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# Sustainable Approaches for Utilizing Waste in Building Construction: Two Case Studies in India

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**Abstract:** Problems associated with increasing waste due to rising urban developments and its environmental concerns are reviewed. The challenges and standards for sustainable construction are outlined. This study explores potential utilization of different types of waste materials in building construction for its efficient and sustainable management. The benefits and challenges in utilization of waste for building applications are reviewed. Two case studies which demonstrate effective utilization of waste in construction projects carried out in India are outlined. These sustainable approaches of managing waste in building construction shall help private and governmental agencies to incorporate effective waste management strategies in future. This study will offer a background and useful guide for engineers and material scientists to develop standards and specifications for cost effective alternate building materials and techniques for economy, energy, and environmental benefits.

***Keywords:*** *wastes, building materials, sustainability, recycling, construction, waste management.*

## 1. Introduction:

Building industry is one of the largest sectors, which consumes enormous natural resources, manpower, energy, and economy. Manufactured building materials which consume large quantity of energy, such as steel, cement, glass, aluminum, plastics and bricks, are commonly used for building construction. Increased use of these energy intensive materials will not only deplete the energy resources, but they also produce adverse environmental effects (Reddy, 2004). The main aim of sustainable construction is to minimize natural resource consumption and also the impacts on ecological systems (Kibert, 2013). The growing demand for materials in building industry cannot be fully met by the natural resources or energy efficient traditional materials. Hence there is a need to develop potential alternatives and innovative techniques to solve the increasing needs in building construction.

Managing waste is one of the challenging issues in fast developing world due to the inadequate manpower, financial resources, implements, and machinery which result in environment pollution (Kartam et al., 2004). Utilization of local waste as well as optimizing use of high energy intensive materials in construction has been identified as one of the potential solutions to this problem (Reddy, 2004). Utilization of waste in building industry not only saves environment but aid in meeting housing demands for the economic weaker sections (Zaharieva et al., 2003).

This paper reviews problems associated with increasing waste and its potential utilization in various building applications. The benefits and challenges of utilization of waste in building construction are also presented. A classification of waste based on its probable utilization in building applications are presented for future utilization and management strategies. These sustainable approaches in waste management will help governmental agencies to evolve modifications policies and in building standards. This paper will form a guide for engineers and scholars to explore various options to improve the current waste disposal methods and activities and also to meet the acute demand in material resources for meeting building construction needs.

## 2. Waste Management and Environmental Concerns:

Waste Management Act of 2001 defines waste as "any substance or object belonging to a belonging to a category of waste which the holder discards or intends or is required to discard, and anything which is discarded or otherwise dealt with as if it were waste shall be presumed to be waste until the contract is proved" (Torgal and Jalali, 2011). Generation of waste and inadequate disposal mechanism exerts unavoidable pressure over the natural environment (Zaharieva et al, 2003). 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. Disposal of waste in landfills and other methods has been challenging due to environment standards and economic reasons. Rising amounts of wastes, cost of landfills and environment issues has triggered problems and concerns in disposal methods. Environmental concerns in disaster management has become a critical priority, requiring the sound management of natural resources as a tool to prevent disasters and lessen their impacts on people, their homes, and livelihoods (Tiwari, 2001). The environmental and health risk due to creation of large volume and hazardous constituents after disasters in developing countries necessitates regulations for post disaster waste management planning for effective debris management.

## 3. Challenges in Waste Management:

Waste management has become more challenging all over the world due to population increase, unplanned urban developments, improvements in living standards, and lack of data. Improper management of municipal solid waste (MSW) is one of the major environmental problems and hazards to inhabitants. Disposal of rising amounts of waste has been challenging due to environment protective regulations and high cost of land. Studies reveal that about 90% of MSW is disposed of unscientifically in open dumps and landfills create problems to public health and the environment (Kumar, 2009). In most countries even though building waste problem is of increasing magnitude, there is lack in reliable statistics due to disposal by illegal dumping (Torgal and Jalali, 2011). 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). Establishing a successful waste recycling operation in USA is a challenge and reusing waste can help communities to preserve their local landfills (Chun-li-Peng et.al., 1997). In India, about 960 million tons of solid waste is being generated annually as by-products during industrial, mining, municipal and agricultural processes (Pappu et. al, 2007). Management of building waste needs multi-disciplinary expertise in planning, engineering and material management. The inertia of the building professionals and the difficulty of changing building codes are few significant obstacles in the construction industry. Uncertainty and fears of liability and litigation over the performance of alternative building materials and techniques also pose appreciable challenges. Despite the instinctive environmental or economic benefits of green building approaches, most of them has not been scientifically quantified (Torgal and Jalali, 2011). Lack of a collective vision and guidance for future green buildings, including design, components, systems, and materials, may affect the present rapid progress in this field.

