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Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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USE OF COAL WASTE IN ROAD CONSTRUCTION

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Abstract

Large coal waste dumps are sources of environmental pollution. At the same time, these dumps are potential sources of materials for construction of embankments. Coal waste consists of fine-grain components created mainly by weathering and of large fragments varying in strength, water and frost resistance. Coarse soil stability characteristic is accepted as a holistic criterion for evaluating the possibility and the necessity of creating the dense structure of multicomponent coarse soil. At that, strength of aggregates system at compaction may serve the criterion for evaluating the possibility of creating the dense structure. Resistance to weather effects and climatic factors may serve the criterion of necessity. Studies of changes in mine rocks gradation under the influence of compaction, wetting-drying and freezing – thawing were conducted. Based on this, technological classification of coal waste as a multicomponent coarse soil was developed and special design and technological solutions

Keywords: coarse soils, embankment, strength, stability

1 Introduction

For the construction of roads hundreds of millions of cubic meters of soil are needed. These raw materials are extracted from quarries which occupy large areas of potentially fertile land. At the same time, coarse man-made soils which amount is measured in billions of cubic meters are accumulated on the land surface. One of the ways of their utilization is the use in road construction.

Coarse man-made soils are non-cohesive fragments of rock containing more than 50 % of fragments of more than 2 mm in size. Except for crushed stone, screening, pebbles and gravel, coarse soils include secondary products of mining industry such as crumbled rock of ore mining and processing enterprises and coal waste (hereinafter referred to as coal waste). The above coarse man-made soils are sufficiently homogeneous material from each source of extraction except for coal waste.

Multiple dump pits, slagheaps where huge amounts of coal waste are stockpiled, are specific characteristic of industrial regions of Ukraine. It should be noted that only 5 % of the total volume of coal mining and coal-cleaning waste was utilized.

Using coal waste as construction material in the engineering practice solves simultaneously the issue of dump pits liquidation and brings significant economic and ecological effect. All coal mining regions have practical experience in using coal waste in road construction, for example, the construction of a highway bypass round Donetsk in the direction of Zaporizhzhia (Fig. 1). For the first time this technology was tested at the construction of a road bypass round Luhansk [1, 2].

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Figure 1 Construction of a highway bypass round Donetsk in the direction of Zaporizhzhia

2 Coal waste characteristics

Coal waste is classified by source of extraction, type of fuel, plasticity number of mineral matter, content of combustible part, gradation and chemical and mineralogical composition, softening interval, the degree of swelling.

Mining rock is presented as sedimentary rock that has been changed under thermal influence, chemical and physical weathering. The instability of composition and properties is one of the main factors hindering its widespread use. However, on condition of observing the recommended methods of preparation and processing of rock, high-quality products can be obtained from it [3, 4].

Burnt rock can be found in many dump pits, mainly in their lower part [5]. In the areas of burnt rock small fragments (usually up to 1 cm) of oxidized loose coal are contained. Voids between them are filled with finely ground material. Accumulation of rock mixed with coal stockpiled in huge slagheaps causes oxidation and spontaneous ignition followed by gas emission.

By lithology this rock is a mixture of sedimentary rock associated with coal-seams, namely: mudstone, siltstone, sandstone, shale, limestone and pyrite [6,7]. Physical and chemical properties of the rock are significantly changed within the slagheaps influenced by thermal-oxidation. By the degree of natural thermal processing dumping rock can be divided into:

- unburnt rock (virtually no debris of burnt rock, low mechanical strength. This is mainly fresh coal mining and coal-cleaning waste);
- poorly burnt rock (characterized by a high content of burnt rock fragments);
- burnt rock (characterized by the absence of unburnt particles; fragments of rock are of red color range).

Compared to mining dump rock, coal mining waste is characterized by a high content of coal in the rock, more stable gradation and substance composition.

Burnt rock is more resistant to the destructive influence of water; soil layers built using it have better strength characteristics than soil layers built using fresh coal waste. However, in both cases strength characteristics are significant. According to a general rule of soil mechanics, soil strength and rigidity increases with the upsize of its grains. Thus, coarse soil has better values than fine-grained soil. Dump mining rock is a valuable geotechnical material due to its properties.

