



Materials for Sustainable Sites Defined

Since the mid-nineteenth century when Olmsted excavated stone from the meadows of Central Park to build the park's bridges, walls, and stairs, the construction materials industry has undergone major changes. There has been a shift away from localized use of materials to centralized large-scale production and global distribution; from minimally processed materials to highly processed ones; and from simple materials to engineered composites, mixed materials assemblies, and liberal use of chemical additives to impart a wide array of properties.

Materials of site construction have evolved in response to many twentieth-century trends: the shift from skilled craftsmen to cheap labor in construction, increasingly nationalized standards that do not specifically address regional materials or conditions, centralized production of building materials and products, cheap and abundant resources where "real" costs of ecosystem destruction and pollution are not factored in, increasing use of composite materials, and huge growth in the global materials industry.

The result has been a consumptive and sometimes wasteful materials industry with use of a limited palette of nationally standardized site construction materials (e.g., concrete, asphalt, pressure-treated lumber, powder-coated steel). Local, low embodied energy structures,

such as earthen construction in the Southwest or dry stone construction in New England, have decreased in use as labor costs are high, workers skilled in these techniques are increasingly scarce, and national building codes hamper their use.

Abundant resources, inexpensive labor, and minimal environmental regulations in developing countries have shifted production of many building materials overseas. This has further reduced designers' capacity to understand the impacts of construction material production, or even to know where they come from. Aggregate may come by train from a quarry 200 miles from the site, while the aluminum for the handrails may have visited three continents before it arrived at the site. This means that today, a far greater portion of the impacts of building materials are those related to energy consumption incurred in trucking, shipping, and train transport. These are not insignificant, given the weight of many site construction materials.

Site construction materials of the twenty-first century must respond to an entirely different set of forces—global climate change, air pollution, rising fuel costs, ecological destruction, and loss of biodiversity. These forces are shaping the site and building construction industry through the rapidly growing sustainable development movement.

And they will necessitate significant changes in the materials industry. These changes may involve closed-loop material manufacturing systems that eliminate waste; use of renewable energy sources for manufacturing, processing, finishing, and transport activities; “mining” of construction demolition sites for “raw materials”; substantial reductions of pollution from material manufacture, use, and disposal; an emphasis on minimally processed local or regional materials; and greater reuse of site structures in place or on-site.

To address the goal of sustainable development, the construction material production and construction industries must shift their use of resources and fuels from nonrenewables to renewables, from waste production to reuse and recycling, from an emphasis on first costs to life-cycle costs and full-cost accounting, where all costs such as waste, emissions, and pollution are factored into the price of materials (Kibert et al. 2002).

And this shift has already begun. The first decade of the twenty-first century has seen the start of what will be significant changes to the construction materials industry:

- Global warming is well acknowledged by global decision makers and treaties such as the Kyoto Protocol for greenhouse gas reduction.
- Policies for waste reduction and reuse in the European Union and to a lesser degree in the United States are fostering growth in salvage, recycling, and industrial materials exchange industries.
- In the EU, policies are increasing the responsibility of producers to reduce and recycle packaging, increase the recycled content of their products, recycle more of their waste, and even take back and recycle components of their own products.
- Industrial designers and product manufacturers are looking to natural systems for closed-loop design, new material compositions, and green chemistry to reduce waste and pollution of their product production.
- Standards and criteria for reducing the environmental and human health impacts of materials and products are being developed and increasingly used by product specifiers to make decisions. The LEED system, Cradle to Cradle Certification, Greenguard, EPA Comprehensive Procurement Guidelines, Green Globes, and others offer criteria and standards for material or product selection.

- Life-cycle assessment (LCA) studies are increasingly available, yet still limited, for construction materials and products. In the United States, BEES and the Athena Environmental Impact Estimator interpret and weigh LCA results for building assemblies and some site construction materials.

Yet while progress is being made, selection of materials and products with the least environmental and human health impacts remains a challenging, confusing, and sometimes even contentious issue. The appropriate materials for sustainable sites will vary by impact priorities, regional issues, project budgets, and performance requirements. Some will emphasize materials that conserve resources by being reused without remanufacturing, by being extremely durable, or by closing material loops with high recycled content and manufacturer take-back programs. Others place great emphasis on low toxicity of products and emissions throughout their life cycle, while others may regard low ecological impacts or conservation of water as the highest priority. With this wide variety of priorities comes an even wider variety of “right answers.” Portland cement concrete may appear to be a “green” material for those with durability or regionally produced materials as a priority, whereas it might be rejected by those who are concerned about the global warming impacts of material manufacture or high embodied energy materials. Composite lumber (a mix of recycled plastic and wood fibers) seems like a good alternative to wood lumber for those concerned with the ecological impacts of clear-cutting forestry practices, but it may be rejected for its mixed material composition by those concerned with the closed-loop recyclability of materials.

