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Application of "opened gallery" structures in Albanian infrastructure

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Abstract:

While reconstructing and expanding the segment Qafe Thane - Pogradec, positioned in most of its length along the Ohri lakeside, the necessity came to protect two historical objects "bunker type" from the First World War.

In order to preserve the historical and environmental resources it was a necessity applying technical-engineering solutions, to protect the field from sliding and massive rockfall.

There are several options to reduce the risk of rockfalls. The construction of a structure that protects permanently, the goods and people located in the trajectory of the rockfall is a common option.
Protection galleries are a good choice when the protected area is narrow and well limited, like in our case, and the safety of the area below the structure can be neglected.

From the geotechnical study, the bearing capacity of the soil is enough for a rigid structure like a opened gallery and the length of the protected area was designed limited because of the high construction cost of these structures. Those opened galleries, were designed with a soil layer over their cover, to protect in front of either medium or small sized rock falls.

In Albania, the main problem when designing a protection gallery is the non existence of neither official regulations nor a widely accepted reference method. Some countries like Switzerland and Italy have regulated the design of these structures but, despite this, these regulations only concern protection galleries with a soil layer over their cover, which have been in use by the authors. For analysis and design of protection gallery structure, a three dimensional linear model is formulated, using an comercial FEM software.

The propsed solution predicts the utilization of a reinforced concrete "opened gallery", which not only protects the historical landmarks from slopping and rock falls, but also creates a recreation landscape, taking under consideration that the riverside it is used as a beach during the tourists season.

Key words: road, rockfall, "opened gallery", historical object, environmental protection.

1. INTRODUCTION

The fast development of Albanian infrastructure in the last years, not only has made a necessity building new axis, but also intervening in the rehabilitation and parameter improvements of existing axis. Lin – Pogradec road is located on the East-Sothern part of Albania, near Macedonian and Greek border. The last part of segment Lin – Pogradec is outlined on the left by the lake shore and on its right by a large slope. The existing road has a traveled way of 6.0 m and both sides shoulders of 0.5 m, it must be constructed with a 9.0 m width and concrete gutters of 0.75 m on both sides. Based on the memorandum signed November 2014, between the Ministry of Culture, Environment and Tourism Urban Development and the Ministry of Transport and Infrastructure, in which is required that interferences on this segment must be carried out to develop the touristic areas, preserving the historical cultural monuments, based on European and international standards [1]

Taking under consideration that this area is connected to the urban part of the Pogradeci city, has been predicted along the lake shore a walkway with 3.7m width. As to the applied solutions, more than ever the attention is focused on technical solutions that preserve the historical, cultural inheritage and environment. From all the studied options, the only one that preserves the historical object "bunker type", maintains the expansion of the beach area, is the shifting the road axis right side by excavation. This solution demands excavation in an area with soli low stability and high slopes.

Fig. 1: Images of the segment and the areas where the bunkers are located

2. PROPOSED SOLUTION

From the detailed geological engineering survey, geological drilling with 10 m depth, and laboratory analysis is drafted a detailed geological engineering study report and a geological-lithological map. From this report is derived that this area has rocky sediments from the Neogene and Upper Triassic. The quaternary sediments are represented by medium silt, medium sand, sand and rarely from gravel [2].

Taking under consideration the full topographic survey, the proposed solution envisions shifting right the road axis by excavations. The deviation of the axis on the right creates high slopes (35÷45) m, with a high risk of sliding and massive collapses, for which there are necessary to be taken engineering

stabilizing and protecting measures. In literature for such slope protections are available many types of solutions.

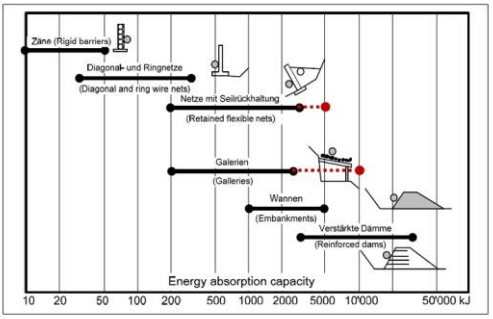

Fig. 2: Types of proposed protection from Descoeudres 1997 [3].

