CORPUS PUBLISHERS

Corpus Online Journal of Civil Engineering (COJCE)

Volume 1, Issue 1, 2023

Article Information
Received date : 22 March, 2023
Published date: 22 June, 2023

*Corresponding author
M Vukčević, Department of Metallurgy and Technology, University of Montenegro, Montenegro

DOI: 10.54026/COJCE/1004

Key Words
EoW; Bauxite; Red mud; Construction and demolition waste; Geotechnical composites; Geopolymers

Case Report

End-of-Waste Criteria of the Bauxite Red Mud

A Mauko Pranjić[1], A Mladenović[1], M Vukčević[2*], M Karadžić[3]

[1]*Slovenian National Building and Civil Engineering Institute (ZAG), Ljubljana, Slovenia*

[2]*Department of Metallurgy and Technology, University of Montenegro, Montenegro*

[3]*Farmont, Podgorica, Montenegro*

Abstract

The main objective of this document is to present the End-of-Waste (EoW) criteria for the bauxite red mud. EoW criteria are based on the different EoW approaches and criteria existing around the European Union (EU), especially for Construction and Demolition Waste (CDW) and the results obtained in the CINDERELA project (EU contr. No. 776751).

This EoW criteria protocol could facilitate the recycling process of bauxite red mud thus guiding Republic of Montenegro to implement EoW criteria for this waste, which is landfilled in huge quantity (8 million tonnes) near Podgorica. This document will define the product status, its technical quality and applicability as well as its environmental and human health issues.

Introduction

End-of-Waste criteria specify when certain waste ceases to be waste and obtain a status of a product (substance, mixture or an object) based on the revised Waste Framework Directive – WFD (2008/98/EC and 2018/851/EC) [1]. According to the Article 6 of WFD, certain specified waste shall cease to be waste when it has undergone a recovery (including recycling) operation and complies with specific criteria to be developed in line with certain legal conditions, in particular:

a) The substance or object is to be used for specific purposes

b) There is an existing market or demand for the substance or object

c) The use is lawful (substance or object fulfils the technical requirements for the specific purposes and meets the existing legislation and standards applicable to products)

d) The use will not lead to overall adverse environmental or human health impacts.

Such criteria should be set for specific materials by the Commission using the procedure described in Article 39(2) of the Waste Framework Directive (so called "comitology"). An initiative to set EoW criteria was introduced by European Commission (EC) to provide a higher level of environmental protection and economic perspective. The aim is to encourage recycling in the EU through creation of the legal certainty as well as removal of the unnecessary administrative burden.

Different protocols for EoW criteria have been established over the EU depending on the local regulations on waste. Therefore, although the EU regulates EoW criteria in the WFD, no clearly and harmonized protocol can be found for defining the parameters that should be complied by the different wastes in order to be potentially valorised with respect to the technical, human health and environmental requirements.

Materials and Methods

Bauxite red mud - occurrence and properties

Bauxite red mud is a waste, which generates during the digestion of bauxite ore with sodium hydroxide in the Bayer process of alumina production. One tonne of produced alumina generates up to 2 tonnes of red mud. The usual waste management practice of red mud is landfilling, either in a form of slurry or filter cake. It is estimated that more than 85 million tonnes of red mud have been dumped in the tailings in the South East Europe (Montenegro, Slovenia, Bosnia and Herzegovina, Hungary and Greece). Some of them are covered by protective layer of soil whereas some of them are still exposed. These tailings are environmental hot spots, with potential leakage of alkaline contaminants into the groundwater, the overflow of liquid during rainy seasons as well as emission of dust. On the other hand, these tailings shall be considered as potential sources of rare earth elements (REE), scandium, titanium, yttrium, hafnium, zirconium and other valuable metals. It is well known that Europe faces a lack of certain raw materials including heavy and light REE, Sc, Y, Hf, and Zr, all of which are connected with both severe supply risk and high economic importance [2]. Therefore, a logical first step in recycling of bauxite red mud landfills would be extraction of valuable metals. Reliable and sustainable technologies are still scarce or not matured enough; however in the future these activities will be unavoidable. After extraction of metal, the residues have to be recycled or processed into new products thus establishing near-zero waste service. Utilization of recycled residues in construction sector of the local environment would be the most beneficial. These products can replace virgin materials and are especially suitable for geotechnical works, where large quantities of materials are needed (embankments or fills, both for mechanically strengthened structures in civil engineering). In most such cases mixing with other waste based-materials (e.g. fly ash) or virgin materials is requested, in order to improve the strength and bearing capacity of the material or/and ensure the immobilization of potential toxic substances. The same recycling and final use have to be applied in case where bauxite red mud has not been subjected to the metal extraction.

Podgorica red mud tailing

At the red mud tailing near Podgorica (Figure 1) a deposition has stopped since 2009 when the production of alumina in the nearby plant has been abandoned. Accumulation of red mud is estimated at 7.5 million tonnes. Minor quantities of other types of waste were dumped in the tailing (building rubble, metallurgical waste). The tailings are exposed and no reclamation have been done by now.

Figure 1: Aerial view of the tailing of red mud near Podgorica.

Within the scope of the Reebaux project- the drilling campaign in 2019 was executed. Six boreholes were drilled in order to recover the representative samples [3]. The maximum depth of the boreholes was 12m (Figure 2).

