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TECHNOLOGICAL AND STRUCTURAL DESIGN OF A CONVEYOR UNDERPASS FOR THE COMBINED COAL TRANSPORT SYSTEM FROM THE ROOF EXPLOITATION ZONE OF THE GACKO-CENTRAL FIELD OPEN PIT MINE[**]

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Abstract

This paper presents the technological and structural design solution of a tunnel-shaped underpass constructed for the coal conveyor belt of a combined transport system, serving the Roof Exploitation Zone of the Gacko – Central Field open-pit coal mine. The underpass has a clear opening of 6.1 meters in width and 2.5 meters in height and is positioned at an azimuth of 140 degrees. It is integrated beneath a haul road intended for ultra-heavy-duty mining trucks, specifically BELAZ trucks with a payload capacity of 110 tonnes, used for overburden transport. The underpass is equipped with wing walls on all sides, to ensure structural stability and seamless integration with the surrounding terrain. The solution ensures uninterrupted operation of the conveyor system while maintaining the safety and functionality of the haul road for continuous mining operations.

Keywords: *Gacko coal mine, coal transport, conveyor underpass, open-pit mining, construction*

1 INTRODUCTION

The exploitation of coal i.e. lignite, in surface mines is characterized by the use of both group of equipment, continuous and discontinuous. Specifically, in the surface mines of the Kolubara and Kostolac coal basins, but also in North Macedonia (Suvodo and Brod-Gneotino surface mines), Bosnia and Herzegovina (Raškovac, Gacko-Central Field, Dubrave surface mines), in Kosovo and Metohia (Sibovac surface mine) they use continuous equipment either completely or for overburden excavation. On the other hand, the mass application of discontinuous equipment is characteristic for the exploit-tation of coal in the surface mines of the Ugljevik and Pljevlja coal basins. The use of both group of equipment has its benefits and drawbacks, but it is cer-

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tainly a decision of strategic importance, the decision which is made by analyzing a large number of important factors (morphological, geological, structural, hydrogeological, tectonic, logistical, organizational, etc.). The use of both types of mining and transport machinery is not uncommon and is used in situations where it is necessary to take advantage of the specific features of both types of equipment [1, 2] or within a single system - combined exploitation systems that use discontinuous equipment in one part and continuous equipment in the other. A common case is excavation with excavators and transport by trucks to the crusher, and continuous transport by conveyors and disposal by spreaders or depositing of mineral raw materials in a dump.

Position of transition from discontinuous to continuous part (and vice versa) or places of intersection of continuous and discontinuous transport routes, as a rule, imply certain infrastructure facilities (e.g. crusher foundations, bridges, tunnels, etc.), which is why they have a stationary character or they are in the same position for a longer period of time which is measured in years.

During the construction of these infrastructure facilities, the key issue is their positioning, considering the stationarity and influence on the process of mass transport, where the volume is measured in millions of cubics meters. The intersection of continuous and discontinuous transport routes is defined by the main directions and routes of movement of trucks (the main representatives of discontinuous transport equipment) and, to an even greater extent, belt conveyors (the main representatives of continuous transport equipment). A special problem is the dynamic nature of surface mining works, which is reflected in the changing position of the work site over time and the constant need to change, extend or shorten the network of roads and conveyor routes. When it comes to the transport of mineral raw materials, it is usual for its final destination to be a dump, a processing plant, or a place of loading into the customer's transport equipment, and these places are usually stationary. In the case of overburden and tailings transport, the most common case is that both the place of loading and the place of disposal change over time. This dynamic character of the works during the exploitation of mineral raw materials and excavation, transport and disposal of over and interbred has a significant influence on the definition of the intersection of discontinuous and continuous transport routes.

Such a characteristic case is present at the surface mine of lignite Gacko-Central Field open pit and thermal power plant Gacko. As part of the reconstruction of the combined system for coal transport, the economically and technologically favorable solution was chosen which includes the crossing of discontinuous and continuous transport routes, and it is necessary to solve the task of positioning the intersection and its technological and constructive solution.

