Increase of Impact Strength and Frost Resistance of Concrete Hydrotechnical Piles at Deaeration of Concrete Mixture with Air-Entraining Admixtures

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Abstract. In the article the main technological factors of influence on frost resistance of concrete are given. It is proved, that the reduction of air content in concrete mixture with air-entraining admixtures during continuous vibration does not lead to a decrease in frost resistance of concrete with an increase in its strength. The completed researchers have shown that when the concrete mixture is deaerated, the number of micro-destructions under the impact effects on concrete is significantly reduced. The obtained data allowed to offer a method of manufacture of piles, submerged by impact effects, for severe climatic conditions. The main parameters that must be provided during the production of piles and their clogging for increased durability are indicated. Deaeration of concrete mixture with air-entraining additives and initial air content does not lead to decrease of subsequent frost resistance of concrete. The creation in concrete mixture of initial excess air content increases mobility of concrete mixture, and subsequent deaeration allows getting concrete of especially high frost resistance with increase of its tensile strength. Deaerated concrete allows to increase the level of multiple impact tensions without further reduction of durability. This method of obtaining high-frost-resistant concrete of increased impact tensile strength is expedient to use in manufacturing piles for sea hydraulic installations. The tensile strength of concrete piles (after deaeration) should be not less than 50 MPa.

1. Introduction

The high frost resistance of concrete is most difficult to provide in piles of sea hydrotechnical structures, submerged by impact effects or vibration methods, as multiple dynamic influences on concrete cause significant micro-destruction, increasing water permeability of concrete and reducing its frost resistance.

[1,2,3]

Long-term research and production experience [4,5,6] have shown that high frost resistance of concrete with a sufficient degree of reliability can be obtained only with the use of complex additives containing air-entraining and plasticizing components. Air-entraining admixtures form conventionally closed "buffer" air pores in concrete, which dampen the overpressure of water during freezing, but at the same time reduce the strength of concrete. The plasticizer as part of a complex additive helps to reduce water consumption and compensate the decrease in strength. Thus, the injection of a complex additive allows increasing the air content in concrete up to 5-7% (at content of 0.5% - in concrete without additives) without reducing the strength. At the same time, the ability of the structure of concrete to hold the entrained air in the process of freezing and defrosting is crucial for the frost resistance of concrete.
2. Statement of problem
The purpose of the article is parametrical analysis of the indicators. On this basis should be selected an optimal method of graphic’s correction taking into account the method of organization construction and installation works. High efficiency of the method of increasing frost resistance of concrete due to formation in it watertight system conventionally - closed air pores is shown in practical recommendations and in normative documents regulating the design and manufacture of high frost resistance concrete [7,8,9,10,11,12,13].

3 Analysis of concrete parameters
It is known [5] that the effective pore range, contributing to the increase of frost resistance of concrete, is in the range of 10 - 100 microns, while air-entraining admixtures increase the air content of the concrete mixture in a wider range. Larger pores result in additional reduction of concrete strength, and their volume depends on the way and duration of concrete mix compaction [14].

Therefore, the optimal structure of the pore space of concrete can be obtained by regulating the vibration intensity of the concrete mixture at its compaction. In the production conditions (at concrete plants), air content in the concrete mixture is determined by means of air-meters after compaction of the experimental portion of the concrete mixture on a standard vibration site. The time of vibration is prescribed based on the mobility of the concrete mixture. The required air content (usually 3 - 5%) is regulated by dosing the air-entraining admixtures.

While laying concrete in the structure, the vibration intensity and, therefore, the residual air content differs from the control (on a standard vibration platform). In the manufacture of prefabricated products at the factories, this difference, as a rule, is insignificant. For example, in the production of piles at one of the factories, the air-meter bowl was installed on the vibration table near the pile shape and after the concrete was laid into the form, the measured air content was 3% at a value of 4.5%, obtained with the previous control measurement using a standard vibration platform. When installing monolithic structures using deep vibrators, deaeration occurs more intensively and the difference between the initial air content measured at the concrete plant, and the real air content in the concrete structure can differ in several times. This is confirmed by the measurement of air content at the concrete plant immediately after the preparation of the concrete mixture - 5% and the subsequent measurement of air content made on the construction site when the concrete mixture is compacted by a depth vibrator, which amounted to 1.8%. The strength of the samples in the lake 28 days, selected at the concrete plant (air content of 5%) was 23% lower than the strength of the samples selected on the construction site (air content of 1.85). Parallel tests on the frost resistance of the selected samples showed that there was no decrease in the frost resistance of concrete with significant deaeration.

The influence of the deaeration process of the concrete mixture on the subsequent frost resistance of concrete was studied in more detail by testing the frost resistance of 4 batches of concrete prisms with size 7х7х24 cm, in which the time of compaction changed from 5 to 120 s. The initial air content was from 3 to 9% and the final content - 1.5 to 2.5%. In none of the batches there was a decrease in frost resistance when the compaction time changed and the air content decreased by 2 to 4 times. At the same time, in a number of samples exposed to alternative freezing and defrosting, there is a greater increase in the dynamic modulus of elasticity than in control samples not tested for frost resistance.

