



**ITA TUNNELLING
AWARDS 2019**



MODERNIZATION OF VLADIVOSTOK TUNNEL OF FAR EASTERN RAILWAY 2017-2019

Project stakeholders:

Client: OJSC «Russian Railways»

Engineering company: Directorate for the comprehensive reconstruction of railways and the construction of railway facilities

General contractor: JSC «Mosmetrostroy»

Subcontractors: LLC «MMS International», LLC «Energopromstroy»

Major suppliers: LLC «Masterbau», LLC «NPO «Strim», LLC «Asia Trans Trade».

Project history:

The Vladivostok tunnel is located within the city of Vladivostok, Primorsky Territory. Single track tunnel with service drainage heading. The length of the tunnel is 1380 meters. The tunnel was commissioned in 1935. Above the tunnel is a high-density urban area and urban communications. A survey of the tunnel conducted in the early 2000s showed that the tunnel is in poor technical condition and requires the implementation of measures to eliminate existing defects and their causes.

Major defects that prevent normal operation of the tunnel:

- reduction of the bearing capacity of the tunnel lining;
- destruction of seams between lining rings through which active water inflows into the tunnel, as well as rock falls of the ground;
- partial destruction of the existing lining along the length of the tunnel;
- availability of oversized lining places;
- significant formation during the winter period of frost on the lining of the tunnel (during the winter period 1,800 m³ of ice is cut down and removed from the tunnel at average).

The initial project for the reconstruction of the Vladivostok tunnel, developed by the Customer, provided for the complete closure of the tunnel for the period of reconstruction with switching train traffic bypassing the tunnel to the central part of the city and re-passing the tunnel by traditional methods. This project was not agreed upon by the administration of Primorsky Territory due to its high cost and great organizational difficulties in arranging the detour of the tunnel for the period of its reconstruction.

The main condition for the local authorities was not to cease the operation of the tunnel during the construction, as it performs important transport functions for servicing the seaport and urban infrastructure.

Having received a refusal from the Primorsky Territory Administration to completely close the tunnel for the period of its reconstruction, the Customer (Russian Railways) applied to JSC Mosmetrostroy with a request to suggest alternative ways to bring the tunnel into a standard condition taking into account the following conditions: to ensure the operation of the tunnel during construction, save the existing size of the tunnel, reduce the cost and time of work in relation to the original project.

After conduction an engineering analysis of the actual state of the tunnel, Mosmetrostroy specialists offered a set of modern technologies for the modernization of the tunnel, taking into account innovations from world practice and own experience.

As a result, Mosmetrostroy, together with the Bamtonnelproect Institute, developed a project to create a multi-layer permanent tunnel lining, which managed to apply the most advanced innovative developments used in world practice to modernize tunnels and provide a solution of the problem.

All works on the modernization of the tunnel were carried out in the technological "window" without stopping the movement of trains.

To bring the tunnel to a safe condition for operation, it was necessary:

- to fix the soil mass with the elimination of voids behind the lining;
- to stop the degradation processes in the existing lining of the tunnel, which is made of rubble concrete masonry;
- to provide water suppression of active flows along the entire length of the tunnel;
- to eliminate oversized areas in the lining of the tunnel;
- to cut the plaster layer along the entire length of the tunnel to maintain the existing size;
- to waterproof joints (expansion joints) between the semirings of the old lining;
- to waterproof the tunnel along its entire length, which was missing in the old construction;
- to increase the bearing capacity of the existing lining due to the providing of an additional bearing layer;
- to renew engineering communications and the track superstructure;
- to bring the adit into a normative state and restore the drainage system by drilling new wells from the adit and cleaning the existing drainage system.

As a result, all works on the modernization of the Vladivostok tunnel were carried out in the period from October 2017 to March 2019 with a total value of 3.2 billion rubles (\$ 49.3 million).

The object is a historical heritage monument, therefore, the portals of the tunnel were also restored while preserving their historical appearance.

Brief description of the project:

- For the first time in Russia, Mosmetrostroy developed a project and applied the technology of modernization of a railway tunnel, built 82 years ago, where one facility was adapted to specific working conditions and applied various modern world achievements and innovations in the field of tunneling.

- The following modern technologies were successfully implemented in the project:
 - various methods and compositions were used for injection into both the back-lining space and the body of the old lining;
 - waterproofing the joints of the old lining with the use of water-swelling rubber;
 - sprayed waterproofing of the entire tunnel with two-side adhesion;
 - the cracks of the old lining are filled with special compounds;
 - an additional inner layer of permanent lining of sprayed concrete was constructed using polymer and metal fiber;
 - chemical anchors connecting all layers of the lining and soil mass construction are applied;
- Mosmetrostroy specialist developed confirmed with the Customer a special project for the organization of construction with a detailed schedule taking into account the methods and technology of work, which made it possible to implement a “window” contract without stopping the movement of trains and to ensure all safety requirements for the movement of trains and the labor protection of builders during work
- The applied technical solutions made it possible to obtain a fundamentally new multi-layer lining of the tunnel, consisting of old and new structural elements, with high technical and operational characteristics, in which all layers are included in the construction.
- The technologies proposed by Mosmetrostroy for the modernization of the tunnel have provided the development of cost-effective technical solutions that increase the reliability of tunnel structures and structures.
- The task was successfully implemented with a significant reduction in terms (by 1.5 years) and the cost of work (2 times) relative to the initial project, according to which it was planned to carry out reconstruction of the tunnel with a complete tunnel closure for train traffic for the period of work with the construction of the bypass railway section through the city center.
- With the use of modern technologies during tunnel modernization, a significant social effect was achieved: uninterrupted delivery of goods by rail to the seaport of Vladivostok and from the port, to a heat power-station, as well as for urban needs for the entire duration of work at the facility.
- The implementation of this project by Mosmetrostroy allowed to increase the throughput capacity of the modernized railway section and reduce operating costs, improve the environmental situation in the tunnel zone due to the organized drainage system.
- The positive results achieved make it possible to further disseminate this technology when modernizing numerous other tunnels located on a huge railway network in Russia and abroad, many of which are of considerable age from the moment of construction and also require modernization to meet modern requirements and operating conditions.

