Material Development in the Building Ecosystem

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Abstract: This paper presents the Building Ecosystem as a peculiar physical environment existing in the Building Industry with the various participating units of the industry as they interact for its effective performance. It further highlights the phases involved in material development process and the requisite steps for acceptance and utilisation by the various interacting units of the Industry. It was observed that major efforts at materials research and developments in Nigeria has been on utilisation of waste materials and ashes in concrete, mortar and masonry units as partial replacement to Portland cement or as stabilising agents for lateritic materials and soils with very low acceptance level in their utilisation. It concludes that material development in the Building Ecosystem requires a business-like approach with good collaboration amongst the various institutions and participating units of the Industry.

Keywords: Building Ecosystem, participating units, materials development, recycling, product acceptance.

1 Introduction

An Ecosystem is simply defined as a community or group of living organisms that live and interact with each other in a specific environment. It further refers to the basic unit of the field of scientific study of nature. It is a physically defined environment made up of two inseparable components: the biotope (abiotic) and the biocenosis (biotic). The abiotic refers to particular physical environment with specific physical characteristics such as climate, temperature, humidity, concentration of nutrients or pH-value. The biotic on the other hand implies the set of living organisms, which are in constant interaction and are therefore, in a situation of interdependence. The Building Ecosystem can thus be discussed as the physical environment in the Building Industry and the various participants that interacts and are interdependent for an effective performance of the Industry. The focus of this article is to discuss the phases involved in materials development in the Building industry and the requisite steps for ensuring effective product acceptance and utilisation by the various institutions and participating units of the industry.

Research and development effort on materials in the Nigerian Building Industry has been focussed on waste recycling (Hossain 2003 & 2005; Hassan, 2006; Olawuyi, 2011), utilisation of agricultural and industrial ashes in concrete, mortar and masonry units as partial/full replacement of Portland cement (Okpala, 1987; Chaowat, 2001; Abalaka & Okoli, 2013, Raheem, 2010, Elinwa & Mahmood, 2002), or as stabilising agent for lateritic materials and soils (Jimoh et al, 2013) with very low acceptance level in their utilisation. The issue of concern therefore is to x-ray what could be responsible for the low patronage of the products of the research and developments efforts and how to address this issue and enhance good acceptability and utilisation of the products from our research development efforts for an effective Building Ecosystem in Nigeria.

2 Components of the Building Ecosystem

The two basic components (biotope and biocenosis) of the Building Ecosystem can be discussed as presented in Figure 1 below.

