doi.org/10.62683/SINARG2025.052

Review paper

POSSIBILITY OF APPLICATION OF ASH, SLAG AND FLOOD GYPSUM AS COMBUSTION PRODUCTS FROM THE KOSTOLAC THERMAL POWER PLANT IN CONSTRUCTION

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Abstract

The use of ash, slag and waste gypsum resulting from the flue gas desulfurization process as a combustion by-product from thermal power plants is becoming increasingly relevant in the context of sustainable waste management and reducing negative environmental impacts. The use of ash, slag and waste gypsum resulting from the flue gas desulfurization process as a combustion by-product from thermal power plants is becoming increasingly relevant in the context of sustainable waste management and reducing negative environmental impacts. In order to mitigate negative effects and improve efficiency in the construction industry and other sectors, these materials can be used in various ways. Using these products reduces the amount of waste, while at the same time reducing the need for the use of natural resources. This contributes to sustainable development, although it is necessary to carefully determine the quality of combustion by-products from thermal power plants due to the possible negative impact on the long-term stability of buildings. The fact that depositing these materials requires not only space but also significant financial resources is very important. Above all, the use of fly ash, slag and spent gypsum in the construction industry can contribute to the reduction of carbon dioxide emissions (CO_2)

Key words: *Ash, Slag, FGD gypsum, Carbon-dioxide*

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1. INTRODUCTION

Electricity production in thermal power plants of Electric Power Company of Serbia is based on the use of lignite (about 70%). This process generates large amounts of ash and slag, which, despite having useful value, are disposed of in ash landfills within power plants. Ash, slag and, in recent years, FGD gypsum are most often disposed of in landfills located in the immediate vicinity of thermal power plants [1]. Thermal power plants in Serbia consume 35 to 40 million tons of coal annually, resulting in around six million tons of fly ash. In order to start selling ash, in the branch "Thermal Power Plants and Mines Kostolac", it was necessary to install appropriate equipment and apply appropriate technology. All necessary activities, completed in the previous period, are manifested in the sale of coal combustion products in thermal power plants, increasing the energy efficiency of the system for transporting ash, slag and FGD gypsum, saving electricity. Its use in construction and road building significantly reduces the amount of ash in landfills, which has a positive impact on the environment. By implementing activities in the sale of by-products, for industrial application, positive economic effects are achieved, partly due to the sale itself, and partly due to the reduction in the amount of fees for the deferred amount of combustion products from thermal power plants. In this way, environmental benefits are also increased, as the disposal of ash, slag and FGD gypsum in landfills will be reduced or eliminated, and therefore their impact on the environment.

2. TREATMENT OF BY-PRODUCTS FROM THE KOSTOLAC THERMAL POWER PLANT

Fly ash, which is generated in the process of generating electricity by burning coal in the boilers of both thermal power plants, is the largest waste in terms of quantity in the TE-KO "Kostolac" branch. The necessary documentation for the registration of fly ash in the European Register of Chemicals (REACH) is currently being collected, which is a condition for delivery to the European market. Otherwise, gypsum produced at the Kostolac B thermal power plant is included in the REACH regulation of the European Union on the registration, evaluation, authorization and restriction of chemicals, which ensures its sale in European Union countries. In Serbia, it is sold as non-hazardous waste, and the Law prescribes a document on the movement of non-hazardous waste, which waste control and management engineers fill out and monitor the entire process of handing over waste to operators. The goal is to sell as much gypsum as possible on the Serbian and European Union markets and reduce disposal costs. For example, the quality of gypsum obtained in the flue gas desulfurization process is fully suitable for the production of gypsum products, as confirmed by users from Romania. By the way, the Kostolac branch of the Serbian Electric Power Company has been selling fly ash for several years, thus fulfilling the ecological principle that lignite combustion products are used in the economy, instead of just being disposed of in landfills. Specifically, companies that have been users of these by-products obtained from the flue gas desulfurization process at the Kostolac Thermal Power Plant in the past period are "Conal Group", "Lafarge", "Moravacem & CRH Western Balkans", "Titan" and "Hella" [2]. Figure 1 shows the landfill area, cassettes for storing fly ash and FGD gypsum at the internal landfill of the PK "Drmno".

Figure 1. Landfill area / Loading fly ash into customer trucks

As can be seen from the picture, disposing of by-products requires a significant and organized space. On the other hand, selling eliminates the need for manufacturing, transportation and storage.

