part I

DESIGN PRINCIPLES

1 Introduction

The Natural Building Movement

Lynne Elizabeth

Perhaps the soul could remember a little of its origination, when people still belonged to the spirit of a place.

—Martín Prechtel, *Secrets of the Talking Jaguar*

Natural building in the United States is not just a phenomenon, it is a movement—a movement most visibly represented at the dawning of the twenty-first century by a particular set of non-industrialized construction technologies used primarily for residential applications. These include the traditional and modern earth- and straw-based building systems written about in this book, plus timber framing, stone masonry, and numerous indigenous forms.

Natural building is about far more than materials and wall assemblies, however. It encompasses a broad set of ethics, underpinned by a worldview that treats the earth as not only sacred, but alive. Its proponents concern

Alternative Construction: Contemporary Natural Building Methods, edited by Lynne Elizabeth and Cassandra Adams ISBN 0-471-24951-3

themselves with what constitutes a healthy built environment, how to build with the least impact on the earth, and ways in which the built environment can nurture vibrant community. Natural building aligns itself with philosophies of holistic, integrated systems, such as Bill Mollison's Permaculture, Rudolf Steiner's Anthroposophy, or the German Bau-Biologie. Structures are understood not as isolated entities, but as parts of and within interdependent systems for providing shelter, food, clean water, energy, and waste recycling.

In contrast to a pervasive dependence on mechanical heating, cooling, and ventilation that consumes vast amounts of polluting energy, naturally conditioned buildings are designed with sensitivity to the site, the sun, prevailing winds, and the seasons. They offer healthful, inexpensive comfort and preserve the tranquility of our interior spaces. Daylighting is favored over artificial lighting, as is architecture that integrates buildings with their natural surroundings.

The movement is also imbued with an aesthetic appreciation of building materials in their unprocessed or minimally processed state—the beauty of raw earth, uncut stones, unmilled wood, and woven grasses. Architecture is inspired by natural flows, patterns, and an indefinable spirit of place. These values of harmonious ecological design have been popularized by the pictorially rich books of architect David Pearson, such as the *Natural House Book* and *Earth to Spirit.*

Many within the movement hesitate to call it "alternative," lest it be perceived as questionable or in any way be hampered from entering the mainstream. There is hope that architectural historians will look back at this time and note the widespread appearance of natural building as the beginning of a new construction era based on principles of ecological balance.

"Natural" as the norm may, indeed, not be far off. In October 1999, the American Institute of Architects Committee on the Environment held a conference in Chattanooga to explore "Mainstreaming Green." "Green" architecture has, in the last dozen years or so, grown from a minor pocket to an enormous presence. During this period it has defined itself largely as conventional construction that has been improved to meet higher environmental standards—standards that in the eyes of many natural builders often represent compromised solutions rather than those reflecting a deeper ecological awareness. All views considered, the territories of "green" and "natural" do overlap.

The 1990s have also witnessed the rise of the cult of "sustainability," which popped into popular parlance during that period and is now used to describe almost any enlightened response to environmental, economic, or social concerns. As much as it can be understood, sustainability is rapidly being adopted by nearly every civic institution as the ultimate policy. At its core lies a recognition that the prevailing operating system of our society is not capable of being maintained at its current pace or in its current form.

Some describe the problem as being out of step with nature; hence arose, also during the last decade, a deductive scientific movement from Sweden called the Natural Step. Its mission is to adjust the misalignments of our industrialized culture with natural operating systems.

The values of natural, green, and sustainable development, then, go hand in hand as guides for ecologically sound construction practices.

The Environmental Imperative

To baby-boomers, it is usually a surprise to learn that lightweight wood framing has become the predominant building method in the United States only since the end of World War II, when returning GIs and a flourishing economy latched onto it because it was expedient and cheap. Stick-frame, as it is popularly known in the United States, has only very recently been adopted to any extent in other parts of the world. At a time when forests throught the world are being clear-cut at unprecedented rates, it is tragic that wood framing should now take the fancy of builders in wood-poor countries—countries where masonry and other indigenous building systems have predominated within a more or less balanced ecology for centuries, if not millennia.

