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DETERMINATION OF CRACK RESISTANCE PARAMETERS OF CONCRETE UNDER STATIC LOADING

Abstract. Building structures made of concrete are widely used in the construction of buildings, structures, transport facilities. Strength is the main characteristic of concrete as a structural material. The article describes in detail the process of manufacturing concrete samples based on various binders. The experimental determination of the cubic strength of concrete and the ultimate strength of concrete during bending is considered. To determine the ultimate strength of concrete during bending, an upgraded laboratory testing facility with a maximum load of up to 10 kN was used. It has been experimentally determined that the samples made from cement of the PC-D20-B brand have a greater value of the compressive strength of concrete after 28 days compared with samples from cement of the PC-D20-B brand + gypsum of the G-5 brand and only gypsum of the G-5 brand. The manufactured samples-beams made of cement of the PC-D20-B brand have a greater value of the tensile strength of concrete during bending over a period of time from 1 day to 28 days compared to samples made of cement of the PC-D20-B brand + gypsum of the G-5 brand and only gypsum of the G-5 brand. Thus, the results of tests of control samples made on the basis of a binder (cement and gypsum) for compression and stretching during bending fully give an idea of the methodology for determining the physical and mechanical characteristics of building materials.

Keywords. Concrete, cemen, gypsum, crack resistance, concrete strength.

Introduction.

Concrete is an artificial stone material obtained as a result of solidification of a concrete mixture consisting of components dosed in a certain ratio: a binder (matrix), small (sand) and large (crushed stone, gravel) aggregates, which can be called reinforcing elements, water and, if necessary, additives.[1]. In the context of concrete, cement stone, individual grains of aggregate, as well as individual micro-volumes of cement stone may differ. The contact zone (layers of cement stone adjacent to the surface of aggregates), as well as the main mass of cement stone, is heterogeneous and contains defects, microcracks and unreacted grains that reduce the uniformity of the material.

Strength is the main characteristic of concrete as a structural material. Compression and bending strength are mainly determined. There are also non-destructive methods for determining the strength characteristics of concrete and reinforced concrete in structures [2]. Various additives and plasticizers are used to improve the physical and mechanical properties of concrete.

Materials and methods.

Tests for axial compression before destruction were carried out to assess the nature of changes in the compressive strength of concrete.

The main indicators of concrete include the following parameters:

R_m - cubic strength of concrete;

R_{eesg} is the bending strength of concrete.

As shown in Figure 1, the main shapes and sizes of the samples must correspond to the specified parameters [3].

a *b*

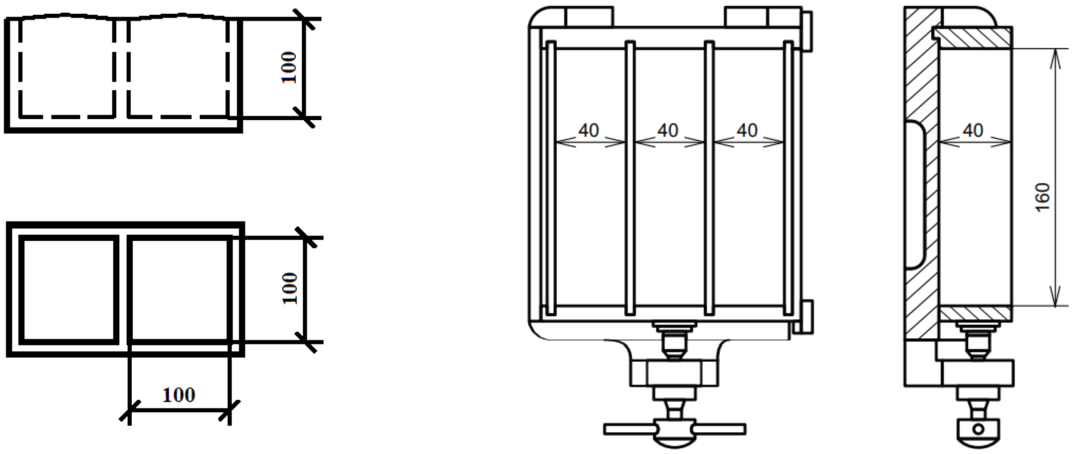

Figure 1 - Schemes of standard forms for the manufacture of samples:
a – cubes; b – beams

The production of samples is carried out in laboratory conditions. To do this, 1 kg of gypsum or cement binder is mixed with inert materials and the amount of water necessary to obtain a normal density, on a laboratory mechanized stirrer or manually [4]. The resulting mixture is immediately transferred after cooking into pre-lightly oiled standard metal molds (Table 1 and Figure 2). All cells of the mold are filled at the same time, and after filling, the surface of the samples is smoothed with a knife moistened with water. After 2 hours from the beginning of the sealing of gypsum, samples in the amount of 3 pcs. are removed from the mold and examined. The faces of the samples should not have deviations from the plane by more than 0.5 mm.

