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Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR

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ECOLOGICAL ASPECT OF BIOASHES AS ROAD BUILDING MATERIAL

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Abstract

Numerous research into application of some waste materials and by-products in construction has resulted in knowledge of the behavior of such materials, its impact on the environment and the creation of guidelines and standards for their application. But in order to protect the environment and keep up with demands of sustainable development, people are turning towards renewable resources. Thus less known but potentially reusable and beneficial waste materials and byproducts are being generated. Waste materials that will be increasingly accumulated in coming years, due to European directive (Directive 2009/28/EC) on usage of renewable energy sources, are bioashes. In Croatia first power plants that incinerate biomass for energy production were developed in the last few years. Some of the largest of this newly built power plants are situated in eastern Croatia due to its good predisposition for biomass cultivation. So it is necessary to find different solutions to reuse locally generated ashes, as opposed to disposing it to landfills which is in most cases current practice. Research on locally accumulated bioashes as alternative construction material is currently being conducted on Croatian universities, mostly by testing mechanical properties of application in concretes and different aspects of road construction. Along with testing mechanical properties, ecological impact that utilization of bioash has on environment cannot be neglected in desire to enable their wider application. This paper deals with legislative treatment and ecological acceptability of bioashes as road construction materials with emphasis on heavy metal content in wood biomass fly ashes.

Keywords: bioash, alternative materials, road construction, ecological acceptability

1 Introduction

Alternative materials, such as waste and by-products, have been long researched in attempt to protect the environment and meet the requirements of sustainable development. Vast research has resulted in knowledge on behavior of such materials and creation of guidelines and norms for their application. In recent years, as a way of sustainable development, people are increasingly turning towards renewable sources of energy, one of which is biomass. In European Union there is a Directive 2009/28/EC [1] that obliges countries to produce 20 % of energy form renewable resources by 2020. Production of energy from biomass generates bioashes, a by-product that has great potential to be reused or recycled, especially in field of road construction. Estimations are that worldwide production of bioashes could be approximately 480 million tonnes annually, a number comparable to 780 million tonnes of coal ashes produced at present [2]. Currently smaller amounts are used in agriculture as soil supplement, but most of the bioashes are landfilled. Inappropriately disposed of and managed bioashes could have adverse effect on environment due to possible air contamination of fine particles by wind which causes respiratory

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problems [3]. Further, there is a possibility of leaching of heavy metals into underground and surface waters and soil contamination [4, 5]. As studies have shown [2] that contrary to common belief, bioashes do contain high concentration of toxic metals, sometimes exceeding those of coal ashes. High content of heavy metals dismisses their possible application as soil fertilizer, in spite high concentration of plant nutrient, and points to use as construction material.
Possible advantages but also the challenges of bioash utilization as construction material, are still at an initial stage, especially in Croatia, so there is a need for extensive studies on its properties. Some foreign examples point at possibility of using coarser fractions of bioashes as substitution of filler or aggregates in both bound and unbound bearing layers of pavements or concrete and using fly ashes as partial binder replacement because of its particle size and reactivity/binding properties. Research on locally accumulating bioashes, both mechanical properties and environmental aspect of its application, is necessary to enable and encourage its wider application. In Croatia this is most evident in its eastern counties where large part of biomass power plants are situated. Some researches into bioash application in construction are currently being conducted at few Croatian universities, while the chemical analysis of ash in this paper was conducted in Slovakia at Technical University of Košice. The paper shows legislative treatment and ecological acceptability of wood biomass fly ash generated in eastern Croatia.

2 Bioash production in eastern Croatia

As a member state of European Union, Republic of Croatia has incorporated obligations prescribed by European Directive 2009/28/EC [1] on renewable energy in its Strategy for energy development [6]. Strategic goal of producing 20 % of energy from renewable resources by 2020, amongst other, resulted in increase of energy produced from biomass and construction of new biomass fueled powerplants. In 2011 first power plant was opened and today there are 12 power plants that use biomass as fuel for energy production and another 48 are planned to start operating [7]. With this, installed power will increase from current 25,955 MW to 114,778 MW. A large number of newly built power plants are situated in eastern Croatia due to its good predisposition for biomass cultivation.

