ON DEVELOPMENT OF YEREVAN METRO TO AJAPNYAK DISTRICT

Background and Brief information about Yerevan Metro

The construction of the Yerevan metro began since 1972. Geological research has revealed that the static groundwater level is at a depth of 9 meters above the ground. This meant that the tunnel structures of the metro had to be installed in the most saturated parts of the groundwater. Under conditions of unprecedented infiltration of water drilling was impossible, which inevitably led to an artificial lowering of the groundwater level. This process was carried out by digging shafts up to 58 meters deep from the surface of the tunnels along the proposed route, high-efficiency deep pumps were installed in them (approximately 220 m 3 / hour), which continuously lowered the water level for 24 hours, somehow creating an opportunity to drill tunnels. The total number of exploration and labor shafts was more than 100, however, it was not possible to lower the water level below the lower level of the tunnel under construction, and to make a free drilling. Due to the difficult hydrogeological conditions of Yerevan, subsoil did not allow to make drilling without expelling huge amounts of accumulated water to the surface. Except the many water supply pumps, pumping stations were built and installed in the tunnels, which together pump 10-12 thousand cubic meters of water per hour. Under these conditions, it was impossible to provide high performance or high-speed tunnel crossing. It was impossible to drill or fasten more than one meter per day from each crossing point. Tunnel workers from different cities of the Soviet Union, who drilled 10 meters more every day in their cities. were convinced of this. Due to these and a number of other difficulties, the metro, which was being built in unprecedentedly difficult conditions, was not completed on time. The planned date of November 29, 1980 had to be postponed to the beginning of March 1981.

The first five metro stations under construction were put into operation in March 1981, and later in 1983, 1984, 1985, 1987, 1989, unfinished stations of the route: "Gortsaranain", "Shengavit", "Garegin Nzhdeh Square", "Zoravar Andranik", assembly station (depot), were subsequently put into operation, and later in 1998, "Charbakh" station. Thus, the metro has 10 stations, 7 of which are located in underground tunnels, and 3 are above ground, Approximately 12.5 km total operating length, power plant with 45 wagons, 24 escalators, 13 substations. The organization has more than 1100 employees.

Metro underground stations are located at a depth of 20-50 meters. Each metro station has one entrance equipped with three escalators, except for Shengavit station. Each above ground station has one staircase entrance. There are no lifts in the metro. The average length of the stations is 105 meters. The operating tunnels were built both mechanically and by drilling and blasting. The outer diameter of the tunnels is 5.5 meters, which gives an inner diameter of 5.1 meters. The total length of the tunnels is 14.25 kilometers.

The tunnels are built using three types of structures: prefabricated reinforced concrete rings, cast iron rings and monolithic reinforced concrete. The system includes 5 bridges and crossings. The influx of groundwater and their destructive effect on the line laid in the tunnels, electrical equipment and rolling stock continues to this day. Artificial methods of lowering the water level, both during construction and after the putting into operation of the metro, did not give the expected results. The presence of water in the operating tunnels, underground structures greatly interfered with the safe operation of the metro and the normal operation of equipment. Under these conditions, the operation of the metro became dangerous. At that moment, dewatering the tunnels from groundwater became an urgent need. The drainage tunnel, which has already given its positive results, was designed, its construction started and is ongoing now, however, as the construction of the tunnel is not fully completed, the water lowering which was achieved as a result of its construction did not significantly lower the groundwater level in the exploited tunnels adjacent to the still unbuilt section. Currently, there are 2 powerful pumping stations for pumping infiltrated water in the metro, as well as the artificial groundwater leveling system is partially operational. The electricity supply of the trains is carried out by means of the third rail in accordance with the requirements of the Soviet standards. The route was built with two underground tunnels and two parallel above ground lines. In the above ground sections, the lines are built mainly in the traditional way: the logs are ballasted with gravel in the form of a building above the line.