2 TECHNOLOGICAL SOLUTION

The open pit Gacko-Central Field, which is located in the Gacko coal basin, uses both continuous and discontinuous mining and transport equipment, as well as their combination as part of two combined systems. One of the problems with the application of both types of equipment is the positioning of the equipment, that is, on the transport routes. The entire system and production organization should be organized in such a way that these two types of equipment cross in as few places as possible, but in practice it is often the case when this crossing cannot be avoided, either because of the positions of the excavation and depositing or disposal works themselves, or because their crossing has an economic justification (e.g. shortening of transport routes).

This problem is not unsolvable, but it requires the introduction of special infrastructure facilities whose position does not change for a long period of time and are practically stationary. The problem of crossing transport lines of discontinuous and continuous transport can be solved in two ways:

1. By creating transport bridges for the crossing of trucks over the belt conveyor corridor (Figure 1a).
2. By creating bridges for transporters with a lane across the road (Figure 1b).

Figure 1 *The method of crossing the routes of continuous and discontinuous equipment*

About the reasons for the relocation and extension of the Crusher-Belt Conveyor-Crusher (CCC) system, has been written in the author's previous publications [2, 3]. These publications explain the reasons, ways and benefits of extending the CCC system for coal transport, as well as its final form. Also, in the publication [2], the method of crossing connections with the bridge for the belt conveyor under which there is a one-way transport road for trucks Belaz 75135 is shown.

During the year 2025, the Investor changed the concept of the way of crossing the conveyor belt corridor and the transport road. A new way of solving this problem foresees the expansion of the corridor of the TU-3 belt conveyor and the formation of a bridge for trucks over the conveyor. Figure 2a shows the original crossover concept, while 2b shows the new crossover concept.

The new solution consists of the construction of an underpass intended for the passage of a conveyor belt for the transport of coal, which is located under the haulroad designed for the movement of mining trucks (eg BELAZ) with a capacity of 110 tons.

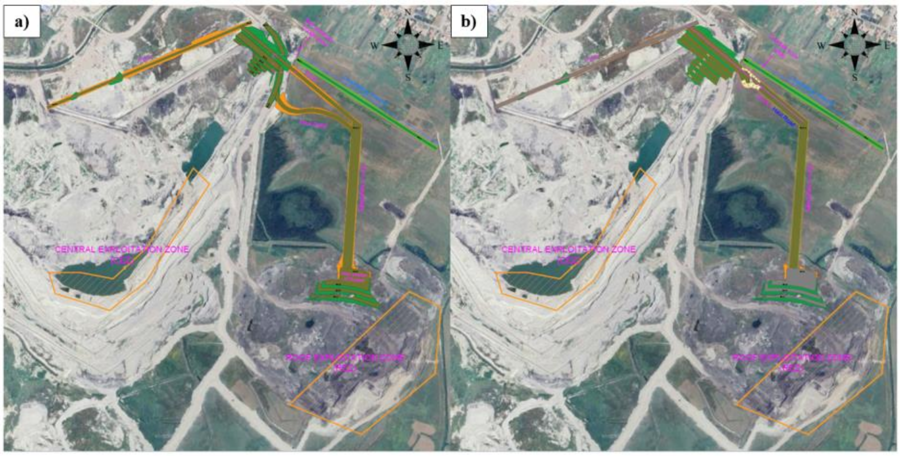

Figure 2 *Object position suggestions*

Both solutions have their positive and negative aspects. The advantages of the truck overpass described in this paper primarily lie in the fact that its maintenance and operation over time are significantly simpler. In addition, its construction ensures the integrity and complete compactness of the TU-3 conveyor embankment, even though significantly larger quantities of material are required for its formation. A third, but equally important aspect, relates to the water collector (marked as VS-C3). By constructing a unified embankment, there is potential for a significant increase in the active storage volume, as well as an expansion of the collector's flood zone. This is important not only for the functioning of the transport system but also for protecting the entire surface mine from water coming from the northern side.

