes with an edge size of 2 cm (1:4 ratio).

Such ratios are determined from the initial position of a sample homogeneity and the result obtained with this sample. If the ratio of sizes to samples heterogeneity is disturbed, the sampling is heterogeneous and the test results are not accepted.

There are two direct methods for determining the physicomechanical characteristics of concrete: a parallel test method, twin specimen tests (sometimes molds for molding specimens during production, are placed in the product body) and a method for extracting concrete samples from the structure. The first method requires strict adherence to technology, but despite this, there are always differences in scale, features of compaction and hardening of the sample and the main body of concrete. This method is applicable only to a specially developed research methodology (i.e., a project). For a usual research of exploited structures, the second method is practically the only one. However, the extraction

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of reference materials from the structures being used is often not possible due to the size of a sample and due to differences in the characteristics of concrete.

Therefore, if we remove the condition of homogeneity of sampling, we can reduce the size of extracted sample to 2 cm (and less) and greatly facilitate and speed up the testing process. Based on the above, we can conclude that if we can eliminate the heterogeneity of concrete caused by aggregate, we can reduce the sample size. If the maximum size of aggregate in mortar part of concrete is considered to be 5 mm, then the sample size may be 25x25x100 mm.

Earlier, a method was proposed for estimating the stress-strain state of reinforced concrete structures based on the extraction of small-sized samples from the structure [4, 5]. The works are known that justify the use of samples of small size when testing stone materials [6, 7]. But the question of application of small samples of concrete, the dimensions of which differ from the recommended, still remains.

2 The first part of the test

For preparation of concrete mixture the following composition is used: Cement, Sand: Crushed stone = 1:0.7:3:0.46. The size of crushed stone is 10-20 mm. A total of 14 cubes measuring 100 × 100 mm and 12 prisms measuring 100 × 100 × 400 mm were produced. Prisms were divided into series in accordance with the test method. The sample age for testing is 8 months.

The testing procedure involved the use of non-destructive and destructive control methods. For non-destructive method we used ultrasonic materials tester "pulsar". Using the destructive method, specimens were tested at Central compression. To measure the longitudinal deformations, indicators with a scale of 0.001 mm and the device for automatic measurement of deformations AMD-1M together with strain gauges of 50 mm base were used. The lateral deformations were measured with a 20 mm base strain gauge and Huguenberg strain gauges and Aistova systems.

Samples of standard sizes 100x100x400 were tested for central compression using IP-2000 press. For testing small samples we used piston installation. A general view of a piston device for testing small concrete samples is shown in Fig.1. Characteristics of prisms are given in table 1.

Fig. 1. Piston set for testing small samples.

Table 1. Characteristics of standard prisms.

№ sample	ρ, kg/m^3	$E_{b,dyn}$, MPa·10^{-3}		ρ, kg/m^3	$E_{b,dyn}$, MPa	R_b, MPa	$E_{b,n}$, MPa·10^{-3}
	2 months			6 months			
1/1	2.44	48.6		2.41	46.8	30.9	28.8
1/2	-	-		2.41	46.1	33.6	29.2
1/3	-	-		2.39	50.5	35.1	31.2
2/1	2,47	51.0		2.43	48.6	34.6	27.1
2/2	2.44	47.0		2.41	47.6	34.0	29.9
2/3	-	-		2.40	48.0	32.2	26.6
3/1	2.45	49.1		2.41	45.0	32.0	29.6
3/2	2.49	50.2		2.40	47.1	36.3	28.6
3/3	-	-		2.38	43.9	31.7	27.3
4/1	2.47	49.2		2.41	47.2	-	-
4/2	-	-		2.40	46.1	-	-
4/3	-	-		2.39	49.7	-	-
Average	2.46	492		2.40	47.2	33.4	28.7
Variation		2.6%					

The test results for cubes are presented in Table 2. The results of compression tests for cubes at a fixed deformation rate are shown in Fig. 2. For comparison, this figure shows the measurement of the ultrasound velocity when testing concrete prisms.

Table 2. Characteristics of cubes.

