Compressive strength properties of hyper-compacted concrete

Bakhridin Khasanov[1*], *Alisher* Tillaev[2], and *Timur* Mirzaev[3]

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan
[2]Academic Lyceum "INTERNATIONAL HOUSE TASHKENT", Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan
[3]YEOJU Technical Institute in Tashkent, Tashkent, Uzbekistan

Abstract. The most important property of a concrete mix is concrete workability, i.e., the ability of the mixture to spread and take a given form while maintaining solidity and uniformity.
The main influence on the workability of the concrete mixture is exerted by water consumption and, in part, cement consumption. Workability is determined by the mobility of the concrete mixture at the time of filling the mold and plasticity, i.e., the ability to deform without breaking the continuity.
In the process of vibrating and pressing the concrete mixture placed in the mold, the total volume of the mixture changes until the pressure is balanced by the resistance forces. Deformation of concrete mix or, more precisely, freshly laid concrete with any compaction methods, including vibration compaction, is divided into elastic (reversible) and residual (irreversible). Residual deformations during vibration compaction occur as a result of water squeezing out and redistribution of aggregate fractions.
Permanent deformation is part of the total. Its value at the same composition of the concrete mixture depends on the shape and size of the pressed sample. At the same time, it is noteworthy that after reaching a certain pressure, only elastic deformations will be characteristic of the freshly laid concrete mixture. So, A.D. Nikitin, in the course of the experiments, found that at a pressure of 2.2 MPa, the elastic moduli of the components of the concrete mixture have the following values: for cement paste - 0.16 · 104 MPa, aggregate - 4.5 · 104 MPa and air - 3 MPa ... After reaching a static pressure of 2.2 MPa, the compressible mixture showed only elastic deformation. This indicates that by the time the specified pressure was reached, the relative movement of the aggregates had ended, i.e., they are located most compactly.

1 Introduction

To obtain concrete of maximum strength on Portland cement without the addition of the Chimkent plant with an activity of 44 MPa, with sand of average size with a density of ρp =

[*]corresponding author: mr.bakhridin@mail.ru

3.57 g / cm3 and crushed stone with the largest particle size of 20 mm, it is necessary to optimize the composition of the concrete mixture. Table 1 shows part of the composition of the mixture with V / C from 0.31 to 0.40 [1-12].

The production of high-strength concrete by vibration-impact pressing is achieved by densely filling the intergranular space with cement paste and mortar with a simultaneous displacement of air bubbles, squeezing out part of the free water behind the portions of the compacted mixture [13-19]. In case of an unsuccessful selection of the composition of the concrete mixture, a rigid, practically incompressible frame of aggregate grains can form [20-26].

Table 1. Influence of forming methods on concrete strength (Zh-10s)

№	Initial, V/C	Consumption of materials for 1 m^3 of concrete, kg				Vibrationpress mode	Amount of squeezed water, %	Residual, W/C	Compressive strength, MPa, 28 days	$\Delta = \frac{R_b{}^{VP}}{R_b{}^{V}}$
		C	C	Ch	V					
1	0.31	530	495	1272	165	1	14.0 / –	0.269 / 0.31	101.3 / 46.7	2.17
						2	14.5 / –	0.267 / 0.31	104.6 / 46.7	2.24
						3	15.7 / –	0.263 / 0.31	110.7 / 46.7	2.37
2	0.33	490	506	1300	162	1	16.7 / –	0.276 / 0.33	93.6 / 45	2.08
						2	17.9	0.271 / 0.33	96.3 / 45	2.14
						3	19.1 / –	0.268 / 0.33	100.4 / 45	2.23
3	0.35	460	508	1308	161	1	19.9 / –	0.280 / 0.35	85.5 / 42.1	2.03
						2	20.5	0.278 / 0.35	88.4 / 42.1	2.10
						3	21.7 / –	0.275 / 0.35	90.5 / 42.1	2.15
4	0.37	430	512	1316	159	1	22.6 / –	0.287 / 0.37	79.4 / 40.3	1.97
						2	24.5 / –	0.280 / 0.37	85.4 / 40.3	2.02
						3	24.5 / –	0.280 / 0.37	85.4 / 40.3	2.12
5	0.40	397	516	1326	159	1	27.7 / –	0.290 / 0.40	67.1 / 34.6	1.94
						2	28.3 / –	0.288 / 0.40	69.5 / 34.6	2.01
						3	29.5 / –	0.283 / 0.40	72.7 / 34.6	2.10

Note: Above the line is test results of concrete samples, compacted; vibro-impact pressing, under the line - the same, compacted by vibration,

Where: R_{bvp} is the strength of vibro-impact-peristaltic pressed concrete; R_{bv} is the strength of vibro-compacted concrete.

