UDC 624.19:006.354

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CONSTRUCTIVE SOLUTION OF A TUNNEL UNDER THE EXISTING HIGHWAY

Urban underground structures (shallow tunnels), which are usually built in conditions of urban area with heavy traffic, are considered. It was clarified that the reinforced concrete lining are performed of concrete, reinforced concrete, natural and artificial stones in most cases. The types of tunnels road cutting are given. The geometrical dimensions and characteristics of using materials in the construction of tunnels are given. It was established that the existing methods of tunnel construction do not allow to solve the problem in cramped conditions and intense traffic. The new constructive solution of the transverse tunnel under the existing highway was proposed. It is found that the proposed design of the transverse tunnel may be performed in cramped urban environments with the use of modern technological equipment and the proposed method of tunnel meets the requirements of strength, reliability, durability.

***Keywords:** cross-tunnel, tunnel lining, installation of horizontal directional drilling.*

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КОНСТРУКТИВНЕ РІШЕННЯ ТУНЕЛЮ ПІД ДІЮЧОЮ ТРАНСПОРТНОЮ МАГІСТРАЛЛЮ

Розглянуто міські підземні споруди (транспортні тунелі дрібного закладення), які споруджують звичайно в умовах забудованої міської території при інтенсивному вуличному русі. З'ясовано, що монолітні оброблення виконуються в більшості випадків з бетону, залізобетону, природних і штучних каменів. Наведено типи оброблень автодорожніх тунелів. Надано геометричні розміри та характеристики використаних матеріалів при споруді тунелів. Установлено, що існуючі методи спорудження тунелів не дозволяють розв'язати завдання в стиснутих умовах і при інтенсивному транспортному русі. Запропоновано нове конструктивне рішення поперечного тунелю під діючою транспортною магістраллю. З'ясовано, що запропонована конструкція поперечного тунелю може бути виконана в стиснутих міських умовах із застосуванням сучасного технологічного устаткування, а запропонований спосіб прокладання тунелю задовольняє вимоги міцності, надійності, довговічності.

***Ключові слова:** поперечний тунель, тунельні оброблення, установка горизонтально направленого буріння.*

Introduction. World practice of urban planning shows that one of the most effective ways of territorial, transport, environmental and energy issues decision is comprehensive underground space development, which can accommodate structures of different purposes [1, 2].

In recent decades, the growth in the volume and extent of underground construction is observed in large cities of Ukraine. Large underground complexes for various purposes, transportation and communication tunnels, underground parking lots and garages, manufacturing and warehouse facilities are built, the length of subway lines is increased.

Review of the latest research sources and publications. The development of large cities and the continuous growth of traffic demand improvement of the urban transport system. To ensure the rational organization of traffic and improve urban transport linkages there are provided dof facilities of transport crossings in different levels on the busiest routes and transport hubs, construction of subways lines, underground parking lots and garages. In the general complex of urban underground structures traffic and pedestrian tunnels of shallow are occupied an important place, that are pitched usually in terms of a built up urban area with heavy traffic. In the construction of these tunnels it is necessary to ensure the safety of buildings and structures on the route of the tunnel and continuous passage of vehicles on highways, which intersection is constructed in tunnel. Urban shallow tunnels are erected mainly by the open method with the reverse surface. In this work they are consistent in certain areas, the length of which is prescribed under minimal compression of traffic [3 – 8].

Definition of unsolved aspects of the problem. One of the main issues is the design of the transverse tunnel, which can be performed in cramped urban environments with the use of modern technological equipment.

Problem statement. The task of the research is development of transverse tunnel new constructive solutions with the use of devices atroscine technology for large and industrial cities with high density and intense traffic.

Basic material and results. Underground structures were known in ancient times. They were first for habitation and burials, in the construction of temples, and then for the extraction of stone and ore, and later for water supply purposes and irrigation. Then transport, communications and other types of tunnels came [9].

