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BEARING CAPACITY OF PRECOMPRESSED LOAD-BEARING ELEMENTS MADE OF HEAVY CONCRETE UNDER SINGLE DYNAMIC LOADS

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ABSTRACT: - At dynamic load of high intensity, but of short duration, developing as a result of shock, explosive and seismic effects, there is an increased tensile strength of concrete-dynamic strength. This phenomenon is explained by the energy-absorbing ability of concrete operating during a short period of loading with a dynamic load only elastically.

In this work, the effect of long-term compression of heavy cement concrete of class B-15 on its strength and deformations under single dynamic loads was investigated.

KEYWORDS: Compression, concrete, dynamic load, seismic, samples, prism, strength, deformation, testing.

INTRODUCTION

As established by instrumental observations, long-term ground accelerations during strong earthquakes significantly exceed the calculated ones. Thus, in [6], data are given on a five-fold increase in normalized accelerations over the period from 1952 to 1973. Under these conditions, during earthquakes, one could expect severe damage and even collapse of most buildings. At the same time, as the experience of past earthquakes shows, well-designed and well-built structures have certain reserves that allow them to endure high seismic accelerations.

At the present stage of development of the theory of seismic stability, refined design schemes are used that more closely reflect the actual properties of structures, which requires the use of more accurate solution methods.

Methods of research. For the first time, the problem of dynamic calculation of structures beyond the limits of elasticity was posed by A.A. Gvozdev in [7]. It shows the expediency of taking into account the reserve of bearing capacity due to plastic deformation of structures in calculations for emergency loads.

The development of studies of building structures in the elastic-plastic stage was significantly influenced by the introduction in the work of I.I. Goldenblat and V.A. Bykovsky [8] the concept of the limiting state of buildings and structures being built in seismically active areas, according to which the main purpose of the structure is to ensure the safety of the population and the safety of material assets.

But given the rare recurrence of seismic events, it is inappropriate to require the complete safety of structures. They allow damage, plastic deformation, failure of secondary elements.

Accounting for the operation of structures in the elastic-plastic stage is associated with serious refinements compared to elastic calculations. Firstly, stiffness characteristics change during elastoplastic deformations, which in most cases leads to a decrease in seismic loads. Secondly, when operating in a nonlinear region, the structure absorbs a much larger amount of energy than during elastic vibrations, which also leads to a decrease in the dynamic load.

Before seismic impacts, the bearing elements of structures, as a rule, experience the action of static compressive loads for a long time (from the weight of structures, useful ones, etc.). It was shown in [1] and other works that long-term compression of materials (concrete, mortar, masonry) affects strength and significantly changes their deformative properties, leading, in particular, to a decrease in plastic deformations. In this regard, studies of the dynamic properties of materials held for a long time under static load are of great practical interest.

In works [2,3], the strength of heavy and light concretes was studied under single dynamic loads and, in particular, those that can be under seismic impact (loading duration t≈1-0.5 sec). However, concrete samples - prisms were in an unloaded state until the moment of dynamic load application.

In this work, we studied the effect of long-term compression of heavy cement concrete of class B-15 on its strength and deformation under single dynamic loads.

Experimental prism samples 10x10x40 cm in size were tested for central compression. Tests of prototypes for dynamic single loading [10] were carried out using an SBE pulsate with a hydraulic jack with a capacity of 300 tons and two steel cylinders with a capacity of 200 liters each (batteries). Oil is pumped into the batteries with the help of a pulsate up to a certain pressure. At the time of the test, the pipeline was opened, supplying oil to the hydraulic jack, due to which there was an impulsive (fast single) loading of the prototype. According to the deformations of the steel cylinder - a dynamometer with glued calibrated strain gauges, the load on the prototype was controlled. Longitudinal deformations of concrete were measured using calibrated strain gauges with a base of 50 mm, glued to each face of the prism. The readings of the sensors were recorded by an H-700 oscilloscope.