Figure 2: Red mud tailing near Podgorica in Montenegro during sample collection.

Visual appearance of red mud is in figure 3.

Figure 3: Visual appearance of red mud.

Chemical analyses of the samples are presented in Tables 1 & 2. The most variable component is CaO which indicates the level of carbonization within the tailings.

Table 1: Results of chemical analyses of red mud.

	Sample-ID¤	Sampling depth (m)¤	SiO_2¤	Al_2O_3¤	Fe_2O_3¤	MgO¤	CaO¤	Na_2O¤	K_2O¤	TiO_2¤	P_2O_5¤	MnO¤	Cr_2O_3¤	Ba¤	Ni¤	Sc¤	LOI¤	Sum¤
			%¤	%¤	%¤	%¤	%¤	%¤	%¤	%¤	%¤	%¤	%¤	ppm¤	ppm¤	ppm¤	%¤	%¤
MONTENEGRO (Podgorica-red-mud-landfill)*¤																		
Landfil B (borehole B-1/19)¤	CGBR.01¤	0-4¤	9.43¤	29.98¤	27.13¤	0.56¤	5.89¤	4.35¤	0.28¤	3.51¤	0.25¤	0.17¤	0.082¤	76¤	177¤	81¤	17.9¤	99.54¤
	CGBR.02¤	4-7.5¤	13.12¤	22.24¤	26.5¤	0.69¤	11.91¤	4.27¤	0.35¤	3.66¤	0.23¤	0.2¤	0.086¤	77¤	202¤	81¤	16.2¤	99.5¤
	CGBR.03¤	7.5-10.5¤	25.17¤	11.27¤	12.25¤	1.19¤	22.9¤	2.1¤	0.7¤	1.65¤	0.08¤	0.11¤	0.06¤	95¤	141¤	35¤	22.3¤	99.76¤
Landfil A (borehole B-2/19)¤	CGBR.04¤	0-3¤	10.97¤	25.06¤	30.24¤	0.68¤	7.56¤	4.76¤	0.34¤	4.29¤	0.1¤	0.24¤	0.09¤	75¤	231¤	93¤	15.1¤	99.51¤
	CGBR.05¤	3-7¤	11.96¤	21.63¤	34.47¤	0.58¤	6.38¤	6.29¤	0.36¤	4.37¤	0.11¤	0.27¤	0.098¤	75¤	246¤	105¤	12.9¤	99.43¤
	CGBR.06¤	7-11¤	10.91¤	21.88¤	34.39¤	0.63¤	7.57¤	5.59¤	0.28¤	4.92¤	0.09¤	0.26¤	0.103¤	76¤	258¤	107¤	12.8¤	99.44¤
Landfil A (borehole B-3/19)¤	CGBR.07¤	0-3¤	8.86¤	31.12¤	29.75¤	0.51¤	4.27¤	5.02¤	0.34¤	4.16¤	0.1¤	0.2¤	0.086¤	72¤	198¤	92¤	15¤	99.44¤
	CGBR.08¤	3-6¤	10.45¤	25.08¤	32.21¤	0.55¤	4.9¤	6.51¤	0.36¤	4.5¤	0.07¤	0.24¤	0.093¤	78¤	224¤	100¤	14.5¤	99.48¤
	CGBR.09¤	6-10¤	10.49¤	23.3¤	33.77¤	0.65¤	6.02¤	6.5¤	0.28¤	4.72¤	0.08¤	0.25¤	0.101¤	72¤	244¤	106¤	13.2¤	99.46¤
Landfil A (borehole B-4/19)¤	CGBR.10¤	0-4¤	11.47¤	21.92¤	35.97¤	0.57¤	4.9¤	6.18¤	0.38¤	5.07¤	0.08¤	0.28¤	0.106¤	86¤	252¤	114¤	12.4¤	99.43¤
	CGBR.11¤	4-7¤	10.86¤	23.03¤	33.94¤	0.6¤	7.3¤	5.59¤	0.28¤	4.64¤	0.07¤	0.25¤	0.098¤	75¤	238¤	105¤	12.7¤	99.45¤
	CGBR.12¤	7-10¤	10.47¤	26.9¤	32.4¤	0.6¤	5.37¤	5.76¤	0.27¤	4.56¤	0.07¤	0.24¤	0.095¤	72¤	248¤	101¤	12.7¤	99.47¤
Landfil B (borehole B-5/19)¤	CGBR.13¤	0-3¤	10.47¤	17.38¤	31.98¤	0.79¤	12.56¤	5.06¤	0.34¤	3.92¤	0.16¤	0.21¤	0.085¤	71¤	196¤	95¤	16.5¤	99.47¤
	CGBR.14¤	3-6¤	13.35¤	19.04¤	35.22¤	0.61¤	6.1¤	7.67¤	0.35¤	4.8¤	0.11¤	0.32¤	0.099¤	83¤	250¤	113¤	11.68¤	99.38¤
	CGBR.15¤	6-9¤	11.59¤	19.39¤	39.08¤	0.55¤	4.74¤	6.57¤	0.32¤	5.48¤	0.11¤	0.29¤	0.11¤	83¤	263¤	124¤	11.1¤	99.36¤
	CGBR.16¤	9-12¤	11.94¤	20.42¤	37.67¤	0.56¤	4.53¤	6.96¤	0.34¤	5.26¤	0.12¤	0.29¤	0.11¤	84¤	257¤	120¤	11.1¤	99.37¤
Landfil B (borehole B-6/19)¤	CGBR.17¤	0-3¤	12.4¤	19.76¤	33.67¤	0.72¤	8.68¤	6.16¤	0.41¤	4.27¤	0.12¤	0.22¤	0.091¤	91¤	234¤	99¤	12.9¤	99.43¤
	CGBR.18¤	3-6¤	12.28¤	19.54¤	35.34¤	0.68¤	7.02¤	6.87¤	0.4¤	4.73¤	0.11¤	0.26¤	0.101¤	91¤	246¤	108¤	12¤	99.4¤
	CGBR.19¤	6-9¤	12.36¤	19.86¤	38.55¤	0.54¤	3.62¤	7.36¤	0.38¤	5.45¤	0.1¤	0.31¤	0.113¤	88¤	255¤	123¤	10.7¤	99.37¤
	CGBR.20¤	9-12¤	12.72¤	19.41¤	37.71¤	0.56¤	4.12¤	7.82¤	0.36¤	5.34¤	0.11¤	0.33¤	0.11¤	82¤	253¤	122¤	10.7¤	99.35¤