The implementation of a flue gas desulfurization system in the Serbian Electric Power Company represents a significant contribution to environmental protection. All blocks of the Kostolac B Thermal Power Plant are integrated into this system. The Kostolac port is of exceptional importance for the efficient distribution of gypsum, located in the former Dunavac branch, connected to the Danube via the Kostolac Canal. Since its commissioning, the port has seen, among other things, an increasing turnover of raw materials, such as gypsum and ash.

3. APPLICATION POSSIBILITIES

Gypsum is not a significant problem at this time, as are ash and slag. They are very similar in their chemical and other properties. They are a mixture of oxides of silicon, aluminum, iron, calcium, and contain heavy metals, radionuclides, and some organic matter. Possible applications include the synthesis of zeolites and geopolymers, the extraction of rare earths, and environmental protection. In construction, ash is used as an additive to cement, so that concrete with the desired mechanical properties can be obtained, and it can be installed directly on the construction site, without prior treatment. Ash is used in the construction and reconstruction of roads in both bound and loose states [3]. In its bound state, it is used in hydraulic mixtures for road stabilization and in concrete for road construction [4]. In its free state, fly ash is used in the base layers of roads as fill, in the construction of dams or to improve soil quality. Fly ash is used significantly in the production of dry, powdered hydraulic binders for masonry and plastering, for stabilizing road surfaces, and for the production of rolled concrete. The application in environmental protection is reflected in the fact that fly ash is used as an absorbent for highly contaminated wastewater, for example from mines.

The fact that the use of ash itself is very profitable is evidenced by the fact that all highly developed countries have a higher consumption of ash than production, the USA, Germany, Japan, the Netherlands, Great Britain, etc. Otherwise, in the Republic of Serbia, the most favorable logistical options available are in Kostolac, because it has a port, silos. However, the port does not have pneumatic filling for barges for transporting ash, which is the only problem at the moment. Another way to transport these by-products is by rail, which is nearing completion.

In addition to landfills in the area of Kostolac, Thermal Power Plants Kostolac A and B (4-Srednje Kostolacko ostrvo, 5-Ćirikovac, 6-Drmno), there are also landfills in the immediate vicinity of Thermal Power Plant Obrenovac (2-TENTA and 1-TENTB) as well as near Lazarevac, Thermal Power Plant Kolubara A (3-Veliki Crljeni).

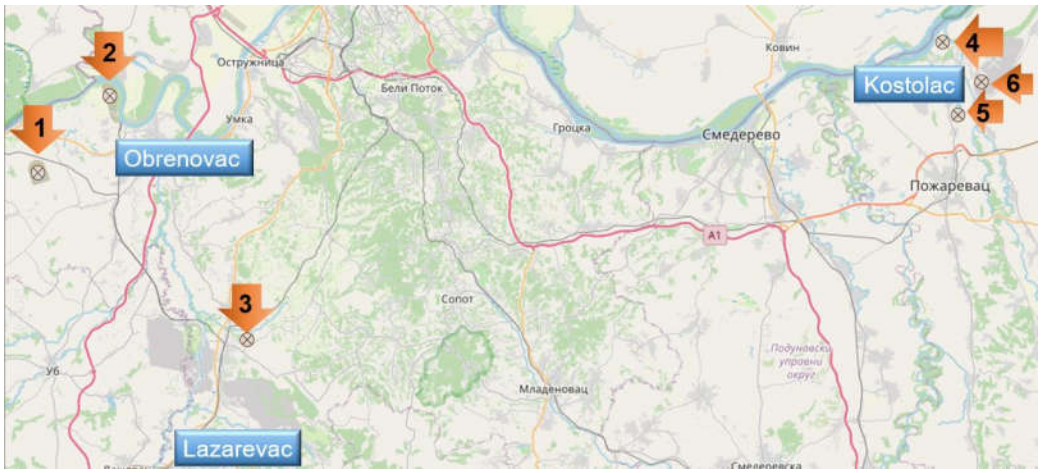

Figure 2. Fly ash landfill locations

4. SPECIFICITIES OF COAL COMBUSTION BY-PRODUCTS IN KOSTOLAC TPP

FGD gypsum in drained conditions has low cohesion values, typically 5 kN/m², and a relatively high angle of internal friction, typically greater than 30° [5]. In undrained conditions, the angle of internal friction is slightly greater than one-half of the angle of internal friction in drained conditions, but the value of cohesion is of the same order of magnitude. This proves that FGD gypsum behaves similarly to sands even when subjected to external loading in drained conditions. The load is taken by the friction force between the particles, not the cohesive force.