2 Methods

In the concrete mix, the compressible element is cement paste. To acquire the ability to deform under the action of normal forces, it is necessary that the cement paste covers all the aggregate grains and occupies the voids between them. Consumption of cement and components for studying the effect of the composition of the mixture on the efficiency of its compaction was determined following the instructions and the manual [27-31]].

From the calculated compositions, two series of concrete samples with a diameter and height of 150 mm were prepared: the first series of concrete samples was compacted by vibration for 5 minutes with an amplitude of 0.4 ... 0.6 mm, a frequency of 50 Hz, with vibration compaction, water filtration is insignificant; the second - after a 2-minute vibration, it was compacted by vibro-impact pressing for 8 minutes. Vibration impact pressing was carried out in three modes:

I - pressure from 0 to 20 MPa increased within 3 minutes;

II - the same for 5 minutes;

III - the same for 8 minutes.

To establish the pressure rise mode, the squeezed out water was collected in a measuring vessel. At the same time, it was revealed that the amount of squeezed water during vibration-impact pressing with a pressure rise mode from 0 to 20 MPa for 8 minutes is 23% more than during vibration-impact pressing of a mixture with a pressure rise mode from 0 to 20 MPa for 3 minutes (Table one).

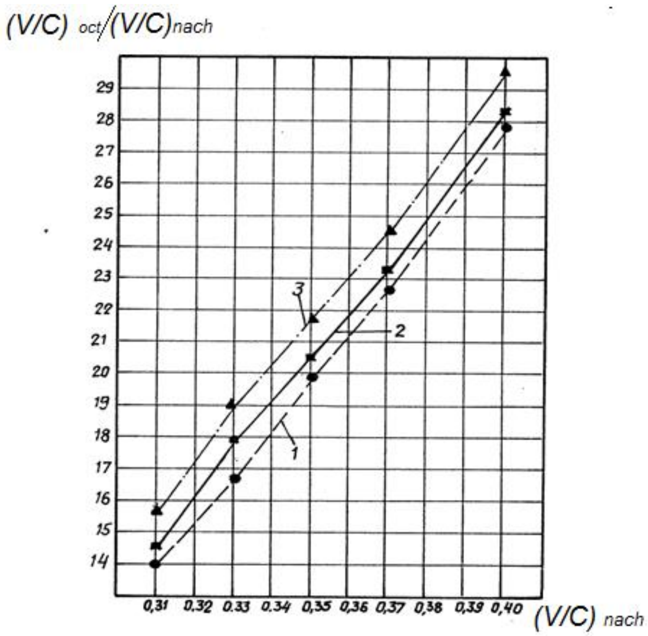
3 Results and discussion

Numerous studies [24-29] have established that the degree of squeezing out excess mixing water during vibration-impact pressing depends on its initial content in concrete, on cement consumption, the initial volume of voids in the mixture, and the intensity of compaction, fig. 1, and the highest compression ratio corresponds to a pressure of 3 to 7 MPa.

Storage and strength testing of samples was carried out under the same conditions following the requirements of GOST 4795-87. The obtained test results of samples of cylinders are given in table 1 and reflected in the graphs in Figures 1 a and b.

