ECONOMIC ADVANTAGES AND SUSTAINABILITY OF BASALT CIVIL/STRUCTURAL MATERIALS FOR NIGERIAN MODERN ENGINEERING STRUCTURES; POSITIVE IMPACT ON LANDFILLING CONSTRUCTION

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Abstract - One of the well-known challenges structural engineers have been facing in the modern sustainable construction is the disappointment they experience in structure building. For decades now, scientists have been searching for materials that will give best assurance and regain the confident of engineers on structuring. Considering the value of human life and the scarcity of resources in this present day consumption pattern, engineers and the environmentalist needs to validate, monitor and use the best proven materials before erecting a structure to avoid regular collapse. This research led to the discovery of a valuable and sustainable material which are gotten from basalt rocks. Basalt materials derived from basalt fibre has been able to out-power the current building materials in terms of strength, durability, fire and corrosion resistance just to mention but a few. Therefore, this paper is meant to introduce as well as explain to Nigerian civil, structural, ecologyand environmental the convenience nature and the importance of using basalt materials in constructions and structure erections due to the economic and sustainable value of the materials embedded in it. Apart from withstanding harsh situations or hazard occurrences which could be disastrous for people and ecological structures, it has been found safe and durable for modern landfilling construction and management as a result of its biocompatibility and bioreactor advantages. The production process was explained also, the benefits it may have in landfilling construction using basalt fibre. The raw basalt resources which is the basalt rock can be obtained in some locations in Nigeria serving as a plus to the immediate needs for sustainable structuring and to the environment.This study thereforewill benefitcivil/ structural engineers, environmentalist project managers, institutions, research students and lectures in the high institutions among others.

Keywords - Location of basalt rocks in Nigeria, production of basalt fibres, products of basalt rock in civil/structural engineering, modern landfilling and ecological importance.

I. INTRODUCTION

Basalt fiber which is the first product in production from basalt rock is a relative newcomer to fiber reinforced polymers (FRPs) and structural composites. In the world of structural engineering, significant growth is observed in the manufacture of composite material. With this in mind energy conservation, corrosion risk, the sustainability and environment are important when a product is changed or new product is manufactured. Basalt fiber originates from volcanic magama and volcanoes, a very hot fluid or semi fluid material under the earth's crust, solidified in the open air. Basalt is a common term used for a variety of volcanic rock, which are gray dark in colour. The molten rock is then extruded through small nozzles to produce continuous filaments of basalt fiber.
The basalt fibers do not contain any other additives in a single producing process, which gives additional advantage in cost. It has a similar chemical composition as glass fiber but has better strength characteristics, and unlikemost glass fibers is highly resistant to alkaline, acidic and salt attack making it a good candidate for concrete, bridge and shoreline structures.

II. LITERATURE REVIEW

Basalt could be defined as a dark-colored, fine-grained, igneous rockcomposed mainly of plagioclase and pyroxene minerals. It most commonly forms as an extrusive rock, such as a lava flow, but can also form in small intrusive bodies, such as an igneous dike or a thin sill. It has a composition similar to gabbro.
As defined by Oxford English Dictionary Online; Basalt is a common extrusive igneous (volcanic) rock formed from the rapid cooling of basaltic lava exposed at or very near the surface of a planet or moon. Flood basalt describes the formation in a series of lava basalt flows [1].

According to International Union of Geological Sciences (IUGS) [2,3,4] classification scheme,basalt is an aphanitic (fine-grained) igneous rock with generally 45-53% silica (SiO_2)[5] and less than 10% feldspathoid by volume, and where at least 65% of the rock is feldspar in the form of plagioclase. Structural basalt materials are those materials used in constructions that are products basalt igneous rocks. These materials can be in form of finished products or in form of raw grained materials.

A. Advantages of basalt materials

Basalt material is described as having the properties and characteristics which have more preferences or value in use in a structure. These advantages bring about the economics and sustainability of basalt materials. Considering the world economy in the recent years, it is of great importance that structural engineers use high quality structural materials that can be gotten at cheaper rate.

The search of this strong and high quality structural material brought about basalt materials. From this explanation above, it can be said that the economics of basalt material is the ability of basalt material to serve and replace other material types of structural materials to give a better structure at cheaper rate. This includes the transportation, production, manpower in site of use, etc. When the economic advantages of basalt materials are known, engineers now consider the sustainability of these materials, like the trust to the structures from basalt materials, the ecological value and effects, the after math environmental hazards: earthquakes, fire outbreaks, explosion etc. Sustainabilityof basalt material is best described as the ability of these materials to withstand challenges and changes in the environment, the recyclability of these materials and the trust of the engineers and users of structures where these materials are used.

