

Maximizing Reuse and Recycling of Construction Materials

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The demolition of building structures produces significant amounts of materials that are for the most part landfilled. The total Construction and Demolition (C&D) waste in U.S. was estimated to be 154 Million Metric Ton (MMT) in 2003. As its primary purpose, deconstruction seeks to maintain the highest possible value for materials in existing buildings by dismantling buildings in a manner that will allow the reuse or efficient recycling of the salvaged materials. This paper intends to provide an overview of U.S. construction and demolition waste and includes sections on waste statistics, benchmark data, policies, and strategies to maximize reuse and recycling.

Key Words: Reduce, Reuse, Recycle, Deconstruction, Construction and Demolition Waste

Introduction

The construction industry uses more materials by weight than any other industry in the United States (Horvath, 2004). More than 40% of domestically extracted materials in U.S. are consumed by the construction industry and some estimates suggest that close to 90% of all materials ever extracted reside in today's buildings and infrastructure (NY Polystell, 2011). In addition, humankind will construct the same volume of buildings within the next generation as that which exists today (Dorman, 2011). If realized, this volume requires the use of massive amounts of materials. Whenever a building is constructed, it imposes loads on the environment in various forms namely: resources depletion and contamination of air, soil and water, etc. These loads are generated while various demands, such as materials and energy, are met to furnish the designed building. In addition, the construction industry contributes a large amount of waste to the municipal solid waste stream each year. The generated waste causes depletion of already diminishing natural resources, causes air and water pollution from waste that is improperly disposed of, and put pressure on premium landfill space.

The best approach to manage construction waste is to reduce waste and maximize reuse and recycling (see Figure 1). Deconstruction may be defined as the disassembly of structures for the purpose of reusing components and building materials. The primary intent is to divert the maximum amount of building materials from the waste stream. Top priority is placed on the direct reuse of materials in new or existing structures. Immediate reuse allows the materials to retain their current economic value. Deconstruction of buildings has several advantages over conventional demolition. It increases diversion rate of demolition debris from landfills, provides potential reuse and recycling of building components, preserves the invested embodied energy of materials by reducing the need for raw materials, and saves landfill space.

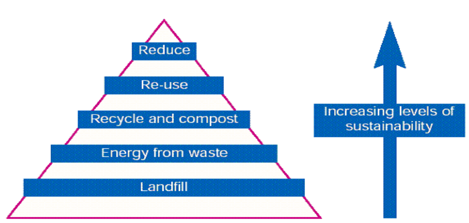

Figure 1: Waste Management Hierarchy

This paper intends to provide an overview of U.S. construction and demolition waste and includes sections on waste statistics, benchmark data, policies, and strategies to minimize waste and maximize reuse and recycling of construction materials.

Waste Statistics

The most thorough attempt to estimate the total tonnage of Construction and Demolition (C&D) waste was made by Franklin Associates in 1998 when they published their report for the U.S. Environmental Protection Agency (EPA). This report provided a reasonable estimate of tonnage of C&D waste generated by residential and non-residential demolition, renovation and construction for the year 1996 (Franklin, 1998). Chini and Bruening estimated the tons of C&D waste produced during the year 2000 by utilizing the U.S. Census information for the year 2000 combined with research statistics taken directly from the Franklin Associates Report (Chini and Bruening, 2005). EPA updated the 1996 report for the 2003 C&D waste statistics and published it in 2009 (EPA, 2009). Table 1 shows the total C&D waste generated for the years 1996, 2000, and 2003 and Figure 2 is a graphical representation of total wastes generated in these years.

Table 1

Estimated C&D Waste Generation in Million Metric Ton (MMT)

	Residential			**Non-residential**			**Totals**		
	1996	**2000**	**2003**	**1996**	**2000**	**2003**	**1996**	**2000**	**2003**
Construction	5.8	8.79	9.07	3.81	5.99	4.53	9.79	14.79	13.60
Renovation	28.93	34.50	34.47	25.40	30.19	29.93	54.34	64.69	64.41
Demolition	17.87	17.89	17.23	40.91	45.89	58.96	58.78	63.79	76.20
Totals	52.79	61.19	60.78	70.21	82.10	93.44	**122.92**	**143.24**	**154.22**

