A Qualitative Study of Green Building Indexes Rating of Lightweight Foam Concrete

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Abstract

Green building index is considered as the rating tool for evaluating the siting, design and performance of buildings and infrastructures based on worldwide acceptable six main criteria's It was invented after the Kyoto protocol, Japan, on 11th of December 1997 and the adoption in Marrakesh in 2001 by the United Nations and her subcommittee. It was developed in the built environment industry by the Government support of each country to combat the issue of green house gas emission. Carbon dioxide is acclaimed as one of the main greenhouse gas emission which is mainly through the activities of human race in the world resulting into global warming hence the effort to make the environment lighter enough to inhabit. Construction industry was assessed through studies to be contributing 5% of the world total carbon dioxide emitted through cement production. It was also claimed that a tonne of concrete produces carbon dioxide in the range of 0.05 to 0.13 tonnes. Foam concrete being a new innovative green technology material for sustainable building and civil construction needs to fulfill the criteria's of this rating tools for it to be considered as sustainable materials. This paper study the assessment of this lightweight concrete material in view of green building index criteria's and the result are hereby analyze and concluded that foam concrete can be effectively used as sustainable material for building and civil engineering construction.

Keywords: Green building index, Foam concrete, Greenhouse gas emission

1. Introduction

RIO summit, June 1992, in the land of Brazil, representatives of governments from all over the world, about 178 countries, gathered and mutually agreed on what we referred to as agenda 21 today. This comprises of twenty one agendas of sustainable development strategies that every member countries present are expected to follow for regional sustainability programmes. The main goal of this agenda as of the summit was to propose a practiceable development that can provide environmental and social values to the benefits of the populace in each region.

Sustainability is the enablement to maintain a state or nature as it is now in the present and without any negative effect or hazard to the unborn generation potentials.

In the area of shelter the agenda concern itself with the development of residential buildings that are environmental friendly, just as Ahmad (2004), rightly put it that the agenda concern itself with adequate shelter for all families with a satisfactory water supply, sanitation, electricity, safety and a healthy environment. Grubb et al. (1993) summed the ideal of the agenda in this way by saying that "The programme address the specific needs of the people and ensure sustainable use of natural resources; improve the quality of life of the people and enhance environmental quality".

The world wide known problem of global warming has resulted into many innovative in the area of greening of nature through the activities of human kind. The incessant release of carbon dioxide through various faces of human activities has caused the increase in the atmospheric temperature, a situation that has being shown through studies and researches that if not abated the present generation and the generation to come will surely bear the consequences. Nearly all facets of human activities now witness the most orchestrated word, going green. Construction industry, worldwide, not being left behind, resulted into operation green building which can also be referred to as sustainable building or green construction in another favorable terms and these new innovated technology are being embraced worldwide to combats the unfavorable climatic condition of global warming and it effect on earth surface.

The most commonly used materials in the building and civil engineering construction today is concrete. Study by Neville (1996), shows that an ordinary concrete contains almost 12% of cement contents and 80% of aggregates content .It has also been established through research by Mehta (2001) that 1.6 billion tonnes of cements with 10 billion tonnes of sand, gravel and crushed rock are being consumed every year globally and that seven percent of the whole global emission of carbon dioxide was accounted for by the yearly production of cement (1.6 billions).

Mining large quantities of raw materials for the production of cement such as limestone and clay and fuel such as coal often results in extensive deforestation or denudation and top soil loss. All these need of vast quantity of natural resources to produce an estimated billion of tonnes of concrete each year resulted in great impact on the immediate environment. Apart from the estimated 7% of the global loading of carbon dioxide CO_2 into the air annually, the cement industry through the production of Portland cement is also considered to be energy intensive. In addition to these, quite a large quantity of water are required for the production of concrete and this is considered burdensome considering the availability of good and fresh water suitable for concrete production.

