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Document N 001

Rehabilitation of the water supply tunnel

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1. General description

1.1 Location and description of the facility

The project water supply tunnel is located in the territory of Chugureti district in the city of Tbilisi. The tunnel is a cone-shaped structure lined with concrete.

1.2 General description of works

The tunnel inspection and research works were carried out from March 16 to March 20 of this year.

The inspection was carried out in the tunnel from the entrance which is located in Chugureti district, adjacent to Otar Chechelashvili street and which represents

A metal pipe with a diameter of 1.3 m. The purpose of the inspection was to determine the nature and quantity of the visible damage caused by tunneling. It should be noted that a large part of the bottom (reverse) of the tunnel is covered by water, which is why it was not possible to determine the exact number of injuries. However, the main types of injuries were determined, and accordingly it became possible to determine the technology for their elimination.

In parallel mode, a group of surveyors started working in the tunnel to carry out tunnel planning works. Through the data obtained as a result of the measurement works, it will be possible to determine the rehabilitation measures and also the possibility of arranging alternative temporary accesses to the tunnel for the planned rehabilitation works.

In addition, a separate group performed the determination of the thickness of the concrete lining of the tunnel and the voids between the lining and the surrounding rocks. Initially, it was decided that the said inspection would be carried out on a trial basis every 20 meters at three points in the tunnel, on the arch and on the walls on both sides, and if necessary at closer intervals. However, due to the homogeneity of the results, the mentioned bid was not changed along the entire length of the tunnel.

Due to the fact that there are no exact picket markers inside the tunnel, the distances were determined using a 50-meter measuring tape. Therefore, there may be slight errors (within about 5 meters) in marking the pickets in the report.

1.3 Objectives of the study

The purpose of studying the water supply tunnel was its visual inspection and measurement works. As a result, the types of injuries and their volumes and exact location were determined. Based on the received information, probable rehabilitation measures and their volumes were determined.

2. Tunnel inspection

The project tunnel is a non-pressurized, cone-shaped construction covered with concrete and in certain sections with reinforced concrete, the height of which varies within 1.6-3.0 meters and the width within 1.5-2.2 meters. Large sections of the tunnel are flooded and the height of the water reaches 1 meter in some places.

According to the information received from the GWP employees, neither the design-execution documentation of the tunnel, which would necessarily contain the geological characteristics and the construction solution of the excavation, as well as the measurement drawings to be executed in the later period, will not be obtained. Accordingly, neither the exact location of the tunnel in relation to the ground nor the construction of the tunnel itself was known.

However, certain conclusions can be made based on the cross-section of the tunnel itself and the shape of the concrete. As is known, engineering-geological conditions have a significant influence on the shape of the cross-section of the tunnel and the type of excavation. Under low mining pressures, the tunnel roof may be flat or slightly convex. As the mining pressure increases, the bulge of the arch increases. In case of horizontal mining pressures, the bending walls are completed in non-linear form. In particular, according to the strength coefficient of different rocks, the following types of tunnel forms are recommended:

- Rectangular, with convex arch, strength coefficient >8 - absence of mining pressures in the rocks;
- Semi-circular arch, in rocks8>SC>4, only in the presence of vertical mining pressures;
- Curvilinear walls and a small radius of the arch4>SC>2, in vertical and horizontal pressures in soils;
- Nalis-shaped cross-section SC <2, in the case of significant vertical and horizontal, as well as downward, mining pressures in rocks.

Based on the mentioned theoretical assumption and also the shape of the tunnel cross-section, it can be said that the ground around the tunnel is characterized by low strength.

3. Discovered defects

3.1 Tunnel inspection results

In general, the quality of the tunnel excavation (during the construction period) is quite low: the concrete surface, on quite large sections, is uneven and is obviously insufficiently treated with a vibrator; The construction seams between the stages of concrete pouring (Bij 6 meters) do not seem to have been processed at all, at least there are no traces of this, and almost all seams are open: on the floor there are remnants of concrete and wood material left over from the construction period; Also, in certain sections, the rods of the armature are exposed to the surface of the plow and they are significantly corroded.

It should be noted that the current general condition of the tunnel is more or less satisfactory and there are no signs of any danger in the short term. However, as a result of the visual inspection of the tunnel, various types of defects were revealed, the dynamics of which, after a certain period of time, may become the cause of significant damage.

In particular, as a result of the inspection, the following types of injuries and defects were found:

- Irregularities of the tunnel bottom;
- Damaged back (bottom);
- Holes on the arch and walls (artificially broken openings);
- Damaged and opened construction seams;

- Materials and waste deposited on the bottom of the tunnel;
- tunnel cutting cracks and erosions;
- Insufficient thickness and voids of the tunnel lining;
- Crystallized discharge on the surface of the tunnel.

In addition, rehabilitation works performed in different periods can be observed on the surface of the tunnel, which are mainly of a temporary, preventive nature and are not characterized by a high quality of performance. Therefore, such sections should be opened again and their proper processing should be carried out.

