Application of Sustainable Construction Practicesin Design and Construction of a Hostel Project

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Abstract

The relationship between construction activities and the natural environment is symbiotic. Natural resources such as land, water and trees feed into construction activities while waste from construction activities are given back to the natural environment. Construction activities can therefore not be sustained when natural resources are depleted. Sustainable methods and technologies must therefore be adopted by stakeholders in the construction industry in order to preserve our ecosystem for today and future generations. In view of this, this paper investigates into how sustainable construction principles and technologies are applied by construction professionals on a construction project at the design and construction stages in order to promote sustainable construction in the Ghanaian Construction Industry. Through a case study approach, interviews and field observation were conducted. Qualitative examination of the primary data obtained was carried out. The results indicate that the level of compliance to the principles of sustainable construction principles and application of sustainable technologies were very low on the hostel construction project selected for the study.

Keywords: *Case study, Construction professionals, Design and construction stages, Ghana, Sustainable construction*

Introduction

Sustainability is a broad and complex concept, which has grown to be one of the major issues in the construction industry. Based on the report of World Commission on Environment and Development, WCED (1987), sustainability can be defined as a quality that gives a development or an object the ability to meet the needs of the present generation without compromising the ability of future generations to also meet their needs. To achieve sustainability in this industry, there is a need for an all-inclusive approach in adapting Sustainable principles into the construction of a building project. Sustainable construction is a holistic process aimed at restoring and maintaining harmony between the natural and built environments, and creating settlements that affirm human dignity and encourage economic equity (CSIR &CIB, 2002).

Sustainable construction, which is sometimes referred to as green construction, is a construction process that should ensure energy efficiency, environmental sustainability, low carbon and resource efficiency. It is defined by Kibert (1994) as *"The creation and responsible management of a healthy built environment based on efficient resources and ecological principles"* as cited in Zhou *et al*. (2008).Hill and Bowen (1997) have since then divided Kibert's principles into four 'pillars': social, economic, biophysical and technical and successfully explained the four themes of sustainable construction. They advocate that, it is always necessary to pursue sustainable construction in these themes.

Du Plessis (2002:6) also defines sustainable construction by linking it to sustainable development:

"Sustainable construction means that the principles of sustainable development are applied to the comprehensive construction cycle from the extraction and beneficiation of raw materials, through the planning, design and construction of buildings and infrastructure, until their final deconstruction and management of the resultant waste. It is a holistic process aiming to restore and maintain harmony between the natural and build environments, while creating settlements that affirm human dignity and encourage economic equity."

The definitions given above cover the application of the principles of sustainable construction throughout the entire life span of a building. A more focused direction on the construction process of the building life cycle is taken in this research. This direction becomes more affirmed in light of the assertion of Horvath (2004) that literature on environmental impacts of infrastructure is still limited and that most attention has been devoted to the use-phase energy consumption of residential, commercial, and industrial buildings, especially in heating, ventilation, air conditioning, and lighting. He added that although future research should continue with the study of the use phase and energy issues, it should also focus more on the other lifecycle stages of the infrastructure that have received limited attention but are just as important.

Buildings being put here in Ghana do not seem to have sustainability principles and construction practices considered at the design and construction stages of building projects. The construction industry contributes enormously to environmental degradation and thus more effort is needed by the stakeholders thereof to breed sustainability and sustainable development oriented practices into its processes. To what extent do construction professionals comply with sustainability principles in construction?

The focus of this research is to investigate into the awareness of and compliance to sustainability requirements of design and construction processes among built environment professionals in the Ghanaian construction industry. Getting it right at the early stages is highly likely to lay a foundation upon which future sustainable strategies and technologies would easily fit.

Literature Review

The environment is basically our surroundings and everything that affects us during our lifetime. Construction activities take resources from all aspects of the environment and gives back construction wastes to the environment it took from. The damage to the environment is caused both by natural (non-anthropogenic) and man-made (anthropogenic) reasons. The natural impacts are non-preventable and on many occasions unpredictable. On the other hand, anthropogenic detrimental impacts on environment are eminently preventable but only with a focused global effect. Globally, the construction sector is arguably one of the most resource-intensive industries. Concern is growing about the impact of building activities on human and environmental health. Clearly, it is necessary to take actions to improve the sustainability of the built environment and construction activities (Zainul Abidin, 2010). The construction industry as well as its stakeholders, especially construction professionals must therefore take a leadership role.

