Managing Building Waste for Sustainable Urban Development: Challenges, Opportunities and Future Outlook

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ABSTRACT: Expansion in construction activities due to population growth and fast urban developments has resulted in increasing quantities of building waste. Rising quantities of such waste materials has adversely affected cost of landfills, construction cost, and environment quality. Disposal of waste in landfills has been challenging due to stringent environment protective regulations and high cost of land. Management of building waste needs multi-disciplinary expertise in planning, engineering and material management. This paper presents an overview of current building waste management and then highlights challenges, opportunities and future outlook for sustainable urban development based on a comprehensive review of research studies undertaken worldwide. Resource needs posed by construction industry ought to be supported by recycled alternative building materials and re-use for effective waste management and sustainable urban development. This approach is demonstrated to be sustainable due to broader embodied energy, environmental, economic and societal benefits.

INTRODUCTION

Increase in population, improvements in living standards, and infrastructure developments have resulted in the generation of building waste at an alarming rate. Building waste (BW) consists of all types of construction and demolition wastes generated from construction, renovation and demolition activities. Consumption of large quantities of natural resources to meet the fast growing demands in building construction and generation of abundant waste due to construction and demolition activities exerts unavoidable pressure over the natural environment (Zaharieva et al., 2003). In the United States, an average citizen produces six tons of solid waste per year, and disposal of these wastes in landfills has become prohibitive and challenging due to the environment protective regulations (Sharma and Reddy, 2004). Building
waste has been identified as a major problem in construction projects that has important implications both for the industrial efficiency and for the environmental impacts. In most countries building waste problem of is of increasing magnitude, but due to illegal dumping there is a lack in reliable statistics (Torgal and Jalali, 2011). Minimizing the waste and efficient building waste management can be regarded as an effective way to assess the project performance towards a more sustainable path of development (Formosa et al., 2002). Illegal deposit of waste has increasing pressure on construction costs and environment quality. MOEW (2012) has identified water and waste management as two priorities in environment protection. Sustainable development aims at improving the standard of life without compromising the environmental qualities. These interconnected objectives can be achieved through rational management of resource and building waste. The concept of sustainability has been defined as meeting the demands of present without compromising the future needs. The growing significance of sustainability concept throughout the world has resulted in attitude change in consumption of natural resources for infrastructure development projects (Yeheyis et al., 2013). The fast growing concept of 3R’s in waste management, namely Reduce, Reuse and Recycle, is important for conservation of 3E’s, namely Energy, Economy and Environment. Improving the quality of environment and cost reduction are the challenges faced by professionals involved in building industry (Kartam et al., 2004).

Waste in construction industry is attributed to managerial problems and design inadequacies such as lack of modular co-ordination, poor integration of building systems, and lack of optimization in use of resources, and poor detailing and imprecise specification of components. Improper site layout planning, mistakes in procurement and lack of onsite delivery of materials and their distribution at workplaces contribute in growth of wastage. Improving management strategies of construction companies at design, procurement and construction stages can minimize waste. Waste control implementation involves various stages of project and construction for such as design of material supply, and must be integrated with project planning and control process (Lu, 2010) These universal guidelines will be of use for experts involved in building industry such as architects, engineers, project managers and contractors to achieve management guidelines of sustainable building waste management. Waste management and control should be fully integrated in the project planning and control process (Formosa et al., 2002). An international approach in building waste management could enable exchange of expertise and recycling equipment for implementation of advanced techniques in waste management over the world.

This paper presents an overview of building waste, types and quantities of building including the general construction and management principles, environmental policies and then describes the challenges and possibilities of building waste management to evolve strategies in tackling this emerging field of concern for future. The main objectives of this paper are to:

- Understand the state-of-the-art about the issues in building waste management and sustainable development world wide
- Identify challenges and possibilities in building waste management; and
- Evolve strategies and guidelines for efficient waste management for
SUSTAINABLE CONSTRUCTION PRINCIPLES AND ENVIRONMENTAL STANDARDS