## 4. Standards in Sustainable Construction:

Sustainable development aims at improving the standard of life without compromising the environmental qualities and for future needs. These interconnected objectives can be achieved through rational management of demand of material resources and proper management of building waste. International Council of Buildings (CIB) in1994 defined sustainable construction as creating and operating a healthy built environment based on efficient use of resources and in project based on ecological principles (Kibert, 2013). 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 (Sharma and Reddy, 2004). The growing significance of sustainability concept throughout the world has resulted in attitude change in consumption of natural resources for infrastructure development projects (Yeheyis, 2013).

Utilization of large quantity of natural resources for meeting the fast growing building activities and generation of waste has exerted unavoidable pressures on natural environment. With the growing significance in green building concept, and the mandatory inclusion evaluation of life cycle assessment (LCA) in building design standards such as US LEED, German DGNB, and the Australian Green Star Building, sustainable building has proven substantial benefits to environment and economy (Kibert, 2004). 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).

## 5. Post-Disaster Waste Management:

Post-disaster building waste management offer numerous challenges due to generation of unexpected large volume of building waste and inadequate capabilities to manage them in developing countries

(Karunasena et al., 2012). Large amount of waste generated after earthquakes and other natural disasters (e.g., hurricanes and floods) should be utilized for reconstruction projects with recycling technology methods and re-use approaches (Xio et al, 2012. Minimizing the waste and its proper management can be regarded as an effective way to assess the project performance towards a more sustainable path of development (Formosa, 2002). Solid waste materials can be effectively utilized in producing cost effective alternative building materials to replenish the scarcity of traditional materials such as bricks, blocks, tiles, aggregates, ceramics, cement, lime, sand and timber for cost effective housing. Industrial waste and bi-products were utilized as aggregates and raw materials for structural components (Asolekar, 2009). Re-use of waste materials in construction allows waste management, sustainable conservation of energy, economy and also minimizes the environment pollution. The success of recycling and building waste management depends on the regulations imposed on waste management plan and also on the demonstration of economic advantages associated with its application (Torgal and Jalali, 2011).

## 6. Waste Management in Building Construction-Potentials and Possibilities:

Recycling and reuse of waste started since nineteenth century with the introduction of laws to encourage recycling of increasing wastes. Even though every state of US has set high goals of recycling up to 70%, the recycling rates for different states remained 5 to 50% as the success depends on economic feasibility and markets for the recycled products (Sharma and Reddy, 2004). Reuse and recycling is recognized as a solid waste management strategy that is preferable to landfilling or incineration and more environmentally desirable. Waste materials generated by the urban community such as plastics, glass and metallic objects can find a variety of applications in the building construction, landscape elements, utility structures, pavements and decorative fittings. Various types of wastes and their potential utilization are given in Table1.

***Table1:*** *Potential applications of various types of waste in building applications*

| Waste Category | Waste type & Source | Potential building applications |
|---|---|---|
| Agriculture Waste (organic) Pappu et. al. (2007) | Baggage, rice and wheat straw and husk, coconut shell, fibers and husk Cotton stalk, Saw mill waste, ground nut shell, banana stalk and jute, sisal and vegetable residues. | Particle boards, insulation boards, wall Panels, printing paper and fillers, roofing sheets, fuel, binders, fibrous building panels, bricks, acid proof cement, coir fiber, mats, reinforced composite, Polymer composites, cement board. |
| Industrial waste/ Municipal waste ( inorganic) Pappu et. al. (2007), Sharma and Reddy (2004) | Coal combustion residues, steel slag, bauxite red mud, Construction debris | Cement, bricks, blocks, tiles, paint, aggregate, concrete, wood substitute products, ceramic products |
| | Fly ash | Mineral filler in asphalt paving mixtures, soil stabilization and structural fill |
| | Blast Furnace slag | Aggregate, surface course in asphalt and addition to Portland cement concrete |
| | Foundry sand | Landfill, precast concrete manufacture |
| | Glass | Used in place of aggregates |
| | Plastics | Many uses for recycled plastics such as fencing, furniture and outdoor landscape elements. |
| | Scrap tires | Tire chips are used in embankments, retaining walls and as backfills in abutments. Used in rubberized asphalt pavements, rail road crossings as panels to be fitted with tracks and with timber crossings. Shredded tires are used as alternative aggregate material. Scrap tires used economically for shock absorbing and as a noise barrier in construction. Other uses, such as stair treads, mats, flooring tiles, sewer rings, guard rails, golf driving mats and playground covers |
| Construction and demolition debris | Recycled Concrete | Raw material in cement clinker, admixture in cement and as aggregates in concrete. Can be used as aggregate base for pavements, sub base for new |