The ecosystems on our planet most discernibly threatened by human exploitation are the forests. We have lost nearly half (46 percent)—3 billion hectares—of the forests that originally blanketed the earth, and deforestation continues to expand and accelerate. Most of this forest cover was cleared during the twentieth century for timber or to convert land to other uses. Between 1980 and 1990 alone, 200 million hectares—together equivalent to an area larger than Mexico—were destroyed. The World Resources Institute has reported that only 22 percent remains of the world's irreplaceable "frontier forests"—areas of "large, ecologically intact, and relatively undisturbed natural forests." Within the temperate zones, that encompass much of the United States and Europe, the percentage of remaining frontier forests drops to 3.[1]

Ancient forests support roughly half the world's biodiversity; they also renew our air, stabilize our climate, and maintain our watersheds and soils. Most people take these and many other benefits of forests for granted; they consider trees valuable for fuel, construction, and paper.

Wood frame residential construction in the United States is a leading cause of global deforestation. Forty-five percent of all the wood harvested in the world in 1995 (3.33 billion cubic meters) was used for industrial roundwood—this is the wood that is used to make lumber, paper, plywood, and similar products. Nearly one-quarter of that roundwood is consumed in the United States, and 40 percent or more of this is used for construction. Ultimately, about 10 percent of the world's industrial roundwood is used by the U.S. construction industry, and most of that for residential buildings.[2]

Despite the critical need to stop this voracious forest consumption, the warning signs that filter into the construction market—diminished quality of lumber stock and higher prices—are minimal. They give little if any incentive for significantly changing building practices.

Organizations such as the National Association of Home Builders and the Natural Resources Defense Council have published recommendations for reducing wood demand, which include more efficient framing techniques and engineered wood products. Specifying lumber from sustainably managed forests is gaining more awareness as an important solution, as are salvage and recycling options. Considering, however, population growth and the fact that the size of the average single family home in the United States has more than doubled since 1950,[3] all these measures for improving wood-frame building, even when combined, appear stop-gap at best.

Other insidious threats to health caused by industrialized construction include toxins emanating from buildings and pollution generated by the extraction and manufacturing of building materials. Transportation of the raw materials that go into building products and transport of the products themselves to construction sites are contributors to energy consumption and pollution of all kinds. These issues are well documented in a growing body of literature addressing the ecology of the built environment (see Appendix A).

Building with locally derived, unprocessed materials—materials as simple as the soil beneath our feet—is a natural response to this crisis. It significantly reduces the amounts of energy and secondary resources needed for extraction, processing, fabrication, and shipping. Rammed earth, adobe, cob, light-clay, and straw-bale wall systems can abate our demand for wood.

Coupled with vaulted, domed, or bamboo roof systems, these alternatives can significantly reduce reliance on wood. Designed with natural heating, cooling, ventilation, and lighting systems, such structures can substantially lessen our consumption of energy and resources and eliminate much pollution.

Reducing building size, designing with sensitivity to the site, and clustering development to preserve open space and lessen infrastructure demands are additional strategies for improving the ecology of our built environment. These are approaches the natural building movement has brought to the fore, but are also strategies that can be employed with any kind of development.

With so many obvious benefits for our local and global health, nonindustrialized materials and systems are receiving wide recognition as solutions. Articles on the subject are appearing with increasing frequency in mainstream media such as the *New York Times*, the *Wall Street Journal, Good Morning America, National Geographic,* and *Metropolitan Home*. In addition, a rising number of trade periodicals cover alternative construction (see Appendix B), and a national consumer magazine was launched in 1999 called *Natural Home.* Architecture schools, too, are now beginning to teach alternatives that utilize earth-based or indigenous systems.

It also seems possible that the residential builders in this country, despite their vast numbers and entrenched habits, may smell the danger ahead and, like a herd of hoofed mammals all charging in the same direction, suddenly change course altogether. Perhaps, less dramatically, they will discover the greener pastures of natural building and migrate for many positive reasons. To some extent, the public is already demanding that they do so.

Building Craft, Building Community

Much of the natural building movement is underpinned by a renaissance of the blended trade and profession known as the master-builder. Christopher Alexander wrote about it more than a decade ago in *The Production of Houses*; essentially, it is a shift away from highly specialized roles—the architect as a conceptualizer and draftsperson and the contractor as a narrowly defined construction tradesperson—toward more overlapping, if not entirely enmeshed, roles. This holistic approach to design and building offers closer and more creative kinship with materials. The architect is not divorced from the medium and the contractor is not working under the restriction of faceless blueprints. It allows better response to subtleties of the site and the interface of building forms. It respects the unique talents of each participant in the building process and affords opportunity for greater self-expression in planning, execution, and embellishment. A master-building climate encourages innovation and is the ideal setting for the growth of alternative building methods. It has also spawned a revival of building as craft.