In the process, the following innovative technologies and materials were used:



- to fill the voids behind the lining of the tunnel and fix the soil massif along with the injection of cement-sand and cement-silicate solutions, injection of a solution based on microcement was used MasterRoc MP 650 (BASF);
- for water suppression of active leaks, injection of the lining and behind the lining of the massif with polyurethane resins Akvidur TS-N and Akvidur TT (NPO STREAM) were performed;
- to isolate joints of expansion joints, the sealing profile "Plug" (NPO STRIM) was used, swelling upon contact with water based on hydrophilic polyurethane and sealing tape for expansion joints MasterSeal 930 (BASF);
- membranes applied by spraying and having two-sided adhesion, MasterSeal 345 (BASF) and Streamflex N (NPO STIM) were used for waterproofing the tunnel;
- a special composition based on a thixotropic quick-hardening dry mortar mixture, with shrinkage compensation, reinforced with polymer and metal fiber Remstream TM10 (NPO STRIM) was applied to the device for additional working lining. The working layer is made by the method of "wet" spray on the reinforcing mesh associated with the existing lining with chemical anchors.

Environment, social and economic criteria of the project

A) Environment:

- All construction sites, including a construction camp, warehouses, platforms for the placement of equipment, machinery and equipment were equipped in the technical area of the tunnel without additional seizure of urban land for the duration of the work;
- technical solutions developed by Mosmetrostroy for the modernization of the tunnel completely eliminated the negative impacts on the environment and water resources of the city of Vladivostok;
- noisy processes were completely excluded during the work, which is very important in the conditions of urban development to ensure comfortable living of residents of houses located in close proximity to the construction site;
- the applied technologies have gave a significant saving of electricity consumed during the work compared to the traditional methods of work envisaged by the initial project;
- a significant reduction of harmful emissions into the atmosphere was achieved due to the preservation of train traffic through the tunnel for the period of its modernization, which eliminated the need to use heavy vehicles to ensure the delivery of goods for the life support of city residents.

B) Social criteria:

- more than 90% of the workers employed in the modernization of the Vladivostok tunnel were attracted by Mosmetrostroy from among the local population;
- all employees were trained and certified to perform work at the facility;
- Mosmetrostroy in the period of work on the object was sponsored to repair the city kindergarten;
- for the entire period of the tunnel modernization work, the movement of trains delivering goods for urban needs has not stopped.



B) Economic criteria:

- The technical solutions proposed by Mosmetrostroy made it possible to significantly reduce the amount of building materials used compared with the traditional methods of work envisaged by the initial project;
- as a result, the total value of the object was reduced by 2 times compared with the original project;
- substantial budget savings were achieved in the Primorsky Territory due to cheaper freight transportation by rail through the tunnel in the period of its modernization compared to road transport in the event of complete closure of the tunnel for reconstruction according to the original version;

Safety performance of the project

Technical solutions proposed by Mosmetrostroy to modernize the tunnel not only led to a reduction in the cost and reduction of the work time, but also ensured a high level of safety in the production process.

Prior to the commencement of work at the facility, work production projects were developed that take into account the performance of work in technological “windows” under the conditions of the existing tunnel without stopping the movement of trains. These projects were coordinated with all services of the Far Eastern Railway, responsible for the safety of the tunnel.

All workers allowed to perform work were trained and instructed in safe working methods in the existing tunnel.

Also, throughout the entire term of work at the site, Mosmetrostroy occupational health and safety service carried out periodic checks of the knowledge of all workers on safe working methods.

In addition, constant monitoring of occupational health and safety compliance during the work was also carried out by the relevant services of the Far Eastern Railway.

This comprehensive approach to observing occupational health and safety compliance ensured that for the entire time the works at the site there was not a single accident related to safety violations.

This, in turn, completely eliminated injuries with loss of working ability and working time during the implementation of the contract.



Joint-stock company “Mosmetrostroy” has more than 85 years of experience in the construction industry. Today it is one of the largest construction companies in Russia, which is capable of qualitatively performing work on the construction of infrastructure and commercial facilities of any complexity within the time limits established by the customer. The main activity is the construction of the metro and other underground structures.

The company is equipped with the latest mechanisms, uses advanced construction technology, but most importantly, it has a highly qualified staff. Nevertheless, the success of any large association determines the professionalism of each enterprise within its structure. One of such enterprises is the Limited Liability Company “MMS International”, which in the summer of 2017 began to work as a subcontractor on the modernization of the Vladivostok tunnel of the Far Eastern Railway.

The done work deserves respect and fully reflects the high level of competence of the specialists involved in construction, the fruitful cooperation with all involved enterprises and organizations.

Especially important in any case is the close interaction with the customer of the production work. The “Russian Railways” Joint-stock company has been a reliable partner for many years, setting a worthy example of effective and fruitful cooperation.



The team of JSC “Mosmetrostroy” is ready to continue to apply its experience and knowledge in cooperation with such reliable partners.

Historical reference.

The Vladivostok tunnel is located within the city of Vladivostok, Primorsky Territory, on the line of the Second River - Cape Churkin. Urban buildings and communications occupy the surface above the tunnel. The length of the tunnel is 1380 meters.

