Third International Conference on Construction in the 21st Century (CITC-III)
"Advancing Engineering, Management and Technology"
15-17 September 2005, Athens

Enhancing Construction Materials Recyclability

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Abstract
The demolition of building structures produces enormous amounts of materials that in most countries results in a significant waste stream. Deconstruction is emerging as an alternative to demolition around the world (Kibert and Chini, 2000). Deconstruction is the systematic taking apart of the building for the purpose of materials reuse as opposed to destructive demolition. As its primary purpose, deconstruction seeks to maintain the highest possible value for materials in existing buildings by dismantling in a manner that will allow the reuse or efficient recycling of the materials that comprise the structure. While the process of demolition often leads to the mixing of various materials and contamination of non-hazardous components, deconstruction helps to preserve and reuse materials. This paper is an overview of current practices in recycling of construction materials in the US and shows how deconstruction increases material recyclability by creating the opportunity for material reuse and upcycling, whereas demolition promotes downcycling and landfilling (Chini, 2005).

Keywords
Recycling, Upcycling, Downcycling, Deconstruction, Closed-loop

1. Introduction

In a perfect world, the term recycling would describe a process in which raw materials achieve an endless useful life. Each conversion for reuse of the material would have future reuse possibilities designed in. Michael Braungart, of McDonough Braungart Design Chemistry, describes this process, "Korean rice husks used as packaging for stereo components are now being reused as building insulation. After use as insulation, the rice husks can be used again as bricks" (Cannell, 2000). It is true that nothing can be used forever. The passing of time eventually renders all materials useless. However, the concept of an endless useful life potential for raw materials is achievable. "Closed-loop" recycling should be the end goal of the recycling industry in order to maximize the usefulness of virgin materials and minimize the necessity to extract them.

Currently, the recycling of materials frequently does not allow for future use of the material after the initial conversion. When lumber extracted from deconstruction or demolition site is ground into mulch and poured into somebody's back yard, the materials useful life is extended and that quantity of virgin materials is preserved. However, the possibility for future use after that is virtually eliminated. Processes such as this, which we usually call recycling, are not actually recycling at all. The process of reducing a raw material's quality, potential for future uses, and economic value, is called downcycling. The process of reusing a material for similar uses, thus maintaining the possibility for reuse again later, is recycling. The process of increasing the material's quality, potential for future use, and economic value is called upcycling.

1.1 Downcycling

Downcycling currently holds an important position in our society. Most forms of recycling today are actually down-cycling. Currently, the technology is not available to recycle most products in such a manner that they are not degraded in some way. As long as this is the case, downcycling will be the best means of maximizing the useful life of raw materials and minimizing extraction of virgin materials. The recycling of paper, on the surface, appears to be a closed-loop cycle. In reality, however, it is not. Inks cannot be reused and are disposed of as waste sludge. The paper fibers are reduced in length and their strength is reduced. New fibers must be added to reinforce the paper's strength. Thus it is not a closed-loop recycling system. Downcycling should be the last option in the recycling contingent. Whenever possible, techniques utilizing a higher level of sustainability should be incorporated. The following section, *Recycling Issues for Specific Materials*, will look at some specific examples of downcycling construction materials.

1.2 Upcycling

Upcycling, as stated earlier, is a process in which the material's quality, potential for future reuse, and economic value is increased during the conversion process. Upcycling maximizes the lifecycle of raw materials. The above mentioned example of the Korean rice husks exemplifies the upcycling ideology. The husks are used as packaging material, a low value product. From there they are used in building insulation, a slightly higher value product. And from that point they become bricks, an even higher value product. Additionally, the bricks have the potential for further recycling down the road. The value of the raw material, the rice husks, is increased for us, the users of the material, at every stage. Upcycling is the ideal form of conversion of materials for reuse due to its high level of environmental and economic impact. The following section addresses some specific examples of upcycling of used building materials.

2. Recycling Issues for Specific Materials

Nearly all building materials have the potential for reuse following their initial useful life. Although reuse possibilities are available for building materials following demolition, deconstruction maximizes this potential because it allows these materials to be recovered with the least possible amount of damage. Additionally, the organizational nature of deconstruction involves sorting separate materials, which further facilitates reuse opportunities. Wood, steel, concrete, carpet, brick, plastics, and drywall all have high reuse potential.

2.1 Wood

Every year in the United States over 42 billion board feet of lumber gets dumped into landfills (Recycled Wood, 2003). Reuse of wood recovered from demolished and deconstructed buildings is an important means of reducing this landfill burden. It is estimated that for every 2,000 square feet of wood floor recovered, an estimated 1 acre of woodland is spared from being cleared (Recycled Wood, 2003). With the exception of scrap steel, wood products have the highest recoverability level of any building materials. This is due to the large amount of recoverable wood in the deconstruction and demolition market. Additionally, the ways in which wood can be reused are numerous (Chini and Nguyen, 2003).

