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NEW STRUCTURAL AND TECHNOLOGICAL SOLUTIONS FOR FOUNDATIONS OF SUBMERGED UNDERWATER TUNNELS

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This paper presents new design and technological solutions for bases and foundations for deep underwater transport tunnels. Tunnels are less susceptible to seismic effects, since they do not have resonant phenomena, unlike ground structures. During the passage of seismic waves, tunnels are deformed in the same way as the surrounding soil mass, if the soil is solid, or significantly less if the soil is weak. These deformations are usually small and do not pose a serious danger to tunnel linings.
Keywords: *submerged tunnels, underwater tunnels, tunnel bases, pile foundations, foundations with extensions.*

НОВЫЕ КОНСТРУКТИВНО-ТЕХНОЛОГИЧЕСКИЕ РЕШЕНИЯ ДЛЯ ФУНДАМЕНТОВ ЗАТОПЛЕННЫХ ПОДВОДНЫХ ТОННЕЛЕЙ

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В статье представлены новые конструктивно-технологические решения оснований и фундаментов глубоководных транспортных тоннелей из сборных секций для слабых и структурно-неустойчивых донных грунтов. Тоннели менее подвержены сейсмическим воздействиям, чем мостовые сооружения, так как в них нет резонансных явлений (в отличие от наземных сооружений). При прохождении сейсмических волн тоннели деформируются так же, как и окружающий грунтовый массив, если грунт твердый, или значительно меньше, если грунт слабый. Рассмотрен практический опыт закрепленных донных оснований и устройства конструкций свайных фундаментов с уширениями.
Ключевые слова: *подводные тоннели, тоннельные основания, свайные фундаменты, фундаменты с растяжками.*

Introduction

As time goes on, technologies become more advanced, structural engineering barriers in construction break down, and restrictions expand, generating mind-boggling innovations that make us think. One of the most common methods in the development of railway construction is the device of lowering underwater tunnels when crossing water barriers. Which have different cross-sections.

Researches show that the conditions of crossing the Straits by sinking tunnels are assessed as uniquely complex due to natural, climatic and engineering-geological factors. A good example is the proposed underwater floating tunnel in Norway, which is estimated to be 4,000 feet long and 100 feet underwater, at a cost of about $ 25 billion. Construction is expected to be completed in 2035.

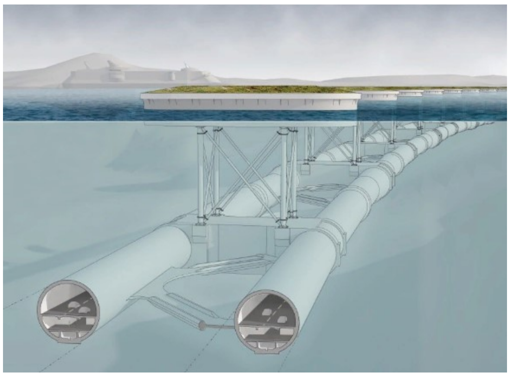


Fig. 1. Underwater tunnel Under construction in Norway

Materials and Methods.

Therefore, according to the design and technological solutions, long crossings over straits and wide rivers, especially on the territories of dissected landscapes by water barriers, can be divided into a tunnel-bridge version, combined with bridges (fig. 2, a), tunnel crossings from lowered sections combined with ground highways (fig. 2, b) and a tunnel version from lowered sections combined with a tunnel constructed by mountain method (fig. 2, c).

Usually, sections are designed so that when finished they have at least a small negative buoyancy, which guarantees against the need to take measures against the ascent of the tunnel. However, in this case, to keep the sections afloat, it is necessary to connect them with pontoons or, for circular sections, fill only partially the space between the steel shells with concrete before launching. This process continues in the floating state of the section and ends only after it is delivered to the place of lowering.

Before lowering the partition in proper position in the bottom of the watercourse, such as underwater dredging, develop the pit, the slopes of which give the slope, depending on the degree of stability of bottom sediments, rate and direction of flow, as well as from the content in the flow of suspended soil particles that can be deposited in the trench, forming a reclamation, impeding the lowering of the sections in proper position. The question of the purpose of the slopes of the pit slopes is solved in the process of hydrological studies of the watercourse.