In addition to varying priorities and goals in green material selection, there are shades of green. For instance, the ideal green material might be a natural, renewable, local and indigenous, nontoxic, low embodied energy material such as willow cuttings for slope stabilization or rammed earth for a retaining wall; however, these materials may not be feasible in all situations. They may not be able to perform to current construction standards, construction workers may not be skilled in techniques to build structures with these materials, or they may not be appropriate for the scale of construction or performance requirements.

Claims of green abound as product manufacturers capitalize on the rapidly growing “green” segment of the construction materials industry. Yet it can be difficult for designers to cut through the hype and determine just how green the product is, let alone compare it with six or seven alternatives. Evaluating multiple products for a given use can be like comparing apples and oranges. One product may pose global warming impacts while another may involve a known human carcinogen; a third product may require large amounts of fossil fuel-powered energy to produce, but it may be more durable with the potential to last twice as long as the first two alternatives.

True life-cycle assessment (LCA), an accounting of all inputs and outputs through a product’s life cycle, can potentially offer some answers for sustainable site material selection. But it is outside the time and skill constraints of most designers. And while LCA information is becoming available for a wide variety of products through Athena or BEES in the United States, to date these tools have focused on evaluating building assemblies and materials with only minimal analysis of site construction materials.

Materials for Sustainable Sites Defined

This section defines characteristics of materials for sustainable sites. It is important to note that all of the strategies summarized below and addressed in this book are not equal. Just diverting a waste material from the landfill is not always enough. While it is a step in the right direction, what is actually done with the diverted material will determine whether it is a large or small step. In resource conservation, as in other aspects of designing for sustainable sites, there are shades of green from light to dark. For example, chipping a reclaimed old-growth oak beam into mulch is not the highest and best use of the material. Instead, reusing it in whole form is the best use. Better yet, if the beam came from an old barn that is no longer needed, keeping the beam in place and adapting the barn structure to another use will maintain the resource in place, incurring no transportation costs and maintaining the integrity of the beam—and the old structure.

So the definition of materials for sustainable sites can vary widely, and some materials or products will be

slightly green while others may be dark green. It can all be a step in the right direction, and taking the largest step possible in a given situation will help push the site construction industry incrementally toward substantial changes.

Materials and products for sustainable sites are those that minimize resource use, have low ecological impacts, pose no or low human and environmental health risks, and assist with sustainable site strategies. Within this definition, specific characteristics of materials for sustainable sites are summarized below. These attributes are also woven throughout the chapters on individual materials in this book, and are discussed there in greater detail.

Characteristics of “green materials” listed below are not in a ranked order as priorities will vary among projects. Environmental priorities as ranked by the EPA Science Advisory Board are discussed in Chapter 3 and a hierarchy of waste reduction strategies is discussed in Chapter 4.

MATERIALS OR PRODUCTS THAT REDUCE RESOURCE USE

Reducing use of virgin natural resources in the production and use of construction materials can substantially reduce their environmental impacts. Using fewer materials in construction by reducing the size of a structure or by retrofitting an existing one will not only save virgin resource use for the new product or material, but it will also reduce the “ecological rucksack” of waste, often many more times than the actual product entails, that is created through the raw material acquisition and manufacturing processes. Reusing materials or using waste as feedstock for new products will reduce virgin resource impacts as well.

Impacts associated with virgin resource use will also be reduced with reuse or recycling of resources. Habitat destruction, waste generation, energy, and air and water pollution are minimized with reduced use of virgin resources. Energy is saved in the processing and manufacture of new materials as primary processing steps are often eliminated with use of recycled materials. And, if materials are reused on-site or even in place, transportation impacts can be eliminated. Use of reclaimed, refurbished, and recycled content materials is discussed in greater detail in Chapter 4.

Use No New Materials, Don't Rebuild

While not always feasible or appropriate, this is the best way to minimize use of resources. This might mean a choice is made not to build or rebuild a structure, and a site can be used as is. Designing sites for adaptability with open plans and multiuse spaces, so the site and its structures do not require adaptation in a short period of time, can help minimize future use of resources.