The tremendous continuous urban infrastructure development worldwide, especially in developing countries necessitates sustainable construction approaches to minimize environmental and economic concerns, while leading to the social good. The term sustainable construction comprehensively addresses ecological, social and economic issues of a building in context of its community. International Council of Buildings (CIB) in 1994 defined sustainable construction as creating and operating a healthy built environment based on efficient use of resources and in project based on ecological principles. Some tools have also been developed to assess sustainability of buildings such as life cycle assessment (LCA) in general, Building Research and Consultancy’s Environment Assessment Method (BREEAM) in UK in 1990, Leadership in Energy and Environment Development (LEED) in USA in 1998, and the GB Tool in Canada in 1995 (Torgal and Jalali, 2011). Sustainable construction emphasizes on energy efficiency due to the high consumption of energy and associated perpetual costs (Torgal and Jalali, 2011). The world Business Council for Sustainable Development (WBCSD, 2000) introduced the term sustainable development with the concept of eco-efficiency in 1991 as “the development of products and services at competitive prices that meets the needs of human kind with quality of life, while progressively reducing their environmental impact and consumption of raw materials throughout life cycle, to a level compatible with the capacity of the planet”. This eco-efficient concept is implicit of sustainable construction and aims at producing more products with less resources and waste and present less environmental impact. The growing significance of sustainability concept throughout the world has resulted in attitude change in consumption of natural resources for infrastructure development projects (Yeheyis et al., 2013).

ENVIRONMENT PROTECTION LEGISLATION AND POLICY

Environmental laws and regulations promulgated to manage building wastes can lead to significant waste reduction as well as sustainable approaches to manage the wastes that are being generated (Torgal and Jalali, 2011). Long-term regional and municipal recycling strategies and programs could be evolved in building waste management by effective multi-disciplinary research and multi-agencies partnerships. The process of demolition and new construction should be treated within integral urban policies. Implementations of environment protection laws and regulations and waste management policies have proven to provide favorable opportunities for recycling of building waste (Zaharieva et al., 2003). The remarkable demand for the inert materials (such as gravel and sand) and the inability of extraction of natural resources due to environment protection laws has encouraged the re-use of construction and demolition waste provided by continuous urban redevelopment (Bianchini et al., 2004).

Environmental protection laws developed in different countries have been aimed at
protecting and safeguarding the environment. Environmental laws often emphasized the need for waste prevention as first priority followed by proper management of waste that is generated. The prevention principle often involved “polluter pays” concept so that the responsibility of waste management falls with the most responsible parties. For example, Zaharieva et al., (2003) reported Bulgaria’s National Strategy for Environment (NSE) which includes specific action plan for waste management with the main objectives as: (1) prevention and reduction of waste generation, (2) environmentally sound waste disposal method, and (3) re-use and recycling of waste materials. Solid waste management legislation has mandated 40% reduction of waste by year 2001 by reuse and recycling of materials. The increased regulations and fees imposed on landfill operations forced the contractors to maximize the benefits of recycling by effective separation of recyclable and non-recyclable materials (Sharma and Reddy, 2004).

Many international organizations are making efforts to formulate guidelines and best practices for sustainable construction with due consideration to waste prevention, minimization, recycling and re-use. Some of the agencies include:

- US Green Building Counsel (USGBC)
- Building Research Establishment (BRE)
- Counsel International Building (CIB)
- International Initiative for Sustainable Built Environment (IISBE)

Some of the guidelines developed include:

- Leadership in Energy and Environmental Design (LEED)
- CIB task group 8 for building assessment and task group 16 for sustainable construction 1992
- British Green Building Rating System
- Building Research Establishment and Environment Assessment Method (BREEAM)

**TYPES AND QUANTITIES OF BUILDING WASTE**

Building waste includes all waste materials produced in the process of construction, renovation and demolition of structures. Demolition debris and recycled concrete are generated due to construction demolition and maintenance of roads, bridges and buildings. Millions of tons of concrete wastes are generated every year which is about 75% of all construction material (Sharma and Reddy, 2004). Construction activities consume 32% of the world’s natural resources including 12% of water and 40% of energy. Building waste management in Canada accounts for 27% of total municipal solid waste disposed in landfills and 75% of the waste generated by the construction industry has residual value which could be recycled, salvaged and/or reused (Yeheyis et al., 2013). Missouri Department of Natural Resources (2008) classified the residuals during construction and demolition activities as clean fill, recovered materials, regulated construction and demolition wastes, and hazardous materials, which follow the order of decreasing utility.

In developing countries due to increase in waste quantity, scarcity of landfills and ever increasing building cost, management of building waste is a major objective (Kartam et al., 2004). Environmental and resource management issues faced by
developed and developing nations alike are becoming highly uncertain, urgent, complex, and interconnected, we can no longer afford to address individual environmental and social problems in a convenient isolation of their context (Blengini, 2011). Research studies to manage building waste are being addressed worldwide, and some of these studies are summarized in Table 1.