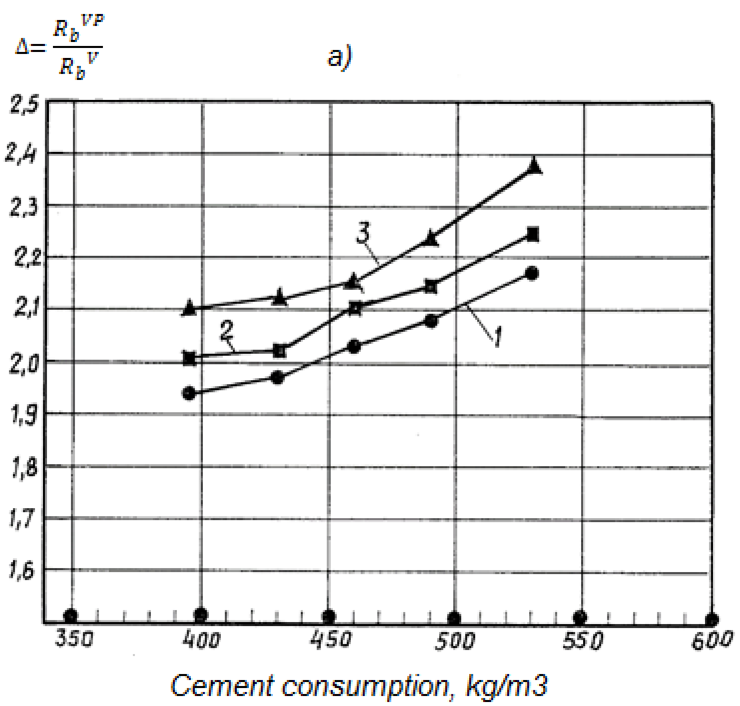
Analysis of the experimental data given in table 1 leads to the conclusion that the strength of hyper-compacted concrete, as well as vibration-compacted concrete, depends on the value of V/C or C/V. In vibrated concrete, this value is (V/C) start, and in hyperexpanded concrete - (V/C)oct.

The amount of squeezed water depending on the initial W / C and the compaction mode



1 is mode I; 2 is mode II; 3 is mode III

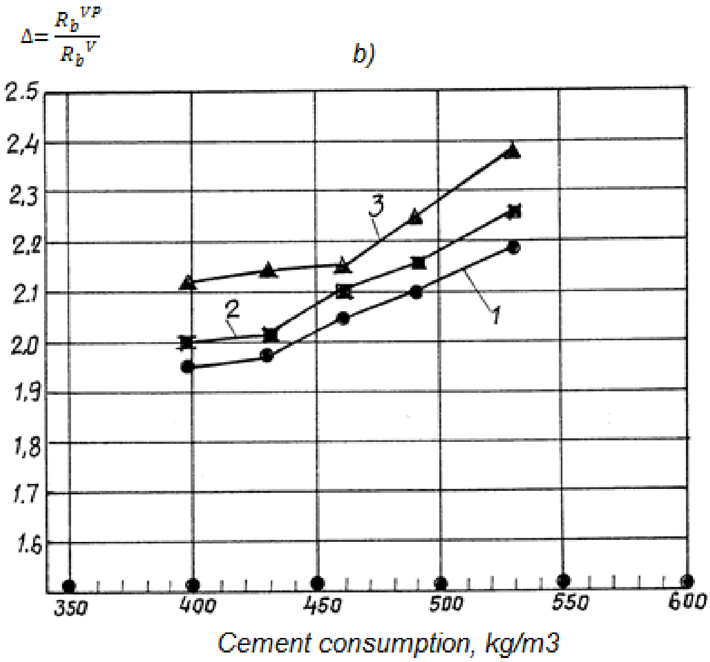
Fig. 1. Influence of cement consumption on the strength of concrete by vibro-impact pressing (Akhangaran Portland cement)



1 is mode I; 2 is mode II; 3 is mode III.

Fig. 2. Strength ratio of concrete of different compaction: R_{bvp} ~ strength of vibro-impact compacted concrete at $(V/C)_{ost}$; P_{bv} - strength of vibro-compacted concrete at (V/C) bost = $(V/C)_{bnach}$.

Left side: Strength ratio of concrete of different compaction



1 is mode I; 2 is mode II; 3 is mode III.