Table 2: REE abundances in the red mud samples (in ppm).

Sample	Sample -ID	Sampling depth (m)	Y	La	Ce	Pr	Nd	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	ΣLREE	ΣHREE	ΣREE
Landfil -B - (borehole -B- 1/19)	CGBR -01	0-4	121.50	199.70	409.60	39.48	148.50	28.17	5.78	24.67	3.88	22.47	4.70	13.94	2.09	13.97	2.16	831.23	209.38	1040.61
	CGBR -02	4-7.5	128.60	204.40	424.70	40.52	148.40	28.34	5.93	25.19	4.10	24.04	4.97	14.97	2.23	15.30	2.31	852.29	221.71	1074
	CGBR -03	7.5-10.5	58.20	86.30	183.00	17.24	66.30	12.20	2.60	11.22	1.70	10.24	2.16	6.34	0.97	6.77	1.02	367.64	98.62	466.26
Landfil -A - (borehole -B- 2/19)	CGBR -04	0-3	153.40	239.70	491.20	46.74	174.40	32.79	6.68	28.35	4.63	27.38	5.70	17.33	2.54	17.24	2.68	991.51	259.25	1250.76
	CGBR -05	3-7	177.20	357.40	575.30	64.78	241.10	44.18	9.11	38.23	5.91	34.41	6.96	19.64	3.03	19.51	3.05	1291.87	307.94	1599.81
	CGBR -06	7-11	180.90	287.90	556.40	56.18	206.2	40.56	7.90	34.69	5.46	31.52	6.77	20.16	2.99	20.30	3.17	1155.14	305.96	1461.10
Landfil -A (borehole -B- 3/19)	CGBR -07	0-3	166.00	275.50	487.10	52.76	195.60	36.91	7.46	32.24	5.08	29.23	6.09	18.20	2.67	18.46	2.77	1055.33	280.74	1336.07
	CGBR -08	3-6	167.90	275.20	535.80	51.99	191.80	35.52	7.35	32.34	5.06	29.46	6.21	18.57	2.80	18.43	2.90	1097.66	283.67	1381.330
	CGBR -09	6-10	172.50	273.50	554.80	55.51	208.30	40.27	8.26	35.05	5.42	32.20	6.68	20.06	2.95	19.78	3.02	1140.64	297.66	1438.3
Landfil -A (borehole -B- 4/19)	CGBR -10	0-4	189.00	311.20	603.20	60.08	217.30	41.18	8.60	36.51	5.72	34.50	7.05	22.02	3.21	21.52	3.27	1241.56	322.8	1564.36
	CGBR -11	4-7	173.20	281.20	561.80	55.05	199.60	38.33	7.93	33.79	5.30	31.29	6.36	19.52	2.84	19.38	2.94	1143.91	294.62	1438.53
	CGBR -12	7-10	173.10	279.10	542.70	54.60	204.90	39.10	8.09	34.38	5.42	31.97	6.58	19.11	2.90	19.58	2.93	1128.49	295.97	1424.46
Landfil -B (borehole -B- 5/19)	CGBR -13	0-3	154.10	261.70	534.30	54.22	205.50	39.24	8.13	34.39	5.06	29.24	5.98	16.85	2.44	16.57	2.51	1103.09	267.14	1370.23
	CGBR -14	3-6	208.40	408.00	583.50	74.41	283.20	51.69	10.79	47.76	7.01	40.20	8.04	23.20	3.33	22.11	3.35	1411.59	363.4	1774.99
	CGBR -15	6-9	222.50	352.70	649.20	65.17	234.50	43.95	9.38	41.27	6.47	38.29	8.13	23.46	3.64	24.18	3.58	1354.9	371.52	1726.42
	CGBR -16	9-12	223.00	366.80	619.20	68.43	254.00	46.97	9.72	43.48	6.74	40.25	8.15	24.26	3.57	23.47	3.60	1365.12	376.52	1741.640
Landfil -B (borehole -B- 6/19)	CGBR -17	0-3	169.10	309.30	577.60	64.97	245.80	46.41	9.12	39.23	5.80	32.25	6.48	19.27	2.74	18.19	2.80	1253.2	295.86	1549.06
	CGBR -18	3-6	185.00	325.30	602.70	64.62	238.00	44.73	9.11	38.95	6.06	34.43	7.15	20.22	3.03	20.56	3.10	1284.46	318.5	1602.96
	CGBR -19	6-9	221.30	364.00	655.90	64.78	231.10	43.22	8.96	40.06	6.44	38.16	8.08	23.62	3.50	23.88	3.67	1367.96	368.71	1736.67
	CGBR -20	9-12	224.00	388.20	637.40	69.78	256.00	45.89	9.74	42.59	6.62	39.41	8.13	23.47	3.50	23.35	3.57	1407.01	374.64	1781.65

