ISSN: 0976-3031

Available Online at http://www.recentscientific.com

CODEN: IJRSFP (USA)

International Journal of Recent Scientific Research
Vol. 10, Issue, 01(F), pp. 30656-30666, January, 2019

International Journal of Recent Scientific Research

DOI: 10.24327/IJRSR

Research Article

LIGNOCELLULOSIC PLANT FIBERS (LPF) FOR CONCRETE MASONRY BLOCKS (CMB): AN INSPIRATION TO INNOVATION RESPONSE TO THE 21STCENTURY'S ENDEAVOR FOR ENVIRONMENTAL CHALLENGES

Lorie E. Malaluan[1]*, Winalene Joy E. Sescar[2] and Justine James E. Sescar[3]

[1]MIMAROPA Regional Science High School, Pag-asa, Bansud, 5210 Oriental Miindoro, Philippines
[2]San Beda University, 638 Mendiola St, San Miguel, Manila, 1005 Metro Manila, Philippines
[3]MIMAROPA Regional Science High School, Pag-asa, Bansud, 5210 Oriental Mindoro, Philippines

DOI: http://dx.doi.org/10.24327/ijrsr.2019.1001.3099

ARTICLE INFO

Article History:
Received 4th October, 2018
Received in revised form 25th October, 2018
Accepted 18th December, 2018
Published online 28th January, 2019

Key Words:
green, sustainable, agricultural wastes, engineering

ABSTRACT

In the Philippines, agricultural waste-by-products is an environmental concern. This study investigated the possibility of utilizing agricultural lignocellulosic plant fiber (LPF) in the development of green reinforced composites for concrete masonry blocks (CMB). Specifically, this study determined the external morphology and orientation of materials that make up the LPF; the chemical composition of the rice husk ash (RHA), coconut fiber, and rice husk; the difference of the CMB with 0%, 5%, 10% and 15% concentrations of LPF mixed with varying ratio of cement, sand, RHA (cement:sand: RHA:LPF) in terms of its compressive strength after 7, 14, and 21 curing days. This study made use of four setups, each setup with varying concentrations of 0%, 5%, 10%, and 15% LPF. Batch formulations for each setup were prepared by ratio (cement: sand: RHA:LPF). and mixed thoroughly. All samples were cured for a period of 7, 14, and 21 days for mechanical testing in terms of its compressive strength. Results of this study showed that the compressive strengths of the concrete blocks increased as the percentage of the natural fibers has increased. Using lignocellulosic plant fiber (LPF) from agricultural waste in producing green composite materials significantly respond to the twenty-first century's environmental challenges: slows down the resource depletion, lowers the pollution, and establish shared responsibility towards resource productivity. Thus incorporating waste materials and reducing the use of natural aggregates is an acceptable performance on saving natural resources.

INTRODUCTION

The Philippines, agricultural waste-by-products is an environmental concern which has been a vulnerable challenge to be utilized as biomaterial resources. Considering abundantly available, this study attempts to develop environmentally and sustainable green construction materials based on plant fibers.

Since the undervalued waste-by-products is a critical factor to the environmental challenges that we are facing right now, the bio based and biodegradable materials have become invaluable gifts to the mankind by utilizing them in the development of new materials with high performance at affordable costs to meet the demands of time. New dimensions for green materials may pave way for environmental friendly and sustainable future since utilizing them addresses twin issues of sustainability and environmental impact.

Environmental devastations are commonly associated with the activities related to aggregate extraction and processing of construction materials. Buildings that were constructed using these materials produced from vast amounts of resources results to high energy consumption which has detrimental impact to the environmental degradation that is now happening all over the world for centuries.

The greater demands by an ever increasing human population has placed the environment in an immense strain and drain the earth's limited natural resources, leaving not enough time for the environment to recover and regenerate. Consequently, how much of a resource can be consumed at a given time should be in balance to the rate of replenishment to the finiteness of resources.

The Philippines is mainly an agricultural country with a land area of 30 million hectares, 47 % of which is agricultural. The total area devoted to agricultural crops is 13 million hectares distributed among food grains, food crops and non-food crops.

Corresponding author:* **Lorie E. Malaluan
MIMAROPA Regional Science High School, Pag-asa, Bansud, 5210 Oriental Miindoro, Philippines

Among the crops grown, rice, coconut and sugarcane are major contributors to biomass energy resources. The most common agricultural wastes in the Philippines are rice husk, rice straw, coconut husk, coconutshell and bagasse[1].Thus, the agricultural waste which are widely available, renewable, and virtually free cannot be simply thrown away anymore, but can be converted into an important resource for industrial productive uses, since one-third of the country's agricultural land produces rice and coconut.

Consequently, the raw materials such as agricultural wastes have attractive potentials to adopt projections of future green products advocating the use of agricultural biomass as reinforcing materials for various industrial applications. With the global campaign to combat waste reduction, this approach will contribute to produce sustainable and energy efficient construction materials reducing fossil fuel dependency in the production process, hence, limiting the magnitude of carbon dioxide emissions in compliance with the environmental requirements.

Building materials from agricultural waste fibers are of notable economic and cultural significance all over the world [2] as these wastes constitute a significant proportion of worldwide agricultural productivity. Concerns about potential adverse impacts to the environment could be altered by the application of natural fiber to provide a solution to conservation of natural resource and energy. Thus, the use of agricultural waste fibers in the Philippines could be a significant reinforced composites in the construction sector which can then be a commitment to the efficient use of natural resources.

In addition, the development of a more sustainable, green, and eco-friendly building materials including bricks, wood, cement, aggregate, steel, aluminum, cladding and partitioning material are in escalating demand due to the endless construction activities for housing and other building. Moreover, providing positive environmental benefits from using fibers from renewable resources such as agricultural wastes complements the essential of proper disposal waste utilization [3].

Due to the escalating demands in the construction sector, an increasing interest of using natural fibers as reinforcement composites has gained attention to replace man-made fibers for its high strength, availability and sustainability. The use of waste and by-products is a sensible option for producing an alternative construction material, which is effective, environmental friendly while meeting structural design requirements [4]. Hence, incorporating waste materials and reducing the use of natural aggregates is an acceptable performance on saving natural resources. Thus, producing green concrete materials agrees with the development of agricultural activities and farming prosperity.

Hence, a pressing need exists to produce eco-friendly construction units that use sustainable and energy efficient raw materials. Replacing high portion of the cement by fly ash and using the wood fibers in concrete masonry unit production is one approach toward using sustainable materials with the potential to provide better thermal insulation [4, 3]. Moreover, coconut fiber has been tested for filler or reinforcement in different composite materials [3, 5]. Coir has potential to be used as reinforcement in concrete and its cheap and durable non structural element [3, 7] reduced thermal conductivity of block specimen. The additions of coir also yield a lightweight product and it would resolve the environment and energy concern [7]. The literature reviews shows that innovation is an important element in today's fast-changing economy and that developing new products and services is a vital component for companies to stay competitive [3, 4, 5, 6, 7]. However, the pace of environmental progress while maintaining our nation's economic competitiveness is an environmental challenge that we are facing right now.

