USE OF SUSTAINABLE MATERIALS IN CONSTRUCTION INDUSTRY CONTRACTOR'S PERSPECTIVE

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ABSTRACT

Buildings are the largest energy consumers and greenhouse gas emitters, both in the developed and developing countries. Therefore, it is a dire need in the present status quo to shift to sustainable buildings. Sustainable buildings can be identified as a spectrum of buildings, designed and constructed using methods and materials that are resource efficient and that will not compromise the health of the environment, wellbeing of the building occupants, construction workers, general public or up and coming future generations. In the process of construction of sustainable buildings, while striking a balance between the triple bottom line, environmental, social and economic sustainability, construction material is given a higher priority. Therefore, this research reflexes the use of sustainable building materials in the construction industry.

In the research process, initially a comprehensive literature synthesis was carried out to get an insight on the concept of sustainability and sustainability construction. This was then followed by a questionnaire survey among the M1 and M2 contractors of Sri Lanka. Through the study it was evident that there is perfect knowledge available on the concept of sustainability even though only 48% of the contractors have used sustainable materials in construction. It is necessary to comment that sustainability has now become mandatory in order to tackle many environmental problems. Thus, the usage of sustainable materials in construction is at the verge of being a mandatory requirement in construction. Therefore, this research provides a firm basis to use sustainable materials in construction industry in the perspective of construction contractors.

Keywords: *Construction Industry, Contractor, Sustainability; Sustainable Material.*

1. INTRODUCTION

Global warming and many other environmental issues are considered the most stressing issues that are currently being faced by humanity. There are controversial arguments being made among professionals of different spheres in order to develop strategies to face these issues which put the entire human race in to lurch. One of the major solutions for these issues is to introduce a major change in the current lifestyle in order to preserve the planet (Toufic, 2011). However, with the rapid changes to lifestyle of people meeting the two ends of catering the human needs while preserving the planet has become an impassable gulf. Hence in the present status quo, in order to balance these two extremes the concept of "Sustainability" has come in to light and it considered to be the buzz word of the decade.

Earlier in 1987, Bruntland, illustrated on sustainability as meeting the needs of today without compromising the ability of future generations to meet their own needs. According to Singhaputtangkul *et al*. (2005), the core of mainstream sustainability thinking, is to strike a balance between three dimensions namely, environmental, social and economic sustainability. Simplistically it can be argued that sustainability will be achieved when all consumers can make choices to conserve, to minimize damage and to maximize benefits. The term sustainability has been adopted as a panacea for change and development (Hayles, 2004). Hence, in a nutshell it can be depicted that sustainable

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buildings have a minimal negative impact on the built and natural environment. Further, these buildings should meet a number of certain objectives: resource and energy efficiency, CO_2 and Green House Gas (GHG) emissions reduction, pollution prevention, mitigation of noise, improved indoor air quality and harmony with the environment (John *et al*., 2005).

As far as a building is concerned, the material used in construction has a greater impact on the sustainability. This is due to the fact that all materials are ultimately derived from the bio-Geo-sphere. The choice of materials for construction controls whole life cycle impacts such as environmentally unhealthy emissions, increase in non degradable wastes and many other adverse impacts. Moreover, materials strongly influence on lifetime energies, user comfort and durability (Harrison, 2006). Hence it is a need of the society to further study on the inputs of materials in sustainable construction.

2. LITERATURE REVIEW

2.1 SUSTAINABLE CONSTRUCTION

The need to enforce sustainable construction is important as what is built today will provide the built environment of the future and will influence the ability of future generations to meet the needs (Dickie and Howard, 2000). Sustainable construction, a subset of sustainable development, advocates the use of technology and knowledge to improve the sustainability of designing, constructing, and operating infrastructures (Chong *et al*., 2009). According to Ospina *et al*. (2010), sustainable construction is the process of planning, designing, constructing, maintaining, and operating building projects, with the goal of minimizing overall environmental impacts and maximizing the benefits to the final users and to the surrounding community. As per Ospina *et al*. (2010) in order to develop a sustainable project, it is necessary to rethink design, construction and operational aspects of energy, water and resource use, indoor air quality, recycling programs, alternative transportation access, landscaping strategies, construction waste management, construction site planning and management, wastewater management and maintenance among others. Hence it is necessary to derive the fact that sustainable construction is not merely a product, it is a process in the very outset. Moreover, from the very beginning, which is from the design stage onwards "sustainable construction" approaches must be adopted and practiced. According to Tres (2000), in order to reach a sustainable design, it is necessary to design for material substitution with higher environmental impact to most superior materials in terms of sustainability.