Metro technical specifications

Features of the existing rail wagons and rolling stock information

The metro system currently operates on 15 double-decker trains, 8 of which work on the main line, 1 provides suburban services, and 6 trains pass the regular technical inspection in accordance with the approved schedule. Trains run from 6:30 a.m. to 11:00 p.m., during peak hours, with a frequency of five minutes, and during off-peak hours, with a frequency of eight minutes. At present, the Yerevan Metro has transported an average of 50,000 passengers per day and 19 million passengers per year in 2019. Maximum flow of passenger: between 1993 and 1994, thanks to well-known events, more than seventy million passengers were transported per year.

Types of rail wagons	81-717 / 81-717-5
Year of production	Since 1976
Maximum length	19210 mm
Maximum height	3695 mm
Maximum width	2712 mm
Maximum net weight	34 tons

Maximum operating speed	
Number of traction engines per car	
Maximum power of each traction engine	
Acceleration	
Wheel diameter	
Power supply	
Electricity receiving	

Route description

The description of the metro route is as follows:

- the total length of the route for passenger transportation - approximately 26.57 km;
- the total length of the depot route - about 3.55 km.
- the total length of other routes - approximately 5.16 km
- the total length of the whole route - approximately 35.28 km.
- Number of stations - 10.

Operating metro stations

Underground stations are located at a depth of 20-50 m. Each underground station has one entrance with three escalators. Each above ground station has one entrance with stairs. There are no elevators in the metro. The length of the stations is 105 m, which allows receiving four wagon trains.

Flow of passengers

The current metro transports only up to 70,000 passengers a day. And many more passengers travel daily by public traffic in the capital. In this overall balance, low metro rates are largely due to a short route and a small number of stations, which are located on the same operating line and naturally, they cannot directly include the service sector in densely populated districts of the city and the passengers arriving from the suburbs. The above ground traffic problems in the capital are largely connected with the expensive energy and means of transportation, imported to the republic from other countries. Since the 90s, the metro has been considered the most promising means of transportation in the capital due to its speed, safety, comfort, and, which is the most important, it is ecologically clean, it works with locally produced electricity.

If we look closely at the results of the last 3 years of transportation, it will become clear, that the number of subway passengers has significantly increased, and there is a growth tendency year by year. The above mentioned once again confirms the fact that the metro is becoming the most important traffic component of the capital. No concrete funds have been allocated before and no measures have been taken for the development of the metro. Currently, the Armenian government is trying to develop the metro to Ajapnyak district,

giving preference to the possibility of using the previously built 1054-meter running tunnels, building only one station complex - a metro bridge.

Development of the operating metro to Ajapnyak

Also substantiated:

In case of need to solve the traffic problem of the spectator of a social issue in the district, as the population of the district exclusively use public traffic.

Due to the scarcity of roads connecting Ajapnyak with the city center (there are currently only two of them: Kievyan and Davtashen Bridges).

by the possibility of significant unloading of the Kievyan and Davtashen Bridges from the city traffic.

On the left bank of the Hrazdan River there are drilled metro tunnels, which will significantly facilitate the construction of the station.

The implementation of the development program to Ajapnyak will allow to have comfortable, fast, ecologically clean traffic, which will connect the two parts of Yerevan divided by the Hrazdan River Gorge, which is very important from a strategic point of view.

General information on the organization of completed and upcoming works in the direction of the development of the operating metro to Ajapnyak

The project of a section of the Yerevan metro to Ajapnyak and with a length of 3.58 km and a cost of 77,849.98 thousand Soviet rubles was studied by the Department of Expertise of the Soviet Union (Ministry of Railways of the USSR), and has been approved in September 25, 1987. This project, except the process of continuing the metro line, included the continuation of a number of other major ancillary facilities. The project was developed in accordance with the requirements of the technical equipment of that time, according to which, crossing the metro line to the Hrazdan River Gorge, it should have reached the "Aragats" cinema, then to the newly built G-3 district, including 3 new stations, and the operating line would be extended by 3.58 kilometers, involving the service sector of the metro with a significant part of the population of Ajapnyak 15th C-3, Davtashen, Malatia and Shahumyan districts.

