Demolition (far left) constitutes nearly half of all building related C&D debris, whereas new construction (left) is estimated by EPA to be the smallest sliver, primarily containing "cut-offs" and leftovers versus remains of buildings.

SURVEY STATISTICS

ANALYZING WHAT'S RECYCLABLE IN C&D DEBRIS

Data compiled by EPA staff will help guide programs to recover the concrete, wood and drywall that comprise between 65 and 95 percent of the C&D waste stream.

Ken Sandler

CONSTRUCTION and demolition (C&D) debris keeps rising higher on the national radar screen, but sorting out the data is a tricky task. Here at the Environmental Protection Agency in Washington, D.C., we took our first stab at analysis in 1998, with the *Characterization of Building-Related Construction and Demolition Debris in the United States*. Lacking survey data, we aimed at extrapolating national estimates of building related C&D debris by multiplying numbers of buildings being constructed or demolished (based on permits issued) by amounts of debris estimated to be generated per square foot (based on waste composition studies that had been performed at various sites). Renovation figures were derived from estimates of consumer and business spending on specific remodeling and replacement activities.

While this methodology yielded a good snapshot of the overall national picture, it was not designed to provide much of a close-up on the finer details of the C&D debris stream. In particular, this methodology did not enable us to say what percentages of the total consist of which materials. This has limited our ability to figure out how much of each C&D material is currently being recovered or disposed and to estimate how much has the potential to be recovered.

In this article, we have aimed to take our analysis to the next step, by estimating the material composition of total building related C&D debris generated annually. Due to the fragmentary nature of the information available, our analysis is a patchwork, bringing together results of the following: C&D debris composition studies with EPA tonnage estimates for each of the C&D sectors; information from industries and experts representing the major materials in C&D; and the few state and local governments that have analyzed their C&D debris streams. All debris estimates are by weight. Table 1 presents the data as a percentage of the total.

UNDERSTANDING THE C&D FAMILY

Before tackling the issue of materials, it is important to distinguish the sectors underlying C&D debris. Rather than a monolithic stream, C&D debris should be understood as a family of waste streams, and — as with many families — despite some resemblance between the members, each has its own quirks. Hence, analyses of C&D debris will come out differently depending upon the extent to which they favor or exclude one or another side of the "family."

The broadest definitions of C&D debris — including the official definitions of some states — include not just waste from the construction, renovation and removal of buildings, but also *infrastructural debris* — from the construction and demolition of roads, bridges and other nonbuilding structures; and *land-clearing debris* — from the clearing of rocks, trees, dirt, etc. from sites to prepare them for construction. EPA's efforts at characterization, research and fostering more reuse and recycling to date have targeted *building related debris*, which is also the focus of this article.

But even within the universe of building-related C&D debris, there are variations worth noting. New construction, renovation and demolition activities each produce different waste streams, and within these cate-

Table 1. Building related C&D debris generation: Estimated percentages by material

Material	*Estimated Building Related C&D Debris Generated Annually(%)*
Concrete and mixed rubble	40-50
Wood	20-30
Drywall	5-15
Asphalt roofing	1-10
Metals	1-5
Bricks	1-5
Plastics	1-5

Due to the large size of existing building stock and continual efforts to keep it up-to-date, C&D generated by renovation is estimated to constitute over 40 percent of the total stream.

gories, residential and nonresidential buildings add additional complexities. Here, in quick brush strokes, is a family portrait:

1) *New Construction:* EPA estimated this to be the smallest sliver of the C&D debris stream, containing "cut-offs" and leftovers from the construction process rather than the remains of buildings or their components. Residential construction debris is dominated by the presence of wood and drywall. We have less data on the composition of nonresidential construction debris.

2) *Renovation:* Just take a stroll through your local hardware superstore to see the multitude of items that could end up in renovation debris. This is a waste stream generated by countless renovation contractors and do-it-yourselfers, sharing the characteristics of both new construction and demolition wastes. Due to the large size of our existing building stock and continuing to keep it up-to-date, this waste stream was estimated to constitute over 40 percent of total C&D debris. It is a diverse waste stream, owing to the many different types of remodeling, e.g., alterations and replacements to driveways, roofs, kitchens, heating, ventilation and air conditioning equipment, etc. Once again, we have less data on the nonresidential side of the equation.

3) *Demolition:* Constituting nearly half of all building related C&D debris, waste from building removals serves as a kind of time capsule. One can follow building trends over the past century through the demolition debris stream. For example, materials that have been more widely used only in the last few decades, such as drywall and chromated copper arsenate-treated wood (now being phased out of production), will continue to increase their share of the C&D debris stream as buildings built since the 1950s reach the end of their life spans. Wood, concrete and drywall are the primary wastes found in residential demolition debris, while nonresidential debris is dominated by concrete and mixed rubble.

