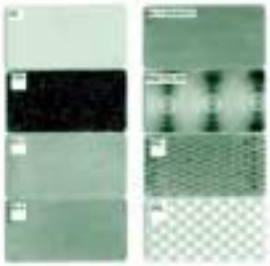


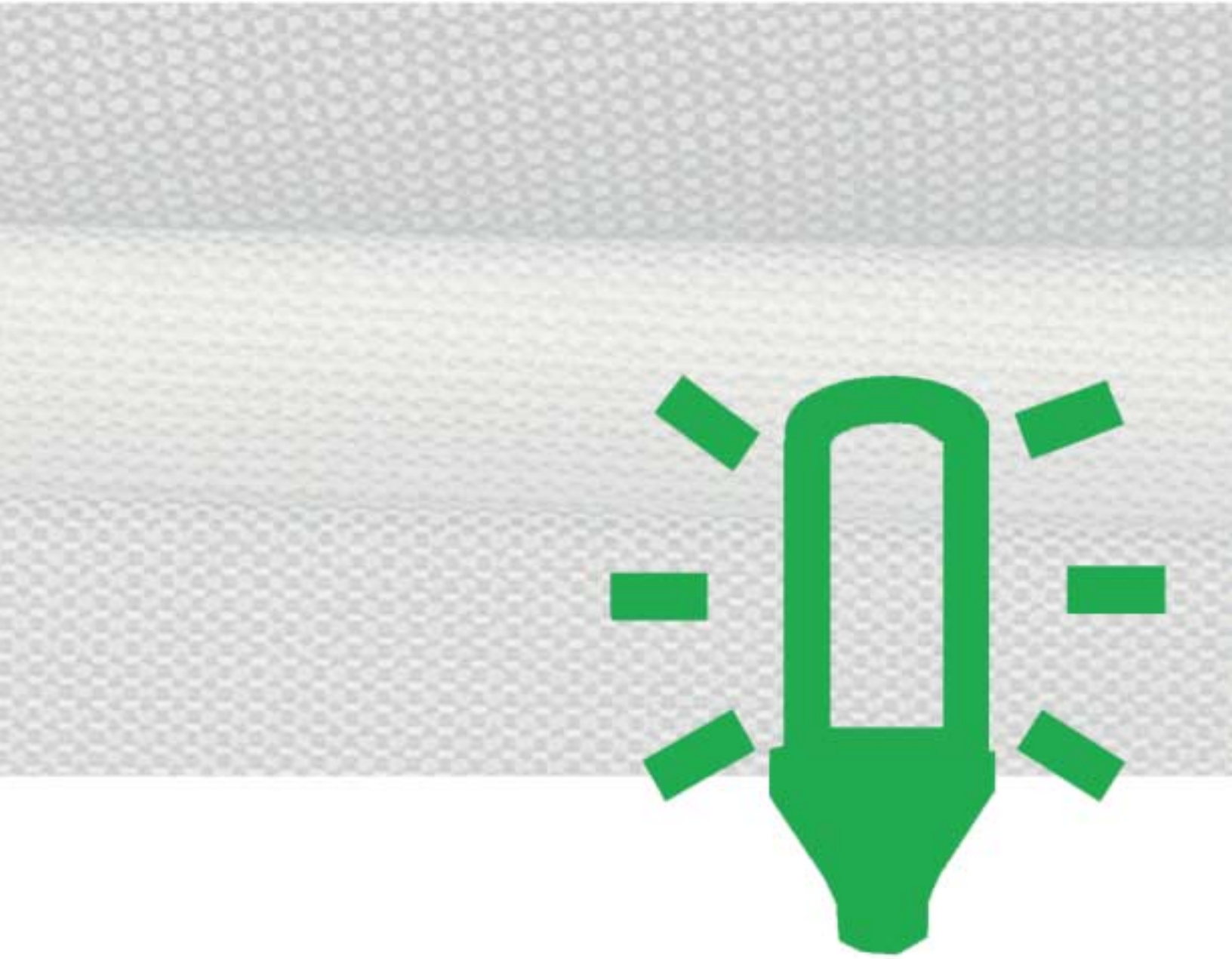
Vol 1. - fall 04

university of colorado, denver

college of architecture and planning

MATERIALs

GREENBUILDING RESOURCE GUIDE



MATERIALs
GREENBUILDING RESOURSE GUIDE

Table of Contents

Introduction to the GBT Resource Guide

College of Architecture and Planning, University of Colorado, Denver.
Instructor: Fred Andreas, AIA, Assistant Professor Adjunct

Greenbuilding Technology Resource Guide

The Resource Guide will provide an overall understanding of each material explored. It will be valuable for architects, clients, and students interested in utilizing green building concepts and designs. This document and CD ROM publication provides a template for continued research, development and documentation of green building materials and systems.

The format of the guide was based on Transmaterial, a catalog of materials, products and processes that redefine the physical environment, developed by Blaine Brownell http://transstudio.com.

Overview

This Resource Guide was developed during the fall term of 2004 at the University of Colorado's College of Architecture and Planning. This document provides a compilation of work by 30 graduate students in the Greenbuilding Technology Seminar. That Seminar specifically studied the latest in available green materials and systems for use in LEED projects and other green building applications. This Resource Guide covers green building materials and systems in 5 major categories in LEED including: Sustainable Sites, Water Efficiency, Energy & Atmosphere, Materials & Resources and Indoor Environmental Quality. This Resource Guide will provide the user with a readily usable and understandable source for green building materials and systems. The standardized guide follows a clear and concise format to guide and educate designers on green building technologies. This Resource Guide will be added to in future terms and represents only the beginning for a continuing Greenbuilding Technology Resource Guide.

Purpose of the course

Investigate alternative, greenbuilding approaches that include all aspects of greenbuilding design including: materials, equipment, systems, methods, resources and cutting edge research

Description of the course

This course will use the Construction Specifications Institute or CSI Format to provide a framework for assessing green building opportunities and meeting sustainability goals. Students formed groups of 2-3 and choose one material type for in depth exploration. Exploration methods included research, field trips, case study, & project application.

Explanation of checklist criteria

A checklist is used to gauge the many different aspects of materials and systems. It aims to target key principals and compare different technologies that otherwise might not assessed in conventional building practices. It also can be seen as tool to educate the many disciplines, government agencies, and communities about the impacts and tradeoffs of using certain materials over others. The categories include:

- Cost
- Maintenance
- Properties
- Life cycle
- Embodied energy
- Recycling
- Health
- Benefits & disadvantages

On-going green projects incorporated within this course:

I. Sustainable Settings, Carbondale, Colorado: http://www.sustainablesettings.org

Mission Statement
"Sustainable Settings is an entrepreneurial non-profit organization that inspires people and communities to embrace integrated solutions for sustainable development. To accomplish this mission we research, design and demonstrate whole-systems strategies in sustainable agriculture, green development, micro-enterprise, land stewardship and art for daily life."

Overview from Sustainable Settings Web Site: aspect
Sustainable Settings' Whole Systems Learning Center is an unprecedented effort in the inter-mountain West to provide an experiential learning environment for the cultivation of a sustainable future. By utilizing place as pedagogy and harvesting nature's intelligence, the whole systems learning center offers a rich and dynamic context in which people are inspired to embrace integrated solutions for sustainable development.

Core Elements
The core elements of the whole systems learning center form a foundation from which learners of all ages experience and develop ways to live more sustainably. These core elements are:

Sustainable Agriculture
Green Development
Micro-Enterprise
Land Stewardship
Art for Daily Life
Education & Ecological Literacy

Our educational programs are rooted in the concepts and methodologies of ecological literacy. By teaching and learning within a whole-systems pedagogical framework that favors a symbiotic relationship between learning and locality, we seek to:

- Equip people with a basic understanding of systems and to develop habits of mind that seek out patterns that connect human and natural systems.
- Teach people the analytical skills necessary for thinking accurately about cause and effect.
- Give the practical competence necessary to solve local problems.
- Teach people the habit of rolling up their sleeves and getting down to work.

II. Sustainable Youth Zone, Commerce City, Colorado

* From the original Project Proposal by UCD's Engineering Department

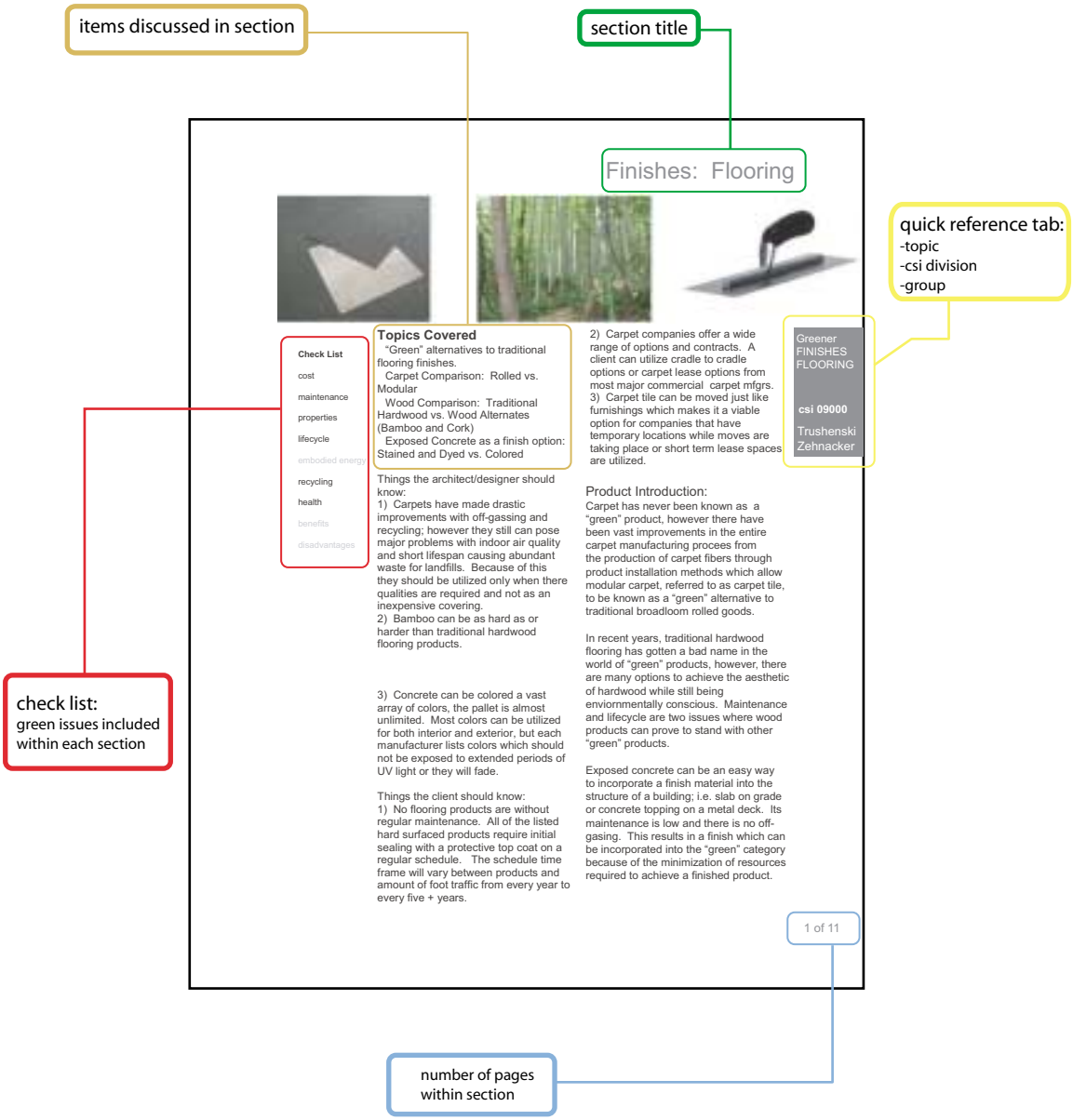
CU Denver's Sustainable Youth Zone Project has the potential to offer an alternate transforming vision of the future. Commerce City Youth have long desired a youth center that can help revitalize their age group and their community (*See Letters*). In Year 2002, a 17 acre parcel of land in the midst of Commerce City was voted to be home of the first Youth Center in Commerce City, serving youth from ages 4 to 24. Although the Commerce City Citizen's group obtained the land for their project, they did not have the architectural and engineering skills needed to build such a Youth Zone. Although they had many recreational plans for the site, educational and vocational programming ideas were absent. In Year 2003, citizens from Commerce City approached the CU Denver USIEP to seek assistance in visioneering and engineering their Youth Center. From discussions with the USIEP Director, Dr. Anu Ramaswami and the Citizen's group, the following vision emerged for the CU Denver SYZ project:

SYZ Vision Statement:

- **CU Denver will partner with the community** to design a Youth Center Complex of buildings on the 17-acre site, representing *the highest ideal in sustainable urban infrastructure planning and design.*
- **To verify and demonstrate the efficacy of sustainable design**, CU Denver will aid in the construction and monitoring of a 15,000 square foot building on the site dedicated for use by youth in 8th grade and above. Design principles identified and tested in this first building will be incorporated in other buildings on site that target other age groups and other needs, e.g., Head Start.
- **Sustainable Design Features**: The CU Denver SYZ building will be constructed largely from recycled/agricultural waste products, and will be designed and engineered to minimize water use, minimize exposure to environmental pollutants, consume net zero energy over a year and produce zero waste, while being structurally safe and aesthetically pleasing. Water, energy, and materials audits of the complex will be performed and a life cycle analysis will be completed to quantify the environmental sustainability of the building complex.
- **Educational & Vocational Programs** for Commerce City Youth will be offered at the CU Denver SYZ building to improve the knowledge and skill base of the youth, thereby enhancing socioeconomic sustainability in Commerce City through higher retention and graduation rates from high school, and steady employment options thereafter.

* While these projects were used during the course, the resources provided are not limited by project specific criteria.

MATERIALs
GREENBUILDING USER GUIDE



User guide

FORMAT - The goal of the GBT guide is to bridge disciplines and expertise into one concise source. As there are many aspects to any one particular topic or CSI division, the organization here relies on the formatting accompanied by succinct descriptions to educate the reader on the fundamentals of greenbuilding. The format was designed to act as a quick and easy way of communicating the basic 'need to know' information with further ways to research and explore the topics within. For example, what does the designer need to know about the subject or technology before he or she starts thinking about considering using it. And on the other hand how can they(the designer) convey that information back to the contractors, developers, and municipal leaders. It aims to demonstrate an unbiased look at greenbuilding materials and related technologies by presenting facts and acting as an educational tool. It can be seen as falling somewhere between the two spectrums of the **Transmaterial** research and **GREENSPEC**. It is envisioned that future versions of this prototype might elaborate on the Checklist and concepts behind it to further engage the reader on the set criteria to best gauge performance and environmental concerns.

Disclaimer

Greenbuilding Technology Resource Guide is a resource for current and future materials and technologies. It is intended to serve students, architects, designers, and others interested in learning more about green building. The Green Building Technology Resource Guide, the University of Colorado, Fred Andreas, and the students themselves assume no responsibility for accuracy, completeness or usefulness of the information provided. Users are cautioned to consult with the manufactures and professionals before specifying or recommending any of the products or technologies within.

MATERIALs
GREENBUILDING RESOURSE GUIDE

Green Roofs




Check List

cost

maintenance

properties

lifecycle

embodied energy

recycling

health

benefits

disadvantages

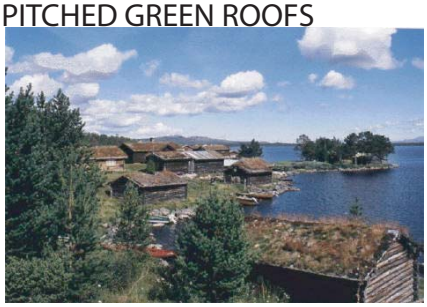
GREEN ROOF- an area of planting and or landscaping , built up on a roofed/waterproof structure at any level, that is separated from the natural ground by a man- made structure.

EXTENSIVE ROOFSCAPE- low to no maintenance green roof landscaping Ideally suited for locations that will receive little or no maintenance, or where structural capabilities are a concern. Recommended plants include sedum, herbs, grasses and other vegetation that can withstand harsh growing conditions. The soil mixture, composed primarily of mineral materials mixed with organic medium, can be very shallow (as little as three inches). The entire system is very light, weighing little more than a traditional ballast roof, allowing for safe installation on almost any existing roof.

INTENSIVE ROOFSCAPE-incorporates plants that require regular maintenance, such as watering, fertilizing and mowing. The variety of plants possible is numerous, including sod grass lawns, perennial and annual flowers, shrubs, and even small trees. The system is ideal for roofs and plazas that will serve as pedestrian recreational areas.

TYPES OF GREEN ROOFS

PITCHED GREEN ROOFS



FLAT GREEN ROOFS

SUSPENDED GREEN ROOFS

COVERED UNDERGROUND PARKING GARAGES AND EARTH-SHELTERED BUILDINGS

EARTH - SHELTERED BUILDING

Courtesy of William Morgan Architects

GREEN ROOFS INTRO & DEFINITIONS

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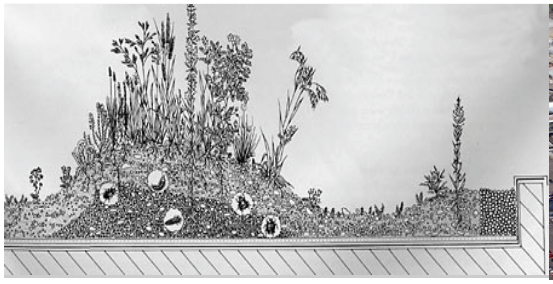
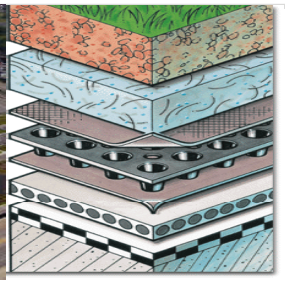
group 2

Green Roofs Essentials- Anatomy





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The following components are installed, working from the roof deck on up...

ROOFING MEMBRANE– generally a hot, fluid applied, rubberized asphalt applied in two coats, with a layer of fabric reinforcement between layers.

PROTECTION COURSE/ROOT BARRIER - For extensive roofscapes standard protection layer and root barrier work together to prevent roots from penetrating the waterproofing /roofing membrane. For intensive roofscapes a heavy-duty protection course/root barrier must be used. It is intended for more intensive roofscapes or plaza decks which will be subject to high amounts of construction traffic or where plants with deeper and more aggressive root structures are to be planted.

INSULATION/ AIR BARRIER- a CFC free, closed cell, extruded polystyrene that exhibits high compressive strength and moisture resistance, while maintaining excellent long term insulation value. Use of insulation is optional, (not depicted) depending on the thermal value requirements of the structure.

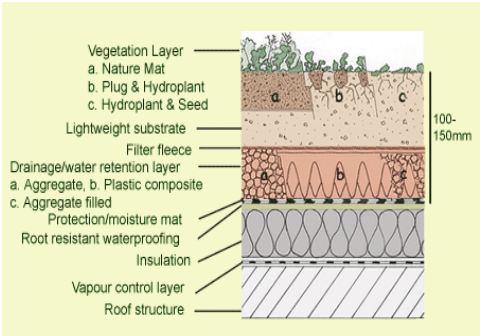
WATER RETENTION - Depending on the needs of the vegetation, additional water retention can be achieved through the use of a Moisture Retention Mat. It is composed of recycled, non-rotting, polypropylene fibers stitched through a polyethylene carrier sheet that is rolled out over the root barrier or insulation/air layer.

DRAINAGE/ WATER STORAGE/ AERATION - lightweight panels of 100% recycled polyethylene, molded into specially designed retention cups and drainage channels. The unique design allows for the free drainage of excess water, achieving flow rates from 2.5 to 28 times higher than that of conventional drainage methods. At the same time, the system is engineered to promote irrigation through capillary action and evaporation into the soil/vegetation level.

FILTER FABRIC- a geotextile filter sheet made of non-rotting, non-woven polypropylene fibers. It is highly resistant to all natural acids and alkalis, and chemically neutral. It is unrolled over the entire roof area completely covering the drainage elements in both extensive and intensive systems.

SOILS - the most critical part of any green roof system is the soil. The soil needs to provide a stable structure for the anchorage of the plants' root system, while remaining as light as possible to prevent excess loading of the roof structure. It must also supply essential nutrients, water and oxygen.

VEGETATION - A wide variety of typical landscape/garden plants are suitable for a Green Roof. The selection of the appropriate plants depends on the building construction, anticipated use of the roofscape, whether an extensive or intensive roofscape is desired and the local climatic conditions. Typical characteristics for plants utilized in Extensive Green Roof assemblies include shallow root system, resistance to direct radiation, regenerative, and drought, frost and wind resistant. A much larger variety of choices are available for intensive roofscapes, including sod grass lawns, perennial flowers, shrubs and even small trees.



GREEN ROOF ANATOMY

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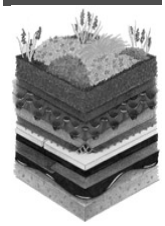
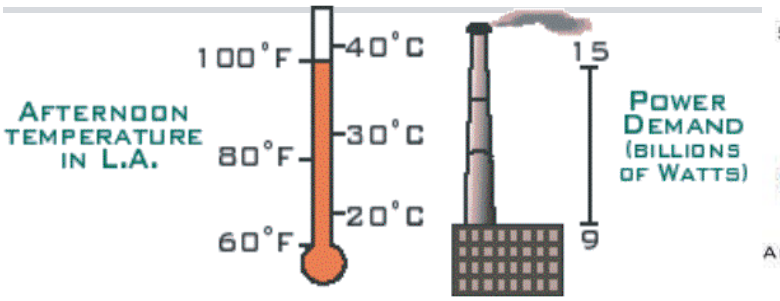


Green Roofs Ecological Benefits



GREEN ROOFS ECO BENEFITS

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IMPROVED AIR QUALITY

Filtration of Airbourne Particulates:A green roof will not only absorb heat, decreasing the tendency towards thermal air movement, but will also filter the air moving across it. 1.5 m2 (10.76 ft2) of uncut grass, produces enough oxygen per year to supply 1 human with their yearly oxygen intake requirement.

Carbon Dioxide/Oxygen Exchange:Through the process of photosynthesis, plants convert carbon dioxide, water and sunlight/energy into oxygen and glucose. This cyclical process supplies animals and humans with oxygen and food. 1 m2 (10.76 ft2) of grass roof can remove between 0.2 kg of airbourne particulates from the air every year.

TEMPERATURE REGULATION

Moderation of the Urban Heat Island Effect:Through the daily dew and evaporation cycle, plants on vertical and horizontal surfaces are able to cool cities during hot summer months. It is mainly due to the expanse of hard and reflective surfaces, such as roofs, which absorb solar radiation and re-radiate it as heat. Reduction of the 'Urban Heat Island Effect' will also reduce the distribution of dust and particulate matter throughout the city and the production of smog. This can play a role in reducing greenhouse gas emissions and adapting urban areas to a future climate with warmer summers

CREATION OF MICROCLIMATES

A green roof will have a noticeable impact on the heat gain and loss of a building, as well as the humidity, air quality and reflected heat in the surrounding neighbourhood. In conjunction with other green installations, green roofs can play a role in altering the climate of the city as a whole.

WATER CONSERVATION

Water Stormwater Retention- In summer, depending on the plants and growing medium, green roofs retain 70-80% of the precipitation that falls on them; in winter they retain between 25-40%.

Water Filtration:Green roofs not only retain the rainwater, but also moderate the temperature of the water and act as natural filters for any of the water that happens to run off.

Temporal Delay of Stormwater Runoff and Reduced Runoff Volume:Green roofs reduce the amount of stormwater runoff and also delay the time at which runoff occurs, resulting in decreased stress on sewer systems at peak flow periods.

PRESERVATION OF HABITAT & BIODIVERSITY

Habitat:Rooftop habitats can play one of two roles: a 'stepping stone' habitat connecting natural isolated habitat pockets with each other, or an 'island' habitat remaining isolated from other habitats at grade. Green roofs can be specifically designed to mimic endangered ecosystems/habitats.

Fauna:Green roofs designed for minimal maintenance are very protected and can become home to plants easily damaged by walking and to birds that nest on the ground. Since the soil on these green roofs is also less likely to be disturbed, it becomes a safer habitat for insects, and the deeper the soil the more diversity the roof can support.

RESOURCE CONSERVATION-

Recycled content of roofing material

Green Roofs Tech, $$$ & Other Benefits



BUILDING TECHNOLOGY BENEFITS

-Reduces temperature extremes on the roof
-Prevents mechanical damage to the roof
-Reduces noise transmission into the building
- Increased energy efficiency
-Sound Insulation- Sound waves that are produced by machinery, traffic or airplanes can be absorbed, reflected or deflected.
-Reduced temperature extremes inside the building

$$$$$$$ BENEFITS

-Additional usable space for tenants
-Increases property value
-Creates therapeutic and peaceful environments- selling point
- Potential government enticements...$$$. -
-Protection of roof membrane resulting in a longer material lifespan (green roofs will last up to twice as long as conventional roofs)
-Decreased maintenance and savings in replacement costs
-Savings on energy heating and cooling costs, depending on the size of the building and type of green roof. A typical one storey building with a grass roof and 10 cm (3.9 inches) of growing medium would result in a 25% reduction in summer cooling needs.
-Potential to reduce the size of HVAC equipment on new or retrofitted buildings.
-Potential to reduce the amount of standard insulation used.
-Potential to incorporate cooling and/or water treatment functions.
-Potential for local, regional, and national market exposure, depending on the uniqueness of the project.
- Building Insulation: Shading the external surface of the building envelope has been shown to be more effective than internal insulation. This could play a role in reducing greenhouse gas emissions and adapting urban areas to a future climate with greater incidences of drought and extreme heat. -
-Industrial Cooling:The Possman Cider Cooling and Storage Facility in Frankfurt, Germany yielded a 2-3 year payoff of their green roof system through savings in heating and cooling costs, as well as in equipment costs, since additional cooling towers had become unnecessary.

ADDITIONAL BENEFITS

-Amenity Space and Aesthetics Provision of amenity space for day care, meetings, and recreation
-Aesthetic appeal, increasing the value of the property and the marketability of the building as a whole, particularly for accessible green roofs. For example, American and British studies show that "good tree cover" adds between 6 to 15 per cent to the value of a home. Green roofs offer the same visual and environmental benefits.
Satisfying the aesthetic needs of people looking down upon the roof from adjacent buildings.
Food Production The Fairmount Waterfront Hotel in Vancouver grows herbs, flowers, and vegetables on its accessible roof, saving its kitchen an estimated $30,000 a year in food costs.

Green Roof Maintenance




GREEN ROOFS
Maintenance

csi 02000

group 2

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Once a properly installed green roof is well established, its maintenance requirements are usually minimal. However, of the two basic types of green roofing systems, extensive and intensive, the latter due to its increased weight and more intensive plantings tends to have higher maintenance requirements. These maintenance requirements include inspection of the roof membrane, the most crucial element of a green roof, as well as routine inspection and maintenance (as needed) of the drainage layer flow paths.
Regardless, for any kind of green roof initial watering and occasional fertilization are required until the plants have fully established themselves. Supplemental irrigation in addition to natural precipitation at least once a week may be required in the first six months or so depending upon the type of roof membrane and water requirements of the planting material. Plants for green rooftops must be selected with care if the roof is expected to stay more or less maintenance free.
Extensive green roofs sometimes rely on a permanent drip tubing system which directly targets the root zone, and that can be put in place during the green roof installation process. Once the plants are healthy and well established extensive green roofs no longer need to be irrigated except in cases of extreme drought. Green roofing systems can vary in thickness from two to inches (5 to 18 centimeters). The term "extensive" is used to describe the lighter roofing systems, while the term "intensive" is used to describe the heavier roofing systems. While a roof's effectiveness in managing runoff generally increases with the thickness and weight of the roofing system, so do the maintenance requirements.1

MAINTENANCE

WATERING & FERTILIZING- For any kind of green roof, initial watering and occasional fertilization are required until the plants have fully established themselves. Supplemental irrigation in addition to natural precipitation at least once a week may be required in the first six months or so depending upon the type of roof membrane and water requirements of the planting material.

TRIMMING & WEEDING- If properly designed and established, a typical green roof does not need to be cut.

INSPECTION FOR DRAINAGE-Because of the severe consequences of drainage backups, inspection of the drainage flow paths (or channels) is crucial, especially on extensive roofs.

INSPECTION FOR LEAKS- Roofs can leak from drainage backups or root puncture or if the correct waterproofing membrane system, root barrier, and/or drainage layer are not selected. Areas where occasional inspection for leaks is advisable include possible such as abutting vertical walls, roof vent pipes, outlets, air conditioning units, perimeter areas, etc.

ROOF REPLACEMENT-Green roofs are generally more effective than conventional roofing systems in protecting the roof membrane. This reduces regular maintenance costs and extends the life of the membrane itself. According to a study in Germany, a vegetated roof on average can be expected to prolong the service life of a conventional roof by at least 20 years (ZVG, 1996).

Vendors of Green Roof Products




GREEN ROOFS VENDORS

csi 02000

group 2

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benefits

disadvantages

Emory Knoll Farms
3410 Ady Rd.
Street, MD 21154
Phone: 410-452-5880
Fax: 410-452-5319
www.greenroofplants.com

Barrett Company
33 Stonehouse Rd.
Millington, NJ 07946
Phone: 908-647-0100
Toll-free: 800-647-0100
Fax: 908-647-0278
www.barrettroofs.com

Intrinsic Perennial Gardens, Inc.
10702 Seaman Rd.
Hebron, IL 60034
Phone: 815-648-2788
Toll-free: 800-648-2788
Fax: 815-648-2072
www.intrinsicperennialgardens.com

Building Logics, Inc.
3213 Virginia Beach Blvd.
Virginia Beach, VA 23452
Phone: 757-431-3170
Fax: 757-431-3172
www.buildinglogics.com

Midwest Trading
P.O. Box 1005
St. Charles, IL 60174
Phone: 847-742-1840
Fax: 847-888-3818
www.midwest-trading.com

Carlisle SynTec Incorporated
P.O. Box 7000
Carlisle, PA 17013
Phone: 717-245-7000
Toll-free: 800-479-6832
Fax: 717-245-7143

White Premium Organics, Inc.
2560 Foxfield Rd., Ste. 200
St. Charles, IL 60174
Phone: 630-377-9966
Toll-free: 866-586-1563
Fax: 630-377-9934
www.garveyintl.com

GreenTech, Inc.
1301 Macy Dr.
Roswell, GA 30076
Phone: 770-587-2522
Fax: 770-587-2445
www.greentechitm.com

The Garland Company, Inc.
3800 E. 91st St.
Cleveland, OH 44105
Phone: 216-641-7500
Toll-free: 800-321-9336
Fax: 216-641-0633
www.garlandco.com

American Hydrotech, Inc.
303 E. Ohio St., Ste. 2700
Chicago, IL 60611
Phone: 312-337-4998
Toll-free: 800-877-6125
Fax: 312-661-0731
www.hydrotechusa.com

Roofscapes, Inc. (SM)
7114 McCallum St.
Philadelphia, PA 19119
Phone: 215-247-8784
Fax: 215-247-4659
www.roofmeadow.com

W. P. Hickman
30700 Solon Industrial Pkwy.
Solon, OH 44139
Phone: 440-248-7760
Fax: 440-248-3137
www.wphickman.com

American Wick Drain Corporation
1209 Airport Rd.
Monroe, NC 28110
Phone: 704-238-9200
Toll-free: 800-242-9425
Fax: 704-296-0690

Soprema USA, Inc.
310 Quadral Dr.
Wadsworth, OH 44281
Toll-free: 800-356-3521
Fax: 330-334-4289
www.sopremaworld.com

Weston Solutions, Inc.
20 N. Wacker Dr.
Chicago, IL 60606
Phone: 312-424-3319
Fax: 312-424-3330
www.greengridroofs.com

MATERIALs
GREENBUILDING RESOURSE GUIDE

Concrete Fly Ash

Concrete and Fly Ash

CONCRETE:
Fly ash

csi 03000

group D

Check List

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Cement and CO2

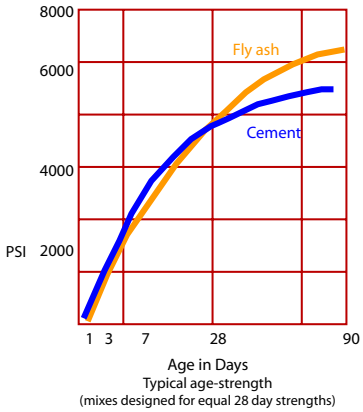
Cement only comprises about 10-15% of concrete but exudes a high embodied energy in its process. The process includes firing lime and other minerals in a kiln at 2700 F. Its result includes using enormous amounts of fossil fuels producing high amounts of Carbon Dioxide. One ton of cement consumes 6.5 million BTUs of energy.

The cement industry alone produces 7%-8% of the worlds CO2 emissions. For every ton of cement approximately 1 ton of CO2 is emitted into the atmosphere.

6% Air
11% Portland Cement
41% Gravel and Crushed Stone
26% Sand (Fine Aggregate)
16% Water

Fly Ash

Fly ash on the other hand is a by-product of coal generated power plants. Fly ash is residue from the combustion of ground or powdered coal from the firebox through the boiler by flue gases. In the U.S. alone, 60 million tons of fly ash are produced with approximately 70% residing in landfills.



Advantages of using Fly Ash

Fly Ash is known as a supplementary cementitious material(SCM). By replacing the cement ratio with fly ash, we reduce the land filling of this post industrial waste product and reduce the proportioning of cement in the concrete mix.

Physical benefits include:

- Enhanced workability of concrete
- Reduced bleeding
- Less water to cement ratio
- Greater ultimate strength
- Resistance to sulfate attack
- Reduced drying shrinkage

Environmental benefits include:

- Lowered carbon dioxide emissions
- Less water usage
- Recycled post industrial by-product
- Less land fill requirements

Types 'C' and 'F'

ASTM accepted by both the Uniform Building Code(UBC) and the International Building Code(IBC), recognizes two classes of Fly ash: Class F – burning of anthracite or bituminous coal and Class C – burning of lignite or subbituminous coal. Class F has little or no cementing value while Class C has self-cementing properties.

Basic characteristics of class F:

- Minimizes heat gain(mass concrete and high strength mixes)
- Good solution for summer concreting problems
- Concerns in cold weather(longer curing)
- Sulfate resistance
- Alkali-Silica reduction
- High strength concrete

Disadvantages:

- Longer set time

Basic characteristics of class C:

- Typical early strength as cement
- Can be used in cold weather
- May enhance early strength
- High strength concrete

Disadvantages:

- Limited sulfate and alkali-silica resistance

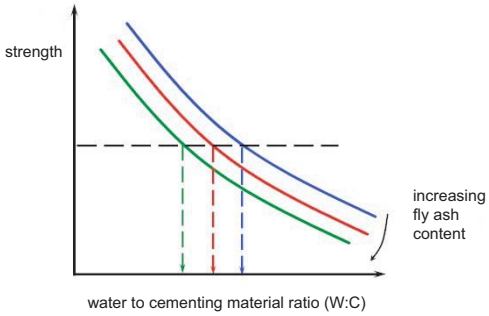
Ratios

The American Concrete Institute(ACI) recommends class F fly ash replacement from 15-25% and class C replacement from 20-35%. Currently testing is being done on high volume fly ash (>50%) which ultimately creates a better performing mix and uses significantly less water than the standard 20-30% replacements. Although many building codes will not allow more than 25%.

ASTM C618

The American Society for Testing and Materials (ASTM) is probably the most widely recognized and used national standards-setting organization in the United States for engineering-related materials and testing. The ASTM C618 specification is the most widely used because it covers the use of fly ash as a pozzolan or mineral admixture in concrete. The three classes of pozzolans are Class N, Class F, and Class C. Class N is raw or calcined natural pozzolan such as some diatomaceous earths, opaline cherts, and shales; tuffs, volcanic ashes, and pumicites; and calcined clays and shales. Class F is pozzolanic fly ash normally produced from burning anthracite or bituminous coal. Class C is pozzolanic and cementitious fly ash normally produced from burning lignite or subbituminous coal. The table below shows the chemical and physical requirements listed in the ASTM C618 specification.

Slump test with fly ash demonstrating a better consistancy.