**Table 1. Building Waste Management Research Worldwide**

<table>
<thead>
<tr>
<th>Reference/Country</th>
<th>Research</th>
<th>Findings</th>
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<tbody>
<tr>
<td>Kartem et al. (2004)</td>
<td>Building waste disposal system in Kuwait and alternative solutions to manage and control waste in an economically efficient and environmentally safe manner. Recycle approximately 90% of the waste material and small part is being reused in Kuwait.</td>
<td>Highlights the major benefits and problems with the existing recycling facility. All public and private agencies should take appropriate measures to encourage prevention and reduction of waste.</td>
</tr>
<tr>
<td>Yeheyis et al. (2013)</td>
<td>A conceptual C&amp;D waste management framework to maximize the 3R (reduce, reuse and recycle) and minimize the disposal of construction waste.</td>
<td>This approach can be used to make decisions related to selection of material, sorting, recycle/reuse and treatment or disposal options for C&amp;D.</td>
</tr>
<tr>
<td>Fernandez et al. (2014)</td>
<td>Computerized mathematical modelling to study analysis of a simulation of the sustainability in the use of timber as a major structural component in construction.</td>
<td>The study demonstrated that timber could represent an opportunity for desperately needed economic regeneration. It has previously been thought that the use of timber in construction would lead to deforestation and desertification.</td>
</tr>
<tr>
<td>Bianchini (2004)</td>
<td>Chemical–mineralogical characterization of recycled building waste. Wastes can be re-utilized for the preparation of new mortar and concrete, while finer fractions could be considered as components for industrial processing in the preparation of cements and bricks/tiles.</td>
<td>More complete re-evaluation is generally hampered by the lack of suitable recycling plants.</td>
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Blengini et al. (2011) EU  
Eco-efficient recycling to maximize resources and energy recovery from post-consumer waste glass, through integrated waste management and industrial production. Utilized multiple waste streams in a multi-output industrial process.  
Environmental gains that are higher than those related to landfill avoidance. Recourse to highly energy intensive recycling should be limited to waste that cannot be closed-loop recycled.

Zaharieva et al. (2003) Bulgaria  
Waste streams in Bulgaria in the context of the social and economic restructuring and recent urban development undergone by the country.  
Building-waste management is regarded as an effective way towards a more sustainable path of development.

Causes of waste in construction industry and its connection with the construction practices.  
Sorting of waste at source, employment of skilled workers and material management to promote waste reduction.

RECYCLING AND RE-USE OF BUILDING WASTE

For economic and environment benefits, landfilling of building waste is undesirable. Recycling of building waste will provide opportunities for saving land, energy, time, resources, and money. The advantages of recycling such as conservation and preservation of land areas for city expansion, cost effectiveness of using recycled products, saving in transport of materials both waste and raw materials and improving the general environmental status (Kartem et al., 2004). Recycling provides the opportunity to reduce the embodied energy by using the possible materials/components and the recycled materials (Thormark, 2002). Recycled materials are generally utilized as secondary construction materials with same needs. The technologies available for recycling with respect to the origin, constitution and removal of impurities mainly are classified into three groups, namely selective recycling, in situ recycling and industrial recycling (Zaharieva et al., 2003). Recycling of building waste can be economical when these plants are located nearby large urban areas with intense construction activities and facing storage for natural resources. However, implementation of economical, environmentally-friendly and pollution-free recycling techniques is one of the greatest technological challenges faced by the industry today.

Large amount of building waste generated after earthquakes and natural disasters were utilized for reconstruction projects with recycling technology method and re-use way (Xio et al., 2012). Recycled building materials can be directly re-utilized as first-order material in the building-related activities. In particular, this fraction could be employed in the preparation of new mortar and concrete as secondary construction (Bianchini, 2004). Eco-efficient recycling route has been implemented to maximize resources and energy recovery from post-consumer waste glass, through integrated
waste management and industrial production. Life cycle assessment (LCA) recourse to highly energy intensive recycling should be limited to waste that cannot be closed-loop recycled (Blengini et al., 2011). To increase the environmental benefits, the choice of building materials as well as the aspects of re-use/re-cycling is of great importance in design of new buildings.

Torgal and Jalali (2011) outlined a systematic waste management plan to reduce building waste for construction projects: (1) characterization of the construction works, (2) main waste streams, (3) waste management framework, (4) estimation of quantities of each material, (5) proposal for minimization, reuse and recycling, and (6) transport of the building waste. All major development projects that exceed a specified scale should require such waste management plan (DELG, 2006). Several other initiatives have been suggested to help implement the waste management plans such as use of purchased management, use of prefabricated components, education and training, proper site layout planning, on-site waste recycling operation, implementation of environmental management systems, high level management commitment, installment of underground mechanical wheel washing machines, identification of available re-cycling facilitate, and on-site sorting of construction and demolition materials.