In addition, concrete structures have life span, a service lives of several decades up to a century or more. Those structures that failed after achieving their life span and could no longer fulfill their original purpose are demolished. The demolition and the disposal need of the debris or left over of concrete constitute another environmental problem. Construction as well as demolition debris constitute a considerable fraction of solid waste in developed countries even as concrete is considered as the largest single components of it all. Mehta (2001) claimed that the annual worldwide output of concrete and masonry rubble has been estimated roughly as one billion tonnes. The continuous use of natural aggregate and the use of cement in the production of concrete conventionally likewise has negative effect on the environment. This effect on the habitat as stated by Winfield and Tailor (2005), is the extraction of aggregates from pits and quarries results in the destruction of the natural habitats of many organisms and in the disturbance of the pre-existing stream flow and water resources. There are great impact of the natural aggregate production on the quality of both groundwater and running surface water. The flow patterns of the water are disturb – in the course of natural aggregate production and likewise the ground water storage capacity deposits are considered as the reservoirs for underground water.

After quarrying, the natural aggregates have to be transported; the cost of transporting the already crushed aggregates from quarry to the place or location of use visa a vise the transportation of the ready mix concrete has great financial impact. Despite, all these short coming of concrete production impart on the environment, concrete is still considered as an inherent environmental friendly structural materials.

With all these being in mind, the newly embraced lightweight concrete assist in no small measure to reduce the impact of all these demerits of normal concrete especially in the area of fulfilling the Kyoto protocol measures and most importantly environmental friendly.

Lightweight concrete generally are concrete that make use of an expanding agent that increases the volume of the mix and at the same time giving additional qualities and lessen the dead weight. The main merits of lightweight concrete includes among others, low density, low thermal conductivity, light in weight and faster construction rate, lower haulage and handling cost. Lightweight concrete can either be no- fine concrete, lightweight aggregate concrete and aerated foam concrete. For the purpose of this research, lightweight foam concrete is used and it is an aerated concrete with surfactants of proteineouse source as a foam agent.

Green building indexes considered worldwide as an environmental rating tools system for the assessment of residential, commercial or public buildings. It was developed to give adequate measure to green constructions in general. It also provide basis for classification of buildings or infrastructures to either green or non green. It is aims to assist the building industry all around the world, to achieve the sustainable development. The indexes are developed in each country with focuses on some peculiarities to culture, construction methods, weather and climatic condition but all these focuses and targeted six main criteria's throughout the world.

Many research work and studies have been done and still in the offing to see that concrete production achieve greenish features hence green concrete. Among the contemporary research studies is the use of some cementitiouse materials such as fly ash, ground granulated blast furnace slag and silica fumes as a substitute to Portland cement in the production of concrete. In some part of developed countries, many achievements have been reached with partial substitute of Portland cement with some cementitiouse materials in the ratio of either 70% of cementitiouse materials and 30% of Portland cement or 60% of cementitiouse and 40% of Portland cement. For instances, in Denmark according to Ecoserve (2006b), the blending of Portland clinker with supplementary materials mainly takes place at the concrete plant whereas the trend in central and southern Europe goes towards blended cements where the blending take place at the cement plant.

However, the application of various types of supplementary materials depends strongly on the availability and traditions in the various countries. For instance in North America, the concept of environmentally friendly concrete is closely related with high volume fly ash concrete where about half of the cementitiouse materials consist of fly ash as established by Malhotra (2006) and Obla (2003). This paper seek to assess the green nature or features of this environmental friendly concrete, called lightweight foam concrete using green building index rating and look at its effects on global warming.