LCA - BEES Calculation

Check List

cost

maintenance

properties

lifecycle

embodied energy

recycling

health

benefits

disadvantages

Life-Cycle Analysis of Concrete

BEES performance data apply to four concrete building elements: 3ksi Slabs on Grade and Basement Walls; and 4ksi or 5ksi Beams and Columns. From the result of BEES calculation , we found Beams and Columns have pretty much higher values than Slab and wall.

Economic performance covers the costs of initial investment, replacement, operation, maintenance and repair, and disposal. Using higher percentage's fly ash wouldn't make additional cost, even the cost is lower.

Also by comparing the Statistic of Environmental performance from Bee's calculation, we can get which performance causes the most effect toward our environment.

Human Health > Criteria Air Pollutants = Ecological Toxicity > Smog Formation Potential > Global Warming potential > Fossil Fuel Depletion > Eutrophication > Water Intake
*Fly Ash only causes slight effect on Acidification and Ozone Depletion.

The descriptions of first five performances are discussed below –

Human Health –
There are many potential human effects from exposure to industrial and natural substances, ranging from transient irritation to permanent disability and even death.

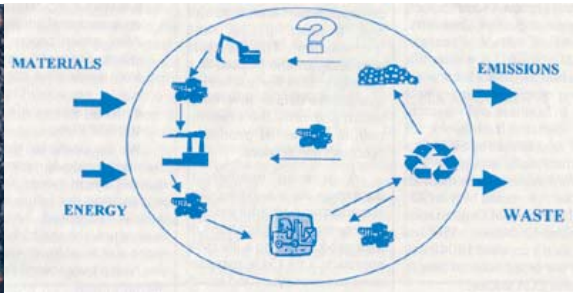
Criteria Air Pollutants –
Criteria air pollutants are solid and liquid particles commonly found in the air. They arise from many activities including combustion, vehicle operation, power generation, material handling, and crushing and grinding operations.

Ecological Toxicity –
The ecological toxicity impact measures the potential of a chemical released into the environment to harm terrestrial and aquatic ecosystems.

Smog Formation Potential –
Under certain climatic conditions, air emissions from industry and transportation can be trapped at ground level, where they react with sunlight to produce photochemical smog

Global Warming Potential –
The Earth absorbs radiation from the Sun, mainly at the surface. This energy is then redistributed by the atmosphere and ocean and re-radiated to space at longer wavelengths.

LCA - BEES Calculation



Greener CONCRETE: SCM's

csi 03000

group D

Check List

cost

maintenance

properties

lifecycle

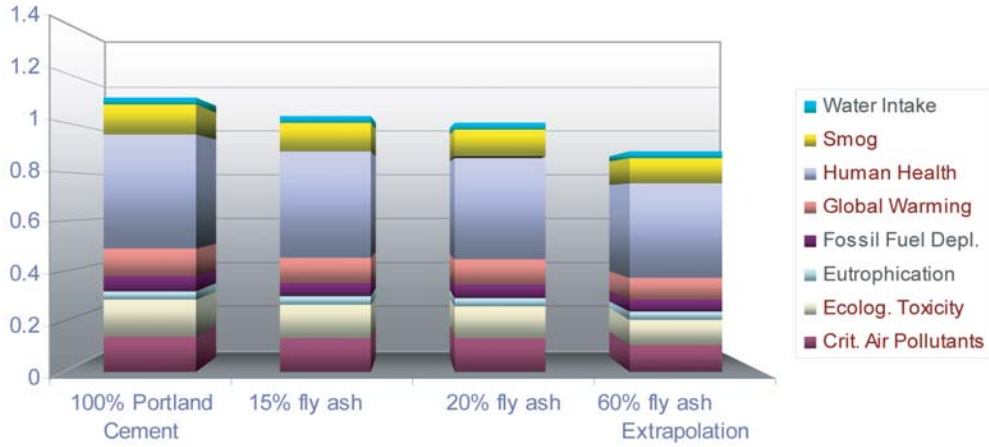
embodied energy

recycling

health

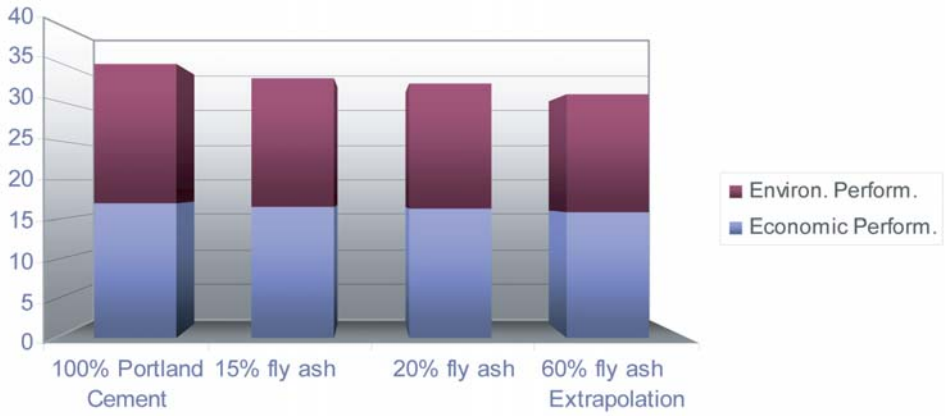
benefits

disadvantages



Beam 4ksi Environmental Performance

*Lower Values show better Performances
*Lower Strength Cement shows better performance (comparing to 5ksi)



Beam 4ksi Overall Performance

Environmental and Economic performance are combined into an Overall performance measure. Adding additional fly ash won't increase the cost.

Building Codes and Specification

Several important specifications and standards are being utilized in the areas of fly ash benefaction and utilization to bring fly ash into conformance with current AASHTO, ASTM, IBC and UBC specifications for use in concrete. As the fly ash utilization industry has matured, quality control, quality assurance, and improved product performance have increasingly become important.

Although there is no limit of fly ash content dictated in the UBC or IBC (unless exposed directly to de-icing salts where a maximum of 25% is dictated), (as seen on tables 1904.2.3, 1904.3).

There is a perception among engineers and architects that concrete construction codes are “prescriptive” in the sense that there is a maximum permissible limit of fly ash. The confusion arises from the governing standards as, for instance, ASTM 595 limits the proportion of the Pozzolan in the cement to 40% by mass while a new, performance-based cement standard ASTM C 1157 does not limit this type and the content of components in the blended cement. The UBC generally refers to ASTM 618 in regards to fly ash content.

TABLE 1904.2.3
REQUIREMENTS FOR CONCRETE EXPOSED TO DEICING CHEMICALS

CEMENTITIOUS MATERIALS	MAXIMUM PERCENT OF TOTAL CEMENTITIOUS MATERIALS BY WEIGHT[a, b]
Fly ash or other pozzolans conforming to ASTM C 618	25
Slag conforming to ASTM C 989	50
Silica fume conforming to ASTM C 1240	10
Total of fly ash or other pozzolans, slag and silica fume	50[c]
Total of fly ash or other pozzolans and silica fume	35[c]

a. The total cementitious material also includes ASTM C 150, ASTM C 595, ASTM C 845 and ASTM C 1157 cement.
b. The maximum percentages shall include:
1. Fly ash or other pozzolans present in Type IP or I (PM) blended cement, ASTM C 595, or ASTM C 1157.
2. Slag used in the manufacture of an IS or I (SM) blended cement, ASTM C 595, or ASTM C 1157.
3. Silica fume, ASTM C 1240, present in a blended cement.
c. Fly ash or other pozzolans and silica fume shall constitute no more than 25 and 10 percent, respectively, of the total weight of the cementitious materials.

TABLE 1904.3
REQUIREMENTS FOR CONCRETE EXPOSED TO SULFATE-CONTAINING SOLUTIONS

SULFATE EXPOSURE	WATER SOLUBLE SULFATE (SO_4) IN SOIL, PERCENT BY WEIGHT	SULFATE (SO_4) IN WATER (ppm)	CEMENT TYPE			MAXIMUM WATER-CEMENTITIOUS MATERIALS RATIO, BY WEIGHT, NORMAL-WEIGHT AGGREGATE CONCRETE[a]	MINIMUM f'_c, NORMAL-WEIGHT AND LIGHTWEIGHT AGGREGATE CONCRETE (psi)[a]
			ASTM C 150	ASTM C 595	ASTM C 1157		
Negligible	0.00 - 0.10	0 - 150	—	—	—	—	—
Moderate[b]	0.10 - 0.20	150 - 1,500	II	II, IP (MS), IS (MS), P (MS), I (PM)(MS), I (SM)(MS)	MS	0.50	4,000
Severe	0.20 - 2.00	1,500 - 10,000	V	—	HS	0.45	4,500
Very severe	Over 2.00	Over 10,000	V plus pozzolan[c]	—	HS plus pozzolan[d]	0.45	4,500

For SI: 1 pound per square inch = 0.00689 MPa.
a. A lower water-cementitious materials ratio or higher strength may be required for low permeability or for protection against corrosion of embedded items or freezing and thawing (see Table 1904.2.2).
b. Seawater.
c. Pozzolan that has been determined by test or service record to improve sulfate resistance when used in concrete containing Type V cement.
d. Pozzolan that has been determined by test or service record to improve sulfate resistance when used in concrete containing Type HS blended cement.

HOW TO
SPECIFY THE USE OF FLY ASH.

GUIDELINES

- 1.0 Specification for fly ash

Fly ash for use in Portland cement concrete shall conform to the requirements of ASTM C618, Standard Specification for fly ash and raw or Calcined Natural Pozzolan Class C Fly ash for use as a mineral admixture in Portland Cement.

The concrete supplier shall furnish a notarized certificate from the fly ash marketer at the time of submittal of concrete mix designs for approval indicating conformance with these requirements. Also, a copy of the most recent chemical analysis shall be provided.

At no time during the course of the project will a change of fly ash source (plant) be permitted with out the prior written consent of the engineer or architect. For sulfate environments, only Class F fly ash will be permitted and under no circumstances will class C fly ash be used.

- 2.0 Fly ash use

Class F Fly ash will typically require an air entraining agent to be added. Class C fly ash will not. Standard concrete procedures can be employed

Regional Availability

Locally class C fly ash is readily available it's manufactured in Pueblo and Brush Colorado. In contrast class F fly ash must be trucked in from Wyoming and as far away as North Dakota. Fly ash is distributed locally by ISG, Boral, La Farge and others.

HVFA

High volume fly ash(HVFA) is categorized as 50% or more replacement of cement.

Fly ash utilization specifications have been developed to produce high performance products such as HVFA. Although their still remains stiff regulatory and other barriers for HVFA. The optimum amount of fly ash or natural pozzolan for any specific project is determined by the required properties of the concrete and other constituents of the concrete and is to be established by testing. However, the time and cost of obtaining the performance data and putting it in the hands of the decision-makers is a significant barrier to commercializing this innovative technology.(1)

	Fly Ash (%)			
	0	25	40	56
Ambient-temperature-cured concretes				
1 day	27.8	26.2	18.1	10.0
3 days	41.4	33.5	30.1	26.9
7 days	46.1	43.5	42.6	41.6
28 days	**61.6**	**59.2**	**60.4**	**57.7**
182 days	69.6	60.9	62.1	64.5
Oven-cured concretes				
3 days	47	56.9	41.8	56.3
7 days	50.2	58.1	43.7	57.2
28 days	**53.7**	**58.3**	**49.8**	**58.6**
182 days	54.8	60.2	55.7	63.7

Chart showing 56% fly ash and strength gained

Check List

cost

maintenance

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Concrete Forefront

Structures USA

Giga-Crete is a precast product, designed for use in 2-ft by 9-ft panels, that requires no reinforcing steel or framing. It's a lightweight concrete utilizing a synthetic cement as the binder. This new concrete matrix does not use Portland cement, sand, or gravel. It is mixed like concrete with dry ingredients, but with very little water. While it costs about $6.50 per sq ft, Giga-Crete is 25% less expensive than wood framing and nearly half the cost of masonry-block construction when labor and material costs are figured in.

..

Bibliography

Malhotra, V.M. and Ramezanianpour, A. R., "Fly Ash in Concrete" Natural Resources Canada, Second Edition, Sept. 1994, 307 pps

Sear, Lindon K. A., "The Properties and Uses of Coal Fly Ash", Thomas Telford, London, U.K., 2001, pp. 261

"The Use of High-Volume Fly Ash in Concrete"
M.D.A. Thomas, D.S. Hopkins, G. Girn, R. Munro and E. Muhl

(1) Mark Reamer PhD student UCD

BEES (Building for Environmental and Economic Sustainability) software used for selecting cost-effective, environmentally preferable building products.
http://www.bfrl.nist.gov/oae/software/bees/download.html

www.epa.gov/globalwarming/index.html

www.buildinggreen.com/features/flyash/index.html

www.ecosmart.ca/kb_viewdocumentdetail.cfm?RecordID=241

www.flyash.com/resourcelibrary.asp

Check List

cost

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disadvantages

Agriboard Wall System

Agriboard INDUSTRIES

Check List

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Topics Covered:

- What is Agriboard?
- Benefits & Disadvantages
- LEED contributions
- Built examples
- Cost comparisons
- Research & Development
- Distributor information

Things the architect should know:
1) Integrated structural wall system
2) Construction efficiency
3) Use of **recycled** content

Things the client should know:
1) **Cost** Savings
2) Energy savings
3) Use of **recycled** content

Introduction

Currently, conventional wall construction is based upon archaic building practices which employ stick-built strategies that are time, labor, and resource intensive. Alternatives to the conventional wall are available and have been successfully executed. One such alternative is the structural insulated panel (SIP). The integration of materials used in a standard wall are applied to the panels and in turn offers a **cost**, labor, and time savings in building, not to mention the savings in energy consumption throughout the **life cycle** of the building. In addition, conventional practices leave job sites with piles of construction waste, which SIPs help to significantly minimize.

What is Agriboard?

Agriboard Industries is a Texas-based manufacturing company that has developed an even “greener” version of SIPs . By **recycling** an wheat or rice straw and applying it as a component in the panels for its insulating **properties**, tons of agricultural waste is prevented from being burned, which releases toxic pollutants into the atmosphere.

Agriboard takes on similar properties to the standard SIP, sandwiching insulation between two oriented-strand board (OSB) panels. Traditionally, SIPs consist of an polystyrene foam core, which has proven to be an economical alternative to standard stud wall construction. What Agriboard does is use compressed straw in the lieu of polystyrene, creating an ehanced green building product. The added **benefits** of using straw as the core material include an increased R-value, which in turn leads to a lower **maintenance cost** for the building. Environmentally its advantages consist of the use of an agricultural waste product as a building material and the lack of toxic adhesives used in the manufacturing process which creates a **healthier** indoor environmnent.

A New Type of WALL: Agriboard

csi 04000

group 4

Check List

cost

maintenance

properties

lifecycle

embodied energy

recycling

health

benefits

disadvantages

Benefits & Disadvantages

Benefits:

• Post-industrial **recycled** content
-Straw is an abundant agricultural waste product
-Reduces pollution caused by standard practices of burning straw

•Renewable resource
-Abundance of wheat and rice in agricultural production

• Acoustical properties
-Reduced noise transmission

• Thermal performance
-Rating of R-25 for 8" panels
-Lowers **maintenance costs** due to decreased energy consumption

• Speedy construction
-Integrated system eliminates need to install separate wall components

• Non-toxic material
-Straw core adhered to OSB panels through heat, pressure, and **properties** of straw
-Eliminates use of toxic adhesives
-Higher indoor air quality leads to **healthier** building environment

• Strength
-Test results demonstrate Agriboard exceeds code requirements
-(See Table 1 on p.9)

• Fire Rating
-Advantage over conventional and polystyrene-core panels
-Potentially lower insurance rates
-Test results by Omega Point Laboratories demonstrate a rating of over 2 hours
-(See Table 1 on page 8)

Disadvantages:

• **Embodied energy**
-Crane required on construction site for placing heavy panels

• Limited manufacturing
-Currently manufactured exclusively in Electra, TX
-Colorado falls outside the 500 mile radius
-Increased transportation **costs** due to lack of local manufacturing

• Unrealized potential
-100% bio-based product if applied strawboard or oriented-strand straw board (OSSB) as sandwich panels

• Insects and Rodents
-Panels are potentially a good environment for insect and rodents
-Guidelines for prevention provided by manufacturer should be followed to avoid potential infestation

A new type of WALL: Agriboard

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Agriboard Wall System

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LEED Credits

Points accrued:

Materials and Resources

- Credit #4.1
  Recycled Content, 5%
- Credit #4.2
  Recycled Content, 10%
- Credit #6
  Rapidly Renewable Materials

Possible Support Points**

- Credit #2.1
  Construction Waste, Divert 50%
- Credit #2.2
  Construction Waste, Divert 75%

Indoor Environmental Quality

- Credit #4.1
  Low Emitting Materials
  (adhesives & sealants)

Possible Support Points**

- Credit #3.1
  Construction IAQ Management Plan
  (during construction)
- Credit #3.2
  Construction IAQ Management Plan
  (before occupancy)

**Support points are possible points that the inclusion of Agriboard would help to satisfy credit toward LEED in the overall building system.

LEED Credit Checklist

LEED

LEED-NC Version 2.1 Registered Project Checklist
Sustainable Youth Zone (SYZ)
Commerce City, Colorado

Yes ? No

Sustainable Sites — 14 Points

Yes	?	No			
Y			Prereq 1	**Erosion & Sedimentation Control**	Required
			Credit 1	**Site Selection**	1
			Credit 2	**Development Density**	1
			Credit 3	**Brownfield Redevelopment**	1
			Credit 4.1	**Alternative Transportation**, Public Transportation Access	1
			Credit 4.2	**Alternative Transportation**, Bicycle Storage & Changing Rooms	1
			Credit 4.3	**Alternative Transportation**, Alternative Fuel Vehicles	1
			Credit 4.4	**Alternative Transportation**, Parking Capacity and Carpooling	1
			Credit 5.1	**Reduced Site Disturbance**, Protect or Restore Open Space	1
			Credit 5.2	**Reduced Site Disturbance**, Development Footprint	1
			Credit 6.1	**Stormwater Management**, Rate and Quantity	1
			Credit 6.2	**Stormwater Management**, Treatment	1
			Credit 7.1	**Landscape & Exterior Design to Reduce Heat Islands**, Non-Roof	1
			Credit 7.2	**Landscape & Exterior Design to Reduce Heat Islands**, Roof	1
			Credit 8	**Light Pollution Reduction**	1

Yes ? No

Water Efficiency — 5 Points

Yes	?	No			
			Credit 1.1	**Water Efficient Landscaping**, Reduce by 50%	1
			Credit 1.2	**Water Efficient Landscaping**, No Potable Use or No Irrigation	1
			Credit 2	**Innovative Wastewater Technologies**	1
			Credit 3.1	**Water Use Reduction**, 20% Reduction	1
			Credit 3.2	**Water Use Reduction**, 30% Reduction	1

Yes ? No

Energy & Atmosphere — 17 Points

Yes	?	No			
Y			Prereq 1	**Fundamental Building Systems Commissioning**	Required
Y			Prereq 2	**Minimum Energy Performance**	Required
Y			Prereq 3	**CFC Reduction in HVAC&R Equipment**	Required
			Credit 1	**Optimize Energy Performance**	1 to 10
			Credit 2.1	**Renewable Energy**, 5%	1
			Credit 2.2	**Renewable Energy**, 10%	1
			Credit 2.3	**Renewable Energy**, 20%	1
			Credit 3	**Additional Commissioning**	1
			Credit 4	**Ozone Depletion**	1
			Credit 5	**Measurement & Verification**	1
			Credit 6	**Green Power**	1

Materials & Resources — 13 Points (2)

Yes	?	No			
Y			Prereq 1	**Storage & Collection of Recyclables**	Required
			Credit 1.1	**Building Reuse**, Maintain 75% of Existing Shell	1
			Credit 1.2	**Building Reuse**, Maintain 100% of Shell	1
			Credit 1.3	**Building Reuse**, Maintain 100% Shell & 50% Non-Shell	1
	x		Credit 2.1	**Construction Waste Management**, Divert 50%	1
	x		Credit 2.2	**Construction Waste Management**, Divert 75%	1
			Credit 3.1	**Resource Reuse**, Specify 5%	1
			Credit 3.2	**Resource Reuse**, Specify 10%	1
x			Credit 4.1	**Recycled Content**, Specify 5% (post-consumer + ½ post-industrial)	1
x			Credit 4.2	**Recycled Content**, Specify 10% (post-consumer + ½ post-industrial)	1
			Credit 5.1	**Local/Regional Materials**, 20% Manufactured Locally	1
			Credit 5.2	**Local/Regional Materials**, of 20% Above, 50% Harvested Locally	1
x			Credit 6	**Rapidly Renewable Materials**	1
			Credit 7	**Certified Wood**	1

Yes ? No

Indoor Environmental Quality — 15 Points (2)

Yes	?	No			
Y			Prereq 1	**Minimum IAQ Performance**	Required
Y			Prereq 2	**Environmental Tobacco Smoke** (ETS) **Control**	Required
			Credit 1	**Carbon Dioxide** (CO_2) **Monitoring**	1
			Credit 2	**Ventilation Effectiveness**	1
	x		Credit 3.1	**Construction IAQ Management Plan**, During Construction	1
	x		Credit 3.2	**Construction IAQ Management Plan**, Before Occupancy	1
x			Credit 4.1	**Low-Emitting Materials**, Adhesives & Sealants	1
			Credit 4.2	**Low-Emitting Materials**, Paints	1
			Credit 4.3	**Low-Emitting Materials**, Carpet	1
			Credit 4.4	**Low-Emitting Materials**, Composite Wood & Agrifiber	1
			Credit 5	**Indoor Chemical & Pollutant Source Control**	1
			Credit 6.1	**Controllability of Systems**, Perimeter	1
			Credit 6.2	**Controllability of Systems**, Non-Perimeter	1
			Credit 7.1	**Thermal Comfort**, Comply with ASHRAE 55-1992	1
			Credit 7.2	**Thermal Comfort**, Permanent Monitoring System	1
			Credit 8.1	**Daylight & Views**, Daylight 75% of Spaces	1
			Credit 8.2	**Daylight & Views**, Views for 90% of Spaces	1

Yes ? No

Innovation & Design Process — 5 Points

Yes	?	No			
			Credit 1.1	**Innovation in Design**: Provide Specific Title	1
			Credit 1.2	**Innovation in Design**: Provide Specific Title	1
			Credit 1.3	**Innovation in Design**: Provide Specific Title	1
			Credit 1.4	**Innovation in Design**: Provide Specific Title	1
			Credit 2	**LEED™ Accredited Professional**	1

Yes ? No

Project Totals (pre-certification estimates) — 69 Points (4)

Certified 26-32 points **Silver** 33-38 points **Gold** 39-51 points **Platinum** 52-69 points

A new type of WALL: Agriboard

csi 04000

group 4

Agriboard Wall System

Built Examples

The Farmhouse
Julee Herdt & Steve Gates
http://thefarmhouse.org/garden.htm
Boulder, CO

Julee Herdt, a professor of architecture at Universtiy of Colorado in Boulder, and Steve Gates designed and built this energy-efficient residence and home office for Julee in the Foothills of Boulder which also functions as a demonstration home for possibilities in environmental architecture. Agriboard and Premier Building Systems SIPs (2) create the building envelope, as shown on the 3-D diagrams below. The **benefits** of high insulation value paired with the resource-consciousness of SIPs made it an obvious choice.

McKinney Stanley Studio
Lars Stanley Architects
http://www.larsstanley.com/arch/studio
Austin, TX

Located on a brownfield urban site, the studio takes advantage of the varying sustainability options available through the use of xeriscaping, solar power (both passive and active), sustainable and reused building materials - including applications of Agriboard SIPs - and accessibility to mass transit.

Front view

Rear view

Interior view

Construction Cost Comparison

Built As Usual:

6” Studs (@ 16” O.C.)
$11.04/L.F.
$10.24/hour
1/2” Sheathing
$0.52/S.F.
$0.36/hour
6” Batt Insulation (@ R-19)
$0.35/S.F.
$0.21/hour
Vapor Barrier
$0.10/S.F.
$0.10/hour

COST (per unit):
$12.01 Materials
$10.91 Labor

TOTAL: $22.92

Building with Agriboard:

8” Thick Panels
R-25
2-Hour Fire Separation

$8.00/S.F. Materials

Energy Cost Comparison

In addition to the bare cost savings on materials and labor, building with Agriboard SIPs are a cost savings in maintenance as well. The high thermal insulation value of the panels decrease energy bills for the building’s lifetime. The chart below delineates estimated the cost benefits of construction with SIPs versus traditional construction over the course of 20 years. There is evidence of great financial savings even within the first 5 years of the life of the building.

	Years	SIP-built	BAU	Savings
Estimated Operating Costs @ 4% Annual Increase	5	$2,464	$5,647	$3,183
	10	$5,463	$11,552	$6,089
	15	$9,111	$17,742	$8,631
	20	$13,549	$24,246	$10,697

Research and Development

The future of Agriboard is bright. Currently there are plans for adding more manufacturing plants across the continental U.S. and Canada. This step will contribute to LEED credits for local manufacturing and decreased **embodied energy**, transportation **costs**, and lead time.

Additionally, there is development in the works to create a 100% bio-based product using the **beneficial properties** of straw both in the compressed straw core and also for the sheathing that the core is sandwiched between. OSSB (oriented straw strand board) is currently being develeoped and is in the forefront of current R&D for Agriboard-based applications. This new material is expected to be widely manufactured and available within the next 5 years. Alberta Research Council's Forest Products group has developed OSSB and the straw-splitting machinery to manufacture these boards (See below). Testing even indicates wheat OSSB as a superior product to standard OSB (See Tables 3 & 4 on page 9).

As the use of SIPs and Agriboard continues to gain in popularity and demand, enhancements like the application of OSSB will contribute to demonstrating the feasibility and economy of building with green products.

Local Distributors

Eco-Build
P.O. Box 4655
Boulder, CO 80306
(303) 545-6255
http://www.eco-build.com/

Straw, Sticks, and Bricks
1734 West B Street
Lincoln, NE 68522
(402) 435-5176
www.strawsticksandbricks.com

Straw-splitting machine

Agriboard Wall System

Agriboard INDUSTRIES

Check List

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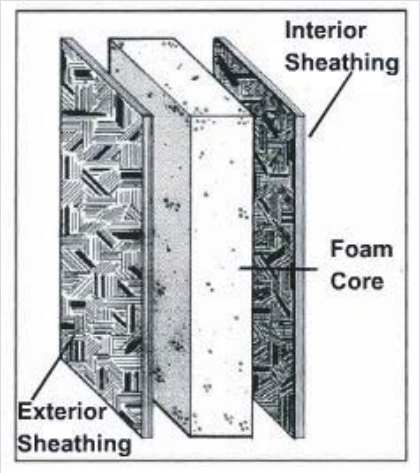
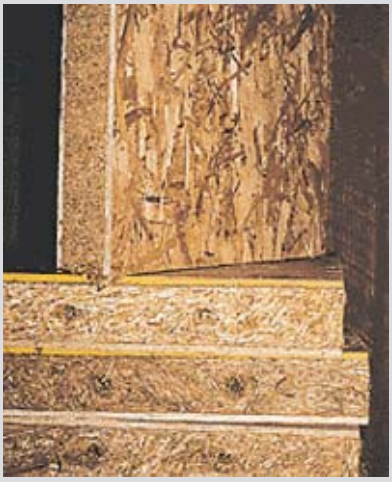
Agriboard & SIPs

Diagram of standard SIP components



Samples of Agriboard SIPs



Construction site photos

A New Type of WALL: Agriboard

csi 04000

group 4

Agriboard Wall System

Check List

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Table 1
Fire Test Chart
(source: http://www.agriboard.com/product.html)

Fire Safety

Agriboard has outstanding resistance to fire and thermal transmission and provides greater peace of mind for life safety. National fire testing laboratories tested walls, floors, and roof panels with exceptional certified results.

One Example: A four inch (4") wall sample of Agriboard with one half inch (½") unrated sheetrock on both sides. Starting at 75° F on the outside wall and increasing temperature to 1841° F furnace flames on the inside wall.

Fire Test Results

Time	Inside Wall	Outside Wall
Starting 0 min.	1000 °F	75 °F wall surface
After 30 min.(1/2 hour)	1513 °F	75 °F wall surface
After 60 min.(1 hour)	1700 °F	77 °F wall surface
After 90 min.(1 ½ hour)	1775 °F	99 °F wall surface
After 120 min.(2 hours)	1841 °F	125 °F wall surface

All testing was done by Omega Point Laboratories of Texas
1-800-966-5253.
ASTM - E119 - Project No #15684-110943, Other ASTM - E119 tests include:101422, 101424, 101425, 101426, 101427.

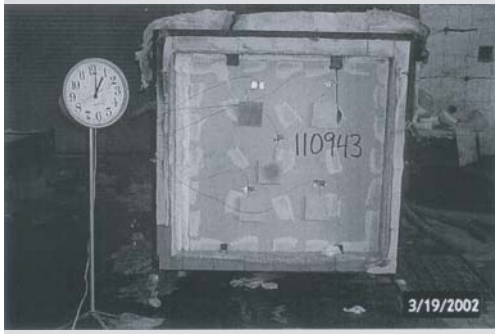
Agriboard is a material that inherently provides an outstand fire rating due to the density of the inner starw core. As a result of the density of the inner straw core it is extremely difficult for oxygen to be present to allow combustion. With a fire rating well over 2 hours, which exceeds most building codes, this product can provide better protection than traditional materials and can be used in several different applications in which extreme fire ratings are desirable or required.

A new type of WALL: Agriboard

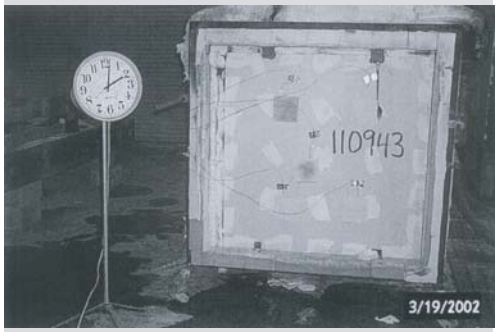
csi 04000

group 4

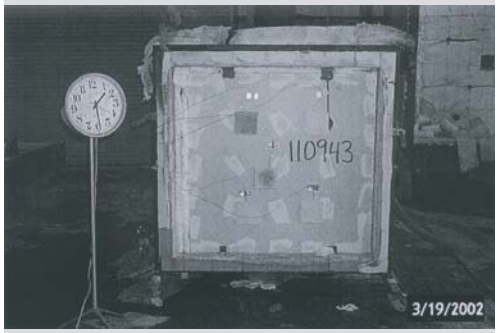
Fire Test Photographs
(source: http://www.agriboard.com/product.html)



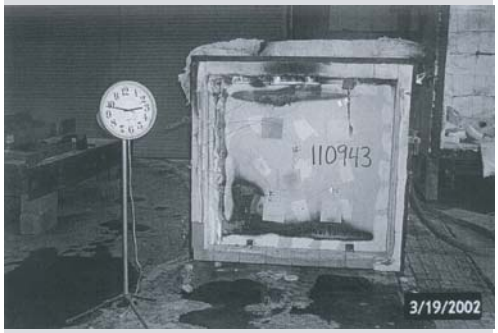
**Flame did not penetrate the panel in the first hour



**Flame did not penetrate the panel in the two hours



**Flame did not penetrate the panel in the first 90 min.



**The panel failed at 2 hours and 45 minutes

Agriboard Wall System

Agriboard INDUSTRIES

Check List

cost

maintenance

properties

lifecycle

embodied energy

recycling

health

benefits

disadvantages

Tables

Table 1
Strength Test Chart
(source: http://www.agriboard.com/product.html)

7-7/8" Enviormentally Engineered Panelized Construction
(OSB skin with a double layer of CAF board)

Overall Thickness	Standard Height	Height Tolerance	Standard Length	Length Tolerance	Squareness Tolerance	Weight
7 7/8"	8'	+/- 1/8"	24'	+/- 1/8"	+/- 1/4"	2000 Lbs

ICBO Number	Insulating Core			
020314	Material	Compressed Cereal Fiber		
Omega Point Labratories #15684	Thickness	3-1/2" Per Layer		
Phone Number (800)966.5253	Density	14 lb. Per Cu. Ft. Minimum		

Design Factors

Axial Compressive Load	Load Per Linear Foot	Deflection Under Load	Deflection After Load Removed	Failure Load Per Linier Foot	Test Type
	17520	0.307	0.032	Tested to 24840 with no failure	ASTM E72-98 Section 9
Racking Load	Load PSI	Deflection Under Load	Failure Load PSI		
	69375	2.406 inches	70000		ASTM E72-98 Section 14
Concentrated Load	Panel Indentation at 1000psi on 1" diameter 0.540				ASTM E72-98 Section 18
			Deflection after Load 0.038		
Transverse Load	Load Per Square Foot	Deflection Under Load	Deflection After Load Removed	Failure Load Per Square Foot	Test Type
	707lbs/sq ft	0.635	0.067	900 lb/sq ft	ASTM E72-98 Section 17, 12, & 20
Fire Seperation Rating	2 hour				ASTM E119
Sound Transmission Field Test Results	Wall	34	Floor/ Ceiling 49		IIC Rating 68

Dynamic Benefit Mass Systems Maximum Effective "R" Value 25.44

Table 2
SIPs vs. BAU

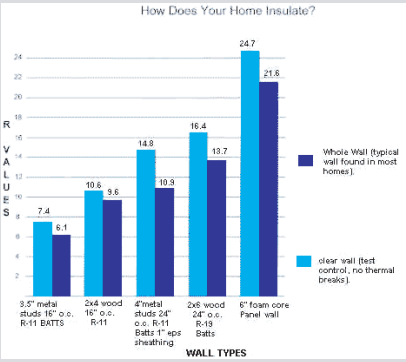


Table 3
Modulus of Rupture: OSB vs. OSSB
(source: http://www.arc.ab.ca/extranet/forpro/topic2.html)

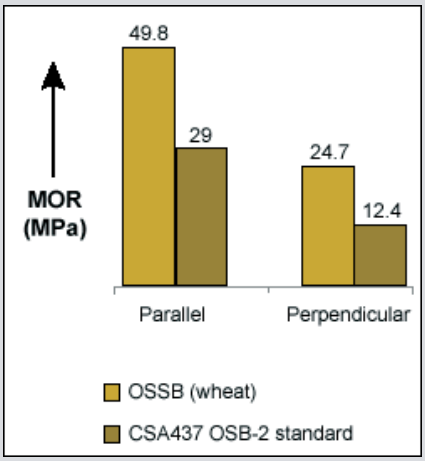
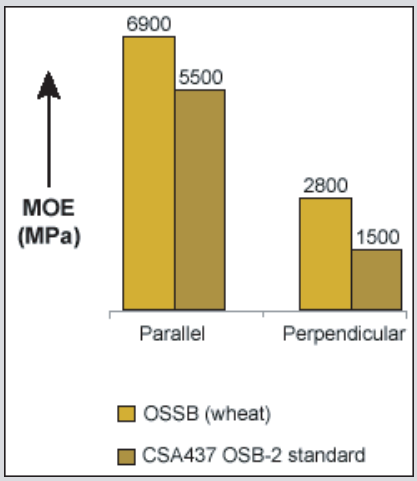


Table 4
Modulus of Elasticity: OSB vs. OSSB
(source: http://www.arc.ab.ca/extranet/forpro/topic2.html)



A New Type of WALL: Agriboard

csi 04000

group 4

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Structural Steel

Check List

cost

maintenance

properties

lifecycle

embodied energy

recycling

health

benefits

disadvantages

Topics Covered:

- Steel Production Processes
- Advantages of a Structural Steel system
- Recylability of Steel
- Integration of Steel with other sustainable systems
- Cellular Beams
- Accessible mechanical ducts
- Re-use and Deconstruction
- Applicable LEED credits using steel

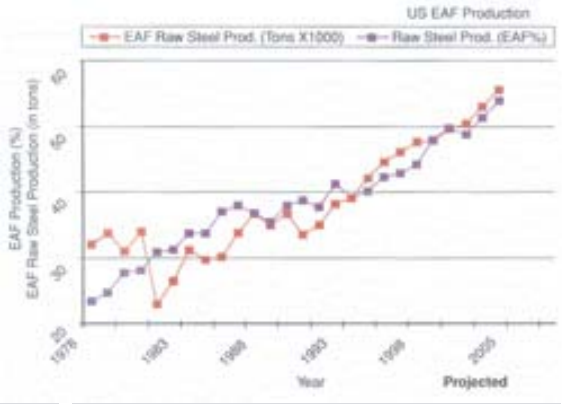
Steel Production Processes:

Basic Oxygen Furnace (B.O.F.)
Integrated Mill approach using raw materials (iron ore, limestone, coke)
Uses 25-35% recycled steel
Produces products who's major characteristic is drawability: auto fenders, refrigerators, packaging

Electric Arc Furnace (E.A.F.)
Mini-mills approach where scrap steel is re-melted
Uses 90-100% recycled steel
Produces products who's major characteristic is strength: structural beams, steel plates, reinforcement bars

Basic Oxygen Furnace production

Electric Arc Furnace production



Green STEEL: SCM's

csi 05000

group 3

Advantages of a Structural Steel system:

- Integration with other building systems decreases environmental burdens
- Efficient, competitive
- Contribution to the national economy
- Rapidly constructed buildings
- Low overall environmental impacts
- Flexible spaces: easily modified and adapted over a buildings lifecycle
- Easily dismantled and reclaimed without degradation of properties
- Off-site manufacturers facilitate fewer iterant workers that promotes safety, stability in the workplace, encourages skill development and community relations

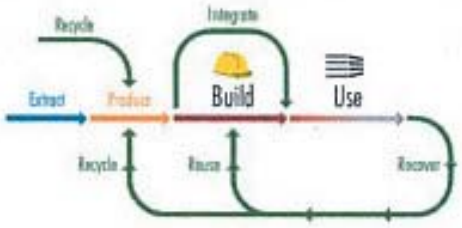
Steel Recyclability:

Steel is the worlds most recycled material

Steel recycling saves valuable energy and natural resources

Studies show that every ton of recycled steel saves 2,500 pounds of iron ore, 1400 pounds of coal and 120 pounds of limestone.