To test the strength of heavy concrete, cube samples with dimensions of 100×100×100 mm are used. On the next day from the beginning of the cement mortar sealing, samples in the amount of 2 pcs. are removed from the mold and examined [5]. The faces of the samples adjacent to the press plates during the test must be parallel and have no deviation from the plane by more than 0.5 mm (Figure 3).

а б

Figure 2 - Molds for the manufacture of concrete samples:
a - cubes 2FK-100; b - beams 3FB-40

Figure 3 - Ready-made samples-cubes and a batch of ready-made samples-beams (28 days)

The procedure for determining the average density of a material by measuring its volume and mass (Figure 4).

$$V = a \cdot b \cdot l = 40 \cdot 40 \cdot 160 = 256 \cdot 10^3\ mm^3.$$

a б

Figure 4 - Determination of the mass of the sample:
a – gypsum sample, b – cement sample

Determination of the cubic strength of concrete.

The stress in the samples during loading should increase continuously at a constant rate of 0.6 ± 0.2 MPa / s until its destruction (Figure 5).

The strength of concrete R_m is calculated from the maximum load on the sample section:

$$R_m = \frac{\alpha F}{A}, \tag{1}$$

where F is the destructive load, Kn; A is the working cross-sectional area of the sample, cm2; a is the scale factor depending on the size of the cube (a = 1.05 at a size of 200 mm; a = 1 at a size of 150 mm; a = 0.95 at a size of 100 mm - for all types of concrete, except cellular).

The destructive force is fixed by the force meter of the technological special hydraulic press with torsion force measurement PT- 1250 with an accuracy equal to the price of dividing the scale [6].

а б

Figure 5 - Testing of concrete samples (cubes) for compressive strength [2]:
a – cube before the test, b – cube after the test

Bending strength of concrete. The tensile strength of concrete during bending is one of the sufficiently sensitive characteristics of the material to assess the destruction of concrete. The ultimate strength of gypsum concrete and cement concrete during bending is determined on samples-beams of standard size 4 × 4 × 16 cm, made of gypsum or cement dough, according to St.S 125-79 Gypsum binders [7].

To determine the tensile strength during bending, we will use an upgraded laboratory testing facility with a maximum load of up to 10 kN, which provides the possibility of applying a load according to a standard scheme with an average load growth rate of 50 ± 10 N / s (Figure 6). The shape, dimensions and relative position of the load element and supports are shown in Figure 7.