Design of tunnel cutting can be applied as prefabricated from reinforced concrete, concrete or metal elements and monolithic concrete or reinforced concrete. At this timein prolect of technical conditions it is noted that the main materials of tunnel cutting construction should be precast concrete and reinforced concrete. The internal design of stations and other tunnel structures, as a rule, is provised of precast concrete.

Concrete and reinforced concrete tunnel structures shall be calculated by the method of limit states (bearing capacity, deformation, the formation and opening of cracks), iron and steel structures can be calculated and allowing for tension.

Calculation of tunnel constructions is conducted on the basic, additional and special combinations of loads, which are taken in the most unfavorable for the individual elements and the entire structure combinations.

Regulatory pressure on the lining depends on the specific geological and construction conditions, tunnel construction: considering work of the breed and unloading of the arch, or on the total weight visaliaca rocks. The horizontal confining pressure is taken depending on physical-mechanical properties of rocks, but not more than 70% of the vertical rock pressure. If the rocks are free (unbound) water is also considered hydrostatic pressure.

The tunnel lining is built by closed method, and calculated considering elastic resistance of rock in the tray and the side parts of the loop processing. When the founding of tunnels is below ground water level, tunnel stability against the ascent is tested.

Monolithic lining are made of concrete in most cases, and of reinforced concrete, natural and artificial stones.

The concrete class is assigned to the B15, B25 for monolithic concrete cutting and B15-B30 is for precast concrete cutting. Masonry cutting of natural or artificial stone is made from cement mortar grade not lower than 50 for structures with exterior waterproofing and not lower than 100 or higher for structures without exterior insulation.

Processing of mining tunnels is satisfied primarily of reinforced concrete or reinforced concrete. The thickness of cutting should be at least 20 cm.

In the construction of mountain tunnels in the rock fractured rocks, renewed ordinary reinforced concrete is used in cutting with sprayed concrete which is deposited on the surface of the generation layer of 5 – 20 cm under the pressure of a 4 – 4.5 ATM. Using this type of concrete is got the reducing of cement consumption, increasing the density, water resistance. It greatly simplifies the process of concreting in absence of formwork.

To increase the bearing capacity of such a lining sprayed concrete, it is often reinforced with steel meshes.