Reuse Existing Structures in Place

Adapting or retrofitting existing structures without deconstruction and rebuilding can give them new life with minimal use of new materials. For example, the cracked concrete deck of an old loading dock might be stained with a natural iron oxide pigment (which is a by-product of iron ore production) to become a terrace for a new condo in the adjacent warehouse. Reuse of existing structures on-site can enhance the design of the site by referencing the identity of the previous intervention. At the start of the project, evaluate project sites and old buildings for materials to reuse. Include known subgrade structures in the evaluation as well.

Reduce Material Use

Designing smaller structures (e.g., smaller decks, thinner slabs and walls, flexible footings, cable balustrades rather than hollow steel tube rails, smaller parking lots and spaces, narrower roads) with fewer elements (e.g., excessive finishes or ornaments) and smaller members (e.g., 4×4 posts, not 6×6 unless structurally necessary) can substantially reduce use of materials. Designing structures to modular material sizes can minimize construction waste (e.g., cutoffs). For instance, wood decks should be sized based on available board lengths.

Use Durable Materials

Designing and detailing site structures with durable materials that will last the life of the site and beyond to other structures will reduce virgin resource use. Ease of repair of the structure will also extend the life. Brick or concrete bricks are durable materials and when sand-set can be easily repaired, replaced, or re-leveled without removal of the entire installation. After the useful life of the paving they can be removed and reused in another installation.

Reclaim and Reuse Materials or Products in Whole Form

Deconstructing previously developed sites rather than demolishing them can allow for reclamation of materials and products that can be reused in new site structures or applications. In addition to reducing use of virgin resources and saving manufacturing energy and pollution, reuse of materials on-site can save energy and costs of transporting new materials to the site. Reduced demolition waste can save on landfill fees, which may offset the increased cost of deconstruction over demolition. A major consideration is storage of reclaimed materials during the construction process. It is important that storage facilities on or near the site maintain the integrity of the material (e.g., recovered wood should be protected from excess moisture) without negatively impacting the site itself (e.g., avoid stockpiles on tree roots). Where deconstructed materials can't be reused on-site, they can be taken to local salvage or reprocessing facilities.

Use Reclaimed Materials from Other Sources

The only major impacts of reused materials are energy consumption in transport, reworking and refinishing, and installation. Reclaimed materials can be obtained from numerous sources beyond the project site. Materials exchanges are increasing in areas of the country with higher landfill fees, and many municipalities will list recycling and salvage facilities in the region. There are many Internet materials exchange websites as well. Materials should be obtained from local sources as fuel use for transport can be considerable with heavy landscape materials.

Reprocess Existing Structures and Materials for Use On-site

Reprocessed materials are those that are broken down or size reduced from their unit or standard size. Although downcycled, reprocessing materials uses less energy and produces fewer emissions than remanufacturing for recycling. Bringing crushing or other processing equipment to the site rather than hauling the materials to a reprocessing facility can save transport fuel use and costs. Plan for processed material stockpiles during construction.

Use Reprocessed Materials from Other Sites

Material reprocessing facilities are growing in number as landfill costs increase. Crushed concrete, tires, asphalt, glass, and other materials can be obtained from reprocessing facilities for use as aggregates or concrete or asphalt ingredients. Care should be taken to minimize haul distances.

Specify Materials and Products with Reuse Potential and Design for Disassembly (DfD)

Materials that are installed in such a way that they can be easily removed at the end of the life of the landscape and reused elsewhere may not be green themselves, but the way that they are assembled is. For example, masonry installations where no mortar is used, such as interlocking retaining wall units, allow for easy disassembly and reuse of the materials. Also, use of metal fasteners rather than welding, where applicable, facilitates removal of reusable parts.

Specify Recycled-content Materials and Products

Recycled-content materials or products are manufactured using reclaimed materials, scrap, or waste as the feedstock. Some energy is used and emissions and waste result from manufacturing of the new product; however, it is often less than with use of virgin feedstocks. Use of recycled materials will also divert waste from landfills or incinerators. Post-consumer recycled content is preferable to pre-consumer as it is more likely to have been diverted from landfills. Pre-consumer recycled content often can be reused in other industrial processes. With the exception of metals and some plastics, most recycled-content products are downcycled from their original use (e.g., wood joists chipped for mulch). An overemphasis on recycled-content materials can result in greater environmental impacts for a given structure. For example, use of steel with a relatively high recycled content may be chosen over wood that has no recycled content, yet even the recycled steel can result in greater energy use, emissions, and waste than a comparable wood member.