Hence, the goal of this study is to recognize the effects of agricultural waste by-products lignocellulosic plant fibers for concrete masonry blocks as an approach to the development of new materials, thereby establishing environmental awareness. Such strategies would help to address issues of sustainability as well as environmental impact where all parts of society actively take responsibility to improve environmental quality and achieve sustainable results.

Thus, the demands underlining the need for clean environment and utilization of renewable resources along with the implementation of sustainable manufacturing strategies in the development of construction materials is an inspiration to innovation response to the twenty-first century's endeavor for environmental challenges.

MATERIALS AND METHODS

General Procedure

Raw materials of natural fibers collected were subjected into NaOH treatment with the intention of breaking the hydrogen bond within the structure so as to increase the roughness of the cellulosic fiber. Dry Fibers were soaked in 5% NaOH (sodium hydroxide) solution for 2 hours and rinsed with clean water removing the impurities. Coconut husk fibers were shredded, cut into pieces, and sundried for 48 hours. The physical and chemical characterizations are necessary to identify the basic structure and property of the natural fibers and to hypothesize its potential in various environmental application specifically in building green concrete construction materials.

Samples of raw and treated natural cellulosic fibers were analyzed using scanning electron microscopy and elemental analysis. Elemental analysis was also done on rice husk ash (RHA) to determine the potential of having silica content to partially replaced the use of sand in making green reinforced cellulosic fiber construction materials. This study made use of a Parallel-group design structure which consists of four experimental setups each with three replications. The treated lignocellulosic plant fiber (LPF) materials were then gathered and screened the discarding foreign materials that had been mixed in the container. Batch formulations for each setup were then prepared by percentage and mixed thoroughly.

Mixed materials were put into a molding machine. Each replication for each setup was molded in cylindrical and rectangular mold using mechanical and hydraulic press. The molded specimens were lifted and placed in the drying area at room temperature. Each batch formulations produced five replications or specimen. Each specimen was then labeled and marked to avoid confusion among the samples for easy identification. All samples were cured for a period of 7, 14, and

21 days for mechanical testing-compressive strength. The ASTM specification used in this study is ASTM C90 which is a Standard Specification for Hollow Load-Bearing Concrete Masonry Units. Arithmetic Mean had been applied to analyze the differences on the observed results of the experimentation. Results were then calculated and compared.

Pre-treatment of Natural Fibers

The dry natural fibers were soaked in 5% NaOH (sodium hydroxide) solution for 5 hours. Pre-treatment was done to increase the surface roughness and the amount of cellulose exposed on the fiber surface, thus increasing the mechanical interlocking of fiber-reinforced composite. Neutralization was followed by rinsing the treated fibers with clean water exposing the lignin cellulose fiber. Lignin cellulose fiber produced was sundried for 24 hours.

Characterization of the Materials

Samples of rice husks and coconut fiber were physically analyzed for its morphological structure through scanning electron microscopy (SEM). Elemental analysis of the raw samples through X-ray Fluorescence - Energy Dispersive Spectrometer (XRF) was also employed to confirm the suitability of the plant fibers as reinforced composite for concrete masonry blocks (CMB) production. Samples of rice husk ash underwent elemental analysis so to determine the silica content which is an essential material in the concrete industry and has become a scarce material due to the continuous depletion of sand river deposits.

Mixture Preparation and Formulations

Mixed proportion of cement, sand, rice husk ash, and lignocellulosic plant fibers (LPF) were weighed according to the ratio tabulated in Table 1 and 2.

Table 1 Proportion of Concrete Block Masonry Blocks (CMB) with Rice husk as Reinforcement Composite

Setups	Cement: Sand: Rice husk Ash	Rice Husk (wt. %)
control	1:10:0:0	0
1	1:0:10:0	0
5%	1:9.5:0.5:50	5
10%	1:9.0:1.0:100	10
15%	1:8.5:1.5:150	15

Table 2 Proportion of Concrete Block Masonry Blocks (CMB) with Coconut Fiber as Reinforcement Composite

Setups	Cement: Sand: Rice Husk Ash	Coconut fiber (wt. %)
control	1:10:0:0	0
1	1:0:10:0	0
5%	1:9.5:0.5:50	5
10%	1:9.0:1.0:100	10
15%	1:8.5:1.5:150	15

Concrete Block Design Production

The materials were gathered and screened for foreign materials before placing in a container. In order to preserve its natural conditions, the materials were sealed to achieve an accurate data for the experiment. The required amounts of cement, sand, lignocellulosic plant fibers (LPF), rice husk ash were measured to obtain suitable amounts of each material. Water was then added after the dry materials were mixed. Batch formulation was thoroughly mixed for eight minutes until homogenous mixture was formed. Mixture was then dumped into an inclined bucket conveyor and transported to an elevated hopper. The concrete mixture was then forced downward into the mold machine and compacted by the weight of the upper mold head coming down on the mold cavities. Compacted blocks were then lifted and placed in the drying area. The dimensions of concrete block design used in this study were 16 inches x 8 inches x 4 inches. Each specimen was then labeled to avoid confusion in the samples. The samples were then placed in the storage and subjected to curing for 7, 14, and 21 days.

Testing Procedures

Thirty specimens of concrete block design were prepared in this study to determine the effects of lignocellulosic plant fiber (LPF) as reinforcement composite combined with rice husk ash as partial replacement for river sand in cement mixture with three replications for each formulation. Testing procedures for the concrete block design was in accordance with ASTM C140. The mechanical testing procedure for compressive strength was administered for each curing days of 7, 14, and 21. The compressive tests under different crushing load was conducted in the Department of Public Works and Highways in Roxas, Oriental Mindoro.

The compressive strength tests were carried out in accordance to ASTM C 140 standard for Testing Concrete Masonry Units. Three samples per mixture underwent compressive strength under different crushing loads. Average of the three samples were then calculated using the formula:

$$GCS = P_{max} / A_g$$

where:

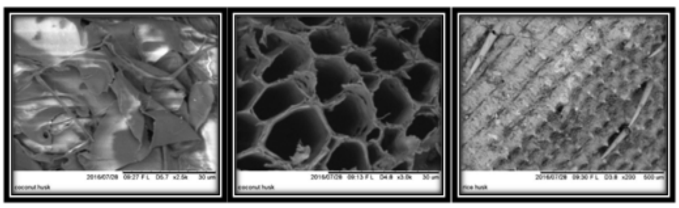
GCS = Gross Area Compressive Strength (MPa)
P_{max} = maximum compressive load, (N)
A_g = gross area of specimen, (mm^2)

Data Analysis

Arithmetic Mean had been employed to analyze the differences on the compressive strength of the concrete masonry blocks (CMB).