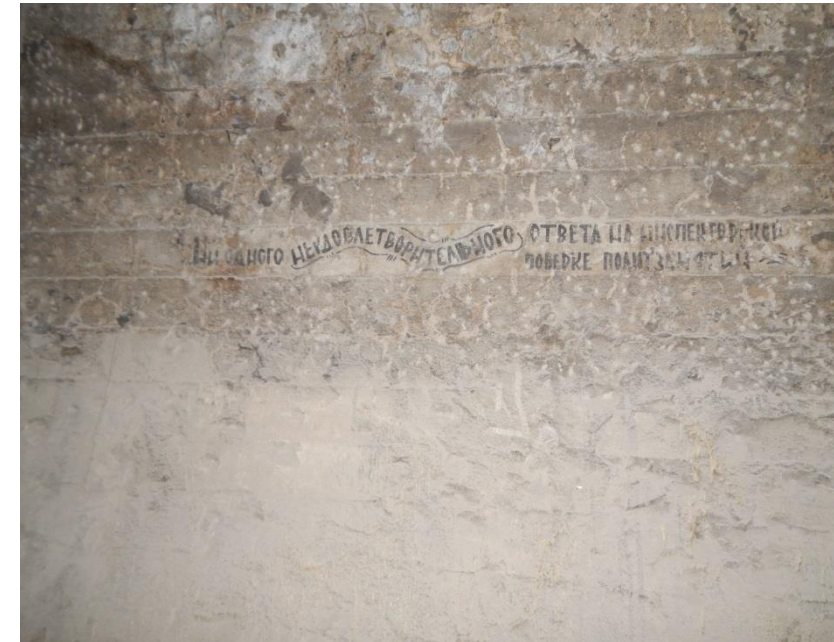
For the first time, the question of the construction of the tunnel arose in the Russian-Japanese war of 1904-1905. The construction of the tunnel was due to the need to connect the First River with a railway branch to the south bank of the Golden Horn and the Ulysses Bay, in order to cover Vladivostok from the Ussuriyskiy Bay.

On December 13, 1912, the project of the railway branch from First Station to station Gniloy Ugol was approved, with the construction of a tunnel with a length of 600 fathoms. Construction began in May 1914. It was assumed that the holing of the directive stroke was to be completed no later than October 1, 1915. Fully tunnel put in commission by May 1, 1916. But due to the outbreak of world war, in 1916 construction was stopped. The issue of resuming construction was returned only in 1931 when the threat of invasion of Japan began to increase. By the end of 1933 construction was continued. The construction of the tunnel was conducted by civilian labors, mainly from the mining villages of Suchan, Tetyukhe and Artyom. In 1934, in order to speed up construction, personnel of military units were thrown at the workers' help, and in 1935, in a solemn atmosphere, the tunnel was put into operation.

The lining of the tunnel was made of rubble concrete, there was no provision for an inverted arch and waterproofing.

According to the Decree of the Duma of Primorsky Territory № 314 dated 03.17.1996, the Vladivostok Tunnel is an object of cultural heritage of regional importance.

From October 2017, a new milestone began in the history of this unique object...



Inscription in the tunnel



ITA TUNNELLING
AWARDS 2019

PROJECT
OF THE YEAR INCL.
RENOVATION
- UP TO €50 M -



Aufeis formation in the tunnel



Miami, USA 18th November 2019

JSC Mosmetrostroy, Modernization of Vladivostok
Tunnel of Far Eastern Railway



ITA TUNNELLING
AWARDS 2019



Aufeis formation in the tunnel



At the beginning of the 2000s, there was a question of the reconstruction of the Vladivostok tunnel of the Far Eastern Railway, commissioned in 1935.

The unsatisfactory technical condition of the tunnel structures, the low waterproofing of the tunnel lining and the inefficient operation of drainage and water intercepting devices have caused an extremely low operational reliability of the structure with an increase in the cost of maintaining it. In the conditions of intensive development of degradation processes in the structures and arrangements of the tunnel structure, it was necessary to take urgent measures to eliminate the existing defects and their causes.

The proposed initial design solutions for the reconstruction of the tunnel suggested the complete closure of the existing structure with switching the movement of trains on the territory of the central part of the city in the area of Korabelnaya embankment and the embankment name of Cesarevitch. However, the complete closure of the tunnel was not possible and was not agreed with the administration of Vladivostok.