*Note. Each Metric Ton is 1.1 Ton

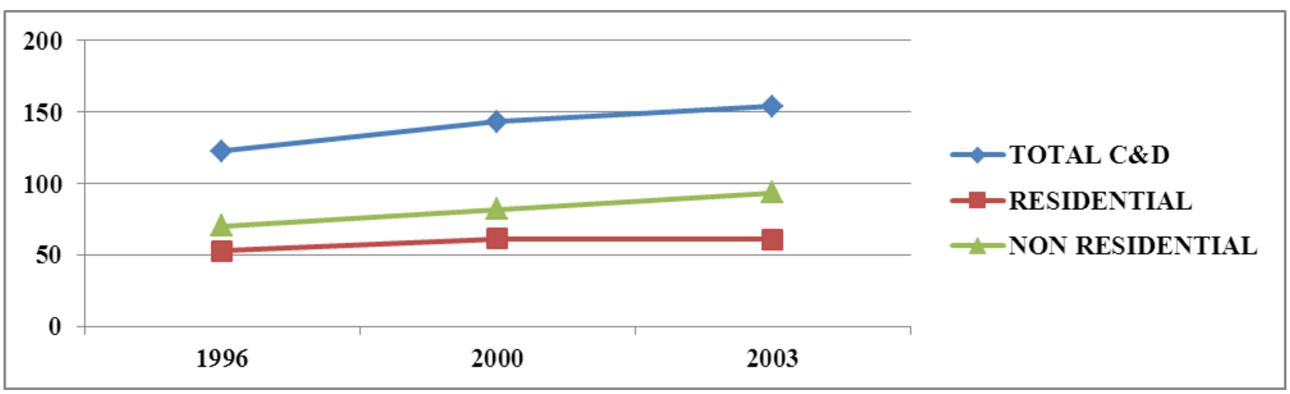

Figure 2: Total C&D Generated in US from 1996-2003 in MMT

Based on these statistics, renovation and demolition produced more than 90% of all C&D waste. This conveys the importance of recovering reusable and recyclable building components and materials. The EPA estimates that 35 to 45 percent of this waste is sent to municipal solid waste (MSW) landfills or unpermitted landfills, 20 to 30 percent is reused or recycled, and the rest is sent to C&D landfill (Franklin Associates, 1998). Using these percentages (see Table 2) more than 115 million tons of C&D waste generated in 2003 was landfilled. Of this, over 76.2 million tons resulted directly from demolition waste, which demonstrates the great potential of deconstruction for diversion of

C&D waste for reuse and recycling. Over 27% (by weight) of the waste that is generated from construction and demolition is wood, 23% asphaltic/concrete/brick/dirt, 13% drywall, 12% roofing, and 9% metal (MSW Factbook, 1997). The recovery rate for wood and concrete is close to 50%, for drywall 28%, and for steel near 85% (Chini, 2007).

Table 2

Estimated Quantities of Materials bounds for landfills and recovery (MMT in 2003)

	C&D Landfills (40%)	**MSW and Unpermitted Landfills (35%)**	**Recovered (25%)**	**Total**
Residential				
demolition	6.89	6.03	4.31	**17.23**
renovation	13.79	12.06	8.62	**34.47**
construction	3.63	3.17	2.27	**9.07**
Non-Residential				
demolition	23.58	20.64	14.74	**58.96**
renovation	11.97	10.48	7.48	**29.93**
construction	1.81	1.59	1.13	**4.53**
Total	**61.67**	**53.97**	**38.55**	

Franklin Associate data shown above assumed 21.4 Kg/m^2 (4.4 lb/ft^2) of waste generation for residential and 21.1 Kg/m^2 (4.3 lb/ft^2) for non-residential construction and used these values to calculate the total C&D waste generation based on the annual volume of construction in 2003:

- Volume of new residential construction $353 Billion
- Cost per m^2 of residential construction $833
- Total area of residential construction 424 million m^2
- Waste generation for residential 21.4 Kg/m^2
- ***Total waste for new residential construction 9.07 MMT***

- Volume of new non-residential construction $257 Billion
- Cost per m^2 of non-residential const. $1190
- Total area of non-residential const. 216 million m^2
- Waste generation for non-residential 21.1 Kg/m^2
- ***Total waste for new non-residential construction 4.53 MMT***