Use Materials and Products with Recycling Potential

In an effort to close materials loops, thinking ahead to the end of a structure's useful life and the recyclability of materials used to build it is an important step in resource

minimization. Simple materials such as concrete, asphalt, wood, and polyethylene plastics (e.g., HDPE, PE, LDPE) are easily reprocessed and recycled. Composite materials such as mixed plastic and wood fiber composite lumber or coated metals have no or limited recycling potential. PVC, a common site construction material for pipes, fences, and decking, is technically recyclable, but many plastics recycling facilities consider it a contaminant to other plastics recycling and will not take it.

Specify Materials and Products Made from Renewable Resources

Materials and products made from renewable resources offer the opportunity for closed-loop material systems. A number of site construction products are made from renewable, biobased resources; however, some will decompose and biodegrade if not preserved in some way. Wood is the most common site construction material that is renewable. It is considered to be a "long-cycle" renewable material as the average regrowth time from trees used for lumber is 25 years for softwoods. Rapidly renewable materials are primarily plants that are harvested in cycles shorter than ten years. Coir and jute are used for geotextiles; succulents are used as stabilizers for loose aggregate paving; and plant oils are used in form-release agents. Bamboo and willow can be used in landscape structures, and fiber from processed crops is used in engineered wood products. Living materials (e.g., slope stabilization with plants, willow wattles, willow fences and domes) are renewable in place. Recycling of renewable materials can often be accomplished by composting or aerobic/anaerobic digestion, using minimal energy and chemicals.

Specify Materials or Products from Manufacturers with Product Take-back Programs

Product or packaging take-back programs are a new trend in manufacturing, particularly in EU legislation and incentive programs. In many EU countries, some manufacturers are required to take back and reuse or recycle the packing for their products. This has resulted in more efficient packaging methods and greater use of recyclable packaging materials. Some manufacturers offer take-back programs for their product as well. Construction material take-back programs are starting to be seen among carpeting and flooring manufacturers.

MATERIALS OR PRODUCTS THAT MINIMIZE ENVIRONMENTAL IMPACTS

Materials and products can cause negative impacts to ecosystems and the environment during all phases of their life cycle. In the materials acquisition phase, mining and harvesting practices can impact habitats and removal of vegetation increases runoff, loss of topsoil, and sedimentation of waterways. Waste piles from mining can leach heavy metals into the soil and ground and surface waters. Emissions and waste from manufacturing can impact air, water, and soil both near and far from the facility. Transport of materials and products between all life-cycle phases uses nonrenewable fuel and releases emissions. Construction and maintenance of materials and products can involve solvents, adhesives, sealers, and finishes that off-gas VOCs or release toxic chemicals to the environment. Dust from unstabilized roads can impact air quality and adjacent vegetation and crops. And disposal of materials and products after their use can fill landfills, impact soil and water around poorly managed landfills, and impact air quality if incinerated.

Use Sustainably Harvested or Mined Materials

Some manufacturers take steps to eliminate or mitigate air, water, and soil pollution from their raw material acquisition processes. While mining operations are largely unregulated, some companies make efforts to protect or remediate negative effects from their mining activities. Growth and harvesting of renewable materials can have environmental impacts from fertilizer and pesticide use, impacting soil health and resulting in eutrophication of nearby water bodies. Attention should be paid to farming and harvesting practices of renewable materials.

Use Certified Wood

As it is renewable and has relatively low embodied energy, wood can be considered a green material if it comes from well-managed forests and is harvested sustainably. Environmentally responsible forest management includes practices that protect the functional integrity and diversity of tree stands, minimize clear-cutting, protect old-growth forests, and minimize wasteful harvesting and milling techniques (Forest

Stewardship Council [FSC]). The Forest Stewardship Council (FSC) has developed standards for third-party certification of sustainably harvested wood. Certification of lumber should be made by an FSC-certified independent party. Chapter 10 discusses other forest certification organizations.

Use Minimally Processed Materials

Materials and products that are minimally processed (e.g., uncut stone, earth materials, wood, bamboo) often pose fewer ecological impacts. Reduced manufacturing and processing can conserve energy use and potentially harmful emissions and wastes. Minimally processed materials are usually associated with fewer hidden wastes.