After the place of intersection of transport routes is chosen, they are tied to that point in area, so the further construction of transport routes must be planned in relation to the place of work, but also in relation to this place. This results in a lower degree of freedom in the construction of routes and their formation in the geological environment that is present on those routes. This factor particularly affects the scope of works and the cost of construction of transport routes, especially when dealing with materials with unfavorable physico-mechanical properties. In this particular case, the surface layer over the entire area is represented by Quaternary sediments, which consists of alluvial deposits made of clay, gravel and sand. Closer to the river lines, there is more clastic material. With distance from the river-beds, the share of gravel and sand decreases, so the sediments become almost entirely clayey. The thickness of these layers is from 0.5 to a maximum of 8 meters. From a hydrogeological point of view, this environment is a collector, and from an engineering-geological point of view, it is an environment with extremely low strength parameters [4,5].

Beneath the quaternary sediments there are different marls of Neogene age, namely marls of the high roof of the main coal seam, and for this issue it is important that they have very good geomechanical characteristics and that they represent a good base for transport routes with good carrying characteristics. In addition, there are roof clays and marls, which are the youngest stratigraphic member of the Neogene. This member is built of clay and clayey marls. From the hydrogeological aspect, they represent an insulator [6].

Figure 3 *Contact of Quaternary sediments and roof clays and marls (red) with the transport path formed in the marls*

The negative aspects of this solution lie in the fact that significantly larger quantities of material need to be excavated along the route of the conveyor corridor and the transport road. This aspect is directly related to the amount of material that needs to be integrated. Due to the characteristics of the materials on which the transport routes are formed in certain parts, where the Quaternary sediments are less thick, it is more convenient to completely dig them out and form the routes on a marl substrate. On parts of the route that are formed in Quaternary sediments, it is necessary to replace the material, that is, to form an embankment made of material with good geomechanical parameters. In the first case, although the volume of quaternary sediments that need to be excavated is somewhat larger, the cost of creating a transport communication is lower, considering the quality of the substrate, while in the second case, the volume of backfilling with suitable material is larger, but it has a favorable effect on the subsequent cost of road maintenance. In general, it is more convenient and economical to form tracks in places where the Quaternary sediments are less thick and to form tracks directly on marls. Based on that, an important factor for the selection of the intersection of continuous and discontinuous transport routes is the structural-geological, engineering-geological and hydrogeological properties of the wider area. As illustrated in Figure 4, a cross-section of the route is presented, showcasing the distribution of Quaternary and marl sediments at the zone where the construction of the crossing will be built.

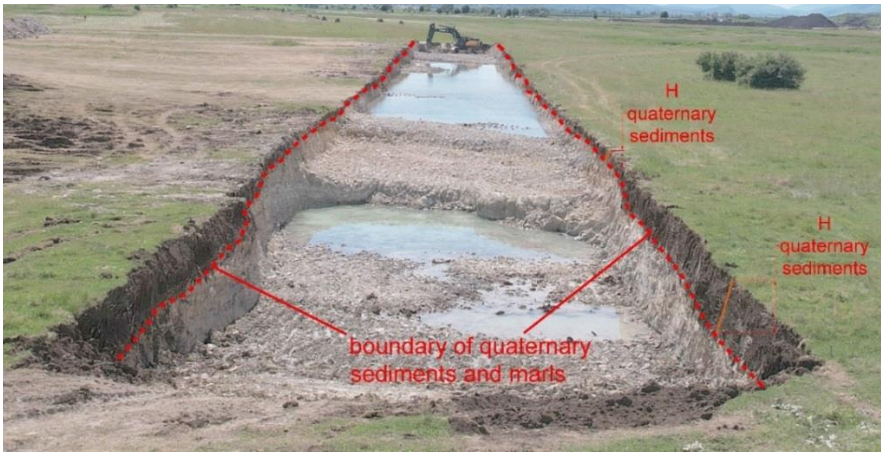

Figure 4 *Distribution of Quaternary and marly sediments at the zone where the construction of the crossing will be built*