Data gaps aside, it is clear from nearly every source that three materials stand at the top of the heap: concrete (including mixed rubble), wood and drywall. A close-up of each of these waste streams, and a brief discussion of the other materials in the waste stream, follows.

CONCRETE — LARGEST COMPONENT

Of the big three, concrete appears to be the largest component. If one combined infrastructural and building related C&D debris, concrete would almost certainly be the dominant material, due to the vast amounts used in highways and other civil engineering projects. In fact, the Construction Materials Recycling Association (CMRA) has estimated that construction recyclers annually recover over 100 million tons of concrete. This number combines building related and infrastructural C&D debris; unfortunately, it comes without the context of estimates of total waste concrete generation, an overall concrete recycling rate and a break down of concrete generation and recycling between building and infrastructural sources. Regarding the recycling rate for concrete, estimates have placed it from 50 to 57 percent. Combining the mid-point of these estimated recycling rates with the estimate of total concrete recycled would put total concrete debris at about 200 million tons.

How much of that comes from buildings? One approach to estimating such a figure would be to compare the percentages of concrete generated at waste sorts at residential and nonresidential construction, renovation and demolition sites (reported in EPA's C&D Characterization Report) with the tons of total building-related C&D debris estimated to come from these different sectors. (In sectors where no waste sorts were available, we assumed percentages based on comparisons with the other sectors.) This method yields the following estimates for concrete composition of C&D debris:

Residential construction debris: 5 percent of 6.6 million tons or 0.3 million tons/year; Nonresidential construction: 5 percent (assumed) of 4.3 million tons or 0.2 million tons/year; Residential renovation: 13 million tons/year (from driveway replacements); Nonresidential renovation: 35 percent (assumed) of 28 million tons or 9.8 million tons/year; Residential demolition debris: 33 percent (weighted average of single and multifamily residential) of 19.7 million tons or 6.5 million tons/year; and Nonresidential demolition debris: 66 percent of 45.1 million tons or 29.8 million tons/year.

This exercise leads to a total estimated building-related concrete waste stream of 59.6 million tons, or 44 percent of the total building-related C&D estimate of 135.5 million tons. Clearly, the driver here is nonresidential demolition debris — not surprisingly, as one would expect the demolition of office buildings to yield a high volume of concrete. It is also a factor in residential remodeling and demolition debris (e.g., of foundations and driveways). It is barely significant in new construction, as, according to the Portland Cement Association, concrete that is measured on-site may be tailored to meet project needs, and leftover amounts can be mixed into new concrete or used as clean fill on the site.

Interestingly, some state and local governments that have tried to estimate the material breakdown of their C&D debris streams — such as California and King County, Washington — have found concrete to be secondary to wood. We believe that this is due to the fact that these estimates measured the amount of debris going to their landfills, in which case the apparently higher recycling rate for concrete has decreased the amount, and hence the percentage of this material being disposed. Lower *disposal* rates for concrete do not prove lower *generation* rates. (Florida, where most homes are concrete block rather than wood-frame, not surprisingly found concrete to constitute more than half of its C&D debris stream.)

WOOD IS EVERYWHERE IN C&D

Wood is ubiquitous in the C&D debris stream. For one thing, the vast majority of

homes in the United States are wood-framed. But there are also copious amounts of wood used in flooring, paneling, siding, roofing, cabinetry, decking, etc.

Probably the best estimate of C&D wood debris generation came from David B. Mc- Keever of the USDA Forest Products Laboratory in the December 1999 issue of *BioCycle* ("How Woody Residuals are Recycled in the United States"). For new construction and remodeling debris estimates, McKeever combined waste generation rates per unit of wood used with estimates of wood products consumed; he based his demolition debris estimates on percentages of wood sent to C&D landfills. His generation figures for 1998 were: Residential construction: 3.4 million tons/year; Residential renovation: 4.3 million tons/year; Nonresidential construction and renovation: 1 million tons/year; and Nonresidential and residential demolition debris: 26.4 million tons/year.

Summing all of these amounts led him to a total estimate of C&D wood debris of 35.1 million tons, or nearly 26 percent of the total C&D debris stream. By comparison, multiplying the percentage of wood found in waste sorts cited in EPA's report times the total amounts of waste per C&D sector yields a lower number, about 27.6 million tons, or 20 percent of the total, broken out as follows:

Residential construction debris: 54.5 percent of 6.6 million tons or 3.6 million tons/year; Nonresidential construction: 15 percent (assumed) of 4.3 million tons or 0.6 million tons/year; Residential renovation: 5.2 million tons/year (based on estimates of 1.4 million tons of wood roofing debris plus an assumed 42 percent of 9 million tons of estimated waste from kitchen and bath remodeling and additions); Nonresidential renovation: 15 percent (assumed) of 28 million tons or 4.2 million tons; Residential demolition debris: 34.5 percent (weighted average of single family and multifamily debris) of 19.7 million tons or 6.8 million tons/year; and Nonresidential demolition debris: 16 percent of 45.1 million tons or 7.2 million tons/year.