2.2 BUILDING MATERIALS USED IN CONSTRUCTION

As explained by Venkatarama-Reddy and Jagadish (2003), building materials, technologies, and building practices have evolved through the ages. Housing and building conditions reflect the living standards of a society. As an example, it is necessary to state that stones, mud, thatch/leaves and timber represent the earliest building materials used for the construction of dwellings. Therefore, hardly any energy is consumed in manufacturing and using of these natural materials for construction in the early days. However, in present these have been drastically changed due to the enhancements of the living standards of the people.

The discovery of natural inorganic binders like pozzolanic materials leads to the use of lime-pozzolana (LP) cement for construction purposes. Experience of using LP cement, paved the way for the invention of Portland cement in 1824 (Venkatarama-Reddy and Jagadish, 2003). Portland cement and steel brought revolutionary changes in the construction practices from the early part of the 20th century. Then plastics and plastic products entered the construction industry. Bricks, cement, steel, aluminium, plastic products, paints, polished stone and ceramic products are the commonly used materials of construction today. However, these materials are energy intensive and the necessity to transport over large distance before being used further add up more energy utilisation (Venkatarama-Reddy and Jagadish, 2003).Hence, with the evolution through the years on construction and building practices have introduced greater problems at present.

Therefore, it is necessary to note that it is a dire need to address these aspects of sustainable materials utilization in the construction industry. To address the goals of sustainable development the production of materials must use resources and energy from renewable sources instead of non-renewable ones. However, Sustainable Building Materials (SBM) should pose no or very minimal environmental and human health risks (Calkins, 2009). According to Joseph and Tretsiakova, (2010), these should also satisfy the following criteria: rational use of natural resources; energy efficiency; elimination or reduction of generating waste; low toxicity; water conservation; affordability. On the other hand, SBM can offer a set of specific benefits to the owner of a building such as reduced maintenance and replacement costs, energy conservation, improved occupant's health and productivity, lower costs associated with changing space configurations, and greater flexibility in design (Joseph and Tretsiakova, 2010).

According to Abeysundara *et al.* (2009) the major environmental burden evolved in Building Materials (BM) relate to the embodied energy of BM and Green House Gass (GHG) emissions originated from each stage of the life cycle. Embodied energy is defined as the amount of energy required to produce a material and supply it to the point of use. It is an important measure of the effectiveness of BM in the environmental terms (Abeysundara *et al.*, 2009). Embodied energy consists of: energy required for the manufacturing of BM; energy associated with the transportation of raw materials to the factory and of the finished products to the consumer; the energy needed for assembling various BM to form a building (Venkatarama- Reddy and Jagadish, 2003). The results presented by Thormark (2006) indicated that the embodied energy in traditional building can be reduced by approximately 10–15% through proper selection of Sustainable Building Material (SBM) with low environmental impacts. Although the values of embodied energy can vary widely, these can be considered as reasonable indicators of an overall environmental impact of BM (Joseph and Tretsiakova, 2010). Hence in order to promote sustainable construction it is necessary to select the most suited SBM based on those aspects.

2.3 SELECTION OF SUSTAINABLE BUILDING MATERIAL

In order for the decision makers to select materials suitable for sustainable construction, the assessment of the relevant environmental burdens is necessary (Joseph and Tretsiakova, 2010). Further, the appropriate materials for sustainable sites will vary by impact priorities, regional issues, project budgets and performance requirements. In addition to varying priorities and goals in the green material selection, there are shades of green. For instance, the ideal green material might be a natural, renewable, local and indigenous, nontoxic, low embodied energy material such as willow cuttings for slope stabilization or rammed earth for a retaining wall (Calkins, 2009). However, there may be certain materials which does not totally contribute as a SBM, but may be considered as a shade of green whereas partly contributing to sustainability.

According to Onyegiri *et al* (2011), each building material has its own advantages and disadvantages. Some of the problems with existing materials are their poor use of environmental resources, poor quality control of the finished product and consequently a significant variation in durability. Hence, based on those facts it is necessary to identify that in order to select SBM, the features related to these materials must be given a consideration. Hence, as stated by Kim (1998) these selection criteria can be surmised as follows which are identified as some of the features of SBM

- Pollution Prevention Measures in Manufacturing
- Waste Reduction Measures in Manufacturing
- Recycled Content
- Embodied Energy Reduction
- Use of Natural Materials
- Reduction of Construction Waste
- Local Materials
- Energy Efficiency

- Water Treatment and Conservation
- Use of Nontoxic or Less-Toxic Materials
- Renewable Energy Systems
- Longer Life
- Reusability
- Recyclability
- Biodegradability