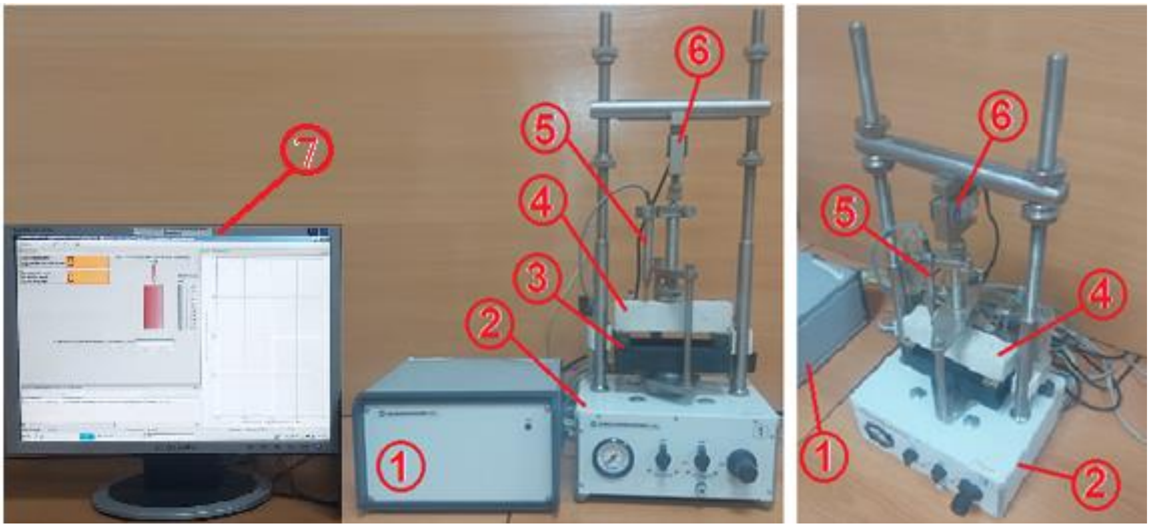

Figure 6 - Installation for bending tests:
1 – automated control unit; 2 – pneumatic load device; 3 – stand with supports; 4 – sample beam; 5 - electronic displacement sensor, 6 – strain gauge, 7 – computer monitor

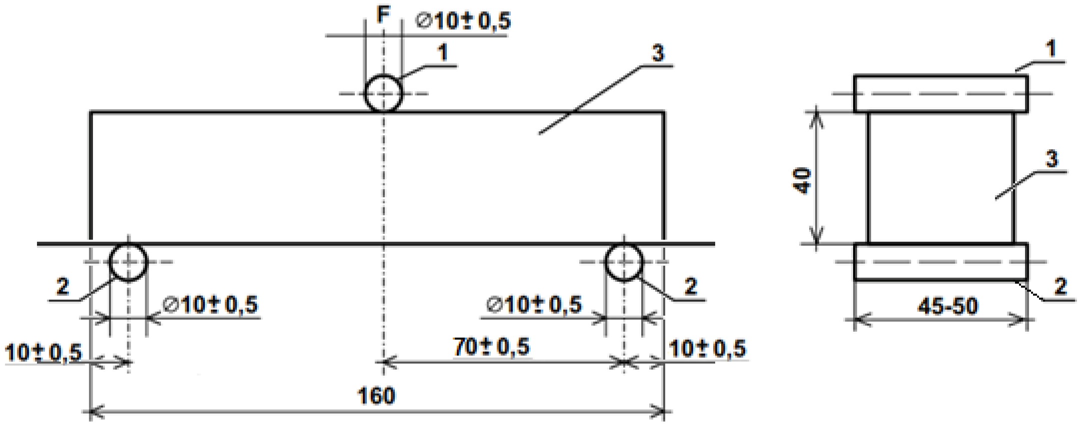

Figure 7 - Layout of the beam sample during the bending test:
1 - upper support; 2 – lower supports; 3 – beam sample

The test installation (Figure 6) and the loading device to it (2, Figure 6), for crack resistance tests, the current vertical load is recorded on the monitor display (7, Figure 6), and then the load destroying the sample is fixed, the value of which is necessary to calculate the critical stress intensity coefficient [8].

For the bending strength of a batch of gypsum binder, the arithmetic mean of the two largest test results of three samples is taken. The bending strength of one sample is calculated by the formula:

$$R_{ben} = \frac{3Pl}{2bh^2}, \quad (2)$$

where *P - the destructive load, kN;*
l - the distance between the axes of the supports, mm;
b - the width of the sample, mm;
h - the height of the sample, mm.

After the experiments, the sequence of processing results is demonstrated. In particular, the value of the critical stress intensity coefficient at a normal K_{dz} rupture is determined by the formula:

$$K_{Ic} = \frac{3P_dL_0}{2b\sqrt{a^3}}\sqrt{\lambda[1.93 - 3.07\lambda + 14.53\lambda^2 - 25.11\lambda^3 + 25.8\lambda^4]},$$

where P_d – destructive load, кN;
L_0 – distance between supports, mm;
b – the width of the sample, mm;
a_0 –the length of the initial crack, mm, $\lambda = \frac{a_0}{a}$ its relative length.

Compressive strength R – is determined by the formula:

$$R = \frac{P_{load}}{S},$$

where P_{load} *– destructive load, kN;*
S – is the area of the loading plates, cm^2.

Tensile strength at splitting R_{pp} – is determined by the formula:

$$R = \frac{2P_{pp}}{\pi S},$$

where P_{pp} – *destructive load, кN;*
S – area of loading plates, cm².

Results.

The preparation of the mixture is strictly regulated by the norms (GOST 7473-2010 Concrete mixtures. Technical specifications) and are controlled in the laboratory by qualified employees. After a different age period from 1 day to 28 days, compression and bending tests of batches of samples were carried out [9].