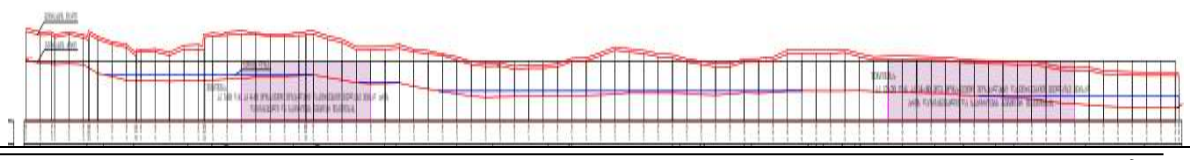
Defects observed as a result of tunnel inspection are shown in the table below:

N	location	Name	Gen. one.	Volume
1	2	3	4	5
1	PK0+08.5	A hole d-800 mm pipe is arranged in the arch of the tunnel. The cross section of the tunnel changes to a large section cut	M3	0.12
2	PK0+40÷0+85	A new bend has been made in the tunnel, the said section is good. It is marked at the junction between the old and the new bend crystallization.	M2	2.5
3	PK0+80÷0+92	On the left side, 60 cm from the base, there is a horizontal crack.	M	11.7
4	PK0+85÷1+00	The section up to pk0+85-pk 1+00 is crystallized	M2	16.2
5	PK0+90÷1+10	Up to PK0+90-1+10, there are broken places on the reverse corner, there are cracks on the concrete bend, the reverse corner is horizontal (flat) in this section.	M3	3.6
6	PK1+08	Construction and imported waste stone and blocks	M3	0.75
7	PK1+05÷1+50	Crystallization is noted on the arch	M2	49.5
		15-20 cm thick crushed stone is laid on the section.	M3	6.0
8	PK1+65÷1+80	Crystallization is noted	M2	12.0
9	PK2+10÷2+15	Crystallization is noted	M2	2.9
10	PK2+57÷2+60	On the left side of the tunnel, at a height of 2.20 m from the reverse arch, local soil inclusions are marked in the arch at a length of about 2 meters. (void) with a width of 20 cm.	M3	2.3
11	PK2+64÷2+70	There is a horizontal crack 2 meters from the back arch on the left side.	M	6.5

12	PK2+72÷2+77	On the right side of the wall, there is a rectangular void 15x20 cm with a depth of 10 cm, which forms a shelf.	M3	0.15
13	PK2+73	There is a hole in the arch of the tunnel, the thickness of the coating is 10 cm, the main rock is visible.	M3	1.6
14	PK3+12÷3+20	Multiple eroded sections of concrete	M2	2.10
15	PK3+34	On the right side of the arch, there are hollows with the size of 20x20 cm, the thickness of the lining around the hollows is 8-10 cm.	M3	0.80
16	PK3+30÷3+37	crystallized section.	M2	2.8
17	PK3+62÷3+70	There is a crack on the right side of the wall at a height of 2 meters.	M	7.8
18	PK3+72	There are hollows in the arch, the thickness of the lining around the hollows is 8-10 cm.	M3	1.1
19	PK3+72÷3+84	There are cracks on both sides at a height of 1.2 m from the reverse arch, 7 m on the right side, 12 m on the left side.	M	19
20	PK3+80÷3+86	There are cracks around the entire perimeter of the tunnel.	M	21.5
		Stripped reinforcement frame from the protective layer Reinforcement grid eroded has lost design parameters.	M2	5.8
21	PK3+80÷3+90	The back corner of the tunnel is eroded, there are cracks of 0.4-0.8 cm, the water poured into the cracks will be absorbed instantly. filtration section. In the same section, there are cracks on the entire perimeter of the tunnel body.	M2	22
22	PK3+97	There is a hole 1.20X0.90 in the ceiling	M3	0.27
		Around the hole in the ceiling, cracks extend in all directions around the perimeter of the tunnel body. Cracks visual By observation, it goes into the depth of the coating.	M	18.5
		On the bottom, gravel and stones with a diameter of 30-40 cm are thrown	M3	1.8
23	PK4+02÷4+15	Deformed sister on the right side The reverse corner is broken.	M3	7.8
24	PK4+03	In the arch there is an oval hole with a diameter of 50-100 cm, closed with reinforcement and asbo-cement slabs, which are arranged from the upper side of the tunnel arch.	M3	0.15
25	PK4+10÷4+28	On P 4+10, 4+16, 4+22, 4+28 there are circular penetrating cracks on the entire perimeter of the tunnel body.	M	52.8
26	PK4+40÷4+65	There are cracks on the walls at a height of 1.7 meters on both sides, the cracks are visible	M	65.5