In addition, one of the most important features of a sustainable building is the material efficiency. Correct selection of BM can be performed by taking into account their complete lifetime (from cradle to grave) and by choosing products with the minimal environmental impacts (Joseph and Tretsiakova, 2010). The use of renewable and recycled sources is widely encouraged as the life cycle of a building and its elements can be closely related (Chwieduk, 2003). The other factors that greatly affect the selection of BM are the costs and social requirements such as thermal comfort, good mechanical properties (strength and durability), aesthetic characteristics and the ability to construct quickly. Ideally, the combination of all environmental, economic and social factors can give a clear description of a material and thus, helps in a decision making process regarding the selection of the materials suitable for buildings (Abeysundara *et al.*, 2009).

Taking all these aspects into a nutshell Subramanian (2007) identified the following rules which can be used. As per Subramanian (2007) selected materials:

- should consume less energy to manufacture
- should not involve long distance transportation (for the raw materials as well as a finished product)
- should not affect the environment
- should be easy to recycle and safe to dispose into landfills
- should be harmless in production and use
- dissipated during recycling must be harmless
- should have long life and durability
- should be easy to disassemble.

Indeed, sustainable buildings generally incur a green premium above the costs of standard construction, and however these also provide an array of financial and environmental benefits that conventional buildings do not (Kats, 2003). These benefits, such as energy savings, should be looked at through a life cycle cost methodology, not just evaluated in terms of upfront or initial costs. Hence it is necessary to that selection of materials for construction is the most effective way in which sustainability can be promoted.

3. RESEARCH METHODOLOGY

The research problem statement of this study was developed as; “Use of sustainable materials in the construction industry: contractor' perspective”. Therefore in order to collect the opinions and issues from contractors and their perception about the usability of sustainable building construction materials in local industry, a quantitative research approach has been used in this research study. Hence a questionnaire survey was carried out in order to rank the priorities of contractor's perception.Initially, the questionnaire focused on contractor's approach on material selection in building constructions. This was then followed by a series of questions attempting to identify the contractor's opinion of using sustainable materials. Finally, the questionnaire survey focused to identify and reveal the key issues and barriers faced by the contractors while handling sustainable building materials.

In the questionnaire which was distributed among Grade M1 contractors requested to respondents to indicate the relative importance ratings for the listed building materials, factors, characteristics and problems regarding sustainable building constructions. A five-point Likert scale (i.e.5 = very high

contribution and 1 = very low contribution) and a three point Likert scale (i.e.3 = very high contribution and 1 = very low contribution) were used.

The data analysis was done by using the Relative Important Index (RII) formula. Many researches (El-Sayegh, 2008; Jeyamathan and Rameezdeen 2006) have identified RII as a data analysis technique in order to rank the factors and identify the most significant factors. To determine the relative ranking of the factors, the results obtained from questionnaire survey were transformed to importance indices based on the following formula (Kometa *et al.*, 1994 as cited in Gunawardana *et al.*, 2004).

$$RII = \frac{\Sigma (W\,n)}{A \times N} \times 100\ \%$$

Where;

W = Constant expressing the weighting given to each response
A = The highest weighting.
n = The frequency of responses.
N = Total Number in the Responses.

Thus, the relative index shall change from 0% to 100%.For this research thirty (30) questionnaires were distributed among thirty Grade M1 contractors, who are involved with building construction projects, and only 25 questionnaires were answered leading to a response rate of 83.33 percent.

4. DATA ANALYSIS AND FINDINGS

4.1. CONTRACTOR'S AWARENESS ON THE CONCEPT OF SUSTAINABILITY

Through the questionnaire survey the contractors were questioned on the awareness on concept of sustainability. It is interesting to note that all the respondents were aware of the concept very well. This simply shows that sustainable concept is not a "total alien" concept to the industry and especially among the contactors. However, although it is familiar within the industry it is required to further investigate to which extent this concept is put in to practice in the present status quo.

Hence as a result, most of the contractors were into an in depth study of this concept. According to certain individual opinion, still it was not successful and popular in Sri Lankan industry. Moreover, it was revealed that as an active stakeholder in the construction industry, the respondents expect to work with modern technologies and change the existing traditional situation as soon as practicable.

4.2 SUSTAINABLE CONSTRUCTION IN PRACTICE: SELECTION OF MATERIAL

Although there were 100% of awareness among the contractors on sustainable construction practices within the industry, out of them 36% were involved in practicing sustainable materials for building construction work.

This figure of 36% could provide a better picture of the prevailing situation of the industry and its actual perception towards sustainable construction. Further, 64% of the respondents identified sustainable construction as impracticable in the general scenario. However, in certain cases respondents agreed with some aspects of sustainability and further it was mentioned that although the concept is not directly put into practice certain aspects were put in to practice within the industry.