By changing the position and manner of intersection between the two types of transport (trucks and conveyors), in this case—it is brought up to the surface level. This step results in increased noise emissions throughout the year, as well as a greater spread of dust emissions during dry months (summer period), especially considering the proximity of the settlement area. In this case the transport routes are positioned near settlements, negative impacts of transport on the environment are expected, primarily an increase in noise and dust concentration. In order to reduce these negative effects, it is planned to build a protective embankment with a green belt. The embankment would be formed from excavated Quaternary sediments suitable for reclamation and as a substrate for green belt plants. The position, dimensions and costs of creating a protective embankment are directly related to the excavated amount of quaternary sediments and the position where it is excavated, and is also a function of the choice of the position where transport routes crosses each other. Therefore, it can be concluded that the choice of the place where the routes cross depends on environmental factors, but also influences them.

In addition to positioning, from the technological aspect of transporting over and interburden or mineral raw materials, whether it is a discontinuous or continuous transport, it is important to define the dimensions of the crossing points, which depend on the dimensions of the truck, the dimensions of the belt conveyor, the longitudinal slopes of the routes, the turning radius of the trucks and the dimensions of the water protect facilities of the transport routes. The dimensions and general geometry of the object of crossing routes is a function of the frequency of discontinuous transport, as well as the requirements that this object must meet in terms of the subsequent efficient and convenient maintenance of transport routes.

3 TUNNEL SHAPED UNDERPASS

The subject micro-location of the intersection of mining roads at the Gacko-Central Field open pit is shown in detail in Figure 5.

Figure 5 *Underpass location*

From a structural engineering standpoint, the underpass is designed as a rigid reinforced concrete frame system, capable of withstanding significant vertical and lateral force generated by heavy mining trucks (BELAZ, 110-ton payload). Technical characteristics of BELAZ truck are illustrated in Figure 6.

Weight	100.1 t	Standard tyres	33.00-51
Dump capacity	71.2 m³	Net load	110 t
Steering	VL	Transport length	11.5 m
Transport width	7 m	Transport height	5.9 m
Travel speed	48 km/h	Turning radius outside	13 m
Loading height	4.8 m	Model series	7513
Engine manuf.	Cummins	Engine type	KTA 38-C
Engine power	895 kW	Displacement	37.8 l
Revolutions at max torque	1300 rpm	Max. torque	4726 Nm
No. of cylinders	12	Cylinder bore x stroke	159x159 mm

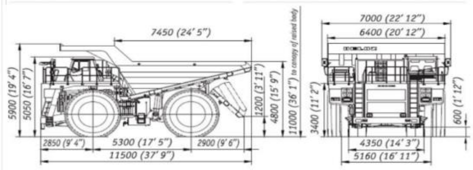

Figure 6 *BELAZ heavy mining truck*

The clear dimensions of the tunnel are 6.1 meters in width and 2.5 meters in height, with a total length of 18.5 meters. The structural elements - including the base slab, side walls, and top slab - are all 40 cm thick, providing robust resistance to bending and shear stresses. Figure 7 represent microlocation.