		It is penetrating with observation.		
27	PK4+50	Throw concrete fragments with a diameter of 20-30 cm and gravel	M_3	0.7
		Water flows in 10-15 cm from the right side	M_2	1.3
28	PK4+50÷4+62	Crack in center of reverse	M	12.8
29	PK4+60÷4+80	Crystallized section, filtration from arch	M_2	48.2
30	PK4+65÷4+80	crystallized section	M_2	24.6
31		5-8 cm thick crushed gravel.	M_3	0.7
32	PK4+70	A pipe with a diameter of 250 mm is arranged obliquely in the tunnel arch on the right side.	M_3	0.1
33	PK5+00÷5+15	Average crystallized section.	M_2	6.8
34	PK6+00÷6+40	Average crystallized section.	M_2	10.4
35	PK6+50÷6+75	Average crystallized section.	M_2	9.1
36	PK7+25	The groove in the arch is 10-15 cm wide, the concrete thickness of the arch is 10 cm.	M_3	1.2
37	PK7+57÷7+60	There are hollows on the arch, the thickness of the arch covering is 10 cm, the main soil is visible in places.	M_3	0.6
38	PK7+75÷8+15	The crystallized section has a filtration water-inflow on the perimeter of the arch.	M_2	46.2
39	PK8+10	Opening on the left side at 1.65 m from the back corner 80X55 cm cladding thickness 22 cm, the main ground is visible.	M_3	0.11
40	PK8+18÷8+27	Sinks (hollow body places) in the left body of the wall in 45 cm from the back corner, the length of the sinks is 40-45 cm, there is a place for filtration from the body of the wall.	M_2	1.68
41	PK8+70÷8+80	Average crystallized section.	M_2	6.2
42	PK8+10	Sink in the body of the wall at a height of 1.6 with a length of 40 cm, coating thickness of 10 cm.	M_3	0.011
43	PK9+10	The hole on the right side is 70X40 cm. The coating thickness is 7-10 cm.	M_3	0.07
44	PK9+38÷9+43	crystallized section.	M_2	7.2
45	PK10+15	A metal pipe with a diameter of 100 m runs in the tunnel.	M	8
46	PK10+90÷11+00	Horizontal and vertical cracks follow the tunnel arch. Some of the cracks have been repaired, but the problem is not solved. Three cracks on the arch.	M	28.8
47	PK11+05÷11+10	Crystallized section, cracks are noted on the walls and arch, which have been treated improperly (artificially).	M	8.2

48	PK11+40÷11+50	Crystallized section, cracks on the walls and arch are marked, which were processed improperly.	M	19.8
49	PK11+56÷11+61	Hand-treated cracks at a height of 0.5-1 m need to be removed and treated with appropriate technology.	M	7.5
50	PK11+80÷12+20	A crack in the arch.	M	86.2
51	PK11+90÷12+05	crystallized section	M_2	11.7
52	PK12+20÷12+65	crystallized section	M_2	68.5
53	PK12+50	The opening in the arch 50X40 cm is filled with concrete.	M_3	0.01
54	PK12+50÷13+05	crystallized section	M_2	77.1
55	PK12+50÷13+05	Cracks on the arch.	M	87.8
56	K13+30÷13+35	There are cracks on the walls and arch, which are treated improperly (artificially) eroded sections.	M	21.3
57	PK13+38÷13+45	There are cracks on the walls and arch, which are treated not (artificially) eroded sections.	M	14.6
58	PK13+38÷13+50	The entire perimeter is crystallized, water drips from the arch and filters from the walls.	M_2	63.2
59	PK13+50	The opening in the arch is filled with concrete.	M_3	0.2
60	PK13+57	A crack at the base, on the right wall at a height of 50 cm, the crack crystallized	M	3.5
61	PK13+95÷14+00	crystallized section.	M_2	7.3
62	PK14+00÷14+75	Cracks on the walls from the arch	M	186
63	PK15+15÷15+25	crystallized section.	M_2	13.2
64	PK15+40÷15+57	Cracks on the walls 1.10-1.40 cm from the arch, the said section crystallized	M	53.2
65	K15+67÷15+75	crystallized section.	M_2	15.1
66	PK16+05	An air pipe with a diameter of 250 mm is installed in the arch.	c	1
67	PK16+10	A hole in the concrete with a diameter of 55 cm	c	1

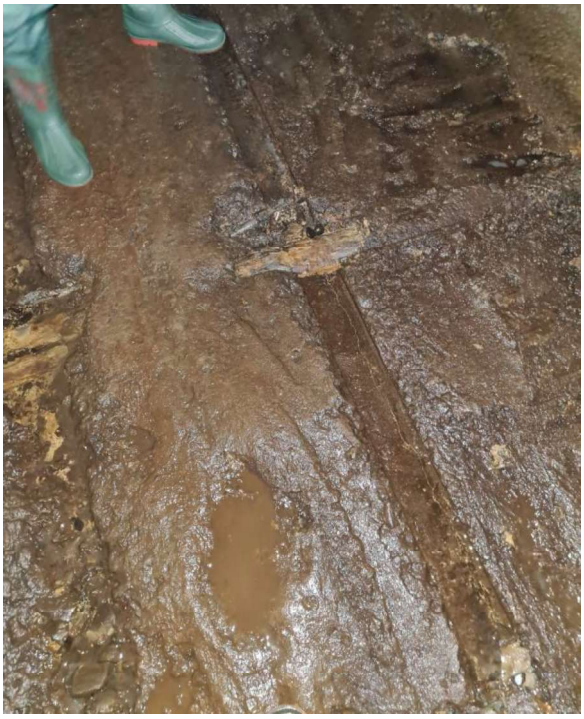


3.2 Irregularities of the tunnel bottom and walls

At the bottom of the tunnel there are some irregularities, which seem to be left over from the construction period.

The slope of the base is significantly variable, and in certain sections we have reverse slope, due to which a significant amount of water is trapped in the tunnel.

It should be said that under the conditions of tunnel operation, as the visible water level line on the walls of the tunnel shows, it is quite low and there is no danger of switching to the pressure mode. Therefore, such a defect cannot be considered as a threat to its stability.