Compared to new manufacturing, steel recycling saves enough electrical energy annually to power about one-fifth of all U.S. households (18 million homes) for a year.



Multiple Lifecycle of Structural Steel

Check List

cost

maintenance

properties

lifecycle

embodied energy

recycling

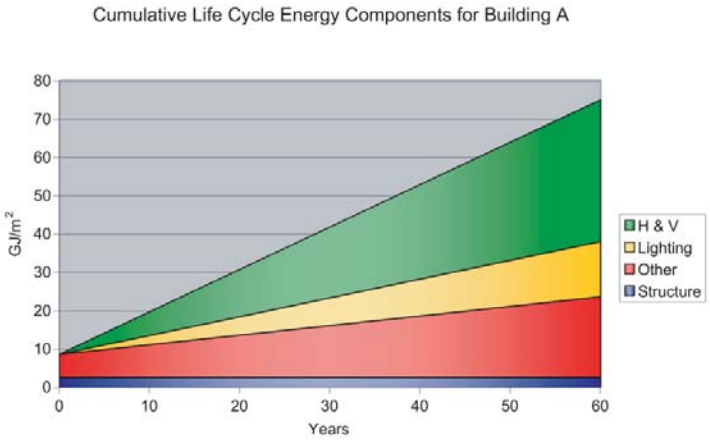
health

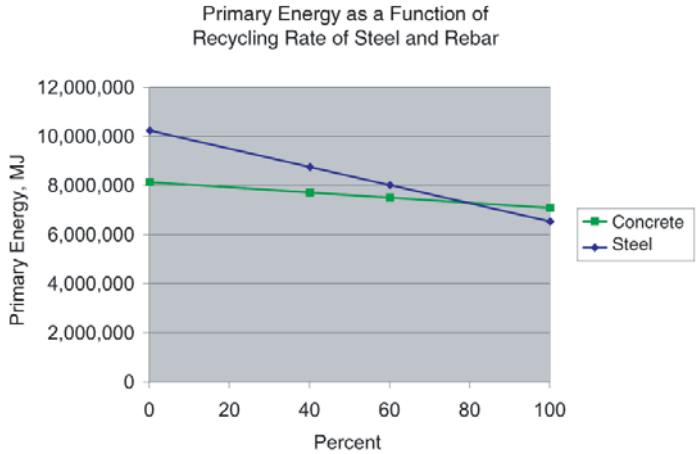
benefits

disadvantages

Heavy and Light Steel Recyclers in the Denver area:

Atlas Metals And Iron Corporation
318 Walnut Street Denver, CO 80201
303-825-7166
Neiman Industrial Recycling Inc.
905 W. Iliff Ave. Denver, CO 80223
303-935-1200
Fagan Iron & Metal Corporation
4601 Glencoe St. Denver, CO 80201
303-377-6598
Iron & Metals Inc. Buy Back Center
5555 Franklin St. Denver, CO 80201
303-292-5555
Commercial Iron & Metal Company
1100 Umatilla St. Denver, CO 80201
303-623-6238





Structural Steel manufacturers:

The Steel Manufacturers Association is the primary trade association for scrap-based electric arc furnace (EAF) steelmakers. www.steelnet.org

Members of the SMA who supply structural steel in the United States are as follows:

Bayou Steel Corporation
www.bayousteel.com
LaPlace, LA 70069
(985) 652-4900

CMC Steel Group (SMI Steel)
http://www.smi-arkansas.com
Magnolia, AR
800.258.0022

Gerdau AmeriSteel
www.ameristeel.com
Jackson, Tennessee
(731) 424-5600

Nucor Corporation
www.nucor.com
Charlotte, North Carolina
704.366.7000

Oregon Steel Mills
www.osm.com
Portland, Oregon
503-223-9228

Roanoke Electric Steel
Roanoke, Virginia
www.roanokesteel.com
1-800-765-6567

Schnitzer Steel Industries
www.schnitzersteel.com
Portland, Oregon
503-224-9900

Sterling Steel Company
(713) 690-0347
Houston, Texas
www.sterlingsteelco.com

TXI (Chaparral Steel)
www.chaparralsteel.com
Provides greater than 98% of the raw material for E.A.F. production of structural steels
About $305/ton
Manufactured in Texas & Virginia
972-647-6700

Cellular Beam Manufacturers:

CMC Steel Group (SMI Steel): Smartbeam®

Hope, Arkansas
(877) 764-2326

www.smisteelproducts.com

SMI Steel Products is the exclusive cellular beam manufacturer for the Americas. A hexagonal design is also offered. Both start with a standard beam, which is cut in half longitudinally.

Integration with other Sustainable Systems:

Why structural integration?

A flexible and versatile steel structural system could enable the integration with other sustainable building systems, resulting in a more efficient building with fewer materials used.

Cellular Beams:

What are cellular beams?

Cellular beams are a form of castellated beams containing circular holes, a small upper tee and a large lower tee. This results in a shape that maximizes its efficiency in both structure and ducting. Their use results in reduced floor plate thickness, further reducing the height and weight of the structure.

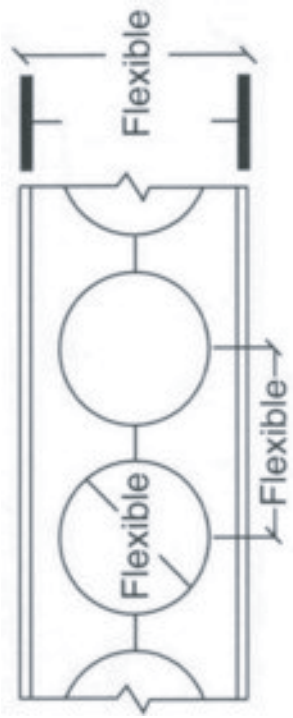
Advantages:

With the ducts integrated into a deeper beam span lengths double, equating to fewer necessary columns, fewer footings dug into the ground and a much more versatile open floor plan. This flexibility would then encourage reuse rather than eventual demolition.

The holes in the beams allow circular ducting to reduce the materials needed for the ducts fabrication.

Efficiency:

Circular ducting performs more efficiently than conventional square ducting. The shape reduces the risk of Sick Building Syndrome since higher velocity airflow is possible. In addition, cleaning is easier and dust has less of a chance to collect in corners.



Re-use and Deconstruction:

What is deconstruction?

Deconstruction is the process of building disassembly in order to recover the maximum amount of materials for their highest and best re-use. Re-use is the preferred outcome because it requires less energy, raw materials, and pollution than recycling does in order to continue the life of the material. A consequence of deconstruction involves many opportunities for recycling other materials along the way.

Why design for deconstruction?

Deconstruction combines the recovery of both quality and quantity of reusable and recyclable materials. The re-use of materials can serve a broad set of goals including the provision of low-cost building materials to a community and the avoidance of demolition debris going into landfills.

Advantages of Deconstruction include:

- Reduction of overall costs of building removals
- Provides lower cost building materials to the community
- Extends the life of landfills
- Protects the natural environment by reducing the need for the extraction of new resources
- Job creation and economic development

Design for Deconstruction:

Use mechanical fasteners for nonpermanent connections

Limit use of composite design for structural members

Steel allows for an easily assembled and disassembled building

Modular design and prefabricated components allow a building to be quickly constructed and dismantled for reuse or recycle

Check List

cost

maintenance

properties

lifecycle

embodied energy

recycling

health

benefits

disadvantages

Metal specification to ensure recovery of construction and demolition materials:

Benefits:

- Reduces the environmental effects of exctraction, transportation, and processing of raw materials
- Reduces project costs through avoided disposal costs, avoided purchases of new materials, revenue earned from materials sales and tax breaks gained for donations
- Helps communities, contractors and/or building owners comply with state and local policies, such as disposal bans and recycling goals.
- Enhances the public image of companies and organizations that reduce disposal
- Conserves space in existing landfills

DIVISION 5: METALS

REFER TO THE FOLLOWING RELATED SPECIFICATION DOCUMENTS AND SECTIONS FOR TECHNICAL SUPPORT, PROCEDURES, AND COORDINATION WHEN USING THIS WASTESPEC DIVISION:

00000	DOCUMENTS
DIV 1	GENERAL REQUIREMENTS
01010	SUMMARY OF THE WORK
01094	DEFINITIONS
01500	CONSTRUCTION FACILITIES
01505	CONSTRUCTION WASTE MANAGEMENT

SIGNIFICANT FACTORS IN THE GENERATION OF WASTE IN THIS DIVISION INCLUDE PACKING MATERIALS, FIELD CONDITIONS, TEMPORARY BRACING, PROTECTION, AND METAL OFFCUTS.

UNDER THE FOLLOWING OR SIMILAR HEADINGS, INSERT APPLICABLE STATEMENTS.

05000 DIVISION 5 METALS

PART 1 GENERAL

DELIVERY, STORAGE, AND HANDLING

A. Store materials in a safe, dry, above ground location.

B. Prevent contact with material that may cause corrosion, discoloration, or staining.

RELATED SECTIONS

A. Section 01500 Construction Facilities.

B. Section 01505 Construction Waste Management.

PART 2 PRODUCTS

ENVIRONMENTAL CONSIDERATIONS

[THIS IS AN APPROPRIATE LOCATION FOR ADDITIONAL LANGUAGE PERTAINING TO ENVIRONMENTAL ISSUES BEYOND THE SCOPE OF THIS WASTESPEC, SUCH AS THE FOLLOWING PROVISION:

-- Where choices exist, preference is to be given to products and materials with [EDIT TO SUIT PROJECT] recycled content or resource efficient characteristics [EDIT TO SUIT PROJECT].]

PART 3 EXECUTION

WASTE MANAGEMENT

A. Separate and handle general construction waste in accordance with the Waste Management Plan.

B. Separate for recycling and place in designated containers the following metal waste in accordance with the Waste Management Plan and local recycler standards: [EDIT LIST TO SUIT PROJECT] steel, iron, galvanized steel, galvanized sheet steel, stainless steel, aluminum, copper, zinc, lead, brass, and bronze.

C. Fold up metal banding, flatten, and place in designated area.

D. Use the least toxic primers and sealers necessary to comply with the requirements of this section.

SPECIFIC SECTIONS

[SECTIONS FOR WHICH THE SAME ADDITIONAL PROVISIONS ARE APPLICABLE ARE SHOWN GROUPED. INSERT THE FOLLOWING ADDITIONAL PROVISIONS UNDER PART 3 EXECUTION, WASTE MANAGEMENT, UNLESS OTHERWISE NOTED.]

05120 STRUCTURAL STEEL
05500 METAL FABRICATIONS
05510 METAL STAIRS

ENVIRONMENTAL CONSIDERATIONS

[THIS IS AN APPROPRIATE LOCATION FOR ADDITIONAL LANGUAGE PERTAINING TO ENVIRONMENTAL ISSUES BEYOND THE SCOPE OF THIS WASTESPEC, SUCH AS THE FOLLOWING PROVISION:

-- The work of this section shall be manufactured or fabricated from metals with X% recycled content. [EDIT TO SUIT PROJECT.]

[DESIGNING TO ACCOMMODATE EARLY INSTALLATION AND PROTECTION OF PERMANENT STAIRS, HANDRAILS, AND TREADS MAY AVOID NECESSITY FOR TEMPORARY WORK.]

END OF DIVISION

LEED credits possible with Structural Steel construction:

LEED™ Category		Steel Frame
Sustainable Sites		
	Stormwater Management (2 possible points)	Not relevant
	Reduce Heat Islands (2 possible points)	Not relevant
Energy and Atmosphere		
	Energy Optimization (10 possible points)	Not relevant
Materials and Resources		
	Building Reuse (2 possible points)	Steel buildings are flexible and adaptable and easily reinforced.
	Construction Waste Management (2 possible points)	Steel is consistently recycled or salvaged
	Resource Reuse (2 possible points)	Structural steel can be re-fabricated and reused
	Recycled Content (2 possible points)	Steel has close to 100% recycled content from scrap steel.
	Local/Regional Materials (2 possible points)	Locally manufactured, but not locally extracted materials are available.
Innovation and Design Process		
	(4 possible points for Innovation)	The following ideas may apply: Exposing structure. Using composite members. Design for future recyclability. Designing for deconstruction. Using structure for plumbing.

CSI 0600: Plastics

I. Motivations/Abstract

Plastics are among the most versatile and ubiquitous of materials. There are literally millions of applications for plastic in industry and the home.

Much of the success of plastic is due to its cost-effectiveness. Relative to other materials with similar characteristics, it is inexpensive to manufacture. Over one hundred years of synthetic plastic manufacture and research have turned the chemistry of plastics into a mature science, and large-scale production allows for very low-cost products.

In this article, we will address a different kind of cost: ecological. Is plastic a material that can and should be used in a sustainable world?

To help answer this we adopt a view like that put forth by Lester Brown in his book *Eco-Economy*. His thesis is that rather than the common (if tacit) understanding of the global economy as a system running next to or parallel to the global ecology, the economy is more accurately understood as a system *embedded within* the ecology. In this way, the connection between economic choices and ecological consequences may be more clearly drawn.

We find good evidence that the cost of plastic in this eco-economy *is not* too high for its continued use. Promising technologies — bioplastics in particular — offer ways to not only mitigate the ecological costs of plastic, but make plastic products first-class members of a sustainable economy.

II. Method

We expect the reader of this article to be an individual interested in green technology, perhaps as an architect, a builder, a student, or an educator. We do not assume prior knowledge of the plastic or building industries, but we have tried to be somewhat technical in our discussion about *why* plastics may be benign or malign in an ecology. We feel it is important to have a decent layman's grasp of the chemistry of plastic in order to more fully appreciate and judge the products and technologies available.

Our research may be divided into three parts, with which we hope to address the audience in a useful way:

- chemistry/a plastics primer
- state-of-the-art in plastic technology
- what can you do today?

III. Plastics Primer

III.1 Chemistry of plastics.
The definition of a plastic is not quite exact, but plastics always have some combination of common physical and chemical properties.

Practically, they are solids which have been shaped while in a liquid-like state during production. The final artifact may have a greater or lesser degree of elasticity and fall anywhere in the spectrum of other characteristics such as color, transparency, brittleness, and tensile and compressive strength.

Chemically, plastics have as their essential ingredient linked chains of molecules known as organic **polymers**. These linked chains may be composed of a single kind of molecule (a **monomer**), or they may be a composite of different molecules, in which case the chains are known as

copolymers.

Pure polymeric substances typically exhibit undesirable characteristics, so an industry of plastic **additives** has developed, and it is the additives which often provide plastics with their wide ranges of characteristics.

> *QUICK FACT: Around 90% of plastics produced today are thermoplastics and therefore recyclable. (Stevens, 39)*

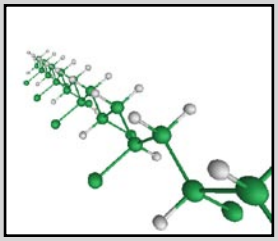
There are two broad classes of plastic, known as **thermoset** plastics and **thermoplastic** plastics. These classes differ in the amount of cross-linking among polymer chains that occurs when the plastic cures.

Thermosets cross-link extensively, forming a solid that cannot be melted and re-shaped.

Thermoplastics exhibit little or no cross-linking. Their polymeric chains can therefore become disassociated with one another without substantially damaging the chains themselves. In other words, thermoplastics can be melted and reworked.

This leads to the important distinction that thermoplastic products may be recycled. The same is not true of thermosets.

III.2 Synthetics.
While human-kind's first plastics were in fact bioplastic, the creation of hydrocarbon polymers produced from petroleum in the early 1900s set the plastics industry into motion on a huge scale. Chemists quickly created products with superior characteristics than those available beforehand. The common plastics available today are all synthetic, or petroluem-based.



model of polyvinylchloride (aka, PVC)

symbol	name	properties	uses	recycled in
1 PET	*Polyethylene Terephthalate*	*Clear, tough solvent resistant, barrier to gas and moisture, softens at 80°C*	*Soft drink and water bottles, salad domes, biscuit trays, salad dressing and peanut butter containers*	*Pillow and sleeping bag filling, clothing, softdrink bottles, carpet*
2 PE-HD	*High Density Polyethylene*	*Hard to semi-flexible, resistant to chemicals and moisture, waxy surface, opaque, softens at 75°C, easily coloured, processed and formed*	*Crinkly shopping bags, freezer bags, milk bottles, ice cream containers, juice botles, shampoo, chemical and detergent bottles, buckets, rigid agricultural pipe, milk crates*	*Recycling bins, compost bins, buckts, detergent containers, posts, fencing, pipes*
3 PVC	*Polyvinyl chloride* ***PVC-U*** *Unplasticised Polyvinyl Chloride* ***PVC-P*** *Plasticised Polyvinyl Chloride*	*Strong, tough, can be clear, can be solvent welded, softens at 80°C* *Flexible, clear, elastic, can be solvent welde*	*Cosmetic containers, electrical conduit, plumbing pipes and fittings, blister packs, wall cladding, roof sheeting, bottles* *garden hose, shoe soles, cable sheathing, blood bags and tubing, watch straps*	*Flooring, film and sheets, cables, speed bumps, packaging, binders, mud flaps and mats*

Common synthetic plastics, their properties and recycling uses. Source: Plastics New Zealand.

While as with any plastic, specific properties are determined by raw ingredients, processing, and additives, synthetic plastics are typically light-weight, strong, chemically, electrically, and thermally resistant, and are recalcitrant, or resistant to degradation.

Around 10% of annual petroleum refinery output is used to produce plastic. Fossil fuels are the product of organic and geochemical processes that require time on the order of millions of years. They are considered non-renewable resources and dependence upon them an economic and social liability. When burned for fuel they release carbon which has been trapped under earth's crust for millions of years, changing the dynamic of the global carbon cycle. Fossil fuel dependence is widely regarded as a potentially ecosystem-damaging problem.

For this reason it has been argued that non-degradable synthetic plastics are relatively ecologically benign in that, when disposed of, they effectively re-sequester petrol-carbon in landfills.

III.3 Bioplastics.

> Biopolymers are inherently biodegradable, as they must be in order to take part in nature's cycles of renewal .... Biopolymers almost always have oxygen or nitrogen atoms in their polymer backbones; that is the feature that is mainly responsible for their biodegradability.
>
> *(Stevens, 83)*

In contrast, explains Stevens, petrochemical polymers have backbones of carbon-carbon bonds, which are difficult to break. Note that it *is* possible to create biodegradable, non-toxic synthetic plastics. They often find application in the health industry today as, for example, drug delivery mechanisms and sutures.

Regardless, **bioplastics** may be defined as plastics whose polymer

symbol	name	properties	uses	recycled in
4 PE-LD	*Low density Polyethylene*	*Soft, flexible, waxy surface, translucent, softens at 70°C, scratches easily*	*Plastic Food wrap, garbage bags, squeeze bottles, black irrigation tube, garbage bins*	*Rubbish bin liners, pallet sheets*
5 PP	*Polypropylene*	*Hard but still flexible, waxy surface, softens at 140°C, translucent, withstands solvents, versatile*	*Dip bottles and ice cream tubs, potato chip bags, straws, microwave dishes, kettles, garden furniture, lunch boxes, blue packing tape*	*Pegs, bins, pipes, pallet sheets, oil funnels, car battery cases, trays*
6 PS	*Polystyrene* ***PS-E*** *Expanded Polystyrene*	*Clear, glassy, rigid, brittle, opaque, semi-tough, softens at 95°C. Affected by fats and solvents* *Foamed, light weight, energy absorbing, heat insulating*	*CD cases, plastic cutlery, imitation 'crystal glassware', low cost brittle toys, video cases* *Foamed polystyrene hot drink cups, hamburger takeaway clamshells, foamed meat trays, protective packaging for fragile items*	*Coat hangers, coasters, white ware components, stationery trays and accessories*
7 OTHER	*Letters below indicate ISO code for plastic type e.g SAN, ABS, PC, Nylon*	*Includes all other resins and multi materials (e.g. laminates). Properties depend on plastic or combination of plastics*	*Car parts, appliance parts, electronics, water cooler bottles, packaging*	*Car parts, concrete aggregate, plastic timber*

Common synthetic plastics, their properties and recycling uses. Source: Plastics New Zealand.

raw materials are created in plants and other natural processes. As such, it is possible to design plastics using biological feedstocks that never leave the **grand cycles** of the ecosystem. The raw ingredients in these plastics — carbon, hydrogen, nitrogen, and so on — were already present in the ecosystem before being harvested. The plastic product "borrows" these chemicals in a unique and useful structure (say, a plastic water bottle), and when the useful life of the product is over, biodegradation returns the elements safely and harmlessly to the cycle from which they came, in much the same way that a human body "borrows" the minerals in its bones for a time before they are returned to the earth.

These atoms temporarily captured in a water bottle may, after biodegradation, reappear in the stalk of a corn plant, which may be harvested for food, fibers, fuel, and biopolymers. Those polymers may then used in a biodegradable plastic product, which will eventually mineralize into humus and be captured by the roots of a corn plant ...

III.4 Lifecycle.
We will briefly cover the plastic product lifecycle, in the case of both a synthetic plastic and a bioplastic.

III.4.1 Cradle.
Petrochemical plastics begin life in a process of **polymerization** of hydrocarbon monomers produced in turn from refined petroleum.

The polymeric raw materials in bioplastic are typically drawn from one of three sources:

- plant carbohydrates are polymerized
- microorganisms are employed to grow biopolymers, or
- corn or other crops are genetically modified to produce biopolymers

Once the raw materials, or **feedstocks**, of the plastic have been procured, additives are added and any of various shaping and extrusion techniques are used to manufacture the final product.

The cradle phase of any product lifecycle requires energy: energy for procuring raw materials, energy for transport, and energy for manufacture. The costs of this energy in ecological terms depends mostly on the energy source. In a fossil-fuel-centric economy, the costs include pollution, fossil fuel depletion, and the release of greenhouse gases.

III.4.2 Use.
The use phase of a typical plastic product is very short compared to the lifetime of the product itself. Plastic packaging is particularly renowned as a human artifact with a useful life of months, days, or even minutes, and an actual lifetime on the order of millions of years.

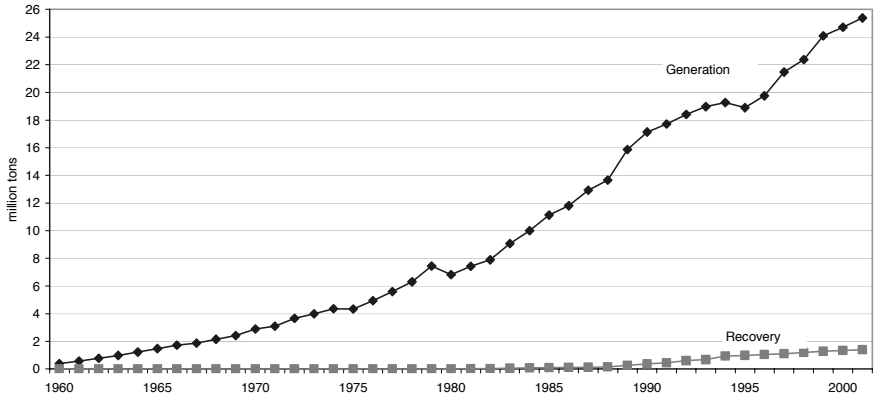
III.4.3. Grave.
Several **waste management strategies** exist for non-degradable plastic.

III.4.3.a Landfill. The most likely grave site for a plastic product is the landfill. According to the EPA, around 30 millions tons of plastic per year enter the **municipal solid waste** stream in the U.S., representing about 11% of the total pre-recycling waste stream. Of that, about 94.5% of the plastic goes to landfill. (EPA, 2001)

III.4.3.b Combustion. Plastic waste can be burned to generate energy or to transform post-consumer waste into fresh plastic feedstock via a process called **pyrolysis**. Ninety-seven so-called Waste-to-Energy facilities were in operation in 2001. Around 15% of all MSW in the U.S. was combusted in 2001.

III.4.3.c Mechanical Recycling. Recycling of post-consumer plastics packaging began in the early 1980s with state-level bottle deposit programs, accepting PETE bottles. With the addition of HDPE milk jug recycling in the late 1980s, plastics recycling has grown steadily but continues to have a marginal effect at best on the waste stream.

Roughly 80 percent of the U.S. popu-



Plastic generation and recovery for recycling, 1960 to 2001. Source: EPA.

lation — nearly 200 million people — have access to a plastics recycling program.

The two common forms of collection are:

curbside collection - consumers place designated plastics in a special bin to be picked up by a public or private hauling company (approximately 9,700 programs in 2001)

drop-off centers - consumers manually deposit their recyclables at a community facility (around 12,000 such facilities were in operation in 2001)

Recycling programs are rarely equipped to deal with every kind of plastic polymer, however usually PETE and HDPE — the most common resins found in consumer products — are accepted. Once collected, the plastics are delivered to a material recovery facility (MRF) or handler for sorting into single resin streams to increase product value. The sorted plastics are then baled to reduce shipping costs to reclaimers.

The website for the American Plastics Council continues the story:

> Reclamation is the next step where the plastics are chopped into flakes, washed to remove contaminants and sold to end users to manufacture new products such as bottles, containers, clothing, carpet, plastic lumber, etc. The number of companies handling and reclaiming post-consumer plastics today is nearly six times greater than in 1986, growing from 310 companies to 1,792 in 1998. The number of end uses for recycled plastics continues to grow. The federal and state government as well as many major corporations now support market growth through purchasing preference policies.
>
> *APC website*

As an industry advocate, the APC is understandably optimistic about the growth of plastics recycling, however as the chart above depicts, the increase in plastic recycling has so far been linear while the output of plastic waste appears to be exponential. Granted, plastics recycling is an immature industry, so the value of this comparison is not clear.

III.4.3.e Source Reduction. Source reduction simply aims to reduce waste by creating less waste to begin with. Some ways to accomplish this are:

- redesigning products to use fewer and lighter materials, or designing products to last longer and thereby delay entry into the waste stream
- redesigning packaging to reduce damage to the product, thereby reducing losses in shipping and shelf-life
- changing consumer habits, en-

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couraging less consumption
- reusing products and packaging wherever possible
- on-site alternatives to entry into the municipal waste stream (eg, back-yard composting)

While these source reduction techniques are good approaches from a design point of view, it seems unlikely that they will dominate waste management strategy over the long term.

III.4.3.f Degradation. When the mechanical or chemical integrity of a material is compromised such that it cannot perform its intended function, it may be said to have **degraded**. Plastics, like all materials, will degrade under the right conditions. Of course, these conditions may be easier or more difficult to find or create depending on the specific plastic's characteristics. In the extreme, disposing of so-called non-degradable plastics in the sun would certainly "degrade" them, but of course this is not likey to be an economically viable option on a large scale. Also, the products of such degradation may be toxic.

III.4.3.g Biodegradation. It turns out that we can easily find conditions promoting degradation in nature. Our ecosystem has its own degradation mechanisms which form a critical link in the so-called grand cycles. In this system, no elements are ever lost or "discarded," but the basic chemicals present on the planet are re-cycled over and over in biological or geochemical forms, a closed loop driven largely by the energy of sunlight.

The most prevalent means of natural degradation are the bond-breaking action of sunlight (**photodegradation**), **oxidation** in the presence of air, **hydrolysis** in the presence of water, and simple mechanical forces.

After degradation has broken polymer chains into smaller chunks or even further into fragments invisble to the naked eye, microorganisms form a bridge from the world of organic compounds to global inorganic cycles of carbon, nitrogen, hydrogen, and other basic elements.

Landmarks in Plastics

The first man-made plastic was unveiled by Alexander Parkes at the 1862 Great International Exhibition in London. This was an organic material derived from cellulose and would later be known as Parkesine.

In 1907, chemist Leo Hendrik Bakeland, developed a new synthetic polymer generated from coal tar, while trying to produce a synthetic varnish. It was an excellent electric insulator used in the production of cameras and telephones. Leo named it "Bakelite".

Cellophane was discovered, and the first patent for polyvinyl chloride (PVC) occurred in 1914.

Henry Ford pioneered research into large-scale bioplastic use and even built a prototype car with a soy-based plastic body.

Plastic production significantly changed after the first world war when petroleum became a preferred raw material over coal. Plastic use quickly gained popularity and is still used and redeveloped to meet new opportunities.

Biodegradation is degradation of materials by the natural metabolitic work of microorganisms. **Mineralization** is the conversion of biomass into gases (such as carbon dioxide, methane, and nitrogen compounds), water, salts and minerals, and residual biomass. **Complete mineralization** represents the re-entering of all chemical elements into the biogeochemical cycles.

It is important to note that degradation is a general term that does not imply any effects, positive or negative, on the ecology. A PVC pipe crushed into a fine powder is still a powder of PVC. Biodegradation, on the other hand, *does* imply the harmless return of elements to the cycles of nature, and the complete mineralization of a plastic implies that the plastic has achieved successful, harmless integration into the ecosystem.

In this process lies the value of biodegradable plastics.

IV. Current Technology

For the past 100 years plastics R&D has focused on the product use portion of the material lifecycle alone. This effort has been very succesful in making plastic one of the most ubiquitous and useful materials ever created. It has also generally produced products that do not degrade, ever. While this is a sensible strategy with respect to industrialization and rapid economic growth, it is too narrow a focus for sustainable growth. It ignores the implications of an economy that is part of a larger ecology.

Post-consumer recycled plastic products are a growing market and represent a solid step forward in the sustainability of plastic use. Still, recycling has been compared to pitstop on the way to the landfill. Product integrity and quality is inevitably degraded after mulitple recyclings. For this reason William McDonough and Michael Braungart refer to recycling as *downcycling*. Recycled plastic products are less bad, but why should we not strive to be “100% good?” they argue.

It appears to us that bioplastics offer technologies that will genuinely integrate plastics into a sustainable eco-economy, but much work has to be done to make bioplastics economically viable. If the amount of effort devoted to synthetic plastic over the past century is directed towards bioplastic research going forward, we may speculate that the technology will catch up to the need.

We provide a list of website links to current plastic technology:

IV.1 Recycled plastic content.

http://tensys.com/etfe.htm
Engineering ETFE foil brought to you by Tensys engineering and analysis.

http://www.cool-roofs.com/sp-flibrary/develop.htm
Examines the development of a sustainable roofing system with spray polyurethane foam.

http://designinsite.dk/
The designer’s guide to manufacturing that covers processes, terms, references, and environmental issues.

http://www.vinyl-siding-info.com/vinyl_siding_pro_con.html
The pros and cons of vinyl siding according to Tyvek home wrap.

http://www.usplasticlumber.com/apps/index.php?fuseAction=viewApp&pageID=2
A structural lumber link provided by U.S. plastic lumber with products, and specs.

http://www.healthyhomedesigns.com/articles/information13.php
Health home designs talks about plastic composite lumber made from recovered HDPE, PET, or several commingled plastics.

http://www.cobblumber.com/

plastic_lumber.htm
Some wood and plastic comparison specs from Cobb lumber.

http://www.toolbase.org/tertiaryT.asp?TrackID=&CategoryID=1402&DocumentID=2059
Recycled wood and plastic composites from Tool Base services.

http://www.polywood.com/
Recycled plastics from post-consumer and post-industrial used to create lumber.

http://ryanlinks.com/div065lk.htm
A specification resource for structural plastic presented by Ryan Design Structural Engineering Consultant.

http://www.new-technologies.org/ECT/Civil/frp.htm
Emerging construction technologies and materials website.

http://renewwood.com/
Eco-shake is an environmentally safe shingle explained here with specs, photos, and test reports.

http://www.insulspan.com/structure-new.html
Structural insulation panel site with some diagrams, and helpful statistics.

http://www.structall.com/Content/Panel/SIPA_article.htm
Excellent site with a comprehensive description of SIP (structural insulated panel) that entails history, construction, strength, and energy efficiency.

http://www.plastifab.com/main.html
Home page to a EPS product solution company PlastiFab.

http://www.feedscrews.com/supplierlist/104
A list of plastic product carriers around the world including recyclers, processors, plastic and lumber.

http://www.altree.com/
Altree is a plastic verses solid wood resource.

http://www.plasticsmag.com/ta.asp?aid=3711
A plastic production company displays their product types, and uses.

http://in.dir.yahoo.com/Business_and_Economy/Business_to_Business/Construction/Wood_and_Plastics/Plastics/Timber/
A list of plastic timber companies for quick reference.

IV.2 Bioplastic technology.

http://www.cargilldow.com/ingeo/home.asp
The Cargill Dow LLC site that introduces their man-made fiber Ingeo made from 100% from renewable resources.

http://www.materbi.com/i_a/
Novamont talks about Mater-Bi (the starch based bio-material) and it's environmental potentials.

http://www.ag.uiuc.edu/~stratsoy/research/ia9.html
A research database that delves into the production of soy protein plastics: a non-petrochemical alternative. This site also provides a great list of publications.

http://www.designinsite.dk/htmsider/m0956.htm
This site provides a definition of PLA (polyactide), a biodegradable thermoplastic with descriptions of products and processes.

http://www.biopolymer.net/
An excellent site rigged to a variety of links regarding green plastic developments including starch, lactic acid, polyvinyl, wood, and medical grades.

http://www.degradableplastics.com/News4b.html

A detailed examination of biodegradable plastics brought to you by Ecosafe, specifically environmentally degradable plastics based on oxodegradation of conventional polyolefins.

http://www.dow.com/dow_news/speeches/spe_stav_oct14.html
A speech on the development of sustainability: On the Road to Sustainable Development.

V. Taking Action

E.S. Stevens' book *Green Plastics* provides an excellent resource for educators in the appendix: recipies for making bioplastic at home. We reprint a recipie here, as a starting point, along with suggestions for a curriculum for a kids' sustainable learning module.

Make your own Bioplastic
It may be surprising to learn that bioplastic can be made and disposed of safely and usefully at home or at school using non-toxic ingredients available in pharmacies and the grocery store. The characterstics of a given plastic depend upon the proportions of ingredients used, additives selected, and processing.

We envision a children's curriculum in which students make their own plastics for use in school, and then, after use, dispose of these plastics in a garden for composting. Some possible uses for these homemade plastics are

- sandwich bags
- lunchware
- "glass" for picture frames
- buttons or jewlery

Or anything else you or the students can think of. Stevens includes a recipie specifically for a bioplastic rootball wrapping.

It should be emphasized to students that even though ingredients will probably be bought off-the-shelf, the raw ingredients are derived solely from plants, and therefore the plastic produced in some sense "belongs" in the soil as much as the plants themselves.

Older or more advanced students could be introduced to aspects of the scientific method by varying ingredients across many samples to discover how glycerol, for example, affects product brittleness.

In any case, experimentation should be encouraged. There are no rules, and there is no reason that a novel forumlation based on these simple procedures cannot produce something that has never been seen before.

