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Development of Interlock Bricks Utilizing Waste Boiler Ash

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Abstract: Industrial waste is a significant source of pollution worldwide. Improving the circular economy is the best available solution today. A circular economy is a system of closed loops in which raw materials, components, and products lose their value as much as possible. It focuses on production processes and describes waste recycling, repair, and recycling to increase sustainable production and consumption. Boilers are a major essential component of an industry when considering the industrial sector. Boiler ash plays a considerable impact on the financial status of the company. Therefore, adding value to waste ash is an essential step for the stability of the economy. It also leads to a solution to pollution through various types of ash disposal methods.

Index Terms: Boiler Bottom Ash, Environment Friendly, Interlocks, Reuse, Upcycling, Waste Ash, Waste Management.

1 Introduction

Energy development is most important from an economic and social point of view. To ensure a high standard of living and the well-being of future generations, renewable resources must be used as an energy source and environmentally sound technologies. The transition from a linear economy to a circular one is more essential for the present, as all new products created can be reused several times, and the amount of waste left is minimized.

In industrialized countries, the future of bioenergy is expected to be through the direct combustion of biomass residues and wastes. This fuel source is considered to be carbon neutral and is a fast-growing application of bioenergy production using wood biomass. Residual volumes and ash will increase as a result of increased demand for biofuels. The primary problems of ash are its storage difficulties, disposal problems, and the presence of unburned carbon. The continued increase in ash volume will reduce ash storage facilities (in cases of limited landfill space), as well as increase handling, transportation, and disposal costs. Sustainable use of biomass bottom ash in the agriculture sector and forestry sector is mostly caused to the occur organic pollutants due to its heavy metal content. Common applications of this by-product include the construction of roads and parking lots, the use of ash as a layer of ash on landfills, and the mixing of ash for the manufacture of concrete, bricks, or cement.

CBL Foods International (Pvt) Limited at Ranala (CBLF), which is one of the best subsidiaries of the CBL Group, is a major and fast-growing confectionery manufacturing company in Sri Lanka. Its list of products contains mainly, biscuits, cakes, rice crackers, chocolates and chocolate coated items, wafers, and wafer sticks which come under the brand names, Munchee, Tiara, Ritzbury, Revello, and Kome. The plant carries on its productions on the land of 200,000ft^2. This locally and internationally recognized and awarded organization has always been carried on its operations as an industrially ethical and quality-assured body, since its establishment in 2002. In this company, Steam, compressed air, LPG and chill water are the most used utilities. Steam is used in the organization for many purposes like in production applications, heating, drying, cleaning, etc.

All members of the company have a personal responsibility for the way their conduct impacts the environment and ensure that all new technologies are in the proper policy. The company always prioritizes ensuring full legal compliance for waste management activities, as well as leading to best practices when possible. Furthermore, the company has mimicked activities related to the waste management system to minimize the environmental impact.

2 Research Problem

I came across a problem they face at a biomass boiler plant. That is, the volume of ash to be landfilled incurs an additional cost to the company. I have taken their problem as my research and discussed it below.

Large amounts of ash are generally allowed to accumulate in permitted wastes. However, it can damage the land and surrounding area, contributing to air pollution and water pollution. Commonly boiler bottom ash in CBLF company is collected and stored as Fig. 1 before sending to a landfill for disposing of.

Fig. 1. Collected and stored ash

Extensive research is required to find the solution to alternative reuse techniques and disposal ways for ash produced in the biomass boiler plant of CBLF and contribute towards a sustainable environment by reducing pollution. However, those reuse techniques should be marketable and attractive to end-users. So, the most suitable proportion of ash content that can be used in construction materials, is to meet the strict standards set by the regulatory bodies to be recognized. In the company, the Biomass boiler is designed as a compact tube boiler with a pressure of 10 bar. From this biomass boiler, it generates about 7 tons of ash per month. But the problem is, that there is no proper ash disposal system at the biomass plant. The current situation is that they are landfilling their ash and have to pay 15,000 rupees per month adding the transporting cost. Also, it reduces soil fertility and causes heavy metals to seep into groundwater sources.