Table 1 – Prepared mixtures for the manufacture of concrete samples-beams

Batch / number of samples, pcs	№ 127 / 18	№ 134 / 24	№ 138 / 20
Mass of the finished mixture, g	500 ± 2	540 ± 2	510 ± 2
Water, % / g	9 / 45	8 / 43	8 / 41
Inertmaterial: Sand, % / g Dropout (fr. 5 mm), % / g	 29 / 145 50 / 250	 30 / 162 49 / 265	 30 / 153 50 / 255
Astringent: Cement (PC-D20-B) Gypsum (G-5)	 12 / 60 -	 - 13/ 70	 6 /31 6/31

Table 2 – Density of concrete samples (beams and cubes)

Batch / number of samples, pcs	№ 127 / 18	№ 134 / 24	№ 138 / 20
Density of the finished sample, g/cm^3	1.95	2.10	1.99

Table 3 shows the strength of concrete at different ages compared to the strength 28 days after pouring impassable concrete for compression testing.

Table 3 – Compressive strength of concrete samples

Ageofconcretesamples	Minimum compressive strength (N/mm^2)	Batch (averagevalue)			Percentage of strength
		№ 134	№ 138	№ 127	
1 day		3.2	5.2	6.8	16-17%
3 days		9.2	16.3	22.1	46-55%
7 days		13.5	20.0	28.0	64-70%
14 days		18.4	28.1	36.7	90-92%
28 days		20.0	31.2	40.1	99-100%

Table 4 shows the strength of concrete at different ages compared to the strength 28 days after pouring impassable for testing concrete during bending.

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Table 4 – Bending strength of concrete samples

Ageofconcretesamples	Minimum compressive strength (N/mm²)	Batch (averagevalue)			Percentage of strength
		№ 134	№ 138	№ 127	
1 day		2.48	2.55	2.71	50-82%
3 days		2.63	2.79	3.85	61-87%
7 days		2.88	3.78	4.26	82-95%
14 days		2.92	4.18	5.12	92-99%
28 days		3.02	4.56	5.41	99-100%

Discussion.

Three batches of samples were experimentally studied (No. 127, No. 134, No. 138 compositions, which are shown in Table 1). To experimentally determine the crack resistance of concrete during compression, samples were used-cubes with a size of 100x100x100 mm. From Figure 8 it can be seen that the samples made from cement of the PC-D20-B brand have a greater value of the compressive strength of concrete after 28 days compared with samples from cement of the PC-D20-B brand + gypsum of the G-5 brand and only gypsum of the G-5 brand. If we consider each curve separately, we can observe the following: for samples from all batches, the strength of one-day, three-day and seven-day-old samples is significantly inferior to the strength of fourteen-day and twenty-eight-day-old samples [10].