Demolition wastes were estimated based on 560 Kg/m^2 (115 lb/ft^2) for residential and 850 Kg/m^2 (174 lb/ft^2) for non-residential buildings and an estimate of number of demolished buildings in 2003:

- Number of residential demolitions: 240,000 units

- Average size of demolished residence: 128.5 m^2
- Estimated waste generation per m^2 560 Kg
- ***Total residential demolition waste*** ***17.23 MMT***

- Number of non-residential demolitions: 52,500 units
- Average size of demolished building 1,321 m^2
- Estimated waste generation per m^2 850 kg
- ***Total non- residential demolition waste*** ***58.96 MMT***

A different approach is to calculate the total C&D waste based on population. Using the annual volume of C&D waste collected from various landfills in each region and the population of that region, one can find the waste per capita per day using the following formula:

Waste in Kilogram per capita per day = (Annual Waste in MMT x 1000) / (Population x 365)

The estimated per capita per day C&D waste reported by several states and large cities ranges from 0.75 to 1.45 kilograms. Using the average per capita rate of 1.1 kilograms and U.S. population the total waste generated in each particular year can be calculated:

1. Total waste generated in 1996
   Population of U.S. in 1996 = 266,490,000
   Total C&D Waste generated in 1996 **= 107 MMT**

2. Total waste generated in 2000
   Population of U.S. in 2000 = 281,421,900
   Total C&D Waste generated in 2000 **= 113 MMT**

3. Total waste generated in 2003
   Population of U.S. in 2003 = 294,043,000
   Total C&D Waste generated in 2003 **= 118 MMT**

Estimated total C&D waste generation in 1996, 2000, and 2003 using per capita method above are 13%, 21%, and 23%, respectively less than the C&D waste calculated based on annual volume of building construction. The latter approach (Franklin and Associate) is more accurate because it is based on actual volume of new construction, renovation, and demolition. The per capita method is indirectly related to volume of construction and does not include direct reuse or illegal landfill in rural areas. However, it provides large communities such as counties and local municipalities a practical way in estimating the volume of C&D waste generation in their region.

Benchmarking

One activity that can promote waste reduction is to establish benchmarks for waste production linked to construction activity, for example typical wastage rates due to demolition. This enables targets to be set for improvement and waste reduction can then be measured. Based on the data from various sources throughout U.S. summarized in previous section one can establish benchmarks for current practices for waste generation on a site for residential or non-residential buildings. The Franklin and Associates data of 21Kg/m^2 (4.3 lb/ft^2) of waste generation for residential and non-residential construction was used as current practice. Similarly for demolitions waste the

Franklin and Associates estimate of 560 Kg/m^2 (115 lb/ft^2) for residential and 850 Kg/m^2 (174 lb/ft^2) for non-residential buildings were adopted as current practices. Table 3 shows these benchmarks.

Table 3

Benchmarks of Kg/m^2 for current practices

		CURRENT PRACTICE
RESIDENTIAL	Construction	21
	Demolition	560
NON- RESIDENTIAL	Construction	21
	Demolition	850

Public Policy

Although the federal government has largely avoided any effort to set construction and demolition waste recycling rate targets, many states and smaller jurisdictions have active programs that encourage construction and demolition waste recycling.

California adopted a legislation in 1989 that required counties to recycle 50 percent of their waste streams. With C&D waste material making up such a large percentage of those streams, it did not take long for county and city officials to begin devising C&D recycling initiatives. In Sonoma County, California C&D waste loads that have not been sorted for recyclables must pay a 25 percent surcharge for the county to handle resorting (Taylor, 2007). In 2010 the California legislature passed The California Green Building Standards Code which, among other requirements, mandates that any new building constructed after January 1, 2011 be required to divert at least 50% of construction waste. City of Oakland requires contractors to submit a job-site recycling and waste reduction plan along with their initial bids to the city (City of Oakland, 2011). The contractor that wins the bid must also submit required reports prior to receiving the final payment. In San Jose, contractors have the option of bringing material to one of more than 20 city-certified facilities that are expected to meet pre-determined recycling rates (City of San Jose, 2011). The City Council in Irvine requires builders of large projects (more than one residential unit; nonresidential structures measuring 5,000 square feet or more and nonresidential properties that are 10,000 square feet or more) to submit recycling plans. Companies will have to pay a material diversion deposit to the city that will be refunded after the project is complete. At least 75 percent of concrete and asphalt and 50 percent of other construction and demolition debris must be taken to material recovery facilities for a company to get its deposit back (City of Irvine, 2011).