Specify Low Embodied Energy Materials

Products that are minimally processed, such as stone and wood, usually have lower embodied energy than highly processed materials such as plastics and metals. Embodied energy is the total energy required to produce and install a material or product during all stages of the life cycle. Evaluating the embodied energy of materials can be a useful baseline for comparing two different materials; however, this type of analysis does not take into account other factors of production such as pollutants and toxins released, resources used, or habitats disturbed. If a product is complex (made from more than one material, such as a steel and wood bench), the embodied energy of the bench would include the energy inputs from both the wood and steel components plus the energy inputs to assemble and finish them.

Specify Materials Produced with Energy from Renewable Sources

Materials and products produced using renewable energy sources (e.g., solar, wind, hydroelectric, biofuels, geothermal) can have reduced environmental impacts. Combustion of fossil fuels, the primary energy source in a high percentage of manufacturing activities, releases greenhouse gases and air pollutants contributing to global climate change, acid rain, and human respiratory health problems. Any comparison of embodied energy of materials should include an examination of energy sources as a product with relatively high embodied energy may be considered lower impact if it is

produced with energy from renewable sources. Aluminum requires around eight times as much energy to produce as a comparable amount of steel, yet its primary energy source is renewable hydroelectric power, whereas the primary fuel energy source of steel is coal.

Use Local Materials

Transport of building materials, especially heavy or bulky ones, not only requires a tremendous amount of fuel energy, but also contributes to air and water pollution. Using regionally extracted and manufactured materials can help lessen the environmental impact of a material, by reducing environmental impacts of transport. Transportation costs may also be reduced; at the same time the local economy is supported. Availability of regionally manufactured materials depends on the project location. Ideally, heavy materials such as aggregate, concrete, and brick should be procured within 100 miles, medium-weight materials within 500 miles and lightweight materials within 1000 miles of the project site (Living Building Challenge). Distances between raw material extraction locations and manufacturing/processing facilities should be included in these calculations. Researching regionally available materials and products during the schematic design phase can facilitate use of local materials. Creating databases of regional materials and products can save time on future projects within the same region.

Specify Low-polluting Materials

Some raw material extraction, manufacturing, or disposal processes for construction materials produce waste, by-products, and emissions that can contribute harmful pollutants and particulates to air, water, and soil. Some manufacturers minimize pollution from their processes through equipment or process improvement or state-of-the-art pollution controls. Materials with relatively high-polluting processes are metals mining, primary metal production, metal finishing, cement production, and PVC production and disposal.

Specify Low-water Use and Low-water-polluting Materials

Some materials and products require large amounts of water during processing, manufacturing, or construc-

tion. The used water is often contaminated with heavy metals, hazardous chemicals, or particulates and sediments, and is a disposal risk if not treated and remediated. Material manufacturing processes that use large amounts of water or can result in water pollution are metal mining and primary processing, PVC production, stone working, brick making, and lumber processing. Disposal of some materials, such as PVC pipes, can affect groundwater quality. Some manufacturers recycle wastewater back into manufacturing processes. Some employ chemical and heavy metal removal techniques to safely dispose of potential pollutants.

MATERIALS OR PRODUCTS THAT POSE NO OR LOW HUMAN HEALTH RISKS

Low-emitting Materials and Products

Many adhesives, sealers, finishes, and coatings contain volatile organic compounds (VOCs) and other harmful chemical ingredients that can off-gas in use, leading to air pollution, or leach into soil and groundwater in disposal. Construction workers and end users exposed to these chemicals can be adversely affected in many ways. Products containing synthetic chemicals should be carefully examined for harmful effects. Many synthetic chemicals are not biodegradable or easily broken down. The National Research Council estimated that over 65,000 synthetic chemical compounds introduced and in use since 1950 have not been tested on humans (INFORM 1995). Nontoxic, organic, or natural alternative products are increasingly available.

Specify Materials or Products That Avoid Toxic Chemicals or By-products

Materials can contain or emit known toxins during life-cycle phases of manufacture, use, or disposal. Persistent bioaccumulative toxins (PBTs), known and suspected carcinogens, teratogens, and products with hazardous chemicals should be avoided. For example, dioxin, a known carcinogen, is released during the manufacture and incineration of polyvinylchloride (PVC) products such as rigid pipe, plastic fencing and railings, drip irrigation tubing, garden hoses, and lawn edging. The EPA's Toxic Release Inventory (TRI) maintains manufacturer's self-reported data on their toxic releases by compound.

