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Integrating Sustainable Design Principles into the Adaptive Reuse of Historical Properties

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ABSTRACT: The construction of new buildings consumes significant amounts of raw materials and land assets that might be better used for other functions. This consumption of land and materials can be reduced when adaptive reuse of existing buildings is allowed to replace the demolition/reconstruction. Adaptive reuse can also facilitate the preservation of historical structures that might otherwise fall into disrepair and decay, and eventually be demolished. The resulting adaptive reuse of existing structures must incorporate principles of historic and sustainable design. This work formulated specific guidelines to help installation planners integrate concepts of sustainability into the adaptive reuse of historical buildings in a way that will enhance the built environment while preserving the nation's cultural endowment. These guidelines may also be generically applied to the adaptive reuse of any structure.

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Conversion Factors

Non-SI units of measurement used in this report can be converted to SI units as follows:

Multiply	By	To Obtain
acres	4,046.873	square meters
cubic feet	0.02831685	cubic meters
cubic inches	0.00001638706	cubic meters
degrees (angle)	0.01745329	radians
degrees Fahrenheit	(5/9) x (°F – 32)	degrees Celsius
degrees Fahrenheit	(5/9) x (°F – 32) + 273.15.	kelvins
feet	0.3048	meters
gallons (U.S. liquid)	0.003785412	cubic meters
horsepower (550 ft-lb force per second)	745.6999	watts
inches	0.0254	meters
kips per square foot	47.88026	kilopascals
kips per square inch	6.894757	megapascals
miles (U.S. statute)	1.609347	kilometers
pounds (force)	4.448222	newtons
pounds (force) per square inch	0.006894757	megapascals
pounds (mass)	0.4535924	kilograms
square feet	0.09290304	square meters
square miles	2,589,998	square meters
tons (force)	8,896.443	newtons
tons (2,000 pounds, mass)	907.1847	kilograms
yards	0.9144	meters

Preface

This study was conducted for the U.S. Army Environmental Policy Institute (AEPI) under the reimbursable Work Unit No. J0F8K3, "Policy and Guidance for Integrating Sustainable Design Principles into the Adaptive Reuse of Historical Properties." The technical monitor was David Eady, AEPI.

The work was performed by the Energy Branch (CF-E) of the Facilities Division (CF), Construction Engineering Research Laboratory (CERL). The Principal Investigator was Donald F. Fournier. Thomas J. Hartranft is Chief, CF-E, and L. Michael Golish is Chief, CF. The associated Technical Director is Gary W. Schanche. The technical editor was William J. Wolfe, Information Technology Laboratory. The Director of CERL is Dr. Alan W. Moore.

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1 Introduction

Background

The construction of new buildings consumes significant amounts of raw materials and land assets that might be better used for other functions. In the United States, for every six new houses built in the private sector, one house is demolished. In the commercial sector, for every four commercial buildings constructed, one building is demolished. The same pattern of demolition/construction takes place on military installations as well. This consumption of land and materials can be reduced when *adaptive reuse* of existing buildings is allowed to replace the demolition/reconstruction. Often, demolition is unnecessary when older buildings can cost-effectively be adapted to current uses and energy-efficiency expectations—while existing buildings are (or can be made) sustainable.

Adaptive reuse can also facilitate the preservation of historical structures that might otherwise fall into disrepair and decay, and eventually be demolished. In fact, the concepts of historic preservation and sustainability are complementary. This pairing of historic preservation and sustainability is especially applicable to military installations, considering the number of historical buildings—which should be preserved—on military installations.

The resulting adaptive reuse of existing structures can minimize the need for new buildings and infrastructure, and in doing so, must incorporate principles of historic and sustainable design, applied with care, thoughtful design, and flexibility. The Secretary of the Interior's Standards for Historic Preservation Projects and the National Park Service's Preservation Briefs guide the protection, maintenance, and replacement of historic buildings, and are consistent with the sustainable design principles that encourage maximum reuse of the existing building components, restoration of passive aspects of the original design, and preservation of the microclimate created by the historic plantings and site usage. These documents form the basis for specific guidelines to help installation planners integrate concepts of sustainability into the adaptive reuse of historical buildings in a way that will enhance the built environment while preserving the nation's cultural endowment. These guidelines may also be generically applied to the adaptive reuse of any structure.