Uneven tunnel bottom - pictures N1 and N2

3.3 Damaged base

In certain sections, particularly in areas with low water levels or water-free areas, there are visible protruding parts and also cracks on the bottom of the tunnel. It was not possible to accurately measure the damaged parts of the base, due to the high water level in the main sections of the tunnel.

However, in certain sections, significant bulges and cracks are observed, which may be due to high mining pressure or filtration events. The damage mentioned is noteworthy and requires urgent intervention.

In addition, in certain sections of the tunnel, on the bottom along the axis, cracks of different lengths and distribution are visible, which is also noteworthy.


Bulging and damaged bottom of the tunnel - pictures N3 and N4

3.4 Holes on the arch and walls

In the bend of the tunnel, there are artificially created holes at certain sections. The mentioned holes may have remained from the period of construction or subsequent rehabilitations, and they were probably used for communication purposes. In particular, to supply construction materials or to introduce electricity supply, water supply or any necessary network into the tunnel. Most of these holes are currently sealed by artisanal methods. However, in order to carry out the planned rehabilitation works, it is recommended to study the places of their emergence to the surface and use them if proper access and safety measures are ensured.

After the work is completed, some of them may be reinforced and left for future use.

Holes in tunnel bend - pictures N5 and N6

3.5 Construction seams damaged by bending

Along the entire length of the tunnel, there are damage and cracks of the construction seams, which may become a source of water leakage from the tunnel and also cause a weakening of the stability and reliability of the tunnel over time, which in turn will lead to a decrease in the safety of the operating conditions.

Therefore, it is necessary to open and process the mentioned seams using appropriate technologies.

Damaged construction seams - pictures N7 and N8

3.6 Materials deposited on the bottom of the tunnel

At certain sections of the tunnel, piles of both imported waste and construction material waste can be observed. Although they do not pose a threat to the stability of the tunnel, their removal is necessary, even during the planned rehabilitation period, to ensure smooth movement inside the tunnel.

Debris deposited inside the tunnel - pictures N9 and N10

3.7 Tunneling cracks and erosions

Defects such as eroded concrete and especially cracks at the bend of the tunnel occur almost along the entire length. Most of the damages, as determined by the visual inspection, are superficial, although some cracks are quite open and deep, there are also exposed reinforcements.

Cracks extend along the tunnel as well perpendicular in both directions and their length reaches 30-40 meters. In one of the boreholes made earlier in the construction of the tunnel, the purpose of which is unknown, it is clear that the crack has spread to a considerable depth (see photo below).

Concrete wear cracks and other damage are likely to progress and require timely and appropriate treatment.

Tunneling cracks and erosions - images N11 and N12

3.8 Tunnel lining thickness and voids between lining and rocks

As it was already said, the construction works for the arrangement of the concrete lining of the tunnel are performed in a rather low quality. This opinion is also confirmed by the fact that in some places the insufficient thickness of the screed is clearly visible, because the rock is exposed on the surface of the screed. In some places, mainly in the arch of two contiguous concreting sections, the curve is quite thin, and behind it there are quite large voids. This indicates that backfill cementation was either not performed at all or was performed improperly. At least there is no sign of it.

In addition to visual surveys, small-diameter monitoring holes were drilled along the entire length of the tunnel, with a diameter of 20 meters, with three boreholes at each location: in the arch and on the walls on both sides. With the help of drills, it was possible to determine the actual thickness of the concrete bend and the voids behind the bend.

The results of this inspection are shown on the cross-sections of the tunnel, on the corresponding drawings and in the table below:

