**УДК 624**

# THE CONCRETING TECHNOLOGY OF RAPID-HARDENING CONCRETE

# ТЕХНОЛОГІЯ БЕТОНУВАННЯ ШВИДКОТВЕРДНУЧИХ БЕТОНІВ

**Babich Ye.Ye., Candidate of technical sciences, associate professor, Lashchivskyi V.V., candidate of technical sciences, associate professor, Marchuk V.V., candidate of technical sciences, Polianovska O.Ye., candidate of technical sciences, associate professor, Basyuk K., student, Karaban O., student (**National University of Water and Environmental Engineering, Rivne)

**Бабіч Є.Є., к.т.н., доцент, Лащівський В.В., к.т.н., доцент, Марчук В.В., к.т.н., доцент, Поляновська О.Є., к.т.н., доцент, Басюк К., студентка, Карабан О., студент** (Національний університет водного господарства та природокористування, м. Рівне)

**The article deals with the technological issues of using rapid-hardening concretes in construction.**
**The analysis of formwork systems is carried out and the timing of formwork with the use of rapid hardening concrete is considered. The main types of formwork systems in the construction of industrial and civilian facilities are considered.**
**The peculiarities of compaction of concrete quick-setting mixtures are considered. The main types of vibration are given.**
**The technological features of the maintenance of concrete from quick-setting mixtures are considered.**
**Based on the results of the analysis, a conclusion is made about the effectiveness of the implementation of the above technological aspects of the use of rapid-hardening concrete in construction.**

**У статті розглянуті технологічні питання застосування швидкотверднучих бетонів у будівництві.**
**Проведений аналіз роботи опалубочних систем та розглянуті терміни розпалубки виробів з використанням швидкотверднучих бетонів. Розглянуті основні типи опалубочних систем при зведенні обєктів промислового та цивільного призначення.**
**Розглянуті особливості ущільнення бетонних швидкотверднучих сумішей. Наведені основні види вібрування.**

**Розглянуті технологічні особливості догляду за бетоном із швидкотверднучих сумішей.**
**За результатами аналізу зроблений висновок про ефективність впровадження наведених технологічних аспектів застосування швидкотверднучих бетонів у будівництві.**

**Ключові слова.** Швидкотверднучі бетони, модифікатори, опалубочні системи, ущільнення, вібрування, витримування бетонної суміші, терміни перестановки опалубки.
Rapid hardening concrete (RHC), modifiers, formwork systems, compaction, vibration, aging of concrete mixture, timing of formwork replacement.

Modern construction and military actions on the territory of Ukraine require accelerated concrete hardening, especially in monolithic construction and high-speed construction or repair of buildings and structures.

In monolithic construction, the main economic indicator is to reduce the time required to build one floor or section. This technical requirement is dictated by both commercial necessity and the situation in Ukraine, as rapid achievement of the projected strength of monolithic structures is necessary to increase the turnover of forms and formwork, more effective use of equipment and increase the productivity of construction work. Such rapid construction speeds can be achieved by using concretes with accelerated strength gaining - fast-hardening concretes [1]. The key advantage of such concrete mixes is their increased strength in the early stages of hardening, usually within the first few days. This type of concrete is suitable for situations that require the installation of a structure with appropriate strength in a short time.

Several technological methods can be used to accelerate the hydration of clinker minerals and intensify the hardening process of a concrete mix, including reducing the water/cement ratio (W/c) [1]. At low WCl, the water environment is saturated with hydration and hydrolysis products, i.e. cement minerals, resulting in accelerated strength development [1, 2]. This can be achieved by the use of modifiers based on polycarboxylate superplasticisers [3], which has an economic and technological effect.

In recent years, the term 'additive' has increasingly been replaced or identified with the term 'modifier'. Modifiers are also understood as substances that improve (modify) and regulate the technological properties of concrete mixes and the physical and mechanical properties of concrete [4].

Effective modifiers for ready-mixed concrete include superplasticisers and additives which, in the form of components, allow the setting rate, air content and other properties to be regulated.

The aim of this article is to consider some technological aspects of the use of quick-setting concrete in construction, such as

- The economic impact of the use of modifiers in the production of quick-setting concrete.
- Analysis of the operation of formwork systems and the timing of formwork.
- Compaction of concrete mixes.
- Concrete maintenance.

## 1. Economic effect of using modifiers in the preparation of fast-hardening concrete

The recommended compositions of ordinary heavy concrete of different marks with and without the use of modifiers were compared (Table).