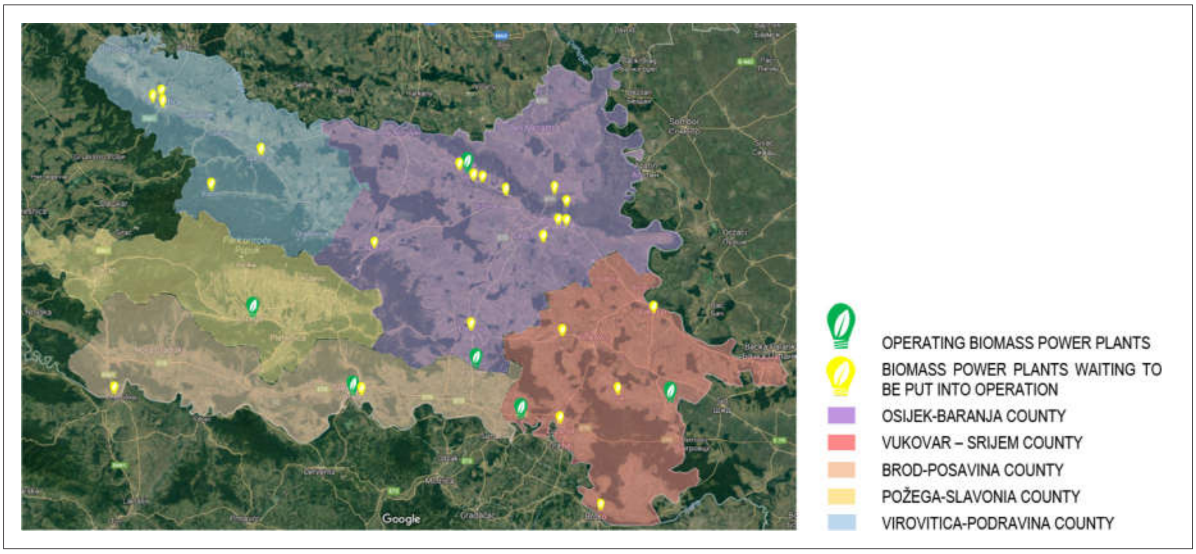

Figure 1 Location of biomass power plants in eastern Croatia

Good natural resources were reason for placement of 29 out of 60 Croatian biomass power plants in 5 eastern counties. 6 of them are currently operating with installed power of 19,155 MW, which is significant part of total installed power in Croatia (12 plants with 25,955 MW). Location of biomass power plants in eastern Croatia is shown on figure 1. First of this plants were built as a way to reduce production cost in wood processing factories by incinerating own waste wood and bark, but some were produced with main purpose of production and selling of electrical energy. Capacity of this plants is up to 8,6 MW of energy and they mostly use combustion technology with fixed bed furnaces. Along with this increase in renewable energy production there is a necessity to find ways to deal with resulting by-products which are bioashes. Current practice of handling locally generated ashes is in majority its disposal at landfills and this can have unwanted ecological and economical effect, considering that the 3,3 MW plant on its own produces around 3-4 tonnes of ashes daily.

3 Legislative frame on application of alternative materials road construction

Bioashes are in Croatian Waste Catalog [8] classified as non-hazardous waste and further more according to Ordinance on by-products and abolition of waste status [9] fly ashes from peat and untreated wood can be reused as part of a construction product. This goes along with EU waste framework (Directive 2008/98/EC [10]) that sets up a hierarchy of waste treatment options, preferring prevention, reuse and recycling over disposal.
In Croatia most of the legislation, guidelines and norms given about quality of construction materials only prescribe its mechanical properties without any instruction given to it ecological impact. When application of alternative materials in road construction are concerned, according to General technical conditions for road works [11], they can be used if they have same quality and properties as conventional materials according to technical guidelines and norms and fulfil all requirements of the construction. But even if mechanical properties of alternative materials are satisfactory, impact on the environment could be harmful because this is still a waste or by-product and toxic compounds could leach out and pollute watercourses [13]. Possibility of leaching is dependent on concentration of toxic compounds, quantity of alternative materials being used but also the type of application. When used in road construction, alternative materials should have less of an impact on environment pollution than landfilling it or using it as soil supplement (bioash). Lower potential of leaching is insured through few mechanisms:

