THE 7th INTERNATIONAL CONFERENCE
"CIVIL ENGINEERING - SCIENCE AND PRACTICE"
GNP 2020 – Kolašin, Montenegro, 10-14 March 2020

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APPLICATION OF REINFORCED EARTH IN ROADS SUBSTRUCTURE

Abstract

In the process of planning, i.e. of designing of the roads, it is very important to find an optimal solution. This goal most often entails many challenges and diverges from the firstly envisaged idea, but it is of extreme importance to select the best technical solution. The application of a reinforced earth construction contributes to reduction of the overall quantity of concrete works and reinforcement, necessary to construct the end pillars and their foundations. The reduction of earthworks, mainly the quantity of the excavation for the foundations and their backfilling. Besides the cost-effectiveness of the construction, the building speed is an advantage that cannot be neglected, which, in any case, implies reduction of the work force costs anyway.

Key words

Road substructure, reinforced earth, panels, RC structure

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1. INTRODUCTION

The basic principles applied in earth reinforcement are simple to understand and have as such been applied throughout centuries. The basic attributes to earth reinforcement appearing as a special advantage in civil engineering are the following: deduction of costs and facilitation of the constructions combined with simplicity and resulting in attractiveness to the engineers. The interest in the subject is more important due to the technical and commercial success confirmed many times by numerous performed designs. Reinforced earth is a fundamentally different construction (system) from the conventional earth bearing systems, where different abutment systems are applied.

The abutment walls and the inclinations of the reinforced earth are considerably more economical and can tolerate higher level of shearing compared to the classic reinforced concrete walls. The key aspect of the internally stabilized system is the increased bearing capacity of the earth construction. By laying reinforcement that accepts the tensile forces, the force of the earth can be significantly improved to the level that the vertical face of the soil, that is, the reinforced earth system becomes self-sustainable.

2. APPLICATION IN THE WORLD AND IN THE REPUBLIC OF NORTH MACEDONIA

2.1. WORLDWIDE APPLICATION

Reinforced earth is applied in all developed countries worldwide, as a multiple-purpose, justifiable and rational concept in civil engineering. The areas of application are the following:

- Highways;
- Railways;
- Bridges;
- Hydrotechnical facilities;
- Mining;
- Ferrous industry and energy production;
- Airports.

2.2. APPLICATION IN THE REPUBLIC OF NORTH MACEDONIA

The original solution envisages two console bridges, respectively for both pavements over the river Vardar and a railway line passing along the river and connecting the new Demir Kapija – Smokvica highway (corridor X), with the newly designed tunnels through the Demir Kapija canyon. The alternative offered as a solution to reduce the construction costs is the replacement of two spans of the console bridge, shown on Figure 1, with a reinforced earth construction, envisaging a retaining (abutment) wall with a maximum height of 25 m, and a total surface of the wall of 7100 m².

The construction of the retaining wall is a mix abutment structure as on Figure 2, where the end pillars are outside of the construction of reinforced earth. The bridge and the reinforced earth are connected by a transitional slab bracketed on the top of the retaining wall, whereas at the end of the console bridge there is an end pillar founded very close to the abutment wall.

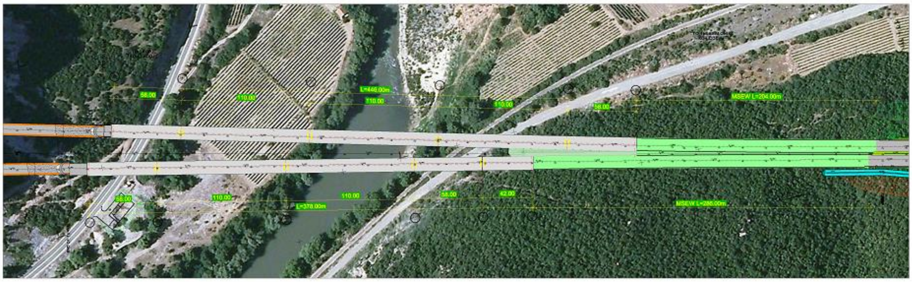

Figure 1. Horizontal layout, console bridge and reinforced earth

This type of combined construction offers an optimal solution related to the stability of the construction and financial economy. Due to the nature of the terrain on which the retaining wall is built, and with the purpose to reduce the excavation and to additionally influence the budget in the sense of reduction of excavations, the basis of the wall has been shifted by 6 m in the length of about 200 m’. This solution additionally influences the disburdening the lower panels from the pressure due to the 25 m height of the retaining wall.