Fig. 2. Influence of cement consumption on the strength of concrete by vibro-impact pressing (Chimkent Portland cement): K_{bvp} - strength of vibro-impact compacted concrete at (V/C) bost; R_{bv} ~ strength of vibro-compacted concrete at (V/C) $_{bost}$ = (V/C) b_{nach}

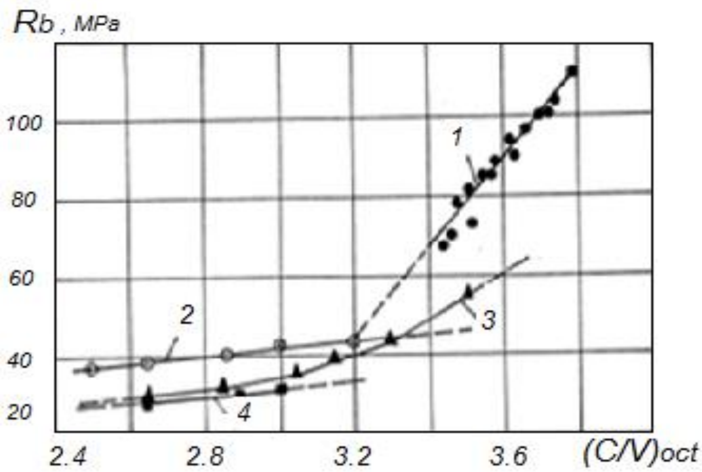
Dependences of the strength of hypersolid and vibrated concrete on C / V are shown in Fig. 3. The same figure shows the data of S.A. Semakova [30] for vibro-impact and vibrated concrete. The given data indicate a significant difference in the dependence Rb = C / V for high-strength concretes of various types of molding. Vibrated and vibro-shock-compacted concretes in the C / V range from 2.5 to 3.5 increase their strength by about 1.5 times, changing almost linearly. Hyperconsolidated concrete in the C / V range from 3.5 to 3.8 also increases its strength by approximately the same value (by 1.65 times). However, the increase in strength occurs from 65 MPa to 107 MPa.

The dependence of the strength of hypersolid concrete in the indicated interval C / V also occurs linearly (Fig. 3. a, b, c). It should be noted that the coefficient of strength gain (Rmax - Rmin) / ((C/V) max - (C/V) min)) is 140. Similarly, for vibro-shock and vibro-compacted concrete, this value is 23. Obviously, hyperexposure and concrete modification leads to a qualitatively new mechanism of strength structure-formation, characterized by the ratio of strength coefficients 140 / 23≈6 groove. The physical mechanism of structure formation for new technological conditions was shown earlier [31, 32]. We repeated these experiments on various types of cement used in the Republic of Uzbekistan. Figures 3 a, b, c also show the dependence of the strength of hyperelastic concretes on the cement-water factor.

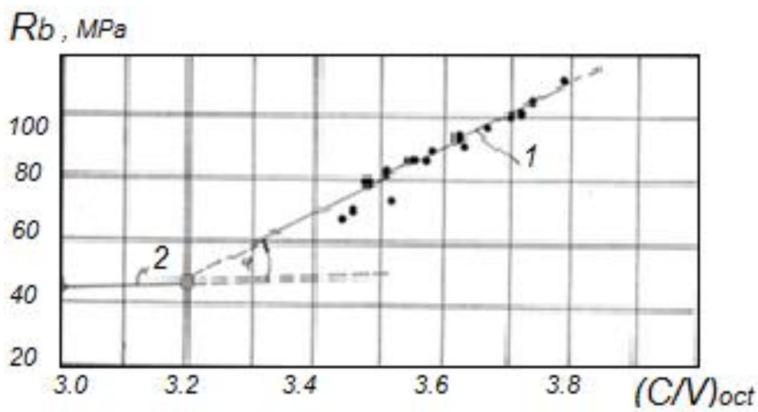
The high values of the strength of hypersolid concretes also required a structural analysis in accordance with the division of concrete performed by us [33]. In this case, the strength of concrete was determined depending on the strength of the cement stone and the components of the mortar part of the concrete. Samples of cement stone, mortar, and concrete were obtained using a laboratory setup on experimental cements of the Akhangran, Bekabad, Kuvasay, and Chimkent plants. The relationship between the mechanical properties of cement stone, mortar, and concrete, shown in Fig. 4, is proposed in the form:

$$R_b=q_p\cdot R_p+q_p\cdot q_c\cdot R_c \quad (1)$$
$$E_b=q^E\cdot E_p=q_c^E\cdot E_c \quad (2)$$
$$\varepsilon_b= q_p^{\varepsilon}\cdot\varepsilon_p = q_c^{\varepsilon}\cdot \varepsilon_c \quad (3)$$