While taking under consideration the memorandum between ministries, some factors affect the selection for protection measures and stabilizing the area with high slopes and massive collapses, after evaluating the areas with high risk of sliding and massive collapses and from risk analysis was determined in base of the risk scale, having the minimal environmental impact that this measure has to have on the surrounding green, was chosen to be applied the "opened gallery" accompanied by a system of nets with cables on the slope [4]. This is the best solution, which ensures protection of the new road, minimal environmental impact, and minimal excavation space both in plan and in elevation. The application of this solution provides the stability of the areas with high risk of sliding, allows the road travelers to reach the lake, minimizes the environmental impact as a result of mountainside excavation and safeguards the new road from her top side massive collapses. The use of the "open gallery" structure, accompanied with a system of nets with cables on the slope is a combined solution as the application of one of the two solutions, nor any other solution, will not satisfy each request and the conditions demanded by the memorandum between ministries signed on November 2014 [1]

3. GEOMETRICAL DIMENSIONING OF THE STRUCUTRE "OPENED GALLERY"

Taking under consideration the transversal profile of the road that will be applied to this segment, has been designed the geometry of the cross section for the structure "opened tunnel". The "opened gallery" will be constructed as a reinforced concrete structure type box with dimensions (12.50x5.80) m with thickness of the walls 0.90m, the side facing the lake will be opened and designed with columns (1.10x1.80) m every 7.00m. The structure was designed this way to ensure that the road traveler shall be as close to the environment and nature as possible while using this road segment.

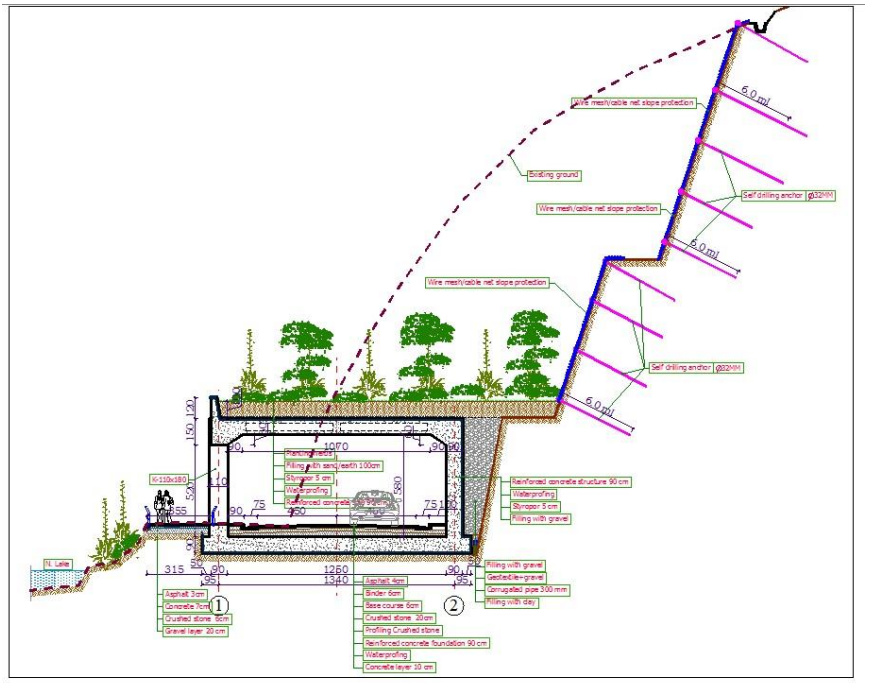

Fig. 3: Geometrical details of the "opened gallery"

The slopes are designed to be protected with a system of nets and cables anchored through self drilled anchors of 6m length.

Due to the geological conditions of the massive rock in case of destruction of the fortification system with steel cables, in order to eliminate the shock impact from the leftover rock massive, the "opened gallery" slab is predicted to be constructed with natural terrain cushions [5] of 1.00 m thickness, which will absorb, suppress the impact energy from the massive [6]. This cushion will serve even as greenness base structure, which will further increase its absorbing impact and minimize the environmental intrusion during the construction of this structure. These several protection measures were chosen after considering the importance of the studied road segment, the historical value of the objects "bunker type", as well as the constant utilization, road flux, by the inhabitants. The solution will be used in the following hierarchy: the impact energy from the possible massive collapse of the rockfell will be absorbed by the system of nets, grid, with anchored cables. Afterwards these massive, now without the impact energy, can be deposit on top of the structures "opened gallery", from where there can be carried out works to recuperate the damages to the fortification system without discontinuing the normal access to the road.