№	ρ, kg/m^3	R, MPa		№	ρ, kg/m^3	R, MPa	E_b, MPa·10^{-3}
1	2.44	48.5		5	2.31	43.4	53.9
2	2.45	50.1		7	2.32	46.5	55.2
3	2.35	48.7		9	2.35	42.5	51.3
4	2.36	47.1		11	2.33	39.7	49.2
6	2.33	40.0		12	2.33	-	50.1
8	2.44	52.2		14	2.42	46.1	52.0
					2.37	45.9	51.3

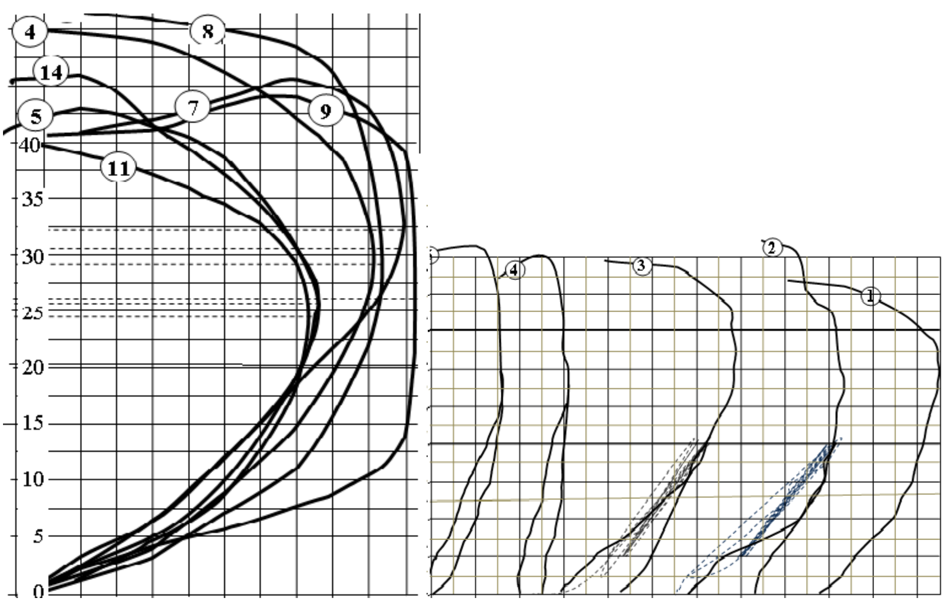

Fig. 2. Test pattern for cubes (left) and ultrasound velocity in concrete prisms, where numbers are sample numbers. The maximum speed is achieved with a load equal to 0.61 (57%, 60%, 69%, 62%, 60%, 56%, 60%) of the breaking load.

On the side surface of cube No. 12, load cells with a base of 20 mm (six pieces) and 50 mm (six pieces) were stuck on three sensors on each side. On this cube, with the help of plaster, other bricks of B25 strength were glued on both sides. The resulting prism was loaded up to 20 MPa, the deformation of prism was measured at step 4, 9, 14, 19 MPa. Centering was performed only according to matchmarks. The measurement results are shown in Fig 3. Later we tried to cut into small prisms cube number 12 with pasted sensors. However, due to the formation of a grid of cracks on the cube, this turned out to be impossible. The formation of a significant number of cracks is associated with the low strength of glued cubes. Then the prisms in accordance with the scheme shown in Fig. 4 were cut from cube No. 13. The cross-sectional dimensions of the cut out small prisms were in the range ... from 23.1 to 23.3 mm, height 100 mm. On the lateral surfaces of the prisms, in the middle, the sensors 50 mm base were glued. Small prisms were tested in a piston system with matchmark centering. The end surfaces of small prisms during installation were covered with gypsum plaster. The prisms were placed in the installation, centered, vertically aligned on a template and pressed by their own weight of the piston together with gypsum. The tests were carried out a day after gypsum setting.

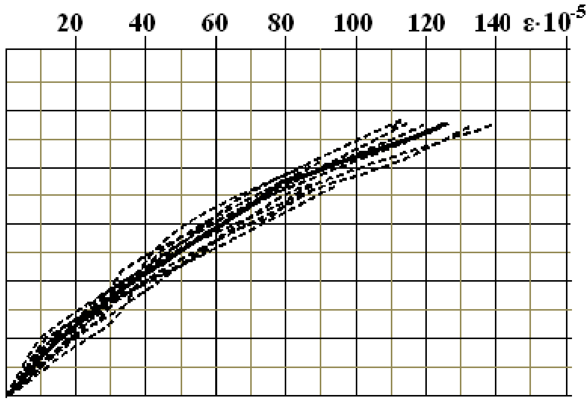

Fig. 3. Graph of strain measurements on the steps 4, 9, 14, 19 MPa.