2.1 Experimental procedure

It should be noted that the feature of coal waste is heterogeneity of its gradation. Reducing to fragments of barren rock occurs as a result of weathering involving weakening the material over time and at short-term processing – at compaction when the break of weak grains edges occurs. The study proposes to classify coal waste by coarse soil stability rate as an integrated criterion of possibility and the need to create a dense structure of multi-component coarse soil. Coarse soil stability is an integral indicator to assess gradation stability of coarse soils mixture, including coal waste containing particles of various strength and resistance, to weathering. At that, strength of the aggregates system at compaction serves as a possibility criterion for creating dense structure.

Table 1 Classification of coal waste as multi-component coarse soil by coarse soil stability rate

Soil type		Characteristic	Characteristic value for		
			Initial state	Initial state of weathering	Final state of weathering
Strong type		Coarse soil stability rate A, %	≥ 95		
		Frost resistant, %	≥ 95		
conditionally strong	I type	Coarse soil stability rate A, %	From 85 to 95	From 80 to 90	From 75 to 85
		Frost resistant, %	From 50 to 70	From 60 to 80	From 70 to 95
	II type	Coarse soil stability rate A, %	From 80 to 90	≥ 75	≥ 60
		Frost resistant, %	From 50 to 70	From 60 to 90	
Weak type		Coarse soil stability rate A, %	≤ 75	≤ 60	
		Frost resistant, %	–		

When weak waterproof material is used, its destruction occurs followed by the creation of a significant number of fine grains at compaction. Further effect of weathering cannot cause subsidence strains. In case of 25-35 % of fine grains content, most of pores between the fragments are filled with fine grains promoting the creation of a stable structure. Therefore, weak soil type are the soils which coarse soil stability rate (A_0) is lower than 75 %, and further, over three cycles of wetting-drying (A_3) it will be less than 60 %. Most of coal waste composed of mudstones and siltstones has high strength in its natural state (150 MPa). It is badly split by compaction efforts. At the same time, the destruction varying in intensity degrees occurs under the influence of weathering. This type of soil called conditionally strong is hard to compact. Special structural and technological measures are provided for its using. Conditionally strong coarse soil also behaves differently at weathering. One part of it is being intensively destroyed at the initial stage of weathering and the other part of it is being destroyed over its life cycle with a small but constant speed. This implies the need to divide conditionally strong coarse soil into two soil types:

- Conditionally strong coarse soils of the first type are more resistant to weathering. Such soils having the coarse soil stability rate of 95 % ≥ A_0 ≥ 85 % are deteriorated under the influence of wetting-drying with decrement;
- Soils of second type in the initial state are also strong enough 90 % ≥ A_0 ≥ 80 % but under the influence of weathering during the initial period sharp loss of strength occurs A_3 ≤ 75 % followed by creation of a big amount of fine-grained soils.

Theoretically, the presence of a large number of strong waterproof rocks in a coal waste mixture is possible. However, they will be classified as strong soil type. These soils are practically not destroyed at compaction and under the influence of climatic conditions.
In this study coal waste of various coal fields of Ukraine was investigated and the change in physical and mechanical properties (gradation, coarse soil stability rate, etc.) of dump mining rock and coal-cleaning waste influenced by road climatic factors typical for road subgrade performance was defined.
According to the research results, gradation differs, sometimes considerably, for burnt rock from various coal fields and for fresh or unburnt rock, as well as for coal-cleaning waste.
Coarse soil stability rate of coal waste (a mixture of coarse soils) was defined and used for evaluation of strength of the entire system and its structural changes under the effect of compaction efforts after 3 and 10 cycles of wetting – drying was determined in the study. The research results to determine the coarse soil stability rate of coal waste of various coal fields of Ukraine are given in Figure 2. The analysis of the research results showed that burnt rock has the highest coarse soil stability rate and fresh rock has the lowest one.