Pioneers of newly evolving alternative construction methods are conducting workshops and classes wherever interest springs up around the country. Timber framers, cobbers, thatchers, and many other experts in traditional building techniques have also been engaging in a great interchange of construction know-how here and abroad. Natural and traditional building schools have been proliferating (see Appendix B, "Alternative Construction Resource Centers"), and there is now an entire second generation of Americans trained to teach alternative methods.

Gatherings and conferences for the purpose of exchanging building technologies have also emerged in the last decade, most notably in the western states but now in the eastern states as well. The largest of these have become known as the Natural Building Colloquia, where during a week of long days the champions of all types of appropriate and intermediate technologies work together on experimental structures, teach newcomers, and share with colleagues what they have learned in the past year. A valuable cross-fertilization results, and several hybrid systems have been developed.

Probably nothing has nourished the growth of natural building more than the camaraderie and robust community spirit of these trailblazers, artisans, scientists, and seekers. Natural building attracts those wanting to build a healthy and healthful community. These new values include sharing the work with all, to cross gender, race, religion, age, skill-level, and just about any other social boundaries. The movement also supports self-help and community-supported building, which is sorely needed in a world of regulated, restricted, and exorbitantly expensive real estate development.

If non-industrialized building methods can be respected in this most industrialized of countries, vernacular methods stand a chance of being valued in other countries as well, and much of the beauty and wealth of human cultures can be maintained. Low-impact construction should not be associated with poverty; on the contrary, simple and regionally appropriate construction offers great freedom of expression and allows us to live closer to the riches of nature.

Mass-produced housing robs our neighborhoods of local color and our tradespeople of meaningful work. In contrast, supporting local building crafts enlivens the culture, and building with the materials and talents of the region strengthens local economies.

The job of shaping the built environment comes with a responsibility beyond the wants of the paying client, and beyond our personal wants as well. May the wisdom that we bring to our practice include an understanding of the effects of our building designs and materials choices on all beings now alive and their descendants.

Clearly, it is easy to be caught up in the concerns of the hour, the fashion of the year, and the powerful thrust of our cultural habits. To work from an awakened perspective is to feel the joy of being alive. May the world we build express that joy.

Notes

1. Janet N. Abramovitz, *Taking a Stand: Cultivating a New Relationship with the World's Forests* (Washington, D.C.: Worldwatch Institute, April 1998). Her primary sources were the report, "Frontier Forests," (Washington, D.C.: World Resources Institute, 1997) and data from the Food and Agriculture Organization of the United Nations.
2. Janet N. Abramovitz and Ashley T. Mattoon, "Reorienting the Forest Products Economy," *State of the World 1999* (New York: W. W. Norton, 1999).
3. Ibid.

The Realities of Specifying Environmental Building Materials

Cassandra Adams

The construction technologies being developed and refined by the architects, artists, owners, and builders featured in this book are their responses to environmental, ethical, and social issues surrounding the extraction of raw materials from nature and their use in construction of the built environment. Although these building materials and methods have traditionally been considered "primitive" and therefore inferior to more highly processed materials in terms of safety, durability, performance, occupant health, and comfort, the stories and photographs in this book provide convincing evidence otherwise.

With respect to environmental issues, consumption of building products and energy within the construction industry has created a significant demand for raw materials (both recycled and virgin) and for energy production, thereby contributing to the many environmental problems associated with the extraction processes (environmental degradation, loss of genetically diverse ecosystems, etc.) and with energy production (polluting by-products emitted into the air/water/soil, which become part of smog, acid rain, global warming, etc.). In addition, the toxic particulates and gases incorporated into building products (especially interior finishes and furnishings) during manufacture are emitted later, degrading interior air quality and contributing to health problems of those with environmental illnesses.

Ethical questions are raised by the fact that the average lifestyle of people in affluent nations directly impacts the lives of the world's poorest people, both to their benefit and detriment, by creating a demand for the export of their resources and agricultural products. In addition, the boom-and-bust type of economy that often accompanies timber and mineral extractive industries as they move from one site to the next is often disastrous for the stability of local communities, especially those that have traditionally depended on nearby forests for their livelihood. This condition occurs in industrialized and developing nations alike.