The compositions of the most common concretes of the following strength classes C8/10, C12/15, C16/20, C20/25 and C25/30 with and without modifiers were considered. The cost and price of materials and concrete mix were calculated. The use of modifiers makes it possible to make concrete mixes cheaper by lowering cement costs. The cement savings can be 20...70 kg/m3, depending on the concrete class. And the cost of concrete is reduced by 125...295 UAH/m3.

## 2. Analysis of formwork systems and formwork timing

The main types of formwork systems used in the construction of industrial and civilian facilities are classified according to their design and technological characteristics:
- Individual - designed specially for a given building for a single use.
- Non-removable - consists of plates, grids and is left in the structure after being concreted. It is used in the construction of structures without deconstruction.
- Collapsible and movable - consists of boards, supporting, fixing and other elements. It is used for concreting various types of monolithic structures. Small-panel formwork consists of elements weighing up to 50 kg. Large-panel concrete consists of elements weighing more than 50 kg.
- Lift-and-slide - consists of load-bearing structures to which it is attached, floor structure, shields, means for tiering, control equipment, etc. It is used for concreting monolithic structures.
- Slipform - consists of shields mounted on jacking frames, a working floor, jacks and other elements. It is used for concreting high-rise and compact buildings and structures.
- Horizontally mobile - moved horizontally without disassembly as the structures are concreted. They are used for concreting horizontally extended structures. There are two types: coil and tunnel.

Material and concrete costs with and without modifiers Table

| Concrete class | Material costs with modifier, kg/м$^3$ | | | | | Concrete mix price, UAH/m3 | Material cost without SP additive, kg/m3 | | | | Concrete mix price, UAH/m3 | Savings, UAH/ m3 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cement | Sand | Crushed stone | Water | Modifier, l | | Cement | Sand | Crushed stone | Water | | |
| C8/10 | 180 | 890 | 1150 | 160 | 1,3 | | 200 | 890 | 1150 | 200 | | |
| Price,UAH | 4,5 | 0,4 | 0,65 | 0,88 | 40 | | 4,5 | 0,4 | 0,65 | 0,88 | | |
| Cost | 810 | 356 | 747,5 | 140,8 | 52 | 2054,3 | 900 | 356 | 747,5 | 176 | 2180 | 125,2 |
| C12/15 | 200 | 870 | 1150 | 160 | 1,4 | | 250 | 870 | 1150 | 200 | | |
| Price,UAH | 4,5 | 0,4 | 0,65 | 0,88 | 40 | | 4,5 | 0,4 | 0,65 | 0,88 | | |
| Cost | 900 | 348 | 747,5 | 140,8 | 56 | 2192,3 | 1125 | 348 | 747,5 | 176 | 2397 | 204,2 |
| C16/20 | 240 | 840 | 1150 | 160 | 1,6 | | 300 | 840 | 1150 | 200 | | |
| Price,UAH | 4,5 | 0,4 | 0,65 | 0,88 | 40 | | 4,5 | 0,4 | 0,65 | 0,88 | | |
| Cost | 1080 | 336 | 747,5 | 140,8 | 64 | 2368,3 | 1350 | 336 | 747,5 | 176 | 2610 | 241,2 |
| C20/25 | 280 | 770 | 1160 | 160 | 2 | | 350 | 770 | 1160 | 200 | | |
| Price,UAH | 4,5 | 0,4 | 0,65 | 0,88 | 40 | | 4,5 | 0,4 | 0,65 | 0,88 | | |
| Cost | 1260 | 308 | 754 | 140,8 | 80 | 2542,8 | 1575 | 308 | 754 | 176 | 2813 | 270,2 |
| C25/30 | 310 | 750 | 1160 | 160 | 2,2 | | 387,5 | 750 | 1160 | 200 | | |
| Price,UAH | 4,5 | 0,4 | 0,65 | 0,88 | 40 | | 4,5 | 0,4 | 0,65 | 0,88 | | |
| Cost | 1395 | 300 | 754 | 140,8 | 88 | 2677,8 | 1743,75 | 300 | 754 | 176 | 2974 | 295,95 |

- Pneumatic - a structure made of air- and waterproof fabric that takes on a given shape under the influence of excess air pressure. It is used for concreting shells, pipes, collectors, and curved structures.
- Block - consists of panels and supporting elements assembled into a spatial block. It is used for concreting structures of the same type. One-piece for concreting small-volume structures, split for large-volume structures.
- Volumetric and interchangeable - the structure of which is in the form of a U or L-shaped section. It is used for concreting residential and public buildings with a long layout.