It must be noted, the assessment made to the high risk areas from sliding and massive collapse resulted that these structures will be constructed in four areas, where are formed considerable slops and there is a high risk of sliding and massive collapse with a total length of 292 ml.

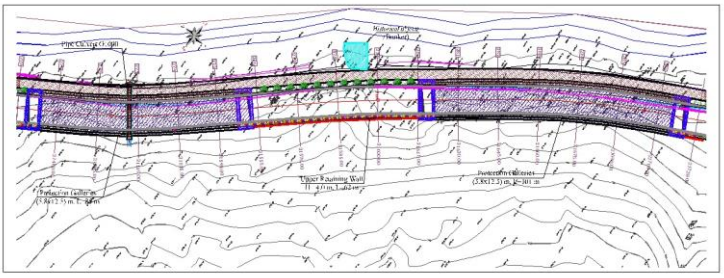

Fig. 4: The application plan of the structure "opened gallery" Km.21+468÷Km.21+553 and Km.21+615÷Km.21+716.

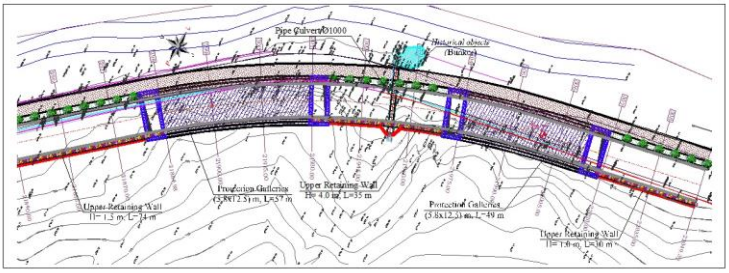

Fig. 5: The application plan of the structure "opened gallery" Km.21+880÷Km.21+937 and Km.21+971÷Km.22+020.

On other areas, where the slope has a lower high and the risk of collapse is much lower would be applied a solutions through bearing walls accompanied with a system of nets and anchored cables through self drilled anchors of 6m length.

4. FINITE ELEMENT MODEL FOR OPENED GALLERY CALCULATIONS

The behavior of the gallery was studied using the finite element analysis. The finite element model of the gallery is shown in Fig. 6.

Reinforced concrete slabs and walls are represented by solid elements for concrete, beam elements for reinforcement as well as stirrups for shear.

Eight-nodded hexahedron constant stress solid elements, and two-nodded beam elements was used for creating the model.

The fem model was designed for a segment of 29.8 m length and modeled with the structural software Tower.

The model was designed in a way so the structure is divided through a dilatation gap, positioned every 20.0 m throughout the structure length.

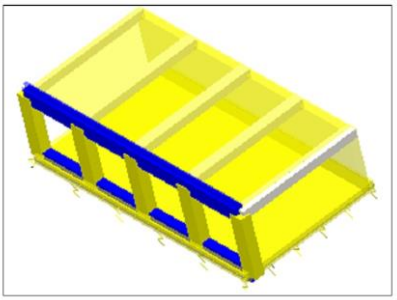

Fig. 6: "Opened gallery", solid finite element

A bilinear model is assumed for concrete in compression; the concrete is assumed to yield after having reached its compressive strength. The constitutive model for the longitudinal bars and stirrups is bilinear, with strain hardening.

The columns and the back wall are assumed to have fix support conditions. A concrete compressive strength of 30 MPa, and a tensile strength of 3.0 MPa are used for these models. The yield strength of steel is 500 MPa. A global damping ratio of 5 % is assumed for the structure. The impactor is modeled as elastic material with a Young modulus of 30 GPa [7].

No	Title	pX [kN]	pY [kN]	pZ [kN]	Mass caluculation coefficient
1	Dead loads (g)	-17071.60	0.00	-38253.60	1.00
2	Live loads	0.00	0.00	-5065.20	0.50

Tab. 1: Applied loads.

No	Seismic categorization		Distribution of the sesimc load			
1	Soli category	B		Kx	Ky	Kz
2	Relevance category	II (γ=1.2)	sx	1.000	0.300	0.300
3	Ratio ag/g:	0.22	sy	0.300	1.000	0.300
4	Behaviour factor	2.6	sz	0.300	0.300	1.000
5	Damping coefficient:	0.05				

Tab. 2: Seismic parameters

	Masses distribution				Rigidities distribution		Eccentricity	
Z [m]	**X [m]**	**Y [m]**	**Mass [T]**	**T/m2**	X [m]	Y [m]	e_{ox} [m]	e_{oy} [m]
8.00	0.00	14.00	13.92		0.00	14.00	0.00	0.00
6.70	6.76	14.00	2399.72	6.40	10.04	14.00	3.28	0.00
0.00	6.84	14.00	1759.06	4.11	13.38	14.00	6.54	0.00
3.88	6.77	14.00	4172.70					

Tab. 3: Distribution of masses, rigidities and eccentricity.

