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Green Design and the City
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Green Highways

Until we can reach our ideals of walkable, public-transit oriented neighborhoods, we need to concentrate on minimizing the environmental impacts of our transportation infrastructure. This can include adding wildlife crossings, using pervious surfaces, lowering air pollution, or using environmentally sensitive methods to locate roadways. Highways are also perfect places to recycle post-industrial, -manufacturing, and -construction byproducts. In many cases, these recycled highways are stronger, more durable, more resistant to temperature fluctuations, and in some cases, can even act as a carbon sink.¹

The most common recycled paving additives include recycled asphalt pavement (RAP), reclaimed concrete materials (RCM), coal fly ash and blast furnace slag. Over the years, these materials have become even more innovative. In one project on I-540 in Raleigh, NC, 19 tons of chipped tires were used to aerate the soil of the embankments, 700 tons of post-industrial asphalt shingles were mixed into new paving materials, and 260 tons of municipal sludge were used as fertilizer.² A private company in Cleveland, Ohio sells foundry sand, mainly from the Ford Motor Company's motor assembly plant, to be used in embankment repairs, creek improvements and road extensions.³ A recent report notes that toner, deemed unfit for printers and otherwise disposed of, can be added to asphalt to improve its strength and temperature resistance (For a summary of materials, see Table 1).⁴

Fly Ash is the incombustible mineral residue resulting from the combustion of coal, which solidifies while suspended in exhaust and is then collected in filters. In 1996, the United States produced 53.5 million metric tons (59.4 million tons) of coal fly ash.⁵ Approximately 20% was recycled in construction projects and the rest was landfilled or

¹ Recycled Materials Resource Center, "Sustainable Highways Through the Use of Carbon Sequestering Construction Materials," University of New Hampshire, <http://www.rmrc.unh.edu/Research/Rprojects/Project35/Project35.asp>

² Triangle Region Public Facilities, "Highlighted Technology: Recycled Materials in Highway Construction," North Carolina Waste Trader, < <http://www.p2pays.org/ref/16/15401.pdf>>

³ Federal Highway Administration, "Use of Foundry Sand in the Cleveland Area," U.S. Department of Transportation, January 29, 2003, < <http://www.fhwa.dot.gov/pavement/recycling/cleveland.cfm>>

⁴ University of Texas, "Technical Report Documentation Page" Report # FHWA/TX-05/5-3933-01-2, < http://www.utexas.edu/research/ctr/pdf_reports/5_3933_01_2.pdf>

⁵ Recycled Materials Resource Center, "User Guide," University of New Hampshire, <http://www.rmrc.unh.edu/Partners/UserGuide/index.htm>

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put in storage lagoons. Fly ash is most commonly recycled as a mineral admixture in Portland cement concrete, but can also be added to asphalt to increase the cohesiveness and stability of the mixture. This material can also be used for stabilized bases, flowable fill (compacted earth backfill), or embankment material. Studies have shown that this addition nearly doubles the life expectancy of traditional concrete, improves workability, improves resistance to sulfates and seawater, enhances protection for reinforcing steel and reduces costs.⁶

Highways themselves can be recycled in the form of RAP or RCM. RAP consists of removed and/or reprocessed pavement materials containing asphalt and aggregates. Once taken away, the materials are crushed and screened before being conveyed to a storage facility. Old asphalt pavements can also be pulverized in situ, incorporated with virgin aggregate and binders, and then compacted in place.⁷ It is possible that as much as 45 million metric tons of RAP are produced each year in the United States and that 80 to 85 percent of it is being reused.

In 1993, the U.S. produced 290 million scrap tires.⁸ Of these, 80% are recycled, with 12% being used for rubberized asphalt (see Table #2). A two-inch thick layer of asphalt rubber uses around 2,000 tires per lane mile.⁹ As a rubber sealant, 500 tires per lane mile are recycled. Ground tire rubber modifies asphalt properties to make it longer lasting, it reduces road maintenance and road noise, it is cost effective, and provides safer roads.

Over the years, recycling post-industrial and post-construction materials into transportation infrastructure has become increasingly common. Recycled Materials Company Inc. (RMCI) recently finished what has been dubbed the world's largest recycling project. The goal was to turn six million tons of runway, taxiway and concourse concrete and asphalt from the old Stapleton Airport in Denver, Colorado, into

⁶ Center for Transportation Research, "Eco-friendly Road Construction," [The University of Texas at Austin](http://www.utexas.edu/research/ctr/research/articles/eco.html), <http://www.utexas.edu/research/ctr/research/articles/eco.html>

⁷ Recycled Materials Resource Center, "User Guide,"

⁸ U.S. Environmental Protection Agency, "Management of Scrap Tires," <http://www.epa.gov/garbage/tires/basic.htm>

⁹ Rubber Pavements Association, "FAQ," <http://www.rubberpavements.org/faq.html>

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new roads around the state.¹⁰ The total material could be used to construct a two-lane roadway roughly 10,000 miles in length. RMCI used gate breakers, machines capable of cracking through pavement 12-to-36 inches deep, to chop up the runways, and roll-behind rotary impactors for the parking lots.¹¹ The asphalt and concrete rubble was hauled to crushing plants, either on site at Stapleton or at other locations around Denver. Forest City Enterprises took the project full circle by using one third of the finished material in the development of a new urbanist community on site. Stapleton is a 4,700 acre environmentally friendly, mixed-use development. Some of the main sustainability features include: compact mixed-use development, pedestrian friendly neighborhoods, energy-efficient building design and construction, innovative storm water management, preservation of open space, extensive recycling and light pollution mitigation (For before and after photos, see Figure 3).