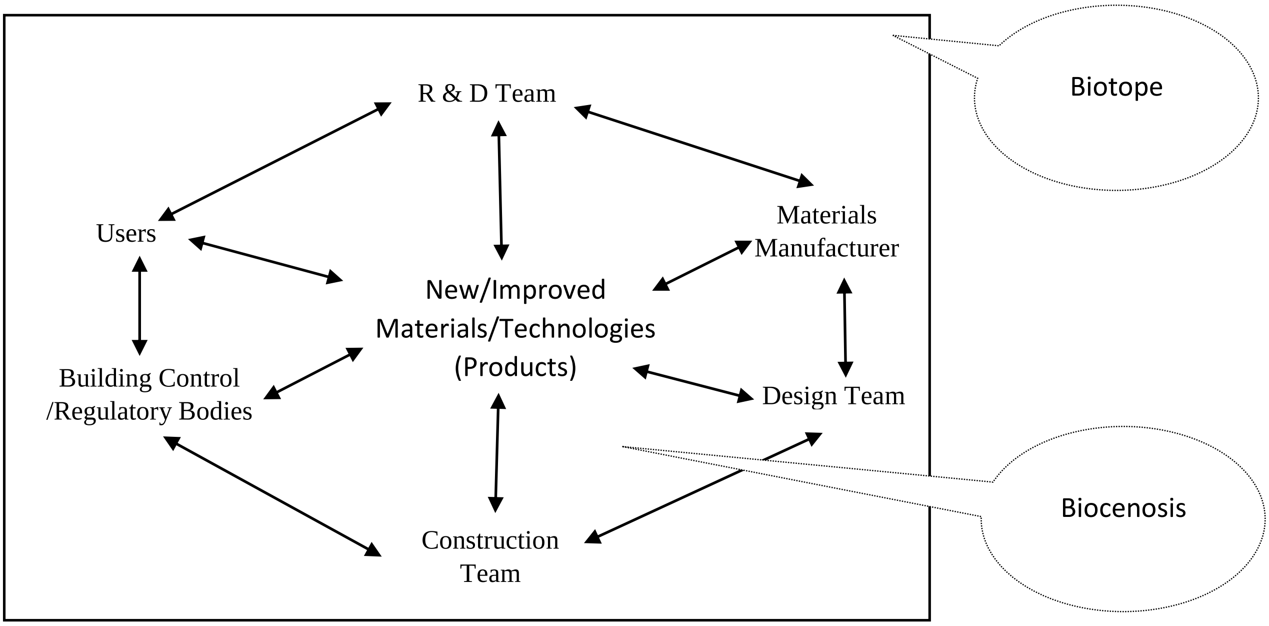

Figure 1: The Building Ecosystem and Materials Development

The biotope (i.e. abiotic) of the Building Ecosystem entails the physical environment, the climate of the particular region, natural materials, agricultural and industrial by-products locally available, manpower, time and available finance for adaptation and conversion towards provision of sustainable building for the users satisfaction.

The biocenosis (biotic) on the other hand are the interacting units/organs or institutions and their effects on the industry performance. Figure 1 above shows these units as the Research and Development (R&D) Team, Material manufacturers, the design team, construction team, building control and regulatory bodies and users. The central focus of the interaction is the final product which involves incorporating the new/improved materials and technologies towards the users comfort and satisfaction. The multi-faceted approach and specific view of the interacting units makes materials development a complex task and requires multidisciplinary approach involving knowledge from different areas such as materials science, marketing development, performance evaluation and environmental sciences.

The R&D team entails our research institutions (i.e. the educational and research institutes) and the R&D departments of the Industry. The current scenario in Nigeria had been that of individual efforts on materials research by the institutions on one hand and the R&D departments of the industry focusing solely on products improvement and sales enhancement. The outputs of the research institutions thereby ends up on the shelves after the certificate sought has been awarded while no collaborative efforts is seen between the Instructions and Industry R&D teams. Approach to material development ought to be that of need identification emanating from the field (i.e. the Industry) to which research efforts (both at the Institutions and the Industry) will be targeted at addressing.

The materials manufacturers aside having R&D team should be interested in the thoughts and ideas emanating from research institutions while inputs should go from the manufacturers on areas of needs concerning product improvement. Research funding targeted at results delivery should flow from the manufacturers to the Institutions (especially for Post-graduate research works), while performance evaluation of the new products or concepts will then be the focus of the R&D team of the materials manufacturers.

The design team (Architects, Engineers (Structural and Services), Quantity Surveyor and the Consultant Builders) requires detailed information from the manufacturers on the new/improved product for its adoption in design and specifications. This goes beyond product marketing but involves display of prototypes, performance details and competitive advantages over conventional materials to reduce resistance to its adoption. The Building control and regulatory bodies has to be directly involved in performance evaluation vis-à-vis its effect on the environment and the users, before its adoption for good level of acceptance for utilisation. The set standards and performance requirements remain the specific purview of the Building Control and Regulatory Bodies. No nation can witness serious development without functional and established materials within and adaptable to her own environment.

Users in the concept entails the Entrepreneur investing in development of new material or the property developer and the end users of the finished products. Users' satisfaction is the core of any product development and the easiest means of advancing the utilisation and acceptance of new products. Feedback from users on every product is an important aspect of material development. An example is the wide acceptance of burnt bricks as masonry units in Makurdi, Benue State (Olawuyi *et al*., 2011). Public buildings (e.g. J.S. Tarka Foundation Building) was noted to have been built with burnt bricks, hence the confidence and high patronage of the materials as masonry units by private organisations and individuals.

