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GREEN BUILDING: EXPLORATORY USE OF BAMBOO LEAF ASH TO REDUCE CO_2 EMISSION AND ENERGY CONSERVATION IN CONCRETE PRODUCTION

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ABSTRACT

The global campaign against depletion of ozone layer and greenhouse effect is on the increase every day. It is in this view that more sustainable materials that could replace or reduce the high emission of CO_2 and high-energy consumption to the environment is discussed in this paper. Bamboo leaf ash (BLA) was investigated with its suitability in energy conservation and CO_2 emission reduction to the atmosphere. It was concluded that incorporating 15% BLA to cement usage for lightweight and mass concrete construction would significantly lower the amount of energy required during cement manufacturing and CO_2 emitted to the atmosphere and environment.

Keywords: Greenhouse, high emission, energy consumption, bamboo leaf ash and cement.

INTRODUCTION

The development and use of Bamboo leaf in construction process is gradually gaining global going by increasing rate of carbon emission, global warming and ozone layer depletion. Cement is a complex and important material used majorly as binder in construction purposes, and it has been proven to be a good source of carbon emission, hence the production of cement should be such that will reduce carbon emission to barest minimum to save the environment.

Bamboo leaf ash is one of different biomass such as corn cob ash, locust bean pod ash, sugar cane bagasse leaf ash etc. which have been proven to be useful in achieving certain compressive strength in cement replacement but their influence in environmental sustainability is yet to be fully examined, hence the need for this research.

LITERATURE REVIEW

Green building (also known as green construction or sustainable building) refers to both a structure and the use of processes that are environmentally responsible and resource-efficient throughout a building's life cycle: from siting to design, construction, operation, maintenance, renovation, and demolition (Wikipedia). A green building is one whose construction and lifetime of operation assure the healthiest possible environment while representing the most efficient and least disruptive use of land, water, energy and resources.

Energy conservation on the hand refers to reducing energy consumption through using less of an energy service. Energy conservation differs from efficient energy use, which refers to using less energy for a constant service. For example, driving less is an example of energy conservation (Wikipedia). The above two parameters makes our environment more sustainable and friendly to live when properly married together for the good of it as outlined in the *Energy efficiency policies World Energy Council 2013.*

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Environmental sustainability is the ability to maintain the qualities that are valued in the physical environment. Threats to these aspects of the environment mean that there is a risk that these things will not be maintained. (*www.green-innovations.asn.au/A-Perspective-on-Environmental-Sustainability)*

The global trend in design and construction of Civil engineering projects within the last decade has been geared towards reduction in the amount of Carbon [IV] Oxide emission and consequent lowering of global warming. Cement manufacturing has been adjudged as one of the ways by which large content of Carbon [IV] Oxide is emitted to the atmosphere through either the wet or the dry process of cement manufacturing. [18]

Cement has been identified as an important component of construction, it is one of the most widely used materials for concrete production, hence they are usually produced in large quantities using either the wet process or dry process. Energy consumption and utilization in manufacturing cement could be generated from different sources such as electrical and thermal as revealed in Figure 1.0.