2. Green Building and Green Building Index

Green building is generally classified as the process of building and structure production that are environmentally responsible and efficient resourceful throughout the building or structure life's span beginning from the sitting to the deconstruction. It can also be referred to as high performance building. Kibert (2004) defined a sustainable or green building as a subset of sustainable construction, representing simply the structure. Years later, he went further to explain that sustainable construction most comprehensively addressed the ecological, social and economic issues of a building in the context of its community Kibert (2007). Ahmad (2010) defined Green Building Index as the comprehensive rating system for evaluating design and performance of buildings based on six (6) main criteria using Malaysia GBI;

- Energy efficiency which carry 35%
- Indoor environmental quality 21%
- Sustainable site planning and management 16%
- Water efficiency 10%
- Innovation 7%
- Materials and resources 11%

The actual reason for the construction of greener building is quite important and this has to do with the main fact that we need to live most lightly on the earth surface as much as possible. The impact of human being with their various activities on the earth's ecosystem cannot be over emphasized and the major factor of concern in most of our activities and operations boils down on the use of energy production, dissipation, use and consumption of energy from various sources. Green building target on increasing the resource use energy efficiency, water and materials efficiency and at the same time reducing the impact of these various activities on human health, well being and the environment during the life time of such building and these can be achieved through better sitting , green nature driving design, construction, operation, maintenance and removal.

In the building and construction sector, 40% of the world's energy is consumed, 12% of water is also consumed with 40% of the waste sent to landfill, and all these contribute majorly to the global problem. The design and choice of materials has most significant ways of affecting our environment, likewise the quantity of energy embodied in the building materials themselves, their transportation and their assemblage duly call for concern in term of global warming. These energy consumption and dissipation has a direct correlation or effect on our environmental quality because of the environmental pollution through the emission of greenhouse gases and other types of emissions. However, the building and construction sector can as well be a major playmaker in the solution of world acclaimed global warming problem.

International researchers confirmed that green buildings consume less energy, water and generate less waste thereby create a healthy and productive environment. It has being claimed through the chairman, world green building, Tony Arnel, that research had shown that green building practices can reduces a building costs by as much as 9% building values and realized a total 6.6% increase in return on investment, so, green building don't just make a sound ecological and environmental sense, they make sound economic sense too.

In line with growing green building delivery system worldwide, quite a number of green building assessment tools have been invented by several international and national research organization, institute and scholars and most of these assessing tools or ratings have being tested and accepted although many are still being improved upon yearly or quarterly. The area of focus of most or majority of these rating tools are;

(a) Energy efficiency of all components of the building, i.e. all the elements, assess one after the other.
(b) Indoor environmental quality
(c) Sustainable site planning and management
(d) Water efficiency
(e) Innovation

(f) Materials and Resources.

And the main objectives of most, if not all of these green building ratings are;

- To evaluate the overall performance of the green building by considering all the elements one after the other
- To monitor and coordinate the process of green building production in other to achieve the basic fundamental principles of green building which are economic growth, environmental and ecological balance equity and social advancement.
- To increase and improve on the evolution of green building construction.

2.1 Notable Green Building Indexes in the World

There are several green building index rating tools developed across the whole continents of the world and many are still being developed .There are few of these rating tools that are considered as the mainstream building index tools for the general use in the production of green building, however, it was found that the generation of this rating tools has to be localized as it has much to do with locality, culture and regional system of building production.

Among these major green building tools are;

(1). LEEDS, which is interpreted to mean Leadership in Energy and Environmental Design. The United State Green Building Council (USGBC) first developed this system of rating in the year 1998. It was developed with a target of evaluating the environmental performance of a green building over the whole life span. Although this version has being improved upon, as we now have LEED (V.2.0) in the year 2000 and LEED (V.3.0) in year 2009. This current one has larger advancement than LEED (V.2.0), although LEED (V.2.0) is still more prominent in use in the prevailing market of green building. (http://www.usgbc.org,July , 26th, 2011).

(2).CASBEE, this is developed in Japan by Japan Green Building Council (JAGBC) in the year 2001 and her subcommittee that includes the government official and the academicians. This green building tool adopts the value of building environmental efficiency in the evaluation used.