Considering that deaeration leads to increase of strength, and at the same time it is possible to preserve the structure of concrete more reliably during the impact immersion of piles, studies have been carried out of the effect of deaeration on the degree of micro-destruction by impact influence and subsequent frost resistance.

Mass tests were carried out using concrete prisms with dimensions of 4x4x16 cm, followed by binding to large-sized samples by comparative tests. Along with samples of normal hardening, samples with hardening were tested in a steaming chamber at Tmax =70 °C. The samples had a tensile strength of concrete in the range from 30 to 70 MPa. Simultaneously with the production of prism samples for determining the tensile strength of concrete for compression, cubes with dimensions 10x10x10 cm were made. A complex additive air entrainment and plasticizer was injected into the composition of concrete
(air entraining and plasticizing components) in various dosages to obtain a given initial air content of 3.5 to 10%. In part of the samples at different seal intensity, the air content was reduced to 1.5 - 3.5%. With up to 26% increased tensile strength and nearly twice the compression strength.

During the deaeration of the concrete mixture, the changes in the volumes of individual pore groups were estimated. It has been established that the reduction of air content occurs mainly due to the removal of pores by radii of over 10 microns. The volumes of pores with 0.01-0.1 mkm and 0.1-1.0 mkm dimensions practically do not change during compaction. The decrease in the volume of pores with a radius of 1.0-10 microns in one of the batches was 15-22% at the long duration of 20-30 times of hardness and at a general reduction of air content by 5 times.

To create impact tensions, similar in their parameters to those occurring during piling, in experimental samples, a laboratory tubular pile-driver (fig.1) was used with a set of hammers weighing from 9.4 to 14.32 kg, dropped from various heights. The impact pulse duration and voltage of tension were regulated by changing the hammer drop height and by changing the corner cushion elasticity and thickness. The sample was subjected to impact 300 times at voltages from 0.3 to 70% from prismatic strength. To measure the dynamic forces in the samples, a power hydraulic capsule with strain meter was used, which was installed on the anvil of the base plate of the tubular pile-driver. The voltage of impact tensions in the samples at different drop heights of a hammer are shown in the figure 2.

To evaluate the physical and mechanical characteristics of samples after impact effects and during tests for frost resistance, the ultrasonic method (device UK 1401) and the resonant method for determining the dynamic modulus of elasticity were used.

According to the results of the tests, it is established that intensive deaeration of the concrete mixture with increased initial air content (up to 10%) significantly reduces the number of micro-breaks with multiple impact loading. When testing for frost resistance with defrosting in seawater after impact loading (300 impacts at σ = 0.6 from prismatic strength) in samples exposed by significant deaeration (up to 1.8%), a slight increase in dynamic elastic modulus and a 3% increase in strength were recorded (after 100 cycles). While in samples with initial air content of 3.5% (at compaction time equal to 2 hardness, the reduction of dynamic elastic modulus after impact loading was 8.6% and after 100 cycles of alternating freezing and defrosting - 9.3%.

Figure 1. Diagram of the laboratory model of tubular pile-driver.
1-base, 2-base plate, 3-guide tube, 4-impact hammer part, 5-pull rope, 6-block, 7-moving rod, 8-adjustable stop, 9-locking pin, 10-holes, 11-test sample, 12,13- upper and lower shims.

**Figure 2.** Graphics of tension changes in samples according to the height of the hammer drop. 1 – hammer weight 14.3 kg; 2 – hammer weight 9.4 kg.

Parallel tests of two batches of samples close in tensile strength (40 MPa) and air content (3%) are most revealing. At the same time, in the first batch air content is initial (compaction time is 2 hardness), and in the second batch - after deaeration from 10 to 3% at compaction time of 20 hardness. Despite the higher W/C volume in the second batch, after impact loading and after 100 cycles of alternating freezing and defrosting, there was no reduction in the dynamic elastic modulus. While in the first batch, the reduction of dynamic elastic modulus was 10 and 14%, accordingly.

4. **Conclusions**
1. Deaeration of concrete mixture with air-entraining additives and initial air content of at least 4% does not lead to decrease of subsequent frost resistance of concrete.
2. The creation in concrete mixture of initial excess air content (7-10%) increases mobility of concrete mixture, and subsequent deaeration up to 1.8-2% allows getting concrete of especially high frost resistance with increase of its tensile strength by 25-30%.
3. Deaerated concrete allows to increase the level of multiple impact tensions to $\sigma = 0.6$ Rpr without further reduction of durability.
4. This method of obtaining high-frost-resistant concrete of increased impact tensile strength is expedient to use in manufacturing piles for sea hydraulic installations. The tensile strength of concrete piles (after deaeration) should be not less than 50 MPa. With the preliminary tension of the armature, the voltage in concrete must not exceed 10 MPa.

5. **References**
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