RESULTS AND DISCUSSION

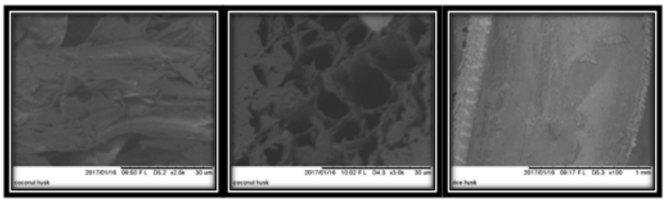
The external morphology (texture) and orientation of materials that make up the Untreated Plant fibers



A b c

Figure 1. *SEM images of comparative variation in the morphology of untreated plant fibers: (a) coconut husk fiber magnified 2500x; (b) coconut husk fiber magnified 3000x; and (c)rice husk fiber magnified at 200x.*

The External Morphology (Texture) and Orientation of Materials That Make Up The Treated Plant Fibers



A b c

Figure 2 *SEM images of comparative variation in the morphology of treated lignocellulosic plantfiber (LPF): (a) coconut husk fiber magnified 2500x; (b) coconut husk fiber magnified 3000x; and (c) rice husk fiber magnified at 100x.*

Based on the images from scanning electron microscopy, coconut fiber husk shows network more network of cellulosic fibers. Figure 1 and 2 shows the network of cellulose nanofibers. Surface of pre-treated coconut husk fiber has sieve tubes of network within the range of 50-100 nm. Brown coconut fiber obtained from matured coconuts has a higher content of lignin [8, 9]. Lignin in this fiber can be used as binders, surface-active agents and dispersant. The principal use of lignin based product in concrete manufacture is as chemical admixtures [10].On the other hand, rice husk has less rough surface as compared to the coconut husk fiber.

In order to develop composites with better mechanical properties and environmental performance, it becomes necessary to increase the hydrophobicity of the cellulose fibers and to improve the interface between matrix and fibers [11]. Lack of good interfacial adhesion, low melting point, and poor resistance towards moisture make the use of plant cellulose fiber reinforced composites less attractive. Pretreatments of the cellulose fiber helps in cleaning the fiber surface, chemically modify the surface, stop the moisture absorption process, thereby increasing the surface roughness [11, 12].

In addition, cellulosic fibers change their dimensions and properties with varying moisture content [13, 14]. The extent of changes in a fiber is determined by the amount of hemicellulose, lignin, crystallinity and surface characteristics of the fibers. Sukumaran *et al*. added that moisture content in fibers influences the degree of crystallinity, crystallite orientation, tensile strength, swelling behavior and porosity of vegetable fibers. An increase in moisture content decreases the electrical resistivity and affects the dimensional stability of composites made from cellulosic fibers. The ability of a fiber to absorb or desorb moisture should be considered when evaluating the suitability of fibers for various applications, especially for textiles, paper and composites.

On the other hand, several researchers [14] discussed that the lower processing temperature is the primary limitation of the use of agro-fibers for composites, which results to the possibility of lignocellulosic degradation. When this happens, it limits the processing temperatures and the type of thermoplastics that can be used with agro-fibers to produce composites [15]. Another limitation is the relatively higher moisture absorption of natural fibers, making it difficult for the hydrophobic fibers and hydrophilic polymers to bond together [15, 16, 17, 18]. The abovementioned limitations and the variability of natural fibers are of great concern when selecting materials for composites [16]. However, biofibers are used for composites because of their low cost, low density, high toughness, reduced dermal and respiratory irritation, ease of separation, enhanced energy recovery and biodegradability [13]. Hence, natural reinforcing materials can be obtained at low cost and low levels of energy using local manpower and technology [19]. Utilization of natural fibers as a form of concrete enhancement is of particular interest to less developed regions where conventional construction materials are not readily available or are too expensive [20].

Composition Analysis of the Plant Fibers

Table 3 Composition Analysis of the Coconut Husk Fiber as determined using X-ray Fluorescence – Energy Dispersive Spectrometer

Element		Composition %
Potassium Oxide	K_2O	63.872 ± 0.069
Calcium Oxide	Cao	18.571 ± 0.069
Sulfur Trioxide	SO_3	7.866 ± 0.063
Silicon Dioxide	SiO_2	4.567 ± 0.177
Iron (III) Oxide	Fe_2O_3	2.348 ± 0.010
Phosphorus Pentoxide	P_2O_5	2.293 ± 0.086
Manganese (II) Oxide	MnO	0.209 ± 0.008
Nickel (II) Oxide	NiO	0.109 ± 0.005
Zinc Oxide	ZnO	0.084 ± 0.004
Bromine	Br	0.080 ± 0.002

Table 3 shows the percent composition of the components present in the coconut husk fiber: Potassium Oxide (63.872%), Calcium Oxide (18.571%), Sulfur Trioxide (7.866%), Silicon Dioxide (4.567%), Iron (III) Oxide (2.348%), Phosphorus Pentoxide (2.293%), Manganese (II) Oxide (0.209%), Nickel (II) Oxide (0.109%), Zinc Oxide (0.084%), and Bromine (0.080%).

Depleting natural resources, regulations on using synthetic materials, growing environmental awareness and economic considerations are the major driving forces to utilize annually renewable resources such as biomass for various industrial applications Lignocellulosic are used for various applications, depending on their composition and physical properties. Primary lignocellulosic agricultural byproducts that are available in considerable quantity and at low cost are corn stover, wheat, rice, barley straw, sorghum stalks, coconut husks (coir), sugarcane bagasse, and pineapple and banana leaves. Using these crop residues for industrial applications could be an additional source of revenue for farmers, without adversely affecting soil fertility [14].

Most recently, there have been considerable efforts to develop natural fiber-reinforced cementations composites for affordable infrastructure [21, 22, 23]. Among those agricultural wastes, coconut fiber or coir fiber has the potential to be used as reinforcement in the development of cement fiber composites. From previous investigations, there is limited application of the coconut fiber except some product based on polymer composite [24, 25]. Coconut fiber is the most interesting fiber as it has the lowest thermal conductivity and bulk density. Some researchers have reported that the addition of coconut fiber reduced the thermal conductivity of the composite samples [21, 23, 26]. Several studies had investigated the effect of chemical composition modification and surface modification of coconut fibers as reinforcement to the mechanical properties of cement composites. They reported that the mechanical properties of composites; modulus of rupture and internal bond, increased as a result of chemical composition modification and surface modification [21, 23]. It was concluded that coconut fiber can be used as reinforcement and to substitute sand in the development of composite cement reinforced coconut fiber. Increasing content of coconut fiber will increase the modulus of rupture and compressive strength of the composites up to a certain optimum composition [27].

Table 4 Composition Analysis of the Rice Husk as determined using X-ray Fluorescence – Energy Dispersive Spectrometer

Element		Composition %
Silicon Dioxide	SiO_2	87.067 ± 0.223
Potassium Oxide	K_2O	7.107 ± 0.016
Sulfur Trioxide	SO_3	3.547 ± 0.038
Calcium Oxide	CaO	1.852 ± 0.009
Iron (III) Oxide	Fe_2O_3	0.216 ± 0.002
Manganese (II) Oxide	MnO	0.184 ± 0.002
Zinc Oxide	ZnO	0.022 ± 0.001
Rubidium Oxide	Rb_2O	0.006 ± 0.000

As shown in Table 4, the percentage composition of the components present in rice husk are as follows: Silicon Dioxide (87.067%), Potassium Oxide (7.107%), Sulfur Trioxide (3.547%), Calcium Oxide (1.852%), Iron (III) Oxide (0.216%), Manganese (II) Oxide (0.184%), Zinc Oxide (0.022%), and Rubidium Oxide (0.006%).

Concrete with partial replacement of rice husk ash can reduce the temperature effect that occurs during the hydration of cement [28, 29]. Further, the material can be applied as building and construction in the high tropical areas for heat resistance or insulation purposes [30]. Also, addition of rice husk ash to Portland cement not only improves the early strength of concrete, but also forms a calcium silicate hydrate gel around the cement [31].