BEE = Building environmental quality and performance / Building environmental loadings. (http:www.ibec.or.jp/casbee, July, 26th, 2011

(3) SBTOOL, this tool is designed with two focuses, which are to assess the environmental and sustainable performance of building. It started in 1996 by a group of more than a dozen team from different countries and later handed over to international initiatives for a sustainable built environment (iisbe) in the year 2002. Initially it was called GBTOOL and it was designed compel the users to reflect the different priorities, technologies, building traditions and cultural values of various regions of the world. It make use of a Microsoft excel workbook configured to fit into any construction condition of all regions of the world. (http://www.iisbe.org. July 26th, 2011).

(4)BREAM Research Establishment. The BRE is owned by the foundation for the Built Environment, a registered charity in the UK, and it provides a range of consultancy, testing and commission research services for all aspects of the built environment, (Kimberly, Henz, and Dale, 2006) .This happen to be the pioneer building index tool in the whole world and this tool make use of environmental assessment method for buildings. A review of this tool was launched in 2008 and two major changes was introduced which include, a new two stage assessment process which are design stage and post construction, the second is the introduction of mandatory credits. (http:www.bream.org. July 26th, 2011.

(5)ESGB, In the year 2006, China ministry of housing and urban rural development came up with education standard for green building and the china government has made this to become a national standard named GB/T 50378- 2006, the ESGB consist of six divisions, each with 3 sub divisions. Morhud PRC (2006)

(6)BCA- GM is another tool that was launched in Singapore in January 2005. This tool was supervised and endorsed by the National Environment Agency with main aim of the production of environment friendly buildings. BCA, green mark consist of assessment criteria for two main categories which are new building and existing building and the criteria is sub divided into two categories BCA – GM non residential building which is the latest version and BCA- GM for residential building. (http://www.bca.gov.sg/GreenMark, July 26th, 2011.)

(7)MALAYSIA GBI, this building rating was generated in year 2008 and was launched in 21st of May 2009. It was developed for new buildings with two ratings one for residential and another one for non-residential. It was created to provide the building industry a common and verifiable mechanism to benchmark buildings within the

Malaysian context. It was formed to set out a vision for sustainability within the built environment and provides guidance that will assist end users to deliver sustainable townships. It was developed specifically for the Malaysian tropical climate, environmental and developmental context and social needs and created to;

- Define green buildings by establishing a common language and standard of measurement

-Promote integrated, whole building designs that provides a better environment for all

-Recognize and reward environmental leadership

-Transform the built environment to reduce its negative environmental impact

- Ensure new buildings remain relevant in the future and existing buildings are refurbished and upgraded to improve the overall quality of the building stock. (http://www.green buildingindex.org/indexhtml.2011).

2.2 Lightweight Foam Concrete

Since 1920, aerated concrete has being in existence, although its use has been restricted to non load bearing and non structural use such as back filling, road embankments, road base thermal insulation, trench filling and building block. And in 1923, the material was first patented according to study by Valore(1954). The detailed study and comprehensive analysis of the study result was first done and presented by Valore1 and 2(1954) and Rudnai (1963), Kinniburgh(1963) did the study of summarizing the composition, properties and uses of cellular concrete.

The introduction of air bubbles into concrete base mix in the cause of mixing brings about the production of concrete. Two main types of aerated concrete are generally known in concrete industry and they are autoclaved aerated concrete and foam concrete. The introduction of hydrogen gas bubbles into mortar paste of cement or base mix which consists of sand or any other type of filler and Portland cement with the addition of aluminium powder of probably 0.2% by mass of cement which eventually reacts with Ca $(OH)^2$ alkali in the solution yields the production of autoclave aerated concrete. In the resulted mixture, the gas bubbles cause the expansion of the mixture to the required density after which the concrete is transferred to curing steam at the atmospheric pressure or temperature of 180^OC under intensive high pressure in an autoclave.