| | | |
|---|---|---|
| | | pavements, shoulders, base course for foundations or backfill for utility trenches. |
| | Wood waste | Scrap lumber can be processed and used for landscaping and building products. Wood fibers used for fiberboard products for various applications such as sub flooring, sheathing and structures for insulation and damping of sound. Wood fibers are mixed with Portland cement to make rigid boards which can be used as fire barriers, sheet roofing systems, or sub flooring for ceramic tiles. Fiber strips made from wood fibers are used to fill expansion joints in concrete roads and walkways. Wood residues are mixed with plastic fibers to make plastic lumber suited for water front docks, piers and dockings.<br><br>Oriented strand boards manufactured using wooden fibers on the outside and a thick inner layer of polystyrene form have good application in residential construction. Composite structural wall system made using wooden fiber up to 90% and reinforced concrete. Wooden particles are used as decorative wood chips, mulch or other ground cover products, including geotextiles which is biodegradable product. Wooden based geotextiles and sheet mulches provide percolation and vegetative layers in landfill designs. |
| | Soil and rubble | Used as aggregates |
| | Asphalt | Asphalt paving |
| | Metals | Sold as scraps for re-use and re-cycling |
| Mining/minerals | Coal washers waste, mining overburden waste, tailing from iron, copper, zinc, gold, aluminum industries | Bricks, tiles, lightweight aggregates, fuel |
| Hazardous waste | Metallurgical residues, galvanizing waste, Tannery waste | Cement, bricks, tiles, ceramics and board |

Demirbas (2011) identified four critical factors for an integrated waste management which comprised of source reduction, reuse, recycling, landfill and gas-to energy and waste to energy conversion namely- reduce, reuse, recycle, compost, incinerate and landfill. The aim of the waste hierarchy was to extract the maximum practical benefits from products and to generate the minimum amount of waste. A six level hierarchy of waste management based on of waste reduction and minimization of environmental impact is shown in Fig.1

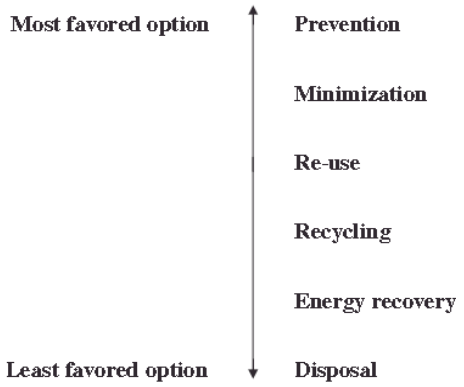


***Fig1:*** *Waste Management hierarchy - adapted from Demirbas (2011)*

## 7. Waste Management for Building Construction-Case Studies:

### *7.1. Case Study 1: Rock Gardens of Chandigarh City, India:*

Chandigarh is the first planned city in India constructed after 1947 when the country got independence (Wikipedia, 2014). Le Corbusier and a few famous town planners from different parts of the world were associated with the concept and planning of the city. The Rock garden of Chandigarh known as Nek Chand's rock garden is considered as one of the most preferred tourist spots in the city. It is situated near Sukhna Lake, which consists of man-made interlinked waterfalls and the garden famous for its sculptures made from industrial and recycled ceramic materials such as bottles, glasses, bangles, tiles, ceramic pots, and electrical goods, which were placed in various locations. It had grown into a 12-acre (49,000 m2) complex of interlinked courtyards, each filled with pottery-covered concrete sculptures of dancers, musicians, and animals. With the support from the government, Chandigarh was able to set up collection centers around the city for waste, especially rags and broken ceramics. The effective utilization of waste for a worthy application of landscape construction is demonstrated through this project as illustrated in Fig. 2 and Fig.3.