The management of the metro under construction with the active support of and with the city authorities of Yerevan, since 1987, rapidly relocated communications from the construction zone, created construction sites, completed the preparatory phase, after which began the above ground construction of the metro and tunnel drilling works, simultaneously with four sections, and lasted until 1992.

Shaft section No.24 Built at the back of the Mathematical Machines Research Institute, Next to Keri street. Two running tunnels were built from this shaft with a total length of 1054 meters (approximately 2X527) from the operating "Barekamutyun" metro station,

which provide access to the platform of the gorge, from where a metro bridge with a length of about 152 meters will be built. The shaft is intended for the construction of the main objects of the first line of civil protection of the metro, such as a powerful underground generating substation, emergency cleaning, air filtration, tunnel supply station, drinking water storage with a volume of 1300 m3, metal sealed doors in tunnels, etc.

Shaft Section No.25 This shaft is located near the intersection of Halabyan and Abelyan streets. It is planned to build a metro station, branch tunnels, an inclined shaft, a substation and other important tunnel structures from the shaft. Technological tunnels with a total length of 345 meters were built, a 48-meter running tunnel was drilled, drilling of the towing compartment adjacent to the middle service room of the station began, an inclined escalator entrance with cast iron panels (temporarily preserved) was built, etc. to start construction through the shaft.

Shaft Section No.26 It was built in the middle of Janibekyan and Bashinjaghyan streets. With the help of this shaft, a 186-meter tunnel was built, of which 166 meters were covered, approaching 230 meters, 220 were covered. Heterogeneous injections were not conducted at all.

Shaft Section No.29 It was built near G-1 district. 22% of the sloping tunnel earthworks were carried out here and the works were interrupted due to the cessation of financing of the structures.

A total of 2370 gm was drilled in the construction sites of two stations in Ajapnyak . different sections and tunnels of significance. 66.9meter tunnels are not concreted (fixed). Empty filling injections were not conducted in 1576 linear tunnels. This means that in non-concrete (unbonded) parts, only temporary fastenings in the form of a board are laid under the stones to protect the metal frames from falling to the ground, which have corroded for many years due to the lack of ventilation in the shafts and have partially rotted, and as a result, they lost most of their design capacity. And the absence of post-casting injections has complicated the condition of the fastener in the areas covered with prefabricated reinforced concrete blocks, as a result of which there are deformation phenomena with extreme violations of the current tunnels.

Observations on the necessary works for the preparation of the underground section from Barekamutyun station to Ajapnyak as a metro

As mentioned above, the tunnel with a total length of 1054 meters from the Barekamutyun station to the gorge is still very far from the state necessary for operation. In two tunnels with a length of 527 meters (1054 linear meters), it is necessary to make a number of measures to perform temporary, basic work.

To organize work in the running tunnels (1054 linear meters), it will be necessary to completely restore the previously laid temporary communications, in particular water pipes, compressed air pipes with automatic distribution points of 1054 meters of electricity supply, in running and auxiliary tunnels, lighting cables, lamps, electric traction with P24 rails, wagons and other large and small equipment for transporting materials and for work.

The previously installed communications are mostly absent in the tunnels, and the existing remains are almost unusable.

Waterproofing works should be conducted in abandoned tunnels that have not been completed for about 30 years. Before starting the basic work, it is necessary to conduct mine surveying (underground geodetic) surveys in order to identify and eliminate deformations.

The two tunnels were drilled mainly by blasting, as the rocks in this section are represented by basalts of 9-11 classes. The main fastenings of the existing tunnels are reinforced concrete rings with an inner diameter of 5.1 m, which are installed from prefabricated elements. The arch (tray) of the tunnels is different in different parts, there are flat elements with round holes, in both cases these structures can work normally in the geological conditions of the section. Groundwater is located in deeper layers, the presence of an insignificant amount of water in the tunnels is associated with disruption of ground communications. The sections of the tunnels leading to the gorge have sections built of cast iron panels with a diameter of 7.5 meters, due to civil defense measures. Shaft No. 24 cannot serve as a ventilation shaft for the metro until the construction of civil defense facilities is completed. The construction of civil defense facilities in the current tunnels and adjacent areas must be built together with the construction of this stage, otherwise, otherwise it will not be possible to build in the future.