Social benefits accrue from the reaffirmation of communal bonds by those who participate in community construction projects (professionals as well as lay persons) or, as in Obregon, Mexico, where the process has led to improved economic opportunity. Another social benefit is the personal satisfaction associated with the experience of "making," the joy of working with one's hands and with sensual materials. Similarly, the aesthetic potential of these materials is considerable, varied, and unique to these materials; as is shown in the elegant simplicity of David Easton's structures, in the sensual shapes and textures found in Carole Crews' decorated walls, and in Simón Vélez' breathtaking bamboo cantilevers.

Strategies for reducing negative environmental impacts and for promoting positive impacts are not always stated explicitly by the architects, artists, owners, and builders in this book, but their presence can be seen in their work. Common to all the projects described in this book are the twin goals of broadening the "palette" of raw materials suitable for construction (thereby lessening the demand on existing supply sources) and the reduction of energy embodied in the production, manufacture, and transport of materials. Additionally, many of the buildings shown in these pages have passive heating, cooling, and daylighting strategies integrated into their design, and, in some, the yearly energy consumption is far below current energy-efficient design standards. Also important is the use of interior finishes that emit few (if any) volatile organic compounds (VOCs), although it should be noted that the emission of particulates from earthen finishes can sometimes be high.

Consumption Patterns

The construction industry's concern with energy and resource consumption is due to the fact that it has contributed significantly to overall consumption patterns. In 1997, according to the U.S. Commerce Department, about 36 percent of total energy use in the United States was consumed in the operation of commercial (16 percent) and residential (20 percent) buildings. This figure represents almost 9 percent of total worldwide energy use for that year and is close to the amount typically expended yearly for world cement production. For a comprehensive energy picture, one must also add the significant amount of energy expended for the construction process itself and for the production of other building products besides cement.

Materials consumption by the construction industry is even higher than its energy use. William Rees at the University of British Columbia estimates that 40 percent of materials consumption worldwide is for the construction and repair of the built environment. Table 1B-1 illustrates the magnitude of construction consumption of selected resources in the United States.

Resource consumption can also be examined from a land-use perspective, which expands our understanding of the broader environmental role of building materials. Rees developed a method to estimate the amount of land needed to support the lifestyles in various cultures. He incorporates energy into his calculations by balancing the carbon emissions from energy consumption with the hectares needed for an equivalent carbon sink (1 hectare = 2.47 acres).[1] The ecological footprints of selected countries are found in Table 1B-2. Note especially the ecological deficits in many of the larger and faster-growing nations.

Table 1B-1. Consumption of Selected Resources for Construction

Raw Materials	Recycled from Scrap	End Use	Consumption
Aluminum	20%	Transportation	36%
		Packaging	25%
		Construction and electrical	14%
		Electrical	8%
		Consumer durables and other	17%
Asbestos	Insignificant	Roofing products	48%
		Friction products	29%
		Gaskets	17%
		Other	6%
Cement	Small amount of concrete	Construction	100% (total)
		Readi-mix concrete	70%
		Concrete products	10%
		Road-paving contractors	10%
		Other construction	10%
Clays	Insignificant	Construction	55%
		Paper	13%
		Foundry and nonconstruction refractory	8%
		Other	24%
Copper	14%	Construction	42%
		Electric and electronic	25%
		Industrial and transportation	24%
		Consumer products	9%
Crushed stone	Insignificant	Construction	83%
		Chemical and metallurgical (includes cement and lime manufacture)	14%
		Agricultural and other	3%
Gypsum	Small amount	Construction (wallboard and cement)	81%
		Agricultural	10%
		Other	9%
Sand and gravel	Limited pavement recycling	Construction	97%
		Industrial	3%
Steel	61%	Warehouses and distributors	21%
		Construction	14%
		Transportation	13%
		Other	52%

Source: USGS.

Table 1B-2. Ecological Footprints of Selected Countries[2]