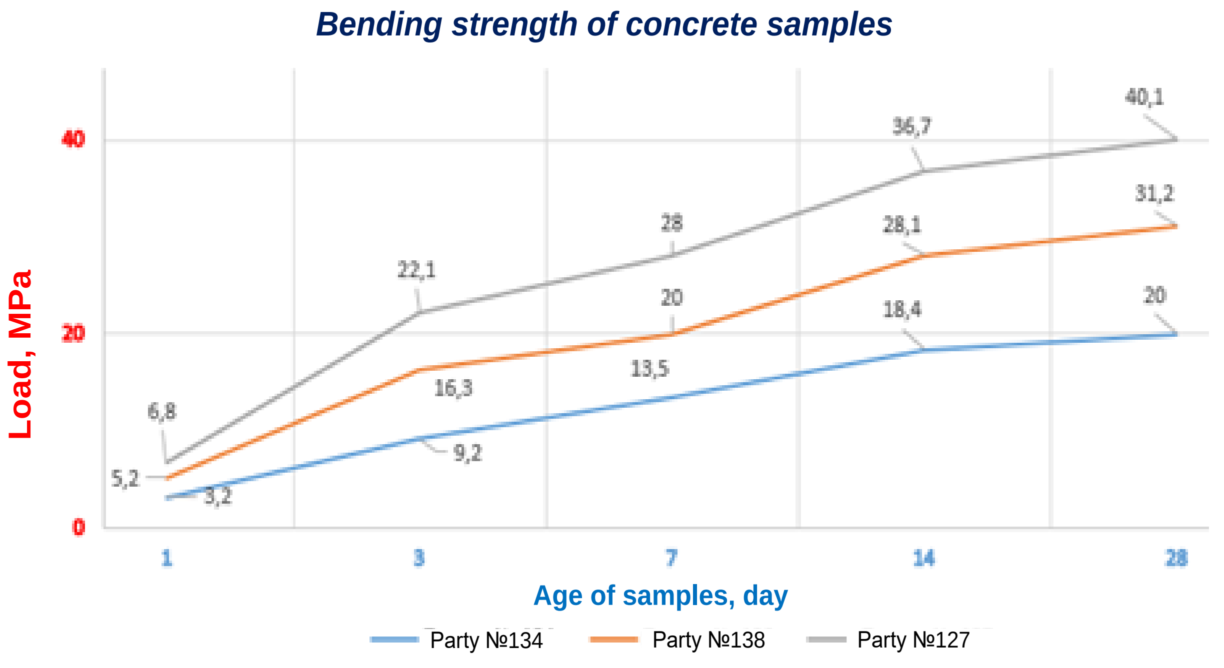

Figure 8 - Compressive strength of concrete samples

To experimentally determine the tensile strength of concrete during bending, the following prototypes were used-prisms with a size of 100x100x400 mm [7].

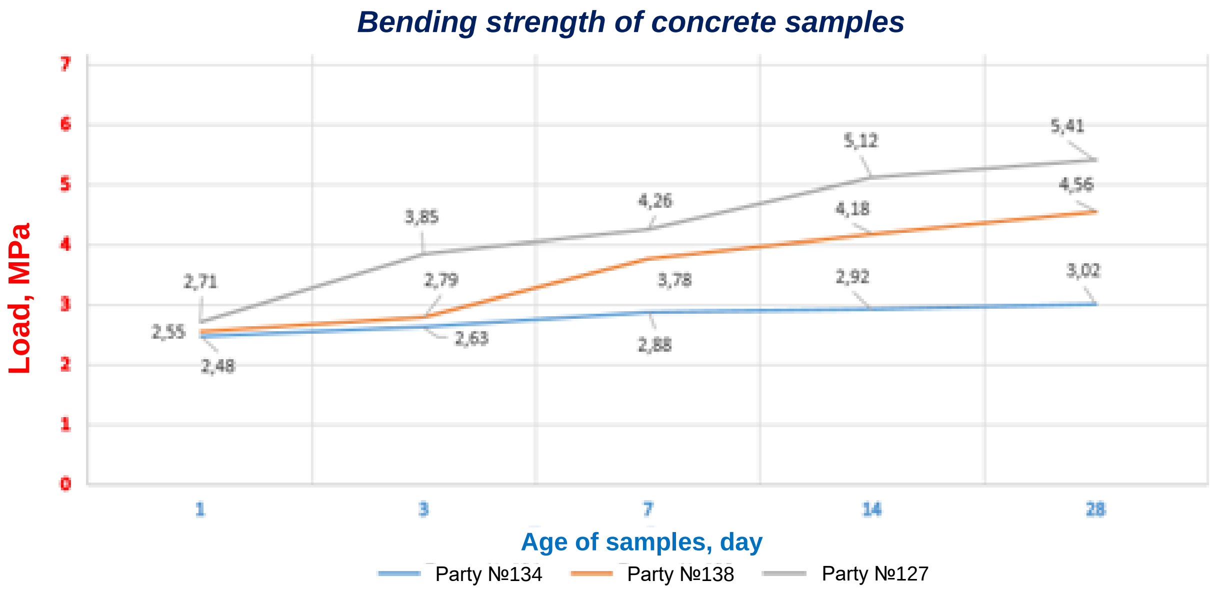

Figure 9 - Bending strength of concrete samples

To experimentally determine the strength of concrete during bending, prism samples with a size of 40x40x160 mm were used. It can be seen from Figure 9 that the manufactured samples-beams made of cement of the PC-D20-B brand have a greater value of the tensile strength of concrete during bending over a period of time from 1 day to 28 days compared with samples made of cement of the PC-D20-B brand + gypsum of the G-5 brand and only gypsum of the G-5. It should be noted that for samples made of gypsum grade G-5 batch No. 127, the strength of one-day and twenty-eight-day-old samples differs by only 18% [11]. All strength, strength, deformation and structural parameters were determined on samples made from a single pariah, which is extremely important for assessing the frost destruction of straining concrete.

Conclusion.