Sustainable development and sustainable construction

The concept of "sustainable development," as devised by WCED (1987) and with it, the term "sustainability" itself, have been recognized increasingly in recent years all around the world. Wide-spread use, however, has been followed by growing vagueness so that today both terms

are employed within a very broad variety of meaning often, to the point of trivialization, (Ben-Eli, 2005).

Sustainable development is about ensuring a better quality of life for everyone, now and for generations to come. This requires maintenance of high and stable levels of economic growth and employment (Zahibi *et al*., 2012).

As at the time the World Commission on Environment and Development, now known as the Brundtland Commission, presented "Our Common Future" a 1987 publication, they wanted to address the problem of conflicts between environment and development goals by formulating a definition of sustainable development:

'Sustainable development is development which meets the needs of the present without compromising the ability of future generations to meet their own needs', World Commission on Environment and Development (1987).

Since then the general dialogue on the topic of sustainable development recognises three aspects of sustainable development, Holmberg (1992); economic, environmental and social. These give features to the principles of sustainable construction.

In terms of the principle for sustainable construction, various efforts have been made to examine several definitions of sustainability in an attempt to enunciate principles to be upheld in attaining sustainable construction. The need to apply principles of sustainable construction has been extensively discussed in literature (Kilbert, 1994; Hill and Bowen, 1997; Department of Environment, Transport and the Regions, DETR, 2000; Long, 2001; Ding, 2008; Du Plessis, 2002; Zainul Abidin, 2010). In all, there is a consensus that the breadth of the principle of sustainable construction mirrors those of sustainable development, which is about synergistic relationships between economic, social and environmental aspects of sustainability.

One of the important ways of knowing if our built environment is meeting sustainability standards is by assessing the performance of the environment. The concept of sustainability has been around for a long time and in effect there are multiple standards that have been introduced in various countries with varying methods to measure and assess sustainability. Table I below gives a summary of criteria used by BREEAM of UK and LEED of USA for assessing the sustainability of buildings. It is important to have timeous involvement of key stakeholders in the decision making process (WCED, 1987). The promotion of interdisciplinary and multi-stakeholder relations (between the public and private sectors, contractors, consultants, and nongovernmental) should take place in a participatory, interactive and consensual manner.

Table I – BREEAM and LEED assessment criteria

S/No	BREEAM	LEED
1	Management	Sustainable sites
2	Health and wellbeing	Water efficiency
3	Energy	Energy & atmosphere
4	Transport	Materials & resources
5	Water	Indoor environment quality
6	Materials	
7	Waste	
8	Land use and ecology	

9	Pollution
10	Innovation

Source: BREEAM New Construction Non Domestic Manual, 2011; LEED v4 User Guide, 2013 of Green Building Research Institute (GBRI)

The Construction Industry and the Ecosystem

There is an intrinsic link between the construction industry and the environment and has been put at the centre of concerns about environmental impact. According to Zainul Abidin (2010), buildings are very large contributors to environmental deterioration. Construction activities affect the environment throughout the life cycle of a construction project. This life-cycle concept refers to all activities from extraction of resources through product manufacture and use and final disposal or recycle, i.e. from "cradle to grave". Even though the construction period is comparatively short in relation to the other stages of a building's life, it has various significant effects on the environment. Therefore the analysis of the impact of the construction industry on the environment may need to look from a 'cradle to grave' viewpoint (Ofori *et al.,* 2000).

The construction industry is one of the largest exploiters of renewable and non – renewable natural resources (Zainul Abidin, 2010). It relies heavily on the natural environment for the supply of raw materials such as timber, sand and aggregates for the building process. This extraction of natural resources causes irreversible changes to the natural environment of the countryside and coastal areas, both from an ecological and a scenic view point (Godfaurd *etal.,* 2005). The subsequent transfer of these areas into geographically dispersed sites not only leads to further consumption of energy, but also increases the amount of particulate matter in the atmosphere.

Raw materials extraction and construction activities also contribute to the accumulation of pollutants in the atmosphere, mostly in the processing of materials for construction. And again, not surprisingly, the construction industry has the biggest effect of all sectors because of the amount of materials used in construction. Dust and other emissions include some toxic substances such as nitrogen and sulphuroxides. These gases are released during the production and transportation of materials as well as from site activities and have caused serious threat to the natural environment.