Consider also embedding seeds into a disposable plastic baggie, and allowing the students to "litter" the bag in the garden. Find ways to add plant nutrients to the plastic matrix. Let's see if we can't design our products to be not only "less bad," but "100% good."

Basics
Gelatin, starch, agar,& sorbitol come as powders. For these measurements, 3g=1tsp.

Also, Water: 120ml=1/2cup

Glycerol: 3g=2.4ml=1/2tsp

Stock Solution
This recipie calls for 1% glycerol solution. Stevens recommends creating a stock solution of 10ml of Glycerol per liter of water or 2tsp of glycerol per quart.

Remember
Increased Plasticizer = more flex
Less Plasticizer = brittleness

Procedure
- Mix all ingredients together (limit the clumps). Heat Mixture to 95 degrees C (roughly to the point of initial froth, make sure to mix during this portion)
- After heating stir the mixture (there should be no Lumps)
- Remove any excess froth
- Pour the mixture into a level surfaced pan (depending on the application)
- Allow to dry. This may take from

hours to days, depending on the climate.

BioGlass
- Combine 12.0g (4tsp) gelatin with 240ml (1 cup) 1% glycerol solution.

Laminate
- Combine 2.25g (3.4tsp) gelatin with 135 ml (9/16 cup) 1% glycerol solution

Gelatin Based
- Combine 0.75g (1.4tsp) sorbitol and 2.25g (3.4tsp) gelatin with 60ml (1.4 cup) 1% glycerol solution and 60ml (1/4 cup) water.

Starch Based
- If a small amount of salt of added to a starch only biopolymer they form better sheets
- Combine 3.0g (1 tsp) starch and 45mg salt with 160ml (2/3 cup) 1% glycerol solution
- 1,2, 3 Plastic solution
- This particular formula uses starch, gelatin, and agar rated by proportion that is relative to cost
- Combine 0.75g (1/4 cup) sorbitol, 1.5g (1/2 tsp) starch, 0.75g (1/4 tsp) gelatin and 0.38g (1/8 tsp) agar with 120 ml (1/2 cup) 1% glycerol solution

VI. Conclusions

It is our opinion that plastic as a material is not fundamentally unsound for use in architecture, industry, and the home. Even today, synthetic plastics make up a *relatively* small percentage of landfill waste and cause *relatively* little ecological impact through fossil fuel use. There is room for much improvement in recycling and source reduction, but if we must choose which battles to fight, other causes may take priority.

However, going forward we feel it is imperative that materials be integrated fully into the grand cycles of the planet. McDonough and Braungart present a model of economy with two nutrient cycles: a technical metabolism and an organic metabolism. Plastics may exist in either realm, as they may be either synthetic or bio-based, but it seems more plausible to us that bio-based plastics will ultimately prove more economically and ecologically viable. Synthetic plastics will forever be subject to the effects of *down-cycling*, finding their way inevitably to landfill, while bioplastics will always be absorbed harmlessly back into the ecosystem.

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Eco-economy: building an economy for the earth, Lester R. Brown. New York, W.W. Norton, 2001.

Cradle to Cradle: remaking the way we make things, William McDonough and Michael Braungart. New York, North Point Press, 2002.

How green are green plastics?, Scientific America (2000, August). Retrieved from http://www.mindfully.org/Plastic/Biodegrade/Green-

Check List

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PlasticsAug00.htm

Websites.

See also our list of resources in section IV.

http://www.mcdonough.com/
William McDonough

http://www.mbdc.com/
McDonough Braungart Design

http://www.cargilldow.com/
Plastic mfg. Cargill-Dow.

http://www.biopolymer.net/
Biopolymer.net | online resources for a better environment.

http://www.plastics.org.nz/page.asp?id=527
Plastics New Zealand. The 6 Most Common Plastics & the Plastic Identification Code.

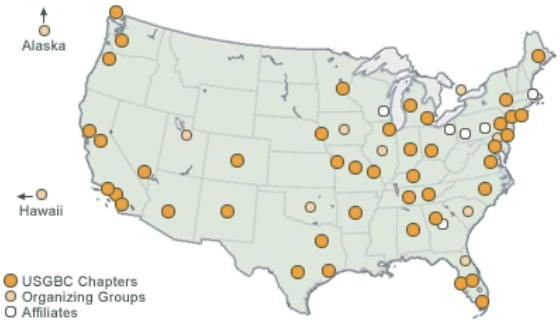
http://www.omnexus.com/tc/polymerselector/polymerprofiles.aspx
Design & Solution Center - Polymer Sector - Polymer Properties

http://www.epa.gov/epaoswer/non-hw/muncpl/msw99.htm
EPA Municipal Solid Waste Characterization Report, 2001

http://www.chem.uu.nl/nws/www/general/personal/Bio-poly.pdf
Dr. Martin Patel, Dr. Catia Bastioli, Dr. Luigi Marini, Dipl.-Geoökol. Eduard Würdinger. *Environmental assessment of bio-based polymers and natural fibres.*

Wood

Wood CSI 06000



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Topics Covered

-What are the major issues and concerns associated with traditional wood products?
-What can be done to combat these issues?
-Introduction to the green wood product market
-Suggested data for product selection

Things the architect/designer should know:
1. be aware of certification differences
2. if the manufacturer is certified not all their products may be certified
3. not all advertised green products are truly green - be sure to review product specifications

Things the client should know:
1. importance of utilizing green products
2. green does not necessarily cost more
3. green can be aesthetically pleasing

Today's vast range of green lumber and engineered lumber products offers many **advantages** over traditional wood products. These **advantages** include low or no VOC content, competitive price points, **recycled content**, and certified sustainably managed sourcing. These materials, which can be utilized in both interior and exterior design as well as for aesthetic and structural purposes, offer a responsible option to traditional wood materials.

Exploration of these products is an important step in integrating environmentally conscious materials into today's construction projects. A thorough understanding of the selection and application of these products allows for comparisons between products and ensures that the best product is selected for current and future applications.

Given the overwhelming number of wood products, how does the designer navigate through the vast amounts of data and products available? Ultimately the designer has the most control over the products used in a building he or she designs and therefore can have a significant impact on the "green-ness" of the design, but determining the best green product for the application can require a significant amount of time, something most designers do not have. An exploration of the green wood market and an understanding of what qualities to look for will significantly increase the likelihood that a designer will utilize a green wood product over a traditional product with which he or she may be more familiar.

Five products will be introduced highlighting the green characteristics they embody including some of the following criteria:

- LEED
  - Certified Wood
  - VOC content
  - Local availability
  - **Recycled content**
  - Resource reuse

- General material **properties**
- **Advantages and disadvantages**
- Characteristics

Greener Wood

csi 06000

group 8

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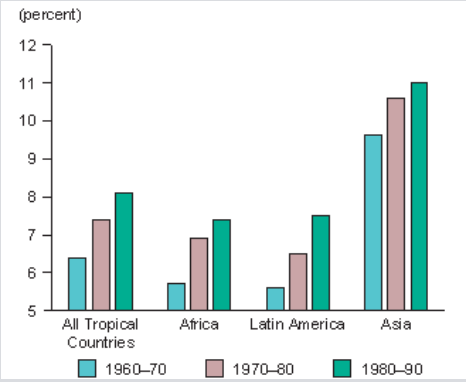
Issues and Concerns: Deforestation

Why is deforestation bad?

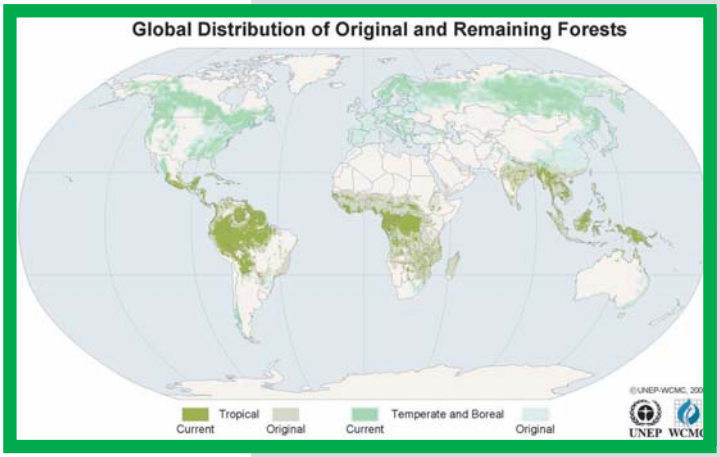
- Global warming
- Ozone depletion
- Erosion and flooding caused by clear-cutting
- Loss of endangered species due loss of habitat
- Cultural issues due to loss of habitat



Rate of Deforestation

Deforestation and... the Global Carbon Cycle

Deforestation increases the amount of carbon dioxide (CO_2) and other trace gases in the atmosphere. When a forest is cut and burned for crop land or pastures, CO_2 is released into the atmosphere. Increased atmospheric CO_2 enhances the greenhouse effect and contributes to global warming.



Deforestation releases 1.6 billion tons of carbon into the atmosphere each year. In comparison, fossil fuel burning releases 6 billion tons/year.

Deforestation and... the Hydrologic Cycle

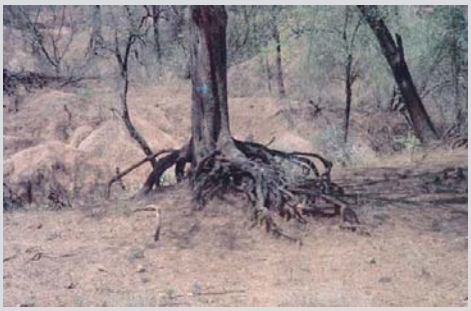
Evaporation and evapotranspiration processes from trees and plants return water to the atmosphere, promoting precipitation. Deforestation affects local climates by reducing and sometimes eliminating this evaporative cooling process. Less evaporation promotes warming of the earth's surface by the sun and, consequently, the air above, leading to a rise in temperatures.

Deforestation and... Biodiversity

Earth is home to tens of millions of species of plants and animals, of which only 1.5 million have been named. Deforestation destroys species whose existence is not even known yet. Many forest plants and animals require special habitats and can only be found in small areas, thus they are very vulnerable to deforestation. If their habitat is destroyed, they may become extinct. Estimates indicate that up to 37 species disappear

worldwide each day. No one knows what kind of valuable information is lost when a species goes extinct.

Deforestation and... Erosion



Although many forests appear to be lush and full, the underlying soils are often very poor because the majority of the nutrients are bound up in the vegetation. When there are no trees to keep soil in place, it becomes ripe for erosion. It dries and cracks under the sun's heat. When the soil temperature exceeds 25 degrees Celcius, volatile nutrients like nitrogen can be lost, further reducing the fertility of the remaining soil. Rainfall washes any remaining nutrients into rivers.

The social impact of soil erosion is also quite severe. Those who settle in forest regions are forced to move every year or so to find fertile soil. When those areas are no longer good for growing, they move to another region.

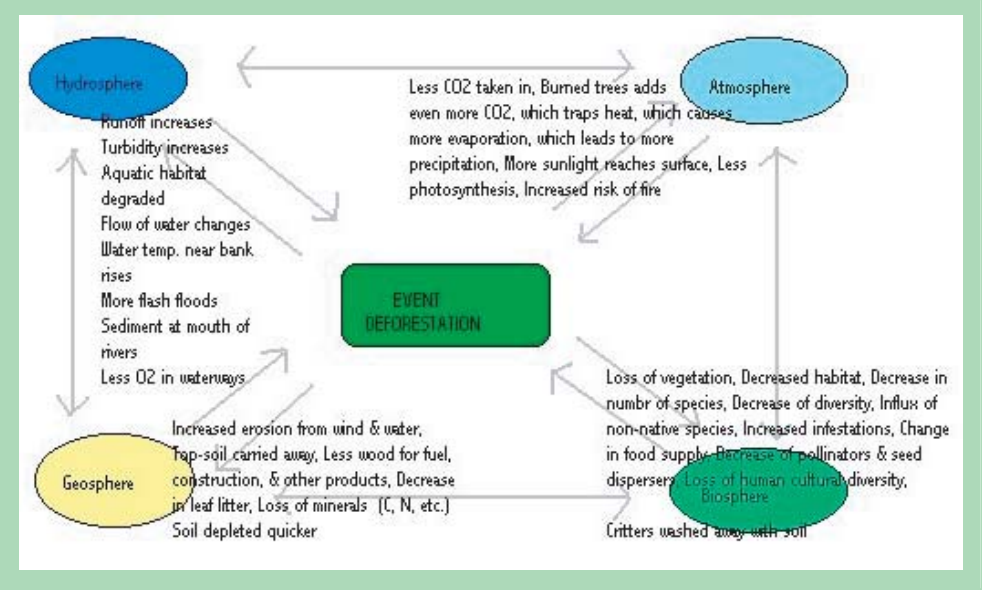
Deforestation and... Flooding

Flooding is another serious consequence of deforestation. Clearing a forest dramatically increases the surface run-off from rainfall, mainly because a greater proportion of the rain reaches the ground due to a lack of vegetation which might otherwise absorb the excess rainfall. In regions where forests are still dense, flooding is not as serious a problem because the vegetation absorbs the rainfall. Areas with little remaining vegetation are more prone to flooding.

Things the architect should know:

Deforestation causes:

- ·Global warming
- ·Ozone depletion
- ·Erosion
- ·Flooding
- ·Loss of species
- ·Cultural issues



Issues and Concerns: Deforestation

Solution

How can the architect be certain that wood products are harvested responsibly to avoid the issues associated with deforestation?

Forest Stewardship Council (FSC)
www.fsc.org

The FSC was founded in 1995 with the following objectives:
·To promote environmentally appropriate, socially beneficial, & economically viable management of the world's forests.
·To respect indigenous rights
·To maintain community well-being
·To protect biological diversity

The FSC combats deforestation through a forest certification program and a product-labeling scheme. Products with the FSC label are sourced from a forest that has been responsibly managed under strict FSC principles and criteria. See www.FSC.org for specifics.

By specifying an FSC certified product, the architect can be certain the chosen product meets the FSC's criteria for sustainable forestry. Choosing a product that is FSC certified requires diligence on the architect's part because many manufacturers are FSC certified, but often not all or even the majority of their products will be FSC certified. The architect must specifically request a product that is FSC certified and request documentation to support the certification.

Other Certification Organizations

Other certification organizations include:
·Sustainable Forestry Initiative (SFI)
www.aboutsfi.org
·Canadian Standards Association (CSA)
www.csa.ca

Each of these organizations has its own criteria for what constitutes sustainable forestry. Most disagree with the others' criteria, stating that they are either too lenient or too strict in various areas, and most will not allow their labeling to appear on a product with another organization's label.

LEED

The FSC is currently the only organization recognized by LEED. Therefore, only FSC certified wood products qualify for Credit 7.0. Products certified by other organizations are not be eligible for this credit, but may be eligible for other credits. See page XX for more on LEED credits.

Things the architect should know:

·FSC is the only certification organization recognized by LEED.
·Many manufacturers are FSC certified, but often not all or even the majority of their products are FSC certified.
·www.FSC.org lists certified manufacturers, but it is often very difficult to determine which products are certified without contacting the manufacturer for specifics.
·Ask a lot of questions and request documentation.

Issues and Concerns: Indoor Air Quality (IAQ)

Issues

·Sick Building Syndrome
·VOCs- especially formaldehyde

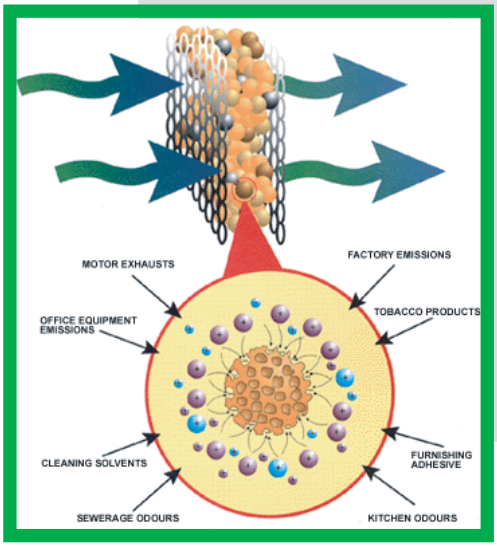
Sick Building Syndrome (SBS)

Sick Building Syndrome is an issue that was been well-documented by the EPA. SBS occurs when building occupants experience acute health and comfort effects that are linked to time spent in a building, but no specific illness or cause can be identified. A 1984 World Health Organization Committee report indicated that up to 30% of new and remodeled buildings are the subject of complaints related to indoor air quality (IAQ).

Symptoms of SBS Include:

·headache
·eye, nose, or throat irritation
·dry cough
·dry or itchy skin
·dizziness
·nausea
·difficulty concentrating
·fatigue
·sensitivity to odors

The cause of these symptoms is not known. Studies show that symptoms may be caused or exacerbated by indoor air quality problems. Most of complainants report relief soon after leaving the building.



Causes of and Factors Contributing to Sick Building Syndrome

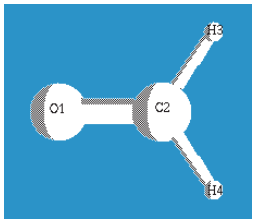
·*Inadequate ventilation:*
Standards have been revised to require a minimum of 15 cfm of outdoor air per person and 20 cfm/person in office spaces. (see ASHRAE Standard 62-1989).

·*Volatile Organic Compounds (VOC)*
Most indoor air pollution comes from sources inside the building that emit VOCs, including formaldehyde:
·adhesives
·carpeting
·upholstery
·manufactured wood products
·copy machines
·pesticides
·cleaning agents

·*Chemical contaminants from outdoor sources:*
These contaminants enter the building through poorly located air intake vents, windows, and other openings.
·pollutants from vehicle exhaust
·plumbing vents and building exhausts such as bathrooms and kitchens.

·*Biological contaminants:*
These contaminants breed in stagnant water that has accumulated in ducts, humidifiers and drain pans, or where water has collected on ceiling tiles, carpeting, or insulation:
·bacteria
·molds
·pollen
·viruses
·insects or bird dropping

·*Tobacco smoke:*
·high levels of VOCs
·toxic compounds
·respirable particulate matter



Check List

cost

maintenance

properties

life cycle

embodied energy

recycling

health

benefits

disadvantages

Why are VOCs bad?

Research shows that some VOCs can cause chronic and acute health effects. Some are known to be carcinogens. Formaldehyde is one of the most common indoor VOCs because it is a component of most indoor building materials. It is also one of the most dangerous.

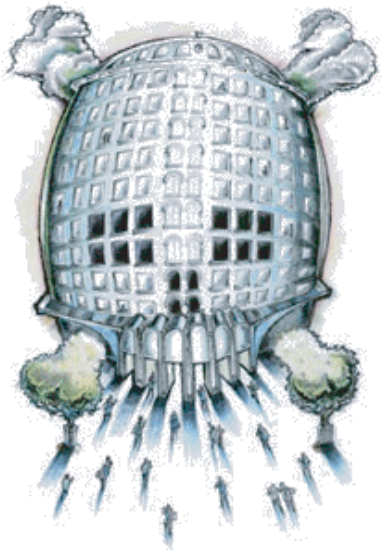
Formaldehyde

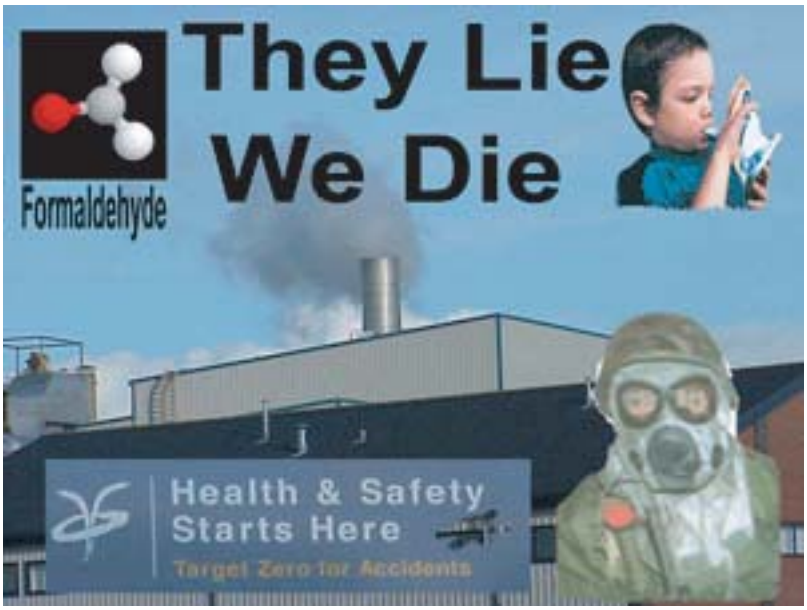
A VOC that is found in:

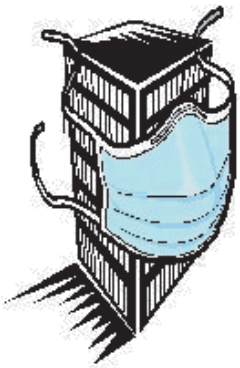
- glue or adhesive in pressed wood products (particleboard, hardwood plywood, and MDF)
- preservatives in some paints, coatings, and cosmetics
- coatings that provide the permanent press quality to fabrics and draperies
- finishes used to coat paper products
- certain insulation materials including urea-formaldehyde foam and fiberglass insulation.

Acceptable Levels of Air-Borne Contaminants

Substance	Maximum Permissable / Recommended Level
Carbon Dioxide	1,000 ppm
Carbon Monoxide	11 ppm
Formaldehyde	0.1 ppm
Particulate	.04 mg/m³
Radon	2.7 pCi/L
Total VOCs	0.2 mg/m³ with no individual VOC > 10% of TVOC
Nitrogen Dioxide	0.05 ppm
Sulphur Dioxide	0.019 ppm
Ozone	0.05 ppm
Microbials/ Micro-organisms	45 CFU/ m³ for a single species







Check List

cost

maintenance

properties

life cycle

embodied energy

recycling

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benefits

disadvantages

Issues and Concerns: Indoor Air Quality

Solutions

How can green wood products assist the architect in designing a healthy building?

There are many green wood products on the market today. By specifying healthy products, the architect can reduce the VOCs emitted by building materials over the life of the building thereby increasing its IAQ.

Consider the following:

·Products that are specified by the manufacturer to contain low-emitting materials. Request documentation to verify what the manufacturer considers to be low level emmittance. Compare to *Acceptable Levels of Air-Born Contaminants* on page XX.

·Board products manufactured with formaldehyde-free glues. Again, documentation from the manufacturer is necessary to confirm advertised statements.

·Fully sealed products that are laminated or coated on all surfaces and edges. This will prevent off-gassing of formaldehyde and other harmful VOCs. These chemicals cannot harm building inhabitants if they cannot be inhaled.

Suggested Products

The following pages tabulate information on several suggested products. These products will meet some or all of the criteria suggested in this documents. The architect should utilize these specifications as examples of the kind of data that should be reviewed when selecting a green wood products. In addition, refer to pages XX for detailed information regarding the possible LEED credits for which these materials may qualify.

Check List

cost

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LEED
Materials and Resources

The following are potential credits that could be earned by using green wood products:

Credit 3: Resource Reuse

Salvage materials: beams, posts, flooring, paneling, doors, cabinetry.

- Credit 3.1 (1 point)
- Specify 5% salvaged or refurbished material.
- Credit 3.2 (1 point)
- Specify 10% salvaged or refurbished material.

Credit 4: Recycled Content

Particleboard, chip board, fiberboard.

- Credit 4.1 (1 point)
  Specify min 25% materials that contain in aggregate, a min weighted average of 20% post-consumer recycled content material, OR a min weighted average 40% post-industrial recycled content material.

Credit 5: Local/Regional Materials

Quantify total percentage of locally sourced materials.

- Credit 5.1 (1 point)
  Specify min 20% materials manufactured regionally within 500 miles.
- Credit 5.2 (1 point)
  Of regionally manufactured materials, specify min 50% extracted, harvested, or recovered within 500 miles.

Credit 6: Rapidly Renewable Materials

Bamboo flooring, poplar OSB, wheat grass cabinetry.

- Credit 6.0 (1 point)
  Specify 5% rapidly renewable building materials.

Credit 7: Certified Wood

FSC-certified wood products.

- Credit 7.0 (1 point)
  Min 50% FSC certified wood-based materials, including framing, flooring, finished, furnishings, and temporary construction applications like bracing, form work, barriers.

Indoor Air Quality (IAQ)

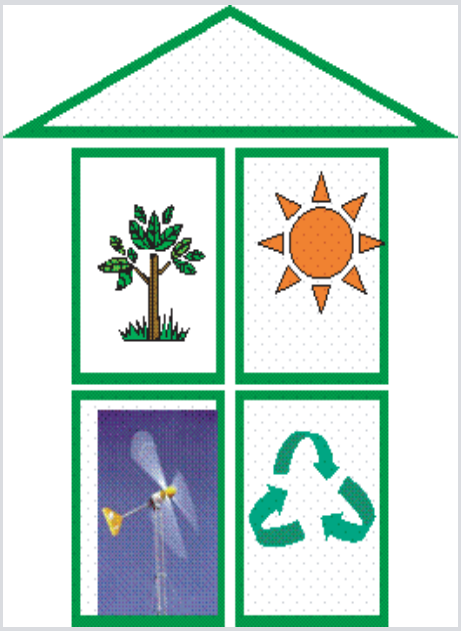
Prerequisite 1: Minimum IAQ Performance

- Meet min requirements of ASHRAE62-1999.

Credit 4: Low-emitting Materials

Use low VOC and formaldehyde-free composite wood products.

- Credit 4.1 (1 point)
  Adhesives must meet or exceed VOC limits of South Coast Air Quality Management District Rule #1168 AND sealants used as filler must meet or exceed Bay Area Air Quality Management District Reg 8. Rule 51.
- Credit 4.2 (1 point)
  Paints and coatings must meet or exceed the VOC and chemical component limits of Green Seal requirements.
- Credit 4.4 (1 point)
  Composite wood and agri-products must contain no added urea-formaldehyde resins.



Appleply-Veneer Core Panels

Features and Benefits:

-Attractive Edges: Uniformly thin core veneers laminated at right angles produces an attractive visual edge that is often used as a design element in fixtures, furniture and architectural installations.

-Sizes and Tolerances: Appleply is manufactured in 8' or 10' lengths and 4' widths. Thicknesses range from 1/4" 5 ply, through 1-1/4" 21 ply. Tolerances comply with the American National Standards Institute (ANSI/HPVA) grade rules HP-1-2000. Appleply can be manufactured to meet more critical tolerances if required.

-Finishes: Like all States' products, Appleply can be ordered with any NOVA ultraviolet cured finish, clear, translucent, opaque, or printed. In addition, it is also offered in four stock colors under the Candy Applecolor name. Bright primary red, blue, yellow, and green are used in juvenile furniture, store fixtures, workstations, and architectural applications. Matching edge stains are available.

-Machinability: Because Appleply is made from low density hardwood veneers, and because it has few voids, it machines without tearing or fuzzing.

Appleply is intended for interior applications including furniture, fixtures, and architectural installations. Appleply is also popular for use as drawer sides because of its appearance when left unbanded. Alternating edge grain absorbs stain and finish at different rates, producing a pleasing light and dark layered effect, crossbands make the panel unsuitable for exterior applications.

Environmental Certification:
Appleply is FSC certified - qualifies for LEED Materials and Resources Credit 7.

States industries provides the following information at www.StatesInd.com:

- -Company History
- -Manufacturing Info
- -MSDS
- -Technical Data
- -Local Distributors
- -Project Resume
- -Certification Awards
- -Membership affiliations

Applications: Appleply is a premium quality veneer core panel constructed from uniform laminations of solid grade 1/16" Alder and Birch. This all hardwood core produces a strong, light weight panel with a naturally attractive edge. This visually attractive pattern of the edge is often used as a design element.

Greener Wood Appleply

csi 06000

group 8

Local Availability	Yes
Local Manufacturing	No
Low VOC Emittance	Unknown
Competitive Cost	Unknown
Recycled Content	Unknown
Resource Reuse	Unknown
LEED Credits Supported	Yes
FSC Certified	Yes
SCS Certified	No
Class I Flame Retardant	Unknown

LEED Credits Supported
Contributes to Achieving Credits for:
-Materials & Resources - 7

Storage & Conditioning:
Storage - store indoors on flat, level surface with adequate support to prevent sagging
Conditioning - For best results, Appleply should be conditioned to the environment for 48-72 hours prior to installation

ArmoreCore EQ-Composite MDF Panels

Features and Benefits:

-***Superior Surface:*** MDF crossbands provide the surface hardness, superior density and uniform texture of a 100% composite panel. The benefit of this superior surface is that when overlaid with wood veneers of other thin materials, core imperfections are not telegraphed to the finish surface.

-***Low Weight, High Strength:*** Particularly important in interior paneling or overhead applications the weight of ArmoreCore EQ is 25% less than particle board, yet the veneer innerplies provide the strength of conventional plywood substrates.

-***Durability:*** Improved joinery results from a Modulus of Elasticity (MOE), that is 50% greater than particleboard and 25% greater than MDF, making ArmoreCore EQ ideal for cabinetry, case goods, and furniture.

-***Machinability:*** ArmoreCore EQ has excellent machinability, so router cuts leave crisp , clean edges. Because only the surface is MDF, therefore, wear on the machine is significantly reduced.

ArmoreCore EQ is intended for interior applications, while the adhesive carries an exterior rating, composite crossbands make the panel unsuitable for exterior applications.

Environmental Certification:
ArmoreCore EQ is 72% FSC certified created with Non-Urea adhesives and is LEED compliant.

States industries provides the following information at www.StatesInd.com:

- -Company History
- -Manufacturing Info
- -MSDS
- -Technical Data
- -Local Distributors
- -Project Resume
- -Certification Awards
- -Membership affiliations

Applications: ArmoreCore EQ is engineered to be overlaid with wood veneer, high pressure laminates, or thin impregnated papers like melamines, polyester, MDO foils etc. It is strictly intended for interior applications. Painted applications require unsanded surfaces which are also available.

Greener Wood ArmoreCore EQ

csi 06000

group 8

Local Availability	Yes
Local Manufacturing	No
Low VOC Emittance	Yes
Competitive Cost	Unknown
Recycled Content	Unknown
Resource Reuse	Unknown
LEED Credits Supported	Yes
FSC Certified	Yes
SCS Certified	No
Class I Flame Retardant	Unknown

LEED Credits Supported

Contributes to Achieving Credits for:

- -Materials & Resources - 7
- -Indoor Environmental Quality- 4.4

Storage & Conditioning:

Storage - store indoors on flat, level surface with adequate support to prevent sagging

Conditioning - For best results, ArmoreCore EQ should be conditioned to the environment for 48-72 hours prior to installation

For more details on working with MDF, consults "MDF From Start to Finish," published by the Composite Panel Association, www.pbmdf.com.
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SierraPine LTD
COMPOSITE SOLUTIONS

Medex - MDF Panels

Features and Benefits:

-Finishing: can be painted, laminated or veneered. Laminating information available upon request through SierraPine.

-Exceptional ***machining*** and low tool wear

-Fastening: Medex readily accepts and holds staples, screws, and other wood fastening hardware.

-Medex is especially suitable in interior applications where moisture is a concern.

Medex is an SCS certified no added formaldehyde, moisture resistant MDF panel engineered for interior high moisture areas.

Medex can be used in place of sanded plywood and solid wood in non-structural applications. This panel provides the flexibility of a composite panel with the emissions of solid wood.

Applications:

- Countertops
- Window Sills
- Bathroom & bay window head and seat boards
- Display cases
- Raised panel door inserts

Limitations:

Medex is not suitable for structural applications, exterior siding, or exterior trim.

Environmental Certification: Medex is an SCS certified for no added formaldehyde and 100% recovered and recycled wood fiber.

For LEED buildings or other projects where indoor air quality (IAQ) is a concern, no added formaldehyde Medex is an ideal choice as product emissions meet and exceed current international standards.

Greener Wood Medex

csi 06000

group 8

Local Availability	Yes
Local Manufacturing	No
Low VOC Emittance	Yes
Competitive Cost	Unknown
Recycled Content	Yes
Resource Reuse	Yes
LEED Credits Supported	Yes
FSC Certified	No
SCS Certified	Yes
Moisture Resistance	Yes

LEED Credits Supported

Contributes to Achieving Credits for:

-Materials & Resources - 4.1 & 4.2
5.1 & 5.2

-Indoor Environmental Quality- 4.4

Storage & Conditioning:

Storage - store indoors on flat, level surface with adequate support to prevent sagging

Conditioning - For best results, Medite II should be conditioned to the environment for 48-72 hours prior to installation

For more details on working with MDF, consults "MDF From Start to Finish," published by the Composite Panel Association, www.pbmdf.com.

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SierraPine provides the following information at www.sierrapine.com:

-Company History
-Manufacturing Info
-MSDS
-Technical Data
-Local Distributors
-Project Resume
-Certification Awards
-Membership affiliations

Medite II - MDF Panels

Features and Benefits:

-***Finishing:*** can be painted, laminated or veneered. Laminating information available upon request through SierraPine.

-Exceptional ***machining*** and low tool wear

-***Fastening:*** Medite II readily accepts and holds staples, screws, and other wood fastening hardware.

Medite II meets (VOC) emissions section 01350 of the Materials Specifications adopted by the Collaborative for High Performance Schools (CHiPs).

Medite II can be used in place of sanded plywood and solid wood. This panel provides the flexibility of a composite panel with the emissions of solid wood.

For LEED buildings or other projects where indoor air quality (IAQ) is a concern, no added formaldehyde Medite II is an ideal choice as it surpasses all current international formaldehyde standards. Medite II was used extensively in the nation's first sustainable residential high-rise: the Solaire in Battery Park City, Manhattan.

Envinronmental Certification: Medite II is an SCS certified for no added formaldehyde and 100% recovered and recycled wood fiber.

Greener Wood Medite II

csi 06000

group 8

Applications:

- Paneling
- Molding
- Architectural woodwork
- Display cases
- Cabinets

Limitations:

-Medite II is not suitable for structural applications or where moisture may be present.

Local Availability	Yes
Local Manufacturing	No
Low VOC Emittance	Yes
Competitive Cost	Unknown
Recycled Content	Yes
Resource Reuse	Yes
LEED Credits Supported	Yes
FSC Certified	No
SCS Certified	Yes
Class I Flame Retardant	No

LEED Credits Supported

Contributes to Achieving Credits for:

-Materials & Resources - 4.1 & 4.2
5.1 & 5.2

-Indoor Environmental Quality- 4.4

Storage & Conditioning:

Storage - store indoors on flat, level surface with adequate support to prevent sagging

Conditioning - For best results, Medite II should be conditioned to the environment for 48-72 hours prior to installation

For more details on working with MDF, consults "MDF From Start to Finish," published by the Composite Panel Association, www.pbmdf.com.

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SierraPine provides the following information at www.sierrapine.com:

-Company History
-Manufacturing Info
-MSDS
-Technical Data
-Local Distributors
-Project Resume
-Certification Awards
-Membership affiliations

SierraPine LTD
COMPOSITE SOLUTIONS

Medite FR2-MDF Panels

Features and Benefits:

-Finishing: can be painted, laminated or veneered. When choosing a finish, confirm that the product will not react with or neutralize the Class I flame spread classification of FR2. Laminating information available upon request through SierraPine.

-Exceptional ***machining*** and low tool wear

-Fastening: FR2 readily accepts and holds staples, screws, and other wood fastening hardware.

Flame Retardant FR2 is especially effective when applied in libraries, schools, hospitals, theaters, office buildings, museums, laboratories, public facilities, and medical facilities.

Environmental Certification: Medite FR2 is SCS certified for 100% recovered and recycled wood fiber with at least 25% post-industrial recycled fiber.

Applications:

- Paneling
- Sheathing
- Display panels
- Doors
- Shelving

Limitations:

-Medite FR2 is not suitable for external or structural applications.

Greener Wood Medite FR2

csi 06000

group 8

Local Availability	Yes
Local Manufacturing	No
Low VOC Emittance	Unknown
Competitive Cost	Unknown
Recycled Content	Yes
Resource Reuse	Yes
LEED Credits Supported	Yes
FSC Certified	No
SCS Certified	Yes
Class I Flame Retardant	Yes

LEED Credits Supported

Contributes to Achieving Credits for:

-Materials & Resources - 4.1 & 4.2
5.1 & 5.2

Storage & Conditioning:

Storage - store indoors on flat, level surface with adequate support to prevent sagging

Conditioning - For best results, FR2 should be conditioned to the environment for 48-72 hours prior to installation

For more details on working with MDF, consults "MDF From Start to Finish," published by the Composite Panel Association, www.pbmdf.com.