The Commonwealth of Massachusetts bans certain materials from its landfills to obtain an 88 percent statewide recycling rate by 2010. In mid 2006 a ban on the disposal, or transfer for disposal, of asphalt pavement, brick, concrete, wood, metals and old corrugated containers became the rule in Massachusetts. The state's Department of Environmental Protection singled out those materials based on a belief that healthy recycling markets existed for all of them. The goal is to add additional C&D materials such as gypsum wallboard, asphalt shingles, carpet and ceiling tiles in the future (Taylor, 2007).

The regional government for the Portland, Oregon approved construction and demolition recycling legislation that went into effect in 2009. The policy requires mixed loads of C&D debris to be sorted for recyclables prior to dumping, leaving no more than 15 percent recyclables in the remaining material. The regulation is part of the overall plan to increase recycling rates in Oregon to 64 percent by the end of 2009. It is anticipated that this policy will keep an approximate 33,000 tons of construction and demolition waste out of landfills in the Portland, Oregon, enough to boost the overall recycling rate by 1.25 percent (Taylor, 2007).

Strategies to Maximize Reuse and Recycling

In order to maximize reuse and recycling various steps should be taken by the states, the local governments, and the project owners. Some of these steps have already been implemented in some regions and have been successful in reducing waste and increasing reuse/recycling of construction materials.

- Establish a mandatory recycling policy when the cost of a project exceeds certain value. For example, city of Chicago adopted an ordinance requiring a certain percentage of construction and demolition waste to be recycled — 25 percent for projects that had a permit issued in 2007, and 50 percent if the permit is issued in 2008 (Martin, 2007).

- Mandate each project to have a construction waste management plan that requires involvement of designers, manufacturers, and builders. This includes:
  - set up waste management requirements in the project specifications
  - assess probable weight of C&D waste to be generated on the project along with the weight of such materials that can feasibly be diverted via reuse or recycling
  - consult local recyclers for and directly involve them in the process
  - work with manufacturers and suppliers for reverse distribution (collection of damaged and unused materials and taking them back to the supplier or manufacturer)
  - provide waste management training for all supervisors, subcontractors and workers
  - Emphasize clean site by continuous cleanup and end of day wrap-up

- Provide tax credit and other incentives:
  - provide sales tax exemptions for recycling equipment
  - provide tax credits for donation of salvaged building materials
  - provide tax incentives to businesses that recycle
  - support reuse centers by providing below market rents on publicly owned warehouse space or selling public space to reuse stores for below-market value

- Increase the tipping fee for disposal of C&D waste which would encourage recycling and reuse. The Figure 3 shows recycling rate (in percentage) as a function of tipping fee (in dollar/ton).

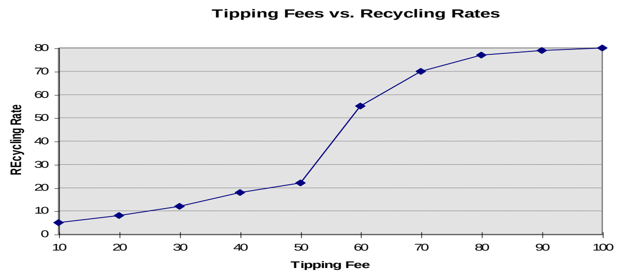

Figure 3: Tipping Fees vs. Recycling Rates

- Offer Deconstruction Permitting that allows for the additional time that deconstruction requires and reduces fees relative to those charged for demolition permits. Permit fees could be calibrated to the amount of materials recovered.

- Upgrade U.S. Green Building Council's LEED rating system. The standards could be further strengthened by prioritizing reuse over recycling. It could offer more points for materials reuse. Currently LEED-NC offers just one point for reusing building materials. Moreover, the reuse section of the LEED standards for new construction and major renovations could be strengthened to include a percentage of reused materials above the current 5 to 10 percent. Additionally, USGBC can be an important partner in providing information and resources on reuse.