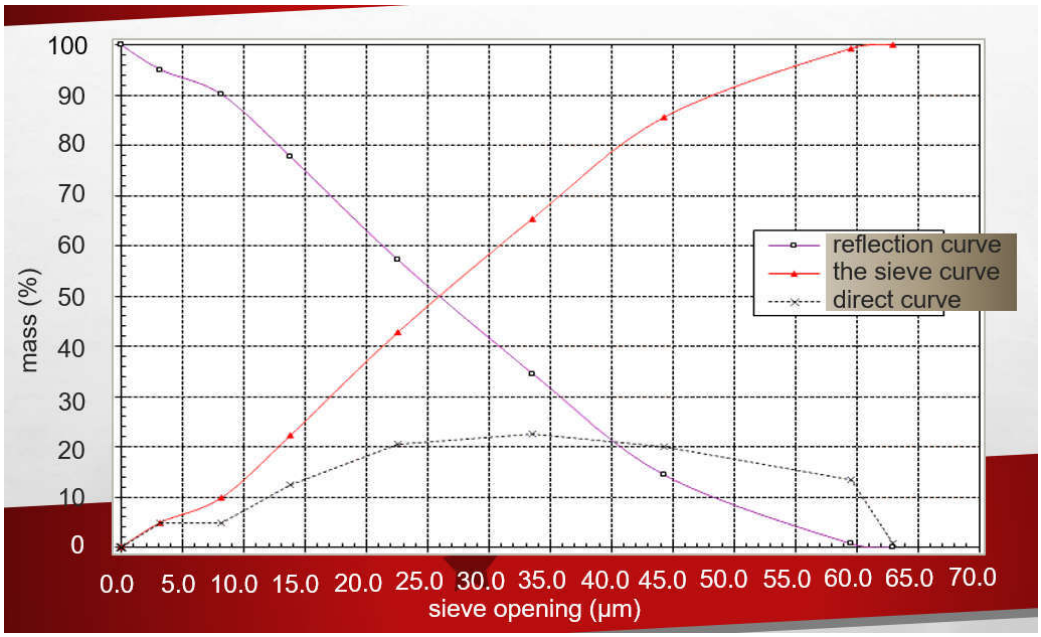

Figure 3. Graphical representation of the particle size composition of gypsum from the Kostolac B thermal power plant [6]

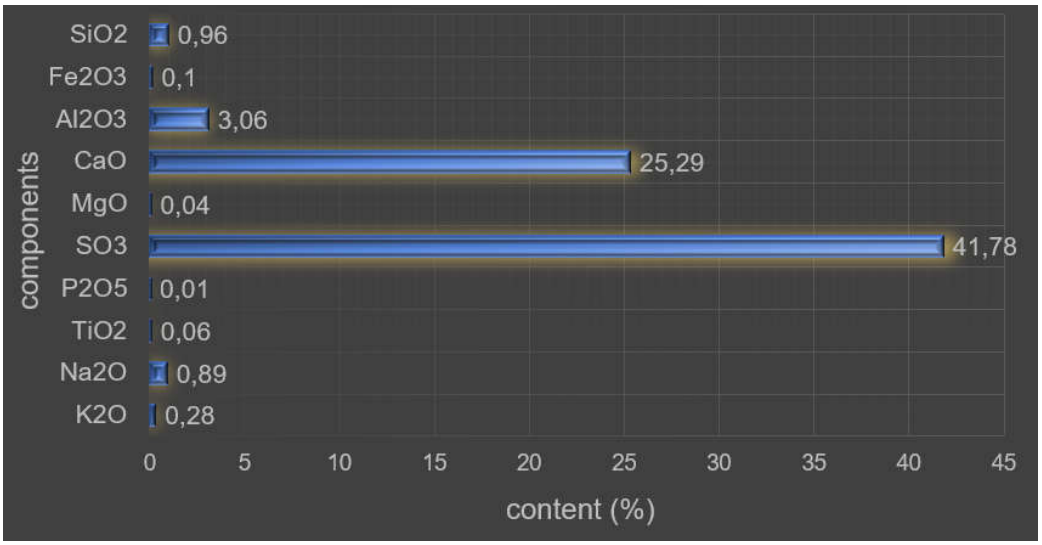

Figure 4. Chemical composition of gypsum from TPP "Kostolac B1"

The following tables show the results of tested samples from three locations: the ash and slag landfill Srednje kostolacko ostrvo (SKO), the Nikola Tesla B thermal power plant (TENT B) and the gypsum landfill from the internal landfill PK Drmno. Figures 5 and 6 show the results of the average values of the 12 tested samples, as well as the min.- max. range, while tables 1 and 2 list the physical and mechanical characteristics of ash and slag.