Waterproofing works: As it was mentioned, the drilling of the tunnels was done with blasting. The peculiarity of this method is that it provides a fairly fast advance, but it’s impossible to control the blasting results completely. Small and large collapses occur, which remain in the fastener in the form of empty cavities. These cavities should be filled with 1: 3 cement solution at the initial stage of injection. Tunnel prefilling in constructed sections is not complete, therefore, all tunnels 1054 meters long must be pre-filled with pressure, and subsequent test injections should only be conducted with cement mortar at higher pressures to ensure that the gaps in the clamp are filled. These injections must be conducted in accordance with the applicable technical specifications (TS). Before injection, reinforced concrete elements, as the joints for the connection of the iron panels should be sealed, and the fronts of the tunnels of different diameters should be concreted and covered with a metal layer not less than 6 millimeters thick. Before conducting waterproofing work, the tunnels should be washed, cleaned of construction debris, and after completion of the planned work, cleaning and washing works should also be conducted in preparation for the installation work.

Line upper structure and collector rail: The length of the line of the site under construction should be selected depending on the location of the station, taking into account the turning's safety's deadlocks. The line should be installed with R-50 first-class high-quality rails, mainly on wooden logs, in accordance with the conditions of the 1520-millimeter rails. Railroad switch must be type 1/9. The line parameters in the plan and profile must comply with the line design norms in the metro and in accordance with the requirements, using vertical curves in the plan and in straight sections, requirements due to radii of curvature and peculiarities of interlinkage. It is necessary to plan the installation of line rappers in accordance with the norms of the curved and straight sections.

Arrow conveyors, station bridge should be planned only on straight sections of the track. The Flat bottom tray of the tunnels is assumed to be the lower structure of the line, and the monolithic concrete is equalized in case of round tray. Accept on an open section of the route either a reinforced concrete foundation or a layer of soil for first class railways, required by SNIP 32-01, if necessary, provide for soil reinforcement and drainage measures. Provide rail wires in the route, install them in the base or on the site according to the requirements of the normative documents, provide lengths in accordance with the project, on the bridges, on some radii of curvature, provide protective and working rails (check rails).

The contact rail should be placed in the direction of travel on the left side. In some areas and in some places of railroad switch in accordance with the design place on the right. The requirements for the installation of the contact rail, its carvings in the building tunnels and on the open sites are included in the regulatory documents.

Power supply: Power must be supplied from two independent sources of power to municipal substations. Calculate the power supply for a normal working emergency power supply of 6 kW. Provide the supply of power equipment, lighting, constant and alternating currents in the metro in accordance with the design norms in the metro. Build one substation for each station under construction. In underground structures (tunnels, stations, car halls, as well as on an open section of the route, basic emergency lighting should be planned, providing the necessary level of illumination for each object in accordance with applicable standards). Provide the installation of equipment at stations in tunnels according to standard solutions. Soil and suction contour should be placed with the justification of the calculation. Provide the substation with the appropriate equipment for tele mechanics and automation.

Ventilation: Metro structures should be provided with ventilation, inlet and exhaust systems for both main and local tunnels. The underground ventilation system includes stations, escalator tunnels, car halls, substations, and other structures provided by the project. Use normative documents SNIP 32-02 and SNIP 41-01 for design and calculation of ventilation. Considering that shaft No. 24 could not serve the main ventilation system, especially after the closure of the bridge in the open section of the route, it is necessary to have new design solutions for the organization of powerful ventilation.

Heat supply: In the structures of stations, lobbies and other production and service blocks to provide local water supply using mainly electricity by relatively fire-safe (closed) means.

