Management of Construction and Demolition Wastes after Disasters

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ABSTRACT

Management of construction and demolition wastes (CDW) from disasters was discussed within the perspective of integrated solid waste management principles by evaluating different management options and technologies. CDW, which consist of an important part of the solid waste stream in many communities, is suitable to environmentally favorable waste management practices i.e. reuse and recycling. Although most of the CDW is generated from daily construction, renovation and demolition activities, natural and man-made disasters may generate one-time very high amounts of waste with specific properties depending on the type of the disaster. Efficient management of CDW based on integrated waste management principles is critical in order to deal with it without damaging the environment and achieving high reuse and recycling rates. Management of CDW from disasters can be further successful when a detailed management plan is prepared before the happening of disaster.

Umwelt und Gesundheit Online, 2009; 2, 19-23.

Introduction

Construction and demolition wastes (CDW) consist of the debris generated during the construction, renovation, and demolition of buildings, roads, and bridges. CDW often contains bulky and heavy materials, such as concrete blocks, metals, glass, and salvaged building components. CDW has a wide range of types of waste materials created by the processes during construction, renovation, or demolition of structures, which include all types of buildings (residential, commercial, and institutional) as well as roads and bridges. Typical components of CDW are listed in Table 1. Land clearing debris (stumps, rocks, dirt) are also included in some definitions of CDW.

According to the European Union (EU) waste strategy, CDW are considered as one of the priority waste streams. Within the framework of the Sixth Environment Action Program entitled "Environment 2010: Our future, our choice," it is emphasized that actions are needed to be taken for the more effective management of this type of the waste stream (Kourmpanis et al, 2008). CDW is a major part of the total waste stream in developed countries and most of its components are suitable for reuse and recycling applications, however, this is not the practical case in many European Union members.

Benefits to CDW Management are numerous. First of all, efficient management of these wastes reduces the production of greenhouse gas emissions and other pollutants by reducing the need to extract raw materials and ship new materials long distances. Another environmental concern of the waste problem is the final disposal. CDW has a large percentage of constituents that are not suitable for combustion or degradation, which leaves creating landfill as the only feasible option. Thus, efficient management may conserve landfill space; reduce the need for new landfills and their associated cost.

By increasing the percentage of reused and recycled materials energy can be saved and an environmental impact of producing new materials by extraction and manufacturing processes can be avoided. This process also creates employment opportunities and economic activities in reuse recycling industries. It saves money by reducing project disposal costs, transportation costs, and the cost of some new construction materials by recycling old materials onsite.

Characteristics, Sources and Quantities of CDW

The amount of CDW generated in developed countries comprises a significant portion of the waste stream. Table 2 presents the quantities and recovery rates of CDW from major European countries. CDW is one of the major waste streams in the EU, and the annual quantity generated exceeds 450 million tons where its current level of recovery of materials is low (25%) (EEA, 2002).

CDW contribute 136 million tons to waste disposed in landfills in USA (Tchobanoglous, 2002). The estimated per capita generation rate in 1996 was 2.8 pounds per person per day. 43% of the waste (58 Mt/yr) is generated from residential sources and 57% (78 Mt/yr) from nonresidential sources. Building demolitions account for 48 percent of the waste stream (65 million tons per year); renovations account for 44 percent (60 Mt/yr) and 8 percent (11 Mt/yr), is generated at construction sites (Franklin Associates, 1998)

Qualitative characteristics of CDW are influenced by a significant number of parameters, such as period of construction, form of construction of a building, main materials used for the construction, techniques that are applied during construction and demolition of the structure and historical, cultural, economic value and importance of a building. General composition of CDW in EU countries consists of 70% mineral waste, 11% timber, 7% glass and plastic, 7% metal and 5% other materials (EEA 2002). For the EU, waste from excavation and demolition activities form 40–50%, where waste from additions and renovation of existing buildings are 30–50% and waste from the construction of new buildings contribute to 10–20% of the waste stream roughly (EEA 2002).

Although CDW are mainly generated from daily activities of construction, demolition and renovation, disasters also create enormous quantities. Figures from different disasters occurred in the past show that the one-time generated CDW has huge volumes (Table 3). These wastes must be dealt with utmost speed to prevent further damage to environment, to ensure the operation civil and infrastructure systems and avoid human health hazards due to diseases and sequential disasters that may occur.