The basic problem Nigerians are facing as long as erecting structures are concerned are the issues of getting quality, durable structural materials at cheaper rates but, what happens to the environment in the nearest future is not considered. Recent examples of environmental hazards are the occurrence of the earthquakes -such as the January 12, 2010, where a 7.3 magnitude earthquake was reported to have ravaged Haiti. More than 230,000 people were killed. Another 300,000 were injured [13] and a 9.0-magnitude earthquake in March 2011 triggered a massive and deadly tsunami, which smashed into the power station and sparked the world's worst atomic accident since Chernobyl in 1986 [14], to mention but a few. Earthquakes may not kill directly but what kills more is the destruction it causes.

These destructions such as erected buildings, dams, landfills, landscapes can be reduced or controlled. This is why prior to erecting structures in Nigeria, it is advisable that the employment of structural materials that can resists environmental disasters be considered. Nigerians must not wait for disasters to happen before they learn. They should learn from what happened to the countries as mentioned above where these earthquakes and other disasters took place. An outcome of result from researches conducted by scientists have revealed that basalt materials have the capacity to withstand heavy disasters. Later in this paper, the explanation and properties of these materials will be given in details.

III. BASALT ROCKS IN NIGERIA

Basalt rocks (fig. 1) are found in different locations in Nigeria. This section of the paper would be stating some of the locations where these material could be found and the names of the basalt rocks formations in the place.

Kahwang Basalt Rocks

Kahwang Rock Formation is a set of beautiful basalt rocks, second to one of its kind found in Switzerland. Located in Bangai village of Bachi District in Riyom Local Government of Plateau state.

Bachit Basalt Rock Formation

Bachit Basalt Formation is located near Jos, towards the south of BarkinLadi, Plateau State, Nigeria.

Ikom Columnar Basalt

The Ikom columnar basalt is located in the western part of Nigeria of the Ikom-Mamfe basin.

Fig. 1 Basalt rock
http://www.skyscrapercity.com/showthread.php?t=991393

IV. PRODUCTION PROCESS OF BASALT FIBRE

Basalt is a kind of volcanic rock, mainly known for its high temperature resistance, strength and durability, widely spread throughout the world, composed of silicon dioxide (SiO_2), and aluminum oxide (Al_2O_3), oxide ferric (Fe_2O_3), calcium oxide (CaO) and manganese oxide (MgO). For this reason, basalts are classified according to the alkaline SiO_2 content (up to 42% SiO_2), slightly acidic (from 43 to 46% SiO_2) and acid basalts (more than 46% SiO_2). Only acid basalts meet the conditions for the preparation of fibers. The productive technology of basalt fiber is similar to the glass fiber's one, but it requires less energy. This aspect, together with a greater availability of the raw material, justifies the lower final cost of basalt fibers production compared to glass fibers'. Basalt fibers derive from a natural fusion process of the basalt rock, without application of any additives. The general scheme of the manufacturing process can be summarized as illustrated in fig. 2. Once removed from the quarry, the basalt is first crushed, then washed and, subsequently, transferred into gas furnaces, for melting at a temperature of 1450℃ to 1500℃. The

molten basalt leaves the oven through a platinum-rhodium bushing with 200, 400, 800 or more holes, from which the fibers are extracted by means of hydrostatic pressure. In output, the surface of the fibers is impregnated with a primer, to give it cohesion, lubrication, and compatibility with the resin. Finally, the melt is wrapped in large spools of continuous filament basalt. Some characteristics of the production process, as the oven temperature levels, are considerably important for the final mechanical properties of the material. For example, in presence of an equal chemical composition, an increase in the fiber drawing temperature of 160°C (from 1220°C to 1380°C) increases their resistance from 1.3 to 2.23GPa and the elasticity modulus from 78 to 90GPa.

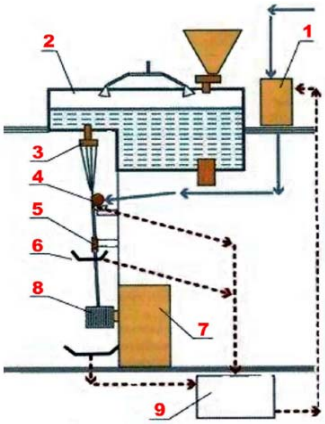

Fig. 2 Production cycle of the continuous basalt yarn: 1.Tank for sizing; 2.Furnace; 3.Bushing; 4.Sizing applicator; 5.gathering shoe; 6.Tray for used sizing collection; 7.Winder; 8.Cake; 9.Tank for used sizing