4.3. UTILIZATION OF SBM IN PRACTICE

In practice, based on the derived results, only 48% of the respondents stated that SBM are consciously used in the construction. Sri Lanka being one of the developing countries, according to the

contractor's perception it was mentioned that enough enforcement is not stipulated for the effective utilization of sustainable materials.

With this set of findings it is necessary to derive that, there is a serious conflict between the awareness of the sustainability concept and the practical adoption of it within the construction. However, further in the questionnaire the respondents were asked to rank the materials as per the usage in the construction industry and further to rank the sustainable materials aspect. Since the awareness of the sustainability concept is higher most of the contactors identified materials such as Clay tiles, Straw, Plywood and Metal as the top five sustainable materials used in construction. Materials ranked as per the sustainability as well as the current usage in the industry are given in Table 1.

Table 1: Sustainable Materials

Material	RII As per the sustainability	Rank as per the sustainability	RII As per the usage	Rank as per the usage
Clay tiles	0.608	1	0.232	13
Straw	0.528	2	0.200	15
Ply wood	0.488	3	0.272	11
Metal	0.472	4	0.472	4
Bricks	0.448	5	0.448	6
Sand	0.392	6	0.736	2
Timber	0.368	7	0.360	9
Carpet	0.336	8	0.200	15
Glass	0.288	9	0.432	7
Rubble	0.264	10	0.296	10
Cement	0.256	11	0.816	1
Blocks	0.248	12	0.472	4
Aggregates	0.240	13	0.384	8
Reinforcement	0.240	13	0.592	3
Asbestos	0.240	13	0.256	12
Plastics	0.200	16	0.200	15

Through Table 1, it is possible to depict a clear picture on the contribution of certain materials towards the sustainability concept. As per Table 1, if materials such as Clay tiles, Plywood and straw were considered, these were identified as the material with the least usage. However, those materials were also identified as the materials which mostly contribute to the sustainability in construction. Further, contradictorily, materials such as cement, blocks, aggregates and reinforcement are heavily used in construction industry although it is identified as the least sustainable materials. Hence, in either way it is necessary to draw the attention that, in most of the circumstances, mostly used materials in

construction does not contribute to sustainability in construction. As a result, a higher consideration must be given to selection of sustainable materials in building construction in order to deploy more sustainable material. For that purpose, it is necessary to identify the factors which affect the selection of SBM in construction.

4.4. FACTORS AFFECTING THE SELECTION OF SBM

As per Section 4.2 it was identified that irrespective of the awareness of sustainability in construction only a very few, which amounting to 37% identified this as a practical solution. Hence it is worth to exploring the reasons behind this conclusion or else identifying the obstacles in selecting SBM in construction. Based on the feedback of the respondents certain factors were identified as the governing factors which directly affect the selection of SBM. Further, these factors were graphically illustrated in Figure 2.