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SierraPine provides the following information at www.sierrapine.com:

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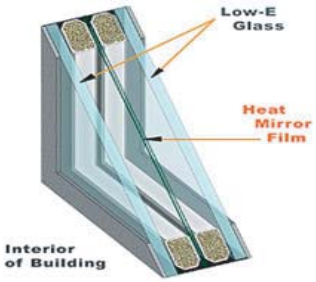
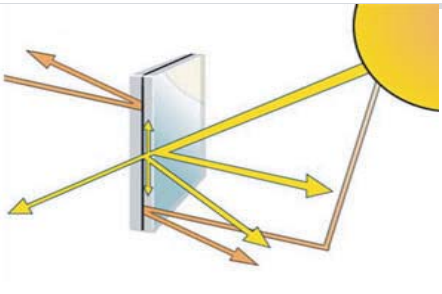
Exterior Windows





Sustainable Window Technology

When it comes to “Green” design the main focus in CSI section 08000 Doors & Windows is the sustainability of the units. Therefore the main focus of this document is to provide insight into the world of efficient window design.

Typically materials used in building construction are given an R-Value (resistance) to represent their ability to resist heat transfer. The higher the R-Value the more insulation the skin of the building is providing. As a method of reference a typical 2x4 stud wall with batt insulation and sheathing on each side provides an R-Value of around R-13. A typical one pane (single piece of glass) window unit has an R-Value of around R-0.2. This is typically accepted in home construction. Commercial construction has found ways to improve upon this number as heating and cooling cost are generally an important issue to building owners.

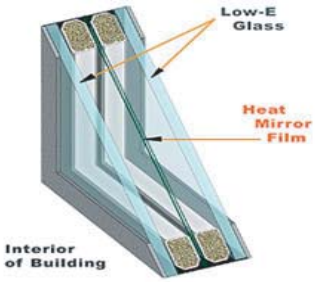
In the following pages we will talk about the newer technologies available for exterior window design. The following will be included:

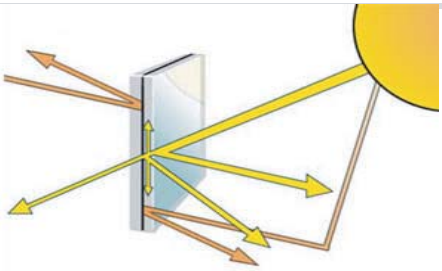
Window Frames – types of frame materials and there ratings.

Glazing Films – these are treatments applied to the glass themselves, including Low-E and Heat Mirror.

Gases – adding dense gases between window panes greatly increases their thermal performance.

Smart Windows – these include state of the art window treatments: Electrocromatics, Polymer Dispersed Liquid Crystal and Suspended Particle Display.





Frames Types

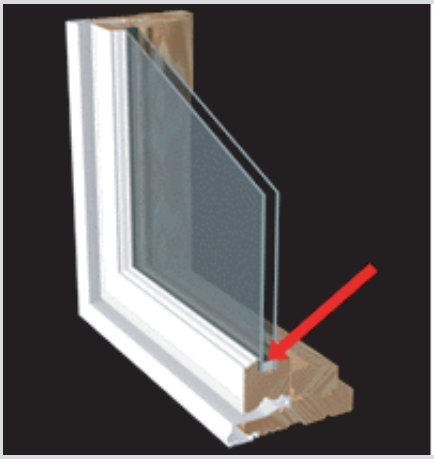
The frame of a typical window can make up for as much as 25% of the total surface area of the unit.[1] Therefore before we get into glazing types and treatments we'll talk a little about the properties of different frame types.

Typical frame construction consists of wood, aluminum and vinyl. As you can see in the graph below the U-Values vary quite a bit between types. The U-value is the inverse of the R-Value. Simplified the lower the U-Value, the higher the R-Value, the better thermal protection you are receiving.

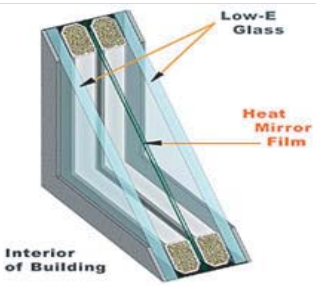
Frame material	U-value
Aluminum (no thermal break)	1.9-2.2
Aluminum (with thermal break)	1.0
Aluminum-clad wood/reinforced vinyl	0.4-0.6
Wood and vinyl	0.3 - 0.5
Insulated vinyl/insulated fiberglass	0.2 - 0.3

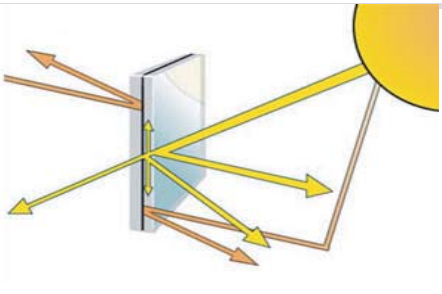
Spacers

Another important part of the frame to consider is the spacer used to separate the pains of glass in a double or triple paned unit. Since the double paned window first began to appear in modern construction in the 40's & 50's it was common to use an aluminum spacer which provided great strength and rigidness. However as can be seen on the chart, aluminum is a very poor insulator but actually a decent conductor.



To remedy this new approaches have been taken to change the material and sometime the overall design of the spacer. A common approach is to use materials that are better at insulating. The most common used is one that incorporates a spacer, sealer and desiccant in a thermoplastic compound that contains a blend of desiccant materials and incorporates a thin, fluted metal shim of aluminum or stainless steel. Another approach uses an insulating silicone foam spacer that incorporates a desiccant and has a high-strength adhesive at its edges to bond to glass. The foam is backed with a secondary sealant. Both extruded vinyl and fiberglass spacers have also been used in place of metal designs.[2]





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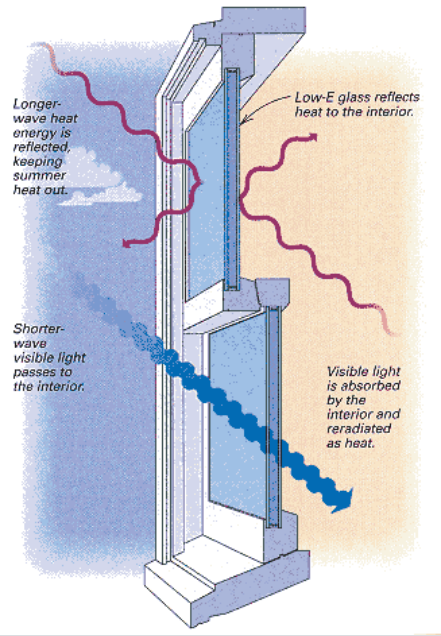
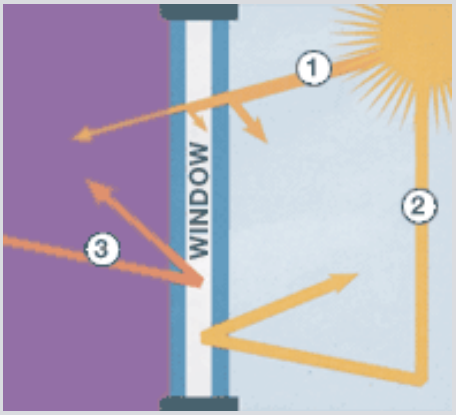
Low-E

Low-Emittance (Low-E) coating is a system applied to the actual glazing in a window unit.

Low-E is a clear, low-emissivity coating applied to one of the interior faces of a dual-paned window system. This microscopically thin, virtually invisible, metal or metallic oxide coating is placed on the glazing to suppress radiative heat flow and therefore reduce the U-factor.[3] In other words this system helps filter the summer sun's heat energy and redirects internal heat back inside during the winter. This can be a huge cost savings as normally up to 30% of a buildings heat gain/loss occurs through the windows.

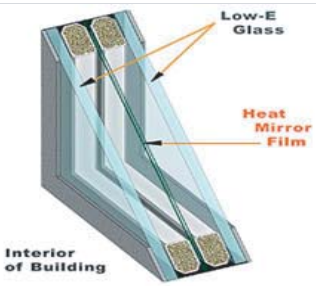


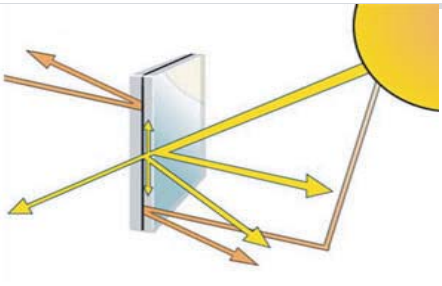


1-Low-E glazing allows natural light to penetrate into the building while blocking a large portion of the ultraviolet (short wave) heat energy.
2-In the summer months, the infrared (long wave) heat energy is reflected back to the exterior, helping to lower cooling costs.
3-In the winter months, long wave heat energy is reflected back into the building, helping to reduce heat loss and therefore reducing heating bills.

Low-E coatings have been designed to suit different climate requirements. There are those developed specifically for high solar gain (cold climates), moderate solar gain and low solar gain (warm climates).[3]

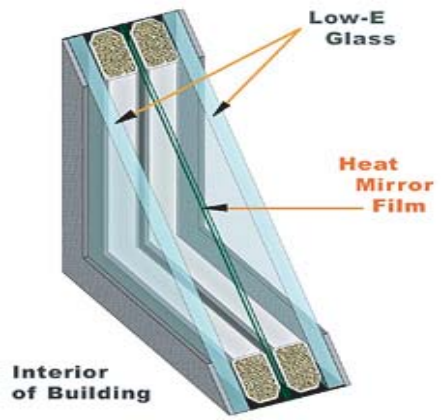
In Colorado an average cost savings of 13% can be realized on windows with Low-E coatings as compared to regular untreated double paned windows.[4] This amount of savings will help to repay the initial cost of the Low-E coating in a matter of years not decades.



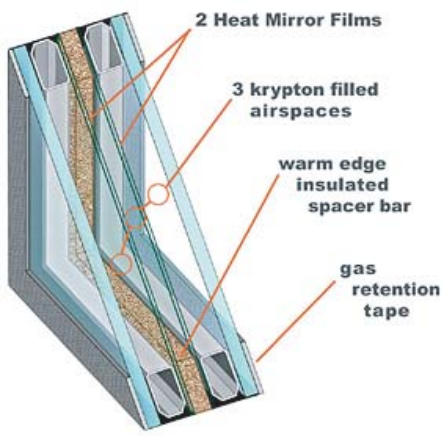


Heat Mirror

Heat Mirror is a low-emissivity coated film product that is place between the glazing in a double paned window unit. This results in a triple paned unit with effectively two airspaces without the added weight of the third piece of glass. This system also provides far superior insulating and shading performance over regular glazing alone.

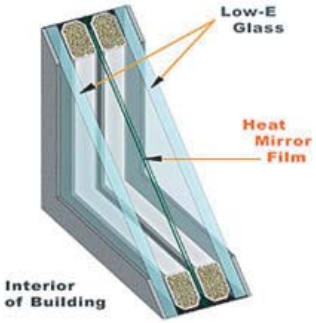


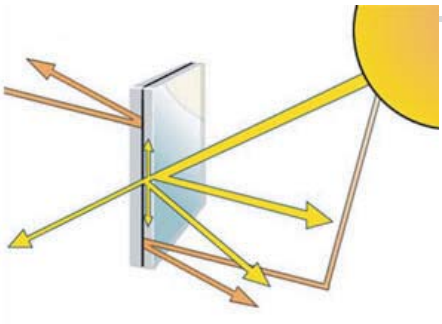
Heat Mirror Plus is a system which exchanges one lite of Low-E coated glass for the uncoated glass used with the Heat Mirror unit. With optional gas filling (Argon or Krypton) a U-Value of less than 0.12 (R-value of 9.1) is possible.[5]



The Heat Mirror Superglass System released in the early 90's is one of the most energy-efficient window glazing systems on the market that stays within the industry standard of 1" nominal thickness.

As you can see on the R-Value chart below, using Heat Mirror alone (without Low-E) glazing even surpasses those types of units. Combining the two systems produces one of the most energy efficient systems available.





Gases:

In windows, the best way to insulate is to eliminate heat conduction as much as possible. By creating an air gap between the glass panes, the conduction of heat is limited to using the air gap element as a vehicle for heat transfer. Argon and Krypton are the two mostly used gasses for windows. They increase a window's efficiency by reducing the rate of heat transmission between the glass panes. Employing a denser, slower-moving gas than air minimizes the convection currents within the space[6].

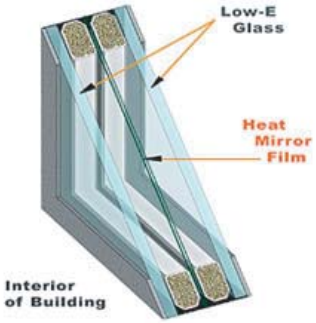
Argon:

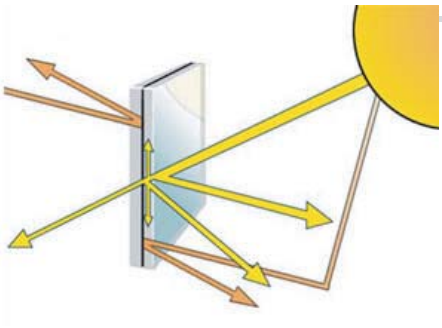
Argon improves a window's energy efficiency by as much as 6%. It is 40% denser than air and makes a much better insulator than air alone. Argon is a safe, odorless, inert, non-toxic gas that is naturally present in the atmosphere. It is the heavier gas remaining after both oxygen and nitrogen have been removed from air[7].

Krypton:

Krypton is about three times heavier than air; this gas is colorless, odorless, and tasteless. Although traces are present in meteorites and several minerals, krypton is more plentiful in the Earth's atmosphere[8].

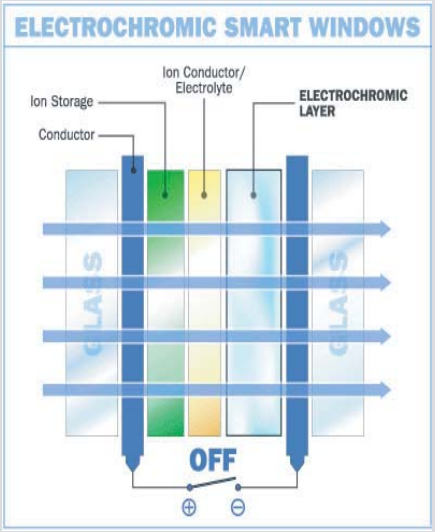
Both argon and krypton are also widely used in light bulbs and in fluorescent tubes.
The only problem with employing these two gases is that once the gas leaks out, the windows thermal properties are lost.

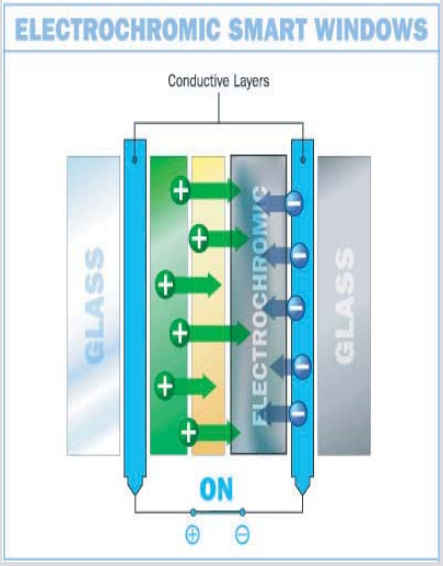




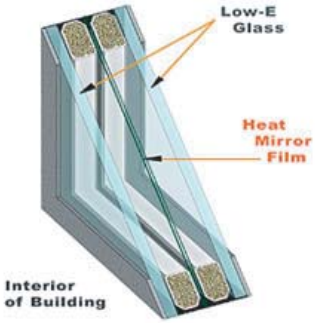
Electrochromatic glass:

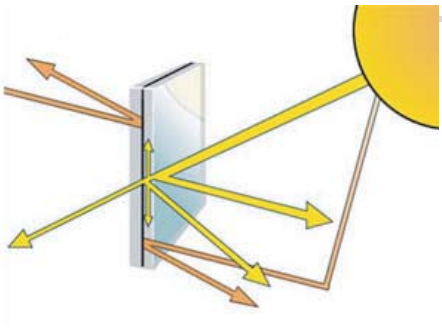
The focus on today's latest technology is geared more towards the control of heat transfer occurring in the glass pane itself. Smart windows incorporate the ability to control the amount of heat transfer in the glass. The two most prominent types of windows are electrochromic and suspended particles. They both reduce glare and can be programmed to absorb a selected part of the light spectrum, such as Infrared.





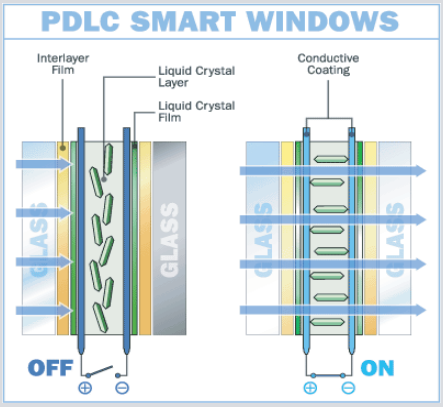
The way this window works is by implementing a small electrical current through conductors embedded in the glass. When voltage is applied, the electrons in the conductive layers are dispersed toward the inner layers of the glass sandwich where they meet in the electrochromic layer to block the light that passes through[9].



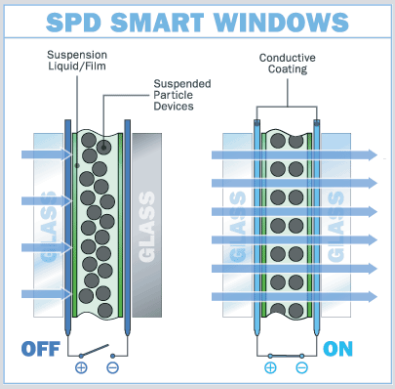


Suspended particles:

The technology to make the window work is essentially the same as electrochromatic, where a small voltage is applied to the glass in order to the window work, except that in this case, applying current allows for light to go through instead of blocking it. The other major difference with suspended particles is that the particles used inside the glass work as microscopic shutter that become more effective in blocking not only the light, but also the heat.

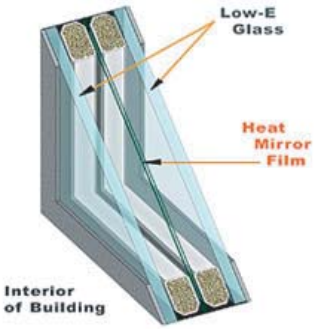


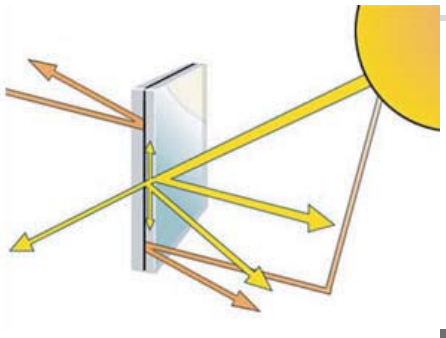
Both a liquid crystal layer and any other suspended particle system constantly block light and heat without using any electrical current, once the small voltage is applied then the window allows for light and heat to pass through[10].



The benefit of employing this type of windows is in the control of heat. For example in a building with high heat gain, the use of electrochromic windows can be used as thermostatic control. Solar heating is controlled by darkening or lightening the window as needed in order to provide control over the living spaces[11]. Also, these windows can save up to a 50% of a buildings energy use.

The disadvantages of these windows can come at the moment of purchase and installation. The extra cost of window varies from manufacturer to manufacturer, but there can be an added cost of up to 90 dollars per square foot; this cost is expected to drop as more windows are manufactured. The installation is more complicated than ordinary windows since electrochromic windows require an electrical source and switch. These windows will likely require installation by a licensed electrician, or some trained professional[12].





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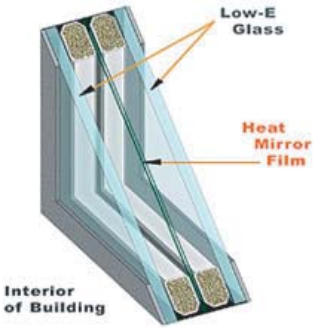

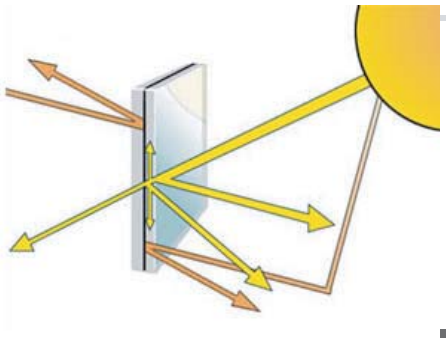

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Bamboo Flooring

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Intro:

Bamboo is an ancient material that has gained recent acceptance in Green Design. It has managed to endure for centuries in relative obscurity, but the ever increasing need for more sustainable and environmentally responsible building materials has presented bamboo with an opportunity to showcase its ability to be green.

Bamboo is considered a flexible material, and has demonstrated its durability throughout time. It takes a special kind of material to survive an atomic bombing (it survived and continued to grow in Hiroshima after the bombing). This kind of resiliency speaks to the versatility that is innate with bamboo, and perhaps explains why over two billion people worldwide rely on bamboo for such things as income, food, shelter, clothing, etc.

It is a material that demonstrates a wide range of abilities, through its performance, its look, and its simplicity.

It is exotic, and comforting, and known to exist on all continents except Europe. It is accessible to most peoples on this planet, and will probably grow to become an even more important component of daily life, as well as the design profession.

***"It** is not only about material, but also about style and innovation. We choose bamboo to be a flooring material, not only for its durability and stability but also for its environmentally friendly nature, plus the exotic and romantic looks without equal".*
http://www.bamboobridge.com/bamboobuilding.htm

As a material that has virtually zero waste, it is certainly attractive to those who would consider its function and role within a manufactured process. A material that possesses such properties is valuable in the world of produced goods.

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Bamboo

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Cost:

Prices for bamboo flooring products vary. The current price range would be $3 to $29 per square foot. The cost comparison for competing flooring products, such as typical domestic hardwoods, is similar in range, but current high-quality bamboo flooring is marginally more expensive than those natural woods.

As with many products, pricing can be an indicator of quality. When attempting to understand quality and related value to money, it is best to inspect and consult the manufacturer's specification sheet.

Bamboo flooring is experiencing a tremendous growth, and it is expected that the costs will continue to diminish. However, beware of deceptively low prices, a warning sign that the product quality is less than probably advertised.

Current prices for environmentally considerate, quality bamboo flooring will be closer to the range of $7 + per square foot. And of coarse the color, size and style of the flooring will all be determinants in the final cost for the product.

Maintenance:

The maintenance program for bamboo flooring is designed to be user friendly. The latest advances in urethane technology are used in the manufacturing process to help aid product performance, maintenance and durability.

While it is true that most current bamboo manufacturers use a urea formaldehyde resin adhesive in the manufacturing process, there are companies in the market that use formaldehyde free processes. When selecting the supplier, formaldehyde free manufacturers should be placed higher on the priority list. Formaldehyde emissions and off-gassing can contribute to poor indoor air and environmental quality, and could result in severe reactions as well.

Most manufacturers have taken the responsibility to remove or reduce these chemical levels to below dangerous levels, but when there is potential for exposure over a long period of time, it is better to be proactive in protecting the indoor environment.

Most urethanes are applied by the manufacturer, prior to being shipped to the consumer. If a urethane is to be used, this is advantageous for the

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purchaser because the urethane has had time to cure outdoors at the manufacturer, as opposed to curing in the interior of the home with a self-applied coating.

Consumer applied finishes and coatings are equally as acceptable if water based urethanes are used. Consumer applied water based coatings generally require more numbers of coats than factory applied urethanes. The water based versions are typically more inert and contain fewer odors and fewer Volatile Organic Compounds (VOC's), which are additional contributors to poor air quality and toxicity.

After installation is complete, regular floor maintenance is extremely simple. It requires only sweeping or vacuuming, and can be cleaned with a mixture of water and white vinegar. Other common sense tips such as installing felt slider pads on furniture with legs, and placing door mats at entries to collect scratch causing debris will help to ensure prolonged life from the bamboo flooring and finish.

It is not recommended to use waxes, oils or soaps to clean the flooring. The combination of urethane, the applied wax or soap and the porous wood surface often result in finishes that become cloudy, and mar the natural beauty of the bamboo flooring.

If it is anticipated that the flooring material will need be refinished several times over its life do to heavy traffic, there are some initial design considerations to follow. Purchasing a thicker bamboo flooring material will provide the purchaser with more of a wear surface, essentially increasing the number of times the flooring material will be able to be resurfaced. The same result can be achieved by specifying a vertical grain surface, as opposed to the horizontal grain style. And last to consider is the color of the flooring. Bamboo, naturally available in a light or dark color, will resist wear more in its darker form. The darker Bamboo finish is naturally stained consistently throughout, and therefore wears more evenly with time, resulting in fewer surface refinishes over time.

Products:

Among many things, bamboo has incredible versatility. Bamboo is offered in a wide variety of products that meet both personal and commercial needs. Bamboo provides materials for food, shelter, clothing, and transportation for a large percent of the human population. In addition to the more personal elements of bamboo, the construction industry has

broad possibilities as well. Highly attractive millwork and cabinetry products have been derived from bamboo, as well as durable wainscoting and trim. Paneling and wall coverings made of bamboo products are also a valuable asset to create attractive interiors. The possibilities of bamboo even move past interior finishes and to the outside. Many fences and structural elements are derived from bamboo. It has even been used for scaffolding in many countries during the construction processes and building erection.

Properties:

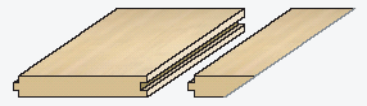
Because bamboo is harder than most domestic woods, it is one of the most logical choices for a finished material. It has an incredible growth rate, with some species growing 24 inches a day and up to 60 feet in 90 days. Because bamboo is such a rapidly renewable resource, we do not diminish any hardwood forests that have matured over time. It is not harmed by the harvesting process. Bamboo grows to maturity and is harvested every 3-4 years with stem sizes between 4-6 inches, unlike 60-120 years like most hardwoods. “It is the fastest growing plant on earth.” (www.ecoproducts.com)

Bamboo is certainly unique. It is flexible enough to be utilized in seismic areas as a building material, and yet it is 20% greater per unit tensile strength than steel. It is not uncommon for bamboo to be used within foundation walls and wall cavities as reinforcement, similar to reinforcement steel (rebar).

Bamboo comes in two natural colors, light natural, and dark brown. The dark brown color is a result of a steaming process known as carbonization, which releases carbon from within the material, creating a permanent natural stain throughout the bamboo.

Natural Bamboo Colors

The flooring properties of bamboo include a variety of applications and systems such as nail / staple, glued / adhesive, and floating / glueless. If using a glue system, products such as Master 400 adhesive, which is an environmentally safe acrylic urethane



Tongue and Groove Nail or Staple

Click Plank Floating Glueless

adhesive designed specifically for bamboo, are more appropriate. It is also low odor and installer friendly, can be used on most subfloor materials, and is water resistant. Low and No-VOC adhesives are available in water based formulas, and careful adherence to manufacturer's directions should be maintained. These kinds of responsible adhesives and sealants are becoming more commonplace, and can be found on websites such as www.ifloor.com. These sites also provide Material Safety Data Sheets (MSDS) and product specification descriptions for the products they vendor. In some of the bamboo flooring situations, machine applied polyurethane coating enhances the durability of the floor. As far as durability and stability issues, bamboo has been ASTM tested to be stronger than northern red oak and hard maple, two common hardwoods. Bamboo also has a very low coefficient of dimensional change, .00144, which means that it moves very little once installed.

Embodied Energy

Comparable to most hard surfaces, bamboo has a very long life cycle. Most of the bamboo used today is imported from Southeast Asia. There have been issues concerning questionable labor laws and social ramifications of financially supporting these suppliers. In the US, however, the bamboo industry is growing. Many bamboo farms exist currently, and are growing in numbers. The rapid growth rate provides high prospects for domestic cultivation and supply.

Recycling

In the process of manufacturing flooring materials, almost 100% of the bamboo is used. The material that is not used because it is too small is recycled into paper, chopsticks, and toothpicks. There are now manufacturers that are reusing the scraps from flooring to make engineered flooring materials. Others are seeking to combine a variety of

recycled materials, such as bamboo veneer over a recycled tire substrate. This process would combine materials to create flexible products that utilize the best characteristics of each.

Health

There are several health issues involved with bamboo flooring. A couple of things to consider are specifications and purchasing your material from a supplier that does not use urea formaldehyde resins with the flooring. It is also important to use a product that has a low VOC content for adhesives used in the manufacture of the product. Also, most flooring comes pre-finished and ready for install, so off gassing has already occurred, not contributing to poor indoor air and environmental qualities. The use of bamboo also caused reduced ecological demand for hardwoods, reducing clear cutting and deforestation. If applicable, use a floating floor system to eliminate more contaminants. If there is a sensitivity to allergens, sealer can be added to the surface of the flooring to lock down any minute emissions that might occur.

Benefits

There are many great benefits to choosing bamboo flooring material. One of the key benefits is the fact that bamboo passes all fire requirements for flooring materials and can be used in all building types and classifications.

- It is harder than red oak according to ASTM testing.
- It is 50% more stable than red oak as a result of moisture content changes.
- It is more durable than any other hard wood flooring
- It is unaffected by termites and carpenter ants after the anti-pest treatment. Besides it is a grass not wood.
- It is fire retarding and naturally moisture and mildew resistant.
- It is easy to clean; it is perfect for people allergic to dust and insects.
- It provides coolness in the summer.
- It is easy to install as other hardwood flooring.
- 25% harder than Red Oak, 12% harder than Rock Maple.
- More dimensionally stable than commonly used wood flooring including oak and maple.
- High quality, tongue and groove, precision-milled.

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- 6' lengths allow for seamless, linear appearance.
- Accepts standard finishes.
- Environmentally friendly
- Competitively priced
- Long lasting and durable
- Designed for commercial or residential
- Can be used in combination with many floor systems, including radiant floor heating.

Disadvantages:

- Limited availability in the United States forces the consideration of importation and energy costs.
- Embodied energy costs increase due to travel distance, as well as location from which the material is imported.
- Currently, prices are slightly more for bamboo when compared to its hardwood competition, but overall price difference is comparable.

Manufacturer Short List:

- www.Bamboohardwoods.com - is currently the only manufacturer not importing their raw bamboo from China (sourced from Vietnam)
- www.Ecotimber.com – responsibly uses low VOC adhesives and urethanes that exceed the strict European standards for material off-gassing.
- www.Plyboo.com – manufactures the strongest, most durable type of bamboo currently made.
- www.Bamtex.com – utilize a completely solvent free process to manufacture they products.

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Topics Covered

- "Green" alternatives to traditional flooring finishes.
- Carpet Comparison: Rolled vs. Modular
- Wood Comparison: Traditional Hardwood vs. Wood Alternates (Bamboo and Cork)
- Exposed Concrete as a finish option: Stained and Dyed vs. Colored

Things the architect/designer should know:
1) Carpets have made drastic improvements with off-gassing and recycling; however they still can pose major problems with indoor air quality and short lifespan causing abundant waste for landfills. Because of this they should be utilized only when there qualities are required and not as an inexpensive covering.
2) Bamboo can be as hard as or harder than traditional hardwood flooring products.

3) Concrete can be colored a vast array of colors, the pallet is almost unlimited. Most colors can be utilized for both interior and exterior, but each manufacturer lists colors which should not be exposed to extended periods of UV light or they will fade.

Things the client should know:
1) No flooring products are without regular maintenance. All of the listed hard surfaced products require initial sealing with a protective top coat on a regular schedule. The schedule time frame will vary between products and amount of foot traffic from every year to every five + years.
2) Carpet companies offer a wide range of options and contracts. A client can utilize cradle to cradle options or carpet lease options from most major commercial carpet mfgrs.
3) Carpet tile can be moved just like furnishings which makes it a viable option for companies that have temporary locations while moves are taking place or short term lease spaces are utilized.

Greener
FINISHES
FLOORING

csi 09000

Trushenski
Zehnacker

Product Introduction:

Carpet has never been known as a "green" product, however there have been vast improvements in the entire carpet manufacturing procees from the production of carpet fibers through product installation methods which allow modular carpet, referred to as carpet tile, to be known as a "green" alternative to traditional broadloom rolled goods.

In recent years, traditional hardwood flooring has gotten a bad name in the world of "green" products, however, there are many options to achieve the aesthetic of hardwood while still being enviornmentally conscious. Maintenance and lifecycle are two issues where wood products can prove to stand with other "green" products.

Exposed concrete can be an easy way to incorporate a finish material into the structure of a building; i.e. slab on grade or concrete topping on a metal deck. Its maintenance is low and there is no off-gasing. This results in a finish which can be incorporated into the "green" category because of the minimization of resources required to achieve a finished product.

Modular vs. Rolled

Full Spread vs. Strip Adhesive

Rolled goods are typically refered to as broadloom carpet: A rolled floorcovering product typically produced in 12' widths, comprised of a face yarn and a primary backing system. A pad or cusion is manufactured and installed seperately, but is rarely utilized in non-residential projects. Typically a full-spread adhesive application of a strong glue is required to adhere the pad and/or carpet to the substrate. A full spread is when the glue covers every square inch of material in order to assure the carpet will remain in place for its entire lifecycle. There are a number of controversial issues with this installation method: 1. Indoor Air Quality (IAC) due to Volatile Organic Compounds (VOC's) off-gassing during installation and for a portion of the carpets lifespan. 2. Damaging or stopping the ability for the carpet to be recycled in the future.

Modular carpet system is typically refered to as carpet tile: A modular floorcovering system which utilizes a backing system that is integral with the carpet. Sizes range depending on the manufacturer, however, most run 18" square - 24" square. In recent years, some manufacturers have been experimenting with alternative sizes and shapes such as rectangular and 3' square products. The required adhering methods will vary depending on the backing systems, room size and the amount and type of traffic. Originally, a full spread was required for all installations, however today there are three major options: Full spread, grid spread and grid strips. The full spread for a modular system is the same as rolled goods. A grid strip system utilizes adhesive along major grid lines of the tiles, but not along each tiles edge. Grid strips are adhesive strips which are applied by the carpet manufacturer after the backing system is attached to the face yarn. On-site a protective cover is removed to expose the adhesive immediately before the tile is placed. The two later methods of adhesion can be viewed as "green" alternatives to the full spread method, with the strips being most desirable for a number of reasons. Minimal adhesion lowers the VOC's, especially in comparison with the traditional glue methods. Limiting the adhesion also speeds up installation lowering project costs and eases replacement maintenance. The tiles can be easily remved and reinstalled as needed by general maintenance staff.

Approximately 10% less waste is produced in the utilization of a modular system. This reduces front end product costs and dumping fees to the client.

The production process is very similar between traditional broadloom and the tile system. The major components are:
- Carpet fiber production
- Dying
- Backing production
- Manufacturing (including yarn construction and the process of attaching the face yarn to the backing.)
- Installation

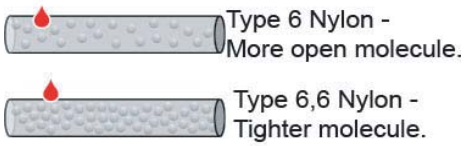
All major manufacturers offer cradle to cradle programs and products with varying amounts of recycled and recyclable content. Recyled content needs to be specified separately for the backing system and face yarn as most commercial carpet tiles can utilize a mix and match approach between these two components.

Carpet Tile Production

The production of carpet tile consists of three components, typically by two independent parties:

1. Face Yarn Construction:
   a. Carpet Fiber Production
   b. Fiber Engineering
   c. Carpet Fiber Dying
   d. Yarn Construction
2. Backing System Construction (by the carpet manufacturer)
3. Carpet Manufacture:
   a. Yarn Texturing
   b. Attachment of face yarn to backing system.