Further preparation of the Foundation is performed in several ways. In some cases, a layer of sand, fine gravel or crushed stone 50–100 cm thick is laid on the bottom of the pit. Bulk materials are sent from the barge down the pipes and leveled with a special planning device suspended from a cart that moves along trusses mounted on two barges. The alignment accuracy of the bulk base is ±3 cm.

In other cases, the section rests on the bottom of the pit through four angular reinforced concrete support blocks suspended and connected in pairs in the transverse direction by steel tubular elements. It also shows the connection of the section to the support block by means of a short steel sub-Jack post passing through a hole in the lower plate into a niche in the wall of the section.

A third method has a more limited use – lowering sections on concrete grillage bushes of piles or anchors fixed in the bottom of the pit. In this case, the grillage is also used to secure cables that pull the section with positive buoyancy to the design position by means of polispastov.

One of the problematic tasks that researchers, designers and builders face when constructing tunnels from sinking sections is structurally unstable ground layers at the bottom of reservoirs. Soil is called the surface layer of the bottom of the reservoir and engineering and geological conditions at the location of the tunnel are often not favorable for construction, and solid soils lie, as a rule, at a depth of 20–30 meters. At the coast, mainly bedrock, as well as thin layers of sand and gravel come to the surface, and the sea floor along the tunnel route, in addition to coastal areas, consists of viscous soft rocks – clay, sandy silty bases or silts with layers of sea clay, so the soil at the base of the tunnel must be strengthened.

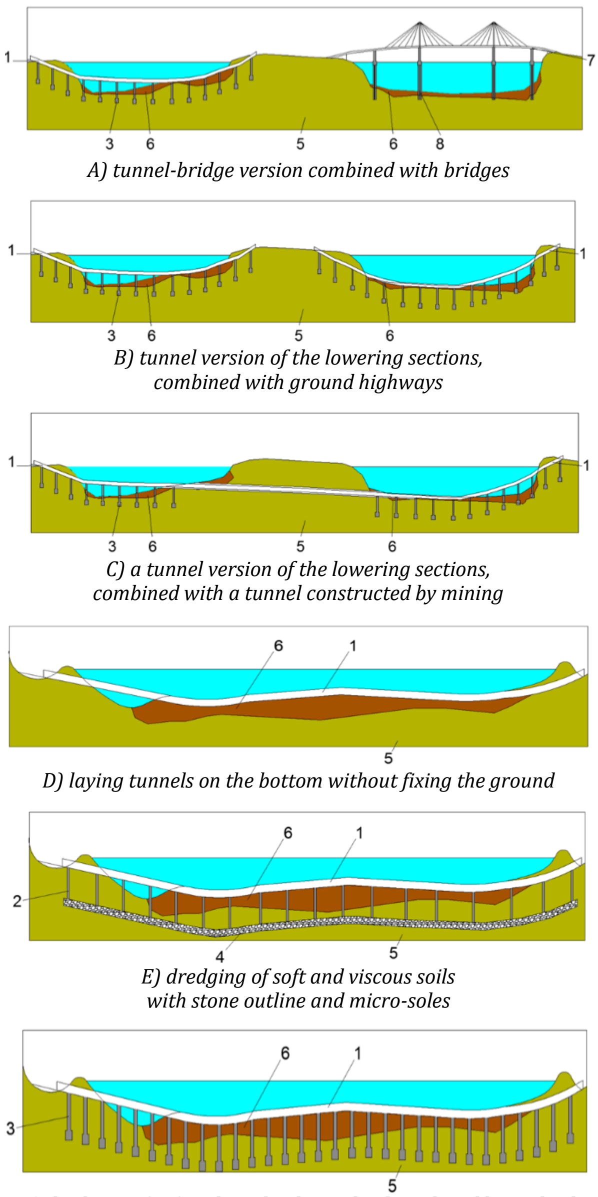
One of the ways to strengthen the weak muddy bases at the bottom of reservoirs is a stone outline. Stone outline is most often considered to be a dam made of sketched or loose stone, which has the shape of a trapezoid with equal slopes, the width of which is at least 3 meters. Great importance in the world has been attached to research to identify more new ways of using stone-fill dams.

In hydraulic engineering, masonry is very often performed without the use of binders in the following ways:

- outline of stone or small stone materials (crushed stone, pebbles, etc.);
- dry masonry, when the stones are selected in such a way that a more or less dense array is obtained with the dressing of rows of stone;
- laying mesh boxes, so-called gabions, filled with small stone.

