Optimization of technological parameters of reinforced concrete production

A G Chiknovoryan, S A Mizuryaev and A Yu Zhigulina

Samara State Technical University, Molodogvardeyskaya str. 194, 443001 Samara, Russia

E-mail address: umu-sgasu@mail.ru

Abstract. The article presents the results of research in the field of improving the technology of production of reinforced concrete products aimed at optimizing the composition of concrete; quality control of concrete for strength, taking into account its uniformity; adjustment of the composition of the concrete mix taking into account the characteristics of the aggregates; improvement of the modes of heat treatment of concrete; stabilization of the geometry of freshly molded products, obtaining a smooth and high-quality surface of the products and reduction of marriage associated with spontaneous damage to freshly molded products. It is shown that rational modes of heat treatment of concrete, allows you to abandon the traditional scheme of heat treatment of concrete with steam and provide the necessary conditions for obtaining concrete with design physico-mechanical properties.

1. Introduction

The production of reinforced concrete building envelopes and load-bearing structures in construction practice is a complex technological process and has its own characteristics. The search for solutions to optimal technologies and methods for the factory production of precast concrete structures is associated with the level of scientific and technological development of the country.

With the development of technology, technology is developing in parallel. A significant improvement in the technology of production of reinforced concrete and concrete structures occurred with the introduction of new modern technological processes [1-5], equipped with high-performance and automated equipment, for example, robots, manipulators, hoisting gears and etc. The modern direction for the development of precast concrete is the introduction of modernized and bench production lines.

The main range of products manufactured on such lines are multi-layer and single-layer external wall panels, internal wall panels, as well as floor slabs. Such lines provide high quality products and reduce the production time of prefabricated reinforced concrete structures due to the optimization of machines, equipment and special production solutions.

2. Technology research

From all that has been said, an obvious conclusion follows that the solution to the problem of ensuring the necessary technological properties of concrete mix and the design strength of hardened concrete and products is directly related to the optimization of concrete composition and the selection of rational technological equipment.
In the production of building materials, products and structures made of reinforced concrete, materials are widely used that can improve the physicomechanical properties of concrete and reinforced concrete products, as well as optimize the material and energy intensity of their production. Intensive development of modern building technologies as one of the main areas also includes increasing requirements for the quality of finished building products and the characteristics of the initial basic and auxiliary materials.

One of the ways to improve the molding properties of concrete mixtures is to improve its connectivity and reduce the water demand of concrete mixtures through the use of modern additives with multifunctional modifying properties. Complex modern additives meet the requirements of the modern production of building products and reinforced concrete structures, which have high plasticizing properties and, accordingly, accelerate the hardening of concrete and increase its strength.

So, for example, the technology of pallet circulation related to the semi-conveyor method of production allows the line to produce a wide range of panels with different sizes and use different rhythms of pallet movement within the same production line through the use of overtaking and dead ends, which is not feasible on classic conveyor lines.

This technology in comparison with traditional has several advantages. The main one is the automation of the technological process, which makes it possible to change the modes of preparatory operations and the molding process. This is due to the use of roller bearings and transmission machines, which allow you to move pallets between different speed parts of the line.

These projects are based on intelligent work processes and technologies that use the most economical equipment selection concept. This is expressed in the main technological features of the production line. These include, for example, the use of transverse lifting trolleys with a digital synchronization system, stationary cleaners from concrete residues from pallets that have rotating roller brushes and steel scrapers, rotating nozzles for applying lubricant to the molds, ejectors for even distribution of the coolant in concrete heat treatment chambers etc.

On the other hand, in the production of hollow core slabs, the most difficult, both from the technical and technological sides, is the formation of voids. The voids in the slab are necessary to reduce its weight and, accordingly, reduce the load on the building. However, this imposes additional requirements on the strength of concrete in the partitions and shelves of the slabs. The solution to this problem is associated with an increase in the strength of concrete slabs by optimizing the composition of concrete and the selection of rational technological equipment. Optimization of concrete compositions can be performed by reducing its water content while providing the necessary for effective compaction during molding workability and cohesion of the structure.

In the manufacture of hollow core slabs, a violation of their geometric dimensions is often observed (creeping of arches, faces, etc.). One of the reasons for these violations is the use of non-optimized concrete mixes. The device of voids in the plates allows to reduce their weight while maintaining the bearing capacity. However, this imposes additional requirements on the strength of concrete in sufficiently thin walls and partitions of hollow slabs. The required concrete strength in a hollow core slab is achieved by optimizing the consumption of binder and aggregates in concrete, reducing the water content of the concrete mixture, and also by choosing the optimal technological equipment.