The concept of utilizing excess biomass or waste from agricultural and agro-industrial residues to produce energy, feeds or foods, and other useful products is not necessarily new. The whole world thinks in the same path to overcome the pollution problems in environmentally sound methods using processes like composting, reuse, recycling, bioconversion, recovery, e.t.c.[32]. Due to conservation of energy and environmental concern, many researches were conducted towards utilization of waste materials. In recent years, there were various researchers that proved different alternative uses of rice husks such as thermal insulator and partial replacement of cement or admixture to concrete [33].

Finding a replacement for cement to assure sustainability is crucial as the raw materials (limestone, sand, clay, iron ore) used in making cements which are naturally occurring are depleting. The raw materials are directly or indirectly mined each for cement manufacturing and it is time to look into the use of agriculture waste by-products in replacing cement [34].

The additions of these waste materials have proven that the waste incorporation is not just environmentally advantageous but it also increases the performance of brick properties. However, the burning of rice husk to produce ash used in the previous researches produce greenhouse gases that can cause air pollution and will affect the people. Thus, the use of a whole rice husk in bricks production could be one of the alternatives to the burning process and the most cost effective way [32].

Concrete is a most widely used building material which is a mixture of cement, sand, coarse aggregate and water [35]. Nano silica is the most abundant material that makes the earth. It has the chemical composition of $Si0_2$ which is similar to a diamond structure. It is a white and crystal-formed material. Nano silica is one of the most applied nanoparticles in concrete [36]. Adding nanoparticles of concrete could maintain its strength during physical and chemical reactions and also compress the particles [37].

Table 5 Composition Analysis of the Rice Husk Ash (RHA) as determined using X-ray Fluorescence –Energy Dispersive Spectrometer

Element		Composition %
Silicon Dioxide	SiO_2	92.144 ± 0.129
Potassium Oxide	K_2O	4.995 ± 0.011
Sulfur Trioxide	SO_3	1.162 ± 0.228
Calcium Oxide	CaO	0.852 ± 0.008
Phosphorus Pentoxide	P_2O_5	0.279 ± 0.008
Manganese (II) Oxide	MnO	0.274 ± 0.008
Iron (III) Oxide	Fe_2O_3	0.207 ± 0.012
Zinc Oxide	ZnO	0.026 ± 0.002
Copper (II) Oxide	CuO	0.021 ± 0.002
Rubidium Oxide	Rb_2O	0.013 ± 0.001
Germanium Dioxide	GeO_2	0.006 ± 0.002
Nickel monoxide	NiO	0.006 ± 0.008
Arsenic Trioxide	As_2O_3	0.005 ± 0.001
Polonium	Po	0.004 ± 0.001
Strontium Oxide	SrO	0.003 ± 0.001
Yttrium (III) Oxide	Y_2O_3	0.001 ± 0.001

Based on Table 5, the percentage composition of rice husk ash(RHA) are as follows: Silicon Dioxide (92.144%), Potassium Oxide (4.995%), Sulfur Trioxide (1.162%), Calcium Oxide (0.852%), Phosphorus Pentoxide (0.279%), Manganese (II) Oxide (0.274%), Iron (III) Oxide (0.207%), Zinc Oxide (0.026%), Copper (II) Oxide (0.021%), Rubidium Oxide (0.013%), Germanium Oxide (0.006%), Nickel monoxide (006%), Arsenic Trioxide (0.005%), Polonium (0.004%), Strontium Oxide (0.003%), and Yttrium (III) Oxide (0.001%).

Rice husk is an agrowaste material which is produced in about 100 million of tons. Approximately, 20 Kg of rice husk are obtained for 100 Kg of rice. Rice husks contain organic substances and 20% of inorganic material. Rice husk ash (RHA) is obtained by the combustion of rice husk. The most important property of RHA that determines pozzolanic activity is the amorphous phase content [38].

Conversion of waste into a commercially viable resource can be a path to relief to a financially depressed community. Engineered materials are manufactured commodities that may introduce financial gain and other opportunities into communities looking to develop sustainable economic growth [39]. Adding value to discarded waste material (such as by engineering agricultural waste-based composites), profits can be generated which, in turn, can provide financial wealth and a more stable economy for communities and countries [40].

Natural fiber when used as an aggregate in cement composite production can contribute in making the material and as a result: the structure enhancing the environment in a friendly manner. Buildup of unmanaged industrial or agricultural solid waste particularly in developing countries has resulted in a greater percentage than before the environment apprehension. Recycling or such wastes as a sustainable construction material comes into view as a feasible solution not only to solve pollution crisis but also as cost-effective solution for designing of green buildings concept [7].Findings of this study is of paramount importance for it responds to the depletion of sand natural resources which is the most consumed natural resources [41]. Chemical composition of coconut husk fiber could be used to strengthen the bond in any construction materials without sacrificing the quality of the materials being produced. Moreover, results of this study found enormous support from the studies of several researcher [7]. Considering the renewable and sustainable nature, natural fiber is growingly being used in composite material especially in building construction.

Natural fiber generally offers low production cost, friendly processing low tool wear and less skin irritation, and good thermal and acoustic insulation properties [42]. Natural fiber also enhances mechanical and reinforcement for composites includes straw for bricks, mud and poles, plaster and reeds [43].

Table 6 Composition Analysis of Sand as determined using X-ray Fluorescence – Energy Dispersive Spectrometer

Element		Composition %
Silicon Dioxide	SiO_2	56.297 ± 0.129
Iron (III) Oxide	Fe_2O_3	15.751 ± 0.011
Aluminium Oxide	Al_2O_3	13.481 ± 0.228
Calcium Oxide	CaO	6.716 ± 0.008
Potassium Oxide	K_2O	4.800 ± 0.008
Titanium dioxide	TiO_2	1.199 ± 0.008
Sulfur Trioxide	SO_3	0.839 ± 0.012
Nickel monoxide	NiO	0.203 ± 0.002
Manganese (II) Oxide	MnO	0.168 ± 0.002
Zirconium Dioxide	ZrO_2	0.110 ± 0.001
Chromium (III) Oxide	Cr_2O_3	0.103 ± 0.002
Thulium Oxide	Tm_2O_3	0.087 ± 0.008
Zinc Oxide	ZnO	0.082 ± 0.001
Rubidium Oxide	Rb_2O	0.058 ± 0.001
Strontium Oxide	SrO	0.049 ± 0.001
Vanadium (V) Oxide	V_2O_5	0.043 ± 0.004
Yttrium (III) Oxide	Y_2O_3	0.015 ± 0.001

As shown in Table 6, percentage composition obtained by sand aggregate are Silicon Dioxide (56.297%), Iron (III) Oxide (15.751%), Aluminum Oxide (13.481%), Calcium Oxide (6.716%), Potassium Oxide (4.800%), Titanium Dioxide (1.199%), Sulfur Trioxide (0.839%), Nickel Monoxide (0.203%), Manganese (II) Oxide (0.168%), Zirconium Dioxide (0.110%), Chromium (III) Oxide (0.103%), Thulium Oxide (0.087%), Zinc Oxide (0.082%), Rubidium Oxide (0.058%), Strontium Oxide (0.049%), Vanadium (V) Oxide (0.043%), and Yttrium (III) Oxide (0.015%) respectively.