Table of estimated volumes of cementation based on drilling results

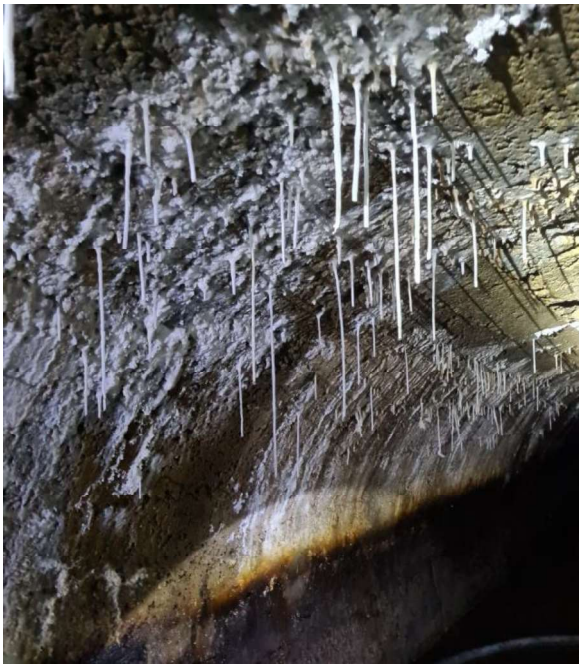
N	picket		the distance M	area m_2		Volume M_3
	the beginning	the end		the beginning	the end	
1	0+00	0+20	20.00	0	0.38	3.8
2	0+20	0+40	20.00	0.38	0.37	7.5
3	0+40	0+60	20.00	0.37	0.32	6.9
4	0+60	0+80	20.00	0.32	0.36	6.8
5	0+80	1+00	20.00	0.36	0.36	7.2
6	1+00	1+20	20.00	0.36	0.38	7.4
7	1+20	1+40	20.00	0.38	0.35	7.3
8	1+40	1+60	20.00	0.35	0.38	7.3
9	1+60	1+80	20.00	0.38	0.34	7.2
10	1+80	2+00	20.00	0.34	0.36	7
11	2+00	2+20	20.00	0.36	0.36	7.2
12	2+20	2+40	20.00	0.36	0.38	7.4
13	2+40	2+60	20.00	0.38	0.38	7.6
14	2+60	2+80	20.00	0.38	0.38	7.6
15	2+80	3+00	20.00	0.38	0.35	7.3
16	3+00	3+20	20.00	0.35	0.35	7
17	3+20	3+40	20.00	0.35	0.38	7.3
18	3+40	3+60	20.00	0.38	0.38	7.6
19	3+60	3+80	20.00	0.38	0.37	7.5
20	3+80	4+00	20.00	0.37	0.36	7.3
21	4+00	4+20	20.00	0.36	0.36	7.2
22	4+20	4+40	20.00	0.36	0.38	7.4
23	4+40	4+60	20.00	0.38	0.35	7.3
24	4+60	4+80	20.00	0.35	0.38	7.3
25	4+80	5+00	20.00	0.38	0.36	7.4
26	5+00	5+20	20.00	0.00	0.39	3.9
27	5+20	5+40	20.00	0.39	0.33	7.2
28	5+40	5+60	20.00	0.33	0.32	6.5
29	5+60	5+80	20.00	0.32	0.28	6
30	5+80	6+00	20.00	0.28	0.31	5.9
31	6+00	6+20	20.00	0.31	0.31	6.2
32	6+20	6+40	20.00	0.31	0.30	6.1
33	6+40	6+60	20.00	0.30	0.34	6.4
34	6+60	6+80	20.00	0.34	0.32	6.6
35	6+80	7+00	20.00	0.32	0.29	6.1
36	7+00	7 + 20	20.00	0.29	0.36	6.5
37	7 + 20	7+40	20.00	0.36	0.35	7.1
38	7+40	7+60	20.00	0.35	0.32	6.7
39	7+60	7+80	20.00	0.32	0.38	7
40	7+80	8+00	20.00	0.38	0.36	7.4
41	8+00	8+20	20.00	0.36	0.38	7.4

42	8+20	8+40	20.00	0.38	0.34	7.2
43	8+40	8+60	20.00	0.34	0.34	6.8
44	8+60	8+80	20.00	0.34	0.32	6.6
45	8+80	9+00	20.00	0.32	0.34	6.6
46	9+00	9+10	10.00	0.34	0.31	3.25
47	9 + 20	9+40	30.00	0.31	0.34	9.75
48	9+40	9+70	30.00	0.34	0.32	9.9
49	9+60	9+80	10.00	0.32	0.29	3.05
50	9+80	10+00	20.00	0.29	0.38	6.7
51	10+00	10+20	20.00	0.38	0.31	6.9
52	10+20	10 + 30	10.00	0.31	0.38	3.45
53	10+40	10+60	30.00	0.38	0.32	10.5
54	10+60	10+80	20.00	0.32	0.37	6.9
55	10+80	10+90	10.00	0.37	0.33	3.5
56	11+00	11 + 20	30.00	0.33	0.34	10.05
57	11 + 20	11+40	20.00	0.34	0.38	7.2
58	11+40	11+60	20.00	0.38	0.36	7.4
59	11+60	11+80	20.00	0.36	0.37	7.3
60	11+80	12+00	20.00	0.37	0.38	7.5
61	12+00	12 + 20	20.00	0.38	0.38	7.6
62	12 + 20	12+40	20.00	0.38	0.36	7.4
63	12+40	12+60	20.00	0.36	0.36	7.2
64	12+60	12+80	20.00	0.36	0.34	7
65	12+80	13+00	20.00	0.34	0.36	7
66	13+00	13+20	20.00	0.36	0.38	7.4
67	13+20	13+40	20.00	0.38	0.37	7.5
68	13+40	13+60	20.00	0.37	0.36	7.3
69	13+60	13+80	20.00	0.36	0.38	7.4
70	13+80	14+00	20.00	0.38	0.38	7.6
71	14+00	14+20	20.00	0.38	0.34	7.2
72	14+20	14+40	20.00	0.34	0.33	6.7
73	14+40	14+60	20.00	0.33	0.36	6.9
74	14+60	14+80	20.00	0.36	0.36	7.2
75	14+80	15+00	20.00	0.36	0.36	7.2
76	15+00	15+20	20.00	0.36	0.35	7.1
77	15+20	15+40	20.00	0.35	0.33	6.8
78	15+40	15+60	20.00	0.33	0.36	6.9
79	15+60	15+80	20.00	0.36	0.38	7.4
80	15+80	16+00	20.00	0.38	0.36	7.4
81	16+00	16+25	25.00	0.36	0	4.5
Bowl:						**561.05**


Insufficient thickness of the tunnel lining and voids - pictures N13 and N14

3.9 Crystallized discharge on the cleaning surface

On the arch of some sections of the tunnel, there are significant centers of crystalline discharge, which over time may become the cause of significant damage and even rupture of the tunnel construction. Therefore, the mentioned sections should be given special attention.




