BIOMASS ASH - ENVIRONMENTALLY FRIENDLY PRODUCT IN A CIRCULAR ECONOMY

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Abstract: The increase in demand for construction materials, derived as a consequence of rapid industrialization has called for an alternative way to develop environmentally friendly building materials from different sources, including biomass ash, generated by combustion oh harvest residues (BA). These materials should fulfill criteria which provide efficient energy consumption, natural resources preservation and the environment protection, from the aspect of CO_2 emission. Researches are already investigating the use of various types of BA (rice husk ash, corn cob ash, wheat straw ash) for the building materials manufacturing as substitutes for sand and/or cement in cement based composites. A description of this application and its environmental contribution, as a way towards a circular economy and environmental protection in civil engineering, is presented in this paper.

Key words: environmentally friendly building materials, waste, biomass ash, resource

1. INTRODUCTION

A Circular Economy (CE) is a regenerative system that replaces the 'end-of-life' concept with 'cradle to cradle' design concept which involves the safe and potentially infinite use of materials in cycles. This concept shifts towards the use of renewable energy, eliminates use of hazardous chemicals and aims for the elimination of waste through the proper design of materials, products, systems, and, within this, business models. Therefore, in a CE, materials are kept in circulation for a longer period of time than in a linear economy thus aiming to minimise the use of natural sources and generation of waste (Image 1).

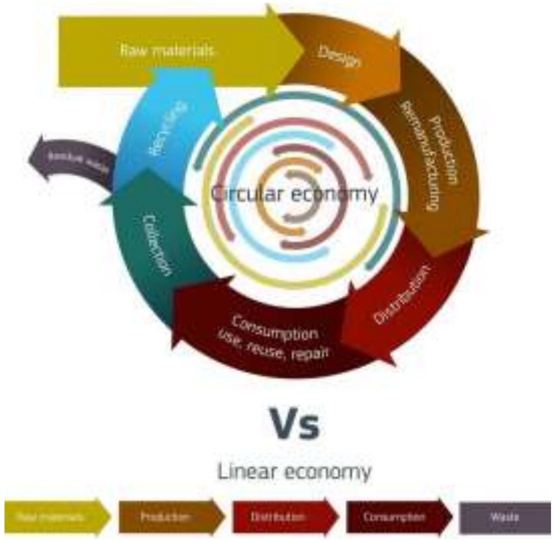

Image 1 - Circular vs. linear economy

There are some obvious environmental benefits of renewable products compared to fossil-based ones. Firstly, during growth, renewable resources absorb CO_2, hence they act as carbon storage. When they are ultimately managed as waste, e.g. incinerated or combusted, they will not contribute to net emissions of CO_2 into the atmosphere, as opposed to fossil-based products [1]. Secondly, the use of renewables instead of fossil products leads to lower rate of resources

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depletion. Renewable products, taken out of the technical cycle, can be further incorporated into new products, which is typically a low or net positive energy (e.g. biogas) process.

The increase in demand for construction materials, derived as a consequence of urban industrialization has called for an alternative way to develop materials from different sources, including biomass ash, generated by combustion oh harvest residues (BA). A number of investigations have demonstrated the validity of using various waste materials from both technical and environmental reasons and, often, economical. The same principle can be applied to biomass ashes, as presented in this study.

2. CIRCULAR ECONOMY IN CONSTRUCTION PRACTICE

The construction industry has major impacts on the social, environmental and economic aspects of sustainability, hence the importance of sustainable building practices becomes an essential issue. The major negative impacts include:

- generate of waste,
- greenhouse gas emission (particularly CO_2),
- generate of noise,
- generate of dust.

Approximately one third of all waste in Europe comes from construction and demolition (C&D) and only one third of that amount is recycled [2]. Recycling concrete from C&D waste reduces country's dependence on primary raw materials (primarly natural aggregate) and reduces the amount of waste landfilled. Over the years, recycled concrete has been successfully used as a aggregate for new concrete.

The researchers worldwide are seeking to increase the use of waste materials for concrete production, both to decrease energy dependence on conventional fossil fuels and to mitigate the adverse environmental impact of clinker production [3]. The possibility of the using of different types of solid waste in construction materials are shown in Table 1.