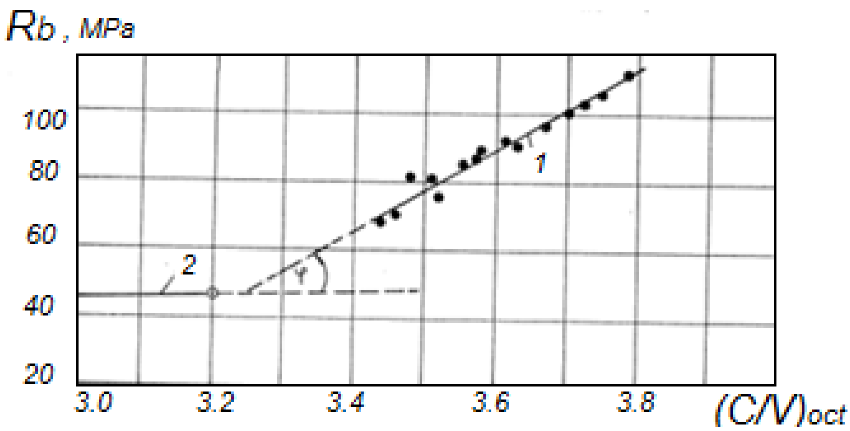
where R_b, E_b, ε_b are cylindrical strength, modulus of elasticity and ultimate deformability of hypersolid concrete; R_p, E_p,ε_p are the same mortar part of the concrete; R_c, E_c, ε_c are the same cement stone concrete; q_p, q_p^E, q_p^{ε} are coefficients for accounting for the influence of the mesostructure (solution) on the strength, elasticity, deformability of concrete; q_c,q_c^E,q_c^{ε}, are coefficients for accounting for the effect of microstructure (cement stone) on the strength, elasticity, deformability of concrete.



a) dependence of the strength of high-strength concrete on the residual cement-water factor (Chimkent Portland cement): 1 is hyper-compacted concrete; 2 is vibrocompacted concrete; 3, 4 are data of S.A. Osmakova (vibroimpact and vibrated concrete (C/V) Beginning)



b) Dependence of the strength of high-strength concrete on the residual cement-water factor (Akhangaran Portland cement)



v) Dependence of the strength of high-strength concrete on the residual cement-water factor (Bekabad Portland cement): 1 is hyper-compacted concrete; 2 is vibrated concrete.