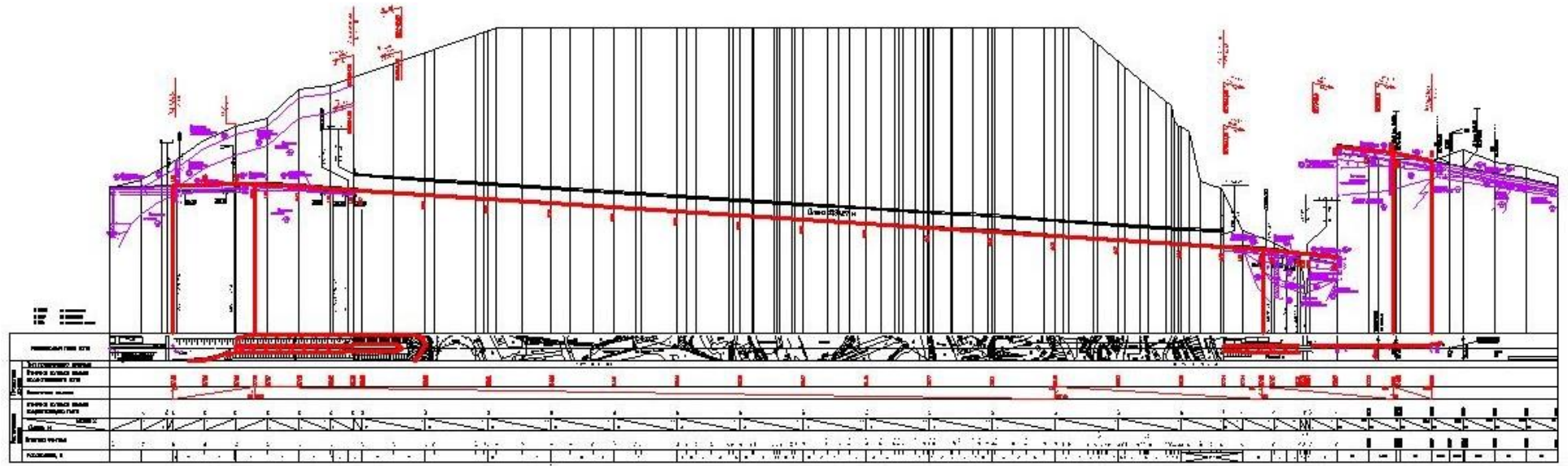


ITATUNNELLING AWARDS 2019



Cityscape of the city in the area of the tunnel location

Longitudinal profile and plan of the tunnel

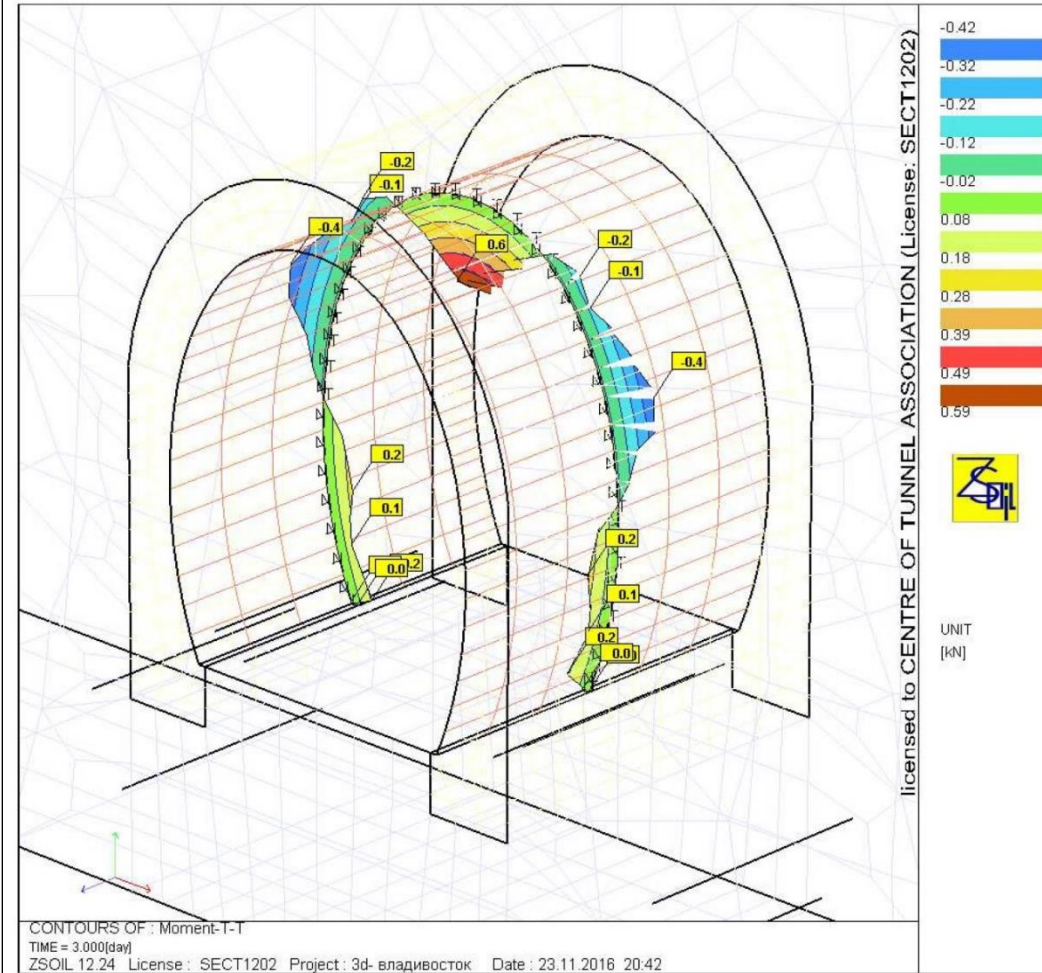


In 2017 specialists of JSC “Mosmetrostroy” have proposed their own new Tunnel Modernization option that satisfies all the initial data, namely: carrying out the project without closing the train movement (working in the “window”), draining and strengthening the lining without reducing the cross-sectional area of the tunnel. To implement the project, technologies and materials were proposed that were not used up to this point in the underground transport facilities of JSC “Russian Railways”.

The main advantage of the proposed solutions was the concentration on the one object the most advanced solutions in the field of underground construction. As a result, a positive result was achieved, which allows obtaining an upgraded facility with high quality, durability and modern operational properties.