V. BASALT MATERIALS

Basalt once produced, basalt fibers are processed into various textures and warping, depending on the uses. Some of which are:

i. Continuous fiber or roving (Fig. 3), constituted by a bundle of parallel strands, without twist; the thickness of a fiber usually ranges from 7 to 24 microns. Roving is a bundle of continuous basalt filaments consisting of basic basalt fibres. It is use for production of composites, mesh, etc. It is the base material, directly produced by the process of fusion of volcanic rock, from which it is then possible to obtain other products with different manufacturing methods;

Fig. 3 Basalt continuous fiber (Roving) http://basalt.today/2016/06/6166/

ii. Basalt woven yarn (fig. 4); fabric forstructural consolidation by confinement [7], as well as for fire retardant and electrical insulation [8]. Basalt woven yarn is obtained by twisting the basalt continuous filaments. Used for the production of fabrics and composites.

Fig. 4 Basalt fabric (Basalt woven yarn) http://basalt.today/2016/07/5691/

iii. Basalt Geo-mesh or grids (fig. 5) for reinforcing wall elements. Geo-mesh is produced from Basalt roving. Used in road construction. Reduce cost of road maintenance by 25%.

Fig. 5 Basalt Mesh(grids) https://armastek.ru/en/composite-grid/basalt-grid/

iv. self-supporting panels for fire retardant, thermal and acoustic insulation[9] (fig. 6).

v.

Fig. 6 Basalt self-supporting panels for fire retardant http://ikinggroup.manufacturer.globalsources.com/si/6008852030272/pdtl/Rockwool-board/1157974529/Acoustic-Basalt-Rock-Wool-Slab.htm

vi. Bars(rebars) of composite fibers (Fig. 7) for reinforcement of cement-concrete (BFRC), replacing the steel bars [10], a particularly suitable solution for structures exposed in

corrodible environments and for the consolidation of stone structures [11]. Rebar is produced from Basalt roving. 2 times stronger and 9 times lighter than steel.

vii.

Fig. 7 Basalt Bars (rebars)
http://technobasalt.com/our-products/basalt-rebar/

viii. Basalt broken/chopped fibers (Fig. 8), produced by the cutting of continuous basalt fiber, used to reinforce concrete and mortars [12]. Basalt Fiber is chopped continuous basalt filaments. Application: reinforcing concrete, asphalt, etc.

Fig. 8 Basalt chopped fibers
http://alisstroy.ru/bazaltovoe-volokno

ix. unidirectional basalt fiber connector for structural reinforcements (Fig. 9).

Fig. 9 unidirectional basalt fiber connector

VI. CHEMICAL, MECHANICAL AND THERMAL PROPERTIES

Basalt fibers are characterized by a good resistance to both low and high temperatures and have better performances, compared to other fibers, in terms of thermal stability, acoustic insulation, vibration resistance and durability. From the point of view of performance, the basalt fiber stands between the carbon fiber and the glass fiber, even if, among others, it has a great advantage: it has an excellent compatibility with the carbon fiber. This feature allows the creation of a high-efficiency hybrid material by adding small amounts of carbon fibers to basalt ones [15]. The wire obtained, which has an insignificant difference in terms of costs (because of the small content of carbon fiber, more expensive), shows considerably better elastic properties than the 'only fiber' basalt (note that the elastic modulus of the basalt fiber is about 11,000 kg/mm^2, while the carbon fiber is 22.000-56.000 kg/mm2). However, the glass fiber [16], for its shape and chemical composition, can be considered as a reference material for a better understanding of basalt fibers' properties. Both of them are inorganic but they are produced by different processes. Glass fibers are produced by molten charge, composed of quartz sand, soda, lime, fluxing agents, etc. Basalt fibers are obtained, as already mentioned, by melting basalt rocks without additives.

Physical Properties

- Color:- It is available in golden brown in color.
- Diameter:- It is available in different diameter like 5.8 micron.
- Length:- Available in 6mm,8mm,12mm etc.
- Density:- density of basalt fiber is 2.75 g/cm^3
- Coefficient of friction:- The coefficient of friction may be between 0.42 to 0.50[21].

Chemical Properties

- Basalts are more stable in strong alkalis (Alkali resistant).
- Weight loss in boiling water, Alkali and acid is also significantly lower.
- Possess resistance to UV- Light & biologic and fungal contamination.
- Are compatible with phenolic resins.
- Absorption of humidity comes to less[21].
- Resistant to acids and aggressive chemicals.
- No carcinogenic risk or other health hazards.
- Completely inert with no environmental risks.