Some of the prism samples (series 7) at the age of 100 days were placed in spring installations for long-term central compression. Three samples were loaded into each setup. The force of long-term compression was 40% of the short-term breaking load of the reference samples. Simultaneously with the dynamic loading, the pre-compressed and control specimens were tested with a short-term static load. The results of these tests, as well as the exposure time of samples under long-term load, are given in Table 1. The strength of the pre-compressed specimens was obtained higher than the strength of the control ones by an average of 6.8%.

Table 1

Type of concrete	**Sample exposure time under load, days**	R_{in}^{PC} **MPa**		R_{in}^{CC} **МПа**		R_{in}^{PC}
		quotient	**average**	**quotient**	**average**	R_{in}^{CC}
Heavy cement concrete	1242	22	21	20	20	0,107
		21		20		
		20		19		

R_{in}^{PC} и R_{in}^{PC} – tensile strength of pre-compressed specimens.

The results of dynamic tests of control and pre-compressed specimens are given in Table 2. The dynamic strength of concrete was compared with the strength obtained at loading speeds corresponding to the speeds of conventional static tests (average ≈1.2 kg/cm^2 per second) - Table 1.

Table 2

Type of concrete	Specimen №	Test duration, t sec.	Prism Strength R^{CC}_{in} (t) MPa	Average download speed $\sigma_{ave}\frac{R^{CC}_{in}t}{t}$ MPa per second	$K_t = \frac{R^{CC}_{in}t}{R^{CC}_{in}}$
Heavy concrete (control samples) TS (k)	1	0,093	24	253	1,2
	2	0,087	24	271	1,2
	3	0,182	21	116	1,08
	4				
	5	0,07	24	343	1,22
	6	0,1	22	224	1,14
	7	0,072	23	314	1,15
	8				
	9	0,178	22	122	1,11
	10	0,15	22	144	1,1
	11	0,11	22	200	1,12
	12				
	13	0,14	22	160	1,14
	14	0,084	23	278	1,19
		0,775	21	27	1,06
		1,43	20	14	1,02
Heavy concrete (pre-compressed samples) TS (according to)	24	0,075	23	307	1,1
	22	0,137	22	163	1,07
	15	0,07	23	334	1,12
	17	0,167	22	133	1,06
	21	0,156	22	142	1,06

Comparison of the data in Table 2 shows that with a decrease in the exposure time, the strength of the pre-compressed samples increases to a lesser extent than that of the control samples. With an average duration of exposure t=0.143 sec. for control samples, the ratio $K_t = \frac{R^{CC}_{in}t}{R^{CC}_{in}} = 1{,}12$, and for pre-compressed samples at t=0.153 sec, the ratio $K_t = \frac{R^{tot}_{in}t}{R^{tot}_{in}} = 1{,}063$. At t=0.08 sec, the value of $K_t = 1.19$, for control samples, and for pre-compressed samples at t=0.07-0.075 sec. value $K_t = 1.11$.

The average values of indicators characterizing the deformative properties of pre-compressed and control samples under static and dynamic single loads are given in Table. 3 and 4, and the increase (in percent) of these indicators with a decrease in the duration of loading in Table 5.

In table. 3-5 are accepted, the following designations: t in sec - duration of loading; ε_{PC} -preferred longitudinal maximum strain on the compression diagram (concrete compression diagrams obtained from the results of both static and dynamic tests had a descending section); ε_{max} - relative longitudinal deformation corresponding to the maximum stress on the compression diagram, A_{PC} in kg m/cm^3 specific work expended to achieve deformations.

ε_{PC}; A_{max} in kg/cm^3 – specific work expended to achieve deformations ε_{max}; E_y in kg/cm^2 is the modulus of elasticity of concrete. From the data given in table. 3 and 4 it follows that, as well as for the control samples, in pre-compressed concrete with a decrease in exposure time, an increase in relative longitudinal deformations A_{PC} and ε_{max} and specific work A_{PC} and ε_{max} are observed. With a decrease in the time of exposure to the values ε_{PC}; ε_{max}; A_{PC}; A_{max} for precompressed concrete change to a lesser extent than for control samples. The initial modulus of elasticity of precompressed concrete, as well as for control samples, changes insignificantly with a decrease in exposure time.