Water supply: The metro is considered a first-class consumer; it must have two independent 24-hour permanent water supply sources. Depending on the nature of use, the water supply can be used simultaneously for drinking and technical water, based on appropriate calculations, based on the number of staff and the number of fire - fighting events, using normative documents SNIP 2.04 and SNIP 2.04-01-85. Underground structures of the metro must be provided with a single system (stations, lobbies, bathrooms, ventilation chambers, etc.). Underground structures of the metro must be provided with a single system (stations, lobbies, bathrooms, ventilation chambers, etc.).

Drainage: Underground stations should be equipped with drainage systems that concentrate collected water from structures to local “main pumping stations”, from where it should be discharged to the surface and then, according to the design, should be removed by appropriate drainage lines. Drainage pipes of underground structures must have a slope of 3%, a diameter of at least 100 millimeters, an angle of direction change - 120 degrees. All other activities should be conducted based on the specific situation, in accordance with the requirements of sanitary standards.

Sewerage: The economic sewers of the ground stations and lobbies will be built according to the technical conditions agreed with the urban structures, which are given in accordance with the possible calculated outputs. Sewage from underground stations and structures flows through pipelines with a slope of 10% and accumulates in sewers, from where it is pumped to the surface through pumping stations.

Communication and alarm system:

Signal

The extension of the metro line, from the operating "Barekamutyun" station to the planned station, it is necessary to envisage a signaling, centralization-blocking system (CBS) in the project. Running from "Barekamutyun" station to the planned station (running line) should be provided by interlocking, with 24 pairs of trains and " Automatic Speed Control" (ASC) system with 40 pairs of trains. It is necessary to provide railway centralized traffic control (CTC), train turning with the installation of a railroad switch with a 1/9 gearbox at the station. It is also necessary to provide a safety (catch) deadlock about 150 m long. In order to extend the existing line, it is necessary to make installation changes in the equipment of "Electrical Concentration" (EC), interlocking and "Automatic Speed Control" (ASC) systems at "Barekamutyun" station, installation of new equipment in the relay room of the station, with replacement of old equipment (re-construction).

It is also necessary to install new equipment in the "Regulatory Concentration" (RC) system. At the planned station, the CB relay and duty rooms should also be provided.

Communication: All types of communication existing systems currently operating in the metro should be provided at the station under construction.

Regulatory (train, energy, electromechanical)

Tunnel

Switch

Train radio communication

Administrative-economic

Loudspeaker

Fire alarm

All these planned communication systems must be equipped with modern technologies, being able to adapt to the technical conditions of the operating old systems.

As all the current communication equipment is morally and physically worn out, it has long been taken out of production, it is not possible to get it, to install it, that is why new modern systems must be provided.

In the station under construction, it is necessary to continue the ring-fiber optic main network from "Barekamutyun" station, the connection of video surveillance systems, fare, integrated time systems and WI-FI networks to existing systems.

Station: As mentioned above, this phase will be limited to one station complex from the operating "Barekamutyun" metro station to Ajapnyak district, and by constructing additional security tunnels adjacent to it.

The choice of this or that point of the station should be based on financial and technical justifications based on serious studies carried out in advance, as well as the results of geological and hydrogeological surveys.

The financial justification is a price offer, which must have a calculation justification in accordance with the conditions of our republic, as well as localization of the cost of construction of one kilometer of the metro, based on the international experience of building similar stations. The technical justification should be based primarily on calculations of the possible traffic flow in the current situation, as well as on reasonable calculations of the expected increase in aboveground traffic flow as a result of changes in public transport routes (associated with the territory). The choice of the site for the station should be made in the coastal zone in accordance with the planned construction. The process of using the passenger station (entry-exit) should be as easy as possible. Provide design solutions to various groups of the population, for example, people with disabilities, use the subway, calculate the difference between the top and bottom planes of the base, and if necessary, provide escalators. Design the possibility of free access and operation of fire, ambulance, accident rescue vehicles in case of emergency. Provide parking spaces for cars coming from the regions and other districts, as well as opportunities to build a last stop as a result of changing public traffic routes. At this stage, the station should be designed as not the last station with the possibility of building one more station in the future. The need to build a second station is based on the following logic:

