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Experience of Concrete Works Execution by the Means of Air-Placed Concreting

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Abstract. This article is devoted to the generalization of production experience of concrete works by means of pneumatic concrete casting, which extends to the production of concrete works on the construction of residential, industrial buildings and other structures, their reconstruction and repair, as well as the manufacture of concrete structures in the factory. The paper considers the technology of production of works in concreting monolithic thin-walled concrete structures by means of pneumatic concrete casting. It is proved the advantages of the method of pneumatic concrete casting. The materials used and the selection of the concrete mix composition are described in detail. The methods of calculation for composition of the concrete mixture, the selection of equipment for the transportation of fine concrete mixtures and mortars, injection, primary and control injection are shown. The differences between pneumatic concrete casting and other methods of guniting are considered. All stages of the production process are described in detail. The article presents the operational characteristics of the installation "pneumatic concrete" for pneumatic concrete casting, in particular, the required amount of compressed air. The description of stages of pneumatic concrete casting is of interest. The issues of the work organization are considered, the service personnel and its duties are given. It is formulated the requirements of safety compliance at work. A detailed description of work technology opens up new opportunities for its improvement. This article will be useful for specialists engaged in the production of concrete works by means of pneumatic concrete casting. The article provides a detailed bibliography on the issue of pneumatic concrete casting, mechanization of production, technology of production of works. The normative documents used in the production of concrete works by the method of pneumatic concrete casting are given.

1. Introduction

Concreting of reinforced concrete structures by means of air-placing is carried out according to pre-developed design for the production of works. Recommendations are applicable for works carried out in temperature of the air above +5 ºC.

1.1 Special features and application field

Air-placed concreting is a variation of the method of pneumatic feeding and application of concrete mixtures, which also includes the method of shotcrete. Moreover, the concrete mixture can be prepared centrally or in the mixing unit "Pneumobeton" [1,2,3].
2. Applicability, scientific merit
The method of air-placed concreting has the following advantages:

- Water-cement ratio, which is one of the main factors ensuring the required physical and mechanical characteristics of the installed concrete, is maintained;
- the dustiness of the working space is significantly reduced, and the general "fogging" is reduced;
- losses of components on the "rebound" are reduced to 4-6%;
- labor costs per 1 m³ of poured concrete are reduced by 20-30%;
- the qualification of the attendants may be lower;
- The accumulation of static electricity, which occurs when the mixture moves through a pipeline, is significantly reduced.

The disadvantage of the method is the compressed air consumption increased by 30-40%.

3. Tasks
The generalization of experience in execution of air-placed concrete works allows us to state that this method is especially effective for coating concrete, reinforced, steel, brick and rock surfaces to make them waterproof and corrosion resistant, as well as creating fireproof coatings on steel and wooden surfaces.

Method of air-placed concreting is used in reconstruction and production of repairing works for:

- Reinforcement of concrete, reinforced concrete, brick, stone and steel structures, for example, silo housings of elevators, span structures of bridges, slabs, overpasses, etc.;
- Restoration of concrete and reinforced concrete structures, for example, walls of river locks, dry docks, cooling towers, bunkers, etc.
- Concrete installed with use of this technology has high physical and mechanical characteristics (density, water resistance, frost resistance, adhesion to various surfaces).

4. Theoretical part
The composition of the concrete mixture is carried out using small and large aggregates in accordance with norms and regulations "GOST" (Government standards effective in Russian Federation).

Fly ash from the combustion of coal, ground granulated and blast-furnace slag, ground quartz sand or stone flour is used as mineral additive for reducing the consumption of cement in fine-grained concretes.

Additives used during preparation of concrete mix should not cause a harmful effect on the skin and respiratory organs of the operating personnel.

Water used for mixing concrete ingredients and watering of the laid concrete must meet the requirements of GOST 23732-2011.

4.1 Selection of the composition of the concrete mixture [1,2,3,14,15,16,17,18,19,20]
The water-cement ratio of the concrete mixture can be 0.40-0.50 depending on the application conditions, the type of construction and the physical-mechanical properties of the constituents of the mixture. As a result of removal of part of mixing water by the compressed air water-cement ratio in the laid mixture decreases by 10-20%, respectively. Mobility of the mixture after immersion of the standard cone while loading into the feeder should be 5-8 cm, and in the laid mixture - 3-5 cm.

5. Calculations
Calculation for the composition of the concrete mixture according to the simplified method in accordance with CH 488-76 (List of norms and regulations) is carried out as per below:

Compressive strength and Η/Β for fine-grained (sandy) concrete, hardening in natural conditions, is determined by the formula:

$$ R_5 = 0.4R_u \left( \frac{H}{B} - 0.43 \right) $$
The quantity of materials per 1 m³ of the mixture is determined by the formula:

\[ \text{Y} = \frac{\text{Ц1} + \text{П1} + \text{Д1м} + \text{В1}}{\text{б.п.с}} \]

Where Ц, П, Дм, and В - consumption of cement, sand, mineral additive and Ц1, П1, Дм1, В1 - the same, in sample mixes.

The composition of the concrete mixture for concrete production with necessary water resistance and frost resistance should be established by physical tests. The selected composition should be corrected according to the results of testing the concrete samples, taking into account the actual losses of the concrete mixture components to the "rebound." The composition of the "rebound" is approximately equal to 1:10 (cement: sand) by weight.

5.1 Equipment [4,5,6,7,8,9,10,11,12,13]
"Pneumobeton" mixing unit is used for the transportation of fine-grained concrete mixtures and mortars, injection, primary and control injection during tunneling.

Constructive design of the mixing unit is based on the conditions for works execution and the type of the constructed building.