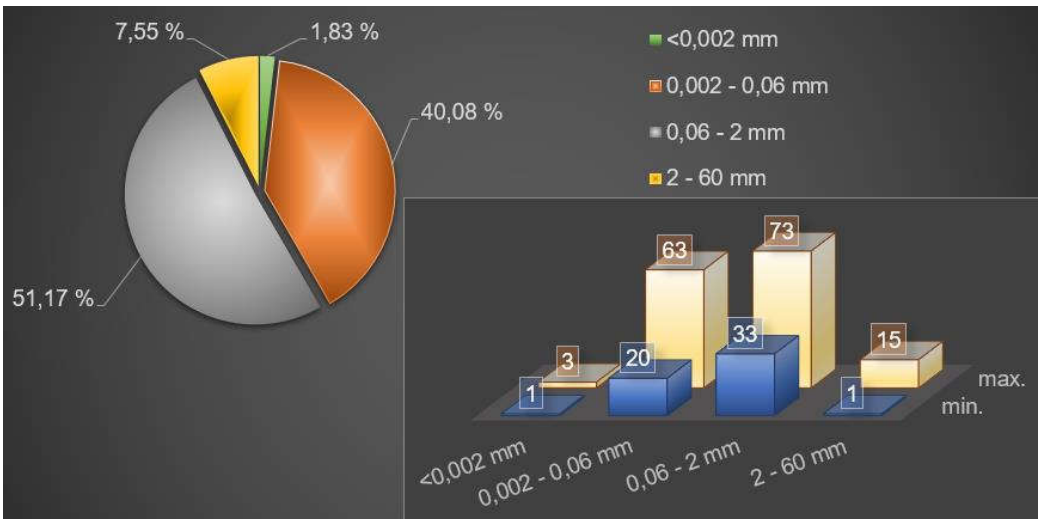

Figure 5. Granulometric composition of ash and slag, landfill "SKO"

Table 1. Physical and mechanical characteristics of ash and slag, landfill "SKO" [6]

HUMIDITY	DENSITY			DIRECT SHEAR D you learn	
***w* (%)**	ρ (Mg/m³)	ρ_d (Mg/m³)	ρ_z (Mg/m³)	Φ (°)	C (kPa)
20,6 – 42,1	0,91 – 1,16	0,73 – 0,83	1,28 – 1,47	26 – 30	0 – 7

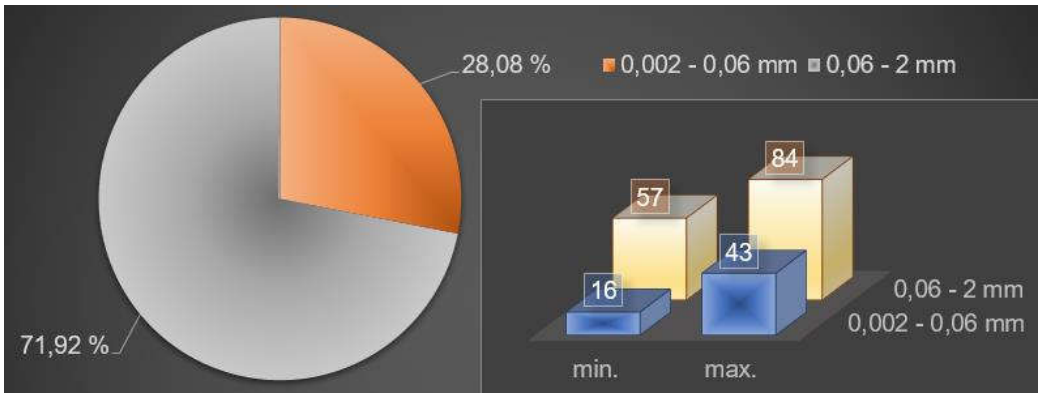

Figure 6. Granulometric composition of ash and slag, landfill "TENT B"

Table 2. Physical and mechanical characteristics of ash and slag, landfill "TENT B" [6]

HUMIDITY	DENSITY			DIRECT SHEAR D you learn	
***w* (%)**	ρ (Mg/m³)	ρ_d (Mg/m³)	ρ_z (Mg/m³)	Φ (°)	C (kPa)
12,4 – 57,7	0,96 – 1,08	0,62 – 0,85	1,32 – 1,43	26 – 30	2 – 5

Figure 7 shows the results of the average values of the 6 tested samples, as well as the min.- max. range, while Table 3 lists the physical and mechanical characteristics of the deposited gypsum.