In case of building one station, the district will not be fully serviced, as a result, a large number of passengers will be left out of the service sector, besides, there will be a need to build an intermediate deadlock. In case of building two stations simultaneously, an intermediate deadlock will be built after the second station, considering that it will significantly exceed the size of a standard station in terms of its workload, making 25-30% of the total costs. In case of installing at the end of the route it turns possible to avoid unnecessary costs by using the means rationally.

Bridge: Design a "Metro Bridge" type bridge, which has been successfully built and operated in the metros of the CIS countries. It will only be necessary to localize one of the existing projects in accordance with the conditions of the city of Yerevan. Irrespective of the bridge's shape, number of flights, types of foundations, and the purpose of its construction, taking into account the changeable and unstable geology of Ajapnyak district, serious, deep geological and hydrogeological research must be conducted to reliably place the bridge foundations. Railways are installed on the railway bridge by special measures, which are included in the substantiating documents and are based on safety rules and necessity. The bridge must be covered, taking into account its approximate length of 150 meters, the impact of dynamic loads, the impact of vibration forces due to the braking of the train, the characteristics of the roof structures and to make calculations in accordance with these conditions. Provide opportunities for ongoing maintenance and inspections of the bridge, as well as closed hall cleaning and drainage measures. When calculating the bridge, take into account the probability of two-way traffic on the rolling stick bridge with 5 wagons.

Open space: The constructed tunnels end in the gorge. The first base of the bridge from its front to the planned bridge is 82 meters. This part of the route is above ground, but regardless of that it must be closed as a bridge or with a separate project. The need to close the open section is due to the peculiarities of train traffic, which can cause additional emotional stress for the train driver by changing the short distance of dark and light sections, where speed must be adjusted by entering the braking zone before entering the bridge. In addition, during the winter months, the change of cold and warm zones can cause the rails to freeze, which can lead to train management problems during the braking process. In addition, the front of the open section (ramp) should be formed to protect trains and structures during possible rock falls, from the gorge with a strong retaining wall. In order to ensure the railways from sediment in that section, if necessary, geological surveys should be conducted and land consolidation measures should be taken. As mentioned above, shaft No. 24 can neither serve as a metro nor participate in the construction of this phase, therefore, Construction organization plans (SOP) should be developed in 1054m. tunnels built for major works.

General requirements:

Design a complete metro with all its attributes, calculation ranges, regular two-way traffic.

Regardless of the type of station, provide all the norms, required by the construction norms, for ensuring sanitary and hygienic conditions.

Environmental protection requirements: Calculate and provide with project the requirements for permissible norms for noise and vibrations.

Develop mechanisms to combat stray currents and protect structures from corrosion as much as possible.

Protect structures from the effects of aggressive environments if necessary.

Design automatic firefighting and sound alarm measures where necessary. Furnish the buildings and compartments in compliance with the requirements of the metro fire regulations.

Develop procedures for the evacuation of personnel in emergency situations.

Develop and propose plans for the construction of the right and left bank, also provide technical and protection zones.

Provide centralized and automatic control system for equipment and train operations.

INVENTORY, MEASUREMENT AND ASSESMENT OF AREAS AFFECTED BY THE PROJECT

The client provides the consultant with cadastral information of real estate and land in the area affected by the project, on the basis of which, in agreement with the client, the consultant conducts the project, covering the areas owned by the community (or) the state as much as possible, and, if this is not possible, makes measurements and assessments, as well as submits to the client an appropriate land acquisition and resettlement program for the areas where the rights of third parties are in place.

<u>Attached to this description and technical task, the preliminary conceptual sketches prepared by the staff of Yerevan Municipality are provided, which can be changed based on the suggestions made by qualified participants, using more effective solutions.</u>