3 Aim and Objectives

- Determining the effect of mixing different ratios of raw materials.
- Produce the most reliable bricks with biomass boiler ash by testing samples.
- Converting waste into useful material and earn from it.
- Find eco-friendly and economical solutions for boiler ash.

4 LITERATURE REVIEW

4.1 Introduction

Boilers come in various sizes and configurations, depending on the characteristics of the fuel, the specific heat output, and the required emissions control. Fig. 2 [1] shows how the summary of the boiler classification. The boilers in which hot air passes through long steel tubes and around which the water to be converted to steam circulates are called fire tube boilers (fire in tube boilers). Likewise, the boilers in which water passes through the tubes and the hot gasses passing outside the tubes are called water tube boilers (water in tube boilers).

When considering the water tube boilers, the steam generation is faster due to the small water-content to steam content [2]. Therefore, it will indirectly help in reaching the steaming temperature in a short time. Most boilers use diesel, coal, biomass, or natural gas to provide heat to the boiler.

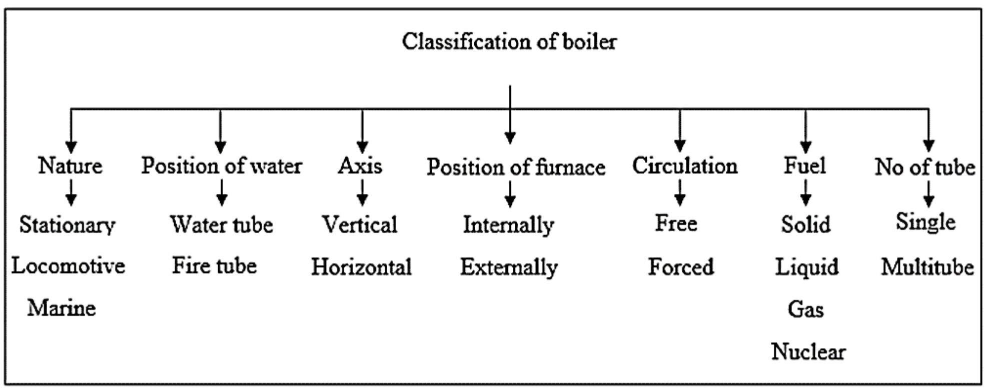

Fig. 2. Boiler Classifications [1]

4.2 Fly Ash and Bottom Ash

The two main types of ash are flying ash and bottom ash. The bottom ash is part of the non-combustible waste found at the bottom of the furnace or incinerator. Fly ash is the part of ash that escapes through the chimney. It is retained to prevent its release into the atmosphere as the quantity and quality of ash produced in a biomass power plant. Those are strongly influenced by the characteristics of the biomass and the biomass combustion technology used; the potential reuse of the ash is determined by its chemical and physical properties [3]. Ash comprises two minerals absorbed from the biomass or added during harvesting and non-combustible organic matter. The properties of the ash varied according to the type of boiler and the fuel used.

Particles of large diameter have a preferred chemical profile. However, when they are not large enough to be used effectively, they may need to be finely ground into fine particles for particular needs [4]. About 20–33% of the paddy weight and about 18–20% of the total weight is converted to ash upon incineration [5].

Rice husk ash is composed primarily of silica and has a wide range of applications to amorphous silica, both in the formless or crystalline form, depending on the combustion conditions. The main components observed in the wood ash were SiO_2 (48.6%), CaO (18.1%), and Al_2O_3 (5.9%). Also, there are some minor components such as Fe_2O_3 (3.3 %), MgO (3.2 %), K_2O (1.9 %), and TiO_2 (1.4 %). Fluxing oxides (K_2O) and auxiliary fluxing oxides (CaO, MgO) have a much strong fluxing effect on silica and alumina at a high temperature [6].