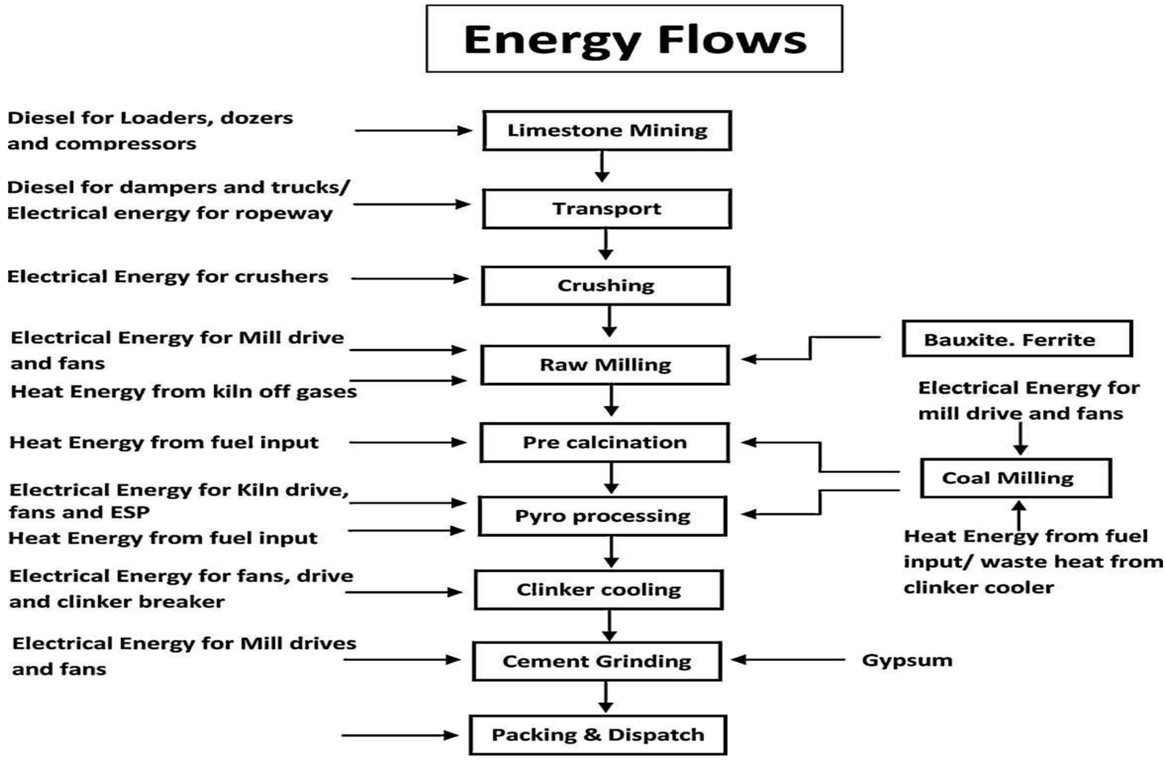

Fig 1.0.Electrical and Thermal Energy Flow for Cement production process   Source: Ref. [10]

The cement industry emits about 814-935 kg of CO_2 for every 1000 kg of cement produced [15]. The chemical decomposition of limestone accounts for 40-50% of CO_2 emissions, and fossil fuel combustion is responsible for the remaining CO_2 emissions. In 2000, global cement production was about 1536.6 million tonnes and the associated CO_2 emissions were estimated to be 1578.8 million tonnes [21]. Cement plants account for 5% of global emissions of carbon dioxide, the main cause of global warming [22]. There are three strategies to reduce CO_2 emissions from the cement industry: (1) improve energy efficiency, thus use less fossil fuel, (2) replace fossil fuel with renewable energy sources such as biofuel and other biomass feedstocks, and (3) substitute part of Portland cement with other cementitious materials such as bio-silica [12]. The third option is the focus of this paper. Typical raw materials in cement production are limestone or chalk ($CaCO_3$), sand (SiO_2), clay (SiO_2, Al_2O_3, and Fe_2O_3), iron ore (Fe_2O_3), and gypsum ($CaSO_4$). Limestone and clay are crushed and blended in a ratio of about 75% limestone to 15% clay, and pre-heated to drive off water and decompose the limestone into lime and CO_2. The material is then transferred to a rotary kiln, which heats up to 1450 C, fusing the calcium from limestone and silicon from clay into calcium silicates (Ca_3SiO_5 and Ca_2SiO_4). The resulting clinker is then cooled, ground and combined with 5% gypsum to control setting [6][11][22]. To reduce CO_2 emissions and improve cement quality, reactive silica (amorphous silica with average particle size finer than 45µmm) is often used as additive in modern cement production to reduce clinker consumption [18]. Successful examples include fly ash collected from coal-fired power plants and silica fume produced from silicone industry.

Reactive silica can also be produced from combustion of organic residues. As long as the ash contains sufficient amorphous silica with particle sizes finer than 45 mm, it can be used as cement additive as well. Because of the organic nature, reactive silica so produced is often called bio-silica. Plant by-products like rice husks, sugar cane, and corncobs can produce bio-silica. When residues containing bio-silica are burned and then blended with Portland cement, the final product is called bio cement. The use of bio cement has showed environmental, economic and technical benefits. It reduces clinker consumption and its related energy use and CO_2 emissions. The raw feed for cement production becomes renewable. The final concrete can have better performance due to the pozzolanic reaction with bio-silica ash.

A number of biomass residues are increasingly being identified as pozzolanas. Utilization of Rice Husk Ash is particularly well developed in the rice producing regions of the United States and Thailand; rice husk is first used as fuel in the rice parboiling plants, with further utilization of the ash residue as pozzolana in making special quality cement concrete [7] Other biomass residues whose ashes have been identified as having pozzolanic properties include Bamboo Leaf Ash [9], Palm Fruit Ash [17] Locust Bean Pod Ash [1], and Corn Cob Ash [3].

According to [20] they concluded that Bamboo is a pozzolanic material, which is a reflection of its high percentage of SiO_2 in its chemical properties and its rate of hydration increases with increase in percentage replacement in mortar over time.

Ref: [16] concluded in their research that with increasing percentage of BLA in a 1:2:4 concrete mix replacement of OPC up to 10%-15% of BLA is useful in producing lightweight and mass concrete.

METHODOLOGY

Materials

The materials used for this research were bamboo leaf ash (Fly ash), Portland cement conforming to BS 12, Sand (Fine aggregate), Granite (Coarse aggregate) and clean and deleterious-free water. The bamboo leaves were fetched in the campus of Federal polytechnic Ado-Ekiti (latitude 7.5^{o} 85' 81''and longitude 5.3^{o} 01' 06'') Ekiti State Nigeria. They were sun-dried and later burnt in a muffle furnace at calcining temperature of 600^{o}C for 2 hours to obtain the ash, at Foundry unit of Federal University of Technology, Akure. The electrical energy required to obtain the ash was measured with the aid of electrical attached to the furnace. The ashed sample was later subjected to sieve analysis at Soil laboratory of Civil Engineering department, Federal Polytechnic, Ado-Ekiti to determine the particle size distribution and the amount passing 75µm sieve used for the concrete mix.