In all cases, mixing unit "Pneumobeton" must consist of the following:
- Receiving-mixing type device with forced action mixer;
- feeder;
- a vibrating screen with cells 10x10 mm;
- material pipeline;
- air pipeline;
- nozzles for application of fine-grained mixtures or flow damper the mixture in the pipeline.

It is recommended to use a SB-97 mortar mixer with a capacity of 325 liters or a forced-action concrete mixer SB-80 with a capacity of 250 liters equipped with a skip hoist as a receiving-mixing device. Also receiving-mixing device of the UTZHR-2,5 machine manufactured by UMOR Glavmosstroy is applicable.

The required amount of compressed air for "Pneumobeton" mixing unit is 7-9 m³ / min, working pressure is up to 0.7 MPa.

It is necessary to determine the actual capacity and the pressure created by the compressor unit before works execution. This information is displayed on the manometer of the "Pneumobeton". The productivity is calculated by the formula:

\[ \text{П} = \frac{\text{V} \times \text{P} \times \text{T}}{\text{П} \times \text{T}} \]

where П is the capacity of the compressor, m³ / min;
V - volume of an air collector and an air pipeline, m³;
P - compression ratio, MPa;
T - time of filling the air collector to the compression ratio P, min.

Dosing of water in the preparation of a concrete mixture is carried out using a water meter included in the set of the receiving-mixing device.

Production of works [4,5,6,7,8,9,10,11,12,13]
5.2.1 Preliminary works. Before starting work, you need to:
- select the composition of fine-grained concrete mixture;
- connect the "Pneumobeton" mixing unit to the electricity supply, water supply, set up the alarm system and, if necessary, forced ventilation of workplaces;
- mount scaffolds or mobile scaffolds, so that the distance between the deck and working surface is 1.2-1.5 m, and the height of the stage is 2.0 m;
- provide workers with necessary tools and individual means of protection;
- organize the lighting of the mixing item and the place of work during night-shifts.
Before repair work and applying waterproofing and anticorrosion coatings to the work surface, it is necessary to prepare the surface, i.e., to cut down the incrustations, to clean potholes, sinks, weak points, to cut off the protruding parts of the reinforcement and wire, then to flush the surface with a mixed air-water jet and make the formwork for through holes.

If necessary, additional reinforcement should be carried out.

Concreting of reinforced concrete structures. [4, 5, 6, 7, 8, 9, 10, 11, 12, 13]

In case concreting complex structures, it is necessary to pre-work out the technology for producing the work on a fragment made in full size.

Surfaces of large sizes are broken into seizures and arranged with working seams. The applied layers are reduced to a "wedge" with a width of 250-300 mm, provided that the total thickness of the layers does not exceed 80 mm. With a larger thickness, the width of the wedge is increased accordingly.

To obtain a smooth surface after setting the last applied layer of concrete, finish the surface by applying a mortar with fine sand, which is immediately smoothed.

Covering with waterproofing, anticorrosive and other coatings

In the case of waterproofing, anti-corrosion, fireproof and other coatings, in addition to the requirements of 5.14, the following conditions must be met: the thickness of the applied layer should not exceed 10 mm; The total number of layers is determined by the project, but can not be less than two; The second and subsequent layers are applied after the end of the previous setting; For application, a nozzle with an outlet diameter of 26-30 mm is used, regardless of the position of the working surface; as a filler concrete mix sand is used with Mkr = 1,5-2; the cement consumption should be at least 600 kg / m3.

Concrete maintenance and quality control

Favorable temperature and humidity conditions for hardening concrete is determined by protecting it from wind, direct sunlight and constant moistening.

Concrete surfaces covered with moisture-retaining materials (burlap, film, sawdust, etc.) are recommended to water periodically.

Surfaces of concrete, which will not be further connected to other structures with concrete or mortar joints, should be coated with film-forming compounds or protective films.

Hardening concrete should be protected from kicks, shakes and other mechanical influences.

The concrete layer, applied by air-forced concreting and in contact with running water, must be protected from its influence for the first two or three days (depending on the intensity of the flow).

During the air-forced concreting works execution, the employees of the construction laboratory constantly monitor:

- Granulometric composition of the aggregates and their compliance with GOSTs; activity of cement;
- Readiness of the sites for concreting (surface preparation, installation of reinforcement);
- the correctness of dosing and the preparation of the mixture (twice per shift); thickness of applied layers (not less than for every 100 m2 of surface);
- Terms of watering;
- Physical and mechanical properties of concrete (for every 50 m3 of laid concrete).

Control samples (cubes, prisms, cylinders) are cut from specially concreted slabs, with dimensions not less than 50x50x12 cm or directly from structures. Samples from the border parts with broken structure, are not applicable for tests.

To simplify the determination of the strength of the laid concrete during compression, a technique developed by the "Orgenergostroy" institute is used, but the conversion coefficient K is included.

The conversion factor is determined by the results of joint tests of not less than 36 standard cubes with dimensions of 100x100x100 mm and 36 samples cut from plates made by air-forced concreting.

Standard samples and test plates are made simultaneously from a mixture of the same composition and mobility.

The conversion factor is calculated by the formula:

$$K = \frac{P}{A}$$

Where is the compressive strength of the test samples;
6. Additions

6.1 Safety of work, fire and ecological safety [4,5,6,7,8,9,10,11,12,13]

During works execution with "Pneumobeton" mixing unit, it is necessary to follow the guidelines from SNiP 12-04-2002 "Health and Safety in construction", as well as "Technical description and instructions for the exploitation of "Pneumobeton" manufactured by TsNIIOIMTP.

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