Table 3.

Type of concrete	**Loading time t sec**	$\varepsilon_{PC}\cdot 10^3$	$A_{PC}\cdot 10^3$	$\varepsilon_{max}\cdot 10^3$	$A_{max}\cdot 10^3$	E_y
Heavy concrete (control samples) TS (k)	Statics 177	2,46	3,59	1,82	2,39	181000
For samples № 8,9,10,3	Dynamics 0,1625	2,95	4,9	2,03	2,97	185400
For samples № 12,1,7,4	0,0797	3,07	5,49	2,22	3,56	193000
Heavy concrete (pre-compressed samples) TS (according to)	Statics 167	2,12	3,2	1,46	1,86	189200
For samples № 21,17,22	Dynamics 0,153	2,28	3,71	1,49	2,07	198370

Table 4

Type of	**The ratio of the corresponding indicators of TS (c) / TS (by)**

loading	$\varepsilon_{PC}\cdot 10^3$	$A_{PC}\cdot 10^3$	$\varepsilon_{max}\cdot 10^3$	$A_{max}\cdot 10^3$	E_y
Static: for TS samples (c) t_{st} =177 sec.	1,16	1,12	1,25	1,28	0,96
for TS samples (according to)t_{st} =167 sec.					
Dynamic: for TS samples (c) t_{dyn} =0,1625 sec.	1,29	1,32	1,36	1,43	0,93
TS (by) t_{dyn} =0,153 sec.					

Table 5

Indicators	**Heavy concrete**		
	TS (by)	**TS (c)**	
	$\frac{t_{st}}{t_\Delta} = \mathbf{1090}$	$\frac{t_{st}}{t_\Delta} = \mathbf{1090}$	$\frac{t_{st}}{t_\Delta} = \mathbf{2200}$
ε_{pc}	7,5	20	25
ε_{max}	2,0	12	22
A_{max}	11,0	24	49
A_{pc}	16,0	36	53
E_y	5,0	2	6

A significant increase in the specific work A_{pc} (by 32%) and the work A_{max} (43%) for control samples compared to A_{pc} and A_{max} for pre-compressed samples should be attributed mainly to a sharp decrease in longitudinal deformations
ε_{pc} and ε_{max} of pre-compressed samples compared with strains $\varepsilon_{pc}$and ε_{max} of control samples. As follows from the data in Table. 5, with the same (on average, 1090 times) decrease in the duration of loading samples from heavy concrete, all indicators characterizing the deformative properties of concrete under single dynamic impacts for pre-compressed concrete change to a lesser extent than for control samples [9].

No works devoted to the study of the effect of long-term compression on the strength and deformation of concrete under single dynamic impacts have been found in the literature available to us. In [4], heavy concrete specimens were held for about three hours before a single dynamic impact under a load of 60% of the prism strength obtained under static loading of the specimens. Experiments [4] showed (three samples were tested) that such pre-compression did not affect the strength and ultimate longitudinal deformations of concrete, slightly increased the initial modulus of elasticity of concrete.

CONCLUSION

1. Preliminary long-term compression affects the strength of heavy concrete of class B-15 by a single dynamic impact, causing some decrease in its bearing capacity (up to 8% under loading conditions carried out in these experiments). The results obtained allow us to conclude that the normalization of the coefficient of working conditions of heavy concrete, taking into account the short duration of the impact of a dynamic load, should be carried out after testing not with ordinary, but with pre-compressed samples.
2. With a decrease in the duration of loading of pre-compressed and uncompressed heavy concrete, the limiting longitudinal deformations and the specific work spent on the destruction of the sample increase, and for pre-compressed concrete to a much lesser extent than for uncompressed concrete.
3. The modulus of elasticity of precompressed heavy concrete can be taken equal to the modulus of elasticity determined from the results of testing uncompressed concrete of the same age. For practical purposes, the modulus of elasticity of heavy concrete (previously compressed and uncompressed) under a single dynamic loading can be taken equal to the modulus of elasticity calculated from the results of static tests.

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