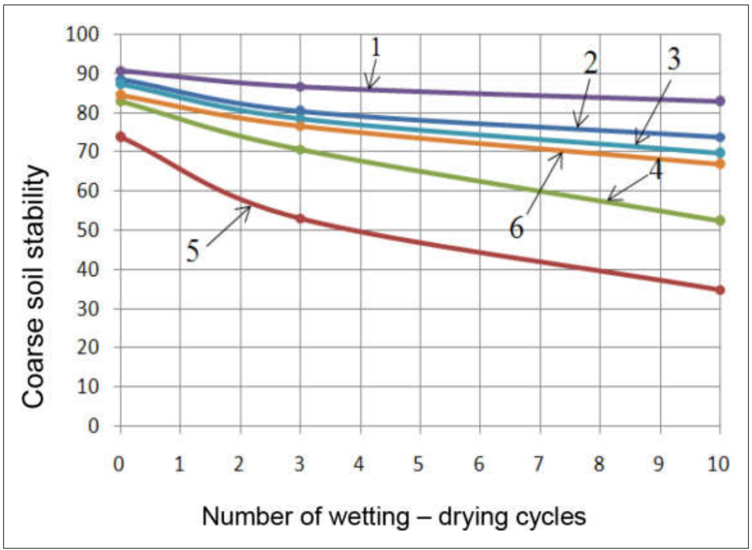

Figure 2 Graph of coarse soil stability rate change: 1) Coal waste of mine number 4 (burnt rock, the Volyn region); 2) Coal waste of mine number 8 (Burnt rock, the Volyn region); 3) Coal waste of "Chervonohradska" mine (burnt rock); 4) Coal waste of "Chervonohradska" mine (fresh rock, the Lviv region); 5) Coal waste of mine number 1 (fresh rock, the Volyn region); 6) Coal waste of mine number 8 (Unburnt rock, the Volyn region)

2.2 Embankment structures containing coal waste

Development of rational structures of embankments containing coal waste is carried out consistently and based on specified properties of the rock, height and width of the embankment. At that, it is necessary to fulfill consecutive calculations.
During the construction of subgrade using weak type coal waste, dense structure is achieved at compaction. Under the influence of compaction efforts coarse fragments are destroyed that is followed by formation of a significant amount (50 %) of fine fragments. This allows creating a stable soil structure which is potentially not prone to subsidence.
Designing of the embankment structure based on weak type rock is performed basing on the creation of dense structure potentially not prone to subsidence which is achieved at compaction. To ensure reliability of the embankment body performance, it should be stabilized by inorganic binder material. At the same time, covering of the embankment with the vegetation soil including grass seeding is provided by the design. In case of strong soil type of coal waste

the embankment structure is not different from the type structures for coarse soils, except for the elements that are introduced, if necessary, in accordance with fireproof calculations. It should be noted that such coal waste contains in its composition a certain amount of hydrolabile rock which at road operation could be potentially destroyed causing subsidence and uneven deformation. In this case, the most efficient option would be to fill the maximum number of pores between coarse fragments with fine-gain material. Then even at the destruction of fragments, the deformation of the whole system will be minimal as the newly formed fragments will not be able to move in the body.

Embankment structure with conditionally strong soil type of waste provides isolation of embankment body from the influence of weather and climatic factors (Fig. 3). For this purpose, protective screens on the slopes are used which prevent weathering of rock and penetration of moisture into the embankment body. The thickness of protective screen is calculated basing on waterproof and frost resistance conditions. Cohesive soil or the rock of slagheaps reinforced by inorganic binder can be used as the material for protective screens. However, to ensure reliability, durability and stability of the embankment, its body must be stabilized by inorganic binders. Using of different types and grades of coal waste in one structural element is unacceptable during the construction of road subgrade. Application of different types and classes of rock in various structural elements of the embankment is allowed by making appropriate changes to the design and technology of works performance.