Biomass fuels have a high content of alkali metals along with other mineral components in the ash. Moreover, it causes severe ash deposition, reducing heat transfer and increasing boiler pipe corrosion. The ash content of the leaves was about 7% [7]. The properties of the ashes formed during the combustion of the fuel mixture cannot be predicted from the known properties of the ashes made from each fuel. When considering the coal fly ash, it is the ash produced by the combustion of coal, which contains particles small enough to be transported by steam boilers. It is essential to include the physical characteristics, mineralogy, elemental composition, solubility, and organic content of the clay ash particles. The properties of fly ash depend on a variety of factors. These are the composition of prominent coal, combustion conditions, the efficiency of emission control devices, by-product storage, and handling, and climate [8].

4.3 Environmental Effect

The amount of biomass ash generated worldwide will continue to rise shortly. Combustion of biomass for heat and energy primarily produces ash consisting of naturally occurring inorganic elements in the biomass. These ashes are often discarded into the environment and become unattractive due to health effects and cost.

Considering whether it is economically viable to use clay ash covered with soil ash and release unwanted amounts of unwanted metals into the environment through plant aggregation. There are several factors to consider when studying the effect of fly ash on agriculture, such as [9]:

- Yield and development.
- Absorption and accumulation of nutrients and non-nutrient elements.
- Seedlings are grown in ash-modified soils.
- Plants were grown in soils of different thicknesses.
- Non-agricultural plant growth.

Surface abrasion (slagging), fouling, and corrosion is ash related problems and should be checked when using fuel mixtures. They can reduce efficiency, capacity, and availability of facilities, thereby increasing energy costs [10]. In addition, volatile heavy metals in the ash residues may pose a significant risk to the environment. If irrationally managed and disposed of due to their possible leaching into nearby underground and surface waters, their fate is relevant to the health of plants and living beings.

Large amounts of ash are generally allowed to accumulate in permitted waste but can damage the land and the surrounding area, contributing to air pollution and water pollution. The significant problems with industrial biomass boilers are [11]:

- Deforestation according to the demand.
- Emission of CO_2 into the atmosphere.
- Water sources are depleted.
- The atmospheric temperature has risen.
- Large amounts of waste ash are generated.
- Expensive and ultimately leads to several environmental pollution problems.

When considering ash disposal and utilization options, it is essential to identify the primary fuels that affect ash composition. The main sources are oil, wood, coal, shale, and peat.

Always must try to emulate methods that can minimize final landfill amounts and maximize material recycled from waste. Here are some key ways to remove bottom ash such as; Disposal in the landfill and Discharge into the water bodies [12]. For example, all boiler ash is landfilled in Switzerland, 90% of boiler ash is landfilled in the United States, and the ratio of landfilled boiler ash is 80% in Italy and 48% in Norway [13].

Landfill disposals are the most common way of disposing of wastes. Landfill leachate pollutes the groundwater and nearby surface water bodies due to the unlined and unmanaged dumpsites [14]. The

Leachate Pollution Index (LPI) can be used to quantify the potential for leachate contamination at a landfill site over a while. In the case of Sri Lanka, almost many landfills operate as uncontrolled or unmanaged landfills due to lack of technology, high operating costs and maintenance, and disposal capacity.

Although many measurements have been made worldwide regarding atmospheric emissions, radioactivity levels, and the concentration of substances deposited in heavy metals, the study of the characteristics of pollutants in other possible environmental pathways and their emission in the surrounding areas is significantly lower. Also, a plant uses a considerable amount of water for cooling, which flows into nearby rivers and lakes after use. Leakage of major and minor elements from various sub-processes can lead to significant deterioration of water quality. Therefore, in addition to atmospheric emissions, the effluent from the plant can have a significant environmental impact on the surrounding area, but this assessment is usually not carried out. Historically, most landfills have been built without engineering liners and leachate collection systems, so groundwater contamination risk is very high. Surface water pollution is caused by the depletion of oxygen from the surface water source, causing ammonia poisoning, which causes changes in the river's flora and fauna [15]. Therefore, there is a need for a cheap and efficient leachate treatment technology or a circulating economy that consumes less energy and labor.