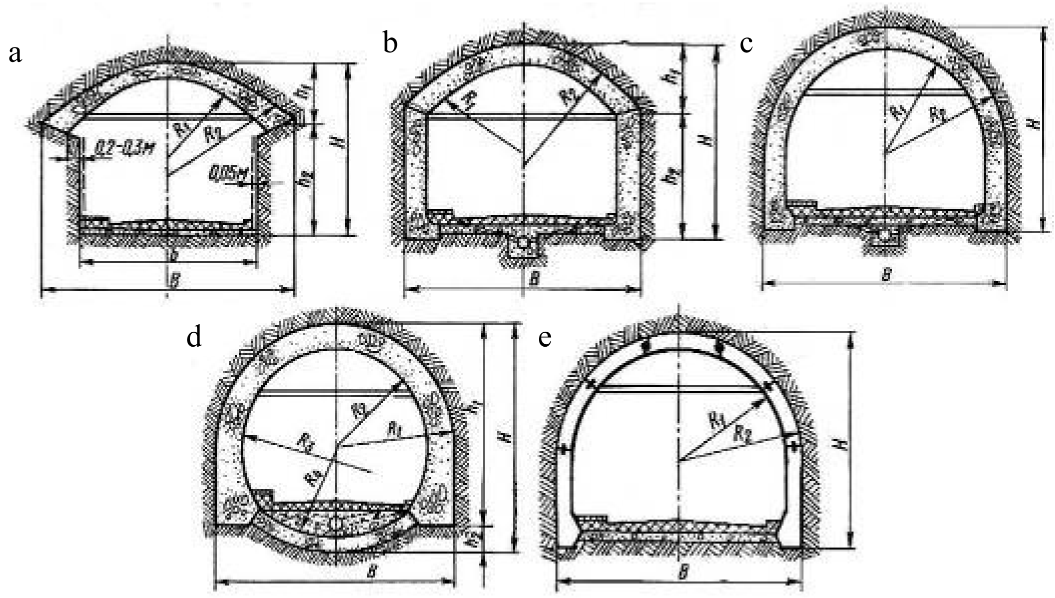

Figure 1 – Types of cutting in road tunnels:
a – cutting of normal cast in place concrete or sprayed concrete;
b – treatment consists of a vault based on a straight wall;
c – processing is in the form of not closed structures without a back arch;
d – treatment with massive walls of curved inner shape and a reverse arch;
e – collective processing in the form of a vault based on breed or monolithic walls

The construction of cutting mining tunnels of reinforced concrete is advisable primarily in complex engineering-geological conditions with increased loads on the structure and significant inflows of groundwater, when the device of massive concrete cutting becomes uneconomical. However, the construction process of reinforced concrete cutting is a difficult installation of rebar, pouring and compaction of concrete mix.

There are different types of monolithic tunnel cutting arched shape [10, 11].

In strong rocks which do not make lateral pressure on the mount, it is applied processing from conventional solid concrete or sprayed concrete in the form of a set of constant or variable stiffness, based on the species (Fig. 1, a). For greater stability the vault is suited the ledges of rocks berm – width of 0.2 – 0.3 m. Wall production can be vertical or with a slight slope and lined with the layer of shotcrete thickness of 5 cm. The ratio of arch height span should not be more than four, because five of shallow arch can obtain the horizontal offset, which will lead to sharp increase in bending moments in lock section.

In the less strong and fissured rocks it is necessary to arrange cutting not only ceiling but walls of the tunnel. With a slight side pressure, walls are suited of straight. If erection produces production parts, the processing consists of the arch, which rests on the rectilinear walls (Fig. 1, b and 1, a). The excavation of the tunnel on the full profile is in the form of open loop construction with no arch (Fig. 1, c 1, b). The roadway in such tunnels is laid directly on rock or concrete preparation.

In weak rocks, that exhibit significant vertical lateral pressure and pressure from below, the processing must have a massive wall to a curved internal shape and a reverse arch (Fig. 1, d). Walls need a bit of deepen in the breed for perception of lateral pressure.

To protect the tunnel against the penetration of groundwater a waterproofing treatment is arranged, and sometimes drainage of the surrounding mountain range is. In addition to waterproofing, to protect the tunnel from water injection, cement processing is used, which fills all voids and cracks that is the source of the leaks.

To drain the mountain range in some cases surface drainage is used, stulnev, gravity and sporovo drains and grouting curtain.

The disclosure of excavations in hard rock on the full profile makes possible the use of prefabricated cutting from pre-fabricated elements of concrete or concrete blocks solid or ribbed cross section.

Collective processing can be arranged in the form of a vault based on breed or monolithic walls and open crypt construction for the entire height of tunnel cross section (Fig. 1, e). To support the precast treatment on the species there should be provided special support units with an extended fifth.

When using prefabricated cutting, the arched shape achieves a high quality of design and reduces the consumption of concrete, however, deteriorates the water-resistant treatment due to the presence of seams between the blocks and the need to fill extra processed space.

Prefabricated MULTI PLATE constructions are well-provided [12].

Design of MULTI PLATE can be used to create pipes, auto and railway tunnels, pedestrian tunnels, tunnels for the distillation of cattle, communication reservoirs, hangars and warehouses, protective galleries, and so on.

Constructions are used as a molded shell, and as a self-supporting structure during the reconstruction of the bridges and water ducts.

All tunnel construction can be equipped with straight or sloping sides and inset light fittings. It should be selected the type and size of the structure depends on the dominant height, loads, and design capacity of the water flow or the movement. The thickness of the metal plates varies from 2.75 to 7.00 mm. Plate between OSA is screwed by M20 (SB8,8). For all designs it is possible to manufacture special parts, holes and the nozzle almost without any restrictions on the form.