	Population in 1997	Ecological Footprint (in ha/cap)	Available Ecological Capacity (in ha/cap)	Ecological Deficit (in ha/cap)
		(All expressed in world averge productivity, 1993 data)		
WORLD	5,892,480,000	2.3	1.8	–0.5
Bangladesh	125,898,000	0.7	0.6	–0.1
Brazil	167,046,000	2.6	2.4	–0.1
Canada	30,101,000	7.0	8.5	1.5
China	1,247,315,000	1.2	1.3	0.1
Egypt	65,445,000	1.2	0.6	–0.5
Ethiopia	58,414,000	1.0	0.9	–0.1
Germany	81,845,000	4.6	2.1	–2.5
India	970,230,000	0.8	0.8	0.0
Indonesia	203,631,000	1.6	0.9	–0.7
Japan	125,672,000	6.3	1.7	–4.6
Mexico	97,245,000	2.3	1.4	–0.9
Netherlands	15,697,000	4.7	2.8	–1.9
New Zealand	3,654,000	9.8	14.3	4.5
Nigeria	118,369,000	1.7	0.8	–0.9
Russian Federation	146,381,000	6.0	3.9	–2.0
Thailand	60,046,000	2.8	1.3	–1.5
Turkey	64,293,000	1.9	1.6	–0.3
United Kingdom	58,587,000	4.6	1.8	–2.8
United States	268,189,000	8.4	6.2	–2.1

Note: Population figures are taken from the World Resources Institute, 1996. *World Resources 1996–1997 Database*, Washington, D.C.: WRI. file “hd16101.wk1”.

Environmental Assessments

As noted by some of the authors in this book, the environmentally conscious building material specification process is more complex than simply making decisions to incorporate recycled and low-embodied-energy materials or to use materials obtained locally. This is due to the fact that every building material, every building system, and every construction practice impacts the natural environment in numerous ways at every stage of its life cycle, beginning with resource extraction and ending with building demolition and recycling of the debris. Every design decision involves an environmental compromise, thereby requiring the designer or builder to evaluate and compare the environmental impacts that occur throughout all the life cycle phases. The necessity of having to make choices is directly related to the fact that "environmentally conscious" design is *not* the same as "sustainable" design.

Currently, the most widely used method for evaluating a building's environmental impact is to conduct an environmental assessment of its life cycle, where the inputs and outputs of energy and resources are identified and quantified for each phase. The phases typically considered include raw materials extraction, processing and manufacture (this may involve several steps), onsite construction, occupancy, demolition, and debris disposal or recycling. Inputs occur during each phase and include all materials and all the process and transport energy. Outputs also occur in each phase, and besides the "product" itself, they include waste energy (such as heat or noise) and by-products (both polluting and nonpolluting). Now being developed in various parts of the world are life cycle assessment software programs that address the particular environmental, construction, climatic, and code conditions of that specific region or nation. Many, but not all, of these programs have been developed for use in designing larger buildings. Examples include BREEM in the United Kingdom, BEPAC in Canada, and LEEDS in the United States.[3]

One might argue that houses should be exempted from this lengthy and time-consuming environmental evaluation process due to the fact that they are much smaller and less resource and energy intensive than larger structures. However true this might be, the fact is that residential construction comprises 40 to 60 percent of construction expenditures in the United States (depending on the economy) and residential buildings (in aggregate) consume 30 percent more energy per year than do commercial buildings. These figures suggest that this evaluation process should not be waived.

Many of the existing assessment programs have been developed to the point where they are now (or soon will be) able to estimate *quantifiable* environmental impacts related to energy-consumption, resource quantities, and carbon-cycle effects. However, some important environmental impacts are not quantifiable in terms of dollars, energy, carbon, etc., and/or are difficult to compare. How does one value the impacts on human life and health, on loss of genetic diversity, on ecosystem degradation or destruction, or on the effect of climate change on agricultural patterns? Some assessment programs address these issues in terms of checklists or sliding-scale rating systems, but work continues on the development of more sophisticated assessment methods that address more of this complex mix of variables.

In addition to the quantitative and qualitative issues described above, there are some other issues that should be considered. These are discussed below.

PRIORITIZATION OF ENVIRONMENTAL IMPACTS

Environmental impacts are *not* all equal. Some are more critical than others and should be given more weight. Important prioritizing factors include:

- *Sphere of influence.* Some impacts have a more widespread area of influence than others (global warming versus streams siltation).
- *Duration.* Some impacts last only a few months or years while others continue forever (nuclear waste dumps versus patchwork clear-cutting).
- *Magnitude of risk to human or ecosystem health.* Some impacts have severe consequences for human or ecosystem health while others have little or no effect (toxic waste dumps versus well-managed municipal landfills). Sometimes the same behavior will have different effects (the reaction to VOC emissions by healthy people versus those with environmental illnesses).
- *Reversibility.* Some impacts are irreversible while others are technologically possible to repair (destruction of a genetically diverse ecosystem versus reclamation of a former strip mine site).