Consequently, sand has by now become the most widely consumed natural resource on the planet after fresh water [41]. Most of our houses, skyscrapers and bridges are made with ferro-concrete which is two-thirds sand (plus cement, water and gravel). 200 tons of sand are needed to build a medium-sized house, 1km of highway requires 30.000 tons of sand. Especially in Asia and the Arab states the hunger of theconstruction industry is ever-growing -cement demand by China has increased exponentially by 437.5% in 20 years, while use in the rest of the world increased by 59.8%.

High quality sand, or more precisely, silicon is needed to produce computer chips and microprocessors and we also use sand in detergents, cosmetics and many other products – yet, once sand has been transformed into concrete, the components are bound forever and are no longer available as resources [44].

Sand has been continuously extracted from the river bed for construction and industrial purposes. Gravel extraction can cause changes to channel morphology in rivers through the lowering of the riverbed during extraction [45]. This is enhanced by the disruption to bed armour caused by excavations and the movement of machinery which makes the bed vulnerable to fluvial erosion [46].

Sand and gravel are mined world-wide and account for the largest volume of solid material extracted globally. Formed by erosive processes over thousands of years [47], they are now being extracted at a rate far greater than their renewal. Furthermore, the volume being extracted is having a major impact on rivers, deltas and coastal and marine ecosystems, results in loss of land through river or coastal erosion, lowering of the water table and decreases in the amount of sediment supply. Despite the colossal quantities of sand and gravel being used, our increasing dependence on them and the significant impact that their extraction has on the environment, this issue has been mostly ignored by policy makers and remains largely unknown by the general public [41].

Globally, between 47 and 59 billion tonnes of material is mined every year [48], of which sand and gravel, hereafter known as aggregates, account for both the largest share (from 68% to 85%) and the fastest extraction increase. Surprisingly, although more sand and gravel are mined than any other material, reliable data on their extraction in certain developed countries are available only for recent years [49]. The absence of global data on aggregates mining makes environmental assessment very difficult and has contributed to the lack of awareness about this issue [41].

One way to estimate the global use of aggregates indirectly is through the production of cement for concrete (concrete is made with cement, water, sand and gravel). The production of cement is reported by 150 countries and reached 3.7 billion tonnes in 2012 [50]. For each tonne of cement, the building industry needs about six to seven times more tonnes of sand and gravel [51].

Thus, the world's use of aggregates for concrete can be estimated at 25.9 billion to 29.6 billion tonnes a year for 2012 alone. This represents enough concrete to build a wall 27 metres high by 27 metres wide around the equator. Taking all these estimates into account, a conservative estimate for the world consumption of aggregates exceeds 40 billion tonnes a year. This is twice the yearly amount of sediment carried by all of the rivers of the world [52], making humankind the largest of the planet's transforming agent with respect to aggregates [53].

Table 7 Strength of Concrete Masonry Block (CMB) with Rice Husk in Mpa and psi after 7 curing days

Name	Units	Area	Height	Maximum Force	Maxi-mum Stress	Ave Stress	Ave Stress
		mm2	mm	kN	MPa	MPa	psi
	A	41616	200	191.4336	4.60		
0	B	41616	200	189.3528	4.55	4.58	664.27
	C	41616	200	191.01744	4.59		
	A	41616	200	175.61952	4.22		
1	B	41616	200	170.20944	4.09	4.24	614.96
	C	41616	200	183.1104	4.40		
	A	41616	200	185.1912	4.45		
5%	B	41616	200	193.09824	4.64	4.55	659.92
	C	41616	200	189.76896	4.56		
	A	41616	200	195.5952	4.70		
10%	B	41616	200	193.5144	4.65	4.67	677.33
	C	41616	200	193.93056	4.66		
15%	A	41616	200	199.34064	4.79	4.77	691.83
	B	41616	200	198.92448	4.78		
	C	41616	200	197.676	4.75		

As shown in Table 7, the compressive strength of concrete masonry blocks (CMB) obtained mean average stress with the following values respectively: 4.58 MPa, 4.24 MPa, 4.55 MPa, 4.67 MPa, and 4.77 MPa.

Table 8 Strength of Concrete Masonry Blocks (CMB) with Rice Husk in Mpa and psi after 14 curing days

Name	Units	Area	Height	Maximum Force	Maximum Stress	Ave Stress	Ave Stress
		mm2	mm	kN	MPa	MPa	psi
	A	41616	200	192.3536	4.62		
0	B	41616	200	190.898	4.59	4.61	668.62
	C	41616	200	192.077	4.62		
	A	41616	200	177.962	4.28		
1	B	41616	200	172.214	4.14	4.28	620.76
	C	41616	200	183.454	4.41		
	A	41616	200	187.992	4.52		
5%	B	41616	200	195.888	4.71	4.61	668.62
	C	41616	200	191.773	4.61		
	A	41616	200	197.752	4.75		
10%	B	41616	200	195.654	4.70	4.73	686.03
	C	41616	200	196.986	4.73		
15%	A	41616	200	201.064	4.83	4.85	703.43
	B	41616	200	200.748	4.82		
	C	41616	200	202.001	4.78		

Table 8 shows the mean values of the compressive strength obtained by concrete masonry blocks (CMB) with varying concentrations: 4.61 MPa, 4.28 MPa, 4.61 MPa, 4.73 MPa, and 4.85 MPa respectively.

Table 9 Strength of Concrete Masonry Blcoks (CMB) with Rice Husk in Mpa and psi after 21 curing days

Name	Units	Area	Height	Maximum Force	Maxi-mum Stress	Ave Stress	Ave Stress
		mm2	mm	kN	MPa	MPa	psi
	A	41616	200	191.4336	4.60		
0	B	41616	200	191.01744	4.59	4.57	662.82
	C	41616	200	188.52048	4.53		
	A	41616	200	186.43968	4.48		
1	B	41616	200	188.10432	4.52	4.53	657.02
	C	41616	200	190.60128	4.58		
	A	41616	200	191.84976	4.61		
5%	B	41616	200	193.514	4.65	4.63	671.53
	C	41616	200	192.68208	4.63		
	A	41616	200	197.676	4.75		
10%	B	41616	200	199.7569	4.80	4.78	693.28
	C	41616	200	198.92448	4.78		
15%	A	41616	200	198.92448	4.78	4.80	696.18
	B	41616	200	200.58912	4.82		
	C	41616	200	199.7568	4.80		

The mean values obtained by concrete masonry blocks (CMB) with different concentrations of lignocellulosic plant fiber (LPF) as shown in Table 9 are as follows: 4.63 MPa, 4.31 MPa, 4.66 MPa, 4.77 MPa, and 4.90 MPa.