The proposed design concept implements the principle of combining types of lining and more fully using the bearing capacity of the existing lining by creating a multi-layer permanent lining structure, including:

- existing rubble concrete masonry tunnel;
- preparation layer of shotcreting;
- a layer of sprayed waterproofing with double-sided adhesion;
- secondary containment (newly constructed working layer) from a special fiber-reinforced material of the thixotropic type





ITA TUNNELLING
AWARDS 2019

PROJECT
OF THE YEAR INCL.
RENOVATION
- UP TO €50 M -



South portal of the tunnel



ITA TUNNELLING
AWARDS 2019

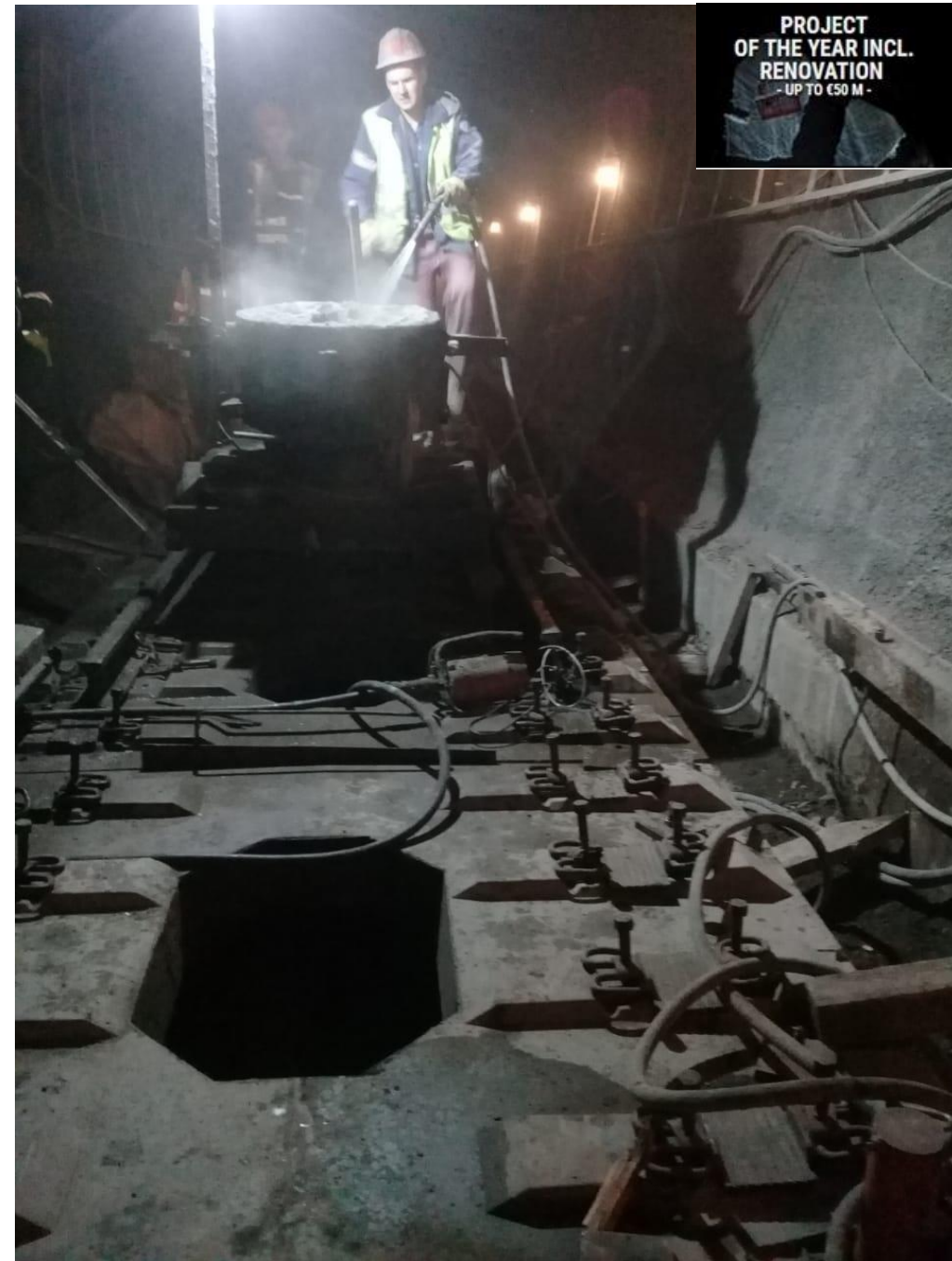
PROJECT
OF THE YEAR INCL.
RENOVATION
- UP TO €50 M -