All design solutions are considered in the analysis which do not help to resolve the problem in cramped conditions and intense traffic.

The distinctive feature of the new constructive solutions of the transverse tunnel is the placement of steel pipe in the workings with the subsequent concreting, while ensuring the continuity of traffic on the street network. The ridge array 1 laid a highway 2. There is made in the array 1 cross tunnel 3. It contains: wall 4 and ceiling 6 through holes (openings) and is filled by pipes 5 with their subsequent concreting, the bottom 7, a cross frame 8. Tunnel design is done using horizontal directional drilling (HDD) 9 (HDD Vermeer Navigator D24×40) (Fig. 2, a – d).

First there is formed skeleton of the tunnel by drilling of production installation HDD Vermeer Navigator D24×40. Before starting of work, the properties and composition of soil, location of existing underground utilities are carefully studied. There is sensing of soils and, if necessary, surfline particularly complex intersections route of drilling with existing communications. The results of these works have a certain significance for the choice of trajectory and tactics of the construction workings. Particular importance should be given to the optimal location of drilling equipment on the construction site and to ensure safe working conditions of the drilling crew and other people.

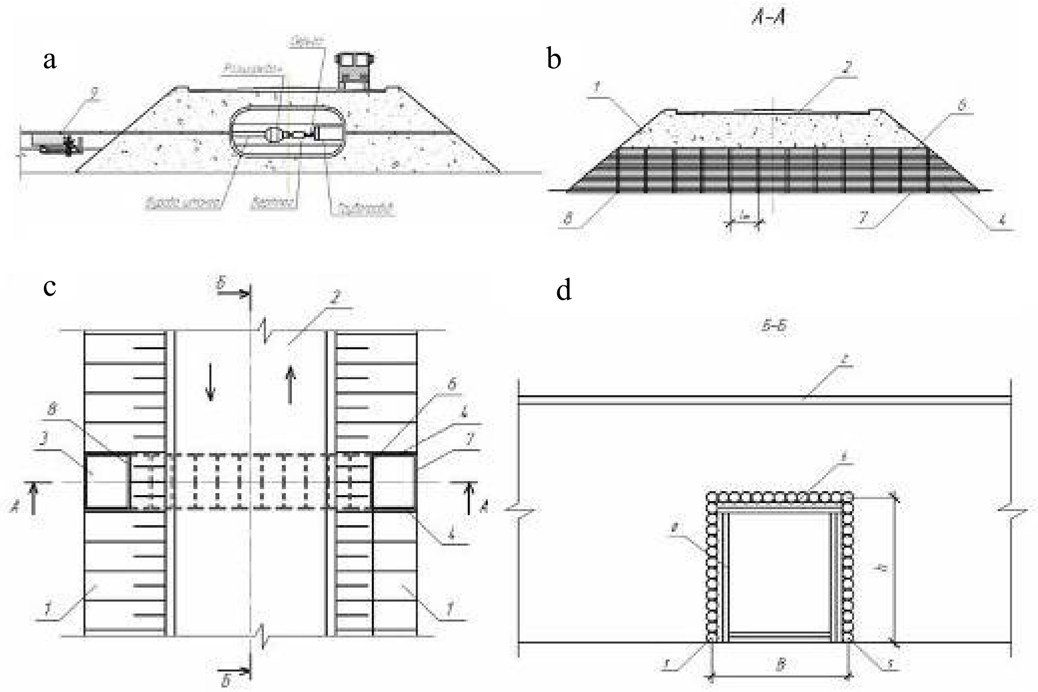

Figure 2 – the constructive solution of the transverse tunnel:
a – pulling of metal pipes; b – section A-A;
c – mound that is on the crest of the highway, with a transverse tunnel in terms ;
d – section B-B;
1 – array; 2 – transport highway; 3 – ross tunnel; 4 – walls; 5 – pipes;
6 – overlapping; 7 – the bottome; 8 – transverse frames; 9 – installing HDD

The construction by the technology of horizontal drilling is carried out in three stages: drilling of a pilot production, scaling up production and extending pipes.