REEs are distributed unevenly within the tailing-in certain areas are more abundant closer to the surface, while for some boreholes REE concentrations increase with depth.

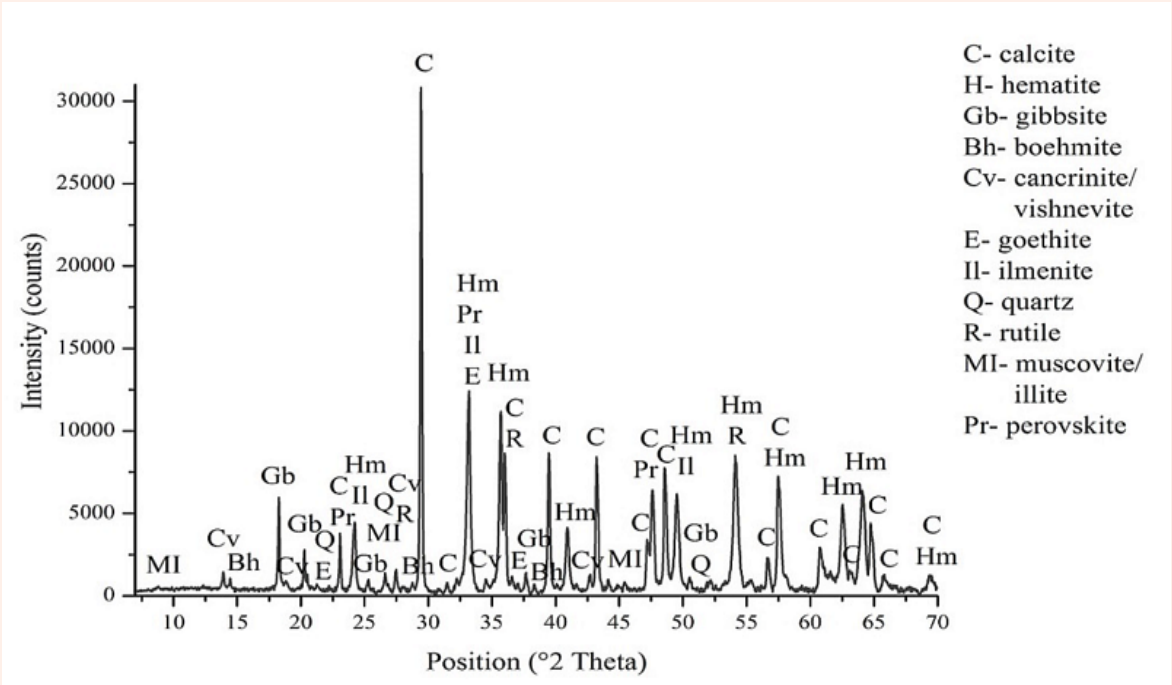

Figure 4: XRD spectrum of red mud.

Related environmental legislation in EU

The European Union hierarchy regarding waste management and the use of recycled-waste based product is as follows:

a) General waste frameworks that regulates the management of all types of waste in a given region

b) Protocols and decrees that regulate the valorisation, management and use of recycled waste-based products in different applications. They generally describe the general administrative and waste management requirements, referring to other specific standards for the technical and environmental aspects

c) Specific local technical and environmental regulation for the use of waste-based materials in different sectors - in this article the focus was put on the construction sector as targeted market

d) Specific harmonized and technical European Standards (EN) issued and updated by the CEN (European Committee for Standardization). The EN standards are a key component of the Single European Market which provides common rules, guidelines or characteristics for certain activities and uses.

Technical regulation for the use of recycled waste-based products

Construction Product Regulation (CPR)

The Construction Products Regulation N. 305/2011 is the EU regulation harmonising performance information on construction products across the EU [4]. It is most visible by the mandatory CE marking of regulated products. CPR provides a common technical language to evaluate the performance of building products. It ensures that professionals, public institutions and consumers have access to reliable information so that they can compare the performance of products from different manufacturers in different countries/regions.