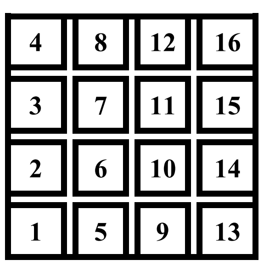

Fig. 4. Cutting the cube into small prisms.

The test results of small prisms are shown in Table 3 and in the diagram in Fig. 5. In Fig. 6 a thick dashed line shows the average graph of the behavior of standard prisms.

According to the test results we obtained data with a large variation in strength. The strength of the cubes varied within 31.7–36.3 MPa (± 13%), for small prisms, the strength was in range of 26.5–37 MPa and the relative variation was 35.5%. On the other hand, the average strength of small prisms and standard prisms differ only by 11%, the mismatch of the elastic modulus is less than 1%.

Table 3. Characteristics of small prisms.

№	Density, kg/m^3	Velocity Ultrasound, m/s	$E_{b,dyn}$, MPa·10^{-3}	$E_{b,n}$, MPa·10^{-3}	R_b, MPa
1	2,37	4608	51,3	41	32,5
2	2,37	4521	49,4	26	27,5
3	2,29	4226	41,7	26	29,5
4	2,35	4492	48,4	38	37,0
5	2,36	4698	53,1	20	27,7
6	2,31	4892	56,4	19	28,6
7	2,43	4525	50,7	30	30.3
8	2,18	4436	43,7	45	28,5
9	2,4	4730	54,7	24	26,5
10	2,39	4699	53,8	22	28,2
11	2,43	4579	51,9	22	27,5
12	2,19	4464	44,5	28	33,0
13	2,45	4730	55,9	17	28,5
14	2,27	4653	50,1	30	29,5
15	2,28	4668	50,64	25	26,8
16	2,20	4105	37,8	44	33,0
Average	2,33	---	**49,6**	**28,8**	**29,6**
Average of standard prisms			47.2	28.7	33.4

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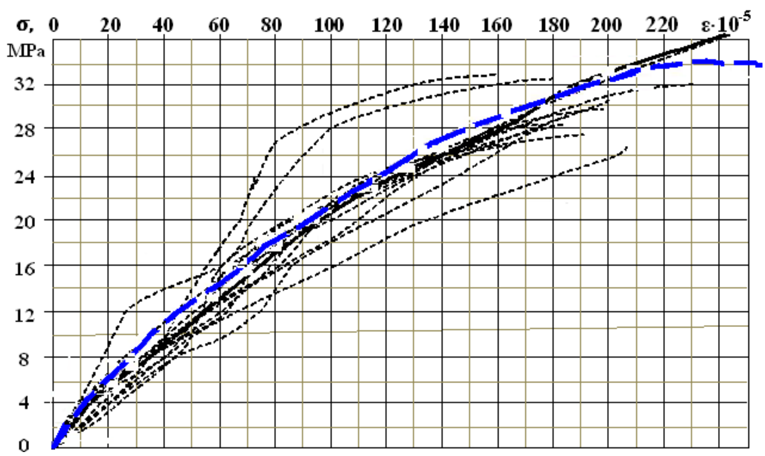

Fig. 5. Test charts of small prisms (dotted line - test chart for standard prisms).

3 The second part of the test

Experiments were performed one year after the first test. For repeated tests, 7 concrete prisms with dimensions of 100x100x400 mm, 12 cubes with a side of 100 mm and 3 cubes with a side of 150 mm were made. For the samples manufacture we used concrete mix in accordance with table 4.

The size of crushed stone is 10-25 mm. The samples hardening took place in normal conditions.

Table 4. Concrete compositions for the second series..

Series	The ratio of series by volume of the mixture			
	Cement	Sand	Crushed stone	Water
1B	1	2	2.1	0.5
2B	1	2	2.1	0.5
S	1	2	–	0.5
C	1	2	2.1	0.5

Tests of samples were carried out similarly as for samples of the first series. On the side of cubes No. 5, No. 8, No. 10, and No. 12 strain gauges with a base of 50 mm were glued on three sides, four pieces on each side. On these cubes, using plaster, other B40 strength cubes were glued on both sides. As a result, the prisms were loaded to 60–62 kN to determine the deformations in the elastic stage. Longitudinal and transverse strains were measured. Centering was carried out according to matchmarks.