Condition of the tunnel lining after modernization



Foundation preparation for track bed structure



PROJECT OF THE YEAR INCL. RENOVATION - UP TO €50 M -

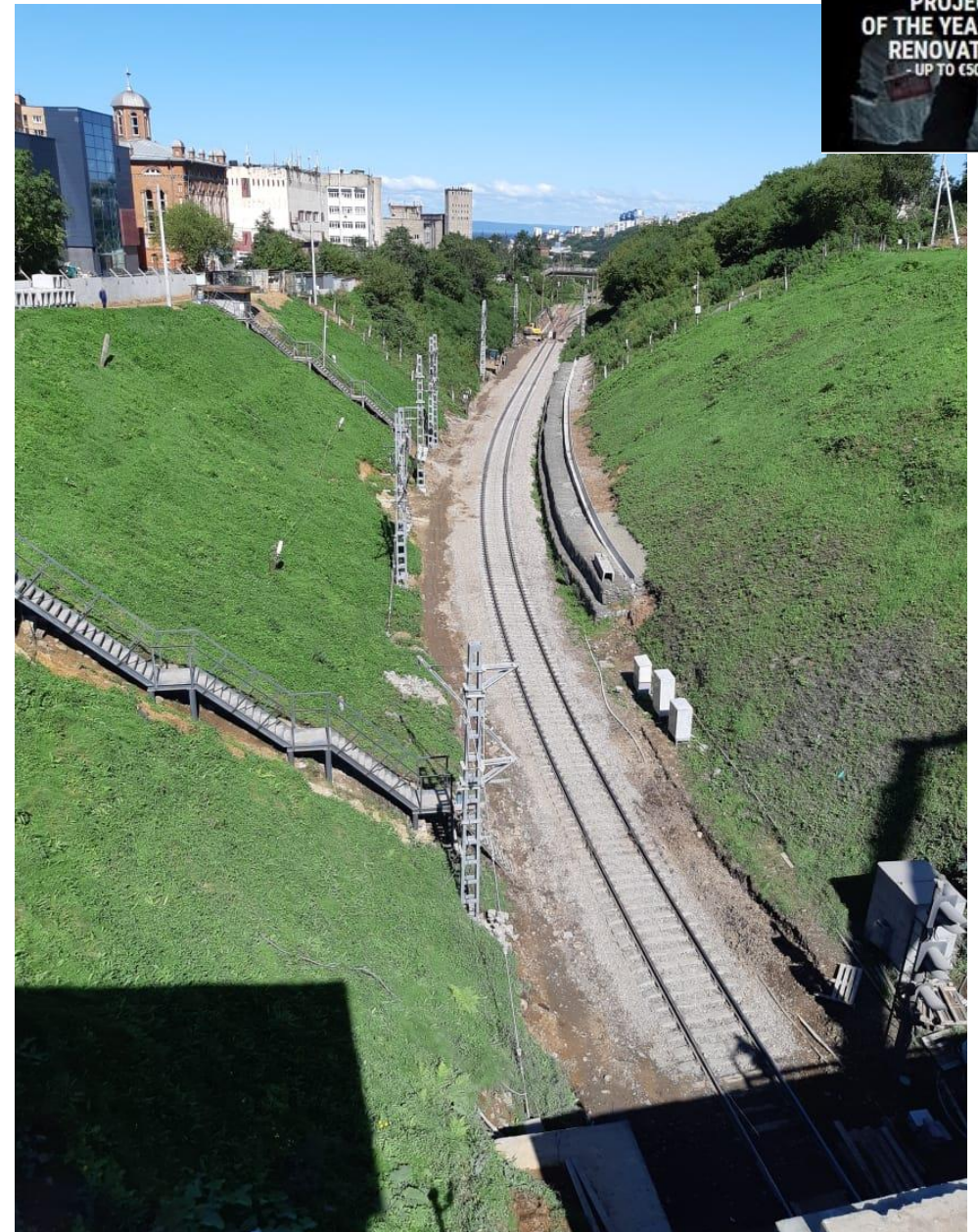
Construction of track bed structure on small-sized frames



ITA TUNNELLING
AWARDS 2019



Construction site of variable rigidity



PROJECT
OF THE YEAR INCL.
RENOVATION
- UP TO €50 M -

Approach to the North Portal



ITA TUNNELLING AWARDS 2019

With a large number of cracks and other defects in concrete structures, water manifestations are eliminated by creating an anti-filtration curtain. Making an anti-filtration protection a solid curtain is created behind the lining of the tunnel of binder soil with polyurethane resins.

TECHNICAL SPECIFICATIONS OF MATERIAL AKVIDUR TC-H

Indicator description	Norm
AKVIDUR TC-H	
Appearance	Homogeneous opaque liquid without mechanical admixtures of brown color
2. Dynamic viscosity at temperature 25°C, mPa*s, no more	300±50
Flashing point, °C	180
ACTIVATOR	
Appearance	Opaque liquid with a specific smell
Density, kg/m ³ at temperature 20 °C	1010±10
Flashing point, °C	110

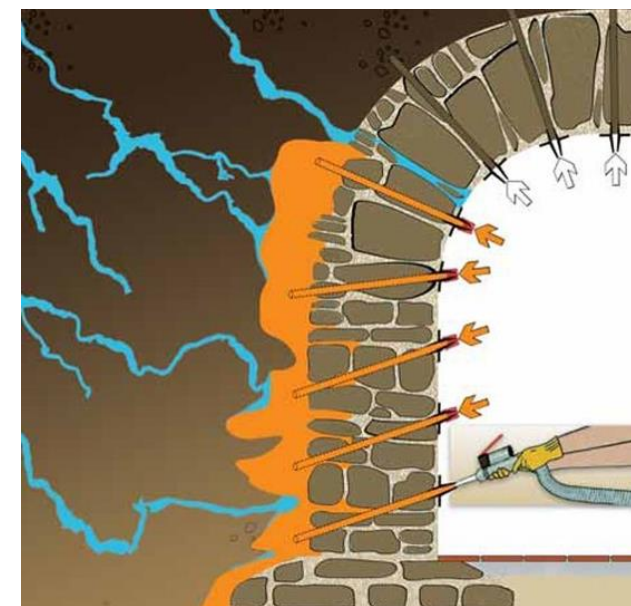
When pumping polyurethane compositions, high-pressure pumps (up to 200 bar) are used. When the discharge pressure is over 3 bar and low temperature, the foaming agent dissolves in the polymer structure, which increases the polymer's fluidity and allows it to penetrate hairline cracks and capillaries, dramatically reduces the foaming factor, which differs significantly from laboratory values and can vary from 1-8 times.

AKVIDUR TCH,

dependence of the foaming factor (volume increase) on temperature

Temperature	5	10	15	20
Start of the reaction seconds, not later	120	60	30	15
End of reaction seconds, not later.	360	240	120	60
FOAMING FACTOR (increase in volume) AKVIDUR TCH (no more), with a constant pressure of 2 bar	2	4	6	8
FOAMING FACTOR (increase in volume) AKVIDUR TCH with a constant pressure of 3 bar	1	1	1	1

With a pressure of more than 3 BAR in the curing process, there is a complete dissolution of gas in polyurethane resins (one and two-component) of any manufacturer and the material does not foam.





