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“QURILISHDA YASHIL IQTISODIYOT, SUV VA ATROF-MUHITNI ASRASH TENDENSIYALARI, EKOLOGIK MUAMMOLAR VA INNOVATSION YECHIMLAR” MAVZUSIDAGI RESPUBLIKA MIQYOSIDAGI ILMIY-AMALIY KONFERENSIYA TASHKILIY QO‘MITASI

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Technology of underwater laying of concrete mortar in the construction of bridge structure foundations

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Abstract: The article discusses bridges, which are engineering structures designed to lay transport highways over natural and artificial water obstacles, and the technologies for their underwater construction. In particular, the technology of laying concrete mix using the VPT (vertical movable pipe) method, which is one of the important stages in the underwater construction of bridge foundations, is analyzed. The VPT method allows maintaining the quality of concrete in an underwater environment, ensuring its hydraulic properties and strength. This method is widely used in areas where groundwater flows under high pressure, drilled wells, pile foundations, and other structures. To prevent the separation and washing away of the concrete mixture, the stability of the water retention systems and the concrete at the end of the pipe is strictly controlled. The article also extensively covers the complexity of underwater and surface works, their technological and engineering features

Keywords: Bridge structures, underwater construction, VPT method, concrete mix, foundation construction, cement layer, hydrostatic pressure, geotechnical reinforcement, segregation, construction technology

1. Introduction

Bridges are engineering structures designed to lay transport highways on water obstacles, including natural or artificial obstacles, such as rivers or canals. Bridges play an important role in ensuring the continuity of traffic, safe and efficient transportation of goods and passengers, and interconnection of transport networks. Bridges can be built not only over water obstacles, but also over gorges, highways, railways, valleys, and other obstacles. Bridge construction is a complex and multi-stage engineering process, in which underwater and surface work is carried out, and it is one of the most complex and important components in the process of installing building structures. This stage consists of such works as underwater construction of foundations, installation of hydraulic structures, soil compaction and geotechnical strengthening works in the underwater part, selection of materials resistant to prolonged exposure to water, and the technology of their installation. The complexity of underwater work is mainly determined by such factors as limited visibility and freedom of movement, the influence of hydrostatic pressure and flow velocity on the structure, and the need to equip construction machines and mechanisms with special devices. Construction and installation works carried out on water include the assembly of intermediate support bodies. The above-mentioned processes are carried out with a deep analysis of engineering and geological conditions, hydrological characteristics of the construction site, and modern capabilities of construction technology.

2. Methods

The main technological methods used in underwater concrete works are:

The method of pouring concrete through vertical metal pipes is the most effective and widespread form of placing concrete mixture underwater, in which concrete is poured through a special vertically placed pipe. The lower end of the pipe is constantly kept in a layer of poured concrete, which reduces hydrodynamic impacts and prevents the mixture from washing away. Pump transfer technology in which the concrete mixture with high mobility is transferred directly underwater using special hydraulic concrete pumps. The outlet of the pump pipes is also located inside the concrete, which ensures high speed and continuous concrete pouring. The method of submerging concrete bags - concrete mix prepared by this method, used for local reinforcement work, is placed in special waterproof bags made of dense textile material and placed on the underwater base. Concreting with the construction of a dry working chamber (coffer dam) with complete water separation in this method, the underwater working area is completely isolated using metal or reinforced concrete barriers, then the internal water is completely pumped out using pumps, and traditional concreting is carried out. The method of submerging prefabricated reinforced concrete blocks - in this method, monolithic blocks manufactured in factory conditions are submerged using special lifting devices and installed as a structural element of the foundation structure. High installation speed and a high level of quality control characterize this method.

3. Results and Discussion

When constructing underwater foundation parts of bridge structures, underwater laying of concrete mix is an important technological stage. This process is usually carried out using the vertical moving pipe (VPT) method, which is widely used as one of the main methods of underwater concreting technology.

The VPT method is effectively used in the following cases:

- during the laying of reinforced concrete sealing layers, especially in underwater foundation pits;
- during the installation of drill piles, when pouring concrete mix into the cavities of drilled wells;
- when filling the internal cavities of pile-shell foundation elements with concrete.