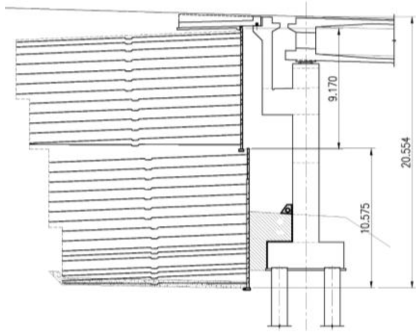

Figure 2. Longitudinal section of the mix abutment structure

The stability of the road is ensured by reinforcing strips of GeoStrap-5 type, as shown on figure, 3, each strip being 5 cm wide and with nominal strength of 25,0 kN, 37,5 kN, 50,0 kN and 65,0 kN. The length of the strips is 12 m to 17 m depending on the strip position.

Figure 3. Longitudinal section of the mix abutment structure

3. COMPARATIVE ANALYSIS

The choice of the type of the construction itself requires comparison and analysis of different types of constructions, finally yielding an optimal solution to be selected. In the case of bridging of a road, the choice is an overpass or an underpass depending on the type of the road or of the railway over which the new road is envisaged to pass. A high-quality alternative solution considering the envisaged use is a construction of reinforced earth combined with elements such as steel or reinforced concrete pre-stressed girders or a laminar construction of steel or of reinforced concrete where the horizontal and vertical forces of the construction's superstructure will be transferred through a bracketed beam and bearings directly onto the reinforced earth wall.

Hence the need for a comparative analysis of this type, making it possible to understand all the positive and negative sides of decisive importance about the type of construction that will be applied in a given case.

3.1. AN OVERPASS WITH A CLASSIC SOLUTION

The overpass is of reinforced concrete with a span of L=23,30 m. It is in straight alignment, with a longitudinal inclination of 2,50 % and the transversal inclination of 2,50 %. The overpass is dispositional with 5 prefabricated and pre-stressed girders positioned at a distance of 1,60 m. The overpass is set at the angle of 50° to the road route. The proper aperture is 21,40 m measured perpendicularly to the end walls with a static width of 9,93 m, and the height of the end walls from the upper elevation of the slab until the lower elevation of the foundations measuring 9,10 m. What is applied is a semi-prefabricated construction of reinforced concrete with a monolithic substucture, prefabricated main pre-stressed girders and a reinforced concrete slab for monolithisation as well as end transversal girders. The static system is a system with a simply supported beam with elastomeric (neoprene) bearings.

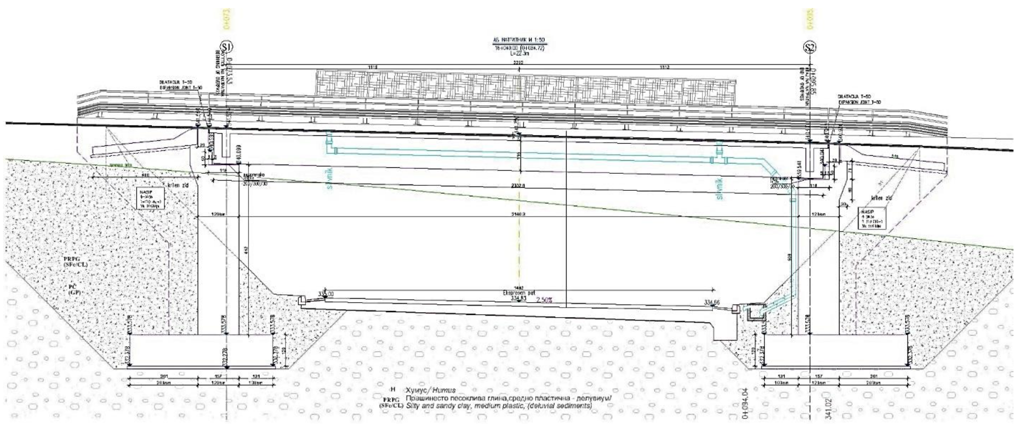

Figure 4. Longitudinal section of the overpass

The construction of the superstructure has been designed as a girder scale consisting of 5 prefabricated beams and a reinforced concrete slab for monolithisation and end transversal girders. The substructure consists of two end pillars. The end pillars have been designed as monolithic walls of reinforced concrete with a constant cross-section of 120/sin (156,70 cm). The upper part features a bracketed beam leaned on by the main girders through neoprene girders. The connection of the end pillars and the foundations with the wing walls is monolithic. The wing walls have been constructed as reinforced concrete walls with a variable cross-section along the height, measuring 50,00 cm in the crown until 100,00 cm in the contact with the foundations. The wing walls end with a console part of 5,00 m and of 4,00 m. In static sense, the wing walls and the end poles are treated spatially.