The CPR involves any construction product or kit that is produced and put on the market and is permanently incorporated into the construction project (or part of it), and its performance affects the performance of the construction project, with respect to the 7 Basic Requirements for Construction Works (BRCW). These are:

a) **Mechanical resistance and stability:** The design and construction method of the construction project must ensure that the loads that may act on it during its construction and use will not cause collapse, unallowable deformation or damage.

b) **Safety in case of fire:** In the event of a fire, the load-bearing capacity must be maintained for a period of time, the generation and spread of fire and smoke must be restricted, and the safety of rescuers must be considered.

c) **Hygiene, health and the environment:** The design and construction works must not pose a threat to the hygiene or health of residents or neighbours, especially the consequences of any of the following:

i. The giving-off of toxic gas,
ii. The presence of dangerous particles or gases in the air,
iii. The emission of dangerous radiation,
iv. Pollution or poisoning of the water or soil,
v. Faulty elimination of waste water, smoke, solid or liquid wastes,
vi. The presence of damp in parts of the works or on surfaces within the works.

d) **Safety in use:** The works may not present unacceptable risks of accidents in service such as slipping, falling, collision, burns, electrocution, and injury from explosion.

e) **Protection against noise: Noise perceived by the occupants or people nearby has to be kept down to a level that will not threaten their health and will** allow them to sleep, rest and work in satisfactory conditions.

f) **Energy economy and heat retention:** With consideration to the climatic conditions of the location and the occupants, the construction works and their heating, cooling, and ventilation facilities must be designed and erected in such a way that the quantity of energy required in use is as low as possible.

g) **Sustainable use of natural resources:** The construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable and ensure the:

i. Reuse or recyclability of the construction works, their materials and parts after demolition
ii. Durability of the construction works
iii. Use of environmentally compatible raw and secondary materials in the construction works.

The CPR has introduced simplified procedures for the CE marking by replacing the Declaration of Conformity (see Construction Product Directive – CPD 89/106/EEC – replaced in 2011 by CPR) with the Declaration of Performance (DoP). These simplifications were designed to reduce above all the costs incurred by small and medium-sized enterprises. In addition, the CPR has also updated the regime that governs innovative construction products (European Assessment Document/European Technical Assessment – EAD/ETA) to facilitate their route to market within Europe. Further information is given in the next sections.

As regards the BRCW, the CPR considers new aspects on life-cycle in term of the 3rd Basic Requirement on hygiene, health and the environment: "The construction works must be designed and built in such a way that they will, throughout their life cycle, not be a threat to the hygiene or health and safety of workers, occupants or neighbours, nor have an exceedingly high impact, over their entire life cycle, on the environmental quality or on the climate during their construction, use and demolition".

Moreover, one of the main innovations of the CPR is the introduction of the 7th BRCW on "Sustainable use of natural resources", according to which the construction works must be designed, built and demolished in such a way that the use of natural resources is sustainable. This is an important contribution for the market uptake of innovative products from the CDW and other waste in line with the EU action plan for the Circular Economy, even if there are still uncertainties about the interpretation of this Basic Requirement.

Harmonized European Standards (hEN)

It is important to note that the CE marking can only be applied to a construction product which is placed on the market either in conformity with the requirements of a harmonized European Standard (hEN) or when the product has a European Technical Assessment (ETA) document. Each hEN contains an Annex ZA which defines the Essential Requirements (ER) for the particular products covered by the standard and the conditions applicable to CE marking of the product. An ETA is an alternative and voluntary

method of CE marking which can be applied when a product is not covered by a hEN. The details for an ETA are set out in the European Assessment Document (EAD). However, in this article reference will be made to aggregates supplied in conformity with both hENs and 'non-harmonized' European Standards for the reasons which will be made clear later in the article.

Technical Committees develop hENs for construction items based on the CPR's core requirements. The CEN's Technical Committee is in charge of creating the necessary set of harmonised European standards and test standards, as well as upgrading the ones that already exist.

The hENs in the construction sector have several advantages, the most important being a common assessment method for construction products and a single European scheme for the DoP of the product. The hENs define the methods and criteria for the evaluation of the performance of construction products by referring to the intended use of the products to which they relate and including the technical details necessary to apply the system of the Assessment and Verification of the Constancy of Performance (AVCP).

Annex ZA lists the regulated mandatory requirements according to the mandate issued to CEN by the European Commission and the clauses in the standard in which they are addressed. Some of these clauses may also refer to separate supporting documents, for example test methods standards. Appendix ZA establishes the conditions for CE marking of a product according to:

a) The identification of the clauses of the standard required to meet the mandate given under the CPR (point ZA.1);
b) The procedure(s) for the AVCP (point ZA.2);
c) The information required to accompany the CE marking and the framework of the labelling (point ZA.3).

In this way, Annex ZA becomes a sort of guide for the CE marking and compliance with Appendix ZA allows the producer affixing of the CE marking.

CE Marking

The CE marking is necessary for the marketing of a product within the EU as it states that the product complies with the applicable legislation. When fixed on a construction product, it indicates that the product conforms to the hEN or ETA.

The letters 'CE' appears on many products traded on the extended Single Market in the European Economic Area (EEA). They signify that products sold in the EEA have been assessed to meet high safety, health, and environmental protection requirements. The CE marking also supports fair competition by holding all companies accountable to the same rules. By affixing the CE marking to a product, a manufacturer declares that the product meets all the legal requirements for CE marking and can be sold throughout the EEA. This also applies to products made in other countries that are sold in the EEA.

There are two main benefits CE marking brings to businesses and consumers within the EEA:

a) Businesses know that products bearing the CE marking can be traded in the EEA without restrictions;
b) Consumers enjoy the same level of health, safety, and environmental protection throughout the entire EEA.
c) The CE marking (Figure 5) is a part of the EU's harmonisation legislation, which is mainly managed by the Directorate-General for internal market, industry, entrepreneurship and small and medium enterprises.