"The spectrum of wood-based waste that might be converted to housing products includes full-sized used lumber salvaged from razed buildings, wood resulting from building demolition, old wooden pallets, scrap wood from new construction sites, preservative-treated wood waste from treating facilities and building construction, old wooden utility poles of railroad ties, wastepaper, yard trimmings, and wood fiber found in the sludge produced by paper mills" (Recycled Wood, 2003). This proliferation of available materials makes wood products an important piece of the waste diversion puzzle. Wood products can be recycled for direct reuse in similar applications, they can be downcycled into mulch, or they can be upcycled into more valuable items, such as custom cabinetry or furniture.

Many wood products can be recovered and reused directly, with little or no processing necessary. Currently, recovered structural timbers are in high demand in the United States because of their lack of availability from any other source. Virgin stocks were overexploited during the years of heavy logging and have yet to recover. People value the timbers for their aesthetic quality and historical significance. Additionally, dimension framing lumber can be recovered and reused as is. The market for recycled dimension lumber is still a fledgling industry. The reuse applications for recovered lumber are currently limited due to a lack of standardized grading requirements. This should change with the establishment of grading requirements. Once the structural uses of recovered dimension lumber are established, the demand will increase exponentially. Reusing recovered wood products in similar applications extends the lifecycle of the product because it maintains the potential for further recycling down the line. The following table looks at Centennial Recycled Wood Products, LLC, a salvaged wood retailer.

Wood products can be upcycled into more valuable products. This is often the ideal situation because it maintains the recyclability of the product while increasing its economic potential. An example of upcycling wood products includes the conversion of recovered framing lumber into custom cabinetry, furniture, or wood flooring.

Downcycling of wood products involves decreasing the future recyclability and economic potential of the wood. For example, most scrap wood from demolition is sent through a grinder and turned into mulch. This eliminates the possibility of further recycling of the wood at a later date and diminishes its economic value. The markets for downcycled wood products include mulch, fibers for manufacturing, animal bedding, and biomass. The following discusses B&B Bedding of Oskaloosa, Iowa, a wood waste processor.

Downcycling of wood products should be the last option when considering reuse possibilities because it degrades the material. However, downcycling is an important nitch in the recycling industry. Many used wood products have no available reuse options. Downcycling this wood serves to divert it from the waste stream and create supply for the mulch, biomass, and animal bedding markets.

2.2 Concrete

Currently, applications for used concrete involve downcycling the materials for use as a lower quality product. For example, concrete can be crushed up into a small aggregate and used in asphalt or new concrete. Currently, no commercial uses of recovered concrete involve upcycling of the material to a higher quality material with high future recyclability. The table below examines the use of recycled concrete at Ball State University.

2.3 Steel

The North American steel industry is far ahead of any other building material industry in its use of recycling to conserve raw materials and create economic opportunity. "Each year, steel recycling saves the energy equivalent to electrically power about one-fifth of the households in the United States for one year and every ton of steel recycled saves 2,500 pounds of iron ore, 1,400 pounds of coal, and 120 pounds of limestone" (Steel Recycling Institute, 2003). The steel industry's overall recycling rate is nearly 68% (Steel

Recycling Institute, 2003). This includes the recycling of cans, automobiles, appliances, construction materials, and many other steel products. All new steel products contain recycled steel.

There are two processes for making steel. The Basic Oxygen Furnace process, which is used to produce the steel needed for packaging, car bodies, appliances and steel framing, uses a minimum of 25% recycled steel. The Electric Arc Furnace process, which is used to produce steel shapes such as railroad ties and bridge spans, uses nearly 100% recycled steel (Steel Recycling Institute, 2003). Every steel product contains recycled steel in it, which helps to close the recycling loop.

2.4 Brick

The preferred method of recycling used bricks is to remove them undamaged and reuse them directly. The only current method used commercially to enable used bricks to be made suitable for reuse in their original form involves cleaning the old mortar from the bricks by hand (Cardiff, 2003). A small blunt hand axe can be used to knock the mortar from the bricks. The problem with this is that it is extremely difficult to remove modern Portland cement based mortar from bricks using the technique described above. Thus only old bricks are generally cleaned and recycled by this method (Cardiff, 2003). There are however, studies in progress involving the use of pressure waves to break the bond between the mortar and the bricks. This may become a viable solution and create more brick recycling opportunities in the near future. The following table lists some advantages of reuse of salvaged bricks.

There are currently studies ongoing concerning the use of crushed brick in road base. The results have been inconclusive to this point.

2.5 Asphalt Roof Shingles

Between 8 and 12 million tons of roofing shingles are manufactured annually in the U.S. (Schroeder, 1994). Around 65 percent of these shingles are used for re-roofing. Thus, between 5 and 8 million tons of old waste shingles are produced annually (Schroeder, 1994). Currently, the most practical use for used asphalt roof shingles involves grinding up cuttings to be used in asphalt road paving. Though this is a form of downcycling of the material, it manages to divert material that would otherwise be headed for the landfill. The following case study examines the use of recycled roof shingle clippings in roadwork in the state of Minnesota.