Foam concrete on the other hand is produced by either two method, one by the introduction of preformed foam solution into mortar slurry of sand, Portland cement and / or any other admixtures in a normal mixer or ready mix truck mixer. Secondly synthetic or proteineouse admixture can be mixed with mortar or cement slurry in a high shear mixer resulting in a discrete bubble of sizes within the range of 0.1mm to 1.0mm.

Foam concrete can be produced on site and with low production cost compared to autoclaved aerated concrete which is mainly factory produced because of the curing process and other chemical mixtures that need monitoring and accuracy, also, it is used while financial means favours mass production.

Foam concrete is classified as lightweight concrete as a result of the presence of entrapped air voids by suitable foaming agent, it has characteristic features of high flowability, low self-weight, minimal consumption of aggregate, controlled low strength and excellent thermal insulation properties as assessed by Ramamurthy et al (2009).

3. Methodology of Rating Foam Concrete Using Green Building Index

Concrete is considered as the most important building materials worldwide because of the readily available of its constituents. It consists of aggregates, which can be coarse or fine as the case may be, cements and water. We have different types of concrete, no fine aggregate concrete and lightweight aggregate concrete. Lightweight concrete is a major improvement through continuous research on the conventional concrete over the years, all to meet up with the global solution of reducing gas emission, which makes the globe to warm.

Looking at the greenish features of lightweight foam concrete in the light of some of the green building index highlighted above, this paper come to conclusion that foam concrete can thoroughly be green hence environmentally friendly and provide solution to global warming in a no small measure. Table 1 compares gas emission and energy consumption of traditional concrete and green concrete as detail by Abbas et al (2006).

3.1 Energy Efficient of Foam Concrete

Thermal insulation can be considered as one of the most important factors relatively to the achievement of energy efficiency in a building. A parametric simulation analysis using DOE 2.1A, for a single house in hot climate of Saudi Arabia has indicated that using thermal insulation for both roof and walls would contribute a reduction of 12.6% of the total annual energy consumption as studied by Said and Abdurrahman(1989). Thermal

insulation is consider as one of the most effective energy conservation measures for cooling and heating in buildings because it reduces heat transfer through the building envelopes to and fro, Ali (2008).

Foam concrete is recently acceptable for use in low strength capacity for building and civil construction purposes due to its peculiar properties ranging from the low thermal conductivity which is lesser than 0.50W/Mk, low self weight which ranges between 800 and 1800kg/m3 and self compacting features hence high workability. This suggested that it has thermal insulation value. The low densities also make it more or less useable and workable anywhere anytime. Easily transportable with lesser cost.

When the cement content is partially reduce or wholly substituted with admixtures such any pozzollan materials, foam concrete will definitely become green and energy efficient because the carbon dioxide emission is definitely reduced such as shown in the table 1. an excerpts from Abbas, et, al, 2007 Results from NUS in-house data showed that energy savings per unit area by using foamed concrete wall (S.G. = 0.8,thermal conductivity of 0.26 W/m.K) as compared to using convectional concrete wall(S.G. = 2.4, thermal conductivity of 2.5 W/m.K) is more than 70 %. Thus, it is showed that foamed concrete can be an effective insulation material to help in energy-saving in buildings. Wong (2006).

3.2 Water Efficiency of Foam Concrete

This is another green building index parameter that concrete that a green concrete must fulfill. Winfield and Tailor (2005) declared that natural aggregates production impacts on the surface and groundwater quality and the natural habitat of many species is a serious concern. Many are the ways that the excavation of natural aggregates changes land and vegetation slope and tamper with the underground water reservoir as natural aggregate is considered a natural reservoir for underground water. For any concrete to be green then it must make use of lightweight aggregates, recycle aggregate or surfactants as in foam concrete. so that the water resources can be conserved.

In term of water consumption, research as shown that foam concrete uses relatively lesser water/ cement ratio than autoclave aerated concrete hence greater strength. This also can be compared to that of normal concrete even in production process, the amount of water required for the production of foam concrete is quite less than that of the one required in the production of normal foam concrete. There are also no waste in the course of production and mixing of foam concrete. The materials are all non hazardous.