3 Materials Development Phases

Materials development in general involves many phases which can be outlined as:

i. Need identification and material availability data
ii. Material Characterisation
iii. Selection of possible application
iv. Development of new products
v. Product evaluation
vi. Technology transference

3.1 Needs identification and materials availability

The first phase is the need identification and material availability data. This involves an examination of the conventional materials and the areas required for improvement or modification. An example is the contribution of Portland cement (PC) manufacturing process noted to contribute above 5% of global CO_2 emission resulting from clinker production and the fossil fuel used for pyro-processing (Rubenstein, 2012) that has led to increase search for alternative binder or partial replacement of PC in concrete and mortar production. The R&D team needs to gather data on the alternative materials and amount of waste produced at the industrial, regional, national or even world-wide levels. This will outline both the market possibilities of the new product and the necessary structure for its production. The frequency of availability especially in the case of agro-waste materials and the effects of processing approach on its characteristics needs to be studied for an establishment of variation in materials properties and possible composition. Need might arise for stockpiles or special arrangement made with the agribusiness organisation to maintain steady supply and uninterrupted production.

Also of importance is the geographical localisation of the waste materials and concern for transportation which might affect the environmental balance of the new product. Legal status, its destination, all associated costs and revenues are of relevant consideration when it comes to waste recycling for materials development. Regulatory aspect of waste disposal and transportation are also issues that can limit waste conversion or recycling for materials development.

3.2 Material Characterisation

Material characterisation is a very vital part of development of new products and has to be as complete as possible. This aspect will be well guided by the data collected at the need identification and materials availability phase. It includes

a. Physical characteristics such as density, particle size distribution, specific surface area and viscosity.
b. Complete chemical composition including environmentally relevant trace species, volatile content and humidity.
c. The microstructure, mineralogical composition (i.e. glass content), porosity, morphology and the different phases
d. Environmental characterisation (i.e. toxicity, ignitability, corrosive tendencies, reactivity as well as its pathogenic potentials).

Microstructural characterisation is very important as it reveals existence of unstable mineralogical phases while attention should be given to materials variability which could be affected by change of source of raw materials too. Material characterisation phase is very vital as only a good knowledge about the raw material and its variability allow for selecting the appropriate technology for best technical and environmental results.

3.3 Choice of possible applications

The objective here is to select the most viable potential use for a locally available material or by-product. The best application is that which will use its true characteristics and properties for an enhanced performance of the new product and minimise environmental and health risks. The choice of application should not be a pre-conceived basis but requires creativity and both scientific and technical knowledge which entails the collaborative work of a multidisciplinary team. The importance of being innovative in recycling technology is stressed by the Business Council for Sustainable Development-Gulf of Mexico (BSCD-GM, 1997). The simple rules for choice of possible applications for waste recycling as outlined in the works of John & Zordan (2000) are:

a. minimise the need for industrial transformation of the waste;
b. minimise the transportation impact of the waste to the industrial plant and the produced material to its consumers;
c. for those containing dangerous chemical compounds, recycling must minimise the leaching or volatilisation of these this dangerous phase. This implies avoiding contact of the new product with the users or any deterioration agent, such as running water;
d. the new product must be recyclable;
e. the new product must present a competitive advantage in comparison to those competitors already established on the market and improve the waste value.

John & Zordan (2000) further stated that different group of characteristics is advantageous and possibly essential for specific applications. For instance, a predominantly organic material can be recycled as fuel on different burning processes, including as an alternative source of energy on cement kiln. A granular waste can be applied as aggregate to concrete production if it is dimensionally stable, does not present any harmful reaction with hydrated cement phase constituents, is water insoluble and has compatible mechanical strength. In order to be suitable for recycling as binder material, a waste must:

a. be soluble in water or in strongly based pH water;
b. have Ca, Si, A1, S elements as major components;
c. be presented in a granular form, preferentially with a high specific surface area;
d. for those requiring on Si is an important constituent, like most ashes or melted products, a high glass content is desirable.

3.4 Development of New Product

Concurrent engineering place emphasis on product development being simultaneous, taking into account production technology, product performance, maintenance, reliability, market competitive issues and environmental impact, all in a cradle-to-grave approach (Swink, 1998).