- in courses where binders such as cement or bitumen are used toxic compounds are encapsulated in material and passage of water is reduced;
- bound courses are quite thin layers where lower volume of both natural and alternative material is used;
- unbound layers, which have significant thickness, are often covered with bound layer that should prevent water penetration in lower courses thus preventing leaching [12].

In Croatian legislative limit values of environmentally harmful substances are only given as maximum concentration of heavy metals in agricultural soil in Ordinance on the Protection of Agricultural Land from Pollution [13], shown in table 1.

Table 1 Maximum values of heavy metal concentration in agricultural soil (mg/kg) [13]

Soil type	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Sandy soil	0,0-0,5	0-40	0-60	0,0-0,5	0-30	0-50	0-60
Silty-loamy soil	0,5-1,0	40-80	60-90	0,5-1,0	30-50	50-100	60-150
Clay soil	1,0-2,0	80-120	90-120	1,0-1,5	50-75	100-150	150-200

4 Bioash generation, composition and properties

Bioash can be defined as inorganic residue left after the combustion of biomass with the aim of energy production. Properties of bioash are highly variable depending on biomass type and part of the plant used, impurities content, collection and processing, ash fraction and combustion technology. Type of combustion technology used highly affects the amount of ash and fractions that are being generated, particle size and chemical composition of ash fractions. Generally fixed bed combustion yields largest amounts (60-90 %) of coarsest fraction called bottom ash, and the rest is entrained in flue gas and known as fly ash, both coarse and filter fraction [14]. Fluidized bed combustion generates higher amounts of ash as part of it is made of bed material used in combustion process (such as silicate sand) and this fractions are 70-80 % fly ashes [14]. Research on chemical composition of bioash shows that bioashes are mostly made of plant nutrients such as Ca, Mg, K, P and Na along with Si, Al and Fe [2, 4]. Composition highly differs between ash from woody biomass which contains higher amounts of CaO to ash from herbaceous biomass which contains more K_2O and SiO_2 and has lower heavy metal content. Variations in chemical content, especially the content of heavy metals, is also evident in different ash fractions and combustion technology used. Generally, fixed bed furnace ashes contain more heavy metals then fluidized bed ashes and finest fractions – fly ashes have highest amount of heavy metals which are highly volatile. Some research has shown that bottom ashes and coarser fly ashes are ecologically harmless when used as soil fertilizer, but that filter fly ashes cross the acceptable limits set for use in agriculture and forestry [14].

5 Environmental impact of bioashes in road construction

In recent years research on bioashes as construction material in the world has intensified and it has been oriented towards both mechanical properties of materials with bioash and environmental impact of bioashes. It has been shown that in road construction bioash can be used as binder in stabilization of clayey soils [15] and sands [16], as binder [17] and aggregate [18] in base layers and also in asphalt mixtures [19].
In literature research on environmental impact is mostly related to application in soil stabilization or in stabilization of forest road courses as this has the greatest potential of harmful impact. Methods of research differ from determining toxic elements in bioash, testing of leachates of bioashes prepared in laboratories and monitoring leaching of harmful materials over a longer period of time on sites where bioash has been used. For instance Nordmark et al. [20] found that concentration of Cd, Cr, Cu, Hg, Ni, Pb and Zn in examined wood bioash are higher than allowed for application in construction works according to Swedish guidelines for usage of waste in construction. Examination of leachate prepared in laboratory showed that limit values only for Cl and SO4 were exceeded which was also initially the case for leachate collected in situ from gravel road stabilized by fly ash. But even though initially allowed values were exceeded there was a significant decrease in leaching of toxic substances measured over time. Another study also report declining trend in concentration of toxic substances over time [21]. The difference in measured values of toxic substances over time and between ash leachate and in situ leachate show that addition of ash to soil changes soil chemistry and affects leachability of materials [21], but also that hardening of the material through time is present which lowers leachability potential.