The UK Department of Trade and Industry, DTI (2006), reports that global greenhouse gas emissions increased by more than four times in the last half of the twentieth century. Other harmful materials, such as chlorofluorocarbons (CFCs), are used in insulation, air conditioning, refrigeration plants and fire-fighting systems and have seriously depleted the ozone layer (Langford *et al.* 1999). Pollutants have also been released into the biosphere causing serious land and water contamination, frequently due to on-site negligence resulting in toxic spillages which are then washed into underground aquatic systems and reservoirs (Huberman and Pearlmutter, 2008).

According to Langford et al(1999), about a third of the world's land is being degraded and pollutants are depleting environmental quality, interfering with the environment's capacity to provide a naturally balanced ecosystem. The BRE defined pollution from construction as involving "particles, noise, vibration and vaporous discharges" (Pitt *et al.,* 2009). If the construction industry continues to overuse these natural resources, a limit on economic growth will eventually emerge. In other words, the destruction of the environment will inevitably affect the construction industry.

The construction industry produces an enormous amount of waste. A large volume results from the production, transportation and use of materials (Kein *et al*., 1999; Osmani *etal.,* 2008). Most construction waste is unnecessary according to Sterner (2002) who says that many construction and demolition materials have a high potential for recovery and reuse.

Screening, checking and handling construction waste for recycling are time consuming activities and it is possible that lack of environmental awareness amongst building professionals may create significant barriers to the usefulness of recycling. The depletion of natural resources by the building industry is a topic of serious concern as most of the recyclable materials from building sites end up in landfill sites and requires a lot of planning for effective management. Sterner (2002)states that implementing a waste management plan during the planning and design stages can reduce waste on-site by 15 percent, with 43percentless waste going to the land fill through recycling, and it delivers cost savings of up to 50 percent on waste handling.

Apart from waste generation, the building industry is rapidly growing, and world energy use and the use of finite fossil fuel resources has already brought up concerns over supply difficulties, exhaustion of energy resources and heavy environmental impacts (ozone layer depletion, carbon dioxide emissions, global warming, climate change (Spence and Mulligan,1995; Langford *etal*.1999;Uher,1999;Perez-Lombard *etal.,*2007). Building material production, the construction, operation and demolition phases consume energy. A completed building consumes energy for heating, lighting, power and ventilation. Decision about the use of these less-energy-consuming materials need to be taken at the design stage and this requires the awareness and competence of construction professionals.

Research Methods

The goal of the research is to ensure that existing construction norms that do not conform to sustainability principles are changed, especially during the design and construction stages of a construction project. Hence the aim of this paper is to define the extent to which sustainable construction practices and principles are applied on a hostel project by design professionals and contractor.

First, critical review of literature was carried out to examine the concept of sustainability and ways of assessing the compliance of buildings to sustainability principles. The main sources of data for carrying out this research are interviewing of construction professionals and field observation of design and construction practices.

To allow for an in-depth examination of events, phenomena, or other observations within a real life context of applying the concept of sustainability on a construction project, case study approach was adopted (Shields, 2009). This involved the use of interviews and observations during the course of the research. This allowed carrying out the in-depth study typical of case-studies (Yin, 2003). Also, the case approach was realized to be suitable in view of the novelty of the concept of sustainable construction in Ghana, which needed a detailed examination.

An interview guide was developed to conduct a semi-structured interview of the professionals on the project. The interview guide comprised both closed-ended and open-ended questions. The closed-ended questions were included to obtain few quantitative data on the work experience and profile of the interviewees. Open-ended question enabled obtaining the majority qualitative data which were critically examined. The questions were made clear and were easy to understand (Fellows and Liu, 2003). As a result its administration was easier and effective. The guide exhibited an array of smooth-flowing questions, motivating length and structure which

enabled all the interviewees to complete the interview (Hoinville and Jowell, 1978). In all six construction professionals were interviewed. The responses (qualitative data) obtained were closely examined issue by issue (*see Table II*) in order to bring out commonalities, differences and subsequently draw the appropriate inferences to aid discussion in a qualitative mode.

Results and Discussion

The work experience of the interviewees ranged between 10 – 40 years and the dominant type of building on which the interviewees had had most of their work experience is the residential type. The interviewees comprised of two architects, three quantity surveyors and one project manager. Structural and services engineers were part of the project team but all efforts to reach them for the interview were unsuccessful.

Among the interviewees there was some moderate level of awareness of sustainable development concept. Some of them were not conversant with the technicalities and some were rather mentioning sustainable procurement as being more disseminated in Ghana than the sustainable development concept itself.