Stone outline for strengthening the banks and bottom is used when there is a sufficient amount of suitable stone on or near the construction site from dense igneous, sedimentary and metamorphic rocks that have the necessary strength, resistance to the destruction of filtration flows, frost resistance for a long time and water resistance. The size of stones and thickness of the outline defined by the project depending on the flow rate, wave height, steepness of slope and the volume weight of the stone.

The stone outline is arranged by pouring stones directly into the water, it is only important to observe the correspondence of the mass of stones to the speed of water movement. During the dredging works, the stone is poured into the water from watercraft, which ensures a high rate of construction. The main drawback is the high cost of the stone outline, but in many cases this design of the bottom and bank protection is the only possible one.



A) tunnel-bridge version combined with bridges

B) tunnel version of the lowering sections, combined with ground highways

C) a tunnel version of the lowering sections, combined with a tunnel constructed by mining

D) laying tunnels on the bottom without fixing the ground

E) dredging of soft and viscous soils with stone outline and micro-soles

F) dredging of soft soils with piles with a broadened lower heel

Fig. 2. Structural and technological solutions for long passages across Straits on the territories of dismembered landscapes: 1 – tunnel of lowering sections; 2 – micro-piles; 3 – pile with end widening; 4 – stone outline; 5 – shoals and; 6 – weak soils of the reservoir bottom; 7 – bridge; 8 – bridge supports

According to the project documentation analysis [1–7], the results of the survey the authors of [8–11] and a number of manuals and recommendations on the design of bottom and bank stabilization silt reason [12–15], the following features enhance rock placement:

1) silty soils of reservoirs are classified as structurally unstable soils, the structure of which does not have strength and stability and can be disturbed by any action of additional (above natural) pressure (often very small);

2) the content of particles in silty soil is less than 0.01 mm, which is 10-30% by weight, i.e. such a base has almost no weight and can be displaced by the pressure of the weight of the stone outline;

3) volume of stone material in the outline should be determined in consideration of the safety factor on seal: for sand and gravel (macadam) mixtures optimal grain structure and gravel fractions 40-70 70-120 mm and brand strength of 800 or more, the safety factor of the material of the seal should roughly make a 1.25 to 1.3 and for gravel marks with strength 600-300 - 1,3-1,5;

4) the coefficient of slag reserve for compaction, depending on its density, should be approximately 1.3–1.5.

Figure 2 (d) shows a structural and technological variant of strengthening weak soils at the bottom of the reservoir when laying tunnels from the lowering sections with a stone outline and micro-trams.

The next constructive and technological method, often used in hydraulic engineering construction on weak soils, is the construction of bored piles with a broadened fifth in the lower part, the principle of which is mainly based on the method with an unrecoverable shell, when there is no possibility of high-quality manufacturing of piles with a removable casing pipe. Such conditions are created in hydraulic engineering construction, where under the pressure of water flows, the pile shaft in some areas can be destroyed during the hardening of the concrete mixture. For rice. 2 (e) presents a variant of strengthening weak soils at the bottom of the reservoir when laying tunnels from the lowering sections with bored piles with end widenings, which contributes to a significant increase in the load-bearing capacity and the required stability of the pile base under the tunnel.

Advantages and disadvantages of tunnels made of descending sections.

The large number of transport crossings built and operated in the world, which include tunnels made of drop sections, indicates the advantages of such projects in comparison with other types of transport crossings. Let's note some of them.

1. Currently, all stages of construction are well developed in the world: construction of sections, transportation of sections to the dive site, methods of diving.

2. Simultaneous production of a large number of sections of tunnels on the shore can significantly speed up construction, while using all the technologies and achievements that are used in the production of reinforced concrete products.

3. There is no impact on shipping during the construction process.

4. When operating transport crossings, neither the height nor the tonnage of vessels passing through Straits, bays and wide rivers is limited.

5. The project of a combined transport crossing consisting of bridges and tunnels made of descending sections may be more economical than the project of a large-span bridge and a mountain tunnel built using the shield method.

Conclusions

It should be noted that tunnels made of sinking sections also have disadvantages, which are their impact on the environment: they can affect fish habitats, change currents and reduce water transparency.