Fig. 3. Dependences of the strength of hypersolid and vibrated concrete on C/V

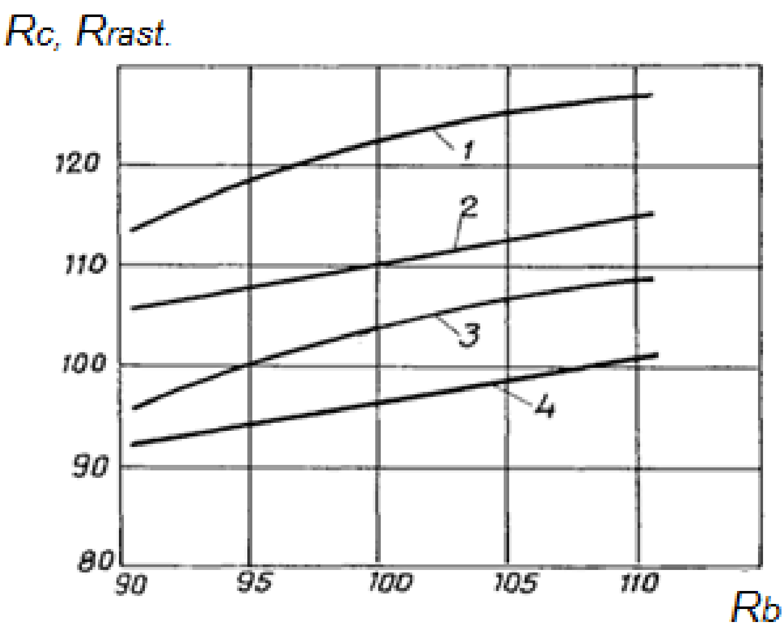


Fig. 4. Dependence of the strength of concrete on the strength of the cement stone and the mortar part of the concrete: 1, 2 are Cement $(W/C)_{oct}$ = 0.27 and 0.29; 3, 4 is mortar part of concrete $(W/C)_{bost}$ = 0.27 and 0.29.

Figure 5 presents the results of testing concrete with a strength of 67 ... 111 MPa. It can be seen that the modulus of elasticity and the limiting deformability of the concretes under study increased from 36 × 103 to 62 × 103 MPa and from 2.2 to 2.9%, with an increase in strength by about three times. At the same time, the ultimate transverse deformation for all concretes remained almost unchanged and averaged 1.2%. This is because hyper solid concrete has increased limiting deformability, since cement-sand mortar, being a matrix in a concrete system, has large deformability due to the use of high-quality materials and low V / C, and it is more later microcracking began due to an increase in the adhesion strength of aggregates with cement potassium and a decrease in the total initial defectiveness of the structure.

Analysis of the results of experimental studies of the modulus of elasticity and ultimate deformability, as well as diagrams b - ε and the change in total deformations and the integral coefficient of transverse deformations Δv under short-term axial compression, showed that microcracking in hyperelastic concrete begins at stresses RcrcΘ = (0.72 .. .0.79) Rb and ends at Rvcrc = (0.84 ... .0.97) Rb.

The modulus of elasticity of hyper-compacted concrete is (50 ... .60) · 103 MPa, and the ultimate deformability is 2.4 ... 2.8%, which is 10 ... 20% more than for concrete with strength <80 MPa. The ultimate transverse deformation obtained during axial compression, 1 ... 1.5%, corresponds to a similar characteristic of cement stone and mortar (Fig. 5) and is approximately equal to their ultimate elongation. This confirms the validity of the fact that the destruction of concrete occurs as a result of a violation of the bonds between its structural elements and components or the structural elements themselves when they reach the ultimate tensile deformation. Basically, the elasticity and deformability of the coarse aggregate, its volume concentration in the concrete composition, as well as the elasticity and deformability of the mortar and cement stone, affect the modulus of elasticity and the ultimate deformability of hypersolid concrete.

Diagrams of deformation (a) and changes in the state of the structure (b) under short-term axial compression of samples

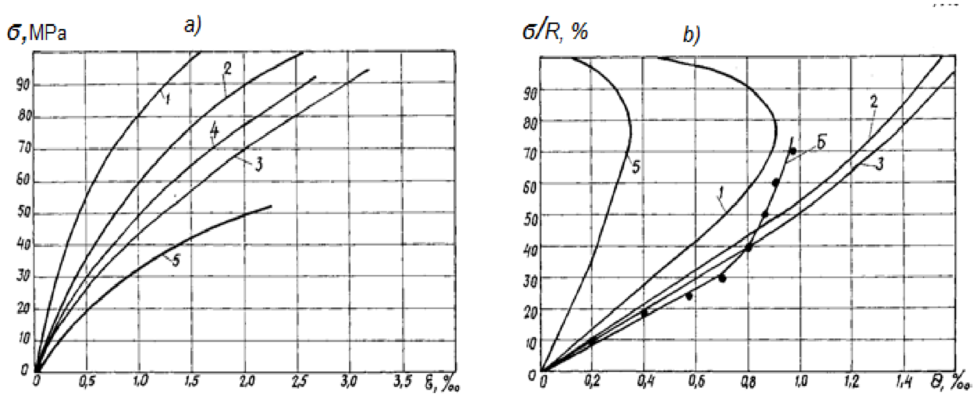


Fig. 5. Presents the results of testing concrete with strength of 67 ... 111 MPa: 1 is hyper-compacted concrete with a cube strength of 111 MPa; 2, 3 is mortar and cement stone of concrete; 4, 5 is concrete with a strength of 95 and 65 MPa; B is according to the data of O. Ya. Berg.