Methods

Direct calculation, interpolation and relation with result obtained by other researchers were used (Table 1.0). The table showed the amount of electrical energy and litres of fuel required to produce 1000kg of cement by wet and dry process. This data was used as reference to form the basis of relating the amount of energy that was consumed during the casting of 96 cubes of (150x150x150)mm concrete samples cured for 7, 14, 21 and 28 days.

Table 1.0: Specific Electrical energy consumption in dry and wet process. Source: Ref: [5]

Process Sections	Electrical Energy Consumption (KWh/tonne)	
	Dry	Wet
Raw material treatment and crushing	4	3
Mashing	44	10
Fans and cooler	23	25
Dust collector	6	8
Cement milling	45	45
Transportation	8	47
Total Electricity required (kWh/tonne)	130	149
Fuel burned in Furnaces (l/tonne)	112.5	156

Calculation

To determine the corresponding amount of energy required, batching by weight was used.

CO_2 Emission

From Ref: [14] between (814-935) kg of CO_2 = 1000kg of cement………………………………. (1)
$96\ cubes\ to\ produce\ a\ mix\ of\ 1:2:4\ and\ batched\ by\ weight$……………………… .(2)
$a\ cube\ of\ (150x150x150)mm =$
$0.003375m^3$…………………………………….................... (3)
$A\ (50kg) bag\ of\ Cement\ \equiv$
$0.0332m^3$………………………………………………………. (4)
$1\ cube = 0.003375m^3$….. (5)
$96\ cubes = 0.324m^3$…………………………………………………………………. (6)
$For\ 1:2:4\ mix\ \frac{0.324m^3}{7} = 0.0463m^3$………………………………………………….. (7)
$0.0463m^3 of\ cement\ \equiv 69.73kg$……………………………………………………… (8)
15% of OPC =BLA $\equiv 10.46kg$
85% of OPC $\equiv 59.27kg$
From equation (1) above mean = 874.5kg i.e. 874.5kg of CO_2 =1000kg of cement
51.83kg of CO_2 = 59.27kg of cement
9.14kg of CO_2 = 10.46kg of BLA
% Reduction in CO_2 using BLA = 100-$\left(\frac{51.83}{69.73}x100\right) = 15\%$

Energy requirement

Ref: [16] has established it that up to 15% replacement of BLA in OPC is workable in mass and lightweight concrete production, and then this 15% of BLA was used as the benchmark

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to form the basis of evaluating the energy consumption and CO_2 emission during cement production in this paper.

15% of BLA in OPC = 10.46kg……..…………………………………………………………(9)

From [8] Energy required to burn 1tonne of Bamboo leaf at dried condition = 34MJ……………………. (10)

$$\therefore 0.01046 tonne\ of\ BLA \equiv 0.35564 MJ$$

From Table 1.0, total energy consumed from electricity and fuel respectively are 130kwh/tonne (468MJ/tonne) and 112.5 l/tonne (2812.5MJ/tonne) for dry process while 149kWh/tonne (536.4MJ) and 165 l/tonne (4125MJ) respectively for wet process.

Total energy required to produce 1 tonne of Cement = (468+2812.5) MJ Dry process = 3280.5MJ.

1 tonne of Cement = (536.4+ 4125) MJ Wet Process = 4661.4MJ
1 tonne of BLA = 34MJ
15% of 150kg = 492.075MJ using dry process.
10.46kg = 34MJ
150kg = 487.57MJ
Energy reduction = 492.075-487.57 = 4.505MJ
Energy reduction = $\frac{4.505}{492.075} \times 100\% = 0.92\%$

DISCUSSION OF RESULTS

CO_2 Emission

The result obtained showed that for every tonne of cement (1000kg) produced almost equal amount (874.5kg) of CO_2 is liberated or emitted to the atmosphere. This is evident from the result presented under the calculation. The result however showed that with 15% replacement of OPC with BLA, much CO_2 could be saved from escaping to the atmosphere. The result also indicates for every 15% OPC replacement with BLA 131.175kg of CO_2 is prevented from emission to the atmosphere when 1000kg of cement is produced.

Energy requirement

The result showed that using either the wet or the dry process require a huge amount of energy of 4661.4MJ and 3280.5 MJ respectively. However to produce 15% of BLA i.e. calcining process, 177.82MJ of energy would be required corresponding to 5.42% and 4.82% of energy required to produce cement using dry and wet process respectively. This is an indication that less energy is required to calcine Bamboo leaf but 15% is actually saved when replaced on the long run. However, the replacement of OPC with BLA saved 0.92% is saved per 15% replacement with BLA

CONCLUSIONS

BLA is a useful biomass as revealed by different researchers, its importance in energy conservation and CO_2 emission reduction during cement manufacturing is further reflected in this work. The work further showed that incorporating BLA to cement for lightweight and mass concrete construction would save considerable amount of energy when the result shown in this research is replicated on a larger scale. Energy saving and CO_2 emission reduction device such as muffle furnace is recommended to be used for producing ash from bamboo leaf and not the open air burning type.

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