Thermal Properties

With a thermal range of –260 ◦C to 982 ◦C and melt point of 1450◦C as well as low thermal conductivity 0.031 – 0.038w/mk, the basalt fibers are ideal for fire protection and insulation applications. Basalt fibers are most cost effective than the other high-temper Materials including E-glass, silica, ceramics, stainless steel and carboby preventing rapid overheating and improving brake life. Offer three times the thermal efficiency of asbestos with no Mental and heat hazards. Basalt fiber is the best solution for asbestos replacement. Basalt fiber is non- combustible and explosion proof. After exposition less than 400 ◦C the basalt fibers loss on their initial strength, while the E-glass loss more 50%[21].

Mechanical Properties

- The specific tenacity (rupture stress to density ratio) of basalt fibers exceeds that of steel, many times.

- Basalt fibers are non-capillary and non-hygroscopic, giving good moisture resistance.
- Basalt has shot content generally less than 3%[21].
- High tensile strength. Tensile strength of BFRP tendon is about twice the tensile strength of steelreinforcement and elongation of BFRP tendons is much more than of steel.
- High modulus of elasticity resulting in excellent specific tenacity, three times that of steel fiber. (Basalt E= 60-80GPa while Steel E= 200GPa)
- Good fatigue resistance
- Electro-magnetic resistant

VII. SUSTAINABILITY OF BASALT MATERIALS

As known, steel tends to corrode if not properly protected. There are different systems to limit its oxidation, among which increasing the concrete layer that covers the armature or using stainless steel (more expensive solution) or bars of glass fiber. The latter solution is limited due to the lower resistance in alkaline environment, associated to the concrete, in addition to having a different coefficient of thermal expansion, compared to the latter. The bars in the basalt fibers are more resistant than glass fiber [17], in an alkaline environment. Their use, therefore, gives the final solution multiple advantages, compared to a conventional structure in concrete/steel, as for example: a lighter structure, both for the lower armature weight (1/3 the weight, compared to steel, to equal the strength characteristics), and for the reduction of the external concrete thickness, necessary to protect the steel from oxidation. Basalt properties, in addition, make it preferable to steel in reinforced concrete [18] for greater resistance to aggressive environments (both alkaline and acidic environments) and, therefore, higher corrosion resistance. While the steel of classic armors can corrode through cracks, which may occur when the structural element is subjected to bending and water, oxygen, chlorides, carbon dioxide transport phenomena, basalt ensures good durability both because it's resistant to cementations' environment, and because it is not subject to corrosion phenomena by contaminants. The basalt fiber is also a sustainable material [17], since its production cycle needs a lower use of primary energy. For each kilo of basalt fiber used instead of the corresponding amount of steel, you can obtain an energy saving of over 9 kWh of primary energy. Moreover, the basalt fiber's thermal and acoustic insulation, heat stability, durability and resistance to vibration properties, are substantially higher than both the steel and all known reinforced plastics. The basalt fiber is a biocompatible material: it has no recycling problems when it is disposed of, since it is a natural element which reduces the wrapper weight, and requires a smaller amount of energy for its processing compared to the one which normally serves for steel. This material's echo compatibility, thus, enables it to be completely recycled together with the concrete; the basalt fiber reinforcements, unlike steel, does not require a preliminary separation of the structural part from the cement before disposal to landfill. Then, savings and cost effectiveness lie in the fact that separation facilities designated to the spin-off of concrete from steel for the material recovery wouldn't be necessary anymore, but everything could be intended for a single treatment with no further disposal processes. From these considerations we can understand how the use of basalt in construction could be beneficial.

If we assumed it to replace the steel already with only 5% of the steel currently used within a year - equivalent to 25 million tons a year - we would save as much energy as the one used in a plant producing 500 MW, being active for 8000 hours per year (with savings of about 4,000,000 MWh/year). In addition, the reduction in overall energy consumption corresponds to a reduction of CO_2 emissions equivalent to 700,000 tons per year, which would bring us closer to the objectives of the climate package - EU energy [18].

Ecological importance of Basalt material in landfilling operation.

The main objective of landfilling is to provide a final destination/storage of waste in a way that it does not impair human health, ecosystem and the surrounding environment. A common theme in sustainability revolves around shifting one's view of whatwould normally be considered as a waste product to instead treating such materials as a resource or commodity.Waste has been expressed as "waste equals food" as a tenet of green manufacturing and design, requiring engineers to rework and develop services and goods that result in closed-loop material flows that are inherently benign and sustaining. Recovering wastes and utilizing them resourcefully is as significant as managing disposal methods especially through modern landfill. This can only be made possible using technologies that are sustainable. Relying on the physical and chemical properties basalt fibre'sfor reinforcing concrete use as channels in collecting leachate. Operating landfills in tropical climates associated with low and middle income is difficult but being able to use solid and sustainable material brings environmental protection into play. Using sustainable containment facilities is essential for microbial biodegradation to contain landfill gas and pollutions resulting from water that comes in contact with wastes in the landfill.