Table 1 - The possibilities of application of different wastes in the production of building materials

No.	Name of waste	Type of waste	Use in construction industry
1	• fly ash • rice husk ash • palm oil fuel ash	agro-industrial	• aggregate • concrete • SCM • bricks, blocks, tiles • wall panels, roof sheets
2	• phosphogypsum • waste glass • slag • rubber tire	industrial	• aggregate • concrete • blended cement • bricks, blocks, tiles • ceramic products
3	• quarry dust	mining/mineral	• aggregate • concrete • bricks, blocks, tiles
4	• C&D waste	industrial	• aggregate • concrete • bricks, blocks

One of the most common wastes and one of the most promising renewable energy sources (RES) is biomass.

3. CO_2 EMISSION AND BIOMASS IN CIRCULAR ECONOMY

Total emission from the cement industry contribute as much as 8% of global CO_2 emissions whereby two aspects of cement production result in emissions: the chemical reaction in the production of clinker (calcination) and the combustion of fossil fuels to generate the significant energy required to heat the raw ingredients - Image 2 [4].

More than 400 billion metric tonnes of CO_2 have been released into the atmosphere from the consumption of fossil fuels and cement production since 1750, half of which was emitted since the 1980s [5]. Image 3 illustrates that the combustion of liquid and solid fossil fuels causes around three fourths of all CO_2 emissions.

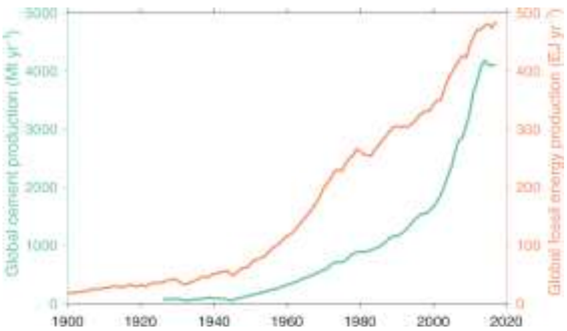

Image 2 - Global cement and fossil energy production [4]

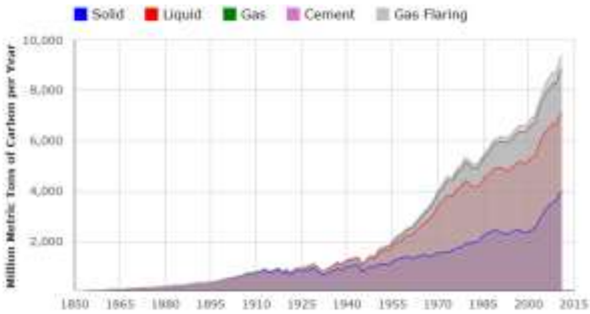

Image 3 - Worldwide CO_2 emission from fossil fuels consumption and cement production [5]

As a renewable source, biomass has the potential to replace non-renewable energy sources, such as fossil fuels, in the process where wastes of biomass activities and disposed products are processed within a supply chain network. Biomass combustion releases CO_2 as well, but the plants, that are the source of biomass, capture a nearly equivalent amount of CO_2 through photosynthesis while growing, which makes biomass CO_2 - neutral energy source.

On a global scale, an average of 140 billion tons of biomass is produced from agriculture annually. In the European Union, in total energy consumption, biomass accounts for 4%. Despite the large consumption of biomass as a energy source, enormous quantities remain in landfills as unused waste/raw materials [6].

Waste biomass is generated in several production sectors: forestry, wood processing industry, crop husbandry, animal husbandry, fruit and vine growing etc. Greatest potential of biomass in Serbia lies in the agricultural residue and wood biomass, a total of about 2.7 million tons. It was estimated that around 9 million tons of waste biomass per year is generated in the agricultural sector of AP Vojvodina [7]. All this suggests that there is a good prospect for larger use of biomass as RES, but also for generating larger quantities of ash produced by its combustion.

The Serbian agriculture is in the process of creating a significant switch towards CE, throughout its innovation system. This could be established, by using biomass as energy source at the larger scale (plants, factories), while generated biomass ashes are used as building materials in concrete production, making this system circular and sustainable.

4. BIOMASS ASH AS A SUSTAINABLE BUILDING MATERIAL

Based on the physical, chemical and morphological properties, it is reported that biomass ash, an industrial by-product of thermal power industries, has a substantial potential for use as a pozzolanic mineral admixture and/or as an activator/binder in cement-based materials.

Based on the availability investigation data, annualy generated quantity of biomass ash in Vojvodina, is approximately 5.000t. Within different types of ashes, following are dominant: wheat straw ash, soya straw ash and sunflower husk ash (separate or mixed combustion). Currently, most of the biomass ash produced in thermal power plants is either disposed of in landfill or recycled on agricultural fields or forest.