MATERIALS OR PRODUCTS THAT ASSIST WITH SUSTAINABLE SITE DESIGN STRATEGIES

Some site structures may be constructed from materials that are not in and of themselves green, but the way in which they are used contributes to the sustainable function of the site. For instance, use of highly reflective white portland cement concrete, not considered a “green” material because of its relatively high embodied energy, will aid in reducing the urban heat island effect over the life of a pavement, potentially saving energy to cool adjacent buildings. Over the long life of a site, the impacts from manufacture of the material may be minimized with the benefits it can provide for the site’s environment.

Products That Promote a Site’s Hydrologic Health

Design of sites to respect natural drainage patterns, minimize impermeable surfaces, maximize storm water infiltration, and improve storm water quality can protect the hydrologic health of a site and a region. While polyethylene filter fabric would not be considered a green material, it can go a long way toward ensuring the appropriate function of storm water structures such as bioswales or rain gardens. Green roof products can also promote hydrologic health.

Materials and Products That Sequester Carbon

Lumber, engineered wood products, and many bio-based products sequester carbon until they decay; then it is released. New technologies are in development that capture carbon, reducing CO₂ from other sources such as carbon-sequestering concrete.

Products That Reduce the Urban Heat Island Effect

Heat island effects result from solar energy retention on constructed surfaces in urban areas, elevating the temperature differential between urban and rural environments. Streets, sidewalks, parking lots, and roofs are the primary contributors to the heat island effect. Use of highly reflective paving materials or open grid pavement structures with vegetation in the cells can reduce the heat island effect. Pervious pavements will cool pavement by allowing air and water to circulate through them.

Products That Reduce Energy Consumption of Site Operation

Products such as solar lights, high-efficiency lights, Energy Star pumps, and irrigation controllers will reduce a site’s energy consumption over the life of the site.

Products That Reduce Water Consumption of Site Operation

Products that use water efficiently, such as drip irrigation, irrigation sensors and timers, and rainwater collection barrels, will reduce the site’s water consumption.

MATERIALS OR PRODUCTS FROM COMPANIES WITH SUSTAINABLE SOCIAL, ENVIRONMENTAL, AND CORPORATE PRACTICES

Social, environmental, and corporate practices of a product manufacturer or distributor can impact the sustainability of a product. Products should be sourced from companies that take responsibility for the environmental and human health impacts of their operations; protect the health, safety, and well-being of their employees; provide fair compensation and equal opportunity for all workers; protect consumer health and safety; and contribute positively to community health and well-being (Pharos Project). Ask manufacturers for corporate ethics statements, fair labor statements, and the location (if applicable, country) of raw material acquisition and production.

The Contents and Structure of This Book

Materials for Sustainable Sites is intended to fill a critically important gap in the literature on sustainable site design. This book aims to be a comprehensive resource that clarifies the environmental and human health impacts of site construction materials and products and, maybe more importantly, provides designers, specifiers, and educators specific and detailed strategies to reduce these impacts. This book does not contain definitive answers for the “best” and “worst” site construction materials to use. This is an impossible goal given the wide range of performance expectations, site conditions, project constraints, and client priorities within which construction materials must be evaluated.

Table 1–1 Materials for Sustainable Sites Defined

Materials or products that minimize resource use:
Products that use less material
Reused material and products
Reprocessed materials
Post-consumer recycled-content materials
Pre-consumer recycled-content materials
Products made from agricultural waste
Materials or products with reuse potential
Materials or products with recycling potential
Renewable materials
Rapidly renewable materials
Durable materials
Materials or products from manufacturers with product take-back programs
Materials or products with low environmental impacts:
Sustainably harvested or mined materials
Minimally processed materials
Low-polluting materials in extraction, manufacture, use, or disposal
Low water use materials in extraction, manufacture, use, or disposal
Low energy use materials in extraction, manufacture, use, or disposal
Materials made with energy from renewable sources (e.g., wind, solar)
Local materials
Materials or products posing no or low human and environmental health risks:
Low-emitting materials and products
Materials or products that avoid toxic chemicals or by-products in their entire life cycle
Materials or products that assist with sustainable site design strategies:
Products that promote a site's hydrological health by reducing storm water runoff quantities and improving hydrologic qualities
Products that reduce the urban heat island effect
Products that reduce energy consumption of site operation
Products that reduce water consumption of site operation
Materials or products from companies with sustainable social, environmental, and corporate practices

This book takes the approach that no effort to reduce environmental and human health impacts is too small, even though larger steps may be preferable. There are many shades of green in construction materials, from use of a small amount of recycled content in a standard material such as concrete to use of on-site earth materials to construct site pavements and walls.