The rest of the material became roadbase, coarse aggregate, sand and gravel as well as its namesake product, the ‘Staplestone’ – a large concrete block suitable for retention walls, barriers and other landscaping projects.¹² The products were sold to the Colorado State Department of Transportation (CDOT), as well as a range of contractors, sub-contractors and developers. The recycled material has been used in residential neighborhoods, commercial shopping centers and golf courses as roads, sidewalks, bridges, curbing material, offices and homes.¹³ CDOT used the material in reconstruction projects on I-70, I-76, I-25, and in the construction of the new Denver International Airport.¹⁴ The city and county of Denver mixed the material into the remediation of the Rocky Mountain Arsenal as well as numerous residential road projects. It was even used by a non-profit group to build handicapped accessible roads and trails in wilderness areas.

RMCI set a precedent for recycling projects worldwide. Not only did it up the ante in terms of scale, but it was able to do so while turning a profit (estimated at \$36

¹⁰ Taylor, Brian, “The urban quarry: the former Stapleton Airport in Denver becomes a high-profile recycling project - C&D Series - Recycled Materials Co.,” *Recycling Today*, Dec 2002, <http://findarticles.com/p/articles/mi_m0KWH/is_12_40/ai_96194792>

¹¹ Taylor, Brian

¹² Recycled Materials Company, “World’s Largest Recycle Project,” <<http://www.rmci-usa.com/stapleton.htm>>

¹³ Portland Cement Association, “World Record Recycling Project,” <http://www.cement.org/concretethinking/case_stapleton.asp>

¹⁴ Givan, Rick C., “The Urban Quarry,” *Green Highway Forum*, 2005 <www.greenhighways.org/ewebeditpro/items/O130F9572.ppt>

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million dollars once all the material has been sold) and pioneering a “no-cost” reuse model.¹⁵ Under the agreement with the city of Denver, RMCI would be responsible for all demolition and transportation costs. In exchange, the city allowed full use of the area for processing and storage for up to ten years while all of the product was being sold.

If it were not for the rebuilding of the airport on a greenfield, this project could be the centerpiece for green design. A private company was able to completely recycle the infrastructure of an international airport and find a market for their product. At the same time, developers were eyeing this empty lot for a massive infill, new urbanism community. In the end, the project resulted in 6.5 million tons less virgin paving and construction material and new homes for 30,000 residents and 35,000 workers.¹⁶

¹⁵ Aven, Paula, ‘Stapleton asphalt hits recycling pile,’ The Denver Business Journal, 21 April, 2000
<<http://denver.bizjournals.com/denver/stories/2000/04/24/story4.html>>

¹⁶ Kearns, Diane, “‘Building Stapleton, One Neighbor at a Time,’ REMAX, <
http://www.buildingstapleton.com/About_Stapleton.html>

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Table 1 -- Summary of Known Uses in Waste Applications¹⁷

Waste Material	Annual Rates in Millions of Metric Tons		Current and Past Highway Uses				
	Produced	Recycled Reused	Asphalt Pavement	Concrete Pavement	Base Course	Embankment	Other
Blast Furnace Slag	??	14.1	Accepted use as an aggregate in base and surface (friction) coarse, research indicates good performance	Accepted use as a cement additive in granulated form, research is ongoing	Accepted use, good, hard, durable aggregate	Limited but accepted use,	Research in Roller Compacted concrete, accepted as ice control abrasive
Carpet Fiber Wastes	2	??	Experimental stages in HMA and SMA no field data	Experimental Stages, no field data	No known use	No known use	No known use
Coal Combustion Byproducts							
Coal Fly Ash	45	11	Past use as a mineral filler, research ongoing	Accepted use research ongoing	Used in soil stabilization	Used in flowable fills, embankment	Used in all types of PCC
Coal Bottom Ash or Bottom Slag	16	5	Combined ash as a fine aggregate, performance data limited	Use unknown	Use unknown	Used as a sub-base material, embankment	Lightweight concrete, abrasives
Flue Gas Desulfurization Waste	18	??	Use unknown	Used as a set retarder	Used with cement in soil stabilization	Used as an embankment material	No known use
Glass	12.0	2.4	Accepted use, long-term performance research under way	Past research indicated performance problems	Used in dense and open-graded bases	Some research projects under way	Limited use as a paint bead, pipe backfill
Mill Tailings	432	<1%	Accepted use, research indicates good performance	Limited but accepted use	Use unknown	Accepted use	Use unknown