Then, Cubes No. 5, No. 8, No. 10, and No. 12, with glued-on strain gauges, were sawn in accordance with the scheme on Fig. 4. Previously, strain gages were covered with a layer of sealant. Sensors on small prisms pasted on all sides. Samples of small prisms were accurately installed in the piston installation. In the upper and lower parts of the prism they were covered with fresh gypsum solution, the excess of which was squeezed out during clamping of the sample between the disks of piston installation. After one day, the piston installation was placed in a hydraulic testing machine. The load on the samples was applied in steps.

The results are presented in Table 5 and 6. On the basis of data obtained by measuring the longitudinal strain of the samples, the "stress – strain" dependences are obtained, which are presented in the graphs of Fig. 6 and 7.

Table 5. The test results of cubes.

№	Series	R	ρ, kg/m^3	$E_{b,dyn}$,MPa $\cdot 10^{-3}$	$E_{b,n}$,MPa	№	Series	R, MPa	ρ, kg/m^3	$E_{b,dyn}$,MPa $\cdot 10^{-3}$	$E_{b,n}$,MPa
1	S	31.567	1788			7	B2	38.248	1970		
2	S	31.547	1768			8	B2	-	2021	5090	18589
3	B1	34.081	2020			9	S	27.16	1788		
4	B1	25.646	2119			10	S	-	1781	4504	12746
5	B1	-	2070	5212	9543	11	C	36.751	2278		
6	B2	34.566	2071			12	C	-	2276	5589	9354

Table 6. The results of testing standard prisms.

№	Series	ρ, kg/m^3	R_b, MPa	$E_{b,n}$, MPa
1	S	1781	29.4	9841
2	S	1781	31.2	16539
3	S	1781	28.5	9959
Average			30.0	12113
4	B2	2020	29.4	16005
5	B2	2020	29.5	10010
6	B2	2020	27.2	13094
Average			28.7	13037
7	B1	2277	22.2	16573

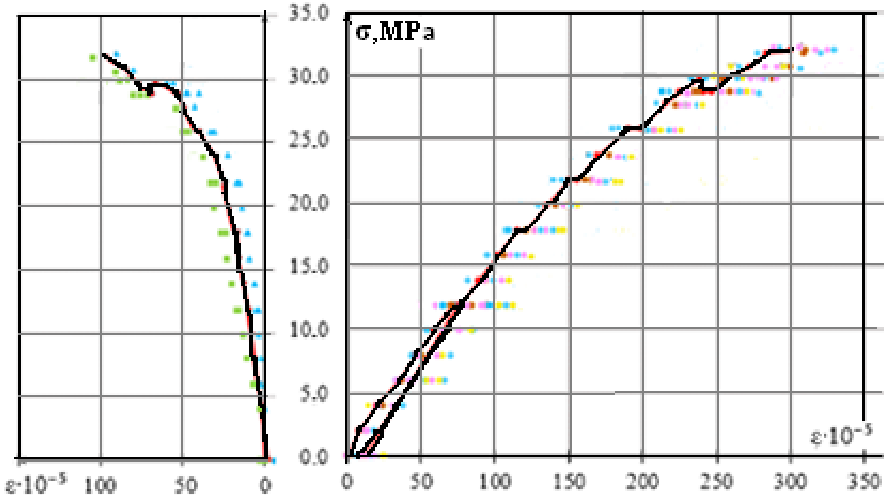

Fig. 6. The diagrams "σ – ε" of the prism 2.

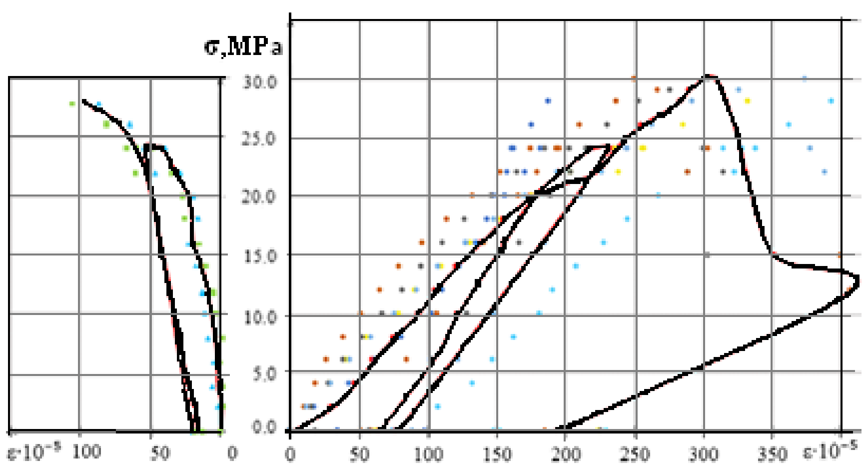

Fig. 7. The diagrams "σ – ε" of the prism 5.