Table 1. Typical Components of CDW (Franklin Associates, 1998)

Material Components	Content Examples
Wood	Lumber, stumps, plywood, laminates, scraps
Drywall	Sheetrock, gypsum, plaster
Metals	Pipes, rebar, steel, aluminum, copper, brass, stainless steel
Plastics	Vinyl siding, doors, windows, pipes
Roofing	Asphalt and wood shingles, slate, tile
Rubble	Asphalt, concrete, rock, earth
Brick	Bricks and decorative blocks
Glass	Windows, mirrors
Miscellaneous	Carpeting, insulation, ceramic tiles

Table 2. Typical Components of CDW (Franklin Associates, 1998)

Country	Quantity (Mt/yr)	% Recovery	% Disposal
Germany	59	17	83
UK	30	45	55
France	24	15	85
Italy	20	9	91
Spain	13	<5	>95
Netherlands	11	90	10
Belgium	7	87	13
Austria	5	41	59
Portugal	3	<5	>95
Denmark	3	81	19
Greece	2	<5	>95
Sweden	2	21	79
Finland	1	45	55
Ireland	1	<5	>95

Table 3. CDW Generation from Disasters in the USA

Community	Disaster	Date	Volume of Debris
Metro-Dade County, Florida	Hurricane Andrew	August 1992	31 million m^3
Los Angeles, California	Northridge Earthquake	January 1994	5,5 million m^3
Kauai, Hawaii	Hurricane Iniki	September 1992	3,8 million m^3
Mecklenburg County, North Carolina	Hurricane Hugo	September 1989	1,5 million m^3

Generation of disaster CDW may be due to the hurricanes, earthquakes, floods or fires. Depending on the type of the disaster, characteristics of the waste differs, resulting in need of tailored waste management plans. Hurricanes leave behind debris made up of construction materials, damaged buildings, sediments, green waste, and personal property. Hurricane debris obstructs roads and disables electrical power and communication systems over wide areas. Most of the damage and resulting debris is in the area where the hurricane first hits land. Earthquakes generate shock waves and displace the ground along fault lines. These seismic forces can bring down buildings and bridges in a localized area and damage buildings and other structures in a far wider area. Secondary damage from fires, explosions, and localized flooding from broken water pipes can increase the amount of debris. Earthquake debris includes building materials, personal property, and sediment from landslides.

Debris from floods is caused by structural inundation and high-velocity water flow. As soon as flood waters recede, people begin to dispose of flood-damaged household items. Mud, sediment, sandbags, and other reinforcing materials also add to the volume of debris needing management, as do materials from demolished and dismantled houses. While fires leave less debris than other types of disasters, they still generate much waste. For example, demolished houses contribute noncombustible debris. Burned out cars and other metal objects, as well as ash and charred wood waste, also must be managed. In addition, large-scale loss of plants serving as ground cover can lead to mud slides, adding debris to the waste stream.

Management of CDW

Integrated Waste Management Approach to the CDW

An integrated waste management strategy which will be used to deal with the issues mentioned above should employ the waste management hierarchy (Figure 1). A well established and effective management is of high importance for the CDW. First, waste is inert and economically valuable, which makes material recovery, reuse and recycling a highly feasible option. Also, direct disposal to landfill is not a good solution for a number of reasons. Landfill space concerns with economic losses due to the inefficient management means high disposal costs for the waste, not mentioning the environmental effects of the waste in the future.

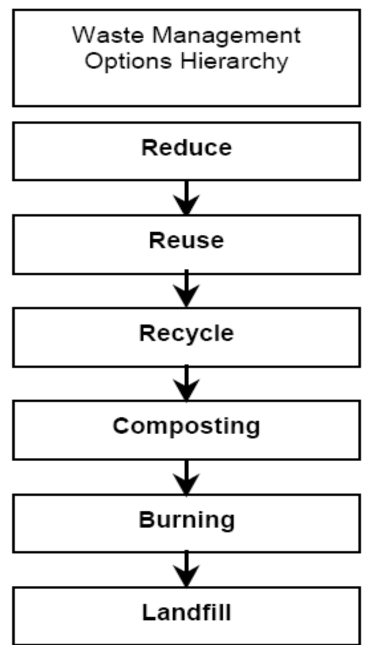
CDW has some important effects on waste degradation behavior in landfills (Johnson et al, 1999). CDW has high calcite, which is an acid neutralizer, and the calcite content actually positively contribute to the retention of metals within the landfill. However, CDW may (and generally do) contain hazardous substances which are not allowed in municipal solid waste landfills. Common hazardous parts in CDW are asbestos containing building materials, lead-based paints, polychlorinated biphenyls, batteries containing Pb and Cd, mercury, CFCs and treated wood.