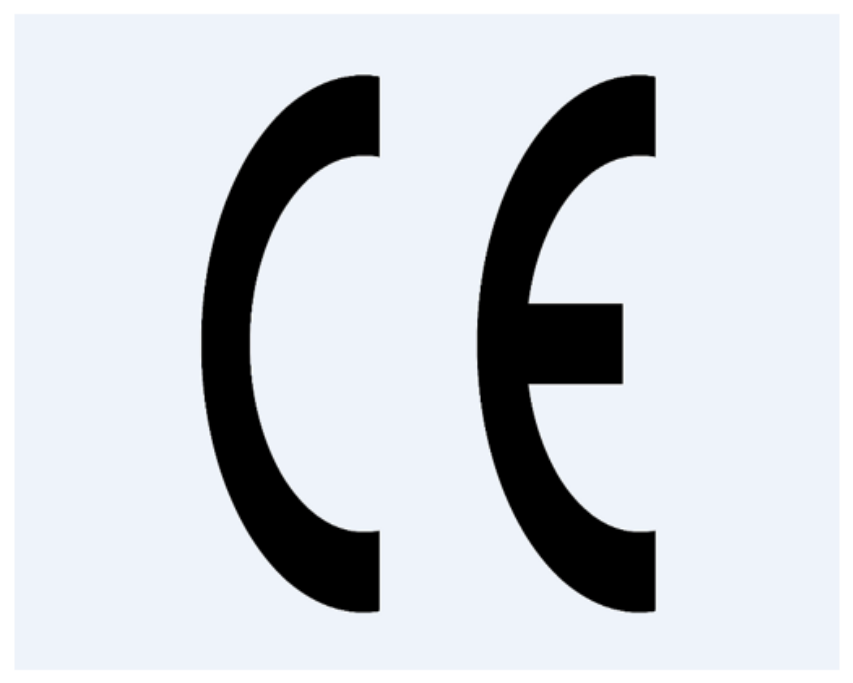

Figure 5: CE Marking logo.

The CE mark denotes the publication of information on:

a) Safety
b) Testing criteria
c) Fire resistance
d) Mechanical resistance and stability
e) User instructions, including hygiene and environmental instructions
f) Protection against noise
g) Energy, economy and heat retention
h) Sustainable use of natural resources
i) Handling instructions
j) Storage recommendations
k) Maintenance
l) Warranties
m) Dealerships.

Manufacturers who plan to CE-mark their products or who are looking for a 'to-do list' can be step-by-step introduced with the CE marking [5], (Figure 6). The guide "CE Marking of Construction products step by step" is available in all EU languages. The guide also explains what to do if the product changes (due to changes in processes, raw materials, testing, personnel, etc.) which makes it necessary to revise certain internal documents and announce the external third party.

Figure 6: CE Marking step by step.

European Technical Assessment (ETA)

The ETA is a method of applying CE marking to construction products that do not meet all of the requirements of a harmonised standard. It provides information on evaluating product performance. The assessment procedure is laid down in the CPR: when a manufacturer realizes his product is not covered by a hEN, a Technical Assessment Body (TAB) designated by EU countries according to national procedures should be contacted. First, the TAB shall check and inform the manufacturer whether the product is fully or partly covered by a hEN (if the product is covered by a hEN, it is not possible to issue an ETA). If the product is not covered by a hEN, the TAB shall assess the product on the basis of EADs, which is harmonised technical specification for construction products developed by the European Organisation for Technical Assessment – EOTA (Figure 7).

Figure 7: EOTA logo.

EADs is the basis for issuing the ETAs as they contain:

a) A general description of the construction product;
b) The list of ER agreed between the manufacturer and EOTA;
c) The methods and criteria for assessing the performance of the product in relation to these essential characteristics;
d) Principles for factory production control to be applied.

The TAB prepares the ETA if the EAD suitable to the product already exists; otherwise, a new EAD must be drafted, submitted to the TAB for adoption, and the ETA must be prepared. This procedure may take some time, particularly for new items that are not covered by existing EADs. As soon as the manufacturer receives the ETA, he has the basis for being able to draw up the DoP and then affixes the CE marking. Diagram in figure 8 summarizes the process leading to the issues of ETAs.