Insufficient thickness of the tunnel lining and voids - pictures N15 and N16

4. Tunnel rehabilitation concept

4.1 General Overview

The concept of the rehabilitation works to be carried out in the tunnel was prepared based on the data obtained on the current condition of the tunnel and its main goal is the rehabilitation of weak sections of the tunnel.

For the successful and timely execution of rehabilitation works, due to the narrowness of the entrances at the head and end of the tunnel, it is very important to arrange additional openings for inserting materials into the tunnel and to organize their proper movement inside the tunnel.

Also, it is important to remove standing water from the workplace during the work, which will make it easier, on the bottom, to find and timely eliminate defects missed during the inspection, and will also improve the working conditions on the site.

4.2 Construction solution to be used on the surface of the lawn

To eliminate small (up to 10cm deep and/or 20cm wide) concrete damage, the designated product MAPEGROUT T60, or a product with similar specifications released by another manufacturer, should be used.

The mentioned product is a specific, dry construction solution, which is used to restore damaged concrete and reinforced concrete surfaces.

MAPEGROUT T60 is a one-component, pre-mixed, cement-based, thixotropic solution consisting of sulfate-resistant hydraulic binders, synthetic polyacrylonitrile fibers, organic anti-corrosion additives, selected aggregates and special water-retaining admixtures.

If the size of the damage significantly deviates from the above dimensions (10 cm deep and 20 cm wide), then B-25 grade concrete should be used, with a maximum aggregate size of 25 mm.

4.3 Rehabilitation of the damaged base

As mentioned above, in several places, the bottom of the tunnel is quite damaged, and therefore the stability of the entire excavation is also weakened. Therefore, it is necessary to restore similar sections, which should be carried out as follows:

- The damaged concrete lining of the tunnel must be removed mechanically;
- Any foreign bodies such as wooden material should also be removed Waste, any contamination, etc.

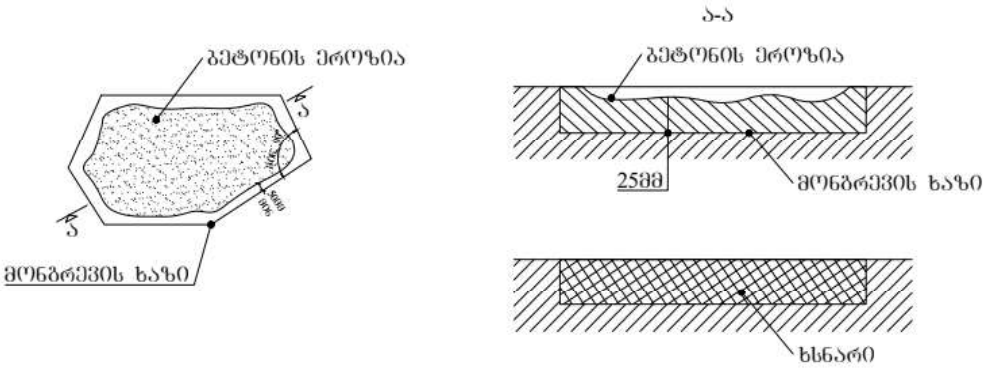
- To achieve a better grip, the screed should be drilled into the old concrete15 cm drills and install rebar anchors, 30 cm long and 14 mm in diameter. The ends of the anchors should point toward the center of the opening being removed.
- If the concrete base is reinforced (at this stage there is none There is no proof), the new reinforcement mesh should be arranged in accordance with the existing one and connecting the reinforcement rods together.
- Places to be filled with concrete should be cleaned and washed of any foreign matter from body and substance;
- NeededIn this case, the existing forms of the tunnel should be arranged according to the parameters;
- Pouring of concrete should be done using vibration.

4.4 Rehabilitation of erosion of the mowing surface

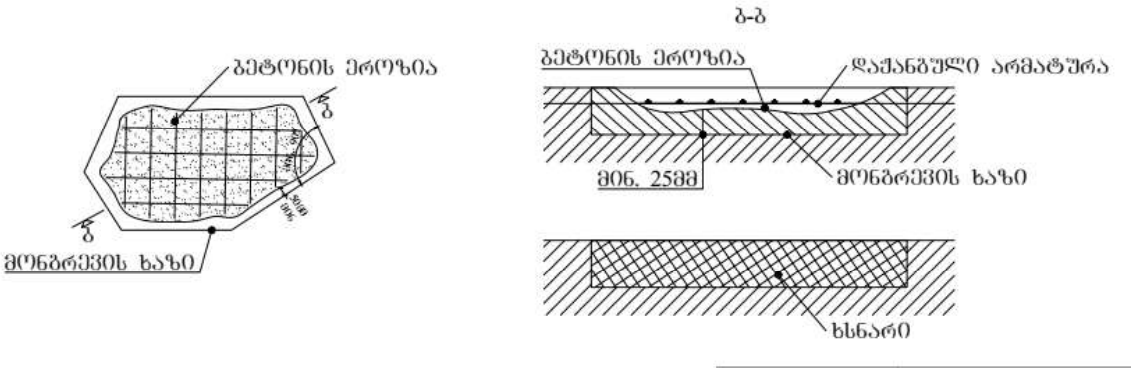
The quality of the concrete grinding performance is quite poor, which is manifested in the high rate of graininess and surface inhomogeneity. However, in some sections, there is an eroded surface, which poses a threat to the construction of the tunnel.