ITA TUNNELLING
AWARDS 2019



Suppression of active tributaries



Miami, USA 18th November 2019

PROJECT
OF THE YEAR INCL.
RENOVATION
- UP TO €50 M -

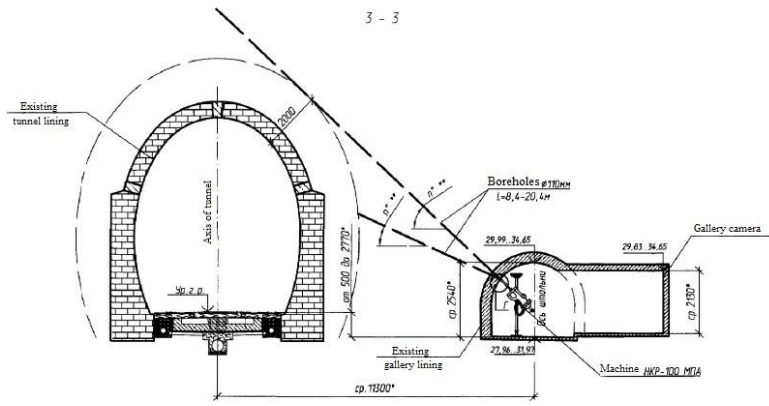


JSC Mosmetrostroy, Modernization of Vladivostok
Tunnel of Far Eastern Railway

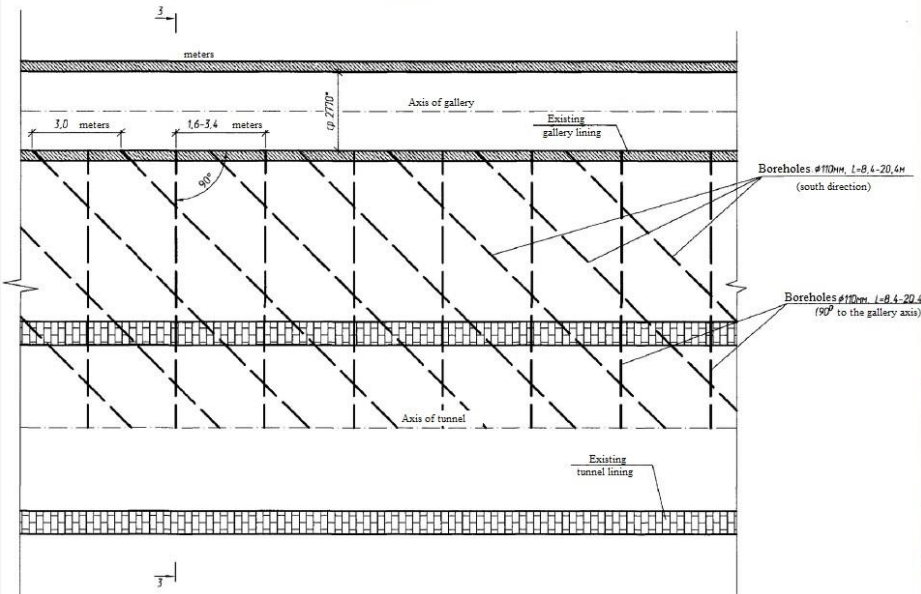


ITA TUNNELLING AWARDS 2019

rilling of drainage boreholes from the gallery



PLAN





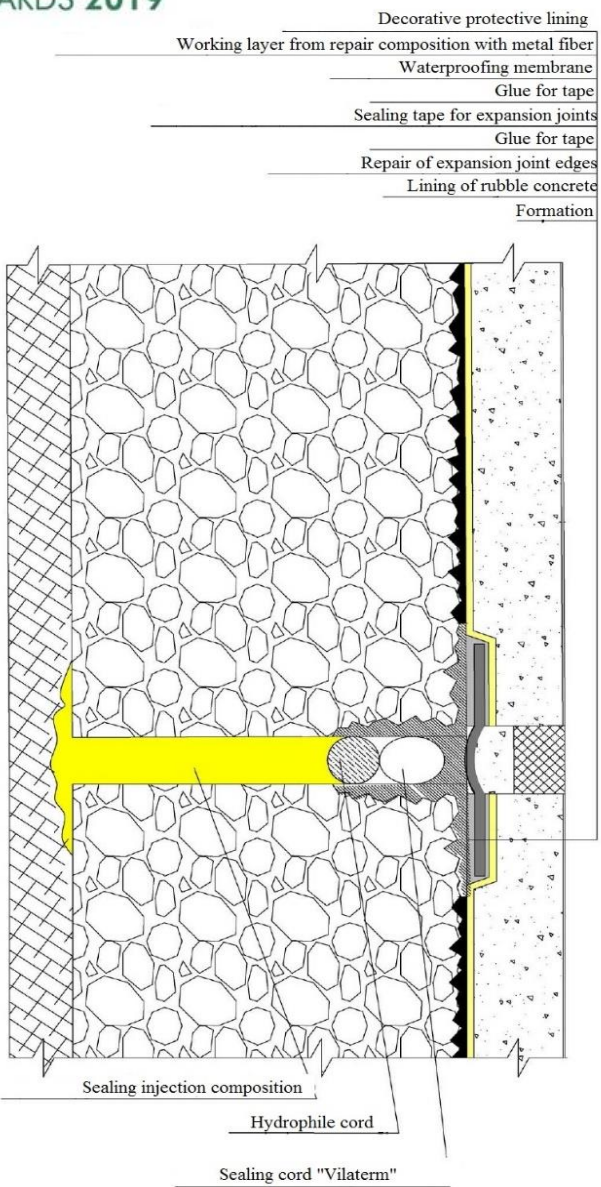
ITA TUNNELLING
AWARDS 2019



Drainage tunnel

Along the entire length of the tunnel, in order to control water release of the lining to drainage gutter, relief wells were made at the base of the tunnel.