***Fig2:*** *and* ***Fig3:*** *Rock garden, Chandigarh: landscape construction utilizing industrial waste*

### *7.2. Case Study2: Coconut Shell Sandwich Panel Construction:*

The demonstration project of coconut shell sandwich panel construction was funded by AICTE-TEQIP and implemented by NIT Calicut in the year 2008 for skill up-gradation of rural craftsmen and women workers at Kakkodi Panchayath -6 kilometers away from Calicut city (Kasthurba, 2007). The training for the coconut shell sandwich panel construction was carried out for the masons and women workers at Kakkodi through instructive demonstration. The demonstration was undertaken for the construction of a vaulted structure with dimensions of 2.4m x 1.8m in plan and a height of 2.7 m. Coconut shells (waste material after removal of coconut) were collected from the locality. The construction steps included- making a hole in the center of each of the hemispherical part of coconut shell using ordinary drilling machine. The coconut shells were held together by stacking closely using a coir string made of coconut fibers. A formwork (re-usable one) made of steel pipe was made as per the required dimension (by industrial fabrication). The formwork was fixed on the basement structure of 60-cm height. A welded wire mesh was then spread over the formwork to cover it fully. The coconut shells in flexible string were placed in rows touching each other till the formwork was completely covered. The thin layer of Ferro cement concrete with 10 mm aggregates was laid over the coconut shell layer after placing a flexible chicken mesh over it. Figures 4 to 7 illustrate the step by step procedure involved in coconut shell sandwich panel construction.

## 8. Waste Management Strategies – Future Outlook:

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. Recycling has been found as an effective way of managing waste for energy efficiency, economic and environmental benefits. Management of building waste through recycling and re-use has been found as an effective way of managing waste due to energy, economic and environmental efficiency. The sustainable approach of development demands minimizing and utilizing waste materials by re-cycling and re-use. Management of waste in building applications has to be viewed within a wider context of environmental, economic and social regards and needs multi-disciplinary expertise in planning, engineering and material management. The utilization of waste in building applications and complexity in recycling operation involves wider contexts of environmental, economic and social benefits. Decision making and action plans need to involve interdisciplinary team of urban planners, economists, architects, and engineers.

***Fig3-6:*** *Construction of Coconut shell sandwich panel structure- 4 stages*

A comprehensive waste management approach should be incorporated in construction project at every stages in planning, design, construction, renovation and demolition stages of construction project for its entire life span. An interdisciplinary approach in waste management which emphasizes the long term and recycling strategies should be set up regionally. An international co-operation for waste management strategies and techniques could enable exchange of technical expertise and recycling equipment. Understanding the beneficial use of waste materials along with their problem is highly necessary to set up industries for recycling and use of alternative materials. Waste can be seen as resources for construction. However, environment friendly, energy-efficient and cost effective alternative materials developed from solid wastes will show good market potential to cater to people's needs for building construction in rural and urban areas. The properties of these alternative building materials from waste recycling should be well documented for their effective applications. In order to maximize the use of alternative building materials developed from different types of solid wastes and to increase the production capacity of lab scale processes, technology-enabling centers should be set-up to facilitate entrepreneurs for effective commercialization. Durability and performance of the newer products and dissemination of technologies emphasizing costs-benefits analyses and life cycle assessment report will significantly contribute to successful commercialization of innovative processes. Inclusion of industrial waste-based newer building materials, emphasizing their environmental significance in the curriculum at higher education level and practical applications of wastes in construction sector will be an incentive to such technology promotion.

## 9. Conclusions and Recommendations:

The growing quantities of building waste due to rapid urban developments throughout the world require development and implementation of sustainable management plans urgently. The challenges, opportunities and strategies for waste management in construction industry presented will help private and governmental agencies to develop sustainable construction methods. Sustainable approach of waste management by recycling and reuse of building waste will aid in 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 cost effective alternate building materials and techniques for the saving of energy, and reap economic and environmental benefits. More scientific studies are needed on environmentally-friendly and efficient recycling methods and new reuse applications in building construction.

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