Face Yarn: Construction begins with carpet fiber production. This fiber can be produced by a number of different materials, some natural from animal hair such as wool, others man-made such as polyester, olefins and nylon. Nylon has become the most common utilized material of carpet fiber for commercial grade carpeting. Two types are produced: Type 6 and Type 6,6. In general, nylon outperforms other synthetics in all categories: texture retention, heat resistance, stain resistance, color fastness and soil resistance. Dupont, now Invista, produces the Type 6,6 and claims it outperforms the Type 6. However, there is some controversy surrounding its recyclability. There are claims Type 6 recycles easier and produces more usable content.



The face yarn can be specified and manufactured with 0-100%-recycled content most with a combination of post-industrial and post-consumer. This does not restrict aesthetic options, but greater recycled content can limit the lifespan of the fiber. Some carpet manufacturers now offer 100% post-industrial face yarn carpets, but with a limited color pallet – typically one color way.

Fiber engineering is the manipulation of three characteristics:

1. Denier – The size of the fiber.
2. Luster - The brightness or reflectivity of fibers.
3. Color – The dyability of the fiber.

Modifying these characteristics produces unique aesthetics ranging from the look of a natural fiber to a metal shine.

The dye method chosen can affect the color as well as the soil hiding ability of a carpet. There are three methods, solution dyed, yarn dyed and piece dyed.

Solution dying occurs during the manufacturing process by adding pigment to the molten polymer (nylon) from which the filaments (fibers) are made. The fibers are extruded in a colored form. Due to this process, the fiber manufacturer, not the carpet manufacturer, chooses the pallet.

Yarn dyeing is a method that applies color to yarns before they are manufactured into carpet. Carpet mills achieve the greatest flexibility with this method.

Piece dyeing is how tufted carpet is dyed. Either batch dying or a continuous dyed method is utilized. Printing is the most popular method of continuous dyeing.

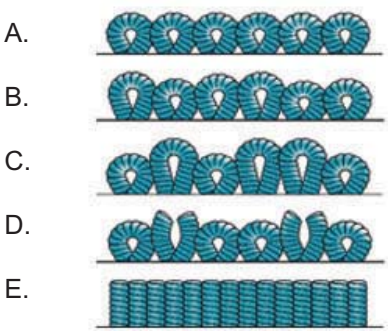
The dying of the fibers can be very water intensive; manufacturers across the board have been attempting to minimize water usage fairly successfully by adjusting methods and creating water recycling on-site. Each

manufacturer achieves different levels of water conservation and their company missions and records should be consulted for specific information.

Yarn construction describes the ways fibers are combined; Twisted or Air-entangled. Twisted is the twisting of yarn, 2-ply. Air-entangled uses 3 or more fiber ends which are combined using air jets. This is often referred to as "heathered".

Backing: Two major types of backing systems are manufactured for carpet tile. A hardback and a cushion back. A hardback, most common for commercial interiors, consists of a primary backing adjacent to the face yarn and a layer of reinforcing material, usually fiberglass sandwiched by vinyl composite or a thermoplastic compound. The reinforcement is the stabilizing portion of the backing. A cushion backed carpet consists of this same system, but with an additional layer between the primary backing and the vinyl or thermoplastic layer making an integral pad. Each manufacturer produces their own backing options utilizing various materials and amount of recycled content. An example of a recycled backing is *Interfaces* "GlasBac RE with Grid Strips". This product contains a minimum of 39% recycled content with a minimum of 19% post-consumer recycled content.

Carpet Texture / Aesthetics: Five carpet textures are standard throughout the industry of carpet manufacturing. Each texture provides a different aesthetic, they are as follows:



A. Level Loop - One pile height

B. Textured loop - Slight variations of pile heights

C. Multilevel loop - Multiple pile heights

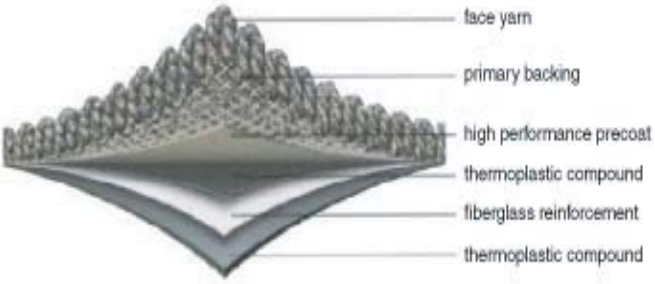
D. Tip Shear - Multilevel loop with the high loops sheared.

E. Cut Pile - all tufts cut- this can have one or more pile heights.

Not shown - Cut and loop - Combination of cut pile and loop pile

Carpet Manufacturing: The manufacturing process includes adhering the face yarn to the backing system. The process can be broken down simply:

- Carpet manufacturers purchase face yarn either pre-dyed or as white fibers, if their aesthetic involves piece dying or printing. The ounce weight is also determined by the manufacturer, each carpet is different with the higher numbers providing a higher quality carpet.
- The carpet texture is determined based on the desired aesthetic.
- The appropriate backing system is chosen and attached to the face yarn.



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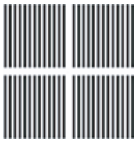
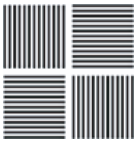
Installation: The installation of carpet tile first requires installers to be educated on the installation methods of the specified carpet. For large installations a pre-installation meeting combined with the pre-installation visit may be required. Per CRI (Carpet and Rug Institute) guidelines, it is recommended that the necessary pre-installation moisture and alkalinity tests be performed to assure the substrate is ready to accept a finish. Moisture emissions must not exceed 3 pounds per 1000 square feet for 24 hours. Too much moisture in a concrete slab for example could cause the carpet tiles to buckle and the carpet's warranty would not cover damages.

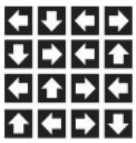
The tiles can be laid in a variety of patterns, each providing a different aesthetic. The two most common installations are monolithic and quarter turned. Other more recent methods include non-directional, ashlar and brick.



Monolithic – All tiles laid in the same direction.

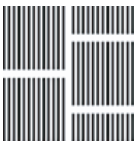


Quarter-turned – Tiles are turned 90degrees from one another (parquet style)



Non-directional – Tiles can be laid in any direction. ("greenest" method, easiest installation and least amount of waste.)

Ashlar – Tile seams installed by offsetting the front and back tile joints.



Brick – Tile seams installed by offsetting the side joints of the tiles.

Costs: The costs associated with carpet tile can be broken down into three categories:

1. Up-front costs
2. Maintenance costs
3. Lifecycle costs

When discussing carpet costs, square yards is the measurement utilized.

The up-front costs of a commercial grade carpet tile including material cost and installation typically ranges from $20 per square yard to $40 per square yard. All facets will affect price, carpet fibers, dying methods, carpet fiber ounce weight, backing systems and installers. The most cost effective technique is to get pricing or bids from various manufacturers and installers to get an adequate price. Cost is always negotiable.

Health: The health issues surrounding carpet are discussed as apart of the indoor air quality (IAQ) of the building. Carpet can be a major cause of sick building syndrome. Off-gassing of new carpets and adhesives have gotten drastically lower over the past decade, however, there are no carpets produced today with no VOC's. There are adhesives with low VOC's that are commercial grade, however, as noted previously, the grid strip method is the best option if VOC's are a concern.

Future:
Biobased products are currently being researched to replace petroleum based products. The meaning of biobased is product fibers made from corn, soybeans or potatoes – renewable resources.

Recyclablilty:
Many new uses are being discovered for recycled carpet: Filter products on construction sites to keep sediment from getting into gutters and local waste-water systems and erosion control products replacing hay bales are both made from 100% post-consumer recycled procucts.

Greener FINISHES: FLOORING WOOD

csi 09000

Trushenski Zehnacker

Check List

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Hardwood vs. Bamboo

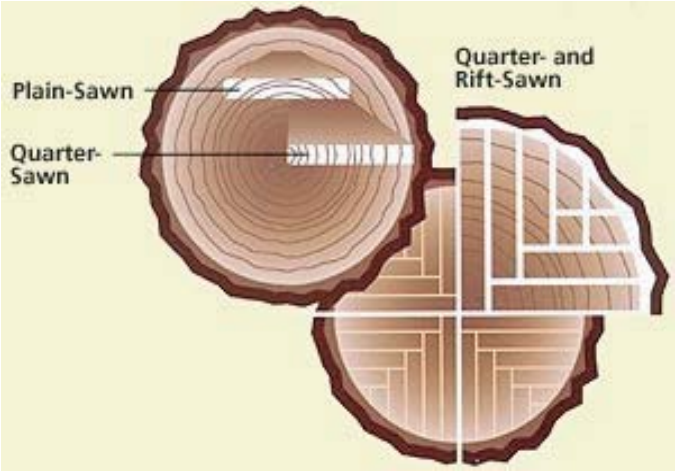
Hardwoods

America has utilized wood in flooring for over 400 years. Wood is an archetypical green material because of its natural, long-lasting and self-renewing qualities. Furthermore, wood does not collect dust and other allergens known to contribute to sick building syndrome, and a wood floor will last for 100 years. Nearly every part of the log is used as lumber or by-products, and finished products are re-useable, recyclable and biodegradable. “Collectively, across all hardwood trees in all American hardwood forests, there is nearly twice as much new wood growth as there is wood removed through harvesting. The volume of hardwood in American forests is 352 billion cubic feet, and 10.2 billion cubic feet are being added each year. This compares to annual removal of 6 billion cubic feet. The volume of hardwoods in American forests today is 90 percent larger than it was 50 years ago” (Hardwood Manufacturers Association).

Hardwoods are deciduous trees that have wide leaves and usually produce a fruit or nut such as, oak, ash, maple and cherry. Hardwoods are crafted into flooring, furniture, cabinetry, and other finish products. Softwoods are evergreen and cone-bearing trees such as spruce, pine, fir and cedar. Softwoods are mainly used as structural lumber.

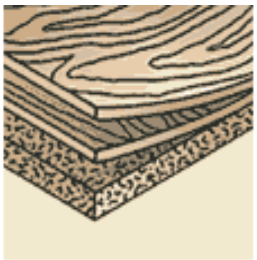
The appearance of the wood determines its "grade." All grades are equally strong and functional, but each has a different look. First grade or “Clear” wood is uniform in color and visually free of defects. Second grade or “Select” wood contains some natural characteristics such as knots and color variations but is fairly clear. Third grade or Common wood (No. 1 and No. 2) demonstrates more natural characteristics such as knots and color variations than either Clear or Select grades. No. 1 Common has a multicolored appearance, knots, flags and wormholes. No. 2 Common is rustic in appearance and highlights wood characteristics particular to the species.

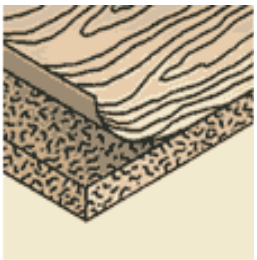
The angle at which a hardwood floor-board is cut determines how the finished product looks. Wood flooring is either, plainsawn, quartersawn or riftsawn.



Hardwoods


Solid Hardwood


Hardwood Veneer


Hardwood Laminate

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Hardwood flooring comes in three types of boards. The first is “Solid wood” meaning that the entire board is comprised of pieces of hardwood. The second type of board is “All-wood”; this board has a hardwood veneer bonded to a composite board. Lastly, “Artificial laminate” are boards coated with a laminate of plastic or paper, etc. printed with photographs of wood grain patterns bonded to a composite board.

The hardness of hardwoods is measured in the amount of pounds the board is able to withstand by the standard "Janka Ball Hardness Test". The test measures the force required to push a steel ball with a diameter of 11.28 millimeters (0.444 inches) into the wood to a depth of half the ball's diameter. Each species has unique physical properties. For example, the hardest commercially available hardwood from the U.S. is Hickory at 1820 PSI, which is five times harder than Aspen at 350 PSI. Hardness is determined in flooring in order to define the board’s resistance to indentation.

United State Hardwood Species

Species (Kiln-Dried)	Pressure To Mar (In Pounds)
Hickory, Pecan	1,820
Hard Maple	1,450
White Oak	1,360
Beech	1,300
Red Oak	1,290
Yellow Birch	1,260
Green Ash	1,200
Black Walnut	1,010
Soft Maple	950
Cherry	950
Hackberry	880
Gum	850
Elm	830
Sycamore	770
Alder	590
Yellow Poplar	540
Cottonwood	430
Basswood	410
Aspen	350

Source: Wood Handbook: Wood as an Engineering Material, USDA, Washington, D.C.

Bamboo:

Wood floors come in more than 50 species, both domestic and exotic, spanning the spectrum of color options, hardness, and price ranges. The most recent trend in “greener” wood flooring is bamboo, which is technically not a wood. Bamboo is a member of the grass family. Bamboo flooring was introduced in the U.S. as a new product in 1990. Initially, there were relatively few manufacturers, mostly government own, and production was of questionable quality. After the privatization that occurred in China during the early 1990's, better qualified entrepreneurs entered the industry. There are between 1,100 and 1,500 species of bamboo living in tropical and subtropical regions ranging from 46 North Latitude to 47 South Latitude. Bamboo is a very adaptable plant; it can grow in elevations as high as 13,000 feet and can be deciduous as well as evergreen. These large “woody” grasses produce several full length (about 60-80 feet) and full diameter (about 8-12 inches) culms (stems) each year and regenerates without the need for re-planting. A single bamboo clump can produce over 9 miles of usable material in its lifetime.

Bamboo shoots reach full size within two years; however, it takes three years for the plant to reach a point where it is no longer feeding. The shoots become “dead weight” after they reach maturity, at this point, removal is beneficial to the plant. On average, bamboo will grow about one foot in a 24 hour period. “Nearly all bamboo flooring sold in North America is produced in the southern Chinese province of Hunan, in an area known as "the bamboo sea" for its extensive bamboo forests. These forests are owned by the government, and individuals or companies can obtain contracts to harvest from them” (Environmental Building News).

The process of creating bamboo floor boards involves: Cutting the hollow shoots into thin strips. The strips are then boiled to remove the starch. Finally, the strips are dried and laminated into solid boards which are then milled into standard flooring forms. The bamboo is treated with a preservative either before or after it is laminated. The most common preservative is a relatively non-toxic boric acid. Bamboo boards are laminated using urea-formaldehyde (UF) adhesives which offgas for a long time post production. However, the amount of adhesives used to laminate bamboo flooring is much less than in manufactured wood products such as particleboard. Manufacturers are experimenting with non-formaldehyde adhesives and less-toxic “white gules”, but practical substitutes are still too expensive.

Bamboo vs. Hardwood:

Both hardwood trees and bamboo fall under the category of renewable resources, however, a 60 foot cut hardwood tree takes 60 years replace, but a 60 foot cut bamboo takes 3 years to replace. Bamboo is the fastest growing plant on Earth, growing 1/3 faster than the fastest growing tree.

Data measured from the standard “Janka Ball Hardness Test”, state that bamboo is able to withstand between 1130 PSI and 1640 PSI. These specs put bamboo in the range of equal to slightly harder than the typical hardwoods used in flooring. Bamboo is about 30% harder than Red Oak and about 15% harder than Hard Maple. Studies show that bamboo grown on slopes and mountains has far greater strength than Bamboo grown in valleys. Greater hardness is obtained when the shoot is allowed to continue growing until the bamboo reaches six to eight years old.

Similar to hardwoods, bamboo is available in several finishes, usually urethanes that remain on the surface of the board and form a protective coating. They are durable, water-resistant and require minimal maintenance.

Like hardwood flooring, bamboo is available in pre-finished boards which alleviate offgasing during installation. The pre-finished products all use UV-cured finishes, which have low-VOC emissions. Various gloss levels are available. Most manufacturers offer both a light, natural color flooring and a darker, amber variety. This amber color is achieved by pressure steaming the bamboo, which darkens it by carbonization. Both wood and bamboo floors need only to be refinished every 10 - 15 years or 10 - 12 times during a floor's life.

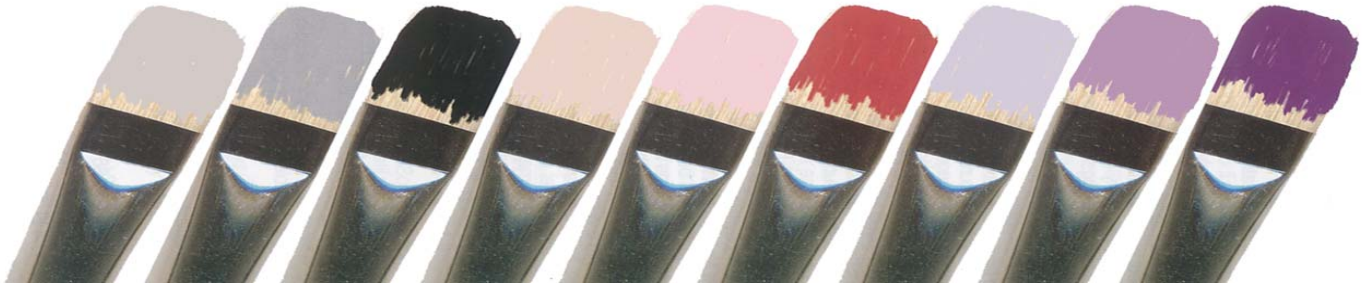
Bamboo flooring is manufactured to mimic hardwood flooring’s width and thickness profiles and therefore installs the exact same way. Bamboo flooring also contracts and expands 50% less than hardwoods. Prices for hardwood range from $3-$12 dollars per square foot and $3-$8 per square foot for bamboo.

Hardwood Floor

Bamboo Floor

Interior Paint

Exploration of Sustainable Options: Interior Paint



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Introduction

Interior paint is a part of CSI division 09000 Interior Finishes. Historically, the market has been driven by the high durability and the low cost of standard materials. However, the chemical make-up of traditional materials is not necessarily sensitive to the environment or the inhabitants of a finished space. Analysis of the effects of paint is complicated by the ever increasing cast of thousands of chemicals that are possible ingredients.

The most notorious environmental offender in the recent past is lead. After the accumulation of vast evidence of its harmfulness, lead-containing paint was banned from production for consumer use in 1978. Also harmful and commonly used, mercury, was banned from use in 1990.

Still interior paint has been identified by the Environmental Protection Agency (EPA) as one of the top five indoor pollutants. This is due to recent understanding of the detrimental effects of volatile organic compounds (VOCs) emitted from paint. VOCs are a broad grouping of harmful chemicals containing carbon which evaporate into the air easily at room temperature. VOCs may be present in a particular ingredient in paint or be produced as a result of a reaction between ingredients. The general effect of human exposure to VOCs is irritation of the eyes, skin, and/or respiratory system and headache. VOCs also contribute to the formation of ground level ozone (smog).

The main three components of all paint are pigment, binder, and solvent. The heaviest contributor to VOC emissions has traditionally been oil based solvent. The Glidden Company introduced the first no-VOC latex paint in 1992. They achieve this in most part by substituting the petroleum based oil solvent and its associated binders with a water soluble latex mixture. While revolutionary at the time, all major paint manufacturers have since followed suit, offering low or no-VOC interior paint product lines.

Concerns about interior finish emission of VOCs are discussed along with other issues under the heading of Indoor Air Quality. With increased awareness of the problems that bad IAQ can cause, more and more companies are marketing products as green, environmentally friendly, sustainable, or, specifically in the case of interior finishes, no-odor, low-VOC, or no-VOC.

While the mainstream paint industry has only recently begun to offer less harmful products, there are ancient natural alternatives. Milk and plant based paints have been used for centuries and offer low or zero VOC content and the absence of petrochemicals.

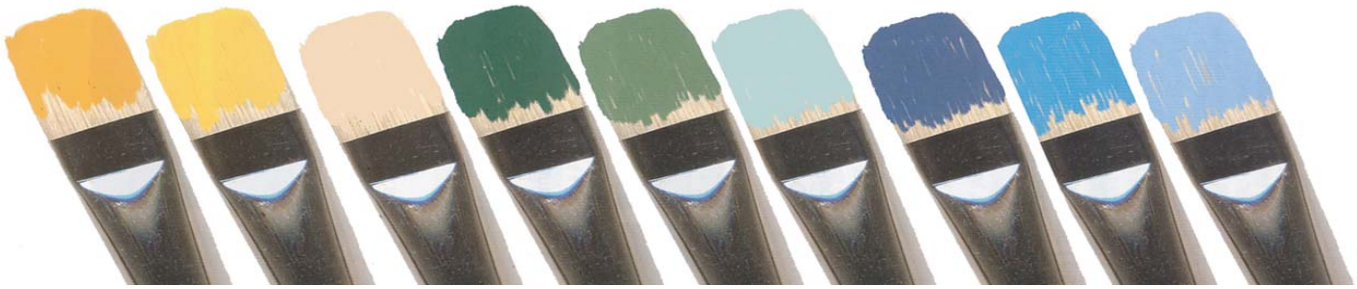
The most stringent industry standard is the Green Seal Standard GS-11. This is the standard referenced by LEED$_{tm}$ v2.1 Indoor Environmental Quality Credit 4.2.This standard specifies that VOC weight in grams/liter of product minus water is 150 for non-flat paint and 50 for flat paint.

Green INTERIOR PAINT

csi 09000

group K

Exploration of Sustainable Options: Interior Paint



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Research Findings

Government regulation and market forces have severely limited, although not eliminated, the effect that paint has on indoor air quality (IAQ), there are still environmental effects remaining.

Continued Effect on IAQ

Having surveyed the existing "green" paint products, several issues rise to the top. While most major manufacturers have addressed the problem of VOC emissions with a special line of paints, this has not eliminated the problem. There are still VOCs found in frequently used biocides, and other paint additives. A recent study also found that formaldehyde may still be found in paint additives and not detected by the current VOC test – EPA Reference Method 24.

Embodied Energy

While the use of acrylic resins in paint has largely rid the industry of necessary use of VOC bearing solvents, it does bear some environmental cost. A Finnish study (Hakkinen) found that aside from VOC emissions, acrylic paints actually had a greater Life Cycle Cost as compared to oil paints because of the embodied energy in their ingredients and shorter life span. The majority of this embodied energy resides in the acrylic itself and in the ubiquitous white pigment Titanium Dioxide.

As discussed earlier, most paints now use acrylic resins and are waterborne. The water is of course inert, but the acrylic is a processed form of acrylonitrile, a derivative of natural gas. There are definite, though difficult to quantify, environmental consequences to using such materials. Without specific quantification, it is safe to say that a non renewable based product has a high embodied energy.

There are paints that use natural alternatives as the resin/binder component. One such is the BioShield Solvent Free Wall Paint. This paint uses a combination of soybean oil and carnuba wax for this part of the paint. Similarly, Auro paints offers a product with natural oil emulsifiers. Another alternative is the use of Milk Paint.

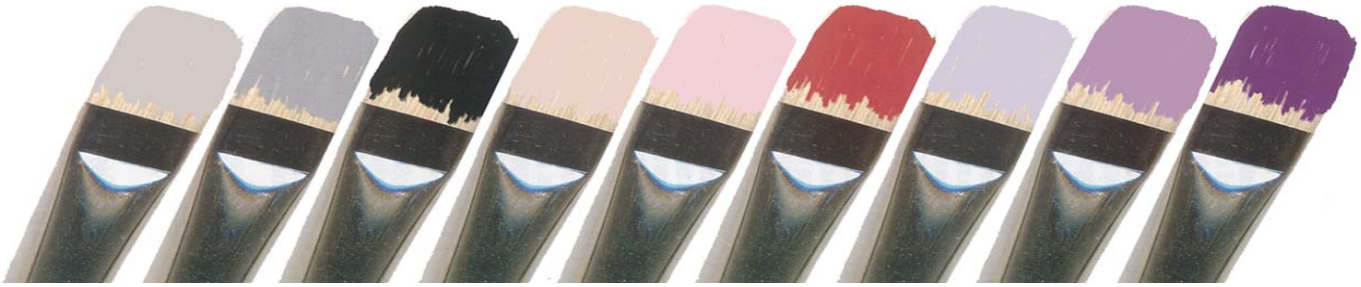
The white pigment used in virtually all paints has similar high embodied energy. Titanium Dioxide is non-toxic, but takes a great deal of energy to produce and the production contributes carbon dioxide, sulfur dioxide and nitrogen oxide emissions to the atmosphere. It is not necessarily true, however that more TiO_2 equates to more environmental impact. In general the use of more TiO_2 means that the coverage and hideability qualities of the paint are increased, perhaps requiring application of fewer coats and less overall use of TiO_2. The only paints I found that do not use TiO_2 as the pigment are milk paints and Auro Natural Wall Paint Economy White. Milk paint is inherently white while the Auro product is tinted using kaolin clay and chalk.

Green INTERIOR PAINT

csi 09000

group K

Exploration of Sustainable Options: Interior Paint



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Reuse and Recycling

Beyond the environmental impacts of paint production and use, there is the challenge of managing leftover paint. As estimated by the Product Stewardship Institute, 16-35 million gallons of paint are leftover annually by consumers. This represents either a huge problem for municipal waste collection, or an amazing potential feedstock for paint recycling programs.

Paint recyclers sort the paint they receive, strain and filter it, retint it, adjust the viscosity, and may add preservatives. While every effort is made to control the end product, chemical interactions may occur to generate VOCs or other unintended harmful content.

Many proponents paint recycling feel that regulatory standards for acceptable levels of various chemicals are too stringent, and therefore prohibitive. However, the environmental benefits of recycling would be severely reduced if regulations used to safeguard human and environmental health were relaxed. Instead, the cleaner the original paint stock is, the cleaner and more predictable the possible recycled product.

Product reuse without reprocessing removes potentially toxic (to water life if not to humans) material from the waste stream. The down side is overall unpredictability and potential inconsistency of source.

Product Comparison

Following is a short comparison of various paint products. Included are both traditional Latex paints and natural products of various degrees. All are interior grade, flat, non-solvent based paints and readily available.

Sherwin-Williams Harmony
Interior Latex Flat Extra White
Product # B05W00951

Pittsburgh Paints Pure Performance
Interior Latex Flat White
#9-100

Dunn-Edwards Paint Sierra
Interior Latex Flat Paint
W 501

Rodda Paint Horizon
Flat Interior Wall Paint
#513501

Auro Natural Wall Paint
Interior White and Economy White
#321 and #320

BioShield Natural Wall Paint
Solvent Free and Casein Milk
#180 & #10

Green INTERIOR PAINT

csi 09000

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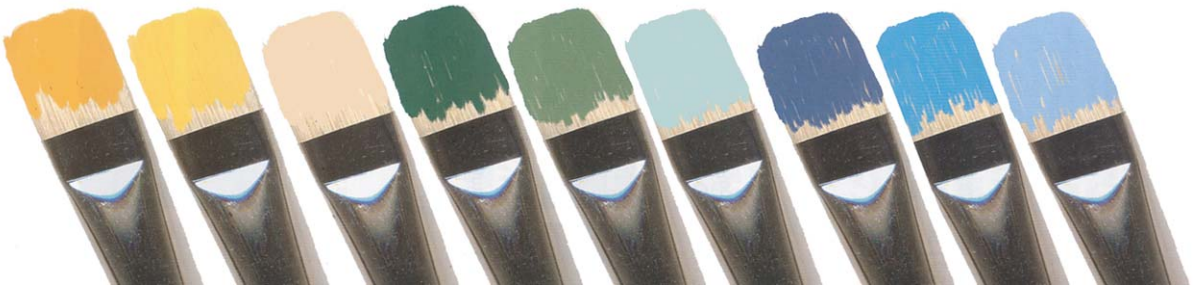
Exploration of Sustainable Options: Interior Paint



Green INTERIOR PAINT

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group K

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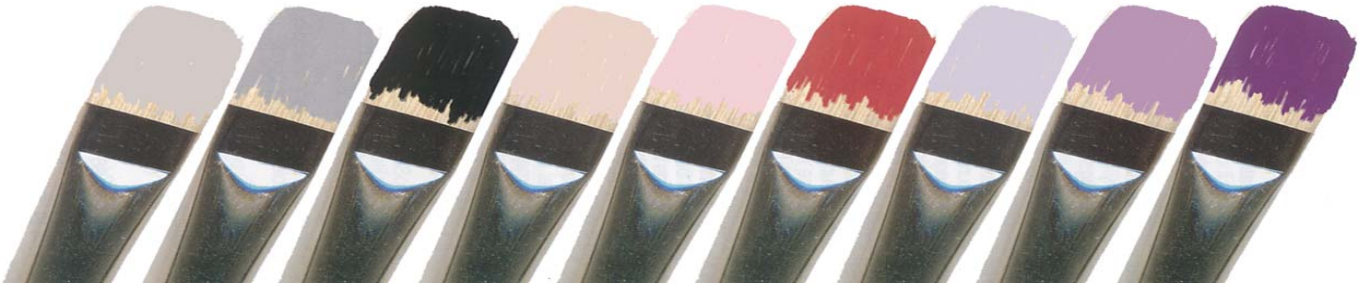
Product Type	Auro Natural Paint #321	Auro Natural Paint #320 Economy	BioShield Solvent Free #180	BioShield Milk Paint
	Flat	Flat	Flat	Flat
Embodied Energy				
Solvent Type	Waterborne	Waterborne	Waterborne	Waterborne
Resin Type	Plant based oil	Plant based oil	Plan based oil	Milk Protein
Titanium Dioxide	Y	N	Y	N
Local/Regional	N	N	Y	Y
Health				
VOC content	0g/L	0g/L	0g/L	0g/L
Maintenance				
Coverage	340sf/g	270sf/g	350-400sf/g	280sf/g
Cost				
$/gallon	$44	$37	$32	$31

Product Type	Sherwin-Williams Harmony	Pittsburgh Paints Pure Performance	Benjamin Moore Pristine Eco-Spec	Rodda Paint Co. Horizon	Dunn-Edwards Sierra
	Flat	Flat	Flat		Flat
Embodied Energy					
Solvent Type	Waterborne		Waterborne		Waterborne
Resin Type	Acrylic copolymer	Acrylic copolymer	Acrylic copolymer	Acrylic copolymer	Acrylic copolymer
Titanium Dioxide	Y-15%	Y-10-30%	Y-24%	Y	Y - 20%
Local/Regional	N	N	N	N	N
Health					
VOC content	0gL	<5g/L	0gL	<5g/L	<10g/L
Maintenance					
Coverage	350-400sf/g			320 sf/g	350-400sf/g
Cost					
$/gallon					

Exploration of Sustainable Options: Interior Paint



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SECTION 09900 – PAINTS & COATINGS

SPECIFIER NOTE:

resource management: Most standard paints contain some materials that are derived from petroleum products. Paints manufactured from natural plant and mineral based finishes are available. They contain extracts from plant sources and minimally processed earth minerals, such as chalk or iron oxides. Solvents for natural paints include citrus oils and small amounts of low odor petroleum solvents (de-aromaticized isoparrafinics.) Milk based paint contains lime, milk protein, clay, and earth pigments.
Recycled content paints are available.

toxicity/IEQ: Most conventional paint and coating products off-gas VOCs that are added to enhance product performance and shelf life. High quality, low-toxicity, and low-VOC substitutions are now available for these products.
Emissions from paints and coatings are primarily from evaporating solvents and other volatile organic compounds (VOCs) released by oxidation. Water-based paints acrylic latex paints are lower in VOCs (<250 mg/L) than solvent-based paints. Low-VOC is generally accepted to mean paint with a VOC content less than 100 mg/L. While a variety of low-VOC and zero-VOC paints are now available to choose from, they vary in cost, toxicity, and performance. Therefore, paint selection should consider VOC content as well as overall composition and required performance characteristics, including hideability and durability.
A paint can be "low-VOC" yet still contain odorous, toxic, or otherwise undesirable ingredients such as ammonia, formaldehyde, crystalline silica, acetone, odor masking agents, and many other compounds, including fungicides and bactericides. Some of these may not be an air quality problem for occupants, but they may be hazardous to painters and those involved in manufacture of the paint. In addition, hazardous ingredients can degrade the natural environment during production and after disposal. Look for water-based paints that are formaldehyde-free, Zero- or low-VOC, and low-toxic. "Zero-VOC" or low-VOC paints minimize the indoor air pollution load and health risks to both workers and occupants. Water-based paints are generally safer to handle and can be cleaned up with water, reducing health risks to workers and minimizing/avoiding hazardous waste.
For additional information, refer to EPA IAQ Design Tools for Schools, "Controlling Pollutants and Sources" www.epa.gov/iaq/schooldesign/index.html

performance: Milk based paint, the most common paint prior to this century, is not recommended for exterior use or damp conditions.
The performance of low VOC paint has improved considerably over the last several years.
Ceramic coatings for field application over typical exterior cladding materials (masonry, stucco, wood) are also available. Ceramic coatings are low emissivity paints that reflect radiant energy. Such coatings can generate energy savings of up to 30 percent during the cooling season, and are extremely durable.

PART 1 - GENERAL

1.1 SUMMARY

A. This Section includes:
1. Interior paint.
2. Exterior paint.
3. Specialty coatings.

1.2 SUBMITTALS

A. Product data. Unless otherwise indicated, submit the following for each type of product provided under work of this Section:

SPECIFIER NOTE:

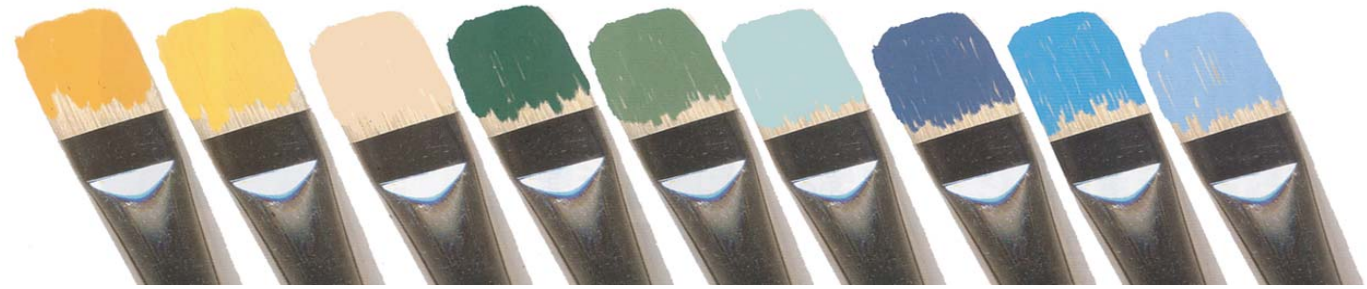
http://fedgreenspecs.wbdg.org DRAFT 04/30/04 09900 - 1 Paints & Coatings

Green
INTERIOR
PAINT

csi 09000

group K

Exploration of Sustainable Options: Interior Paint



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USGBC-LEED™ v2.1 includes credit for materials with recycled content, calculated on the basis of pre-consumer and post-consumer percentage content. USGBC-LEED™ v2.1 includes credit for use of salvaged/recovered materials.

1. Recycled Content: Indicate recycled content; indicate percentage of pre-consumer and post-consumer recycled content per unit of product.

SPECIFIER NOTE:
Specifying local materials can help minimize transportation impacts. Transportation impacts include: fossil fuel consumption, air pollution, and labor. USGBC-LEED™ v2.0 includes credits for materials harvested and manufactured within a 500 mile radius from the project site.

2. Local/Regional Materials:
   a. Indicate location of manufacturing facility; indicate distance between manufacturing facility and the project site.
   b. Indicate location of extraction, harvesting, and recovery; indicate distance between extraction, harvesting, and recovery and the project site.

SPECIFIER NOTE:
USGBC-LEED™ v2.1 includes credits for low-emitting materials, including: adhesives and sealants, paints and coatings, carpets, and composite wood and agrifiber products. Under LEED™ v2.1, paints and coatings shall comply with GS-11.

3. VOC data: Submit Green Seal Certification to GS-11 and description of the basis for certification.

B. Submit environmental data in accordance with Table 1 of ASTM E2129 for products provided under work of this Section.

C. Emissions Test Reports: As specified in Section 01352 – Indoor Air Quality (IAQ) Management.

D. Toxicity Test Reports: As specified in Section 01354 – Environmental Management.

1.3 QUALTIY ASSURANCE

A. VOC Content: Determine VOC (Volatile Organic Compound) content of solvent borne and waterborne paints and related coatings in accordance with ASTM D3960.

PART 2 - PRODUCTS

2.1 MATERIALS

A. Paints and primers:

SPECIFIER NOTE:
US-EPA Comprehensive Procurement Guidelines (CPG) 2002 recommends 20 percent post-consumer content for white and light colors of latex paint. US-EPA Comprehensive Procurement Guidelines (CPG) 2002 recommend 50-99 percent post-consumer content for dark colors of latex paint.
Verify availability of recycled content paint and compliance with applicable VOC requirements; edit below to suit project and location.