Changes can occur incrementally through small steps or may be achieved more drastically through larger steps. Therefore, this book presents a range of options for “greening” the standard materials of site construction in addition to offering information on alternative “dark green” materials such as earthen materials, bamboo, or high-volume fly ash concrete. The aim is to encourage both small and large efforts to minimize the environmental and human health impacts of construction materials. Nearly any material can be “greened” and a small step in the right direction is better than no step if the big step is not acceptable. Many small steps can add up to big impacts, and small steps over and over can result in a changed material industry—an industry that closes material loops; eliminates toxins and toxic wastes; and uses durable, local materials.

For example, if at first concrete is specified with 30% fly ash substituted for portland cement, and it performs well, then for the next project it is 40% fly ash with 10% recycled concrete for aggregate, progress has been made. Then as the clients, contractors, and structural engineers grow more familiar with these alternatives and 60% Class C fly ash, 40% recycled concrete for coarse aggregate, or 40% spent foundry sand for fine aggregate are specified to achieve a more durable concrete wall, substantial changes with far-reaching positive impacts will have been accomplished.

This incremental approach to change is the basic premise of this book. Radical change, if it can be accomplished, can be a good thing, but the reality is that the small steps of incremental change may be a much more realistic approach within the mainstream construction industry.

This book devotes one chapter each to the basic materials of site construction: concrete, asphalt, aggregates and stone, brick masonry, earthen materials, lumber and wood products, metals, plastics, and biobased materials. Each chapter discusses basic attributes of the material, and environmental and human health impacts

during all phases of its life cycle. Then it provides detailed discussion of strategies and technologies to reduce these impacts, and current standards, resources, and items for consideration during specification of these materials and products.

This book is intended for all professionals who design, specify, educate, or regulate sustainable sites. Professionals and educators in landscape architecture, architecture, civil engineering, urban design, and construction management will find valuable information to assist them in material and product selection and evaluation.

And, while this book addresses site construction materials, there is a substantial overlap with many architectural building materials such as concrete, brick, lumber and wood products, metals, plastics, aggregates and stone, earthen materials, and biobased materials. They are used differently in buildings than in site applications, but their life-cycle impacts and some strategies for reducing the impacts are similar. Therefore, this book can be of value to architects as they make decisions about building construction materials as well.

This chapter, Chapter 1, “Materials for Sustainable Sites Defined,” has identified the basic tenets of materials for sustainable sites. These have been carried into each individual material chapter and have shaped the content and issues discussed. There has been no attempt to rank the attributes here because their relative importance will vary by material and site conditions. Discussions of ranking priorities follow in subsequent chapters.

Chapter 2, “Background: Inputs, Outputs, and Impacts of Construction Materials,” begins with a summary of environmental and human health impacts resulting from the production, use, and disposal of construction materials. Relationships between the impacts and materials are illustrated and the life-cycle phases of materials and products are defined. Chapter 2 reveals the sheer magnitude of resources and waste that result from material production and begins to pinpoint the major problem areas to address with material and product selection. The chapter concludes with a hopeful discussion of recent trends in industrial ecology and material manufacture, and ideologies, principles, and policies relating to the sustainable use of construction materials.

Chapter 3, “Evaluating the Environmental and Human Health Impacts of Materials,” takes the position that with careful attention to environmental and human health costs throughout their life cycle, one can minimize their impacts. Therefore chapter 3 discusses the practice of life-cycle assessment (LCA) and offers techniques for sustainability assessment (SA) and embodied energy and carbon analysis of building materials. Acknowledging that an LCA is outside the skills and scope of most designers, the chapter provides explanations of current LCA tools and other information sources to assist designers with material and product evaluation. Establishment of environmental and human health priorities and weightings is also discussed.

Chapter 4, “Resource Reuse: Designing with and Specifying Reclaimed, Reprocessed, and Recycled-content Materials,” addresses one of the most critical and far-reaching principles of materials for sustainable sites—the reuse and recycling of materials and products. The importance of this activity is manifest not only in the conservation of natural resource use, but also in the related reductions of habitat destruction of energy use for primary processing of raw materials, waste, and pollution. The chapter discusses priorities and a hierarchy for reduction of resource use from reusing existing structures in place to recycling down to energy recovery. The chapter provides techniques of design for disassembly and deconstruction so that our existing built environment can be “mined” for resources after its useful life.