Material development has to be done on a scientific basis with the behaviour and characteristics of the new product explained in terms of its microstructure and chemical reactions in a bid to avoid uncertainty. Issues of important concern includes product durability has it affects both environmental and economic performance. The chemical and physical changes that results from the degradation process can also have effect on environmental behaviour like leaching performance. The focus of material development should be the user and the environment. For building products, the ISO/CIB performance methodology is very useful for evaluating end use customer satisfaction from a technical point of view. It is based on typical user requirements lists, that is generic and, of course, non-exhaustive (Table 1).

Table 1: CIB/ISO users' needs

Structural stability
Fire safety
Safety in use
Water tightness
Air purity
Hygiene
Durability
Acoustical comfort
Tactile comfort
Anthropodynamic comfort
Hygrothermal comfort
Visual comfort
Suitability for use
Economy

Source: CIB, 1983

3.5 Product Evaluation

Product evaluation takes two forms (i.e. performance and environmental). Complete performance evaluation is required for a newly developed product once the production process is finished. This is to demonstrate its fitness for purpose and the comparative advantage over main market competitors. Performance in terms of structural stability (i.e. compressive, flexural and splitting tensile strengths) are often easily conducted in the laboratory in comparison with the conventional materials and in accordance to established standards. Evaluating the durability of the new product seems the most complex task in this phase as it might require long term testing procedures. Need for further improvement on the product can also be highlighted by the performance evaluation while an application for a performance evaluation based technical approval issued by an independent body can increase market acceptance of the new product (Hewlett, 1996). This is an area where the Building Control/Regulatory Bodies might come in.

Environmental evaluation is another important part of product evaluation. This helps in evaluating the global environmental impact and involves making a comparison with the traditional market solutions on the same basis. Issues of concern here are environmental contamination risks such as leaching of hazardous components which is mandatory (Kosson & Van Der Sloot, 1997) but not sufficient. Also of importance are other environmental impacts like greenhouse gas emission, acidification, human toxicity, energy use and the effect of degradation on leaching. The environmental evaluation is thus recommended to be carried out using life cycle analysis as summarised by Azapagic (1999) and Schuurmans- Stehmann (1994).

3.6 Technological Transference

Development of a new materials often requires appropriate technology for its application and the need to put them in the market. This makes technological transference an essential part of the material development process in the Building Ecosystem. Many technically excellent new materials and recycling technologies exists which have not succeeded on the market. Clarke (1994) states that even in developed countries like US and Europe which are advanced in recycling technology, fly ash and blast furnace slag are yet to be entirely recycled, despite the fact that they have been on the market for 50 and almost 100 years respectively. Probably no other wastes have received as much scientific attention or had its technical and environmental advantages so well demonstrated. Technological and environmental excellence of a new material notwithstanding, the viability of its industrial production need to be established from different aspects.

The concept of by-product synergy proposed by the EPA and The Business Council for Sustainable Development - Gulf of Mexico (BCSD-GM, 1997) suggests that marketing successful recycling can be more readily achieved by collaboration, motivation, communication, innovation, participation, and evaluation.

The collaboration has to involve the various participating units of the Building Ecosystem as outlined in Figure 1. An important aspect is the commitment of the waste producer to the recycling process, starting with the research and development phase. Skinner (1994), stated that the waste manager has to operate in a business-like manner as a raw material supplier to inspire confidence for an entrepreneur to be interested in new material production. This implies that the R&D projects must be collaborative. A case of study is the Brazilian steel industry which has developed joint research projects with universities and other business companies to improve the recycling of blast furnace slag. Some waste companies even turn their waste product business into a new company, most of the time in a partnership with another company. British East Coast Slag Products is a joint venture of British Steel and Tarmac, a building related conglomerate (John & Zordan, 2000).

4 Conclusion

Materials development in the Building Ecosystem is a very important concept for achieving sustainable development. Research and development of a new building material or component with emphasis on the use of agricultural and industrial waste as raw material, is a very complex and multidisciplinary task, involving technical, environmental, financial, marketing, legal and social aspects. It has to be handled in a business-like manner based on collaboration between the various participating units/organs of the Building Ecosystem. The R&D teams both at the Institutions and Industry has to work together interacting well for new materials of excellent technical and environmental performance with proper attention given to acceptability by the design and construction teams with users' satisfaction uppermost in mind.

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