Drilling of the pilot production is carried out using rock cutting tool – a boring head. The latter, in turn, is connected by way of gentle shell with flexible drive rod that allows you to manage the process of building pilot production and it is detected at the stage of preparation for the drilling of underground obstacles in any direction of horizontal directional drilling method within the natural bending prothomalo working thread. Construction of pilot production is completed with the output of the drill head at a given point.

Expansion of production is carried out after the completion of the pilot drilling. In this case the drill head is disconnected from the drilling rods and instead joins extender reverse action. App traction with simultaneous rotation of the expander is pulled through the target generation in the direction of the drill, expanding required pilot production for pulling the pipe diameter. To ensure smooth pulling of the pipe through the expanded production of its diameter is 20 – 30% larger than the diameter of the pipe.

Opposite the rig side of the production is ready to stretch the pipe. To the front end of the pipe to the head is attached , which senses the traction of the hinge and the extender. There is used steel pipe with an outer protective coating polyurethane (PPU). This coating is a structure consisting of steel pipe, insulation layer of polyurethane foam (gas-filled plastics or foams generated in the reaction process and the formation of air-filled capsules two components: socionatu and pololu), and also pipe-shell made of low pressure polyethylene (HDPE). This protective coating of pipes PPU today is the most effective and perfect way, because it combines the insulation of polyurethane foam layers, which adds waterproofing HDPE pipe shell.

After drilling of excavations and laying of pipes each pipe is filled with concrete.

Then digging parallel conducting installation of the metal cross frames starts. After installing the RAM and seizure the whole ground out concreting of the bottom is carried.

There is used steel pipe with a diameter of 300-500 mm with an outer protective coating of polyurethane foam. Today this protective coating of pipes is the most effective and the best form, as a combination of insulating and waterproofing properties of the pipe shell.

The calculation of loads should be performed in the following condition:

$$N_p \leq N_{кр}, \tag{1}$$

where Np – the calculated load, kN.

$$N_p = \varphi \cdot q_p \cdot \frac{l_{cò} \cdot b}{2} \cdot \gamma_n, \tag{2}$$

where φ – the coefficient of buckling of a compressed strut;
qp – calculated line load, kN;
l_{cm} – the distance between the racks, m;
b – the width of tunnel, m
γ_n – the reliability coefficient for the appointment;
$N_{кр}$ – the critical load, kN,

$$N_{êp} = \frac{\pi \cdot \text{Å} \cdot \mathrm{I}}{h_0^2}, \tag{3}$$

where E – the modulus of elasticity, MPa;
I – the moment of intersection stand inertia, m^4;
h_0 – the estimated length of the rack, m.

The distance between racks is determined by the formula:

$$l_{cm} = \frac{2 \cdot \pi \cdot EI}{\varphi \cdot q_p \cdot b \cdot h_0^2 \cdot \gamma_n}. \tag{4}$$

After installing the RAM and excavating all soil, there is produced bottom concreting 7. Rigid characteristics of a structure are governed by the pipe diameter and class of concrete.

The proposed method of tunnel meets the requirements of strength, reliability, durability.

The problem is solved due to the fact that the design of the tunnel with large cross sections include the excavation contour of tunnel faster with laying pipes and subsequent concreting. The following technological operations are associated with the device support in the leading mines, the connection support between the supporting edges, the recess of the soil core and the implementation of tunnel lining.

Conclusions. The proposed design of the transverse tunnel may be performed in cramped urban environments with modern technological equipment use. The estimated parameters allow to project design in compliance with the requirements of strength and reliability.

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Received 15.09.2017