Objective

The objective of this work was to provide information and guidance for adaptive reuse of buildings consistent with the goals of historic preservation and sustainable design to create more efficient and effective living and working spaces. These guidelines address these goals through design and construction.

Approach

This work gathered information from a number of sources into a consolidated set of practical guidelines for combining adaptive reuse with historical preservation:

1. Two sets of guidelines or rating systems can be used to assess the sustainability or "green" attributes of the design-construction process of a given project.
    a. The *Leadership in Energy and Environmental Design Green Building Rating System (*LEED2.1®*)* is a consensus standard developed by the U.S. Green Building Council (USGBC 2000).
    b. The *Sustainable Project Rating Tool (SPiRiT)* developed by the U.S. Army Engineer Research and Development Center (Schneider et al. 2001) was developed under a licensing agreement with the USGBC to adapt *LEED®)* to the military built environment.
2. Standards for rehabilitation of historic structures include:
    a. *The Secretary of the Interior's Standards for Rehabilitation with Illustrated Guidelines for Rehabilitating Historic Buildings* (Morton et al. 1992)
    b. *Secretary of the Interior's Guidelines for Appropriate Designs: Energy Conservation and Solar Energy for Historic Buildings* (Vonier et al. 1981)
    c. *Secretary of the Interior's Standards for the Treatment of Historic Properties with Guidelines for the Treatment of Cultural Landscapes* (Birnbaum et al. 1996).
3. Chapter 2 of this report explores the scope of project site design and construction for adaptive reuse that will address the disturbance of the existing site, plans for building additions, ameliorating heat island effects, the control of stormwater or run off, and light pollution, and consideration of site ecology, along with recommended approaches to each issue.
4. Chapter 3 illustrates how an adaptive reuse project can facilitate efficient water use through water conservation and efficient irrigation.
5. Chapter 4 addresses building enclosure and energy systems.
6. Chapter 5 provides resource and material recommendations that include maximum reuse of the existing structure, selection of materials, use of salvaged materials, and management of construction waste.

7. Chapter 6 explores a crucial sustainable design goal—a healthy and productive indoor environment.

Scope

This document provides information on specific sustainability issues, alternative courses of action to address them, and their specific application to the adaptive reuse of historic structures. This information is presented under the categories of Site Related Aspects, Water Usage, Building Enclosure and Energy Systems, Building Materials, and Indoor Environment. As these guidelines are not intended to be "all encompassing" and do not constitute a comprehensive primer for sustainability or the preservation of historic buildings, references to more complete technical works and reports are provided. This publication is meant to provide practical help in incorporating sustainable design in the context of the adaptive reuse of historical buildings.

Mode of Technology Transfer

This report will be made accessible through the World Wide Web (WWW) at URL:

http://www.cecer.army.mil

2 Site Related Aspects

Existing structures and site improvements represent a significant investment in energy, materials, services, culture, and heritage. These endowments should be incorporated into any new design or adaptive reuse. Once a building has been selected for adaptive reuse, many siting issues are predetermined and may not be altered by the project. Long ago, when the land was initially developed, alterations to the local ecology and habitat were undertaken and the orientation of the building and siting established. Fortunately, the original design of many historic buildings incorporate the appropriate consideration of these issues, which are now part of their endowment. Other sustainability factors, using existing infrastructure, connectivity to public transit systems, and goals for higher development density, should be incorporated into the decision process for adaptive reuse building selection. Buildings on inappropriate sites such as those located in a flood prone area or within 100 ft of a wetland as defined by 40CFR, Parts 230-233, should be avoided. Once the adaptive reuse choice is made, the scope of project design and construction must address site features and ecology; site disturbance; building additions; parking, impervious surfaces and heat island effects; and the control of stormwater, run off, and light pollution. The following sections addresses each of these issues and makes specific recommendations.

Site Features and Ecology

Issue

Identify and mitigate existing site problems including contamination of soil, water, and air. Site habitat should be enhanced and expanded while optimizing the site's existing natural features and placement or removal of man-made features on the site.