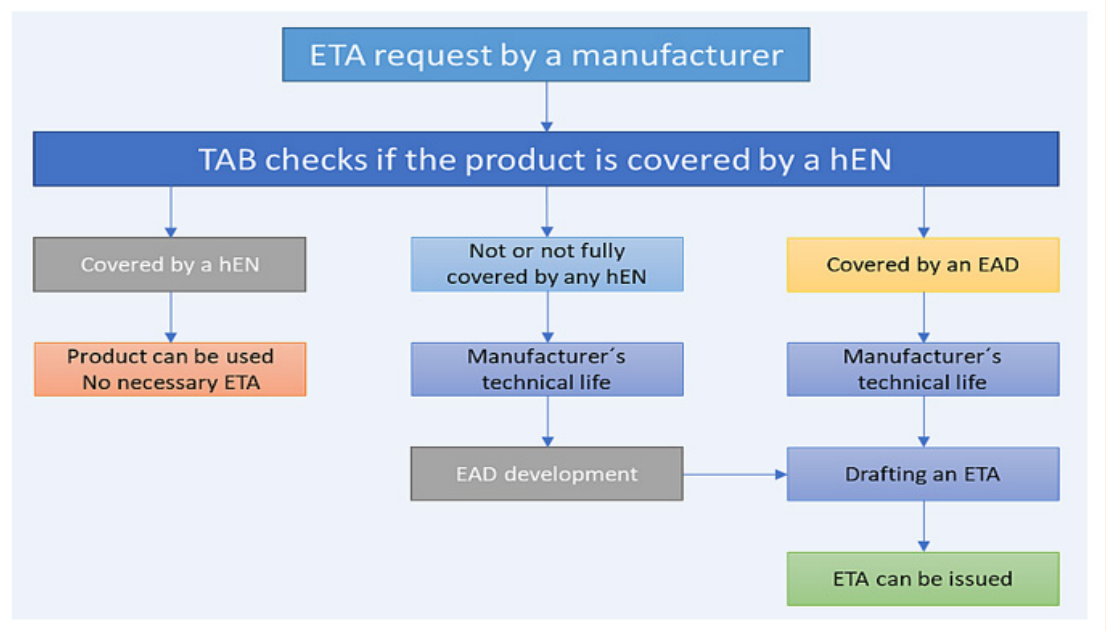

Figure 8: Process leading to the issues of ETAs

Discussion

Technical specification for definition of basic requirements of construction products from recycled bauxite red mud

Recycled bauxite red mud after extraction of REE or without any pre-extraction is recycled into manufactured aggregate. This is the official technical definition for aggregates which are obtained in the recycling process from metallurgical waste.

The following European Standards specify, for different uses, the properties of aggregates (including manufactured aggregates). They also specify the establishment of a quality control system for the factory production control and the evaluation of conformity of products:

a) EN 12620: Aggregates for concrete
b) EN 13139: Aggregates for mortar
c) EN 13043: Aggregates for bituminous mixtures and surface treatments for roads, airfields and other trafficked areas
d) EN 13242: Aggregates for unbound and hydraulically bound materials for use in civil engineering work and road construction
e) EN 13450: Aggregates for Railway Ballast
f) EN 13383-1: Armourstone

These harmonised standards define essential characteristics of aggregate and technical standards upon which they are determined. Additionally, technical standards such as:

a) EN 13286: Unbound and hydraulically bound mixtures – Test methods.
b) EN 13285: Unbound mixtures – Specifications.

are also relevant and also be used as deem appropriate.

National legislation for performing of building works in Montenegro likely defines and specifies criteria and other specific requirements.

Permitted uses of recycled red mud

Taking into account huge amounts of this material, the most logical and beneficial use is in earthworks, such as reclamation of selected degraded area, filling of mining subsidence, construction or hydraulically bound layers for road construction and also embankments and fills which are not subject to dynamic loadings in engineering structures. In such cases, large amounts of material can be installed, and in addition, these geotechnical activities are always available in the local environment, which ensures short transport routes and low energy needs. This type of recycling is also economically and technically feasible in practice and can be carried out with conventional building technology and knowledge/skill. It can easily become a part of daily routine in geotechnical works. Such applications can be validated through a long-term monitoring where durability and other aspects of technical functionality, as well as environmental performance, are assessed. The latter can be additionally assessed with the help of lizymeter tests (analysis of leachates and percolation of water through fill according to the quantity of annual precipitation) and hydrogeological model evaluations in order to prove that the new composites do not threaten the environment. Guidelines about the recycling of red mud in building composites/structures shall be prepared to promote and enhance such utilization.

However, in the case of recycled red mud, it is expected that it will not be possible to use this material as it is. The main reasons are that material

i. is not chemically inert (elevated concentration of some heavy metals in water leachate)
ii. is usually too wet
iii. has low bearing capacity

Therefore, addition of additives is requested. These additives can be either virgin material (zeolites, clays) or waste-based material with sufficient binging capacity (e.g. fly ashes). Proper mixing at optimum water content and proper installation will ensure geotechnical composite with sufficient mechanical strength as well as long-term immobilization of potential toxic elements (PTE) (Figure 9). In recent research activities performed on red mud from Podgorica tailing it has been confirmed that PTE in composites were immobilized by sorption mechanisms with no general time depending trends [6].

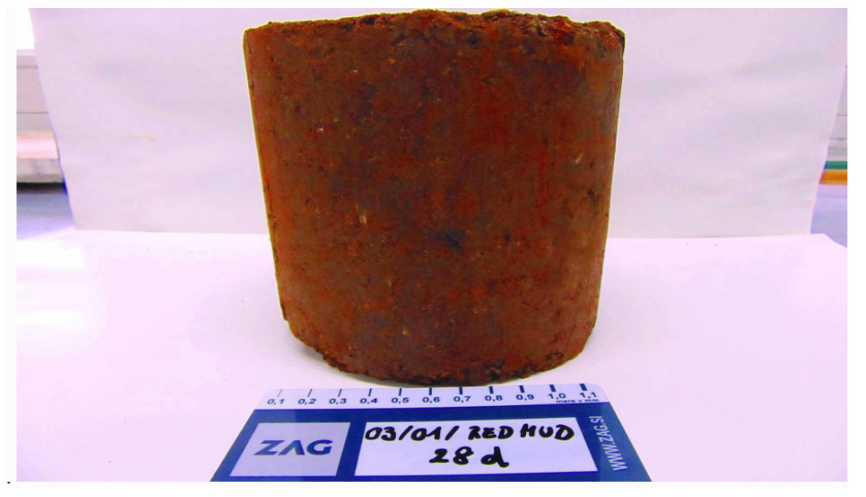

Figure 9: Geotechnical composite made of red mud and paper ash (courtesy: P. Oprčkal).