The rehabilitation of the mentioned eroded concrete sections should be carried out in compliance with the following conditions:

- The eroded section of concrete should be cut out from its contour at least5 centimeters apart, so that the angle between the cutting edges exceeds 90_0(see diagram below).
- Depth of cutout, if no exposed rebar rods are visible should be at least 25mm from the erosion bottom, and if visible - at least 50mm from the inner edge of the reinforcement;
- In case of stripping the armature, the rods must be cleaned from rust;
- If necessary, formwork of the existing shape of the tunnel should be installed Accordingly;
- The cut surface should be filled with mortar or concrete for tunneling Considering the parameters



- *scheme4-1:erozirebuli betonis reabilitacia*



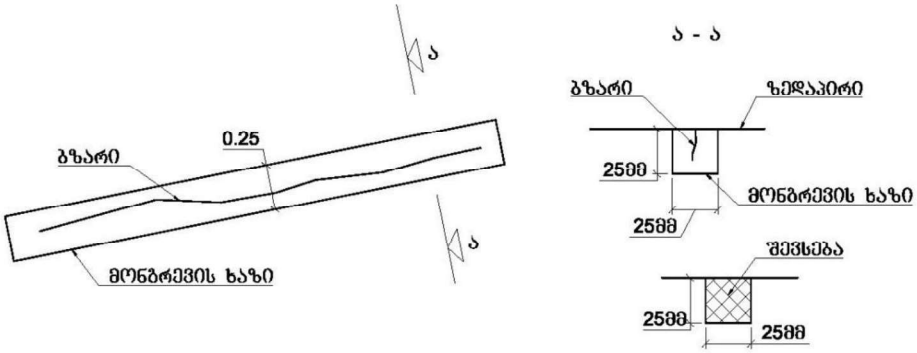
scheme4-2erozirebuli betonis (gaSiSvlebuli armaturiT) reabilitacia

4.5 Rehabilitation of cracks

Cracks found on the tunnel concrete lining should be treated to prevent their further development and damage to the lining.

Cracks should be treated in the following order:

- cut out in concrete along the cracks no less than25*25 mm section groove;
- The groove must be cleaned properly, with a water jet or the required gas using
- The cleaned groove should be filled with solution.

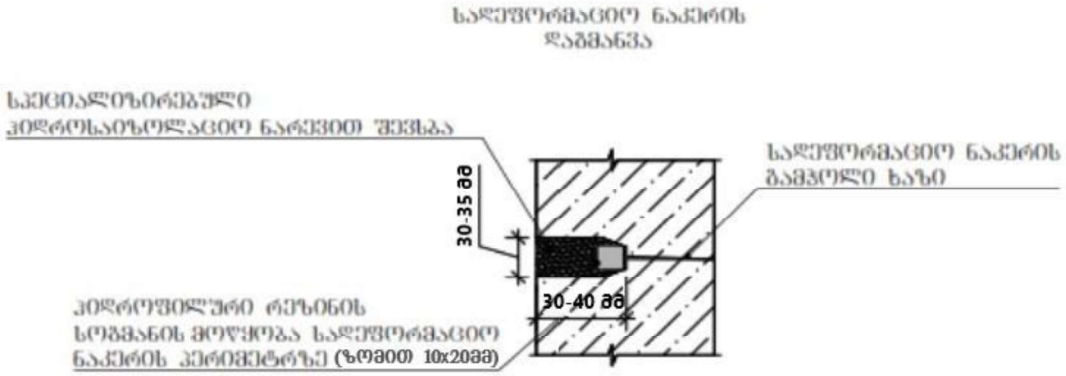


scheme4-3 Crack treatment scheme

4.6 Restoration of cracked construction seams

Repair of the construction seams of the tunnel must be done in the same way as the crack treatment sequence. However, the difference is that the construction seam must be cut to a depth of 3-4 cm, and to improve the waterproofing, a suitable amount of waterproofing material such as Sika "Swellstop" or "Swellstop II", or a product with similar properties, released by another manufacturer, must be placed in the cut groove.

After installation of the water barrier, the seam should be treated in the same sequence as the crack treatment.



4.7 Filling cementation

The voids between the tunnel construction and the surrounding rock should be filled with cementation (filler cementation). Three unit cementing drills should be arranged on each picket - in the arch and in the side walls, at a height of 1.0-1.5 m from the base, with a 6-meter drill (in the middle of the construction seams).

The diameter of the drills should be determined according to the diameter of the tampons to be used. The depth of drilling should be 15 cm added to the thickness of the cutting (variable rate).

At the first stage of cementing works, the following cementing solution should be used with water/cement ratio (by weight):

1/1 + plug (type A).

If the volume of the solution in the drill exceeds 1 m_3, then sand should be added to the cementing solution and cementation should be carried out with the following cementing mixture:

5/7 + 50% sand + additive (type b).

Because the purpose of cementing works is only to fill voids, and also, taking into account that the actual condition of the concrete is unknown, the cementing pressure should not exceed 1 bar.

The blanks should be filled in the following order;

- drilling holes of required diameter and depth;
- tamponage of the drill;
- Hardness of the solution in the drill;
- Removal of tampons, no less than after completion of cementation worksafter 8 hours;
- Drill holes with solution.