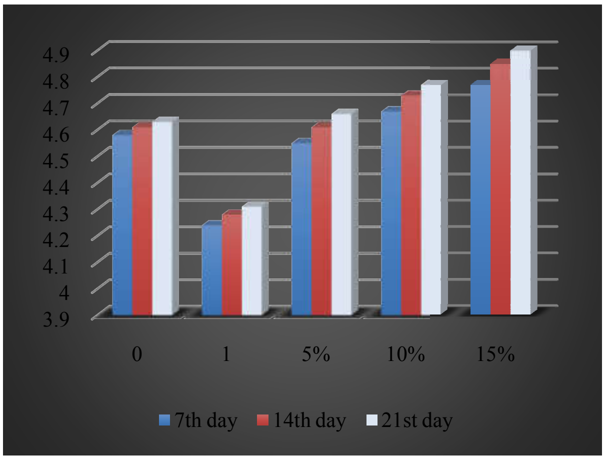


Figure 3 Compressive strength of concrete masonry blocks (CMB) with lignocellulosic plant fiber (LPF) rice husk after 7, 14, and 21 curing days

Results showed that the increased of compressive strength of the concrete masonry blocks (CMB) is due to the increased of lignocellulosic plant fiber (LPF) with respect to its number of curing days. It was evident in the results of the study that the compressive strength of the concrete masonry blocks (CMB) was influenced by the increased of partial replacement of sand with rice husk ash (RHA) with its equal percentage of lignocellulosic plant fiber (LPF).

On the other hand, Table 12 shows the mean values obtained by concrete masonry blocks (CMB) with lignocellulosic plant fiber (LPF) coconut fiber as 4.64 MPa, 4.31 MPa, 4.78 MPa, 4.88 MPa, and 4.99 MPa respectively.

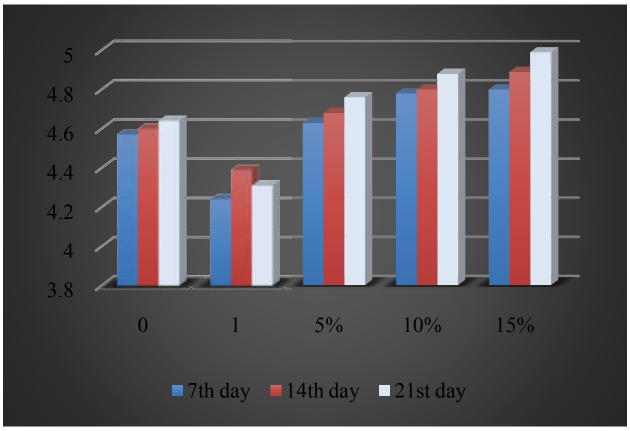


Figure 4 Compressive strength of concrete masonry blocks (CMB) with lignocellulosic plant fiber (LPF) coconut fiber after 7, 14, and 21 curing days

Based on the results from Tables 7 to 12, it has been established that rice husk ash has better performance as partial replacement only for sand when there is also an increased with the same amount of lignocellulosic plant fiber.

Table 10 Strength of Concrete Masonry Blocks (CMB) with Coconut Fiber in Mpa and psi after 7 curing days

Name	Units	Area	Height	Maximum Force	Maxi-mum Stress	Ave Stress	Ave Stress
		mm2	mm	kN	MPa	MPa	psi
	A	41616	200	193.046	4.64		
0	B	41616	200	194.897	4.68	4.64	672.97
	C	41616	200	191.003	4.59		
	A	41616	200	177.962	4.28		
1	B	41616	200	172.214	4.14	4.31	625.11
	C	41616	200	183.454	4.41		
	A	41616	200	198.008	4.76		
5%	B	41616	200	197.068	4.74	4.76	681.68
	C	41616	200	198.582	4.77		
	A	41616	200	204.117	4.90		
10%	B	41616	200	202.199	4.86	4.88	707.78
	C	41616	200	202.919	4.88		
	A	41616	200	207.903	5.00	4.99	723.74
15%	B	41616	200	206.899	4.97		
	C	41616	200	207.873	5.00		

Based on Table 10, the following mean values obtained by concrete masonry blocks (CMB) with lignocellulosic plant fiber (LPF) coconut fiber are 4.57 MPa, 4.53 MPa, 4.63 MPa, 4.78 MPa, and 4.80 MPa respectively.

Based on the results of this study, the compressive strength of the concrete masonry blocks (CMB) had increased in the 14th and 21st curing days.

Table 12 Strength of Concrete Masonry Blocks (CMB) with Coconut Fiber in Mpa and psi after 21 curing

Name	Units	Area	Height	Maximum Force	Maxi-mum Stress	Ave Stress	Ave Stress
		mm2	mm	kN	MPa	MPa	psi
	A	41616	200	192.446	4.62		
0	B	41616	200	191.517	4.60	4.60	667.17
	C	41616	200	190.048	4.57		
	A	41616	200	174.295	4.19		
1	B	41616	200	184.984	4.45	4.39	659.92
	C	41616	200	188.992	4.54		
	A	41616	200	193.849	4.66		
5%	B	41616	200	193.768	4.66	4.68	678.78
	C	41616	200	195.820	4.71		
	A	41616	200	198.876	4.78		
10%	B	41616	200	199.339	4.79	4.80	696.18
	C	41616	200	200.892	4.83		
	A	41616	200	203.948	4.90	4.89	709.23
15%	B	41616	200	202.052	4.86		
	C	41616	200	204.112	4.90		

In addition, it has been observed that the compressive strength of the concrete masonry blocks (CMB) had reached its maximum strength where there are 15% lignocellulosic plant fiber (LPF) at the time of 21 curing days. The compressive strength of the concrete masonry blocks (CMB) dripped down with the absence of lignocellulosic plant fiber (LPF).

Results showed that the compressive strength of the concrete masonry blocks (CMB) was influenced by the increased of lignocellulosic plant fiber (LPF-coconut fiber). However, the addition of rice husk ash (RHA) as partial replacement for sand should be of the same amount of its added lignocellulosic plant fiber (LPF). The use of sand in concrete masonry blocks (CMB) production should not be neglected in the construction industry. In addition, the number of curing days also affects the compressive strength of the concrete masonry blocks (CMB).

On the other hand, the use of sand as aggregate in construction cannot be compromised with the total replacement of rice husk ash (RHA). Rice husk ash (RHA) is a good material but it can only be used as supplement for cement and sand to some extent but the rice husk ash is permissible only to 15% replacement of sand aggregate.

Quality of constituent materials used in the preparation of concrete plays a paramount role in the development of both physical and strength properties of the resultant concrete. Water, cement, fine aggregates, coarse aggregates and any admixtures used should be free from harmful impurities that negatively impact on the properties of hardened concrete. Sand is one of the normal natural fine aggregates used in concrete production [54]. Hence, the use of sand in the construction industry cannot be neglected.

Large quantity of material cannot be extracted and used without a significant impact on the environment [55, 56]. Extraction has an impact on biodiversity, water turbidity, water table levels and landscape and on climate through carbon dioxide emissions from transportation. There are also socio-economic, cultural and even political consequences. In some extreme cases, the mining of marine aggregates has changed international boundaries, such as through the disappearance of sand islands in Indonesia [57, 58].

Results of the present study confirms that coconut fiber can be used as filler or reinforcement in different composite materials [5]. Coir has potential to be used as reinforcement in concrete and its cheap and durable non structural element [6]. Coir - ones of natural fiber is cheap, readily-availability and strong in tension and compression [7]. Abdullah *et al*. reported fracture behavior of composite cement reinforced with coir can be used as reinforcement and substitute of sand. Increasing content of fiber will increase modulus rupture and compressive strength. The best results are using 9% of coir. The fracture behavior of high strength composite consists of crack bridging and fiber responsible to resist the crack propagation and improve strength of composite [59]. Coir has been used and tested to increase shear strength of cement hollow blocks using coir as reinforcement without change in the compressive strength [60].