As obtainable in the developed world, modern landfills are constructed and operatedwith a goal of environmental protection using containment. These facilities generallymeet some sustainability objectives by providing protection of human health and theenvironment in a cost-effective fashion. Imbibing

in this best practice will help to reduce uncontrolled dumping system as at today in tropical regions and Nigeria in particular.

A sustainable Landfilling of waste management encourages waste treatment in a controlled environment. Therefore, we are proposing for the incorporation basalt materials in the design and leachate collection in the poorly operated. The affinity of these materials in bioreactors is important in today's landfilling system.

Environmental impact of Basalt materials on Landfill construction in Nigeria:

This study present opportunity to address a knowledge gap necessary for information that will be usefulfor owners, operators, planners, and designers of landfill. In efforts to ensure additional regulation charged with evaluating plans, designs, and construction of these facilities that often collapse in the country. Providing sustainable construction design in a widevariety of landfill operations, including facilities that supports leachate recirculation ispracticed, sites where MSW is wet (either by nature or because of climate), and siteswhere optimizing methane recovery is paramount.Uncontrolled landfilling can pose a threat to ecological resources. Surface waterresources contaminated as a result of waste disposal often have reduced dissolvedoxygen levels, thus diminishing the ecological health of the water body and potentially affecting surface water. To avoid all manners of unsustainable practice that threatens the poor masses resulting in the spread of disease-carrying organisms resulting in the growth and spread of disease-carrying organisms.

Basalt fiber advantages as biocompatibility and bioreactors on the modern Landfilling system in Nigeria:

Climatic demarcation and geographical location of the tropical or subtropical zones has significant impact in landfilling system.

The mode of operation and application principles also differs when compare with temperate zones. Water dissolution enhances rapid bio-reactions within the landfill. Pollution of water and air resources commonly associated with this, results from uncontrolled landfilling of waste. Leachate is the term used to describe the liquid resulting from watercoming into contact with waste. While chemicals disposed of in the waste or byproductsfrom reactions in the landfill, dissolve (leach) into the water, and when this leachateemerges from the waste and, enters groundwater or a surface water stream, a risk is posed to those consuming water especially local communities. Controlling gases and particulate of matter that are released to the environment from landfill should be in place. Methane gases producedfrom the waste decomposition process, primarily pose a potentialrisk of explosions and fires, and also act as a carrying mechanism for other chemicalsin the landfilled waste, many of which may be toxic to humans.Refined basalt materials have good capacity to withhold some of the components which can sustainably proffer additional advantages such as landfill fires due to its resistance heat or dust disturbed, water retention and better leachate collection.

Long term sustainability of basalt construction materials on composite sites:

The municipal solid waste management has not meet the required attention in Nigeria. One of the major properties of basalt material is the stability ability. The ability of the concrete reinforced with basalt not to crack or breakdown will serve as an optimal option for leachate pool construction. Only long term planning will stop or reduce infiltration into water bodies or soil considering the economic capacity of the middle earners as well as developing countries. Prior to introducing practices that supports sustainable landfilling of MSW, it is useful to generally think alongside considering replacing poor or unsustainable landfill construction material to a better one. For developing countries like Nigeria to attain sustainable development in the nearest future, Nigeria should engage in the best ways that best described uncontrolled dumps rather than landfills. This will assist to redirect challenges and risks of harm to human and environmental health.

CONCLUSION

Basalt fibre which is the first process to other basalt materials has the capacity to withstand high environmental hazards. Nigeria as a nation should consider the use of basalt materials in construction. With all the earlier mentioned properties of basalt materials, the era of bad roads in Nigeria should be a thing of the past as adding these materials to road construction will increase the durability of roads.

This advantages are extensible to landfill construction. The basalt materials are found to be the modern materials used in reinforcement and we advised it should be used in other structural constructions in Nigeria. These will reduce costs, reduce often repair of roads and structures as basalt fibres are highly resistance to cracks. The ecology of Nigeria would be safe in the use of these materials. Basalt materials is the solution to the long lingered difficulties structures in Nigeria have been facing.

ACKNOWLEDGEMENT

This research work was supported by Peoples Friendship University of Russia (RUDN University), on the programs to increase the competitiveness of RUDN University <<5-100>>, project M 3.2.1 П6.

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