It follows from the above that good binders are necessary for the manufacture of high-quality concrete. For concrete of class B 30, it is necessary to add approximately 290-300 kg of M400 cement of the PC-D20-B brand per 1 cubic meter of concrete mix, which will approximately give 1 MPa of concrete strength. Gypsum together with cement also gives good performance, but requires additional testing, since in aggressive environments with high humidity, the effect of leaching is possible. Overspending of the binder will lead to an increase in the cost of products made for concrete with specified strength characteristics. The obtained dependences show that the difference is 22% between the samples made on the basis of PC-D20-B grade binder cement and PC-D20-B grade binder cement + G-5 grade gypsum. The use of a concrete mixture prepared on the basis of PC-D20-B grade binder cement + G-5 grade gypsum will give a positive economic effect for concrete structures in a dry microclimate.

Thus, the results of tests of control samples made on the basis of a binder (cement and gypsum) for compression and stretching during bending fully give an idea of the methodology for determining the physical and mechanical characteristics of building materials.

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СТАТИКАЛЫҚ ЖҮКТЕМЕ КЕЗІНДЕ БЕТОННЫҢ ЖАРЫҚҚА ТӨЗІМДІЛІК ПАРАМЕТРЛЕРІН АНЫҚТАУ

Аңдатпа. Бетоннан жасалған құрылыс конструкциялары ғимараттарды, құрылыстарды, көлік құралдарын салуда кеңінен қолданылады. Беріктік-бетонның құрылымдық материал ретіндегі негізгі сипаттамасы. Мақалада әртүрлі тұтқыр заттарға негізделген бетон үлгілерін жасау процесі егжей-тегжейлі сипатталған. Бетонның текше беріктігін және бетонның иілу беріктігінің шегін эксперименттік анықтау қарастырылған.

Иілу кезінде бетонның беріктік шегін анықтау үшін максималды жүктемесі 10 кН дейін Жаңартылған зертханалық сынақ қондырғысы қолданылды. PC-D20-B маркалы цементтен жасалған үлгілер PC-D20-B + маркалы цементтен алынған G-5 маркалы гипстен және тек G-5 маркалы гипстен алынған үлгілермен салыстырғанда 28 күннен кейін бетонның қысу беріктігінің үлкен мәніне ие екендігі эксперименталды түрде анықталды.бренд. Дайындалған үлгілер-PC-D20-B маркалы цементтен жасалған арқалықтар PC-D20-B + маркалы цементтен жасалған G-5 маркалы гипстен және тек G-5 маркалы гипстен жасалған үлгілермен салыстырғанда 1 тәуліктен 28 тәулікке дейінгі уақыт кезеңінде иілу кезінде бетонның беріктік шегінің үлкен мәніне ие. Осылайша, тұтқыр (Цемент және гипс) негізінде жасалған бақылау үлгілерін иілу кезінде қысу мен созуға сынау нәтижелері құрылыс материалдарының физика-механикалық сипаттамаларын анықтау әдістемесі туралы толық түсінік береді.

Түйінді сөздер. Бетон, цемент, гипс, жарыққа төзімділік, бетонның беріктігі.

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ОПРЕДЕЛЕНИЕ ПАРАМЕТРОВ ТРЕЩИНОСТОЙКОСТИ БЕТОНА ПРИ СТАТИЧЕСКОМ НАГРУЖЕНИИ

Аннотация. Строительные конструкции из бетона широко используются при возведении зданий, сооружений, транспортных средств. Прочность - основная характеристика бетона как конструкционного материала. В статье подробно описан процесс изготовления образцов бетона на основе различных вяжущих. Рассмотрено экспериментальное определение кубической прочности бетона и предела прочности бетона при изгибе. Для определения предела прочности бетона при изгибе использовалась модернизированная лабораторная испытательная установка с максимальной нагрузкой до 10 кН. Экспериментально установлено, что образцы, изготовленные из цемента марки PC-D20-B, имеют большее значение прочности бетона на сжатие через 28 суток по сравнению с образцами из цемента марки PC-D20-B + гипса марки G-5 и только гипса марки G-5 бренд. Изготовленные образцы-балки из цемента марки PC-D20-B имеют большее значение предела прочности бетона при изгибе в течение периода времени от 1 суток до 28 суток по сравнению с образцами, изготовленными из цемента марки PC-D20-B + гипса марки G-5 марка и только гипс марки G-5. Таким образом, результаты испытаний контрольных образцов, изготовленных на основе вяжущего (цемента и гипса), на сжатие и растяжение при изгибе в полной мере дают представление о методике определения физико-механических характеристик строительных материалов.

Ключевые слова. Бетон, цемент, гипс, трещиностойкость, прочность бетона.

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