4.4 Reuse of Biomass Boiler Bottom Ash

Wood ash is separated into the fly and bottom ash during combustion. Fly ash is the lightest fraction formed during the combustion procedure, deposited in the boiler or filters [16]. Ashes include organic pollutants such as polychlorinated dibenzodioxin, dibenzofuran, biphenyls, and polycyclic aromatic hydrocarbons (PAHs), which are of interest for their toxic, mutagenic, and carcinogenic effects. However, high amounts of PAHs are leads to poor combustion performance. When carbon is highly oxidized and burned, nitrogen is emitted from gaseous compounds, but most of the other elements present in plant matter are retained in ash. Wood ash is mainly composed of calcium, magnesium, aluminum, phosphorus, sodium, potassium, manganese, silicon, sulfur and is nitrogen deficient [17]. Depending on the plant species, the origin of the plant, the plant parts used for combustion, the combustion process parameters, and the combustible waste storage conditions, the physical and chemical properties vary considerably. Typical applications in this field include the construction of road and parking areas, the use of ash as a layer of ash on landfills, and the mixing of ash to produce concrete, brick, or cement.

4.5 Utilize Waste Bottom Ash as a Construction Material

Since the material standards sometimes require particle size specifications, various rules must be considered when using ash with cement. Research demonstrated that boiler bottom ash could be milled and screened to closely follow boiler ash and cement [18]. Also, bottom ash increases the material’s porosity, decreasing its thermal conductivity and compressive strength. Research shows [19] that it can be reused for productions such as building parts due to the partial replacement of cement with ash made based on standard criteria. Most literature shows that bottom ash is less toxic than fly ash in general. Also, the ash at the bottom shows low chemical reactivity at room temperature [20].

5 MATERIALS AND /METHODOLOGY

5.1 Materials

Boiler bottom ash from the Ranala CBLF was used in this study to examine the possibility of using ash as a substitute for part of cement with the help of a brick manufacturer. Fine ash was obtained from the bottom of the screening machine at the Ranala CBLF biomass boiler plant. This plant is a fire and water combined tube boiler with a design pressure of 10 bar. Biomass boilers run on rubber wood chips and rubber wood logs. The boiler has an air preheater which is used to preheat the air used for combustion in the boiler. This boiler is a 5-ton boiler; produces 5 tons of steam per hour. From this biomass boiler, it generates about 7 tons of ash per month. The dried ash collected from the boiler bottom was used in brick manufacturing without further treatment.

5.2 Preparation of Samples

Samples are manufactured with the size of 220 mm in length, and 110 mm in width as per the Sri Lankan standard of SLS 1425. The standard ratio of mixing the cement: stone powder: and chip stone is 1:2:3.

Five sample sets were produced as shown in Table 01. The first set (Set 01) consisted of three samples that which 5% of cement content was replaced by ash. The second sample brick set (Set 02) consisted of three samples that 10% cement content replaced by ash. The third sample brick set (Set 03) consisted of three sample bricks that 15% cement content replaced by ash. The fourth sample brick set (Set 04) consisted of three sample bricks that 20% cement content replaced by ash. Then the final sample brick set (Set 05) consisted of three sample bricks that 25% cement content replaced by ash.

Table 01: Preparation of Sample Sets

Sample set No.	Stone powder + Chip stone + Water	Cement percentage (%)	Ash percentage (%)
Blank (3 bricks)	Added	100	0
Set 01 (3 bricks)	Added	95	5
Set 02 (3 bricks)	Added	90	10
Set 03 (3 bricks)	Added	85	15
Set 04 (3 bricks)	Added	80	20
Set 05 (3 bricks)	Added	75	25

The ash and cement samples were measured and spread evenly and then thoroughly mixed as shown in Fig. 3 until a homogeneous mix occurred. The mixing took place on a clean, non-hazardous surface. The water was added gradually to the dry mixture to occur optimum moisture content.

Fig. 3. Mixed raw materials

The inside of the molds is oiled as shown in Fig. 4. Then the mixture was placed in a mold as shown in Fig. 5 and compressed. The remaining mixture was scraped down and the surface was smoothed.