The largest discrepancy between these two estimates comes in the category of wood in demolition debris, which McKeever estimates at a significantly higher percentage. As discussed above, we believe that C&D landfill disposal estimates probably overstate wood percentages and understate concrete percentages due to apparently higher recycling rates for concrete. Therefore, the lower number is probably more accurate. However, our approximation that wood constitutes 20 to 30 percent of building-related C&D debris would encompass both estimates.

Our approximation is that wood constitutes 20 to 30 percent of building-related C&D debris.

DRYWALL IN NEW CONSTRUCTION

Of the big three, drywall is clearly the new kid on the block — having become the dominant interior finish system only since the 1950s. As a result, drywall is a larger presence in new construction and remodeling debris than in demolition debris — although demolition debris percentages are sure to grow in the coming decades. Also known as wallboard, gypsum board or sheetrock, drywall is generally composed of about 85 to 90 percent gypsum and 7 to 15 percent paper.

There was a highly informative Master's Thesis completed at the University of Florida by Allison Barnes entitled "Feasibility of Recycling Scrap Gypsum Drywall from New Construction Activities in Florida" in May 2002. Because this thesis added more waste composition studies to those mentioned in the EPA report, her estimates of percentages of drywall in the C&D construction and renovation debris stream are used, except for residential renovation, for which the EPA used a unique methodology. No estimates were provided for demolition debris, and the demolition waste sorts generally did not break out drywall debris (some of it is likely caught in the "miscellaneous" or "mixed rubble" categories). Applying these percentages to the amounts of debris estimated to be produced under the different sectors yields the following estimated amounts of drywall debris per sector:

Residential construction debris: 21 percent of 6.6 million tons or 1.4 million tons/year; Nonresidential construction: 8 percent of 4.3 million tons or 0.3 million tons/year; Residential renovation: 20 percent (assumed) of 9 million tons of kitchen and bathroom remodeling projects and additions or 1.8 million tons/year; Nonresidential renovation: 34 percent of 28 million tons or 9.5 million tons/year; Residential demolition debris: 5 percent (weighted average of single and multifamily residential) of 19.7 or 1 million tons/year; and Nonresidential demolition debris: zero percent of 45.1 million tons or 0 million tons/year.

Summing these figures yields an estimated total of 14 million tons, or about 10 percent of all building-related C&D debris. This is not too far off from the percentages that states have reported in their waste streams — e.g., 10 percent in California, 11 percent in Florida. Unfortunately, it is quite far off from the estimate provided by the U.S. Geological Survey of "more than 4 million tons of gypsum waste generated every year by wallboard manufacturing, wallboard installation, and building demolition." The USGS estimate would put drywall waste at only 3 percent of total building related C&D debris, less than the percentage found in almost any of the waste sorts cited in EPA's report or Allison Barnes' thesis. Considering the uncertainties in the data, we estimate that drywall equals about 5 to 15 percent of the building related C&D debris stream.

"THE OTHER STUFF"

Of the remaining materials, asphalt shingles are probably the most prominent. ShingleRecycling.org, a website funded by EPA and developed by the CMRA and University of Florida, estimates that 11 million tons of asphalt shingles are generated and disposed annually. As 11 million tons equals 8 percent of the total building-related debris stream, EPA staff estimate shingle waste at one to 10 percent of C&D debris.

Metals — including aluminum, steel, copper and others — show up in single-digit per-

Wood is ubiquitous in the C&D debris stream, not only because the majority of homes in the U.S. are wood-framed, but also because copious amounts are used in flooring, paneling, siding, roofing, cabinetry and decking.

centages in construction, renovation and demolition debris composition studies. Bricks show up in some waste sorts of residential new construction debris, multifamily and nonresidential demolition debris, at levels of one to 14 percent. Plastics – including carpets and padding, vinyl products, plastic piping, etc. — showed up only in residential new construction debris waste sorts, but are sure to grow in the other waste streams as well. Therefore, we have estimated metals, plastics and bricks were each in the one to five percent range. Other materials showed up too rarely to be mentioned.

Despite many information gaps and uncertainties, the data seem clear enough to generalize at least to the level presented in this article. We hope that others can both learn from and build on what is presented here to continue to sharpen our still blurry picture of C&D debris. Doing so will help governments and institutions at all levels to better plan for and coordinate the management of C&D debris, and particularly to guide our efforts to increasingly reduce and recover these materials. ■

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