Improving the technological modes of production of flat products on pallets circulation lines and modern bench lines requires solving a number of problems, including: to optimize the compositions and modes of heat treatment and their effect on the basic physical and mechanical properties of heavy concrete of flat products.

3. Results and discussions
Modern super- and hyperplasticizers are more effective additives for concrete and comply with current sanitary and epidemiological standards. Currently, they are increasingly being used in the manufacture of building products and structures. New RCA additives are developed taking into account the targeted effect on the properties of the concrete mix and hardened concrete, for example, by controlling the rheological properties of the mixture.
These additives are mass-produced by industry and they are actively used, for example, to obtain high-quality concrete surfaces in structures manufactured by continuous formless molding using specialized machines (extruders, splitformers, vibration casting machines, etc.) and on conveyor lines.

In the production of vibropressed pre-stressed molded concrete products on long heated stands by continuous formless molding, these additives have a stabilizing effect on the technological properties of moderately rigid and rigid concrete mixtures, as well as increase the density and strength of concrete and give products water-repellent and water-repellent properties.

Production research of bench production was carried out directly on the bench line of Volgotranszhelezobeton LLC (Samara) for the manufacture of hollow core slabs.

The conducted studies have confirmed the possibility of optimizing the composition of concrete for the production of hollow core slabs.

In the production line, the vibro-extruder of the Russian company Construction-Technological Machines (STM) was used as a molding machine. On this production line, the concrete mixture from the concrete mixer was discharged directly into the dispensing hopper (such as a “shot glass”), which was transported by crane to the molding machine. Further, the concrete mixture was reloaded from the distribution hopper into the storage hopper of the molding machine. Compaction of the concrete mix with the workability grade P1 (1...4 cm) was carried out by the molding machine with two poly-frequency vibrators built into it. Vibroextruder molded products in one pass without the need for formwork (figure 1).

![Diagram](image)

**Figure 1.** Scheme of the technological line for the production of plates.

Heat treatment of products on the stand was carried out using tubular registers built into the floor of the molding line, through which hot water was supplied, which ensured the temperature of isothermal exposure of concrete in products of about 50 °C. The duration of the heat treatment of the products was 24 hours, including a temperature rise of 6 hours, isothermal aging of 12 hours, and cooling of 6 hours.

The concrete mixture was prepared using an additive of the “RCA” type in an amount of 0.16% in finished form by weight of the cement. Before use, the additive is dissolved in water in the ratio of one part of a concentrated solution of the additive to ten parts of water. To prepare the concrete mixture, Portland cement grade B42.5 in the amount of 365 kg/m³, a mixture of fine (Mkr = 1.1) and coarse (Mkr = 3.4) sand in the amount of, respectively, 425 kg/m³ and 505 kg/m³ were used; crushed stone (quarry “Ivanteevka”, Kazan) with a brand for crushability D800 and fractions 5 ... 20 mm in an amount of 1020 kg/m³.

The main characteristics of concrete obtained by research: concrete strength class - B25; the actual average density of concrete is 2290 ... 2320 kg/m³; the required concrete strength is 33 MPa with an average value of the coefficient of variation of concrete strength up to 6%; the transfer strength of concrete made it possible to release reinforcement tension on it after heat treatment.

In the manufacture of wall panels on conveyor lines, it all starts with the cleaning of pallets using a machine for cleaning pallets. On-board equipment is similarly cleaned using a special machine. The movement of pallets is carried out using roller tables: leading and guiding. Further, from the cleaning station, the pan moves to the lubrication station. After lubrication, marking is applied to the pallet with a plotter for the subsequent installation of a magnetic tool on it. Next, the pallet is sent to the post installation rig.
The installation of a magnetic tool is carried out automatically by the robot. After installing the rigging, the pallet goes to the post for installing additional formwork made of polystyrene foam. Next, the pallet moves to the reinforcement post, which is carried out by the robot. At the reinforcement station, elements are installed that ensure the formation of a protective layer of concrete in the product.

After that, the pallet goes to the installation post of embedded parts and sling loops. After the installation of the entire reinforcement, the pallet is sent to the molding station using the lateral movement devices. The concrete mix is laid on a pallet by a screw paver. The auger paver receives the concrete mix from the addressable feed plug, which drives up on separate suspension rail tracks from the concrete mixing unit.

After molding, the pallet goes to the vibratory compaction station of the concrete mixture, where the vibrating platform the pallet is slightly raised to get off the axis of movement, and vibrated using a complex of vibrators. Then, after sealing, the pallet enters the surface smoothing station. Smoothing the surface is carried out using a vibrorail and a blade trowel. After smoothing the surface, the pallet passes to the post of heat treatment in a vertical cell chamber. Using a stacking device, the pallet is transported to a free cell in the chamber for heat treatment. After heat treatment, the pallet with the product enters the striping station at the tilter, where the product is tilted together with the pallet for vertical removal, separated from the pallet and sent to the finished goods warehouse using an overhead crane.