Review of Technologies for CDW Recovery

Selection of technology for CDW management depends on the waste constituent. The largest component of CDW is generally mineral waste. Concrete is commonly recycled. It is crushed, the reinforcement bar is removed, and the material is screened for size. Concrete recycled material applications include road construction, base material, self hardening top coat, drainage material, gravel replacement and aggregate in new concrete. Recycled aggregates may also be used for concrete production in the structural engineering sector (called closed-loop recycling) (Weil et al, 2006), but it is not very common yet due to resulting unpredictable concrete performance. Asphalt is crushed and recycled back into new asphalt. Markets for recycled asphalt paving include aggregate for new asphalt hot mixes and sub-base for paved road. Roofing recycling is based on the type of shingles.

Non-asphalt shingles can be used as reuse sheathing, terracotta, slate, or untreated cedar tiles. Asphalt shingles can be ground and recycled into asphalt mixes after the removal of nails. Bricks can be reused in historical restoration projects. Recycling can be accomplished also by crushing material. Market outlets for recycled brick include aggregate, drainage media and general fill. Applications include road base and drainage layer, recreational trail top coat and mechanical soil stabilizer.

Figure 1. Elements of the Waste Management Hierarchy



Reusable timbers include large dimension lumber, plywood, flooring, molding, lumber longer than 6 feet. Clean, untreated wood can be recycled, re-milled into flooring, or chipped/ground to make engineered board, boiler fuel, and mulch. Wood recycling methods include on site sorting by quality, selling of valuable, old structural timber to woodworkers or sawmills, shredding of scrap wood in-situ or in a centralized plant and magnetic sorting of shredded wood for scrap metal. Wood can be a “green” supplement in coal generators. Production of various pressboards and fiberboards is also possible with the wood fibers. Wood can be used as mulch or compost amendment, however, cleanliness of the product is particularly important for such uses. Another option for the wood recycling is animal bedding.

Recycled metals from CDW include steel, aluminum, and copper. Local metal scrap yards or recyclers that accept metal materials are typically accessible in all around the world. Metals are melted down and reformed into metal products. Markets are well established for metals. Recycling methods for metals from CDW include on site separation from concrete and other materials, manual sorting, shredding on site or in-plant, magnetic sorting for ferrous fractions, eddy current separators to separate out other metals and density separation. Resulting fractions of metals from these methods can be directly added to virgin materials in the foundry.

Integrated Waste Management Approach to CDW

A disaster management plan should address pre-planning activities, ancillary activities and define how the debris will be managed (USEPA, 2008). Debris removal strategy should address harmful materials; determine management method for each type of debris (recycling, waste to energy, disposal, and open-burning). Also the plan should take into account environmental protection, segregation of materials, collection, facility delivery requirements and temporary storage, if needed.

Reduce

Waste reduction for CDW can be achieved in the design phase; however, waste management is not a priority in the design process of most materials and buildings. About one-third of construction waste could arise from design decisions (Osmani et al, 2007). These wastes can be minimized by taking the following actions during design:

- Choose simple plans.
- Use advanced framing.
- Use prefabricated materials.
- Use recyclable and recycled materials.
- Use non-hazardous materials,
- Use waste management plans.

Reuse

Mineral parts of CDW fits better as granular material in roadbeds, likewise MSWI bottom ash and slag (Vegas et al, 2008). Moreover, the following can be reused:

- Easy to remove items include: doors, hardware, appliances, and fixtures. These can be salvaged for donation or use during the rebuild or on other jobs.
- Wood cutoffs can be used for cripples, lintels, and blocking to eliminate the need to cut full length lumber. Scrap wood can be chipped on site and used as mulch or groundcover.
- Gypsum drywall can be placed inside wall cavities to eliminate the need for transportation and landfill disposal.
- Brick, concrete and masonry can be recycled on site as fill, sub-base material or driveway bedding.
- Excess insulation from exterior walls can be used in interior walls as noise deadening material.
- Paint can be remixed and used in garage or storage areas, or as primer coat on other jobs.
- Packaging materials can be returned to suppliers for reuse.