Fig. 4. Oiled Block


Fig. 5. Mixture placed in molds

The drying process is an important step in the brick manufacturing process that needs patience by giving it enough time to become a strong solid. Generally, it takes up to 24-48 hours until the cement dries perfectly. Practically it is considered that cement completes 80% of the setting in the initial 14 days after mixing with water and applying. Hence good curing for 14 days is recommendable. However, proper healing is recommended during the first 7 days to prevent cracks and to get a good strength and hard surface of the plaster. Final brick samples are shown in Fig. 6, Fig. 7, Fig. 8.


Fig. 6. Stacked in the Brickyard for Air Drying – Side View


Fig. 7. Stacked in the Brickyard for Air Drying – Plan View

Fig. 8. Outcome

Brick samples taken from two market locations are shown in Fig. 9

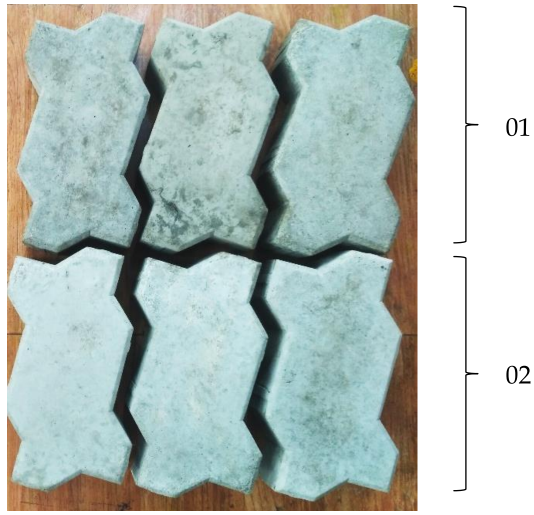

Fig. 9. Samples of bricks taken from two market locations

6 RESULTS AND DISCUSSION

All the tests were done following the Sri Lankan Standard of 1425:2011, a specification for concrete paving blocks. All the tests are conducted by the laboratory at the University of Sri Jayewardenepura. The Rock triaxial test machine used to check the compressive strength of the brick is shown in Fig. 10.

Fig. 10. Rock triaxial test machine

6.1 Test Results

According to the tests, the results of the bricks are shown in Table 02.

Table 02: Received test results of test bricks

Sample No.	Brick No.	Compressive strength (N/mm²)	Median value (MPa)
Blank sample (0% ash)	01	26.455	27.206
	02	27.847	
	03	27.206	
01 (5% ash)	04	26.246	26.246
	05	25.205	
	06	27.334	
02 (10% ash)	07	20.547	21.249
	08	21.249	
	09	22.080	

03 (15% ash)	10	19.622	19.622
	11	20.249	
	12	18.577	
04 (20% ash)	13	18.279	17.913
	14	16.259	
	15	17.913	
05 (25% ash)	16	15.179	14.979
	17	13.884	
	18	14.979	

Table 03 shows the results of brick samples obtained from two market locations according to the tests.

Table 03: Received test results of market place bricks

Market place	Brick No.	Compressive strength (N/mm²)	Median value (MPa)
01	01	17.758	17.758
	02	18.822	
	03	15.941	
02	04	23.885	23.885
	05	23.152	
	06	24.874	

6.2 Impacts that have been Identified in Current Bottom Ash Disposal Practices

The disposal of ash has become an environmental and economic problem as more ash is generated in biofuel incineration. Large amounts of ash are generally allowed to accumulate in permitted waste but can damage the land and the surrounding area, contributing to air pollution and water pollution.

There are some impacts of current ash disposal practices. These are: surface water quality is impacted by ash that is swept away by rainwater, the leaching of ash into the soil has also harmed the quality of groundwater, and this extended to environmental pollutions like surface/groundwater, land pollution, etc. Also, landfill waste generates air pollution, which is explosive and contributes significantly to climate change.

6.3 Environmental Benefits that have been Identified When Ash Reused

The use of ash reduces the need for landfills and ultimately reduces pollution. In addition, it reduces volumes destined for landfills, reduces atmospheric emissions, and stabilizes organic fractions.