The results of ultrasonic testing of cubes shown in figure 8.

63,1	63,1	63,0	62,9
63,1	62,8	62,9	62,7
63,2	63,1	63,0	62,9
63,0	63,0	63,2	63,0

63,1	63,2	63,2	63,2
63,0	63,0	63,1	62,9
62,9	63,0	62,8	63,1
63,0	63,0	62,9	62,8

62,9	62,8	62,7	62,8
62,8	62,7	62,7	62,6
62,7	62,8	62,7	63,1
63,2	63,3	63,0	62,9

63,7	63,8	63,6	63,6
63,7	63,9	63,7	63,6
63,7	64,0	63,9	63,9
63,8	64,0	63,8	63,9

Fig. 8. The distribution of the propagation time of ultrasound in cubes (left to right) No. 5 (Re = 63,00 μs); No. 8 (Re = 63,01 μs); No. 10(Re = 62,86 μs); No. 12(Re = of 63.79 μs).

The test results of cubes with sensors are summarized in table 7.

Table 7. The results of measuring the deformations of the cubes under load of 6.15 MPa.

Strain gauges \ Cube	№5	№8	№10	№12
1	65	44	51	65
2	59	50	46	63
3	55	58	51	53
4	–	49	44	55
5	–	61	45	60
6	55	47	54	50
7	61	52	47	63
8	76	42	42	48
9	64	56	53	53
10	49	48	46	58
11	59	54	56	42
12	–	56	53	62
Average	60.3	51.4	49.0	56.0
The strain gauge Aistova				
Side 2	65	58	53	53
Side 4	56	49	47	64
Average	60.5	53.5	50.0	58.5

After sawing, each prism was measured. The dimensions of the side section changed from 16.85 mm to 25.55 mm. Unfortunately, not all the prisms were suitable for testing. In series of 16 samples only 9 pieces were suitable. The distribution of the transit time of the ultrasound along the section of the cube is shown in Fig. 9.

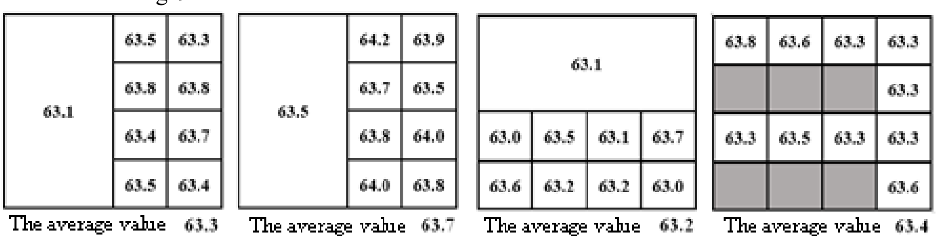

Fig. 9. Distribution of the propagation time of ultrasound for sawn prisms from cubes from left to right №5, 8, 10, 12.

Comparison of the results of ultrasonic sensing of individual prisms, Fig.8 and 9, show that the discrepancy was not more than 1% and was in the field of statistical data variation. It was not possible to identify the features of concrete samples of UT. The test results for small prisms in compression are shown in Fig. 10 - 13.

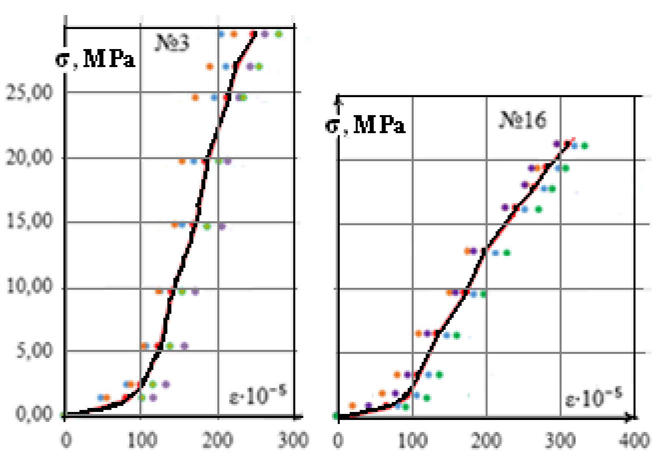

Fig. 10. The diagrams "σ – ε" for small prisms of the series B1 on the testimony of strain gages.