Chapter 5 leads the individual materials chapters with the most commonly used construction material in the world: concrete. The many advantages of concrete are weighed against the severe energy consumption and pollution resulting from cement manufacture. The main focus of the chapter is on use of pozzolanic and cementitious substitutes for portland cement, followed by a discussion of recycled materials that can be substituted for natural aggregates in a concrete mix. Considerations for the specification of porous concrete are provided.

Chapter 6 reintroduces earthen building materials for consideration in the modern site construction material palette. The chapter defines and discusses specification considerations for rammed earth, compressed earth blocks, adobe, sprayed earth, cob, rammed earth tires, earthbag, and soil cement construction methods.

It discusses soils, soil testing and amendments, and stabilizing additives and finishes to allow use of relatively low-impact earthen structures in any climate.

Chapter 7 discusses methods to balance the environmental impacts of brick production by maximizing longevity of the brick product. Clay bricks are known for their durability and when used appropriately can be used over and over again in many different structures, often outlasting the life of a landscape and giving new life to another. Strategies to minimize quantities of bricks used through perforated walls and single-wythe serpentine walls or pier and panel walls are discussed, along with techniques for reducing a wall's structural materials and footings.

Chapter 8 addresses the most ubiquitous paving material, asphalt concrete pavement, and provides many techniques to minimize its environmental impacts, from cooling the mix to recycling asphalt in place to making asphalt porous, supporting sustainable storm water strategies and reducing the pavement's contribution to the urban heat island effect. The chapter concludes that there is much that can be done to reduce the environmental and human health impacts of asphalt pavements.

Chapter 9 provides strategies for efficient use of stone and aggregates with both natural and recycled materials. While aggregate and stone are relatively low-impact materials to produce compared with cement or metals, the sheer volume of aggregate used in construction poses resource consumption and habitat destruction impacts. Use of a wide variety of recycled materials for aggregates in base materials and as block materials in surface pavement and walls is discussed along with techniques to reduce material use with gravel pavements, dry stack walls, gabions, and gravel-based wall foundations. Sustainable site strategies are supported with discussions of porous gravel pavements and structural soils.

Chapter 10 explores the often controversial topic of wood use for sustainable sites and concludes that wood offers the potential to be an extremely sustainable and renewable construction material if it is grown and harvested sustainably or reclaimed from other structures, naturally decay resistant, or treated with one of the newer low-toxicity treatments, finished with a renew-

able low-VOC finish, and detailed to conserve wood resources. The value of efficient wood use and potential impacts of engineered wood products are discussed along with the role that forests and even harvested wood play in carbon sequestration. Emphasis throughout the chapter is on detailing wood structures to last long enough to ensure that the equivalent tree can be grown to replace the lumber used, making wood a truly renewable material.

Chapter 11 addresses metals, the group of materials with the largest environmental and human health impacts of any site construction material. The chapter begins with an extensive explanation of the impacts that metals pose, primarily in the mining and primary processing phases, and to a lesser degree in the finishing phase. Strategies for metal product specification focus on ensuring a long use life for metal products by inhibiting corrosion in an attempt to offset the huge environmental impacts of their manufacture. Benefits and drawbacks of metal recycling are discussed along with the wide variety of available metal finishes.

The wide range of plastics used in site construction materials is the topic of chapter 12. While all are petroleum-based products, impacts from plastics manufacture, use, and disposal vary widely. HDPE plastic is a relatively benign plastic with the ability to be easily recycled into new plastic products—many of which are used in site construction. At the other end of the impact spectrum is polyvinyl chloride (PVC), the most commonly used plastic in construction, which poses severe impacts in manufacture and disposal and is virtually unrecyclable. The chapter discusses the often-contested impacts of PVC and provides alternative materials to consider.

Chapter 13 discusses the expanding range of non-living, biobased materials for site construction. Short-cycle materials grown on a ten-year or shorter rotation—such as fiber crops, bamboo, agricultural residues, and plant seed oils—are discussed along with impacts of their growth and processing. Some biobased site construction materials discussed are coir and jute erosion control products; straw mulch and straw bale; cellulose fiber mulch; compost; bamboo products; and plant-based soil stabilizers, form-release agents, finishes, and sealants.

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