The reuse of such waste as building material appears to be a visible solution not only from the aspect of pollution, but also from the aspect of land-filling, conservation of natural resources for future generations, and high prices of building materials - Image 4.

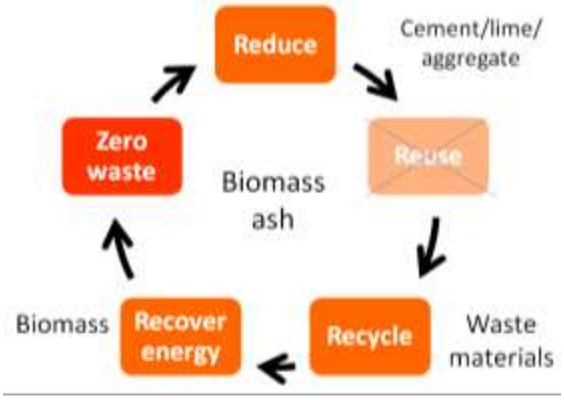

Image 4 - Using biomass ash as building material in circular economy

In this system, biomass is used as RES (recover energy), while nonreweable sources (such as fossil fuels) are preserved and biomass waste is eliminated. Biomass ash, a byproduct of biomass combustion, is recycled and used as a substitute for cement, aggregate or lime in concrete production, whereby natural sources are preserved (and CO_2 emission significantly reduced). Such eco-friendly product, at the end of life-cycle, can be recycled (crushed, separated) and used as aggregate for new concrete, making this system circular in accordance with the principles of CE.

Worldwide, there are countless initiatives to make the biomass sector, especially agricultural, more circular - Table 2. The scope of initiatives is broad and could aim at, for example, using rice husk ash as a highly reactive SCM, oyster shell ash as a lime substitute in concrete, or groundnut shell ash as sand replacement.

Table 2 - The possibilities of application of different biomass wastes as building materials

No.	Biomass ash	Application	Effects of substitution
1	rice husk ash	SCM (mortar, concrete)	• improved mechanical and durability properties [8]
2	oil palm shell	lightweight aggregate	• high strength lightweight concrete [9]
3	oyster shell ash	lime	• a lower carbon footprint [10]
4	sugarcane bagasse ash	SCM (concrete)	• lower permeability, increased resistance to chloride corrosion [11]
5	coconut shell	coarse aggregate	• structural lightweight concrete [12]
6	wheat straw ash	SCM (mortar)	• cement substitution of 50% without compromising mechanical properties [13]
7	sugarcane biomass ash	mineral additive	• 25% replacement level of cement in producing sustainable concrete - an optimum replacement [14]
8	tobacco waste	lightweight aggregate	• low thermal conductivity lightweight concrete [15]

9	wood waste ash	mineral additive	• cement replacement up to 10% by total binder weight can produce structural grade concrete or mortar
10	sewage sludge ash	mineral additive	• 20% addition to a mortar and concrete mixture provides 80% of the strength of the control mortar and concrete [17]

5. CONCLUSIONS

The raw materials used to produce cement and concrete, primarily clay, limestone and aggregates, are plentifully available worldwide. However, construction industry is making strong efforts to reduce their exploitation, as it creates visible irreversible scars on our planet. This can be accomplished through the use of different types of waste from a variety of other industries, such as biomass ash, used as a cement substitute and recycled concrete aggregate, used as natural aggregate substitute.

Using biomass waste and biomass ash in cement based composites would allow companies, building developers and cities to leverage a local, non-toxic resource in a product that is core to our built environment. This approach offers a viable solution to two pressing problems: concrete's high CO_2 emission and the increasing amount of landfilled biomass waste/ash.

If applied, this solution presents a unique opportunity to create a moral circle of awareness and recognition, resulting in greater economy of scale. This circle leads to reducing carbon emissions and increasing health on the one side, and reducing costs on the other. Diverting biomass ash from landfill to be used as a building material is a great example of cascading a technical material to another valuable use - one of the key principles of value creation in the circular economy.

6. ACKNOWLEDGEMENT

The paper presents the part of research realized within the project "**Multidisciplinary theoretical and experimental research in education and science in the fields of civil engineering, risk management and fire safety and geodesy**" conducted by the Department of Civil Engineering and Geodesy, Faculty of Technical Sciences, University of Novi Sad.

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