From this point of use it would be beneficial to perform a screening and identification of potential materials in Montenegro, which could play a role of additives for red mud.

Unfortunately, in the case where mixing of red mud with additive is requested, harmonized standards do not cover such application. Technical Approval, European or National is required, although some aspects from aggregate standards could be adopted and integrated into the Technical Approval. Apart from the unbound application, described before, different bound applications might be feasible, depending on the local market conditions and opportunities. Such applications would act as additional sinks for material, following the rule "don't put all your eggs in one basket" and would probably invigorate the local business community. Three applications are particular interesting in the light of quantities and material properties

i. concrete
ii. bricks
iii. geopolymers [7-11].

More research and investigation of good practice across the globe with regard to these bound applications would be needed.

Restrictions and prohibitions of use of recycled red mud

It is not foreseen that any general restriction or prohibition shall be adopted for use of red mud in building sector in Montenegro. However, specific limitations might be adopted in order to protect groundwater zones of vital importance, particularly for unbound applications.
3.4 Technical requirements for recycled red mud to be used in earthworks
The different technical standards of products and specifications of each country establish criteria for the application of recycled materials. In most countries the following tests are applied:

a) Characterization of red mud and additive:

Determination of particle size distribution (any reliable method which could determine particle distribution of fine materials)

i. Mineralogical composition (XRD)
ii. Particle density (e.g. EN 1097-7)
iii. Water content (e.g. EN 1097-5)
iv. Chemical analysis of water leachate of red mud and additive (EN 1744-3 for preparation of leachate and relevant chemical methods for determinations of metals and anions)

b) Characterization of composite made of red mud and additive:

i. Water content (e.g. EN ISO 17892-1)
ii. Density (e.g. EN 1097-7)
iii. Maximum density (e.g. EN 13286-2)
iv. Optimum density (e. g. EN 13286-2)
v. Uniaxial compressive strength (e.g. EN 13286-41)
vi. Water permeability (e.g. EN ISO 17892-11)
vii. Shear strength (e.g. CEN ISO/TS 17892-10)
viii. Chemical analysis of water leachate (EN 1744-3 for preparation of leachate and relevant chemical methods for determinations of metals and anions)

c) Field control:

i. Tests according to the national earthworks standards and practices (including measurements of density, degree of compaction and strength)

Conclusion

Taking into account that Montenegro is not yet a member of the EU (however it is in the accession phase), and have not yet established a legal way to produce Technical Approvals, it seems that there are two possible ways to overcome this transition period:

a) to establish its own national legislation for issuing the National Technical Approvals, mimicking the protocols that are in use in other EU members,
b) to adopt case-by-case approach in which aren't any particular rules how to cease the waste status of red mud, however, within a general framework the authorities can decide in each case when and under which conditions is allowed to cease the status of waste into status of product. This second option is totally legal on the EU level and is often adopted for different types of waste for which EoW has not been prepared yet.

References

1. Waste Framework directive (WFD) 2008/98/EC and 2018/851/EC.
2. (2020) European Commission, Study on the EU's list of Critical Raw Materials, factsheets on Non critical Raw materials.
3. REEBAUX: prospects of REE recovery from bauxite and bauxite residue in the ESEE region 2017-2020, EIT Raw materials
4. https://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX.32011R0305&from0EN
5. https://ec.europa.eu/docsroom/documents?tags0ce-guide
6. Oprčkal P, Mladenović A, Zupančič N, Scancar J, Milačić R, et al. (2020) Remediation of contaminated soil by red mud and paper ash. Journal of Cleaner Production 256.
7. Bošković I, Vukčević M, Nenadović S, Mirković M, Stojmenović M, et al. (2019) Characterization of red mud/metakaolin-based geopolymers as modified by $Ca(OH)_2$. Materiali in Tehnologije 53(3): 341-347.

8. Vukčević M, Bošković I, Potparić B, Nenadović S, Kljajević L, et al. (2012) Characterization of metakaolin-based geopolymers as modified by organic phase. Journal of Environmental Protection and Ecology 22(1): 127-138.

9. Occhicone MV, Bosković I, Ferone C (2021) Red mud-blast furnace slag-based alkali-activated materials. Sustainability 13(2-3): 11298-11303.

10. Occhicone MV, Bosković I, Mingione S, Ferone C (2022) Alkali activated red mud and construction and demolition waste-based components. Characterization and environmental assessment. Materials 15: 1617-1632.

11. Nenadović S, Gulicovski J, Mirković M, Kljajević Lj, Bošković I, et al. (2022) Structural, Mechanical and Chemical Properties of Low Content Carbon Geopolymer. Sustainability 14: 4885-4898.