No	T [s]	f [Hz]
1	0.2393	4.1789
2	0.1690	5.9187
3	0.1206	8.2910
4	0.1105	9.0537
5	0.0862	11.5961
6	0.0658	15.1864
7	0.0622	16.0876
8	0.0483	20.7145
9	0.0455	21.9675
10	0.0455	21.9849

Tab. 4: Frequencies and periods.

Toni	UX (%)	UY (%)	UZ (%)	ΣUX (%)	ΣUY (%)	ΣUZ (%)
1	60.22	0.00	0.06	60.22	0.00	0.06
2	0.00	21.67	0.00	60.22	21.67	0.06
3	0.12	0.00	44.71	60.34	21.67	44.77
4	0.00	0.22	0.00	60.34	21.89	44.77
5	0.01	0.00	0.04	60.35	21.89	44.81
6	0.00	27.54	0.00	60.35	49.43	44.81
7	0.00	11.26	0.00	60.35	60.68	44.81
8	0.26	0.00	0.15	60.60	60.68	44.96
9	0.02	0.00	0.00	60.63	60.68	44.97

Tab. 5: Mass participation factor

5. RESULT PROCESSING

With the results from the numerical model, data processing was completed, calculation of the reinforcement longitudinal and transverse for each element and their construction. Some of the details for the structural elements reinforcement are demonstrated below:

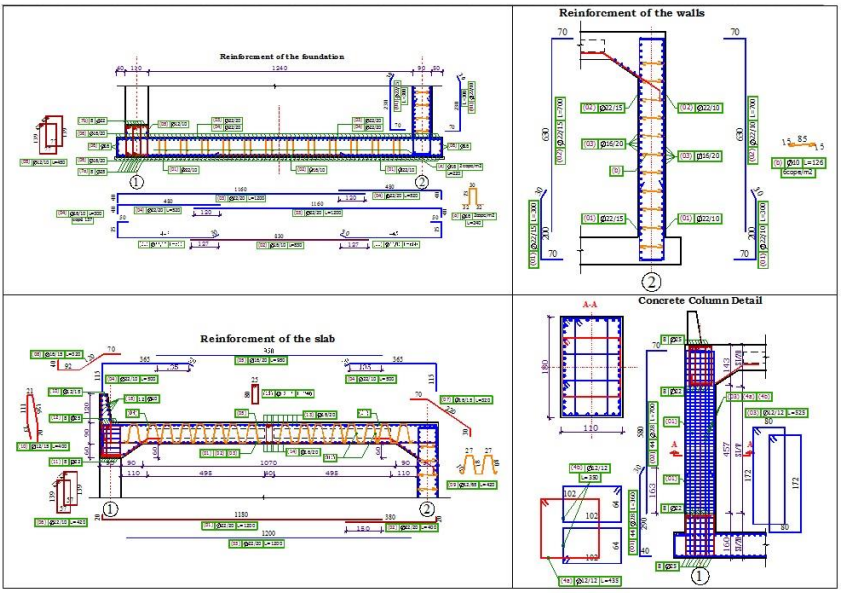

Fig. 7: Reinforcement detailing

Fig. 8: 3D of the applied solution

6. CONCLUSIONS

The application of the solution "opened gallery" is the first project of this kind in infrastructure in Albania.

The application of the solution "opened gallery" in constructing of this segment opens a new era in conception and implementation of contemporary solutions relying on new international standards, full harmony with the environment and cultural inheritage.

Through applying the "opened gallery" solution to the end segment of the roas Lin – Pogradec is ensured:

- Preserving the historical objects "bunker type" positioned between the road and Ohri Lake.
- Preserving the environmental standards and the road expansion in the beach area for the entrance to Pogradec city.
- Realization of the walkway with 3.7 m width, on the lakeshore of Ohr and extension of the exploitable shoreline as a part of Pogradec city

in accordance with the demands from the memorandum between ministries signed on November 2014.

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