Laying the tamping layer When constructing a shallow foundation, if a large flow of groundwater is poured into the pit, it is necessary to lay a tamping layer under this foundation (Fig. 1). In this technology, the concrete mixture is discharged from the pipe through the VPT from bottom to top, i.e., with the help of a pump or gravity. Thus, mixing with water is minimized, and the structural integrity, strength, and hydraulic properties of the concrete are

preserved.The concrete mix used in this case is specially modified for underwater laying, i.e., it has low salinity rates, high plasticity, sulfate resistance, and viscosity properties. In order to prevent the separation and washing away of concrete during the concrete pouring process, it is strictly controlled that the water-retaining systems and the end of the pipe are constantly filled with concrete. The VPT method is one of the most reliable and technologically efficient solutions for concreting works in deeply grounded environments with high hydrostatic pressure.

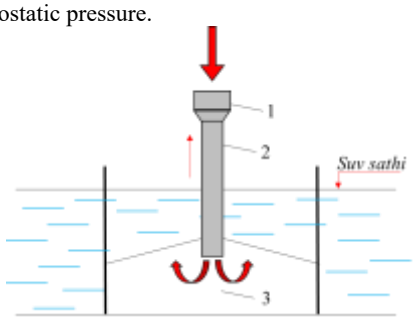

Fig. 1. Underwater concreting by the VPT method:
1 - funnel; 2 - concrete pouring pipe; 3 - underwater concrete

The technology of laying the cementing layer by the VPT method can be as follows:

1. Concrete pouring pipes, consisting of links 3-4 meters long, connected to each other by flanged connections, are installed on substrates (for example, installed on barriers); these pipes have funnels at the top, each with a volume of 1.2-1.5 cubic meters.

2. At the mouth of the funnel, a stopper is placed, connected to the upper part of the funnel with wire (for example, made of a sack-bag filled with loess).

3. The lower end of the concrete pouring pipe is lowered into the water at the bottom of the pit.

4. Poured concrete mixture with cone settlement of 16-18 cm is placed in the receiving hopper of the concrete pouring pipe until the hopper is completely filled.

5. The wire connecting the placed cork to the upper part of the funnel is cut off, and the mass of the concrete mixture, displacing water, is directed down the pipe. If the length of the concrete pouring pipe is large, simultaneously with opening the cork at the hopper opening, the damper of the hopper filled with concrete mixture above the funnel is also opened. Otherwise, the mass of the concrete mixture filled into the receiving hopper of the concrete pouring pipe may not be sufficient to displace water from the pipe.

6. If the concrete mixture has not reached the required level, the pipe is lifted slightly with a crane and immediately placed at the bottom of the pit.

7. A new portion of the concrete mixture is placed in the receiving hopper of the concrete pouring pipe.

8. When laying the cementing layer under the foundation pit, the concreting intensity should be at least 0.3-0.4 $m^3/(m^2hour)$ per hour.

As the concreting work continues, the poured concrete mixture gradually spreads across the surface of the pit. Since the concrete mixture is fed into the previously laid concrete layer, it only contacts the upper layer of concrete with water, and as a result, this layer weakens. After draining the water from the pit, this weak upper layer of concrete must be removed. In the process of laying underwater concrete using the VPT method, after loading a portion of concrete into the concrete pouring pipe, this pipe is slightly stretched and quickly returned to its place. Such a movement is carried out in any case to ensure that the concrete pouring pipe is buried in the concrete mixture no less than 0.8 meters and no more than 2 meters. The construction foreman (master) must constantly measure the concrete level and monitor that the concrete pouring pipe is sufficiently lowered into the concrete layer.

Several concrete pouring pipes are used for concreting the waterproofing bed in the pit. They are located so that the areas of the sections served by them overlap each other, completely covering the concreting area.

The radius of movement of the concrete pouring pipe can be determined from the following expression:

$$R = 6 \cdot K \cdot I \quad (1)$$

here: K – the indicator of maintaining the workability of the concrete mix, i.e., the time required to reduce the cone settlement to 0.15 m (K = 0.65 hours);

I – concreting intensity, in m^3, this intensity should be at least 0.3 $m^3/(m^2hour)$ for pits (it is advisable to have this value of 1-1.2 0.3 $m^3/(m^2hour)$, so the pipe's radius of movement is 3-4.5 meters).

Concrete work begins using one of the pipes located at the edge of the pit. The next pipe is started when the concrete mixture is spread across the pit area and covers the lower end of the pipe to a depth of 30-40 cm. When using several pipes, the laying of the concrete mix is carried out sequentially. During concreting, the distance between adjacent pipes should not exceed 0.7 of the pipe's radius of movement.