Based on the results of experimental studies, taking into account the high homogeneity of the structure and mechanical properties and following the requirements of GOST 26633-91 and GOST 10180-90, it has been established that concrete with a strength of 60 ... 110 MPa corresponds to the compressive strength classes B65 ... B115 (table 2).

Table 2. Dependence of strength (R_b) and deformative (E_b) characteristics for concrete of various classes

Indicators	B65	B70	B75	B80	B85	B90	B95	B100	B105	B110	B115
$R_{b,}$, MPa	60	65	70	75	80	85	90	95	100	105	110
$E_b \cdot 10^3$, MPa	44	46	48	50	52	54	56	58	60	62	64

The normative axial compression resistance of hypersolid concrete was determined at a coefficient of prismatic strength close to 0.8.

4 Conclusions

1. The developed complex method of hyperexposure and modification of the concrete mixture allows increasing the strength of the test concrete by 2 ... 2.2 times compared to the strength of vibro-compacted concrete with the same initial value of W/C.

2.According to the test data of experimental cylinders and drilled cores with a diameter of 150 mm, the strength level reaches 80 ... 110 MPa on ordinary cement (Rc = 42 ... 44 MPa) and unwashed carbonate aggregates when using a vibro-shock-peristaltic hyperelastic wave up to 20 MPa.

3. The functional dependence of hyper-compacted concrete on its structural components, strength, elasticity, and deformability of the corresponding cement stone and mortar part of concrete has been established, while the approximate dependence of Rb on Rc and Crust is linear.

References

1. Desov A.E. Vibrated concrete, p. 229, Moscow, (1956)
2. Instruction on the duration and intensity of vibration and on the selection of the composition of the concrete mixture with increased workability, p. 32, Moscow, (1968)
3. Punagin V.N. Influence of aggregates on concrete properties, Construction and architecture of Uzbekistan, № 4**,** pp.12-13, Moscow. (1965)
4. Sizov V.N., Kirov S.A., Popov L.N. Technology of concrete and reinforced concrete products, p. 518, Moscow, (1972)
5. Soroker V.I., Dovzhik V.G. Rigid concrete mixes in precast concrete production, p. 307, Moscow, (1964)
6. Composition, structure and properties of cement concretes, p. 248, Moscow, (1976)
7. Sheikin A.E. Structure, strength and fracture toughness of cement stone, p. 173, Moscow, (1974)
8. Khasanov B., Vatin N., Mirzaev T., Suyunov A. and Radjabov M. Physicochemical fundamentals of modifying concrete mix and concrete, IOP Conf. Series: Materials Science and Engineering **1030**, (2021) 012022 doi:10.1088/1757-899X/1030/1/012022.
9. Adilhodzhaev A.I., Shaumarov S.S., Makhamataliev I.M., Tsoy V.M. Features Of Forming The Structure Of Cement Concrete On Second Crushed Stone From Concrete Scrap, International Journal of Advanced Science and Technology, 29 (5), pp. 1901-1906, (2020)
10. Shaumarov S.S., Adilhodzhaev A.I., Shipacheva E.V., Kandkhorov S.I. Development of New Constructive and Heat-Insulating Materials. International Journal of Recent Technology and Engineering (IJRTE), 7(5S3), p. 577-580, (2019)
11. Bondarev M.V. The influence of the previous deformation process on the deformation of concrete, p. 114, Moscow, (1966)
12. Lokhvitsky G.Z. Theory of vibropressed concrete, "Concrete and reinforced concrete structures", № 7, pp. 11-12, Tbilisi, (1958).
13. Nikitin A.D. Energy costs for reversible and irreversible deformation of concrete mixtures // Reports of the XX scientific conference LISI, pp. 16-21, Leningrad, (1962)
14. Khasanov B. and Mirzaev T., “Production of extra-strong concrete axisymmetric products,” in E3S Web of Conferences, **97**, (2019), doi: 10.1051 / e3sconf / 20199706011
15. Adilhodzhaev A., Shaumarov S., Tsoy V., Khodzhaev S. Research of the influence of silicon-organic hydrophobizer on the basic properties of Cement stone and mortar //