Moreover, it was evident that coir and rice husk ash not only develop the properties of concrete but it also can reduce the agricultural waste and lead to proper disposal of these wastes and solve the environment problems [7].

CONCLUSIONS

Coconut fiber obtained from matured coconuts has a higher content of lignin which can be used as binders, surface-active agents, dispersant, and as chemical admixtures [10, 9].In the case of 15% ratio of (LPF), the amount of silicon dioxide and iron oxide were found to be greater than 75% which is stipulated in ASTM requirement [31]. From the investigations carried out, the optimum addition of rice husk ash (RHA) as partial replacement for sand is 15%. The compressive strengths of concrete masonry blocks (CMB) increased as the percentage lignocellulosic plant. However, the addition of the lignocellulosic plant fiber (LPF) to the concrete masonry blocks (CMB) should be of the same percentage of the rice husk ash (RHA) as partial replacement for sand. Hence, the use of sand as major aggregate in the production of concrete masonry blocks (CMB) should not be compromised with the total replacement of rice husk ash (RHA). Hence, results of this study showed that the compressive strengths of the concrete The use of sand as major aggregate in the production of concrete masonry blocks (CMB) should not be compromised with the total replacement of rice husk ash (RHA). Hence, results of this study showed that the compressive strengths of the concrete blockshas increased as the percentage of the natural fibers was increased. In addition, the mean of the compressive strength of the concrete masonry blocks (CMB) also increased per mix ratio measured in the 7th, 14th, and the 21th day.

Thus, recycling such wastes as a sustainable construction material comes into view as a feasible solution not only to solve pollution crisis but also as cost-effective solution for designing of green buildings concept [7].

Moreover, using lignocellulosic plant fibers (LPF) from agricultural waste in producing green composite materials significantly respond to the twenty-first century's environmental challenges: slows down the resource depletion, lowers the pollution, and establish shared responsibility towards resource productivity.

References

1. Zafar, S. (2015). Agricultural Wastes in the Philippines.Retrievedfromhttp://www.bioenergyconsult.com/agricultural-resources-in-philippines/
2. Ashworth, A. (2010). Cost studies of buildings. 5th ed. Harlow: Prentice Hall, 2010.
3. Zakaria, N. Z., Sulieman, M. Z., &Talib, R. (2015). Turning Natural Fiber Reinforced Review Paper. International Journal of Advanced Engineering, *Management and Science, 1*(8), 1-2.
4. Gheni, A. A., Aljaberi, Z. K., ElGawady, M. E., & Myers, J. J. (2016). Energy efficiency and thermal characterization of Eco-friendly wood fibre masonry blocks. *Research Gate. 2*.
5. Sen, T. &Jagannatha, R. H. M. (2011). Application of sisal, bamboo, coir and jute natural composite in structural upgradation. *International Journal of Innovation, Management and Technology, 2*(2), 186–191.

6. Majid, A. (2010). Coconut fiber- A versatile material and its application in engineering," Proceeding Iternatinal Conference on Sustainable Construction Materials and Technologies.
7. Zakaria, N. Z., Sulieman, M. Z., &Roslan, T. (2015). Turning Natural Fiber Reinforced Cement Composite as Innovative Alternative Sustainable Construction Material: A Review Paper. *International Journal of Advanced Engineering, Management and Science, 1*(8), 24-31.
8. Rowell, R. M. (2008). Natural Fibers: types and properties, Woodhead Publishing Limited, Cambridge England.
9. Abdullah, A., Baharin, Jamaludin, S. B., Noor, M. M., &Hussin, K. (2011). Composite Cement Reinforced Coconut Fiber: Physical and Mechanical Properties and Fracture Behavior. *Australian Journal of Basic and Applied Sciences, 5*(7), 1228-1240.
10. Nadif, A., Hunkeler, D., &Kauper, P. (2002). Sulfur-free lignins from alkaline pulping tested in mortar for use as mortar additives. *Bioresource Technology, 84*, 49-55.
11. Kalia, S., Kaith, B. S., & Kaur, I. (2009). Pretreatments of natural fibers and their application as reinforcing material in polymer composites-a review. *Polymer Engineering and Science, 49*(7), 1253–1272.
12. Kalia, S., Kaith, B. S., Sharma, S., & Bhardwaj, B. (2008). Mechanical properties of flax-g-poly(methyl acrylate) reinforced phenolic composites. *Fibers and Polymers, 9*(4), 416–422.
13. Mohanty, A. K. *et al*.(2000)., Biofibres, biodegradable polymers and biocomposites: An overview, Macromol. *Mater. Eng*.,1–24.
14. Reddy, N. & Yang, Y. (2005). Biofibers from agricultural byproducts for industrial Applications. *Trends in Biotechnology, 23*(1), 22–27.
15. Burger, H. *et al*. (1995) Use of natural fibres and environmental aspects. *Int. Poly. Sci. Tech.*, 22, 18.
16. Eichhorn, S. J. *et al*. (2001), Current international research into cellulosic fibres and composites. *J. Mater. Sci., 36*, 2107–2131.
17. Netravali, N. &Chabba, S. (2003). Composites get greener. *Materials Today, 6*(4), 22–29.
18. Geethamma, V. G. *et al*.(1998). Composite of short coir fibres and natural rubber: effect of chemical modification, loading and orientation of fibre. *Polymer, 39*, 1483–1491.
19. Kessler, H. G. (1998). Cellular lightweight concrete. *Concrete Engineering International*, 56-60.
20. Jones, M. R. & McCarthy, A. (2005). Preliminary views on the potential of foamed concrete as a structural material. Mag. *Concr. Res., 57*(1), 21-31.
21. Asasutjarit, C., Charoenvai, S., Hirunlabh, J., &Khedari, J. (2009). Materials and mechanical properties of pretreated coir-based green composites. *Composites: Part B, 40*, 633-637.
22. Penamora, L.J. & Go, A. E. (1997). Utilization of coconut husk fibers and other cellulosic materials for the production of cement-bonded panels, Regional Research and Development Symposium, pp: 203-215.
23. Asasutjarit, C., Hirunlabh, J., Khedari, J., Charoenvai, S., Zeghmati, B., &Cheul Shin, U. (2007). Development of coconut coir-based lightweight cement board. *Construction and Building Materials, 21*, 277- 288.
24. Woolley, T., S., Kimmins, P., Harrison & R. Harrison (1997). Green Building Handbook Volume 1: A guide to building products and their impact on the environment, Green Building Digest Spon Press.
25. Savastano, H.Jr., Y. Agopyan, A.M. Nolasco and L. Pimentel, 1999. Plant fibers reinforced cement components for roofing. *Contruction Building Material, 13*(8), 433-438.
26. Khedari, J., Suttisonk, B., Pratinthong, N., &Hirunlabh, J. (2001). New lightweight composite construction materials with low thermal conductivity. *Cement & Concrete Composites, 23*, 65-70.
27. Abdullah, A., Baharin, Jamaludin, S. B., Noor, M. M., &Hussin, K. (2011). Composite Cement Reinforced Coconut Fiber: Physical and Mechanical Properties and Fracture Behavior. *Australian Journal of Basic and Applied Sciences, 5*(7), 1228-1240.
28. Craig, J.S., Garcia, J.A.D., Lim, A.V., Nicolas, C.J.P., Saiyari, D.M., & Acosta, J. (2015). Utilization of Rice Husk Ash (RHA) as Partial Replacement to Ordinary Portland Cement (OPC) in Thermal Resistant Concrete Hollow Blocks (CHB). International Conference on Environmental Quality Concern, Control and Conservation, 2-3.
29. Ghassan, AboodHabeeb, Mahmud, Hilmi Bin, "Study on properties of Rice Husk Ash and its use as cement replacement material", 2010.
30. Tong, L. &Gjorv, O. E. (2001). Chloride diffusivity based on migration testing. *Cement Concrete Research, 31*, 973–82.
31. Bakar, B. H. (2010). Malaysian Rice Husk Ash-Improving the Durability and Corrosion Resistance of Concrete: Pre-review. *Concrete Research Letters, 1*, 8.
32. Chukwudebelu, J. A., Igwe, C. C., &Madukasi, E. I. (2015). Prospectsof using whole rice husk for the production of dense and hollow bricks. *African Journal of Environmental Science and Technology, 9*(5), 493-501.
33. Ramasamy, V. (2008). *Rice Husk Ash Concrete, 3*(12), 1799–1811.
34. Kartini, K. (2011). Rice husk ash – pozzolanic material for sustainability. *International Journal of Applied Science and Technology, 1*(6), 169.
35. Ajay, V., Rajeev, C., & Yadav, R.K. (2012). Effect of Micro Silica on The Strength of Concrete with Ordinary Portland Cement. *Research Journal of Engineering Sciences, 1*(3), 1-4.
36. Atashgah, K. M., Hashempour, H., &Rezaei, M. K. (2014). An Investigation into the Role of Nano-Silica in Improving Strength of Lightweight Concrete. *European Online Journal of Natural and Social Sciences, 3*(4), 1058-1067.
37. Gengying, L. (2004). Properties of high-volume fly ash concrete incorporating nanosio, Department of civil engineering-shantouuniversity.