5.1 Experimental research of “Strizivojna Hrast” wood fly ash

For this research a heavy metal content of electro filter fly ash from power plant “Strizivojna Hrast” was determined, considering it is the ash fraction that could have worst ecological effect. The power plant is a part of wood processing factory that uses its own waste wood and bark along with wood bought from “Hrvatske Šume” for energy production. The incineration is done in a grate furnace at temperatures up to 660 °C. Daily around 110 t of wood biomass is burned and around 3 to 4 tonnes of ash is generated depending on the quality of biomass material burned. Along electrofilter fly ash, there are two other ash fractions: bottom ash and cyclon fly ash. Determination of electrofilter fly ash pH value showed that this is highly alkaline ash with pH of 12,78. Heavy metal content was investigated by X-ray fluorescence analysis (XFR) using SPECTRO iQII equipment. Concentration of heavy metals for which limit values are given by guidelines [1] (table 1.) was determined and results are shown in table 2.

Table 2 Concentration of heavy metals in wood biomass fly ash from "Strizivojna Hrast" in (mg/kg)

Element	Cd	Cr	Cu	Hg	Ni	Pb	Zn
Concentration [mg/kg]	‹5,1	‹5,0	138,2	‹2,0	‹2,0	16,8	349,8

When comparing concentration of heavy metals found in analyzed biomass fly ash with limit values of heavy metal concentration in agricultural soils (table 1.), it is evident that the limits are surpassed for Cr, Cu, Zn and Hg. This means that given bioash cannot be used in agriculture as soil supplement. Solution for recycling of this fly ash could be found as material for road construction. As fly ashes are often used for binder replacement, they are applied in smaller dosage which means that concentration of heavy metals resulting from its application is proportionally smaller than in fly ash on its self. For instance, application of up to 10 % fly ash on dry basis of soil would satisfy all criterium given in table 1. Along that, high pH value is an indicator that given fly ash is rich in alkalies and earthalkalies, meaning it probably has calcium that should induce hydraulic binding and result in reduced leaching of heavy metals. Research on effect of bioash on mechanical properties when used as a binder in hydraulically bound mixtures of local soils for application in low volume roads, is currently being conducted as a part of a doctoral research. Given that preliminary results of mechanical properties are encouraging, additional research into leaching potential of this bioash will be conducted. But in general, research has shown that, if mechanical properties are satisfying and if mode of application is carefully selected (bound courses), possibility of adverse ecological impact should be minimized and amounts of ash being landfilled should be reduced.

Figure 2 Bioash fractions from Strizivojna Hrast", left to right: bottom ash, cyclon fly ash, electrofilter fly ash

6 Conclusion

As production of energy form biomass is increasing so is the production of bioashes, which if not properly dealt with could have adverse effect on the environment. The problem of bioash disposal and possible solutions or recycling should be dealt with on local levels taking into account specificities of locally produced ashes and high variability of bioash properties in literature. In Croatia this in this is particularly noticeable in its easternmost part where a large share of biomass power plants is located. Accumulation of bioashes has initiated research on application of bioash in road construction both on mechanical and ecological level. The wood biomass fly ash investigated in this paper shows high content of heavy metals, with Cd, Cu, Zn and Hg surpassing the limit values for heavy metal concentration in agricultural soils. Given the latter are the only limit values given in Croatian legislative frame considering heavy metal concentration, it is obvious there is a lack of guidelines and limit values on acceptable concentration of hazardous compounds for application of bioash and other alternative materials in road construction. Even though investigated fly ash excides limit values for application in agriculture, foreign research show that this fly ash still has potential to be used in road construction, especially if applied in some form of bound layers that should decrease leaching of harmful substances.

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