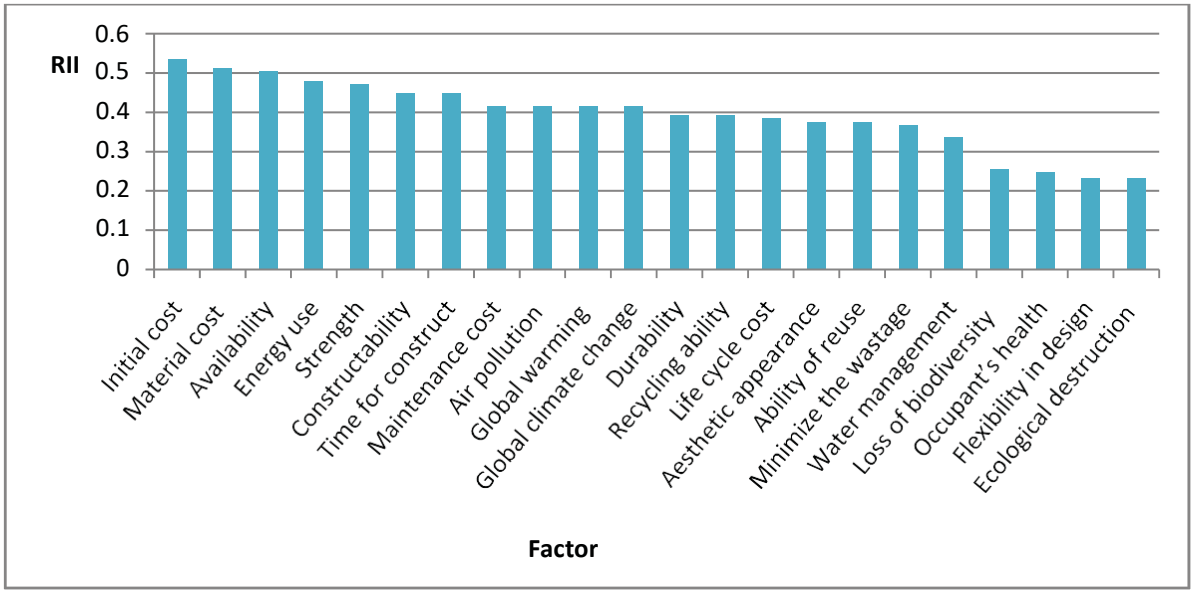

Figure 2: Factors Affecting the Selection of SBM in Construction

Figure 2, illustrated that Initial cost and the material cost have played a major impact on selection on SBM. Further, it was revealed that if the costs relating to SBM are high, that would be the governing reason of lack of usage of SBM in construction. However, factors which depict the essence of sustainability such as Air pollution and Global warming is at the medium range of factors which affect the selection of SBM. Further certain factors such as water management and bio-diversity has a very lower impact in the process of SBM. Hence it is necessary to argue that contractors use SBM within the industry not merely for the sake of sustainability in construction and however, there is a subtle intention of sustainability is available. Moreover, it is necessary to note that there is no major factors affecting the selection and only slight variations of importance in affecting the selection is available.

Further in literature there were certain features were identified many researches (Subramaniam, 2007; Kim, 1998) as feature which should be embodied in SBM. However, as per these results of Figure 1, it is necessary to conclude that due to the cost impact shades of green may be more practicable and accepted within the industry (See Section 4.2).

4.5. PROBLEMS ENCOUNTERED WHEN USING SBM

In the construction industry, the usage of sustainable concept in practice is considerably low (See Section 4.2). However, there may be issues which govern this drawback. Hence the respondents were asked to identify the problems encountered while using SBM and rank them as per the criticality as shown in Table 3.

Table 3: Problems Encountered when using SBM

Problems	RII	Rank
Prices of materials	0.536	1
Initial cost	0.512	2
Suitability for modern world	0.488	3
Effects to the environment	0.480	4
Available alternatives	0.400	5
Strength	0.376	6
Durability	0.376	6
Aesthetic appearance	0.352	8
Prices of alternatives	0.312	9
Thermal comfort	0.280	10
Ability to construct quickly	0.272	11
Necessity of skilled person	0.272	11
Sub contractor's knowledge	0.264	13
Appropriate technology	0.264	13
Appropriate machinery	0.256	15
Weather changes	0.256	15

In conjunction with the results depicted in Table 2, it is inevitable to conclude that higher prices of materials and the higher initial cost are the governing factors which prevent the usage of SBM in physical construction. Further, Table 2 clearly shows that cost or the financial consideration was given a higher impact in selecting SBM. Further this fact was proven that due to the higher cost of SBM were rarely practiced in the construction industry. The availability of the skilled personnel, lack of appropriate technology and machinery were given the least ranking. This clearly illustrates the fact that the industry is at the moment in possession of requires awareness and knowledge. However, certain other factors are refraining the usage and adoption of SBM into the practice.

5. CONCLUSIONS

Nowadays, principles of sustainability have become mandatory in order to tackle global warming and the associated climate change. Governments of several countries have adequate policies in place with a view to control and improve the current state of the construction industry. The major actions include minimization of energy consumption in the buildings, rational use of natural resources and strict control of the emissions. All these measures should systematically apply during the selection of materials which suitable for sustainable buildings and construction activities.

In the arena of sustainability, the contractors' approach on material selection plays a major role. This research attempted to discuss the contractors' opinion on use of sustainable materials, key issues and barriers faced by the contractors. The results of the survey were evident that in the construction industry, the awareness of the concept of sustainability is at its acme. However, the practical usage of this concept is quite questionable. According to the results derived by the survey, irrespective of the awareness, 64% argued on the fact that practicality of sustainable of construction is questionable butsome believes that certain aspects of this can be put into practice.

In the perspective of utilization of SBM, Clay tiles were identified as one of the highly preferred sustainable building material utilized by contractors. In the selection of these materials, financial aspects were given the highest priority. However, it was found that the cost of the material and the initial cost are mostly considered while selecting materials. Moreover, it was necessary to illustrate that both these costs were considerably high in SBM. In addition, it was identified that the required knowledge and skills were at the required level for the construction to be sustainable. However, usage of SBM is lagging behind mainly due to the financial issues stated by contractors.

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