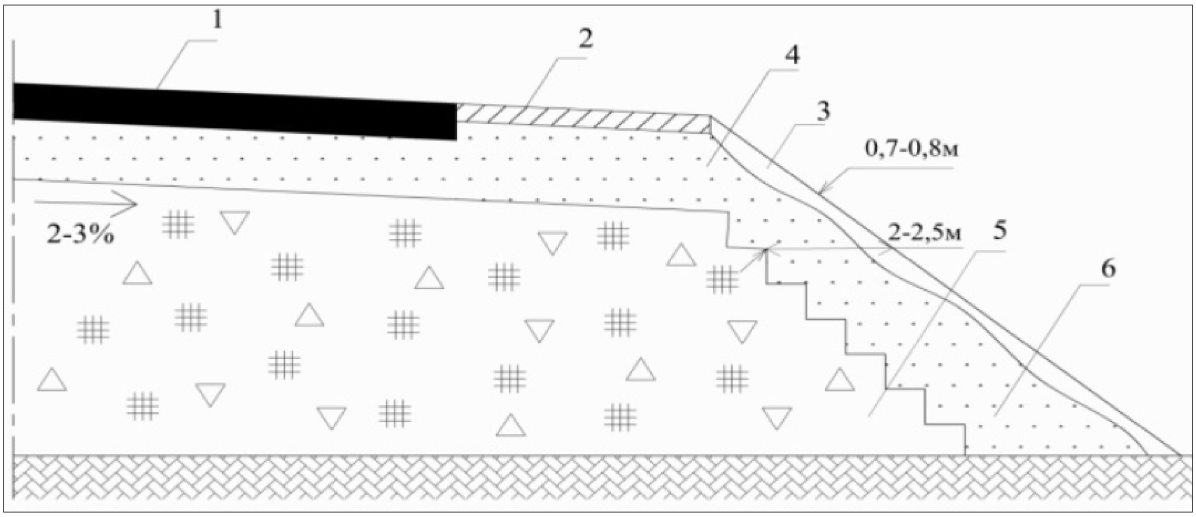

Figure 3 Embankment structure based on conditionally aggregate strong waste: 1) pavement; 2) hard shoulder; 3) layer of vegetation soil; 4) work embankment layer; 5) embankment body of conditionally aggregate strong coal waste; 6) protective screen

3 Conclusions

Secondary products of coal industry (coal waste) are very specific coarse soil. The studies have shown that coal waste contains a mixture of strong waterproof fragments and hydrolabile elements that can soak and of fine-grained component mainly formed during weathering. Density and strength of coal waste depend mainly on the lithification of coal containing rock. The highest strength has the rock that was exposed to burning (burnt rock); the lowest strength is specific of unburnt and weathered rock.

Coal waste relating to special types of soil can be used in subgrade only after a comprehensive study of its physical and mechanical, strength and deformation properties. Standard research techniques considering specific characteristics of coal waste as well as non-standard research techniques (such as coarse soil stability rate) were used for this purpose.

The analysis of the research results showed that dump mining rock is heterogeneous by its structure and properties. In the same slagheap along with a dense well-burnt material you may find weak, unburnt or poorly burnt rock. Gradation also varies greatly within the slagheap. In this regard, it is necessary to apply optimal gradation composition for pavement structure. Stability of characteristics of dump mining rock in structural layers of subgrade and pavement depend on road and climatic operating conditions.
Since the studies have shown that coal waste containing fragments of varying strength and resistance to weathering, it cannot be always used for the construction of subgrade without prior stabilization or strengthening by inorganic binder. This is especially true for unburnt rock. Unburnt and poorly burnt rock can be used in the subgrade structure only if proper waterproofness is ensured. Burnt, well-burnt rock may behave satisfactorily in structural layers of pavement provided that the loads, and especially subgrade wetting during the road operation are considered. Stabilization or strengthening by cement increases adhesion between coal waste particles due to setting and bonding. Coarse soil gains bearing capacity and becomes water and frost resistance.
To use coal waste in the construction of strong, sustainable and stable embankments, it is necessary to classify them. An coarse soil stability rate characteristic is taken as an integrated criterion for evaluating the possibility and the need to create a dense structure of multicomponent coarse soil. At that, strength of the aggregates system at compaction is regarded as such criterion for evaluating the possibility of creating the dense structure. Resistance to weather and climatic factors impact is regarded as the criterion for the necessity. If the fragments are prone to weathering, it is necessary to create the conditions for the non-subsidence embankment behavior.
It should also be noted that the use of coal waste for the construction of strong, sustainable and stable embankments involves the necessity to develop special structural and technological solutions according to their classification.

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