38. Mauro M.T *et al*..“The Possibility Of Adding The Rice Husk Ash (Rha) To The Concrete.” Retrieved from http://congress.cimne.upc.es/rilem04/adm
39. Baillie, C., *et al*., (2011), Advancing Diverse and Inclusive Engineering Education Practices through Interdisciplinary Research and Scholarship, Journal of Engineering Education, Vol. 100, No. 1, pp. 6-13.
40. Garcia, D., Lopez, J., Balart, R., Ruseckaite, R., & Stefani, P. (2010). Composites based on sintering rice husk waste tire, rubber mixtures. *Mater. Design, 28*(7), 2234-2238.
41. UNEP (2014). Sand, rarer than one thinks. Retrieved from http://www.unep.org/pdf/UNEP_GEAS_March_2014.pdf
42. Biagiotti, J., D. Puglia, D., & Kenny, J. M. (2012). A review on natural fibre-based composite part 1: structure, processing and properties of vegetable fibres. *Journal of Natural Fibers, 1*(2), 37–68.
43. Hasan, N. M. S., Sobuz, H. R., Sayed, M. S., & Islam, M. S. (2012). The use of coconut fiber in the production of structural lightweight concrete. *Journal of Applied Science, 12*(9), 831–839.
44. Villioth, J. (August 2014). Building an economy on quicksand. Retrieved from http://www.ejolt.org/2014/08/building-an-economy-on-quicksand/
45. Rinaldi, M., Wyzga, B. &Surian, N. (2005). Sediment mining in alluvial channels: Physical effects and management perspectives. *River Research and Applications, 21*(7), 805–828.
46. Mossa, J. & McLean, M. (1997). Channel planform and land cover changes on a mined river floodplain - Amite River, Louisiana, USA. *Applied Geography, 17*(1), 43–54.
47. John, E. (2009). The impacts of sand mining in Kalladariver (Pathanapuram Taluk), Kerala. *Journal of basic and applied biology, 3* (1&2), 108-113.
48. Steinberger, J. K., Krausmann, F., Eisenmenger, N. (2010). Global patterns of materials use: a socioeconomic and geophysical analysis. *Ecological Economics, 69*, 1148-1158.
49. Krausmann, F., Gingrich, S., Eisenmenger, N., Erb, K-H., Haber, H., & Fischer-Kowalski, M. (2009). Growth in global materials use, GDP and population during the 20th century. *Ecological Economics 68*, 2696-2705.
50. USGS, 2013a. Cement, statistics and information. U.S. Geological Survey, Reston.
51. USGS, 2013b. Sand and gravel (construction) statistics, in: Kelly, T.D., Matos, G.R., (Eds.), Historical statistics for mineral and material commodities in the United States. U.S. Geological Survey Data Series 140, Reston.
52. Milliman, D. &Syvitski, M. (1992). Geomorphic/Tectonic Control of Sediment Discharge to the Ocean: The Importance of Small Mountainous Rivers. *J. Geol., 100*(5), 525-544.
53. Radford, T. (2005). It's the way you tell them, Environment & Poverty Times, 3, Special Edition for the World Conference on Disaster Reduction January 18-22, 2005, Kobe, Japan, UNEP/GRID-Arendal.
54. Orchard, D.F. (1979) Concrete Technology, Propertiess of Material. 4th Edition, Volume 1. Applied Science Publishers Ltd., London, 139-150.
55. Sonak, S., Pangam, P., Sonak, M., &Mayekar, D. (2006). Impact of sand mining on local ecology in multiple dimension of global environmental change. The Energy and Resources Institute, New Delhi.
56. Kondolf, G. M. (1994). Geomorphic and environmental effects of instream gravel mining. *Landscape and Urban Planning, 28*, 225–243.
57. New York Times, 2010. Indonesia’s Islands Are Buried Treasure for Gravel Pirates, March 28, 2010. The New York Times. Retrieved from http://www.nytimes.com/2010/03/28/weekinreview/28grist.html?_r=0
58. Guerin, B. (2003). The shifting sands of time — and Singapore, Asia Times online. Retrieved from http://www.atimes.com/atimes/Southeast_Asia/EG31Ae01.html
59. Subramaniam, P., Subasinghe, K., &Fonseka, W. R. K. (2015). Wood ash as an effective raw material for concrete blocks. *International Journal of Research in Engineering and Technology, 4*(2), 2319–1163.
60. Gampathi, G. A. P. (2011). Application of Coconut Fiber in Cement Block Industry. *OIDA International Journal of Sustainable Development, 2*(9), 83-88.

How to cite this article:

Lorie E.Malaluan *et al*.2009, Lignocellulosic Plant Fibers (Lpf) for Concrete Masonry Blocks (Cmb): an Inspiration To Innovation Response to the 21stcentury’s Endeavor for Environmental Challenges. *Int J Recent Sci Res.* 10(01), pp. 30656-30666. DOI: http://dx.doi.org/10.24327/ijrsr.2019.1001.3099

****