1. Recycled Content: Minimum **[20] [xxxx]** percent post-consumer recycled content for light colors; minimum **[50] [xxxx]** percent post-consumer recycled content for dark colors.
   [a. Interior paint: Recycled content paints and primers will not be permitted for interior applications.]

http://fedgreenspecs.wbdg.org DRAFT 04/30/04 09900 - 2 Paints & Coatings

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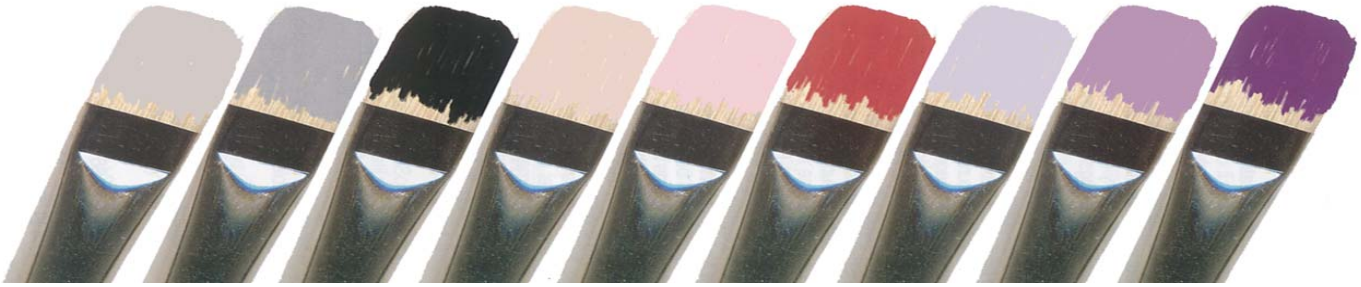
Exploration of Sustainable Options: Interior Paint



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2. Toxicity/IEQ: Comply with applicable regulations regarding toxic and hazardous materials, and as specified. Paints and coatings must meet or exceed the VOC and chemical component limits of Green Seal requirements.
   a. Interior paint: Comply with GS-11.
   b. Exterior paint: Comply with GS-11.

B. Specialty Coatings:
   1. Radiation Control Coatings: Minimum solar reflectance of cured coating 0.8 and minimum ambient temperature total hemispherical emittance of cured coating at least 0.08 in accordance with ASTM C1483.
   2. Anti-Corrosive Paint: Comply with GS-03.

PART 3 - EXECUTION

3.X SITE ENVIRONMENTAL PROCEDURES

A. Indoor Air Quality: As specified in Section 01352 – Indoor Air Quality (IAQ) Management.

B. Waste Management: As specified in Section 01351 – Waste Management and as follows:
   1. Coordinate with manufacturer for **[take-back program].** Set aside scrap to be returned to manufacturer for recycling into new product. Close and seal all partially used containers of paint to maintain quality as necessary for reuse.

END OF SECTION

http://fedgreenspecs.wbdg.org DRAFT 04/30/04 09900 - 3 Paints & Coatings

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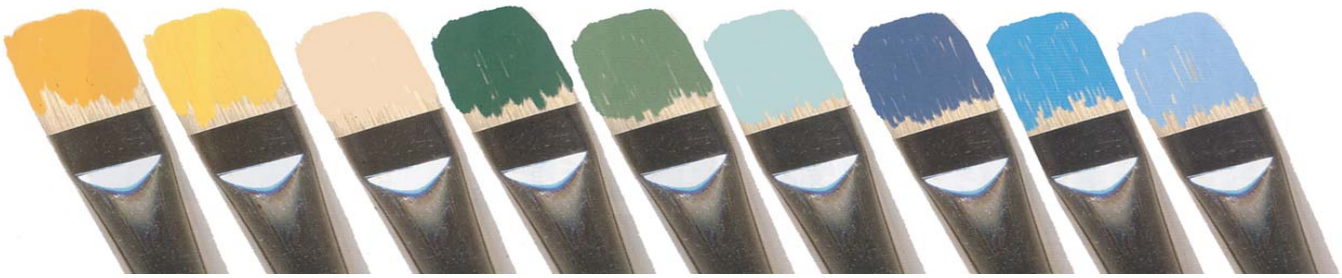

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Conclusions

The best way to avoid uncertainty about VOC content, undetected presence of other harmful chemicals, and high embodied energy is to use truly natural products. It seems that the most economical choice is BioShield Solvent Free Wall Paint. The price is comparable to the conventional products, while its content is far superior. Additionally, this company is located within 500 miles of Denver, qualifying as Local according to LEED$_{TM}$.

Future Outlook

Instead of petrochemical based acrylics, what about using bioplastics?

Greater understanding of the life cycle cost of high embodied energy will lead to greater acceptance of natural alternatives.

Advances in testing making it easier and more economical will help to standardize the paint recycling industry.

Green INTERIOR PAINT

csi 09000

group K

Bibliography

Articles

Greiner, et al. "Paint Product Stewardship: A Background Report for the National Dialogue on Paint Product Stewardship," March 2004.
http://www.productstewardship.us/supportingdocs/DialoguePaintPS.doc

Hakkinen, et al. "Environmental Impact of Coated Exterior Wooden Cladding," VTT Building Technology, Finland 1999
Abstract found at: http://www.kolumbus.fi/finnmappartners/rym/eng/vttjulkaisu834e.htm

Solyan, R. "Environmentally Preferable Paints: Minimize Harm, Maximize Savings," April 1999
http://www.getf.org/file/toolmanager/O16F21521.pdf

Informational Websites

Environmental Protection Agency http://www.epa.gov
Green Seal http://www.greenseal.org
Green Home Guide http://www.greenhomeguide.com/index.php/product/C136
MetaEfficient http://www.reactual.com/metaefficient/archives/paint/index.html

Paint Product Manufacturers

Auro http://www.aurousa.com/products.php?cat=paint#
BioShield http://www.bioshieldpaint.com/catalog/default.php?cPath=11
Dunn-Edwards Paints http://www.dunnedwards.com/
ICI Paints http://www.icipaints.com/Home/Jsp/indexflash.htm
Pittsburgh Paints http://www.ppg.com/ppgaf/pittsburgh/architect/index.htm#
Rodda Paint http://www.roddapaint.com/ps_horizon.asp
Sherwin Williams http://www2.sherwin-williams.com/ProductsServices/default.asp

Only when the last tree has died and the last river has been poisoned and the last fish has been caught will we realize we cannot eat money. ~Cree Indian Proverb

INTRODUCTION:

Green Furniture is the only option for the Commerce City SYZ project. While there is no actual LEED category for environmentally friendly furniture, furniture does have an effect on other LEED categories as it has a huge impact on air quality, just as finishes would. These categories include Indoor Air Quality as well as Recycled Content Use. However, in addition to affecting the outcome of other LEED categories, using **Green Furniture in the Commerce City SYZ project offers a unique opportunity to expand upon and explore other furnishing options that utilize low emitting materials, certified wood, renewable materials, local/regional materials, and reuse of resources.** The individual research and obtainment of environmentally friendly furniture by the Commerce City SYZ project would continue to offer an educational opportunity for those who would use the building as well as create a positive impact on future generations.

While it may be the easier choice (both economically and in acquisition) to buy **regularly manufactured furniture from a department store or supplier,** it is important to know that there are many disadvantages to that decision. One **serious disadvantage** is the use of formaldehyde in the binding ingredients of regularly constructed/manufactured furniture. **Formaldehyde is one of the most common admitters of Volatile Organic Compounds (VOCs) into the air.** Formaldehyde is a colorless gas with an unpleasant smell. It is common in many building materials such as plywood, particleboard, and glues and besides furnishings, it is also found in some types of foam insulation, paints, lacquers and varnishes. VOCs can cause irritation of the eyes, nose and throat, nausea and dizziness, and skin problems. Higher amounts can cause irritation of the lungs and wheezing. Higher exposures to formaldehyde may also cause memory problems and anxiety.

The following pages will act as a manual or a “jumping off point” for obtaining GREEN or Environmentally Friendly Furniture. Topics covered will include:

•How to ask the right questions about Green Furniture

•Products available and their
- Costs
- Materials
- Maintenance and Durability

•Instructions on how to get/make green furniture

•Recipe for “green” furniture polish to re-use recycled furniture

•Directory of Green Furniture Companies

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Questions:

Asking the right questions when shopping for Green Furniture will prevent several confusions and misrepresentations. Many products available advertise themselves as Environmentally Friendly when they actually are not. Manufacturers may claim to us products made from “green” material such as wheat board, strawboard, recycled cardboard, FSC certified wood, but when all is said and they’ve used formaldehyde as the binding ingredient.

Questions to be addressed should be:

- If this is a wood product, is it made of FSC certified wood?
- What materials are used in stuffing upholstery?
- Can THIS product be broken down and recycled?
- Is formaldehyde an ingredient in any of the construction of the product?

It is important to be an educated consumer.

What is FSC certified wood?

The Forest Stewardship Council (FSC) is a nongovernmental organization that promotes standards for sustainable forestry certification worldwide and accredits forestry certifiers. FSC principles include management for biological diversity, long-term forest health and long-term economic wellbeing of local communities.
FSC tracks and monitors wood throughout the chain-of- custody—as it moves from harvesting to manufacturing and distribution and finally to the point of sale—to ensure that the customer is actually getting a certified sustainable harvested product. FSC authorizes third-party certifying organizations to carry out certification. In the United States, these organizations are SmartWood and Scientific Certification Systems (SCS). These groups certify forest lands and chain-of-custody forest products based on FSC standards.

What makes it ‘green’?
FSC certification guarantees that forests are managed in a way that will assure the long-term availability of wood while protecting the health of forests and the natural resources they contain and support.

Products:

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There are many products out there available claiming to be environmentally friendly . It's just a matter of which ones to choose. Here are just some ideas as to what is available, their costs and maintenance and durability.

T h e F o am Cushion

Not to be confused with bean bags, which wear out quickly and lose their loft in a short period of time, the line of floor cushions come with the impressive benefits of the shredded foam they are made from.

These bags need no refills, have no beads and have the added bonus of serving multiple uses: furniture, guest bed , foot rest, napping area or study nook. Available in a plethora of colors and sizes, products can be found to fit pe rfectly into every room .

Price List

- 3 Foot $79.00
- 4 Foot $125.00
- 5 Foot $149.00
- 6 Foot $189.00

Warranty

- 3 Yea r

T h e Foam Lounger

Starting at $99.00

The Foam Source has the perfect solution: a new floor lounger is built from only the highest quality, most durable foam on the market. Shaped to provide the neck and back support you cra ve, watching movies or playing family games has never felt more relaxing !

The Foam Source
www.foamsource.com
3201 Walnut Street
Boulder, CO 80301
1.800.255.0181

Green FURNITURE: Products

csi 12000

Mesack Schulte

Products:

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Children's armchair
AGEN
Stackable. Saves space when not in use.
designer: IKEA of Sweden

care instructions
Wipe clean using a damp cloth and a mild cleaner.
Wipe dry with a clean cloth.

environment
Renewable raw material (rattan).
Renewable raw material (wood).
The entire product can be recycled for material or energy recovery

Width: 16 1/2 "
Depth: 12 1/4 "
Height: 21 1/8 "
Seat height: 10 3/8 "

$19.99 / pieces | |
(price reflects selected options)
website prices may vary from store prices

http://www.ikea-usa.com/webapp/wcs/stores/servlet/ProductDisplay?storeId=12&langId=-1&catalogId=10101&productId=19944

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csi 12000

Mesack Schulte

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The Limerick chair brings comfort to low-cost, stackable seating. It's lightweight and flexible, roomy and supportive. And all parts are 100 percent recyclable.

A Stacking Chair Solution
Stacks high for flexible, space-efficient use in cafeterias, classrooms, and meeting areas.

Hard Working
Stacking up. 10 high on the floor or 36 high on the specially designed cart.

Lightweight. Easy to move and stack.

Ganging glides. Chairs can be linked to create rows of seating for classrooms or auditoriums.

12 year – 3 shift warrenty

Comfortable Design
Generous size. The seat and back are high and wide so the chair fits a large range of people.

Curved, flexible back. Provides lumbar support and moves subtly with the sitter; an opening increases ventilation and makes the chair easy to carry.

Double-front crossbars. Raised out of the way of ankles.

Colorful Aesthetics
Slender profile. Blends with a variety of office environments.
Fun colors. Shells are available in 10 colors, frames in 4 colors.

http://www.hermanmiller.com/CDA/SSA/Product/0,1592,a10-c440-p94,00.html

Green FURNITURE: Products

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Aalto Stool 60 and E60
Designed by Alvar Aalto

Alvar Aalto's used his innovative, solid birch L-legs for the first time on this historic stool, introduced in 1932-33. Since then, the success of the simple design has been proven by the stool's lasting popularity. Available with three or four legs.

Practical Design
Made to stack. Stools stack as high as you can reach.

Simple and sturdy. The seat has a solid birch core with birch laminate and face material.

Compact footprint. The stool top diameter is 15".

Distinctive Aesthetic
Color choice. The seat can be birch, black, red, or white.

Beautiful patina. Birch ages gracefully, taking on a rich, honey color.

Environmentally Sound
Good wood. Birch is a nontropical, renewable resource; two birch trees are planted for every one used in the production of Aalto furniture.

Less waste, less glue. Laminated layers are only used where the leg bends; the rest is solid wood.

Handcrafted. Less industrial processing is needed.

Durable. Aalto furniture is built to last from generation to generation.

http://www.hermanmiller.com/CDA/SSA/Product/0,1592,a10-c440-p203,00.html

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Build Your Own Table

An idea that has the potential for fun as well as to be a tool for education about recycling and reuse would be to build the craft tables for the SYZ building out of old doors. There are several doors available at local recycling centers such as **Resource 2000** in Boulder, **Buds Warehouse** and **A Garrett Lumber** in Denver.

Steps:

- Visit a local recycling center and find doors to specifications.
- Maybe find an old table that needs a new top and attach
- Or visit a local Home Depot or other hardware store that sells FSC wood for table legs.
- Inquire Home Depot employees or local carpenters/wood workers as to the best way to build legs for table
- Attach legs to create a sturdy base for the table.
- Sand, seal and paint doors with non-toxic, formaldehyde and voc-free products
- Enjoy!

This project could involve those who would be using these products so as to promote awareness, knowledge, and pride in the work completed!

Green FURNITURE: Instructions

csi 12000

group 12

Recipe For Green Furniture Polish:

If you want to start establishing a healthier environment, why not start by replacing your chemical furniture polish with a homemade formula?

Ingredients:

- 1 Part Olive Oil
- ½ Part Lemon Juice

Mix it all together:
Add the olive oil to the lemon juice in a glass bowl and mix until blended well.
Substitutions:

- You may prefer to use Jojoba Oil (found at most health food stores) as a substitute for olive oil. Jojoba oil is a natural liquid wax that does not have a scent, and will never go rancid.[
- You can substitute Distilled White Vinegar for the lemon juice.

Get cleaning!
Apply a small amount of the mixture with a soft cloth and buff to a shine.
Use sparingly. A little bit of this mixture will go a long way, so start off with a small amount on a cloth and add more as necessary. Too much oil left on the furniture will only act as a dust magnet, which is precisely what we are trying to avoid!
Storage:
It is usually better to whip up a small batch each time you need it, but if you would rather store it for convenience, follow these guidelines:

- Never make more than you will use in one month's time - these products may lose their effectiveness faster than their harsh chemical cousins.
- Store the mixture in an unused, store-bought container such as a squeeze or spray bottle. Never put them in old food containers.
- Label the container carefully.
- Store this and all cleaning solutions - whether store-bought or homemade - out of reach of children.

Precaution:
Before using any homemade cleaner, be sure to test it on a small, inconspicuous area upon the surface which you plan to use it.

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Green Furniture Manufacturers and Distributors:

CALIFORNIA

Dax Stores
(San Carlos)

Family-owned business that sells electronic educational toys, patio and outdoor furniture, bedroom furniture, children's bedroom furniture, baby cribs, changing tables, organic crib mattresses, organic crib bedding, European crib bedding, fountains, sculpture, statuary and art.

http://www.daxstores.com/

FoundWoodFurnishings.com
(Oakland)

One-of-a-kind pieces of branch & driftwood furniture made from sustainably-harvested wood, artfully designed & using traditional mortis & tenon joinery.

http://www.foundwoodfurnishings.com/

Green Culture Inc.
(Lake Forest)

Strive to find the most eco-friendly products available in the marketplace and make these products available to you.

http://www.eco-furniture.com/

Heartwood Industries
(Los Angeles)
Handcrafted furniture, incl. reproductions of antiques. Some recycled wood.

http://www.heartwoodindustries.com/

Nirvana Safe Haven
(Walnut Creek)

Healing, healthy environments – organic beds

http://www.nontoxic.com/

Planet Squared
(Huntington Beach)

Award-winning company produces a patent-pending line of modular furniture that is not only made from recycled materials but, is also recyclable.

http://www.planetsquared.com/

Royal Pedic
(Los Angeles)

The most comfortable and healthy sleeping environment in the world.

http://www.royal-pedic.com

Stranger Furniture
(Pasedena)

Striking Furniture for a sustainable way of life. Contemporary organic style, salvaged and recycled lumber, non toxic finishes.

http://www.strangerfurniture.com/

Tamalpais Natureworks

(San Rafael)
Original designs and kits for self-assembly of natural furniture.

http://www.tamalpais.com/

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The Wooden Duck
(Berkley)

The Wooden Duck specializes in furniture made from reclaimed lumber. The recycled wood comes from a number of demolition and salvage projects.

http://www.thewoodenduck.com/

Woodshanti
(San Francisco)

As an environmentally certified business, we specialize in building the highest quality custom cabinets and furniture using sustainably harvested and recycled lumber. We also finish our pieces using only non-toxic products.

http://www.woodshanti.com

Whit McLeod
(Arcata)

Arts and crafts wood furniture made from recycled wood (oak wine casks etc) only.

http://www.whitmcleod.com/

COLORADO

Hangouts Hammocks
(Boulder)

Hand Woven hammocks and hanging chairs

http://www.hangouts.com/

The Foam Source
(Boulder)

Natural Latex cushions, mattresses, toppers, pillows and futons

http://www.foamsource.com/

ILLINOIS

Bean Products, Inc.
(Chicago)

Natural Choices for Organic furniture, specializing in hemp uphosltry

http://www.beanproducts.com

EcoLogic, Inc.
(Lake Bluff)

Line of furniture made from recycled materials.

http://www.ecoloft.com/

KANSAS

Natural Tree Furniture
(Wilson)

"Balancing Nature with Creative Imagination!" Reclaimed, naturally felled trees handcrafted by artisan Ray Smith. Environmentally Responsible Designs ~ Specializing in Cat Tree Furniture.

http://www.smithindustries.com/

MASSACHUSETTES

Allergy Buyers Club

Our allergy relief store is unique because we test, review, compare and rate all our own products such as air purifiers and vacuum cleaners, even telling you the minuses of any product before you buy.

We educate our customers how to make wise purchases with reports by consumer experts.

http://www.allergybuyersclubshopping.com/

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Furnature
(Watertown)

Organic, chemical free upholstery

http://www.furnature.com/

Priorities
(Wellesley)

Serving allergy, asthma and chemically sensitive sufferers for over 14 years with superior allergen-free, non-toxic products for healthier living.

http://www.priorities.com/

Staples Cabinet Makers
(Mansfield)

We reuse old barn and house floors to build farm tables, which we custom size for our client's specific requirements. Our environmentally inspired furniture maker builds "green".

http://www.staplescabinetmakers.com/

MICHIGAN

Herman Miller
(Zeeland)

Continues a "Journey toward Sustainability," designing products with consideration for their environmental impact.

http://www.HermanMiller.com

MINNESOTA

Baltix
(Long Lake)

Baltix makes the EcoBUZZ, the modern office workstation. We use environmentally sound materials like Wheatboard, Sunflower panels, LDPE Recycled Plastics , and recycled aluminum. Our award winning system allows the client to use Green products in designing an efficient sturdy workplace. Call us or visit our website!

http://www.baltix.com/

NEW JERSEY

White Lotus Home
(Princeton)

Natural futons and fine furnishings

http://www.whitelotus.net/

NEW MEXICO

EarthSake
(Silver City)

Natural fiber mattresses

http://www.earthsake.com/

NEW YORK

MetaForm Studio
(Suffern)

Modern furniture made from recycled industrial waste. Collection incl. sofas, desks, chairs, tables, lighting, home objects, storage.

http://www.metaformstudio.com/

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Woodstock Furniture Gallery
(West Hurley)

Fine Country Furniture

http://www.woodstockfurnituregallery.com

NORTH CAROLINA

Airedale Woodworks
(Murfreesboro)

Furniture made from recycled wood from old tobacco barns.

http://airedalewoodworks.iplenus.com/

CardboardChair.com
(Chapel Hill)

Chairs made in the USA from environmentally friendly materials using a minimal-impact production process with no harmful industrial waste.

http://cardboardchair.com/

OREGON

D&P Industries, Inc.
(Redmond)

Our mission is to encourage the use of environmentally friendly products, promote recycling efforts, and support organic living endeavors.

http://www.urbangardencenter.com/

Resource Revival
(Portland)

Tables made from salvaged firebeams and recycled bike parts

http://www.resourcerevival.com

TEXAS

Texas Backroads Furniture
(San Antonio)

Custom antique/ranch-style furniture built from barnwood and other distressed and recycled lumber. Quality craftsmanship is evident in every piece.

http://www.texas-backroads.com/

UTAH

Rustic Furniture of Moab

Rustic furniture style with some collections made of recycled wood.

http://www.rusticfurnitureofmoab.com/

WASHINGTON

Abundant Earth
(Port Townsend)

Abundant Earth offers a wide variety of environmentally sensitive products and services for people who want to make a difference in the world.

http://www.abundantearth.com/

Brandrud Furniture
(Auburn)

Organic, chemical free uphostry, wheat, sunflower seed materials

http://www.brandrud.com/home.html

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The Woodsmith
(Clarkston)

Touch of the past rustic furniture combines weathered barnwood with complements of hardwood. These are one-of-a-kind, handcrafted pieces.

http://www.thewoodsmith.com/

WASHINGTON DC

Vivavi

Eco-design boutique

http://www.vivavi.com/

WISCONSIN

Crane and Turtle Futon
(Milwaukee)

Handmade futons using California and Texas grown cotton, post-consumer recycled polyester fibers, and high density foam all combine to make extremely resilient and comfortable futons.

http://www.craneandturtle.com/

International
Cetic Viking Furniture (Hong Kong)

http://www.celticvikingfurniture.com/
Hand built and carved or uncarved Celtic, Viking, Egyptian, Aztec and more, ancient culture artwork furnishings and custom designs, in reclaimed antique elm wood.

GoodWood Cellars (Exeter, UK)

http://www.goodwoodcellars.co.uk/
All furniture is made of 100% recycled wood; original designs.

INTERNATIONAL

Cetic Viking Furniture
(Hong Kong)

Hand built and carved or uncarved Celtic, Viking, Egyptian, Aztec and more, ancient culture artwork furnishings and custom designs, in reclaimed antique elm wood.

http://www.celticvikingfurniture.com/

GoodWood Cellars
(Exeter, UK)

All furniture is made of 100% recycled wood; original designs.

http://www.goodwoodcellars.co.uk/

Reelfurniture
(Norwich, UK)

Creates recycled wooden furniture for home and garden with the knowledge that they are acting positively to protect timber resources and conserve our forests.

http://www.reelfurniture.co.uk/

Rohner Textile
(Switzerland)

Produces Climatix – a pesticide free fabric

http://www.globalnature.org/

Roy Tam Design
(UK)

Scandinavian style furniture from forest thinnings by award winning designer trained at the Royal College and Hooke Park.

http://www.eco-furniture.co.uk/

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Team 7
(Austria)

TEAM 7's philosophy is to make comfortable, functional, and esthetic furniture for humans that are in harmony with nature and the environment. We make furniture for an entire house, day and night we want you to feel comfortable, we want the furniture to grow with your needs.

http://www.team7.at/

Arbor Sculpture

Living tree trunks grown into the shape of furniture, houses and more by bending and grafting.

http://www.arborsmith.com/

Local Sources for Recycled Furniture Materials:

ReSource 2000
63rd St., 1/2 mile south of Valmont
Boulder,Colorado

303-419-5418

Salvages used building materials and resells them at great prices; innovative program that makes it possible to reuse and recycle building materials traditionally discarded during construction & demolition

http://bcn.boulder.co.us/environment/rs2k/index.html

A. Garrett Lumber
7360 Grape Street
Commerce City, CO

303 288-4946

Bud's Warehouse
3390 Brighton Blvd, Denver

303-296-3990

http://www.budswarehouse.org/

Home Improvement Thrift Store

finishing products to furniture

Green Furniture

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*See Directory for additional sources

Introduction:

Straw bales are a natural building material typically used in residential construction in this region and climate zone. We will focus on its use in other applications, specifically a larger commercial project. They can be used in virtually any climate with proper moisture protection consideration. Straw bales can be used in both load-bearing and infill applications and bring the benefits of high insulation value to a building envelope. There is currently a wealth of information available regarding the use of straw bale in residential building projects. We are interested in expanding its use into a commercial context. The general goal of our project is to research the process of straw bale construction and how it can be integrated into a larger scale commercial project attempting LEED Certification. The product of this research will be the creation of a guideline for commercial straw bale construction in an urban setting.

Elliot Fairchild
Patrick McMichael

Index and Key Terms

Topics Covered by Page:

Key Terms:

Straw: The dry stems of cereal grains left after the seed heads have been removed.

Bales: Rectangular compressed blocks of straw, bound by strings or wire.

Flakes: Slabs of straw removed from an untied bale. Flakes are used to fill small gaps between the ends of stacked bales.

Laid Flat: Stacking bales so the sides with the largest cross-sectional area are horizontal and the longest dimension of this area is parallel with the wall plane.

R-Value: Measures a material's resistance to heat flow. The greater the r-value, the greater the resistance.

Embodied Energy: Recognition that total material costs are greater than economic costs. Unit of measurement is MJ/kg.

Price of Bales:

Straw Bales can be purchased directly from the farmer or from a feed store. The cost of transportation accounts for at least ½ the cost per bale so you save if you can haul it yourself. Expect to pay between $1.00 to $3.50 a bale. A small house, 30 feet by 40 feet, would require about 250 bales and cost around $700.

Examples of Local suppliers and prices:

Strawbales for Building, Jerry Gomez. 136 Grouse Circle, **Westcliffe CO** 81252; ph/fax 719-783-3540. 14x18x16 & 14x22x42, 2- & 3-string (twine); wheat, barley. $2.25/bale; delivery $1/bale/175 miles; available September thru July; stored exposed/only dry bales delivered.

Brighton Feed. 370 N Main St, **Brighton CO** 80601; ph 303-659-0721, fax 303-659-4841. 18x24x30, 2-string; barley. $3.25/bale (less for larger orders); delivery can be arranged; available year round; for 200+ order in advance; stored in barn.

Albert Francis, Francis and Sons Inc. 7750 S Co Rd 100, **Alamosa CO** 81101; ph 719-852-4642. 14x18x36, 14x22x46, 2-string & 3-string (twine); wheat, barley, oat. 2-string = $1.75/bale, 3-string = $2.75/bale; delivery can be arranged; available August through April.

Price per Square Foot:

Figures for materials only are somewhere between $15 to $20 per square foot. Although straw is much cheaper than other building materials overall costs are similar to conventional buildings. The inside of the exterior drywall has to be plastered, so the difference is the cost of plastering verses drywall. The plastering cost varies depending on your location, amount of local strucco crews. The cost will depend on the finishes selected, owner/built projects can be much cheaper than professional pricing.

People have found the stucco line item to be more than any other. Stucco is around $4.50 per square foot in central Colorado.

The following is a break down for the Cedar Integrated Primary School built with Straw Bales:

Straw 2%
Timber 25%
Lime, plaster, strapping and mesh 17%
Concrete and foundation 13%
Plant hire and tools 8%
Insulation 3%
Waterproof roofing 5.5%
Construction management 19%
Labor 25%
Electrical Supply 5%

Price per Square Foot:

Here are further estimates for the cost per square foot:

Very Low: 120-1000 sf @ $5-$20
a-scavenging, salvaging materials
b-material costs only, owner-builder labor throughout
c-initial start-up costs, ongoing improvements,
pay as-you-go
d-Nebraska-style, timber frame, and post and beam

Low: 1000-1500 sf @ $30-$50
a-contractor-built, owner-build wall, finishes
b-subcontract foundations, plumbing, mechanical, roof
c-experienced job-site supervisor
d-materials at market cost
e-typically post-and-beam or Nebraska-style

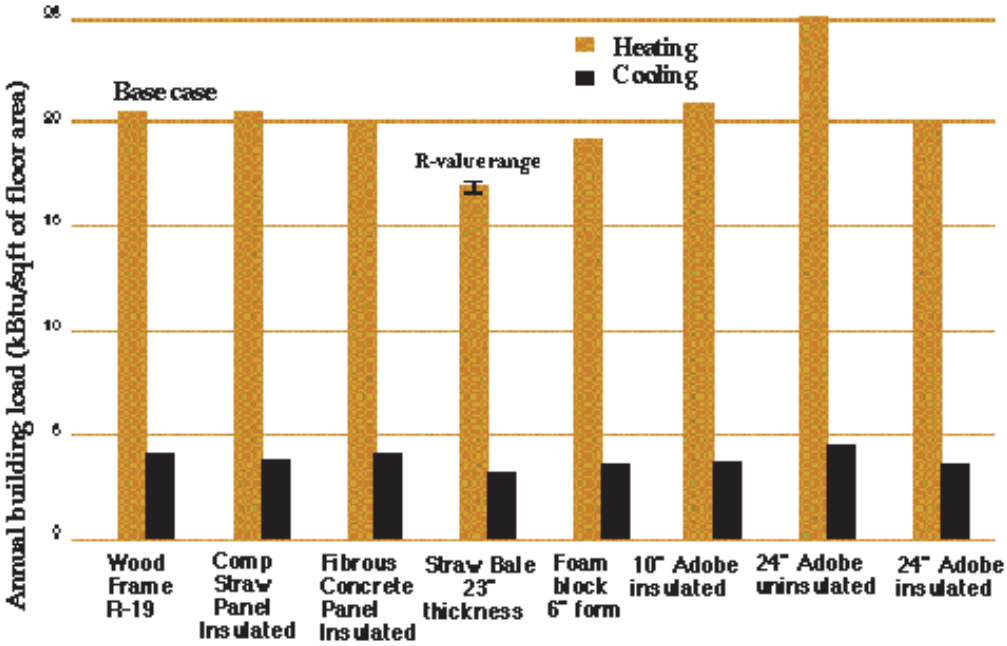
Moderate: 1500-2500 sf @$50-$80
a-standard, contractor-built
b-production housing
c-speculative development
d-typically post-and-beam

High: 2500-4000 sf @ $80-$120
a-luxury homes
b-custom design
c-site specific
d-marginally less than conventional construction
e-typically post-and-beam with custom features

Energy Savings:

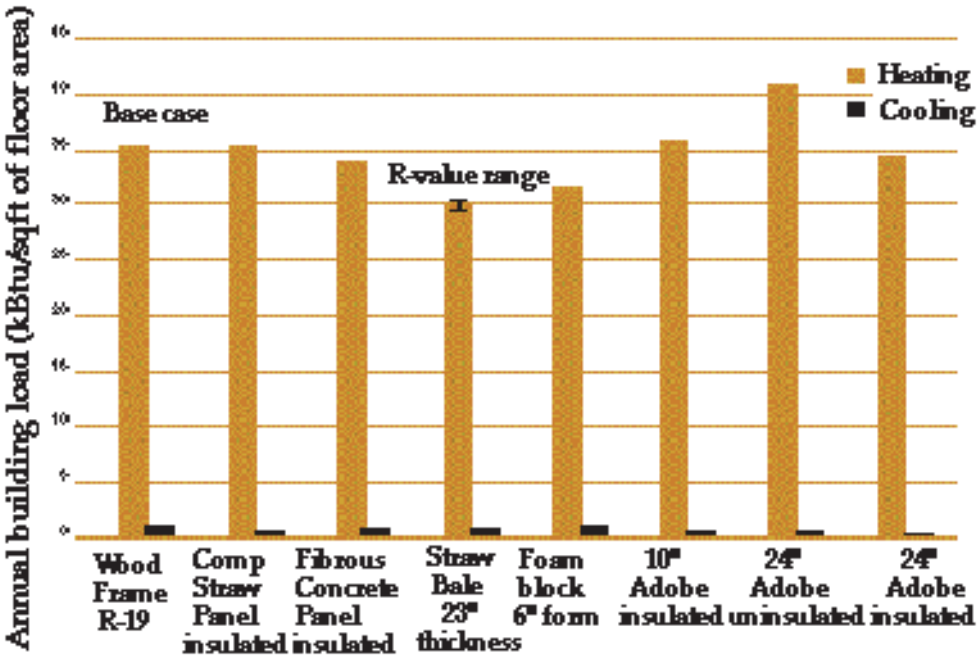
The real savings from using Straw Bale walls come from lower energy bills for the life of the building. Energy needs of the building will be reduced 15-25% because of straw bale's extremely high insulating value. Straw bale walls have R-values 2-3 times higher than conventional post-and-beam walls with fiber glass batting.

Straw bale walls also have sufficient thermal mass. In Colorado's climate, with large swings between day and night temperatures, high thermal mass is very beneficial. The mass absorbs heat during the day and radiates it at night, moderating indoor temperature swings.



The above graph shows the results of a study done on the building performance of alternative walls in Albuquerque, New Mexico.

The graph below shows results from the same study done in Cedar City, Utah.



Energy Savings:

The figures below represent a Life Cycle Cost Estimate for conventional vs. Straw-bale houses conducted by The Plastered Straw Bale Working Group.

The life cycle is over a 100 year period.

Energy is the average cost for heating and cooling a conventional home for this analysis to be $100 per month.

*owner-built walls, finishing, and roofing

Embodied Energy:

Embodied energy is an attitude about materials which recognizes that total material costs are greater than economic costs. Some materials may have low embodied energy but still maybe offensive due to the environmental stress their production, use, or disposal can cause. Rigid styrofoam insulating board, blown urethane foam insulation, and fiberglass insulation tend to fall in this category.

Straw has a very low embodied energy; it's estimated to be 30 times less energy-intensive than wood-frame walls to manufacture.

The unit measure for embodied energy is MJ/kg. It is highly dependent on factors such as geographical location, technology employed in the manufacturing process, the degree of automation, mechanization and local methods of manufacturing, the value is by no means absolute and is different from one location to another.

According to "The Straw Bale House" book, straw has an embodied energy of 0.13 MJ/kg. They estimate lumber at 4-7 MJ/kg and Concrete at 2 MJ/kg.

The RS Means Green Building: Project Planning and Cost Estimating guidebook gives straw bales an embodied energy rating of 0.24 MJ/kg. They compare this to other manufactured insulations like fiberglass (30.3 MJ/kg) and polystyrene (117 MJ/kg).

	Construction	Energy	Total	Savings
Conventional	$82,500	120,000	532,500	------
Straw bale	$78,375	60,000	451,675	83,875
Straw Bale*	$40,000	60,000	260,000	272,500

Embodied Energy:

Building with Straw has other environmental advantages that are not accounted for with embodied energy analysis, such as:

-Turns as extremely abundant waste product with significant associated disposal costs and impacts into a widely available resource.

-The straw walls of each house hold in place a few tons of carbon, helping to mitigate global warming.

-Reduces the use of nitrogen fertilizer, since none is required to replace nitrogen used to break down the straw if no straw is plowed under.

-Reduces the demand for timber so more trees can be left standing, since less wood is needed for construction.

-Straw is already produced in sufficient quantity to provide for all of North America's housing needs, so there is no need for new farmland or significant new practices.

-Reduces carbon Monoxide pollution. Bale burning in the U.S has been a major source of CO pollution. Two hundred million tons of straw are burned annually in the U.S.

-Rejuvenation period is very important. One year for straw and 40 years for 2x4 studs.

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History:

Schwaesdall Winery was the first in the county to have a commercial building made with straw bales. The first permit issued by San Diego County for a residential straw- bale construction was in 1997 for a guest house in Borrego Springs. The first commercial permit was approved two years later for Schwaesdall's tasting room.