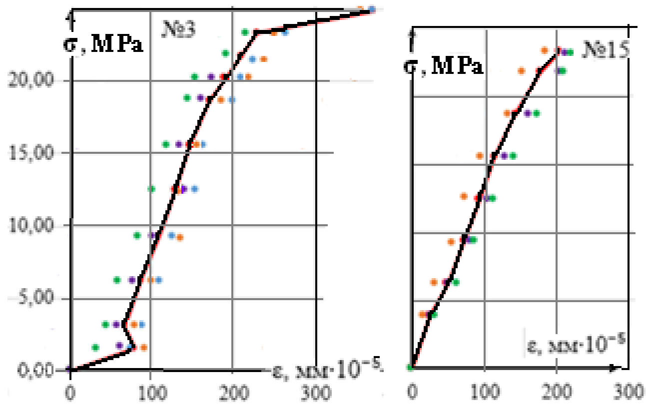

Fig. 11. The diagrams "σ – ε" for small prisms of the series B2 on the testimony of strain gages.

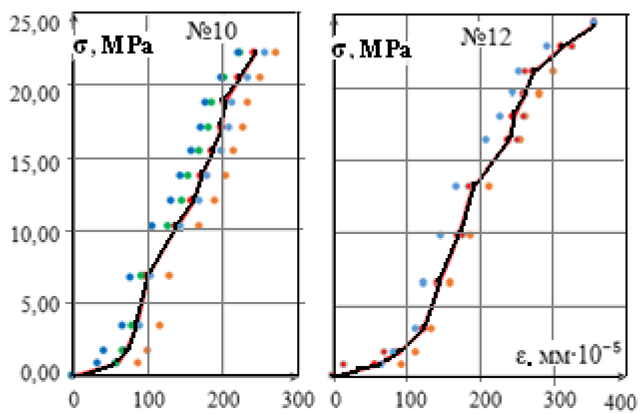

Fig. 12. The diagrams "σ – ε" for small prisms of the series S on the testimony of strain gages.

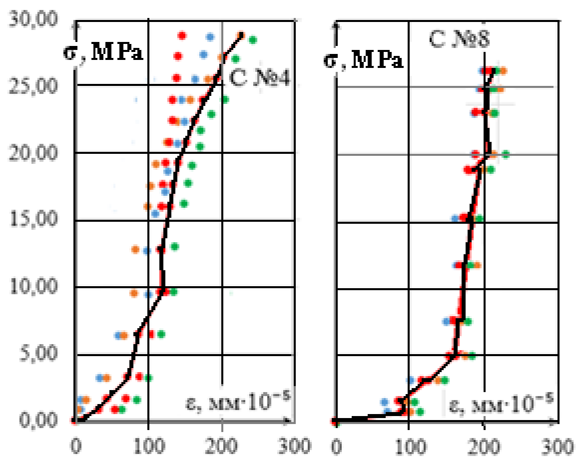

Fig. 13. The diagrams "σ – ε" for small prisms of the series C on the testimony of strain gages.

The difference in strength between standard and small samples calculated from the average values of strength was: series B1 - 22.2 and 22 (+ 1%); series B2 27.2 and 22 (+ 19.1%); in S series is equal to 28.5% and 23.4 (+ 17.8%). The difference in modulus according to the series B1 –16x103 and 15x103 (+ 6%); B2 series - 16x103 and 16.5x103 (-

3%); S series - 12x103 and 12.1x103 (-1%). The difference in limiting deformations for small prisms (266x10-5) and standard ones (300x10-5) was 11.3%.

4 Conclusions

1. Ultrasonic testing did not reveal significant differences in the characteristics, both standard concrete samples and sawed samples.

2. Removing small samples from the concrete body reveals a variation in the characteristics of the concrete in accordance with the structure of concrete.

The use of averaged properties of concrete in assessing its stress state can lead to large errors in the determination of stresses. For each point of study you need to get your own characteristics.

3. The process of cutting and extracting samples from an array affects its strength and deformative characteristics. The strength of all small samples was less than 10% of the strength of standard samples. The deformation characteristics of small samples differed only in the initial stages of loading.

4. The deformation characteristics of small sizes samples, with the exception of initial stage of loading, do not differ from the deformation of standard samples.

5. The use of small samples of concrete when evaluating the stress-strain state of reinforced concrete structures is performed with high accuracy in the range of 0.1 ... 0.8 from the limiting bearing capacity.

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