Methods for ensuring the required consumer properties for
the construction of transport facilities in an accelerated time
frame

I S Pulyaev, S M Pulyaev
Department of Building Materials and Materials Science, Moscow State University of
Civil Engineering, 26, Yaroslavskoe shosse, Moscow 129337, Russia

E-mail: ivanes50@mail.ru

Abstract. The article discusses methods for providing concreting of transport objects without
defects using the example of the construction of a bridge across the Kerch Strait. It is shown
that through the use of modern calculation and analytical methods, it is possible to obtain high-
quality structures and operational reliability under the conditions of the necessary construction
pace. These methods are based on the construction of a thermophysical model of the processes
that occur in hardening concrete during heating and cooling. The existing experience in the
construction of similar facilities is also taken into account. The problem posed today is relevant
in connection with the development of bridge building in our country. It has important
economic and geo-political significance, and its solution is not possible without taking into
account the temperature factor of hardening concrete. The proposed methods made it possible
to ensure the required operational properties of the structures of this type and to withstand the
established deadlines for the construction of the Crimean bridge. They can be used in the
construction of other objects of this type.

1. Introduction
The development of transport infrastructure in the Russian Federation is directly related to
transformations in the economic and financial spheres in the state. This has a significant impact on the
logistics processes that ensure the economic stability and security of our country. An important place
in this process is to ensure the reliability and safety of passenger and freight traffic. In this regard,
today increasingly high standards and requirements are imposed to ensure the durability and reliability
of transport facilities [1-4]. A special place among them is occupied by bridges. Over the past decades,
numerous transport facilities have been built in Russia. Among them are both the same type of bridges
and large construction projects, the construction of which allowed significant changes to be made to
the road transport infrastructure of our country. Among these objects are a cable-stayed bridge across
the Oka River bypassing the city of Murom in the Vladimir Region, a bridge over Russky Island in the
Far East, transport crossings in Moscow and St. Petersburg, and, of course, the Crimean Bridge.
Crimean Bridge is the largest modern facility, the construction of which allowed solving complex
socio-economic and political issues of the peninsula.

The construction of bridges is most often carried out in difficult conditions in rough terrain. In this
regard, special requirements in this case are imposed on concrete transport structures. It is the main
building material that is used in the construction of bridges [5-8]. For the construction of bridge
supports (grillages, racks, crossbars), concrete of class B25 ... 30 is most often used. But in some
cases, such as during the construction of the Crimean bridge, concrete of class B35 was designed for the construction of supports directly in the strait. This is due to the construction of a bridge in rough terrain and difficult geological and geodetic conditions [9-10]. The use of high-grade concrete directly leads to increased heat generation. In this regard, it becomes necessary to solve the problem of optimizing the temperature factor. It is directly related to improving the operational reliability and durability of building structures and ensuring the specified pace of construction of the entire facility.

Designers and builders encountered a similar problem and the search for ways to solve it when erecting the supports of the Crimean bridge. The project provided for the construction of a connected road and railway bridge in difficult geological and geodetic conditions. In this regard, when designing the facility, it was decided to build massive grillages of supports measuring 19.5 x 10.2 x 4.0 m. During the construction, it was supposed to lay the volume of concrete mix 800 m³. Given the economic and geopolitical significance of this facility, the construction contractor set a short deadline for the construction of the facility. This required the search for ways to optimize the time spent on laying and maintaining the concrete structure.

2. Methods
The complexity of the task was that the construction of the bulk of the massive grillages with a production schedule was planned for July - September. During this period of time, at the junction of the Taman and Kerch peninsulas, the highest air temperatures are observed day and night. Therefore, it was decided to conduct thermophysical calculations of hardening concrete using the ZA settlement and analytical complex [11-13]. Preliminary thermophysical calculations showed that the cooling time of the concrete mixture when concreting the grillage at one time to a temperature of 50°C, at which construction of supports and racks is possible, is more than 40 days [14-17]. This does not allow the construction of supports and the entire bridge for the period of time regulated by the construction period of the entire facility. In addition, in the concrete structure during its heating and cooling, large temperature differences are observed. And even taking into account the formation of a favorable thermally stressed state of its own in hardening concrete in the structure, temperature cracks can be formed during the removal of the formwork and subsequent operation of the bridge. This is due to the fact that the basis for the construction of the grillage is a field of bored piles. Their temperature conditions have an uneven effect on the concrete grillage [18-20]. The design scheme of the grillage during concreting in one step is shown in Figure 1. Graphs of the temperature and curing strength of concrete at a concrete mixture temperature of 20°C and an ambient temperature of 20°C are shown in Figure 2.

In this regard, it was decided to carry out phased concreting of the support grillages. It is based on the method used earlier when erecting a cable-stayed bridge across the Oka River in 2006 ... 2009, bypassing the city of Murom in the Vladimir region. The essence of this method is that the massive part of the pylon was divided into three concrete blocks and their construction was carried out in stages. First, two extreme massive blocks were erected, and then a thin block - a jumper. However, in the case of the construction of the Crimean bridge due to the tight construction time of the facility, it was decided to erect the grillages of massive supports with vertical grips with a breakdown into length concrete blocks. In this case, the first grab was taken equal to 0.8 m, the second - 3.2 m. The design pattern of the grillage during phased concreting is shown in Figure 3, a graph of the temperature and strength gain of concrete at a concrete temperature of 20°C and an ambient temperature of 20°C - in Figure 4.
Figure 1. Design scheme of the grillage 19500x10200x4000 mm.