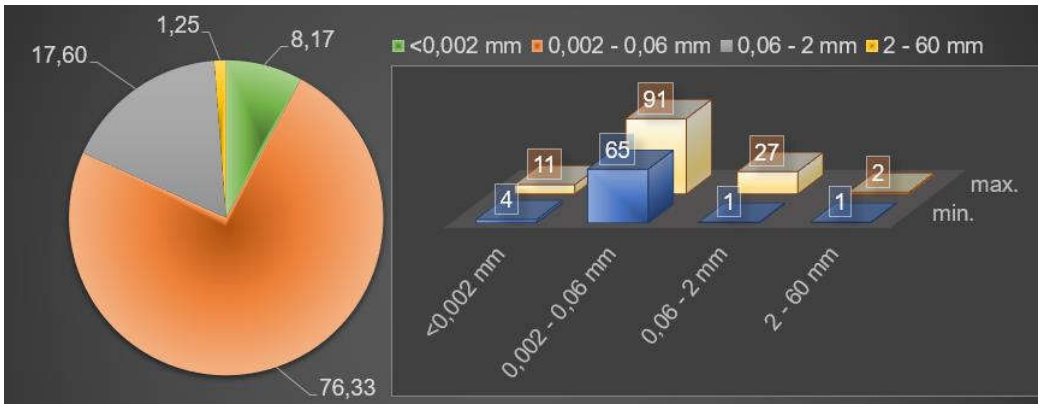

Figure 6. Granulometric composition of gypsum, landfill at the internal landfill PK Drmno

Table 3. Physical and mechanical characteristics of gypsum, landfill at the Drmno landfill [6]

HUMIDITY	DENSITY			DIRECT SHEAR D you learn	
***w* (%)**	ρ (Mg/m³)	ρ_d (Mg/m³)	ρ_z (Mg/m³)	Φ (°)	C (kPa)
12,7 – 33,0	1,37 – 1,90	1,03 – 1,69	1,40 – 1,95	21 – 24	8 – 15

5. CONCLUSION

The most common use of fly ash is in the production of concrete. Using fly ash helps create materials that are less susceptible to cracking or warping at extreme temperatures. This makes it an excellent stabilizer not only for the base of the subgrade but also for the road surface itself. Fly ash is also used in building products such as bricks, reducing the

amount of cement needed, as well as the need for other natural resources. Can also be used as a soil amendment. It provides plant nutrients and minerals that increase soil fertility, which improves plant growth and water retention. Fly ash geopolymers can act as magnets for water pollutants. These impurities bind to the porous fly ash, ensuring easier removal during wastewater treatment. Fly ash is a source of rare earth elements that are expensive and inefficient to mine, but are essential in the production of devices such as smartphones, electric vehicles and wind turbines.

The use of ash, slag and FGD gypsum brings numerous environmental, economic and technical advantages, especially in the construction industry and waste management:

- the costs of storing and disposing of these by-products are reduced or neutralized;
- these materials are reduced or replaced instead of using mineral raw materials;
- carbon dioxide emissions are reduced;
- reduced or eliminated environmental impact;
- reduction or elimination of spatial degradation;
- fly ash from thermal power plants (used as a substitute for cement in concrete, improves the workability of concrete, extends setting time and increases longevity, reduces shrinkage and cracking of concrete, is used in waste recycling);
- slag (used as an additive to cement or aggregate in concrete and asphalt, increases the resistance of concrete to chemicals and frost, has a smaller ecological footprint than traditional construction materials, and acts as a substitute for natural resources such as sand and gravel);
- FGD gypsum (used as a raw material for the production of gypsum boards and gypsum mortars, can be used in the cement industry as an additive, used in agriculture because it improves soil structure and reduces acidity, recycling avoids landfilling and saves space in landfills).

Some of the disadvantages of using fly ash:

- the ratio of concrete to fly ash must be strictly controlled in order to ensure the necessary quality of concrete;
- not suitable for all types of concrete;
- If too much fly ash is mixed into the concrete, it can reduce the strength of the concrete.

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