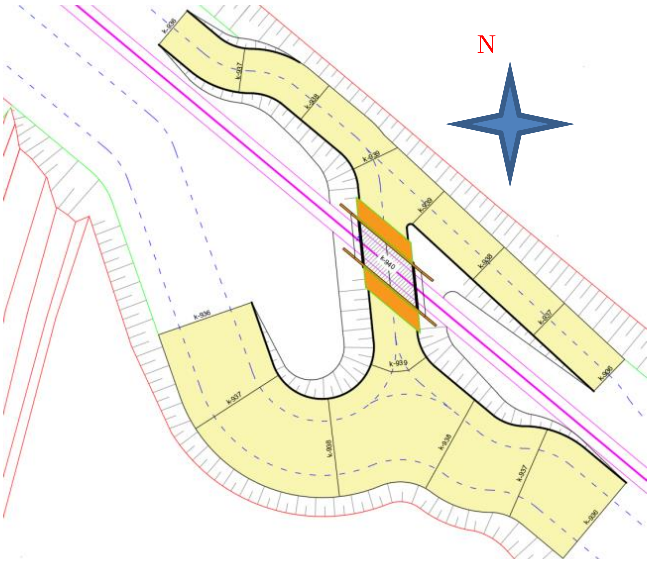

Figure 7 *Underpass microlocation*

To address stress concentration at the wall-slab junctions, especially under repetitive high-load wheel pressures, haunches (corbel-like reinforcements) have been introduced beneath the top slab. These haunches extend 1 meter horizontally and 0.5 meters vertically, effectively redistributing loads and improving the structural behavior at critical connection points. The structure is fully reinforced in accordance with rigid frame detailing principles, ensuring monolithic action and minimizing differential deformation. Additionally, reinforced concrete transition slabs measuring 14.5 × 4.5 meters and 30 cm in thickness are installed on both entry and exit sides of the underpass. These slabs facilitate the smooth transfer of wheel loads from the haul road onto the rigid structure while minimizing differential settlement and edge loading.

A 1-meter-thick crushed stone (graded aggregate) overburden is placed above the tunnel structure. This load distribution layer serves to disperse wheel loads from the mining trucks more evenly across the upper slab of the underpass, thereby reducing point load intensity and improving overall structural longevity. Figure 8 represent an underpass cross section.

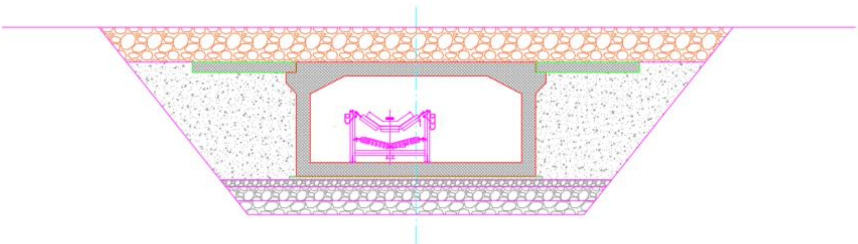

Figure 8 *Underpass cross section*

A longitudinal gradient of 0.5% has been incorporated into the base slab to facilitate drainage and prevent water accumulation inside the underpass. This solution not only guarantees structural stability and durability under extreme operational conditions but also serves as a protective housing for the coal conveyor system passing underneath the haul road. Figure 9 represent an underpass longitudinal section.

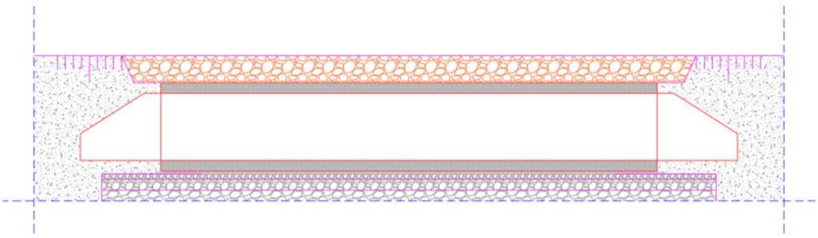

Figure 9 *Underpass longitudinal section*

4 CONCLUSION

The adopted tunnel-shaped underpass solution offers several practical and economic advantages over a potential bridge structure that could have been used to carry the haul road over the coal conveyor. The tunnel (underpass) requires a relatively short construction period, minimal permitting procedures, and lower overall investment costs. It is structurally compact and integrates well with the terrain, with wing walls ensuring slope stability and proper load transfer from the haul road above.

In contrast, a bridge alternative - particularly one capable of supporting ultra-heavy mining trucks such as BELAZ (110-tonne payload) - would have required a significantly more complex and costly design. This would likely involve deep pile foundations, post-tensioned cables, or a composite steel-concrete superstructure to achieve the required load-bearing capacity and durability. Moreover, such a solution would necessitate extensive geotechnical investigations, detailed permitting processes with local authorities, and a longer construction timeline including structural testing and future maintenance protocols.

While a bridge may offer marginally easier access beneath the structure and reduced risk of flooding under extreme weather conditions, the tunnel-shaped underpass was selected as the optimal solution due to its cost-effectiveness, faster implementation, and sufficient load-bearing performance within the specific operational and geological conditions of the Gacko open-pit mine.

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