Figure 2. Graph of temperature change (a) and strength gain (b) of concrete at the temperature of the concrete mix 20°C and the environment 20°C.
Figure 3. Design scheme of the grillage (for step-by-step concreting).

Figure 4. Graph of temperature change (a) and strength gain (b) of concrete at the temperature of the concrete mix 20°C and the environment 20°C (with step-by-step concreting).
3. Results
The presented calculations showed that concrete reaches a predetermined temperature within 24 days. This time was sufficient from the point of view of rearranging the removable formwork of the bridge grillages. In this case, when concreting, the blocks were covered with a layer of plastic film, two layers of heat-moisture material and two layers of plastic film. They protected the heat-moisture material from getting wet in inclement weather. Thus, the total thermal resistance over the surface of the grillage $R = 0.6 \ldots 0.7 \text{ m}^2\text{h}\times\text{°C/kcal}$ was created. For all faces and edges of the structure to a width of 600 mm, a thermal resistance of $R = 1.0 \text{ m}^2\text{h}\times\text{°C/kcal}$ was created. It was provided by additional laying of two layers of heat-moisture material according to the concrete structure and installation of three layers of heat-moisture material and a layer of plastic film on the formwork. Thermal resistance $R = 0.6 \ldots 0.7 \text{ m}^2\text{h}\times\text{°C/kcal}$ was provided for the formwork. It was obtained by setting a layer of heat-moisture material and a layer of plastic film on the formwork. The general scheme for sheltering the grillage is shown in Figure 5.

![General scheme of the grillage shelter.](image)

Figure 5. General scheme of the grillage shelter.

This technology was agreed by the construction customer and allowed to accelerate the process of erecting the facility by reducing the construction time of concrete of massive grillage blocks. In addition, the possibility was realized of the serial arrangement of no less massive bodies of supports and uprights in parallel with the third block - a jumper. The obtained results formed the basis of specially developed technological regulations for the production of preparatory, reinforcing, formwork and concrete work in the construction of the Crimean bridge. They also ensured the accelerated turnover of the formwork system of the support grillages and, most importantly, made it possible to
obtain defect-free structures with the specified consumer properties of the individual structural elements and the entire Crimean bridge as a whole.

References

[1] Solov'yanchik A R and Shifrin S A 2000 Management of thermally stressed state of monolithic reinforced concrete structures in high-speed year-round construction of transport facilities (Moscow: Scientific works OAO TSNIIS) 203 25–32

[2] Tarasov A M, Bobrov F YU and Pryakhin D V 2007 Scientific and technical journal "Bridge building messenger" 1 21–26

[3] Pryakhin D V 2009 Scientific and technical journal "Transport construction" 10 11–13

[4] Zhu H, Hu Y, Li Q and Ma R 2020 Construction and Building Materials 244 118318

[5] Machelski C and Pustelnik M 2019 Proceedings of the fib Symposium 2019: Concrete - Innovations in Materials, Design and Structures pp 1461–1468

[6] Xin J, Zhang G, Liu Y, Wang Z and Wu Z 2018 Construction and Building Materials pp 381–390

[7] Wu J, Liu X, Wu H, Li L and Liu Z 2020 Journal of Testing and Evaluation 48(4)

[8] Nosov V P, Dobrov E M, Chistyakov I V, Borisiuk N V and Fotiadi A A 2017 International Journal of Applied Engineering Research 12(23) 13158–13164

[9] Solov'yanchik A R, Smirnov N V and Il'in A A 2004 Determination of the modulus of elasticity of concrete at an early age and features of its account in the calculations of the thermally stressed state of structures (Moscow: Scientific works OAO TSNIIS) 204 27–32

[10] Shifrin S A 2007 Scientific and technical journal "Appliances" 5 18–22

[11] Pulyayev I, Pulyaev S, Bazhenov Y, Fetisova A and Scherbeneva O 2019 Web of Conferences E3S

[12] Solov'yanchik A R, Shifrin S A, Korotin V N and Veytsman S G 2003 Realization of the concept of "quality" in the construction of the Gagarinsky tunnel in Moscow (Moscow: Scientific works OAO TSNIIS) 217 206–212

[13] Sokolov S B 2002 Influence of air temperature fluctuations in hotbeds on the temperature of hardening concrete during the erection of monolithic slab-ribbed spans during the cold period of the year (Moscow: Scientific works OAO TSNIIS) 213 167–172

[14] Solov'yanchik A R, Korotin V N, Shifrin S A and Veytsman S G 2002 Scientific and technical journal "Bridge building messenger" 3-4 53–59

[15] Ginzburg A V 2014 Scientific and technical journal "MGSU messenger" 1 98–110

[16] Pulyayev I S and Dudayeva A N 2019 Investigation of the temperature regime of hardening concrete of the upper layers of the upper part of the pylons during the construction of the bridge over the Oka River on the bypass of the city of Murom (Moscow: Scientific works OAO TSNIIS) 251 45–52

[17] Kolchunov V I and Iliushchenko T A 2020 Journal of Physics 1425(1) 012095

[18] Vasil'yev A I and Veytsman S G 2015 Scientific and technical journal "Bridge building messenger" 1 2–17

[19] Balyuchik E A and Chernyy K D 2010 Increasing the crack resistance of bridge supports made of solid concrete with constructive methods (Moscow: Compilation of scientific papers TSNIIS) 257 49–57

[20] Kosmin V V and Mozalev S V 2014 Scientific and technical journal "Bridge building messenger" 1 19–24