¹⁷ Schroeder, Robin, "The Use of Recycled Materials in Highway Construction," Federal Highway Administration, 1994,

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Municipal Waste Combustion Ash	7.3	<10%	Past research indicated good performance - Environmental questions	No known use	Used in cement-stabilized bases	Used in soil stabilization	No known use
Plastic	14.7	0.3	Used as a binder additive	Experimental stage	No known use	No known use	Used as fence or delineator posts, guardrail blockouts
Reclaimed Concrete Pavement	3	??	Limited use, long-term performance research under way	Limited use, research under way	Accepted use	Accepted use	Used as rip-rap
Reclaimed Asphalt Pavement	91	73	Variety of accepted uses	Experimental stages	Accepted use	Accepted use	Used as shoulder material
Roofing Shingle Waste Industry-Produced Re-roofing Waste	0.4 7.7	<1%	Limited use, research under way	No known use	No known use	No known use	Used as a pothole patching material
Scrap Tires	2.3	0.4	Accepted use, extensive research being conducted	Experimental Stages	Used as an insulator	Used with some success - research continuing	Being marketed for use as noise or retaining wall, molded posts, many minor uses
Steel Slag	7.5	6.9	Past research indicates good performance	Extensive research, poor performance	Limited use	Accepted use	Ice control
Waste Rock	954	<1%	Accepted use, research indicates good performance	Limited but accepted use	Use unknown	Use unknown	No known use

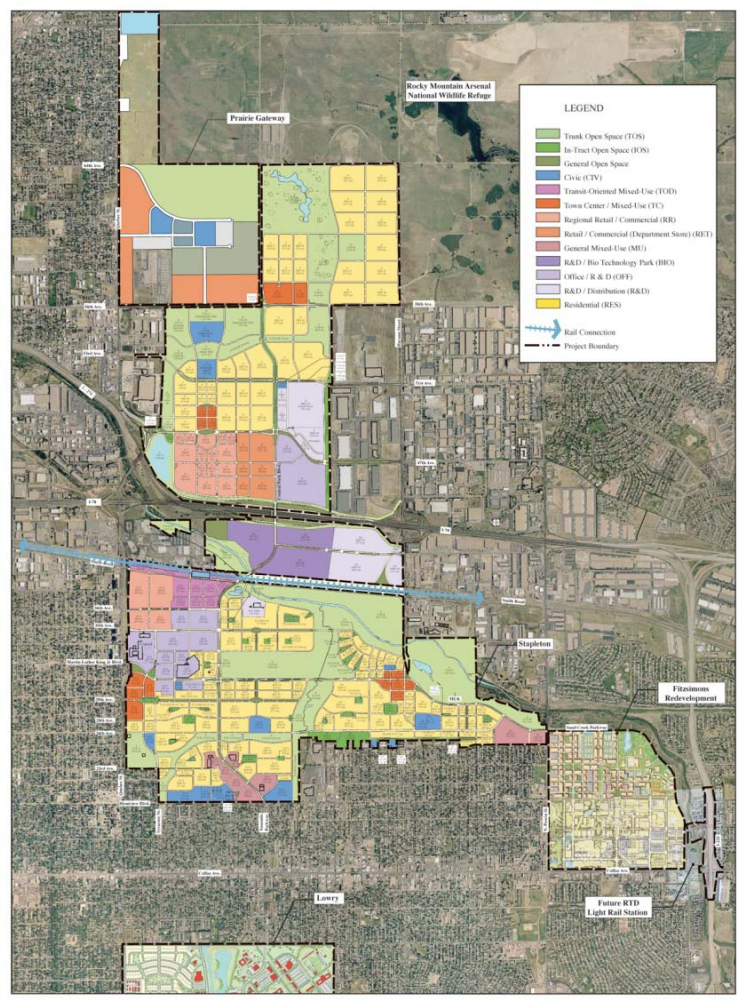
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 Table 2¹⁸

Number of scrap tires generated annually:	290 million
Percentage of total solid waste generated:	2.0 percent
Number of scrap tires going to a market:	233 million
Number of scrap tires used for fuel:	130 million
Number of scrap tires used in civil engineering projects:	56 million
Number of scrap tires used in ground rubber applications:	28 million
Number of scrap tires punched/stamped into new products:	7 million
Number of tires exported:	9 million
Number of tires in stockpiles:	265 million

¹⁸ U.S. Environmental Protection Agency, "Management of Scrap Tires," <http://www.epa.gov/garbage/tires/basic.htm>

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Figure 3: Before and After Photos of Stapleton International Airport



* Note: Acreages, if shown, are for general reference only.
 ** Note: In-Tract Open Space is shown only for those areas which are in the advanced stages of planning.

OVERALL LAND USE MAP (v229)

STAPLETON DEVELOPMENT PLAN
 Denver, Colorado
 February 13, 2007



* This rendering and the development depicted are for illustrative purposes only and should not be relied upon for any purpose. Forest City Stapleton, Inc. makes no guarantees concerning future development and the development depicted in this rendering may be modified at the discretion of Forest City Stapleton, Inc. without notice.

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