The use of recycled aggregates is promoted worldwide. In EU, an environmental protection and waste management policy is developed that provided guidelines for common strategies for a correct reuse of building waste (DGENV.E.3, 2000). Some EU countries such as Germany, UK and Netherlands have already developed suitable programs of building waste recycling, while in others countries such as Italy, France, and Spain, the amount of recycled inert material is still limited, and does not exceed 10%. Crushing and sorting operation for building waste, it is possible to obtain grain-size fractions with roughly homogenous chemical and mineralogical composition.

The recycling law by Japanese government in 1991 which set minimum targets for several by-products has increased the percentages of recycling. Waste plans with increased utilization by recycling were implemented in Belgium, Germany Finland and Spain in consecutive years since 1995. The revised European Union’s waste framework directive targets recycling increase to 70% (by weight) by the year 2020 (Torgal and Jalali, 2011).

**CHALLENGES IN RE-USE OF BUILDING WASTE**

The difficulty in quantification of building waste from the bulk waste either as of measured data or as estimated data is a common challenge in building waste management. Lack of technical specifications, economic constraints and conservatism within the construction industry are factors that cause barriers to recycling and re-use activities in construction projects. Limited financial incentives, high overhead costs, and time-consuming task of onsite site sorting are reported to be the major difficulties in the implementation of the waste management plan (Torgal et al., 2011). The lack of communication between local authorities, waste management companies and policy makers in implementation of new codes in utilization of recycled products is a barrier. Building waste is treated as municipal waste with difficulties in its estimation and effective re-use possibilities. In spite of growing magnitude of problems due to
building waste and absence of reliable statistical data, these kinds of waste are illegally dumped in landfills in most of the countries. Even though employment of building waste through recycling has enormous advantages and opportunities, its use is still limited to general bulk and drainage fills. In spite of its advantages in saving land, energy, time, resources, and money, complete re-evaluation is generally hampered due to lack of suitable recycling plants. However, the active collaborative participation of the public and private agencies through appropriate incentives is essential for large amounts of building waste to take advantage of its economic and environmental benefits (Kartam et al., 2004).

Regulations and specifications to encourage and permit contractors to use recycled products are lacking. Creating public awareness for recycled product applications should be undertaken through seminars and programs presented by expert speakers. Recycling programs should be commercially promoted by private and public authorities. Research institutions should contribute in developing the field of building waste recycling. Location of the recycling plant should take into consideration environment, pollution and safety factors. Extensive testing should be implemented to ensure structural stability and safety for use of recycled products. Recycled product prices should be significantly lower compared to newly imported/produced material to encourage the construction industry in applying recycled (Kartem et al., 2004). The economic availability of natural resources often curtails investment on building waste recycling (Zaharieva et al., 2003).

STRATEGIES FOR SUSTAINABLE URBAN DEVELOPMENT AND FUTURE OUTLOOK

This study reviewed different waste management approaches for sustainable development adopted in various countries. The challenges and opportunities of various waste management systems were understood. They offer a background for engineers to evolve strategies for managing waste and to formulate universal guidelines for building industries towards sustainable urban development. Potential strategies for integrated sustainable management of building waste may include:

- Prevention and reduction of waste by development of optimizing techniques and re-use of waste.
- Proper planning, design, material handling and establishing disposal and recycling facilities into the project scheme.
- Regulations and rules should be set to encourage and persuade use of recycled products.
- Standards and codes to be should be developed for the use of alternative building materials for structural stability and safety and the recycled products.
- Promoting the use of recycled alternative building materials by public and private authorities in the commercial market.
- Recycled products need to be standardized for industrial manufacture for economy and large scale application.
CONCLUSIONS

The growing quantities of building waste due to rapid urban developments throughout the world require development and implementation of sustainable management plans urgently. This paper reviewed several research studies and environmental policies initiated worldwide to address the building waste management. Several challenges, opportunities and strategies are identified to increase the building waste management. Recycling and reuse of building waste is a sustainable approach which reduced cost, environmental pollution, energy demand, and conservation of natural resources. The various factors presented in this paper will serve as guidance for engineers and material scientists to develop standards and specifications for alternate building materials utilising building waste. This study emphasizes the need to plan and develop waste management strategies for construction projects. Further research is needed on environmentally-friendly and energy efficient recycling methods and new reuse applications in infrastructure projects.

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REFERENCES