These ash reuse practices are environmentally sustainable and beneficial. Moreover, it reduces impacts on biodiversity and the ecosystem, increases the quality of surface and groundwater, material saving in brick (cement), and increases employment opportunities. The availability of alkali metals, alkaline soil metals, chlorine, sulfur, and silicon can significantly affect the soil and cause reactivity and leakage to non-inorganic stages that affect soil nutrient recycling. Reuse of ash can reduce land reclamation and at the same time improve perspective on sustainability, reduce energy requirements for production, reduce CO2 emissions and conserve natural resources without compromising the supply of biomass ash.
As demonstrated in this document, the numbering for sections upper case Arabic numerals, then upper-case Arabic numerals, separated by periods.

If the environmental requirements are met, ash mixtures can provide comparable strength and compressive strength to most soils commonly used as fillers and have the advantage of smaller dry unit weights.

6.4 Environmental Benefits that have been Identified When Ash Reused

To conclude whether this research is profitable for the company, the cost-benefit analysis should be done. Table 04 below shows the cost comparison of this research.

Table 04: Cost comparison

Ash Landfilling		Ash reusing for manufacturing interlocks (for 130 bricks)	
Transportation cost	Rs.35,000/=	Cement	Rs.3,000/=
		Stone powder	Rs.1,400/=
		Chip stone	Rs.2,100/=
		Oil	Rs.50/=
		Labor cost	Rs.1,170/=
Total cost	Rs.35,000/=	Total cost	Rs.7,720/=

Ash generation per month = 7 tones
= 7000Kg
Weight of the 5% of ash = 0.086Kg
Weight of the 20% of ash = 0.086 x 4
= 0.344Kg
Number of interlocks can be manufactured by waste ash per month = 7000/0.344
= 20348 bricks
Cost for a brick = 7720/130
= 59.38/=
Cost for 20348 bricks = 59.38 x 20348
= 1,208,264.24/=
Earn by 20348 bricks = 70.00 x 20348
= 1,424,360.00/=
Profit from bricks = 216,095.76/=

Cost benefit than landfilling = 216,095.76 – 35,000.00
= 181,095.76/=

7 CONCLUSIONS

The main ash disposal method used in the biomass boiler plant at CBL Foods International (Pvt) Ltd is landfilling. According to the research results, the optimum ash ratio which is more suitable to manufacture interlock brick mixture was 20% of the total cement volume.

Waste ash is a successful substitute for the production of interlocking bricks for sidewalks, parks and parking lots under the conditions and production methods used in this study. Also, these types of ash recycling practices are environmentally sustainable and beneficial.

This study demonstrated that CBLF could use their biomass boilers as a substitute for ash in the production of interlocking bricks. CBLF can reap many benefits from this. If they used to landfill the ashes, they would also have to pay for transportation, so it would be an additional expense to the refinery. Due to the current situation in the country, it is difficult to spend money on transportation as fuel prices fluctuate.

This study proved that the CBLF can use their biomass boiler ash as a substitute in manufacturing interlock bricks. By this, CBLF can gain a lot of benefits like, if they used to landfill the ash, they have to pay for transport also so, it is an additional expense to the treatment plant. Due to the current country situation, it is harder to spend a money for transportation due to fluctuation of fuel cost. But now they can sell the ashes to the local brick industry or even give them away for free instead of filling up the rubbish at extra cost. Thus, it will make money for them and CBLF will not have to worry about handling and disposing of ashes later. Therefore, this research will benefit the organization in minimizing their struggles and paving the way for the conversion of waste into useful material, which will enable them to profit from it.

8 RECOMMENDATIONS

The below recommendations are taken on the ground of the results obtained from this research;

It is important to have data on ash generation to carry out an effective disposal practice. Therefore, it is recommended to set up a database of ash produced by biomass boiler plant which operating through CBLF. This database should include at least the capacity of the plant design and operation, process details, ash generation, timber capacity required, by-products, disposal procedures and legal requirements related to the plant.

Currently, the environmentally and technically best option of ash removal appears to be cement brick making. It is recommended to start research on the application of boiler ash cement block instead of interlocks. Such alternatives should be explored in the future to introduce recycling. Always must try to emulate methods that can minimize final landfill amounts and maximize material recycled from waste. Before disposing of ashes, it is vital to rethink the impact on the environment and living health

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