3.3 Innovation of Foam Concrete

The introduction of innovative raw materials in the production of foam concrete makes it greener and satisfies the GBI rating measures. The use of some newly innovated cementitiouse materials such as fly ash, ground slag, silicon fumes ,etc for partial or complete replacement of cement in the productions of foam concrete and some admixtures, surfactants , all these put together, which eventually reduce the energy consumption drastically and improve some of its properties to meet some specification and standard .

3.4 Materials and Resources

The materials used in the production of foam concrete has no negative effect on the environment, human being and has no hazardous effect on the climate as postulated by Kyoto protocol hence, it's a green concrete. For instance the following explain the difference between the materials of foam concrete and that of the normal concrete.

The haulage of aggregate materials to processing plants requires enormous energy, so also is the transporting process of aggregates to ready mixed concrete plants. PCA (1993) revealed that 2.7M-joules per tonne- km for sand and gravel and 3.8M- joules per tonne- km for crushed aggregates are required to transport these materials to ready- mixed concrete plants.

In addition to all these energy is the main energy needed in the production of wet concrete itself as established by George and Michael (2001), the production of new concrete using recycling concrete aggregates requires the same amount of energy as producing concrete with natural aggregate and this energy can be approximately estimated as 1.3 to 2.4 GJ/m3. Therefore, for concrete to be green and fulfilled the requirement of building index rating, it must be able to reduce drastically, the energy consumption and dissipation in the course of sourcing and production to the placement process. Foam concrete makes use of surfactants instead of aggregates of any form, size or shapes.

Another area of energy requirement in concrete is in the production of crushed aggregates. PCA (1993) came up with estimated energy requirements for sand and gravel productions to be 5.0 M- joules per tonne while crushed

aggregates requires an energy in – put of 54M- joules per tonne. All these are eliminated in the production of foam concrete hence a drastic reduction in the energy consumption.

4. Effects on Global Warming

The green building index rating tools if employed in the assessment of concrete produced in the building, civil construction industries throughout the world, then the concrete produced will be environment friendly and contribute in the reduction of global warming which is a global problem. Foam concrete production is one good example of green concrete that can meet up with the requirement of GBI ratings.

The following are the ways green concrete, such as foam concrete, can affect global warming;

(a). The energy production will be reduced likewise the green house gas emission.

(b).The use of cementitiouse materials as replacement partially or fully, in the production of concrete will go a long way to reduce gas emission into the atmosphere.

(c).Natural aggregates and sand can be replaced by the use of recycle concrete aggregate and lightweight aggregate as researched in the current years, hence energy are reserved and little disturbances to the natural water reservoir.

5. Conclusion

The invention of green building index with common aims throughout the whole world is a significant indication that the world is seriously facing and tackling the global warming problem as associated with the various activities of humankind. Shelter, which is considered as one of the three main basic needs of life, should be taking as major point of impact to the environment at large. Therefore, concrete that is green in nature such as foam concrete study and assess in this paper, will go a long way to help reduce global warming as the greenish nature can be assessed with green building index parameter as postulate by this paper. Another major area that needs to be studied throughout the world is the parameter to show the effectiveness of the various green building index in the various countries of the world, the activities of the facilitators of the various index and the government policies to back up their work needs to be investigated.

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Table 1. below shows the comparism of the energy consumption and green house gas emission of traditional and green concrete as highlighted by Abbas,Faitfazi et al. (2006)

	Traditional Concrete	Green concrete. E.g. lightweight foam concrete.
GHG Emission tonnes	1.345 tonnes from cement per tonnes	0.875square from cement per tonne
GHG Emission per km.	15,000 per km from aggregate	7,500 cubics from aggregates per tonne
Energy consumption(MJ)	4000MJ from cement	2,800MJ from cement
Energy consumption(MJ)	63MJ from aggregate	31.5MJ from aggregate.