5. Work planning

5.1 Modeling changes

Due to the limited time allotted for carrying out the works in the water supply tunnel, continuous production of the process of rehabilitation works is a prerequisite for their success. Working in 12-hour shifts is recommended to achieve the goal. In order to avoid losses of working time, the rotation of working personnel should be done directly at the workplace. All working groups should be equipped with a portable transmission device and additional electric lights.

5.2 Safety measures for underground works

water supply of the tunnel Rehabilitation works performance should To be carried out in extreme conditions, therefore, attention should be paid to the normative requirements of safety conditions.

All workers must be equipped with personal protective equipment, work areas must be properly lit.

5.3 Fire prevention measures

fire protection Equipment provided for should maybe of the tunnel At the entrance and workplaces.

A fire stand equipped with a 5kg powder fire extinguisher, a wooden handle, shovels, a power cable cutter, scissors, di-electric boots and 1m should be hung at the tunnel entrance.$_{3}$with volume sandbox.

5.4 Environmental protection

In the process of performing rehabilitation works, environmental protection measures should include the protection of the workplace and surrounding space from debris and

Protection from falling material, spilling of toxic materials on the surface of the tunnel, etc.

6. Implementation of works

6.1 Preparatory works

Due to the limited deadlines for the rehabilitation works, the preparatory stage of the works must be performed thoroughly. Stopping the operation of the tunnel should be done only after all the preparatory work and logistic measures have been completed.

Implementation of rehabilitation works is planned in stages. In the first stage, the rehabilitation works of the initial section of the tunnel (Pk. 1+50 ÷ 4+75) should be carried out.

In the preparatory stage, the following measures should be implemented:

- Arrangement of access to the tunnel;
- Arrangement of an alternative access to the tunnel for the delivery of materials;
- Arranging a storage place for materials at the entrance of the tunnel;
- Bringing the necessary communications to the workplace (power supply, water supply);
- Ensuring water pumping from the workplace.

At the initial, preparatory stage of the rehabilitation works, it is recommended to start the works for the construction of an additional communication vertical shaft. At the initial stage, the shaft should be prepared to a depth of at least 1 meter before the construction of the tunnel. And after closing the tunnel for rehabilitation, the last segment should be completed - the junction of the tunnel with the construction of the tunnel. The arrangement of the mentioned communication shaft will significantly facilitate the delivery of materials needed for the work to the workplace, which, accordingly, will affect the cost of the rehabilitation works. In addition, this communication will be able to be used during the next period of work.

In the tunnel, the power supply should be carried out by means of shaft-type, flexible copper cable and insulated conductors for lighting and electrical equipment. All electrical equipment must be of shaft type with IP65 protection. 36W used in the tunnel. Luminaires should be installed at a distance of 6 meters.

The workplaces must be freed from technical and filtration waters, which will interfere with the production of works.

The inflow of water into the tunnel has not been recorded, however, it is necessary to pump out the flooded water at the bottom of the tunnel with pumps of appropriate performance.

6.2 Basic rehabilitation works

In terms of complexity, the water supply tunnel rehabilitation program can be defined as particularly complex.

Movement in the tunnel and movement of materials should be carried out using mechanisms with small dimensions.

Only diesel or electric powered mechanisms are allowed to work inside the tunnel.

As an alternative, it is also possible to use the entrance at the end of the tunnel (Pk. 16+25, Isni side), however, in this case, the transportation time and distance increases significantly.

It is better to make the concrete and solutions needed for the restoration works of tunnel excavation on site. However, ready mixes may also be supplied from outside, provided that the continuity of the processes is ensured and the materials can be delivered to the site in time for their use.

For the production of cementing works, the equipment required for the cement solution may be erected both outside the tunnel (for example, near the communication shaft) and inside it (if the dimensions are appropriate).

All stages of rehabilitation works should be planned properly and consistently. The work program should be carried out consistently to minimize delays.

At the first stage, the removal of waste from the tunnel should be carried out naturally. After that, the damaged concrete must be repaired using appropriate technologies.

Cementing works should be carried out after the restoration of the concrete.

At the final stage, the tunnel should be cleaned of all construction debris and foreign bodies, temporary communications should be removed and the object should be demobilized.

7. Cost estimation of rehabilitation works

cost estimate is prepared only first stage program to implement building works measurement standard of the E-4 edition of the methodology (CESMM4;The Institution of Civil Engineers and The Federation of Civil Engineering Contractors,2012) taking into account the recommendations.

The quantities given in the table are not exact and may change according to the work progress program. The volumes of works shown in the given table are used to determine the approximate budget for rehabilitation works.

The unit prices specified in the cost estimate should include, but not be limited to, the costs of the following listed items:

- personnel and labor;
- Equipment and devices;
- materials and supplies;
- Electricity, fuel, water and other energy carriers:
- operations and technical services;
- general and specific overhead costs;
- Taxes (except VAT), obligations, fees, etc.;
- geodetic, inspection, control and measuring works;
- Testing, analysis and materials, equipment and production, construction before, during and after construction;
- devaluation;
- Any other costs not stated but implied in the documentation of the works to be performed, according to internationally recognized practices.

Any item along which no unit cost is entered shall be deemed to be included in the other prices and unit costs of that resource.