Reducing and recycling CDW conserves landfill space, reduces the environmental impact of producing new materials, creates jobs, and can reduce overall building project expenses through avoided purchase/disposal costs.

Recycle

Most of the items are suitable for recycling, rather than disposal or reuse. These may be:

- Wood waste: accepted by numerous facilities, from animal farms to incineration plants.
- Clean drywall: processed by CDW processing facilities.
- Local industries may accept inert CDW for use as road base.
- Some suppliers will take back used or scrap material. Carpet remains can be taken back to many suppliers. Some manufacturers will pickup used product or packaging when delivering a new order.

A certain portion of the materials from construction and demolition projects are toxic or classified as hazardous waste. Materials generated in new construction that may require special handling include latex paint, chemical solvents and adhesives. The materials should be managed according to local regulations. Lead paint can be planed, removed, and recycled at a lead smelter or disposed of appropriately, while the remaining wood can also be reused or recycled.

The age of structures involved in demolition projects ranges considerably. Many older buildings may contain materials that are no longer allowed in new construction, such as asbestos and lead-based paint. Asbestos abatement is required prior to demolition. Asbestos must be handled appropriately and disposed in a landfill that accepts asbestos-containing material (ACM).

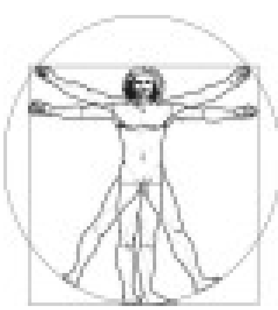
Proper panning of CDW management with respect to the integrated waste management principles provides advantages over poor planning and management. Comparison of the following cases gives a clear demonstration of these advantages. The Kocaeli Earthquake (Turkey) happened on August 17, 1999 and had a magnitude of 7.4 with an offset of 3.5 meters. The casualties were about 15,000 dead and 27,000 injured. In some locations, land subsidence below to sea level has been occurred, roads and bridges were damaged, even collapsed in some locations and severe fires in some industrial facilities caused trouble. A CDW management plan was not present before the Kocaeli Earthquake. After the earthquake, no plans highlighting waste reuse and recycle were prepared and applied, and main effort was put on debris collection and disposal, which took a few years to be accomplished in some locations. Since no planned reuse and recycling effort has been undertaken, fraction of reused and recycled waste was insignificant. Total amount of collected CDW, amounts and percentages of waste reused, recycled and disposed was not clear. None of these figures are still available.

The Northridge Earthquake that occurred near Los Angeles, California, caused extensive damage and loss of life in Northridge, and created casualties of 57 dead as a direct result of the earthquake and 72 additional deaths attributed to its aftermath. More than 9,000 were injured in January 1994. The city of Los Angeles relied on recycling to manage debris from the earthquake. Although the city of Los Angeles did not have a plan for debris management prior to the earthquake, it quickly developed debris management procedures after the disaster. The city immediately developed contracts with existing businesses to recycle clean source-separated materials. City inspectors monitored contractors and kept records. By July 1994, the city was able to recycle 50% of the earthquake debris. By July 1995, the city was recycling over 86% of the debris collected. By the end of the program, the city had recycled 56% of all CDW. The city demonstrated that when sufficient recycling facility capacity exists, the maximum recycling rate of 86% can be achieved. The average cost of the recycling facilities was $21.55 per ton versus $24.92 per ton for disposal facilities, resulting in an average savings of $3.37 per ton.

Conclusions

Integrated waste management approach is very suitable to increase the performance of CDW management after disasters. Step by step application of integrated waste management approach for planning CDW management may provide tremendous benefits since largest fractions of CDW are highly reusable and/or recyclable (i.e., mineral waste, wood and metals). Technologies and procedures for reduction, reuse and recycling of CDW are well established and markets are available.

Disasters generate one-time very large amounts of CDW. This waste is difficult to quantify, characterize, collect, process and dispose by a fast, health-friendly and cost-efficient manner. Examined cases in this paper indicate that having a management plan based on integrated waste management is not only helpful in dealing with the waste professionally, also does reduce the overall disposal cost. Preparing the waste management plan before the disaster and implementing it immediately after further improves the success.



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An earlier version of this paper was presented at the Second Winter Meeting of the International Consortium on Interdisciplinary Education about Health and the Environment, Cologne, Germany, December 18-20, 2008.