But the main drawback at the moment is the lack of experience in building tunnels of this type in the Russian Federation, as well as the lack of necessary equipment. Nevertheless, the time has come to start building this type of tunnel, especially since in Russia there are a large number of water (sea and river) barriers that must be crossed by transport crossings without disturbing navigation.

The analysis of constructed and projected transport crossings that use tunnels made of lowered sections shows that when choosing the option of crossing transport highways, the project of a tunnel made of lowered sections can be the most economical, reliable and acceptable in terms of costs, construction time and the use of modern technologies.

When choosing a bridge crossing option to ensure the passage of high-tonnage vessels, it is necessary to build large-span bridges on high supports. Weak structurally unstable soils, deep bedrock and high seismicity of the area will create serious problems in the construction and operation of such structures.

The natural frequencies of vibrations of large-span bridges fall into the region of the dominant frequencies of earthquakes, which can lead to resonant phenomena and damage the structure even under weak seismic influences.

Tunnels are less susceptible to seismic effects, since they do not have resonant phenomena, unlike ground structures. During the passage of seismic waves, tunnels are deformed in the same way as the surrounding soil mass, if the soil is solid, or significantly less if the soil is weak. These deformations are usually small and do not pose a serious danger to tunnel linings.

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ИССЛЕДОВАНИЕ ТЕХНИЧЕСКОГО СОСТОЯНИЯ ИСТОРИЧЕСКИХ ЗДАНИЙ И АНАЛИЗ СОХРАННОСТИ КАМЕННОЙ КЛАДКИ НЕСУЩИХ КОНСТРУКЦИЙ

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Рассмотрена проблема восстановления исторических зданий с учетом фактических физико-механических характеристик материалов каменной кладки, которая эксплуатировалась в сильно агрессивной среде. Приведен пример технического обследования здания церкви Воздвижения Креста в Воронежской области, в котором расчетным путем на основании обмерных работ и инструментального осмотра обоснована дальнейшая эксплуатация кирпичных сводов покрытия. Определены резервы несущей способности каменной кладки и стальных тяжей сводов, а также численные значения их напряжений с учетом фактических прочностных характеристик материалов. Выявлены причины высокой степени сохранности кладки стен и сводов покрытия, которые заключаются в высоком качестве исходных строительных материалов каменной кладки – кирпича и кладочного раствора швов.
***Ключевые слова**: историческое здание, техническое обследование, каменная кладка, кирпич, поверочный расчет.*

STUDY OF THE TECHNICAL CONDITION OF HISTORICAL BUILDINGS AND ANALYSIS OF THE PRESERVATION OF STONE MASONRY OF BEARING STRUCTURES

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The problem of restoration of historical buildings is considered, taking into account the actual physical-and-mechanical characteristics of masonry materials, which were operated in a highly aggressive environment. An example of a technical building inspection of the Church of the Exaltation of the Cross in the Voronezh region is given, in which the further operation of the brick vaults of the covering is justified by calculation based on the measurement work and instrumental examination. The reserves of the bearing capacity of the masonry and steel ties of the vaults, as well as the numerical values of the stresses in the masonry of the vaults, taking into account the actual strength characteristics of the materials, have been determined. The reasons for the high degree of preservation of the masonry of walls and roof vaults are revealed, which consist in the high quality of the initial building materials of the masonry, bricks and masonry mortar of joints.
***Keywords**: historical building, technical inspection, masonry, brick, verification calculation.*

При выполнении работ по оценке технического состояния несущих строительных конструкций исторических зданий следует особо отметить работоспособную категорию каменных конструкций даже при значительных неблагоприятных воздействиях факторов внешней среды. Цель данной статьи – на примере выполненного обследования здания церкви Воздвижения Креста в городе Новохоперске Воронежской области проанализировать причины высокой степени сохранности и достаточной несущей способности каменной кладки стен и сводов покрытия, которые на протяжении многих десятилетий находились без кровли и были подвержены влиянию атмосферных осадков.

Церковь была построена «восьмерик на четверике» и является объектом исторического и культурного наследия Воронежской области [1, 2]. Здание одноэтажное с подвалом, имеет размеры по осям 22,2 × 48,0 м и высоту до 22,9 м.

В 1930-х гг. церковь была закрыта, а крест с основного центрального свода сорвали трактором в 1960-е, повредив кирпичную кладку этого