It is best to start out by asking the municipal officials if they have ever issued a permit for a straw bale structure. Whether they have or not, you need to ask them what steps are then required to obtain a permit for this type of construction, and what sort of support documents will be necessary. Is all this difficult? Not necessarily. One needs only to be serious, organized and pay attention to details in assembling your project documents so that they may be reviewed by municipal officials.

Commerce City:

Building permits are required for new construction and remodeling of commercial, industrial, or residential structures. This includes residential garages and sheds; residential, commercial, and industrial fences; electrical, plumbing; heating/air conditioning installations or repairs; the application of exterior siding; installation of windows; and the erection or replacement of signs. This list is not all-inclusive, so please call the Building Division at 303-289-3683 to verify the need for a building permit prior to beginning any work.

http://www.ci.commerce-city.co.us/departments/permit_review.html

Local Codes:

Boulder's code for Baled Straw Structures can be used as precedence.

The code limits straw structures to Group R, Division 3 and Group U occupancies of no more than one story in height, with a maximum roof span of thirty-two feet between bearing walls, unless design and structural calculations are submitted by a registered architect or engineer.

The code defines Straw as the dry stems of cereal grains left after the seed heads have been removed and Bales as rectangular compressed blocks of straw, bound by strings or wire.

The code allows various types of straw, including rye, oats, wheat, rice, and similar plants. The bales must meet the minimum requirements for density, shape, moisture content and ties as follows.

Shape: rectangular

Density: 7lbs per cubic foot

Ties: tied with either polypropylene string or baling wire

Moisture Content: shall not exceed 20% of total weight of the bale

The code requires a wall thickness of 14 inches and restricts wall height to one story with a height to width ration of 5.6:1. Moisture protection and a moisture barrier are also required in each wall.

California Codes:

The California code is almost identical to that of Boulder. The following are guidelines from California's Straw bale code.

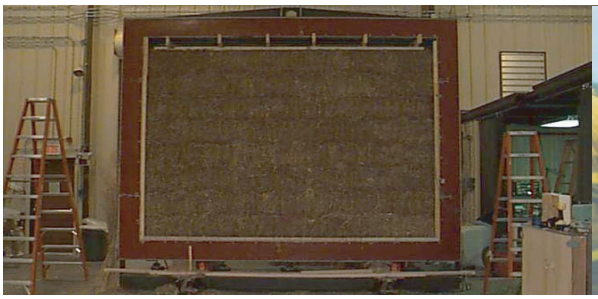
Bales are to be rectangular in shape.

To be bound with either polypropylene string or baling wires.

Moisture content not to exceed 20% of total weight.

Minimum calculate dry density of 7lbs per cubic foot.

Straw bale walls, when covered with plaster, drywall, or stucco, shall be deemed to have the equivalent fire resistive rating as wood-frame construction with the same wall finishing system.



Fire Code:

The density at which a straw bale is compressed to, combined with the stucco and plaster finishes, make a straw bale wall virtually fireproof. Fires require oxygen to burn and the absence of airspace and the seal created by the finishes allows very little oxygen to enter the wall system.

Local and national building codes will generally not accept the fire resistive qualities of straw bale construction as superior to those of wood-frame construction. But they do place them on equal ground. The quote below is taken from the California Straw Bale Code.

Article 3. Construction Guidelines
18944.40. (a) Straw bale walls, when covered with plaster, drywall, or stucco, shall be deemed to have the equivalent fire resistive rating as wood-frame construction with the same wall-finishing system.

SHB Agra Engineering and Laboratory conducted fire tests on both non-plastered and plastered straw bale wall assemblies in 1993. At a maximum heat of 1691 degrees F on the fired side, the non-plastered bale wall assembly lasted for over 34 minutes before a burn-through occurred between two bales. The plastered wall assembly was tested for over two hours and withstood temperatures that reached 1942 degrees F. The temperature rise on the unheated side of the test panel, after two hours, averaged less than 10 degrees F. There was minimal cracking of the gypsum plaster and 2" of charring along those cracks.

As a result of these tests, a professional opinion was given by Manuel Fernandez, who at the time was the State Architect and head of Permitting and Plan Review for the state of New Mexico Construction Industries Division. Fernandez stated, "these tests proved that a plastered straw bale wall assembly is superior to a wood frame wall assembly with the same finishes, in terms of its fire resistivity. It is clear from these results that fire resistivity is one of the advantages, rather than a problem for plastered straw bale wall systems."

Bale Selection

In the bale selection process there are a few main things to check for: **moisture content, bale density, bale shape, and bale assembly**. All of these variables are directly related to the baling process and subsequent storage. Bales may be made of straw, wheat, rice, rye, barley, oats, or similar plants as long as they meet the minimum requirements for density, shape, moisture content, and ties.

The ties should be made of polypropylene string and bales are bound with either two or three strings, three strings being preferred.

Bales should be of consistent size and shape, which is generally not a problem when machine baled. The typical size is 24” thick by 18” tall by 36” in length.

The moisture content of the bales must not exceed 20 percent of the total weight of the bale. This can be determined by using a moisture meter with a probe of sufficient length to reach the center of the bale. Moisture content can be affected by the weather at the time of baling and storage after baling. When the bales arrive on the job site, they should be stacked where they can be easily reached during the installation process. Bales should be stored under tarps to protect them from precipitation, and should be set on pallets or lumber keep them off the ground. This creates an airspace and promote air circulation underneath. The dry density of bales should be a minimum of 7.0 pounds per cubic foot. Density is directly related to the moisture content and should be determined after reducing the actual bale weight by the weight of the moisture content. In general, bales from known sources should meet the above requirements and should therefore be suitable for building.

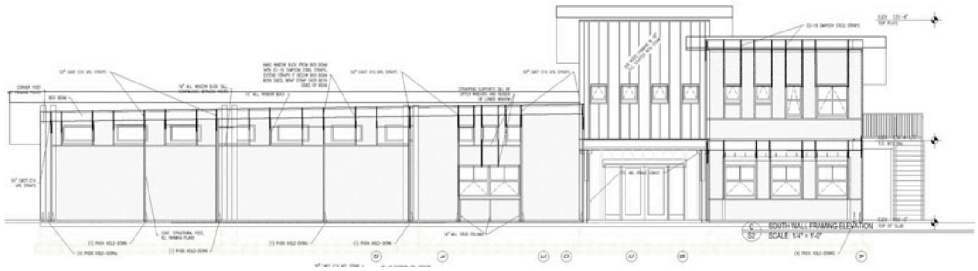
Building Types

This section will identify the two types of building which use bales in wall construction, loadbearing and non-loadbearing. We will then concentrate more on the use of bales in a post and beam system and include information on the thermal properties unique to bale construction.

Loadbearing:
The use of bales to construct a loadbearing wall is perhaps the most efficient use of bales to create a wall system. However, this method is generally used in residential construction as it is limited to 2 levels in height.

Non-Loadbearing:
The use of bales in a non-loadbearing system is not structural but strictly a thermal application. The cost of such a system is higher as a conventional wood-framed post and beam structure is required. This will increase labor and material costs. The money saved in heating and cooling the structure will make up for the higher construction costs in short time.

Straw Bale Construction



Thermal Properties:
The thermal properties associated with bale construction are an example of the sustainability of the building material. Energy simulations on buildings constructed with bales have found that they outperform all other wall types, including adobe, fibrous concrete panel, and standard wood frame. Wheat straw R-values have been determined to range between 2.4 to 3.2 per square inch, depending on how the bales are placed in the wall. Bales stacked against the grain, or on edge, have a greater R-value. A typical 3-string bale is between R-51 and R-55, and smaller 2-string bales are near R-42. As a comparison, the R-value for a typical wood-framed wall system is R-10 to R-15. The addition of stucco or plaster will increase the R-value even more as the materials add thermal mass helping passive solar structures retain heat.

The superior thermal value will translate into lower annual energy costs. According to the 1993 Plastered Straw Bale Conference, the annual energy cost for heating and cooling of a straw bale structure is half that of a conventional one.

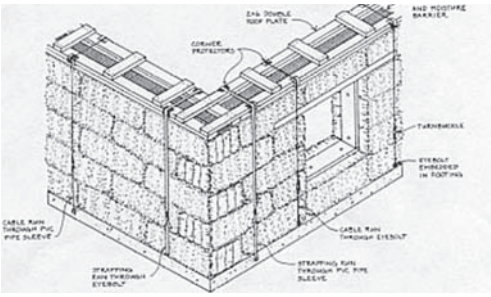
Construction Process

The construction process of a bale wall can be broken down into three areas: the foundation, the wall assembly, and the finish rendering assembly. We will also examine the labor required for construction, detailing requirements around openings and connections, and integration of electrical and plumbing systems and conventional wooden structural building systems with bales.

Foundation:
In a load-bearing situation, the foundation should be sized to accommodate the thickness of the bale wall and the load created by the wall and roof live and dead loads. The bales rest on a treated wood ladder system with a gravel infill. This will give any moisture that is trapped within the bale a place to migrate to and exit the wall system, eliminating mold and decay. In an infill situation the bales also rest on a treated wood ladder placed on the floor plate of each level.

Wall Assembly:
For non-loadbearing walls, bales are stacked flat in running bond courses where the actual straw in the bale is laying parallel to the floor. Each bale must overlap the two bales beneath it by a minimum of 12 inches. Gaps between the ends of bales which are less than 6 inches in width are filled using an untied flake inserted into the gap. Window and door openings are created prior to stacking by building wooden bucks at the size of the rough opening. After stacking has been completed, expanded metal lathe is installed over each wood and bale connection point. This includes all corners, edges, and around all window and door openings. The lathe is stapled to the wood and pinned to the bales using 4 inch landscaping pins. Open spaces beneath the lathe are stuffed with loose straw. These connections are important to the finished product. The lathe is shaped to create curved connections between the walls and the windows, and “steps” on the interior sides of the windows

Straw Bale Construction



Finish Rendering Assembly:
Cement stucco on the exterior and earthen or lime-based plaster on the interior, seal the walls against moisture penetration and protect them against everyday wear and tear. Before applying the stucco or plaster, fill in any major holes or gaps in the wall using flakes of straw. Then use a sledgehammer to persuade problem bales back and forth into the correct position.

The finished rendering assembly is achieved by using three coats of stucco and is around 1.5 inches thick (each coat being ½ inch thick). Between each coat, the surfaces are left rough to give the next coat something to grab onto. Also, a mist of water is sprayed on the surface. The first coat is the scratch coat. The purpose of this coat is to achieve the greatest bond possible between the stucco material and the straw. The material is sprayed onto the wall and rough troweled by hand with care taken to work the stucco deep into the bales. The walls take on a more finished shape after the second coat is applied. This coat contains more sand than the first coat. Finally, the finish coat is applied. Pigment may be added to the finish coat and the troweling process must be done more carefully to achieve the desired finish. The final surface must be misted with water to slow the drying process and avoid cracking.

Research has been done regarding the use of earthen plasters for the entire project in the place of cement stucco. They certainly have a lower embodied energy and they create a more breath-able assembly which will help to draw out moisture from within the wall.

Labor Requirements:
Straw bale construction uses a fairly low-skilled work force. In general, there must be one person to supervise the project who has some prior experience or education in straw bale construction. This person can conduct basic training on the job. Often crews are made up of family and friends in smaller residential projects. This gives a sense of ownership and pride in the completed project. For a larger commercial scale project, it is recommended to hire a professional crew who will complete a larger job much more efficiently.

Construction Detailing:
This topic deals with the connections between bale and non-bale wall systems. There are a few basic rules to follow. Any surface to be plaster finished that is not straw must be covered with expanded metal lathe, which is stapled to the wood and pinned to the adjacent straw, overlapping at least six inches. The second basic rule deals with moisture barriers and protection. The bottom course of bales should be protected with a moisture barrier. Also, openings with horizontal surfaces such as window sills should be protected. And there must be a moisture barrier between the top of the foundation and the bottom of the first course of bales to prevent moisture migration.

Electrical & Plumbing Integration:
Wiring is pinned directly to the bales and electrical boxes are staked in place prior to application of the finish. Sections of the bale wall, after it is stacked, can be trimmed out to create space for plumbing as needed.

Frequently Asked Questions:

Are bale buildings energy efficient?
Yes. Given the superb insulating value of bales, averaging R-50, bale-walled buildings keep a very stable temperature, and require significantly less heating and cooling from other sources, than do comparable buildings with less wall insulation. Of course, other parts of the building envelope must also be thoughtfully designed, like roof insulation, window glazing, and door sealing, since the wall materials are only a portion of the total assembly.

What is it like when the walls are 2' thick?
Quiet. Besides the insulation value, bale walls provide a very peaceful world inside the house. Subjectively, there is something reassuring about thick walls, and the depth also makes it easy to use window seats and wall niches in the design. At the window and door openings, flaring or rounding the walls will spread and soften the light entering the house.

How long do bale buildings last?
Careful building is required for the longevity of any structure, but some bale houses have lasted 90-100 years in Nebraska, where high wind and snowfall is common, and where the building methods were crude. Intact straw has been found in 9000-year old Egyptian tombs.

Do the walls decompose?
Just as with conventional wall-building techniques, moisture should be kept out of bale walls. The primary measures are roof overhangs, and raising the base of the wall above floor level, using a few feet of black paper or similar vapor barrier at the bottom few feet of an exterior wall, and using plastering materials which can pass moisture out of them. Intermittent periods of some moisture, however, can generally "breathe" back out of a wall, leaving the straw dry again, and unable to support fungus or other undesired growth.

Isn't a straw bale wall a fire hazard?
No. Because stucco and plaster seal the densely packed straw in a wall, finished bale walls have excellent fire resistance, with little access for oxygen and no significant air cavities in which fire can spread. The few known fires in bale building projects have occurred when loose straw was accidentally ignited by something like a cigarette or sparks from a welding torch.

What kind of finishes are put onto bale walls?
Builders generally stucco the exteriors and use gypsum or mud plasters on the interior, almost always with stucco wire embedded, and often with at least the first coat applied by gun. The advantage of gun application is a strong bond to the rough straw ends, and hand application of finish coats can be learned by most anyone willing to do some hard work.

How do you put wiring and plumbing into a bale wall?
Plumbing pipes are notched into the bales, and have sleeves where they pass through to the outside. Wiring may be in conduit, or Romex-type conductors laid between courses of bales, and electrical boxes are generally secured to wooden stakes driven into the bales.

Will banks and other lenders finance straw bale construction?
Occasionally, and increasingly so in areas where the success of bale building has been proven by a set of pioneering projects. In the Tucson area, for example, lenders such as Associated Mortgage are familiar with alternative methods and will make loans to qualified people for bale houses. Sometimes clients have had to educate the lenders, by getting them to see bale houses or showing videos of existing projects.

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Earthbag



Topics Covered

- Why build with earth
- State of existing knowledge
- Structure
- Construction materials
- Construction methods
- The future

Things you should know

1) Keep polypropylene bags out of the sun
2) The weaker the fill the stronger the bag
3) Foundation stem wall to be 12 inches above the ground

Why Build with Earth Architecture?

Building with earth is an honest effort towards minimal impact on the environment. By simply using the earth beneath your feet to construct a building, you save energy and natural resources. Not only are you contributing to sustaining the environment, but you can build on almost any site condition, just about anywhere, and improve your construction schedule and costs.

This is not a new idea, since the earliest times up until the industrial revolution; people have lived in the earth, taking up residence by forming and sculpting earth around them.

Existing Knowledge

Through recent history, sandbags and earthbags have been used for varied purposes, mostly in emergency relief work, for example to provide erosion or flood control, when filled with earth or pumped full of concrete or soil cement, then used for fast construction of embankments. Earthbags have also been used by archaeologists to aid in structural support of collapsing walls; by armies; to create bunkers and air-raid shelters; and by landscapers, to create free-form walls.

In Germany architect Frei Otto experimented in 1960 with earthbag buildings. In 1978 a team from the Forschungslabor fur Experimentalles Bauen (FEB), the Research Laboratory for Experimental Building at the University of Kassel in Germany created an earthbag project. This was followed by a joint research project with the Center for Appropriate Technology (CEMAT) and the Universidad Francisco Marroquin in Guatemala, which developed an earthquake proof system.

The recent trend in using earthbag technology in building homes is largely due to the pioneering work carried out by the Californian Institute of Earth Art and Architecture (Cal-Earth) in the Mojave Desert, which was set up by Nader Khalili, an Iranian-born architect.
Cal-Earth is investigating earthbag construction and developing its applications, from straight walls to domed structures. To avoid wood, they have created a stable dome-shaped structure through using the corbeling method. This means that with no material other than bags, barbed wire and local earth, you can build yourself a shelter anywhere in the world.

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Basic Structures from Nature to Build with Earth

Nature generates structures based on the principle of minimum material, and maximum efficiency, so too are earthbag domes.

To be able to build out of earth alone, certain basic structural principles need to be understood. The key to all earth construction is the arch, that singular structural element that enables the construction of arched openings, vaults or domes, and it occurs all around us in nature.

The arch allows us to build strong, resilient structures without high-embodied-energy materials such as timber, concrete, or steel. This shape is strong and stable because gravity pulls equally on each part, and each part supports the weight of the parts above.

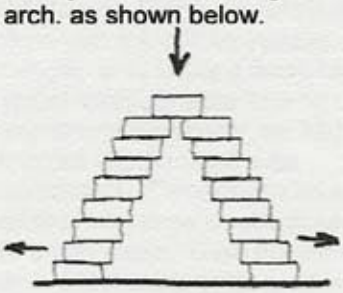
For the purpose of this reference guide, the arch, as it pertains to the dome is only discussed.

A dome is an arch that has rotated on its central axis to create a group of arches with a common peak or central point.

Horizontal forces will tend to push the base of the dome outward, a buttress or continuous tension ring is necessary at the base of a dome. If an opening is made at the top, the horizontal forces will be pressing inward, therefore requiring a *compression ring*, to prevent the structure from compressing, or caving in. If an opening is not required than the *compression ring* becomes a *tension ring* created out of reinforced concrete at the base of the dome.

Buttressing for a dome only needs to provide support up to the *spring line* (the point where the wall starts to curve inward). The buttress can either be constructed along the outside, or the dome can be sunken into the ground so that the ground itself can act as a buttress.

Corbeling: Earthbag domes must be corbeled. Corbeling involves constructing the arch in such a way that units (earthbags) lay flat, but each is stepped inward on successive horizontal curves so that the weight is evenly distributed along the arc of the arch. as shown below.



A corbeled arch or dome.

Construction Materials

The materials needed for earthbag construction are relatively inexpensive, very portable, and available nearly everywhere.

Bags or tubes: The purpose of the bag is to retain the earth during the construction process. It is a type of permanent form to allow eartth placed in a course and tamped solid. As a general rule, the weaker the mix, the stronger the bag should be.

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Bags can come ready-made or can be bought on a roll and cut to the desired length on-site (called tubes).

Two types of bags are available on the market: burlap and polypropylene, in a range of widths. If you can find a source for recycled grain, seed, or coffee bags or "seconds" with flaws the manufacturer will typically sell these cheap.

Burlap is a natural woven fabric that is biodegradable, however if pure sand is used instead of dirt the sand will slip through. In addition, the moisture from the dirt/clay fill and the plaster may cause the burlap to deteriorate.

Polypropylene is made of woven threads of plastic and is not as toxic as PVC. It is not biodegradable, but it will deteriorate if exposed to ultraviolet rays. If you're building project is not completed within three months, all exposed bags should be covered to protect them from the sun.

Fill: The earth used to fill the bags can be used directly from the site. If it contains too much organic material or large stones these will need to be sifted out to ensure good compaction. The soils can range from high clay content to very sandy consistency and may include other materials, such as gravel, pumice or scoria. With clay-rich soils mix more sand and gravel into the mix and extend the stem wall above the ground level to minimize its ability to absorb moisture.

If improving the structures R-value is needed do to your climate, try using Pumice or Scoria. This type of volcanic rock contains embedded airways that naturally creates a better thermal mass than just earth or gravel. People who built with volcanic stone indicate that the R-value imroved to as much as R-40 (with papercrete as a plaster finish).

Water: This is added to the earth to facilitate the tamping, in order to achieve better compaction. The moisture content of the earth should be such that when a handful is picked up and squeezed it holds its shape, but you do not see or feel any liquid. To prevent an excess of moisture, the earth mixer can be soaked overnight.

Barbed wire: This is used between courses instead of mortar to grip the bags. Four-point wire provides a good grip; as a natural alternative, you can use branches of a thorny plant, jagged rocks or stakes pounded into the bags. If metal stakes are used, you should purchase rebar coated with plastic. Barbed wire can be obtained on a coil or salvaged from an old fence. Two rows of wire is recommended, but if bags 12 inches or less are used only one row is needed.

Stabilizers: These are additives mixed with the soil for increased strength, or to fortify a finish coating. Typical stabilizers are lime or cement. If constructed properly, an earthbag structure should require no stabilization. Cement can be used for compression rings or structures that are under water. Care should be taken when using cement since it is associated with negative environmental impacts. Cement-based finishes should be avoided with earthen buildings, since it is important to let the walls breathe over time. An alternative to a cement finish is lime sealant or render. You can increase the R-value of the earthbag structure by adding paper to the fill and/or finish, known as papercrete which is discussed in the methods section further.

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Tools

The tools you will need to build with are easy to find and build.

Coffee can or shovel: You can use either for filling bags. A can will ease the fill process since you can hand it up to the person above you filling the bags.

Shovel for digging: Use a shovel with a good cutting edge, which will make the soil easier to excavate, trench or collect dirt with.

Tamper: An important tool for taming the bags flat once filled and in place. You can purchase tampers from home and garden supply sores or make one out of a piece of $1^{3/16}$-inch diameter x 40 inch long metal pipe welded to a 6x6 inch square metal plate (1/4 inch thick). To make an even lower-cost tamper place an old broom handle stubbed with nails into a coffee can filled with concrete. Let the concrete cure for two weeks before using

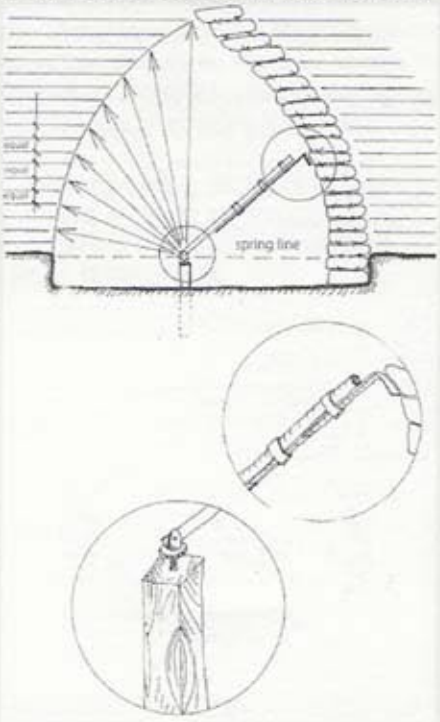
A stand: A fold-out stand will aid in the filing of small bags. A TV table stand with a removable top works great. If longer bags are used it is helpful to prop open the bag with a cut-off piece of pipe.

Water source, or buckets for hauling water: It is important for the soil to be compactable. If its too dry water can be added. However, one of the benefits to building with earthbags is that you can use whatever is beneath your feet. If you're in a dry climate, sand, gravel or shifted soil can be used instead of a clay/dirt mixture.

Water level, wheelbarrow and plumb line: For leveling, and hauling

Compass: Required as a placement guide for the bags in the building of symmetrical domes. A compass can be as simple as a chain or a string, or more complex. When the courses of the dome wall reach the stage at which they must start to curve inwards the compass needs to be extended after each row.

An extendable compass may be made with a length of hollow pipe, an electrical conduit or even a telescoping pole. The end of this is then attached to a caster with the wheel removed. The caster will allow for rotation as well as up and down movement. The caster needs to be affixed to a 4x4 post planted upright in the ground at the center of the dome. At the upper end of the pipe, use pipe clamps to attach a guide made of an L-shaped piece of metal, see below.



Hoe, wire cutters, level, ladder, tape measure, gloves and trowel: All of these items will be useful.

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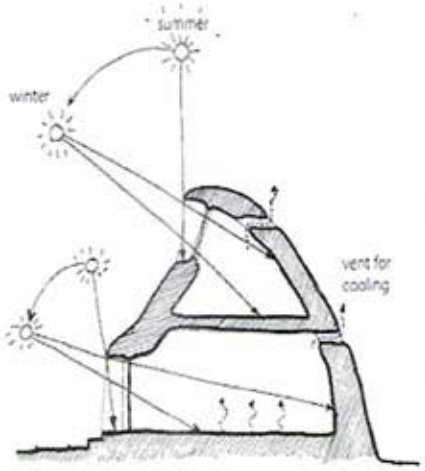
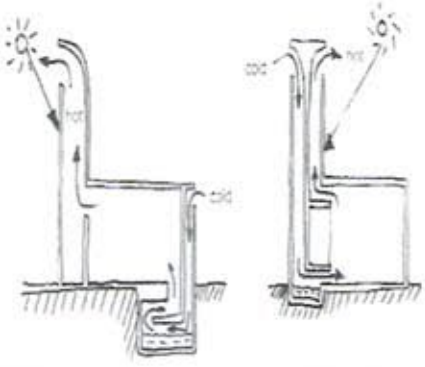
Construction Methods

Before discussing how to construct an earthbag dome structure the location or orientation of the earthbag building should be considered at the beginning.

Passive solar: Earthen walls can be beneficial in either hot or cold climates. Earth or stone walls have good thermal mass, that is, they can absorb the sun's rays during the day (when the sun is on it) and give the heat back into the dome at night. In addition, the earth can retain the cooler temperature at night and release it during the day in the hotter months of the year. Because of this it is wise to locate and design your structure with passive solar design concepts in mind, see diagram below.

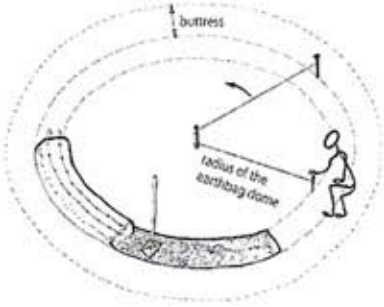




Utilities: At the earliest stages of planning, consider what services or utilities you can include into your structure that will not require living "of the grid" and provide your own electricity, heating and cooling and hot water with solar or wind energy. With access to a nearby stream, you may even be able to harvest hydroelectricity with a microturbine sized for household needs. In addition, if your building location permits it, consider a well and cistern for harvesting rainwater and graywater and a composting toilet for processing wastes.

Site preparation: Precision in the layout of a building's base is most important for locating the foundation in the best possible place. For a monolithic earthbag structure, the foundation will be an integral part of the walls and roof; therefore the shape and size of the foundation will follow through the whole structure. The site should be cleared and leveled prior to setting out lines for the foundation and walls.

A circular building or dome requires a compass to begin construction, as noted in the construction materials section of this guide.



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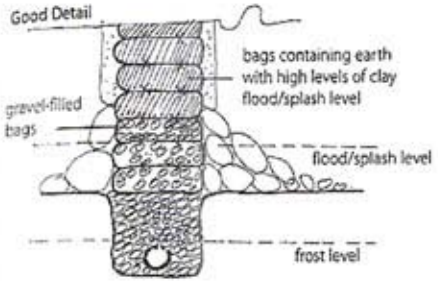
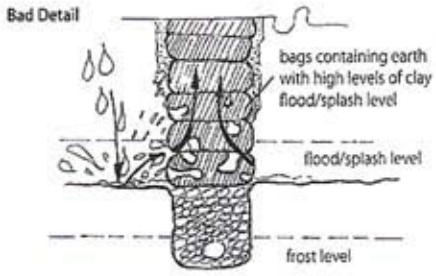
Foundations: The functions of the foundation in any building are to minimize any movement of the ground over time; to spread the load evenly in order to give the building a stable base; to hold the building in one integral unit, especially in earthquake areas; and to keep the building dry, providing a barrier between the walls and any ground moisture.

The connection of the wall to the ground is one of the most important details on an earth house. When constructed poorly, the wall may not last as long and will jeopardize the rest of the building. If care is not taken, moisture will migrate up the wall through capillary action and weaken the earthen walls.

When digging the foundation trench, it is necessary to go down to undisturbed ground, below the frost heave level to bedrock or compressed subsoil, to minimize any ground movement. Once reaching solid ground, you can build the foundation using gravel in a trench or in bags. It is important to remember to fill the bags with gravel, up to at least 12 inches above ground level with the upper course very level to receive further courses filled with earth or any other material, see drawings above and below.



Once the foundation stem wall is complete you are ready to begin filling the bags with earth and building your walls.



Filling Bags: Before beginning to fill the bags, make sure the earth is moist enough to allow compaction. As noted in the material section, bags can be filled with in several ways. Keep in mind it is never necessary to lift the bag itself: the bag stays in place and the earth is brought up to its opening. It is important to have the same person or persons fill the bags. Individual techniques are different and rows should be consistent in thickness, or at least individual rows. Once a row is completed, tamp it well, then place strands of barb wire on top as keying for the next row. As you stack bags in successive courses, remember to always stagger the joints, just as in masonry construction.

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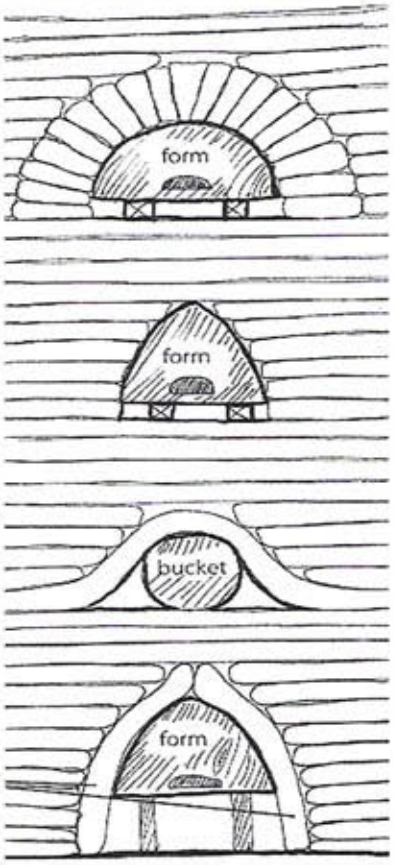
Tamping: To minimize unevenness, each row should be filled to its maximum capacity by the same team. To create as level a wall as possible, do not tamp until the whole row is filled. Once the row is laid it should be tamped until no movement of earth is felt. The sound of the tamping changes as the earth in the bag is compacted, becoming less of a "thumb" and more of a "smack."

You may also wish to tamp the sides of the wall, checking for vertical straightness with a plumb line. An advantage to tamping the sides is that then the wall surface will require less plaster. The disadvantage of a very level or even wall surface is that the plaster has less surface area to key into.

Keying: After tamping each course needs to be keyed with four-point barbed wire or thorny branches which will provide friction to prevent any shifting of the bags over time. If barb wire is not available, the bags can either be well buttressed by tying rows of bags to those below.

Openings: In an earthbag dome the number of openings cannot be too many or else the structural stability of the dome will be compromised. The distance between the openings should be large enough to properly buttress the arch that forms each opening. In general, openings that are square are best suited for non-dome structures.

During wall construction, where there will be openings, leave loops of wire extended out from the strands of barbed wire laid between the bags, which will allow you to tie off these wires up and down around the opening for added strength. There are two types of openings: arched, which do not need wood, metal, or concrete as a lintel above, or square, which will need a lintel.



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Roofs: The ideal roof for earthbag walls is one constructed using the same materials as the walls. The main attraction is the possibility of using no wood, metal, or concrete.

Creating an earthbag dome might not be a good design solution for all climates, nor for every type of budget, culture, or individual. The amazing aspect of the earthbag technology is that it is genuinely adaptable, allowing each individual to create a house tailored to his or her needs.

Surface finishes for domed earthbag roofs can be water-resistant though not necessarily waterproof. If the climate area your building in is rainy, you may want to consider a conventional roof type that provides an overhang to protect the walls from constant rain. Some options are; lime render or whitewash, cement-stabilized soil, papercrete, earthen plaster with lime render and whitewash.

Weatherproofing and plaster: In the earthbag construction system, the wall surface is never the bare earth, but whatever material the bags are made of. Therefore rendering an earthbag house is necessary for several reasons.

If the bags used for construction are polypropylene, they need to be covered within the first two to three months of exposure to direct sunlight, as UV light will cause the bags to deteriorate, exposing the material inside of the bag. If however, your earthbag structure has 10 percent or higher clay content and it the rows where properly tamped they should remain solid and stable even with weakened bags. If you have chosen gravel, scoria or loose composition the bags must be covered. The type of covering used will depend mainly on the climate and on the design of the house. For example, a dome in a rainy climate will require a plaster that is water resistant, such as lime, papercrete, or cement-stabilized soil. In extremely wet climates a waterproofing layer on the top part of a dome is essential if you have not built a conventional roof with an overhang.

Earthen plaster: If any plaster is used on a bare earthen wall that contains clay, the plaster should be a coating that breathes, allowing any moisture that enters the wall to escape. With earthen plasters, whatever moisture does penetrate into the walls will be absorbed automatically by the clay, due to its hygroscopic (water-thirsty) properties, and then released to the outside. There may be no other building material capable of regulating moisture levels as effectively as clay, which continually absorbs and releases moisture in response to the humidity of the home.

Among the advantages of earthen finishes are these attributes:

- Moisture-control
- Fire-resistance
- Odor-absorbent
- Nontoxic
- When dry, are unaffected by frost
- Aesthetically pleasing

The disadvantages of earthen plasters are that they have a low structural resilience; therefore the design of the house is critical. The plaster can erode easily if it possesses small amounts of clay or little if any straw. In cold climates; if moisture is allowed to penetrate the surface, the plaster will expand and contract as it freezes and thaws, breaking up the plaster. In cold areas it is good idea to cap the earthen plaster with a lime plaster.

Application: Earthen plasters are incredibly flexible to work with, allowing everyone to find a personal way of mixing and plastering. They can be applied in two or more stages. The first layer should fill in the large gaps and crevices and to build up the main bulk, creating a fairly even surface for the smoother plaster to go on. This first layer should contain straw that mixes to create a plaster reinforcing network and helps to fill out large holes or build up bulk where it is needed, such as window sills.

Earthbag walls contain indentations between the courses of tamped bags, making it easier for the plaster to "key into" or adhere. No plaster-reinforcing lath is needed. As the first coat of plaster mix (well reinforced with straw) is applied, it should not be smoothed out but left rough so the next layer of plaster will adhere.

The second coat of earthen plaster is more refined and can be very thin, just enough to allow a final smoothing out. The mixture is of finely sieved sand and clay with or without straw or stabilizers.

If your final coat of plaster does not contain enough clay you will need to add a stabilizer to make your plaster more durable and resistant to moisture. It is the glue that binds filler particles together.

Beware of modern stabilizers since they tend to restrict movement and permeability to moisture, which is needed in earthen structures. Lime-based or other natural stabilizers do allow the walls to breathe and move. Sources other than lime are also:

- Vegetable stabilizers
- Processed natural binders
- Animal stabilizers

Papercrete: You can replace the earthen plaster entirely with a paper mixture that is a type of industrial strength papier-mâché. If applied in several 2-inch layers an R-value 2.8 per inch can be achieved.

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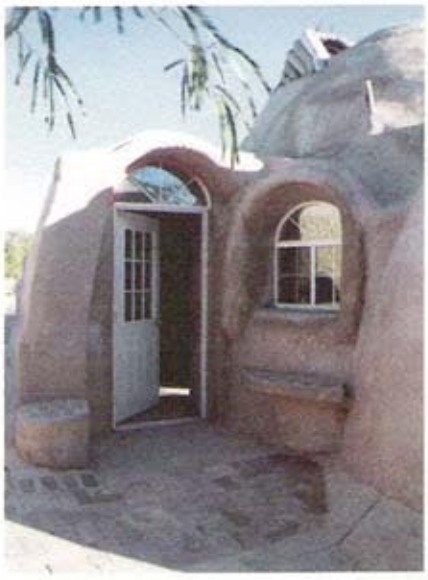
The Future

Approximately one third of the people of the world live in houses built with earth, and tens of thousands of towns and villages have been raised practically from the ground they are standing on. Today, world consciousness about the use of natural resources and the new perception of building codes as the steward not only of individuals' safety, but of the planet's equilibrium, are leading us into the new mellennium of sustainable living.



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