Next, the product is sent with a bridge crane to the finishing station, and the pallet after stripping with the help of lateral movement devices is sent to the cleaning station. After finishing, the product is marked and sent to the warehouse using a self-propelled trolley. Also for the production of three-layer wall panels provides a post installation of insulation. Automatically through the central control system, the installation of on-board equipment, the movement of pallets along the posts of the processing line, the manufacture of a reinforcing cage for the product, the placement of molds with products in the compartments of the rack of the stacked heat treatment chamber are also carried out (figure 2).

**Figure 2.** Panel production scheme.

One of the tasks on the lines of circulation of pallets is to optimize the modes of heat treatment of products in vertical cell chambers.

For heat treatment of concrete, as a rule, chambers for drying products are used, equipped with shelves, heat generators with gas burners and recirculation fans. This allows you to abandon the device costly boiler rooms, supplying steam for heat and moisture treatment of products. It should be noted that the cameras are loaded with pallets with products completely automatically using a lifting and transfer platform controlled by an automated computer system.

Cameras are vertical racks (compartments) with sections (cells) for placing pallets. Each section (cell) contains one pallet. Racks (compartments) are equipped with insulated walls to reduce heat loss. The dimensions of one section (cell) of the heat treatment chamber are about 11.2×4.0×0.6 m.

For heat treatment, a low-temperature regime is used, at an isothermal holding temperature of about 50 ... 60 ° C.
Shows the calculation of the required number of sections (cells) in the heat treatment chamber with a line rhythm of about 35 minutes (see table 1).

**Table 1. Modes of heat treatment of concrete in a vertical chamber**

| The strength of concrete from the design for 28 days, (%) | Temperature of isothermal exposure, (°C) | The duration of the concrete heat treatment of, (h) | The number of sections (cells) in the heat treatment chamber, (pcs.) |
|---------------------------------------------------------|-----------------------------------------|-----------------------------------------------|--------------------------------------------------|
| 70                                                      | 60                                      | 32                                            | 48                                               |
| 70                                                      | 50                                      | 40                                            | 60                                               |
| 50                                                      | 60                                      | 16                                            | 24                                               |
| 50                                                      | 50                                      | 20                                            | 30                                               |

The practice of improving the technological parameters of the production of reinforced concrete has revealed a number of problems that require further research aimed at optimizing the grain composition of aggregates and the content of the mortar component of the concrete mix and at minimizing the water-cement ratio due to plasticization while ensuring the necessary workability, structural cohesion, delamination and water separation of the concrete mixture.

4. **Conclusions**

The formation of precast concrete products using an additive of the type “RCA” leads to a decrease in water demand and an increase in the uniformity and cohesion of the concrete mixture and makes it possible to reduce the adherence of the mixture to technological equipment, which makes it possible to accelerate the set strength of concrete with the possibility of reducing cement consumption, improve the quality of the molded products, to stabilize the geometry of freshly molded products, to achieve a smooth and high-quality surface of products and to reduce defects associated with spontaneous damage to freshly molded products.

The use of the low-temperature regime of concrete heat treatment in vertical batch chambers equipped with heat generators with gas burners or on bench lines with hot water heating allows us to abandon the traditional heat-moisture treatment of concrete with steam and provide the necessary conditions for concrete hardening with design physico-mechanical properties.

**References**

[1] Cao G, Li N Z and Guo K 2017 Analytical study on the change of fluidity of fresh concrete containing mineral admixture with rest time *J. of Adv. Concrete Technology* **15** pp 713-23 (https://doi.org/10.3151/jact.15.713)

[2] Abbas S, Nehdi M L and Saleem M A 2016 Ultra-high performance concrete: Mechanical performance, durability, sustainability and implementation challenges *Int. J. of Concrete Structures and Materials* **10** (3) pp 271–95 (https://doi.org/10.1007/s40069-016-0157-4)

[3] Ma H and Li Z 2013 Realistic pore structure of Portland cement paste: Experimental study and numerical simulation. *Computers & Concrete* **11** (4) pp 317–36 (https://doi.org/10.12989/cac.2013.11.4.317)

[4] Bediako M, Kevern, J and Amankwah E 2015 Effect of curing environment on the strength properties of cement and cement extenders *Materials Sciences and Applications* **6** pp 33–9 (https://doi.org/10.4236/msa.2015.61005)

[5] Hilal A A, Thom N H and Dawson A R 2015 The use of additives to enhance properties of pre-formed foamed concrete *IACSIT Int. J. of Eng. and Technology* **7** (4) pp 286-7 (https://doi.org/10.7763/ijet.2015.v7.806)