When carrying out underwater concreting, water penetration into the concrete pouring pipe is unacceptable. If such a situation is observed, concreting must be stopped. If the interval for concreting does not exceed the time required to maintain the workability of the concrete mix (i.e., 0.65 hours), the concreting work can be continued. If this period is exceeded, reinforcement work is permitted only after the strength of the underwater concrete reaches 2-2.5 MPa.

When pouring concrete mix, low-strength underwater concrete is formed. Even when 400 kg of cement is used per cubic meter of underwater concrete, the strength of such concrete is only around 10-15 MPa.

When it is necessary to obtain high-strength underwater concrete, the density of the concrete mix must be increased, and the amount of cement added per cubic meter of concrete should be significantly increased (up to 600 kg/m^3). However, a dense concrete mix does not spread well in the cofferdam, so vibrators must be used during placement. To place a dense concrete mix with a slump of 6–10 cm into a cofferdam up to 20 meters deep, one vibrator is attached to the lower end of the concrete pouring pipe. If the cofferdam is deeper than 20 meters, two vibrators are firmly secured. Vibration facilitates the movement of the concrete mix through the pipe and its spreading over the cofferdam area. During underwater concreting with vibration, the maximum spreading radius of the dense concrete mix is 3 meters. The duration of mandatory pauses during concreting should not exceed 1.5 hours.

The minimum thickness of the tamping concrete layer laid on the soil bottom of the cofferdam is determined based on the balance between the weight of the layer and the hydrostatic uplift force of water (with a safety factor of 1.1), but in all cases, this layer must not be less than 1.5 meters thick. Water may be pumped out of the cofferdam only after the underwater concrete reaches a strength of at least 5 MPa. The top surface of the underwater concrete mass constructed using the VPT method must be concreted 10 cm higher than

the design level, which allows the weak upper layer of the concrete to be removed after the cofferdam is dewatered.

Pile caps are also often constructed with a waterproof bedding layer (tamping layer) laid using the tremie pipe method (VPT). After dewatering the cofferdam and removing the weak upper layer, the top of the tamping layer must not rise above the bottom level of the pile cap. The thickness of this protective layer (when the concrete mix is laid on an artificial bed) must not be less than 1 meter. The tamping layer is not considered a part of the pile cap structure and is not included in structural calculations.

For low-level pile caps, the tamping layer is placed directly on the bottom of the sealed cofferdam. For high-level pile caps, it is laid over a sand bedding layer poured inside the enclosure. When the water depth in the river is significant, the underwater concrete is placed at the specified level on the bottom of a securely fixed box-frame (as shown in Figure 1). Gaps between the pile walls and the bottom of the box-frame are thoroughly filled in advance by divers.

The technology for underwater concreting of pile caps is similar to that used in the construction of foundations located on natural ground.

Under certain conditions, the tamping layer can also be placed using the upward-flowing grout method. For this, a coarse fill layer is laid inside the cofferdam bounded by barriers, after which grout is pressure-pumped through pre-installed vertical pipes positioned across the cofferdam area.

4. Conclusion

Underwater foundation concreting is a critical process carried out under complex geotechnical and hydraulic conditions. To achieve high-strength concrete, a dense mix containing up to 600 kg/m³ of cement is used, along with mandatory vibration tools. For concrete with a slump of 6–10 cm, one vibrator is used for depths up to 20 meters, and two vibrators are required for deeper placements. Vibration ensures smooth flow through the tremie pipe and allows the mix to spread up to 3 meters. The thickness of the bedding (tamponage) layer must be at least 1.5 meters and calculated to resist hydrostatic uplift (with a safety factor of 1.1). Water can be pumped out of the cofferdam only after the concrete reaches a strength of at least 5 MPa. Using the tremie method (VPT), concrete is poured 10 cm above the design level to allow for later removal of the weak surface layer.

Tamponage layers are also used under pile caps but are not part of the load-bearing structure and are not considered in strength calculations. In deep riverbeds, concrete is placed inside predefined box-frames, and gaps between piles and the frame bottom are pre-filled by divers. In special cases, the rising mix (VR) method can be applied, where concrete is pumped through vertical pipes under pressure to fill voids evenly within the confined area. These technologies ensure the construction of high-quality and durable underwater concrete foundations.

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