International Journal of Advanced Science and Technology, **29** (5), pp. 1918-1921, (2020)
16. Rybakov V., Jos V., Raimova I., and Kudryavtsev K. Modal analysis of frameless arches made of thin-walled steel profiles. IOP Conf. Ser. Mater. Sci. Eng. 883, (2020).
17. Kattakulov, F., Muslimov, T., Khusainov, A., ...Vokhidov, O., Sultanov, S. Water resource saving in irrigation networks through improving the efficiency of reinforced concrete coatings, IOP Conference Series: Materials Science and Engineering, 2020, 883(1), 012053
18. Adilkhodjaev A., Hasanov B., Shaumarov S., and Kondrashchenko V. Aerated concrete with predetermined pore parameters for the exterior walls of energy efficient buildings. IOP Conf. Series: Materials Science and Engineering **1030**, p. 012006, (2021), doi:10.1088/1757-899X/1030/1/012006
19. Khasanov B., Irmuhamedova L., Firlina G., Mirzaev T. Theoretical foundations of the structure formation of cement stone and concrete, IOP Conf. Series: Materials Science and Engineering **869**, p. 032032, (2020) doi:10.1088/1757-899X/869/3/032032
20. Shaumarov S.S., Adilhodzhayev A.I., Kondrazhenko V.I. Experimental research of structural organization of heat-insulating structural building materials for energy efficient buildings. XXII International Scientific Conference on Advanced In Civil Engineering «Construction the formation of living environment», pp.1-7, (2019)
21. Instructions for calculating the composition and control of the strength of high-quality concrete, p. 73, Moscow, (1968)
22. Guidelines for the selection of the composition of heavy concrete, p. 103, Moscow (1979)
23. Khasanov B., Vatin N., Mirzaev T., Suyunov A., and Radjabov M., Analysis of the mode of squeezing out excess water for mixing concrete mixture in the process of peristaltic compaction, IOP Conf. Series: Materials Science and Engineering **1030** (2021), 012021 doi:10.1088/1757-899X/1030/1/012021
24. Khasanov B., Vatin N., Ismailova Z., and Mirzaev T. Physical modification of concrete mix and concrete. Materials Science and Engineering **883** p. 012205, (2020), doi:10.1088/1757-899X/883/1/012205
25. Khasanov B., Choriev R, Vatin N., and Mirzaev T. The extraction of the water-air phase through a single filtration hole. IOP Conf. Series: Materials Science and Engineering **883** p. 012206, (2020) doi:10.1088/1757-899X/883/1/01220
26. Adilkhodjaev, A., Shaumarov, S., Kadir, U. New structure assessment method cell concrete. International Journal of Advanced Science and Technology 2020, 29(5), p. 1889-1893
27. Adilhodzhayev A., Shaumarov S., Shipacheva E., Shermuhamedov U. New method for diagnostic of heat engineering and mechanical properties of cellular concrete, International Journal of Engineering and Advanced Technology (IJEAT), 9(1), pp. 6885-6887, (2019)
28. Adilhodzhayev A.I., Shaumarov S.S., Umarov K.S. New Structure Assessment Method Cell Concrete, International Journal of Advanced Science and Technology, **29**(5), pp. 1889-1893, (2020)
29. Khasanov B., Irmuhamedova L., Firlina G, Mirzaev T. Theoretical foundations of the structure formation of cement stone and concrete, IOP Conf. Series: Materials Science and Engineering **869**, p. 032032, (2020) doi:10.1088/1757-899X/869/3/032032
30. Adilhodzhaev A., Volodya T., Shaumarov S., Igamberdiev B. Influence Of Modified Mineral Fillers With Hydrophobizing Additive On Structural-Forming. Solid State Technology, 63(6), p.409 – 413, (2020)
31. Khasanov B.B., Punagin V.M., Savin, Shishkin O.O. Physico-analytical method of projecting by folding concrete, p. 156, Dnipropetrovsk. NVO "Zakhist" (1994)