The process of maintaining the concrete mix in the formwork system is governed by the requirements for strength gain [5]. The minimum strength of concrete of unloaded monolithic structures when formworking horizontal and inclined surfaces with a span of up to 6.0 m is 70% and over 6.0 m is 80% of the design strength.

Quick-setting concrete gains the required formwork strength almost twice as fast as conventional concrete. This makes it possible to accelerate the timing of formwork repositioning and so save formwork in volume.

## 3. Compaction of concrete mixtures

The process of placing the concrete mix into the formwork is followed by compaction using various measures. The main method of compaction of concrete mix is vibration. The following types of vibration are used on a construction site: internal, external and surface. The most widely used is internal vibration with the use of deep vibrators with a flexible shaft vibrating tip set into the concrete mixture and driven by electricity (electromechanical).

When working with conventional heavy concrete, the repositioning step of the deep vibrators should not exceed one and a half times their radius of action.
When working with quick-setting concrete mixtures with modifiers, the pitch of the deep vibrators can be doubled (i.e. up to three radii of the vibrator). This will greatly save energy and time (by reducing the number of vibrator repositioning) when compacting the concrete mix

## 4. Concrete care

Covering and watering of concrete should be started no later than 10...12 hours after the end of concreting, and in hot and windy weather in 2...3 hours. If the outside air temperature is 15°C and above, watering is performed in the first 3 days during the day after 3 hours and once at night, and in the following days - until 20 % of the design strength is reached (for Portland cement - 7 days, slag Portland cement - 14 days, alumina cement - 3 days) at least 3 times a day.

In the process of concrete maintenance, the main costs for watering concrete are water and electricity (under appropriate natural and climatic conditions).

Conventional heavyweight concrete gains strength within 28 days. Water consumption rates for concrete irrigation are regulated in accordance with [6].

Fast-hardening concretes gain 100% strength within 10...14 days. This greatly minimizes water and electricity costs in the process of concrete care.

## Conclusions

1. The use of modifiers in the preparation of fast-hardening concrete makes it possible to reduce the cost of concrete mixes by lowering the use of cement.
2. Since fast-hardening concretes gain the required formwork strength much faster than conventional concretes, this allows to accelerate the timing of formwork repositioning and in this way shorten the concreting process, by reducing the amount of formwork required.
3. When compacting a fast-hardening concrete mix, it is possible to significantly save energy and work time by minimizing the number of vibrator changes.
4. Due to the fact that fast-hardening concrete gains strength much faster, the time for concrete care is reduced. This leads to a reduction in water and electricity consumption.

1. Dvorkin L.I., Babych Ye.M., Zhytkovskyi V.V., Bordiuzhenko O.M., Filipchuk S.V., Kochkarov D.V. Vysokomitsni shvydkotverdnuchi betony ta fibrobetony. Rivne: NUVHP, 2017. 331 s.

2. Singh, E.R.; Saini, E.L.; Sharma, E.T. Curing of concrete: A technical study to increase rate of curing. Int. J. Adv. Eng. Technol. 2014, 49, 53

3. Dvorkin L.I. Betony novoho pokolinnia / L.I. Dvorkin, V.V. Zhytkovskyi, O.M. Bordiuzhenko, V.V. Marchuk, Yu.O. Rubtsova. NUVHP. 2021. 317 s.

4. Dvorkin L. Y. Proektuvannia skladiv betoniv (Metody, pryklady, vpravy): navchalnyi posibnyk / L.I. Dvorkin. – K.: Vydavnychyi dim «Kondor», 2018. – 613 s.

5. DSTU B V.2.7-224:2009. Budivelni materialy. Betony pravyla kontroliu mitsnosti./ Kyiv. Minrehionbud Ukrainy. 2010.

6. DBN A.3.1-5:2016. Orhanizatsiia budivelnoho vyrobnytstva.

7. Deiaki tekhnolohichni aspekty betonuvannia shvydkotverdnuchykh betoniv. Babich Ye.Ie., Lashchivskyi V.V., Marchuk V.V., Polianovska O.Ie., Kosik I. Resursoekonomni materialy, konstruktsii, budivli ta sporudy: Zbirnyk naukovykh prats. Rivne: NUVHP, 2024. Vypusk 46. S. 348-355.