- Fund research projects on C&D waste issues and opportunities

- Increase awareness of deconstruction by:
  - carrying out training seminars for deconstruction and materials reuse/recycling
  - publicizing the organizations/businesses in building materials recovery and reuse (for example, distributing information about them at mortgage closings and through internet websites)

Case Studies

Orange County North Carolina

In Orange County, North Carolina, an ordinance was passed in 2002 which requires the recycling of specific materials along with plans for an additional C&D landfill. Those requesting building permits are required to apply for a "Recyclable Material Permit". This ordinance resulted in decreased tipping fee revenues. However, the reduced revenue has been partially offset by sales of recyclable material. The important impact on the C&D waste stream was the significant reduction in waste and the increase in the recycling of material, as shown in Table 4.

State Offices at Butterfield Way, Sacramento, CA

The site work construction phase for these 80,000 square meter office buildings realized considerable financial benefits from recycling demolition debris and the project team achieved 99.6% (by weight) waste diversion rate for this phase. This former industrial site composed of over 20 acres of old asphalt parking lots, concrete, and trees. Sixty-nine percent of demolition waste (over 13,605 metric tons) was recycled, stored and reutilized on-site by the contractors saving $104,000 (see Table 5). These savings resulted from eliminated tipping fees, and a reduction in road base and landscape mulch materials the project would have needed to purchase.

Table 4

Construction Waste Disposed and Recycled in Orange County, NC

	FY 2001 / 2002	FY 2002 / 2003
Disposed (at solid waste facility)	25,150 Metric tons	17,310 Metric tons
Disposed (elsewhere)	6,668 Metric tons	6,380 Metric tons
Subtotal	**31,818 Metric tons**	**23,690 Metric tons** (26% reduction)
Recycled (at solid waste facility)	996 Metric tons	3003 Metric tons
Recycled (elsewhere)	0 tons	6,034 Metric tons
Subtotal	**996 Metric tons**	**9037 Metric tons** (9-fold increase)

Note. SOURCE: http://www.recyclecddebris.com/rCDd/Resources/WasteStudy/Chapter05.aspx, VISITED ON 1/17/2012

Table 5

Site Work Recycling Efforts for State Offices at Butterfield Way, Sacramento, CA

Description	Wood/ Green Waste	Concrete	Asphaltic Concrete	Misc. Const. & Land Clearing	TOTALS
C&D Waste (cubic meter)	918	1,911	6,269	278	9,376
Equiv. Metric Tons	270	4,500	14,760	83	19,613
Recycled On-Site	100%	20%	84%	0%	69.20%
Recycled Off-Site	0%	80%	16%	0%	30.40%
Total Recycled by Weight	100%	100%	100%	0%	99.60%
On-Site Recycling Cost	$15,000	$4,269	$158,319	$0	$177,588
Off-Site Recycling Cost	$0	$6,820	$16,693	$0	$23,513
Landfill Costs	$0	$0	$0	$3,396	$3,396
Avoided Material Costs	$11,880	$14,000	$192,864	$0	$218,744
Net C&D Recycling &Disposal Cost	$3,120	$2,911	$17,852	$3,396	$14,247
Potential 100% Disposal Costs	$12,000	$17,500	$57,400	$3,396	$90,296
Total Recycling (Savings)	$8,880	$20,411	$75,252	$0	$104,543

Note. SOURCE: http://www.ciwmb.ca.gov/ConDemo/CaseStudies/DGSDiversion.pdf, VISITED ON 1/17/2012

Conclusions

Maximizing reuse and recycling of construction waste materials preserves their invested embodied energy, reduces the need for raw materials, and saves landfill space. The key issues to drive forward waste reduction and increase reuse/recycling are: providing accurate C&D waste data, establishing benchmarks for waste production linked to construction activities, mandating a minimum percentage of recycling for generated C&D waste, and creating a market for recycling by means of economic instruments like tax credit for recycling and higher disposal fee for waste. An effective approach is to use power of contract and require involvement of designers, manufacturers, and builders in development of a waste management plan. Other elements of a good waste management practices are requiring manufacturers and suppliers to take back damaged and unused materials, providing waste management training for all supervisors and workers, and maintaining a clean site.

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