The issue of environmental assessment of construction projects was viewed as a very essential exercise by the professionals interviewed. However, they admitted that they have not witnessed sustainability assessment being conducted on any other building project they have participated in its management. The Ghana Green Building Council (GHGBC) has been established since 2009 (GHGBC, 2011) with the aim of ensuring that the property industry carries out developmental projects that satisfy the requirements of sustainable development. However, none of the interviewees had experienced green rating on building projects on which they had been part of the project management team.

The issue of whether sustainable materials were selected during the design was an issue on which the interviewees did not find common grounds. The architects were of the opinion that the hostel building had been designed for adequate use of sustainable materials, whilst other professionals were of the opinion that sustainable materials have not been clearly incorporated into the designs. The hostel building is a reinforced concrete framed structure. Observations of the construction methods and enquiry about the major materials used for the construction do not reflect considerable use of sustainable building materials. Using wet construction processes, cement, mild steel iron rods, sand and quarried stone chippings, which are all obtained from non-renewable sources and through unsustainable manufacturing processes, are the major materials used in the construction. The diverse opinions expressed could be a reflection of misunderstanding of what constitutes a sustainable building material.

However, an observation of the large window openings, provision of natural lighting and ventilation to improve indoor air quality portray an incorporation of a bit of sustainability concept into the design. This could be the reason for some of the interviewees' assertion that sustainability was considered during the design and thus that is the most important stage at which sustainability should be considered for any building project.

This study was conducted after the construction had been completed and the building handed over but prior to occupation and usage. Therefore, there was no opportunity for first hand observation of the practices during the actual construction to allow for ascertainment of the sustainability or otherwise of some of the construction practices. However, interrogations during the interview indicated that most of the activities did not amount to sustainable construction practices such as recycling of waste or selective waste disposal (Valente *et al.,* 2013) or adequate provision of health and safety measures (GBRI, 2013) for especially the construction workers.

Site Observations

Energy Renewability

It was observed that the hostel facility source energy from the country's national power grid. Other alternative renewable energy sources such as biotechnology or solar power do not form part of the project (*see Fig 1 at appendix*).

Table II – Responses to questions on interview guide

Issue	Responses	Interpretation
Awareness of SD concept	Aware of Sustainable Development Do not understand the technicalities of sustainability Sustainable construction is now evolving in Ghana Not Fully aware of Sustainability Rather more aware of Sustainable procurement	Awareness level of SD is moderately low
Importance of Environmental Assessment	Environmental assessment is considered in contract packaging. Environmental assessment is considered during tendering Understanding the environmental impacts of design decision is important Environmental issues are considered less at conceptual stage of construction project Environment and sustainability issues are not the priority objectives of projects in Ghana	There is a general agreement that Environmental Assessment is important
Sustainability assessment practices	Assessment of sustainability of buildings should be conducted on every building project Sustainability assessment not done in Ghana Green rating introduction could pave way for sustainability	Sustainability assessments are not performed on buildings
Stage at which sustainability considerations are mostly important	Design stage Sustainability issues are critical at the design stage At conceptual stage sustainability is least thought of	Architects believed design of building considered sustainability

Sustainable Material selection	Materials that are selected are sufficiently sustainable	Most materials used for construction cannot be considered to be sustainable
	Not knowledgeable in sustainability of materials	
	Sustainable materials should be included in specification to promote sustainable building	
	Environmental issues increase cost and time of projects	
	Architects should be held responsible for selection of sustainable building materials	
	Architects should make a life cycle assessment of materials selected in their designs	
	Materials with recyclable contents were not selected for this hostel project	
Compliance with sustainable construction practices	Practices such as large openings, improved internal natural lighting and ventilation are applied on the study	Low compliance to sustainable construction principles
	No recycling of waste/rain water	
	Site vegetation not replanted after clearance	
	No selective disposal of waste during construction	
	No recycling of waste arising during construction	
	No roof top green gardens	
	No water usage efficiency measures	
	Electricity power source non-renewable	
	Appliances chosen were energy-efficient	
	Health and safety of construction workers were partially considered	

The failure to use some of these renewable energy sources increase the dependency on fossil fuels and also fail to provide opportunities for mitigating greenhouse gasses. Nonetheless, the lighting appliances that had been fixed for use were branded as energy-efficient. At the time of observation, the building had not been occupied and the actual efficiency during usage could not be ascertained.

An observation was also made on the effective use and management of water. The design stage failed to incorporate water efficient measures in the building's design and construction. There was no provision of mechanisms for recycling the building's water use, storage or even rain water harvesting.