Case Study: Use of Recycled Roof Shingles in Roadways in Minnesota (Schroeder, 1994)
Benefiting from a public-private partnership between local asphalt producer Bituminous Roadways and the Minnesota Office of Environmental Assistance, Minnesota road crews are using a 5% roofing shingle byproduct in hot-mix asphalt. This recycled aggregate reuses the cuttings from shingles composed of paper or fiberglass mat. The resulting high performance asphalt is suitable for a variety of residential paving and reconstruction applications. Used roofing (tear-off) shingles are not yet allowed in these applications.

2.6 Carpet

The United States carpet industry produces about 1 billion square meters of carpet per year. Of this approximately 70 percent is used to replace existing carpet; this translates into 1.2 million tons of carpet waste produced annually (Schroeder, 1994). Most carpet is downcycled by being ground up and used as a component in other products (i.e. building insulation, asphalt pavements, and Portland cement concrete). The following case study examines BASF's use of upcyling to increase the recyclability and economic value of used carpet.

Case Study: BASF Savant – Upcycling Carpet Fiber (Braungart, 2003)
In the 1990's BASF developed a carpet material called Savant, made from nylon 6 carpet fiber. Nylon 6 carpet fiber is a material that can be easily depolymerized into its precursor, caprolactum. The heat used in this process can be largely recovered, and caprolactum, in turn can be re-polymerized and made again into nylon 6, thus creating a closed-loop recycling process. Because it is made of this nylon 6, Savant can be recycled and used again and again. In response to this technology, BASF has created a carpet take back program in order to recover old nylon 6 carpet. Rather than being downcycled into a material with less value, the used nylon is upcyled into a product of greater quality.

2.7 Plastics

Plastics recycling is now an established national industry. According to the 2000 State of Plastics Recycling, nearly 1700 companies handling and reclaiming post-consumer plastics were in business in 1999. This was nearly six times greater than the 300 companies in business in 1986. The primary market for recycled PET bottles continues to be fiber for carpet and textiles and the primary market for recycled HDPE is bottles. However, a recently updated *Recycled Plastics Products Source Book* lists over 1,300 plastic products from recycled content, including waterproof paper products and even plastic lumber for structural applications. New ASTM (American Society for Testing and Materials) standards are paving the way for plastic lumber that could be used in framing, railroad ties, and marine pilings (State of Plastics Recycling, 2003). The use of recycled plastics for such applications could mean longer life and less maintenance, which translated to lower cost over the life of the product.

The limiting factor in the plastic recycling industry is currently the supply of raw materials that feeds the industry. Because of the maturation of the industry and the fact that nearly every major community has already implemented plastic recycling programs, growth has slowed. There was only a 4% increase in the pounds of plastic collected in 1999 compared with that of 1998 (State of Plastics Recycling , 2003).

3. Deconstruction as a Method for Increasing Materials Recyclability

Demolition results in a non-homogenous heap of damaged materials. The recyclability of these materials is thus reduced by the demolition process itself. There is a positive correlation between the proliferation of building demolition in our country and the proliferation of downcycling of materials. Direct reuse and upcyling of building materials generally requires that they be recovered in good condition. Demolition frequently damages building materials to the point that their only usefulness lies in being downcycled to less valuable materials. This reduction of the recyclability of the materials serves to reduce their economic value, increase their future negative effect on the waste stream, and increase the future necessity of raw materials extraction to take their place.

Deconstruction, on the other hand, serves to increase the recyclability of raw materials. Deconstruction results in numerous piles of homogenous building materials with minimal damage. This is because time and care are taken in recovering and sorting materials with as little negative effect on their quality as is humanly possible. The two factors unique to deconstruction that increase the recyclability of building materials are its organizational nature and the lack of damage incurred by the materials during the recovery process.

The organizational nature of deconstruction increases the recyclability of the materials within the building. Should the same building be demolished by wrecking ball, the resulting trash heap would most easily be disposed of by hauling to a landfill. The individual components would have to be sorted after demolition in order to address their individual potential for recycling. This extra cost serves as a deterrent to recycling for demolition contractors. Deconstruction, by nature, requires the removal and sorting of individual building components. Piles of brick, wood, roof shingles, drywall, and other materials can then be recycled based on their own properties.

4. Conclusions

Great pains are taken during the deconstruction process to recover building materials with minimal or no damage. Methods for efficient and safe extraction of materials are improving daily. Deconstruction improves materials recyclability by creating a supply of used building materials that are in good condition. This supply would not exist on any large scale without deconstruction. For example, structural timbers recovered from deconstruction can be reused in similar applications. This means that their potential for recycling will be available further on down the line. Conversely, structural timbers that have been destroyed by demolition only serve to be mulched up or sent to the landfill. Bricks recovered through deconstruction can be cleaned and sold for reuse, protecting their future recyclability. Bricks recovered from demolition would in far too poor of condition to be reused. Their only potential would be for being ground up and used in lesser applications. To sum it up, deconstruction increases material recyclability by creating the opportunity for material reuse and upcycling, whereas demolition promotes downcycling and landfilling.

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