IDENTIFICATION OF CAUSAL FACTORS

It is important to identify which relationships between environmental problems and a particular design tradition (or construction behavior) are causal relationships; that is, where the environmentally destructive behavior is driven by construction industry demand and where the discontinuation of the practice will improve the environmental situation. If there is a direct causal relationship, then the practice should be avoided or mitigated. However if the driving force comes from some other segment of society and the construction industry is only making efficient use of leftover wastes, then a potentially bad environmental practice becomes environmentally beneficial. An example illustrating this point would be the factors underlying the destruction of world forests. In those regions where agricultural conversion is the primary motivating factor behind forest destruction (such as in some tropical forests), it would be better to use the timber than to burn it. This is the reasoning that supports the broadening of tropical species utilization. In the United States, where demand for construction lumber is the motivating factor for forest destruction (such as in Pacific Northwest forests), the appropriate environmental response is to reduce wood consumption in housing.

RESOURCE INTENSITY Some building products consume less raw material than others in fulfilling the same use. The weight of a 2 × 14 joist required to span a given distance is greater than an engineered-wood I-joist used for the same purpose, therefore some preference should be given to the product that uses raw materials more efficiently. This consideration is more important for products whose raw materials are in limited supply than for abundantly available materials or materials found on site. However, it should be noted that even soil can be in limited supply, as is the case in China, for example, in some of its agricultural regions.

ASSESSMENT BOUNDARIES An environmental assessment must be comprehensive and inclusive, because a single-issue environmental decision can conceivably be worse for the environment than the "standard" practice. Furthermore, the scope of the assessment must be meaningful with respect to its greater context. Energy consumption is a case in point, because this is one place where environmentally conscious design practice can fall short. Currently, the scope of energy assessments is typically restricted to the traditional scope of the design professions; that is, within the building envelope and on the building site. The problem here is that every bit of energy savings designed into a project by careful materials selection (that reduces embodied energy) and by careful design of thermal conditioning systems (that reduce operational energy) can be easily and quickly overridden by a poor choice made during the site selection process and the resulting energy-related transportation issues.

The Issues

There remains a fundamental limitation in the methodology used for assessing the "environmental impacts" of building materials. Current assessment practices work on a building-by-building basis with the implicit goal of the assessment process being an improvement over previous buildings. This is essentially the same method that is used for energy consumption, where the ultimate goal of "sustainable energy use" would be for the building to be off the grid or even to sell energy back to the electric utility. The analogous case for building materials would be for the building to be equipped with the means to extract all its raw materials on site. Obviously this will only be the case for a very few privileged buildings in rural or campuslike settings, which means that existing mines and forests must be shared. The "sustainability" of building materials, then, cannot be determined from an environmental assessment. It can only be determined on an industrywide basis, where the total demand for resources can be balanced with the available supply sources and maximum allocations made to each economic sector. This would require resource management and cooperation among industries of a kind that does not now exist.

Finally, a word of caution to our readers. It is important to emphasize that the construction methods described herein vary in terms of their development to meet current standards of health, safety, and performance. David Easton, for example, has spent several decades developing rammed earth and PISÉ construction in California to the point where his local building officials feel comfortable issuing permits, a condition that also applies to a few other locales in this country, Europe, Australia, and elsewhere. The same situation also exists for adobe and straw-bale construction in some locales.

Other construction methods, however, are presented in earlier stages of their development, so the performance of these materials and methods over longer periods of time, in all climates, and for all structural conditions is still not completely understood nor worked out. Several have not yet been adopted into the building codes, but they hold promise—and it is our hope that their presence in this book will inspire some readers to contribute to their further development. The unknowns about the performance of bamboo, straw walls, long bags, tires, composite wood-cement blocks, etc. will undoubtedly become known and design standards and construction methods will eventually be agreed upon. Meanwhile, in a litigious society like ours, it is important for all parties (designers, builders, *and* owners) to clearly communicate to each other what the unknowns and the risks are and what the implications are for building durability and performance.

Notes

1. Wackernagle, Mathis and William Rees, *Our Ecological Footprint* (Philadelphia: New Society Publishers, 1996).
2. Wackernagle, Mathis, Larry Onisto, Alejandro Callejas Linares, et al. "Ecological Footprints of Nations: How Much Nature Do They Use? How Much Nature Do They Have?" (prepared for the 1997 Rio +5 Forum, The Earth Council, 1997).
3. These and others are described in conference proceedings (the editor is not given) entitled *Green Building Challenge '98* (Vancouver: Natural Resources Canada and University of British Columbia, 1998).