<Fig. 1 near here (see appendix)>

<Fig. 2 near here (see appendix)>

Water efficiency

The roofing drainage system did not support rainwater storage and treatment system, which could have improved water demand of the facility. The only water storage system was the use of "*polytanks*" that would store water pumped out of installed borehole system for subsequent distribution to various parts of the building. From the semi-structured interview it was remarked by one of the architects that sets of water pumping equipment that function based on

the existing non-renewable energy source were to be used for the water supply. This practice was also observed to be unsustainable.

Lack of water recycling system was realized to be a gap that could contribute to water shortage problem during usage of the facility. The 5-storey building had capacity for nearly thousand people; 498 rooms with two students per room. In situations of full occupancy the few storage tanks would not be able to supply adequate water for students' morning usage.

Water use would have been minimized if water conserving fixtures like ultra-low flush toilets and low-flow shower heads were installed. The flush systems and shower heads provided are not in any position to minimize water usage.

Traditional construction methods

The method of construction used was in-situ reinforced concrete frame. Concrete is known to be responsible for 7-10% of CO_2 emissions worldwide, making it one of the biggest climate change factor besides transportation and electricity generation (Faludi, 2004). The process of heating during manufacture of Ordinary Portland Cement (OPC), the main binding material used for concrete, contributes to global carbon emissions. Thus, this construction method adopted for the hostel construction could not encourage sustainable construction practice. Moreover, Aluminium-zinc alloy was used as the roofing material and this is also found to be anti-sustainable with respect to the production process. The production plant of this material in Ghana consumes up to about 24% of the Ghana's electricity (Energy Commission, Ghana, 2013). This is coupled by the rippling effects of CO_2emissions during the manufacturing process.

The British Research Establishment, BRE (2011)new construction manual recommends constructing buildings on a previously developed site more than on a virgin site in order to limit the disturbance of the ecology. Otherwise, upon clearance of fresh vegetation, it is necessary to replant trees, grass and/or shrubs to help the eco-system rebuild itself. From Fig. 3 there was no attempt to embark on an exercise to replace lost vegetation. Meanwhile, interviewees indicated that the building was put up on a land heavily covered with green vegetation.

<Fig. 3 near here; *(see appendix)*>

Occupants' health and wellbeing

The LEED standards, as well as the BREEAM, advocate good indoor environment quality. This boarders on providing comfort and wellbeing and facilitating increased productivity of

occupants by addressing design and construction guidelines with regards to indoor air quality, thermal quality and lighting quality. The hostel facility was designed with adequately large openings of average sizes of about 2150x1400mm placed opposite each other to enhance cross ventilation and. Fig 4(a) and (b) portray well lit internal spaces by natural lighting only.

<Figs. 4(a) and (b) near here; *(see appendix)*>

Conclusion

Among the interviewees, the level of awareness of the concept of sustainable construction is found to be moderately low. Although there was a general agreement that environmental assessment is important, yet respondents admitted that sustainability assessment of buildings is not practiced in Ghana. Interview and field observations revealed that most of the design and

construction practices were not in line with sustainability principles. The issue of indoor air quality and natural daylight were observed to have been adequately addressed.

The result of the study is based on opinions of the core built environment professionals that were involved in the design and construction of the hostel project and can therefore not be generalized. However, the findings are necessary for influencing positive changes in the construction practices of similar buildings in developing countries like Ghana. The results of the studies have given an indication of the importance of professional bodies and associations in the Ghanaian construction industry considering ways of ensuring that practicing built environment professionals conform to sustainable development principles.

In carrying the research forward the number of interviewees can be increased to widen the opinion net of built environment professionals and to cover more than one building project.

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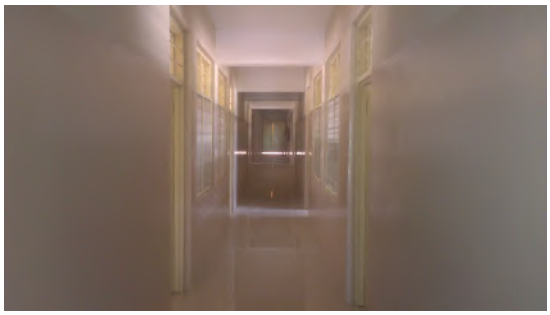
TABLES AND FIGURES

Fig 1 Connection to non-renewable energy source

Fig 2 – Absence of rainwater harvest system

Fig 3-Depletion of natural vegetation without replacement

(a)



(b)

Fig. 4 – Indoor air quality and natural lighting