From a geological point of view, the wider field including the area on and around the location, is mainly presented by Pliocene sediment formations which are, to a larger or smaller extent, covered by quarter deluvial layers.

The wing walls have been designed according to the field conditions. They have a constant thickness along the height. The quality of the construction materials are: concrete MB30, ice grade M-100, reinforcement RA400/500-2. The embankment behind the walls can be performed up to the upper plate elevation before the main abutment is laid, whereby an appropriate static calculation is carried out. Upon the construction of the embankment behind the end and the wing walls, the compacting is performed only by mechanization, preventing damages to the waterproofing of the walls. The overall price of this solution amounts 162.186,28 €.

3.2. REINFORCED EARTH OVERPASS

This technical solution refers only to a replacement of the end wing walls, which implies a replacement of the end pillars, wing walls, the foundations thereof, the inclinations and the cones of the end walls, with reinforced constructions. The remaining part of the substructure of the construction, as are the main girders, the slab, the transient slab, the bearings and the superstructure remain unchanged. The overall price of this solution amounts 131.360,57 €.

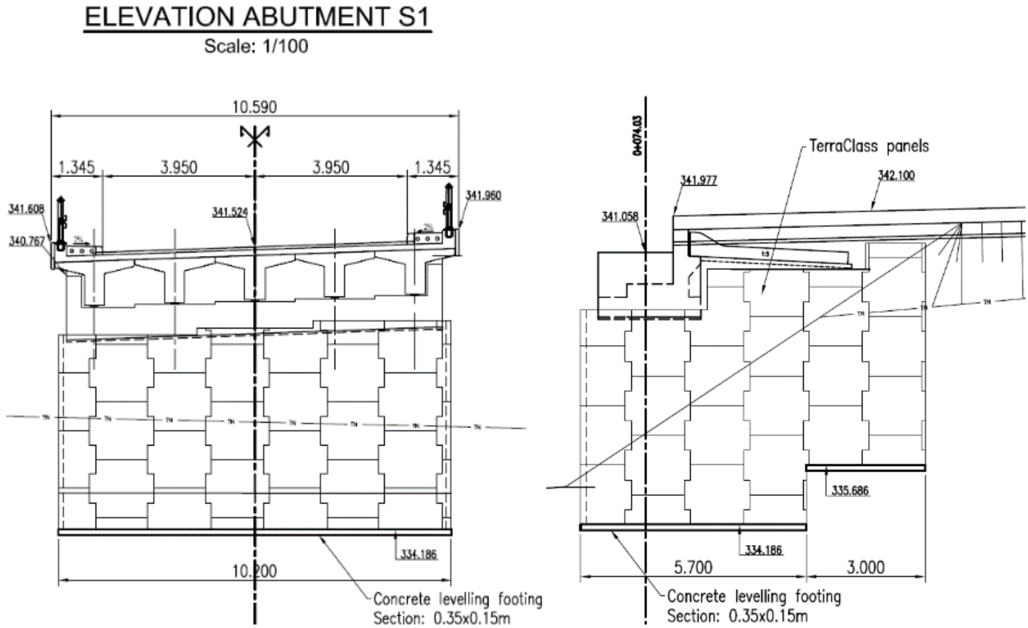

Figure 5. View of the end pillar

4. CONCLUSIONS

Reinforced earth is basically a simple solution combining and activating complex reactions between the construction elements, that is, their interaction, which are: filling, panels and reinforcement strips. This type of combined construction (true abutment) is widely spread and applied in all countries with all its advantages compared to the classic RC constructions, bridges, overpasses and underpasses. The main advantages that can be enumerated in relation to the classical construction method are the following: it is an economical solution, where the total amount of concrete used is reduced, the reinforcement is reduced as well, and the quick performance and the inside performance, which does not impede the traffic flow. It can be applied on soils with weak characteristics and without any deep fundaments and surely, with lower quantities of concrete and its production, which influences the reduction of carbon dioxide emissions.

The comparison between the two demonstrated solutions clearly indicates the 20 % lower amount of funds saved in relation with the classic reinforced concrete construction. Starting from the reduction in earthworks, where the excavation of foundations is reduced to a minimum, implying 99 % of funds saved, the cost of the embankment works has been reduced by 50 %, the cost of the concrete and reinforced concrete works have been reduced by 65 % and 89 % respectively. The comparative analysis of both solutions leads to a result, which shows that, if a combined construction with reinforced earth is applied as a replacement to wing walls, we obtain a solution which is economically more cost-effective compared to the basic classical solution with wing walls of reinforced concrete.

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