Sealing of expansion joints

JSC Mosmetrostroy, Modernization of Vladivostok Tunnel of Far Eastern Railway



ITA TUNNELLING
AWARDS 2019

PROJECT
OF THE YEAR INCL.
RENOVATION
- UP TO €50 M -



Miami, USA 18th November 2019

JSC Mosmetrostroy, Modernization of Vladivostok
Tunnel of Far Eastern Railway

Application of sprayed waterproofing

As a waterproofing of the tunnel lining, the project provides for the use of a polymer membrane (ethanol-vinyl-acetate) "MasterSeal 345" and Streamflex H, applied by spraying on a concrete surface.

The spraying of the waterproofing membrane is carried out using a "Tornado AC-1" concrete placer using the "dry" spray method.

To ensure tightness in the places of installation of anchors, if necessary, waterproofing material is additionally applied manually with a brush.

Sprayed waterproofing is applied overlapped with a previously applied layer of the adjacent area.

At the time of execution of works on applying of waterproofing during the hardening period (at least 24 hours), it is necessary to ensure favorable temperature and humidity conditions according to the technical characteristics of the material.



JSC Mosmetrostroy, Modernization of Vladivostok Tunnel of Far Eastern Railway



**ITA TUNNELLING
AWARDS 2019**

**PROJECT
OF THE YEAR INCL.
RENOVATION
- UP TO €50 M -**



**ITA
AITES**

Miami, USA 18th November 2019

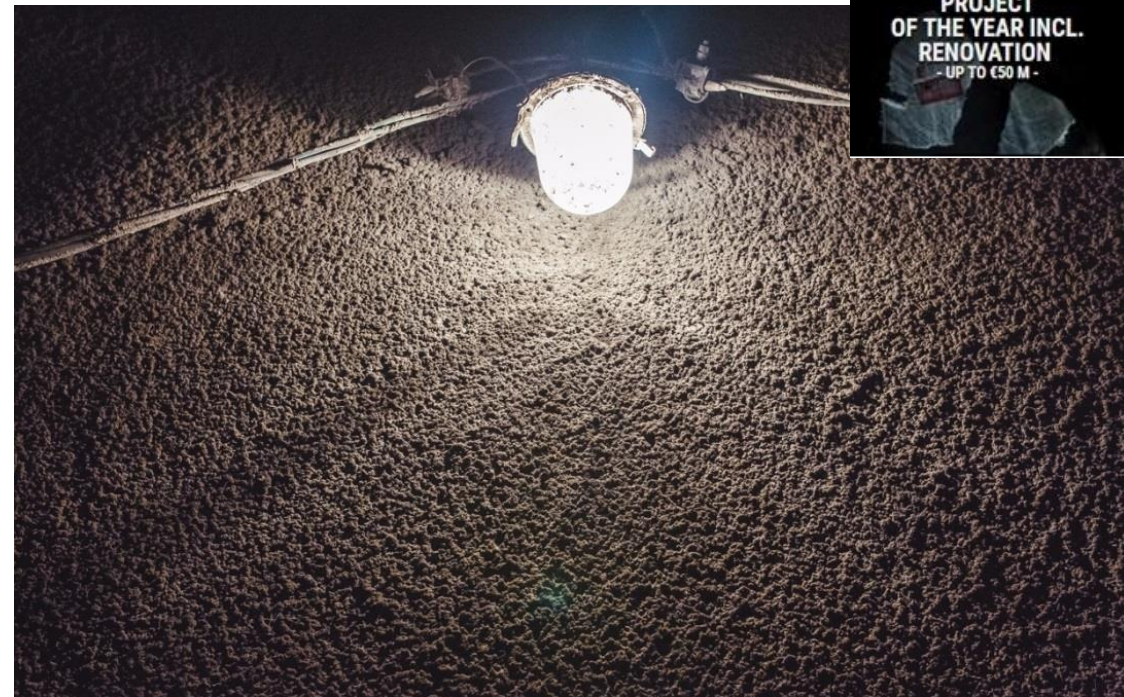
General view of the tunnel lining after applying a decorative protective coating

**JSC Mosmetrostroy, Modernization of Vladivostok
Tunnel of Far Eastern Railway**

As a working layer of reinforcement of the lining, a fast-setting non-shrinking mixture “Remstrim TM10”, reinforced with polymer and metal fibers, is used. The working layer is constructed using the “MEYCO ORUGA” concrete gun, in several layers, using the “wet” spray method. Preparation of the solution for the working layer is made at the place of production of works from a previously prepared dry mix.

The thickness of the working layer is determined by the project based on the calculation.

For the long-term and reliable service of the restored tunnel lining and overall aesthetic perception, a decorative protective coating is applied to the working layer.





In the process of the modernization, the existing engineering networks were replaced and new engineering networks were constructed to ensure compliance with modern requirements for ensuring the safety of trains and service personnel.

The anti-terrorism security of the facility was also enhanced.



ITA TUNNELLING
AWARDS 2019

PROJECT
OF THE YEAR INCL.
RENOVATION
- UP TO €50 M -



Utility networks



ITA TUNNELLING AWARDS 2019



PROJECT OF THE YEAR INCL. RENOVATION - UP TO €50 M -



ITA AITES

Miami, USA 18th November 2019

JSC Mosmetrostroy, Modernization of Vladivostok Tunnel of Far Eastern Railway

Vladivostok is, first of all, the most powerful transportation hub, which largely determines the state of the entire economy, not only in the region but also in other territories of the Far East. The share of rail transport accounts for a significant part of the freight traffic.

The modernization of the Vladivostok tunnel of the Far Eastern Railway will ensure the safety of freight and passenger traffic, as well as the attendants. This will increase the capacity at this site, which, in turn, will have a positive effect on the social and economic development of the region. In addition to economic value, this tunnel is also a historical cultural heritage.

The builders managed to preserve the historical appearance of this object, returning it to its original appearance.