Recommendations

Develop a site environmental management and mitigation plan that addresses the interdependence and interconnectivity of the site and surrounding ecosystem. Maximize the use of free site energy and plan facility, parking, and roadways to "fit" existing site contours, limiting cut and fill, while evaluating site resources to ascertain how each can enhance the proposed project and vice versa. Take maximum advantage of the site's solar and wind attributes, using landscaping to optimize conditions and contribute to overall energy efficiency. The following recommendations apply to historical structures:

- Undertake environmental protection-required work.
- Preserve and enhance existing trees, hydrological features, ecosystems, habitats for native species, and cultural resources.
- Reclaim or re-establish natural resources in a manner that promotes the highest degree of environmental protection and promotes biodiversity, while preserving significant historic features, materials, and finishes. For example, reclaim a wetland to comply with applicable environmental regulations, and re-establish the feature as it historically appeared.
- Retain plant materials, trees, and landscape features, especially those that perform passive solar energy functions such as sun shading and wind breaks.
- Select indigenous plant species for site restoration and landscaping that are compatible with existing landscapes. Consult with landscape architects, historical preservation staff, and native plant societies.
- Remove nonsignificant features that detract from or have altered the spatial organization and land patterns.
- Retain the historic relationship between buildings and the landscape (cf. Figure 1).

Cautions

If the landscape is important to defining the overall historic character of the building, replace or reintroduce vegetation, plants, and trees in a way that is compatible with *"retaining the historic relationship between buildings and the landscape.*"

Comments

The preservation or enhancement of the surrounding site ecosystem is important from a sustainability standpoint and supported by preservation guidelines, as sustainable buildings recognize and reflect their context. The site should be considered as part of a "larger whole," and site design and redevelopment should establish contiguous networks with other natural systems within and beyond the site boundaries. Site design should not fragment the landscape or destroy any existing links that may weave through the site and the surrounding community. Sustainable site design recognizes the importance of native or natural habitat in urban settings (Kobet, Lee, et al. 1999).

Figure 1. The Martin's Point Marine Hospital, ME exemplifies the melding of site features and ecology (source, R. Young).

The location, orientation, and configuration of historic buildings have already been determined. Many were originally designed with these very issues (natural lighting, natural ventilation, shading, wind exposure, passive tempering) in mind and harnessing additional free site energy may be difficult. The removal of surrounding nonhistoric buildings and other obstructions should be considered if they adversely affect a building's access to natural light and wind. Landscape alteration may be considered if it does not affect the historic character of the relationship between buildings and the site. The Secretary of the Interior's Standards recommend "*placing a new addition that may be necessary to increase energy efficiency on noncharacter-defining elevations,*" allowing alteration of noncharacter-defining elevations for increases in energy efficiency. The design and placement of parking and roadways should be carefully considered. It is important from a preservation standpoint to keep additions for new use as unobtrusive as possible. Using existing site contours may or may not be the best way to accomplish this.

Site Disturbance

Issue

Site disturbance should be minimized, conserving existing natural areas, and damaged areas should be restored to maintain habitat and promote biodiversity.

Recommendations

- Reduce the development footprint (including building additions, access roads, and parking) to the minimum required for the new use of the historic structure.
- Reduce the size of construction footprints by careful control of program needs and the stacking of floor plans if consistent with the existing structure.
- Establish and clear marked construction and disturbance boundaries. Delineate laydown, recycling, and disposal areas. Use existing paved areas as staging areas.
- Note requirements on plans and in specifications and establish contractual penalties for destruction of trees and disturbance of site areas noted for protection.

Cautions

Do not introduce heavy machinery into areas where they may disturb or damage important landscape features or archeological resources (cf. Figure 2).

Figure 2. Site disturbance of archaeological resources (source, R. Young).

Comments

Site disturbance is an issue for any construction project where demolition and staging of construction materials will take place (Figure 3). Extra care must be taken when building additions are being considered,

> Because such expansion has the capability to radically change the historic appearance, an exterior addition should be considered only after it has been determined that the new use cannot be successfully met by altering noncharacter-defining interior spaces (Secretary of the Interior's Standards for Rehabilitation).

Erosion and Sedimentation Control and Pollution Prevention During Construction

Issue

During the construction phase of an adaptive reuse, soil erosion and subsequent polluted runoff or dispersion can create significant negative impacts on water and air quality.

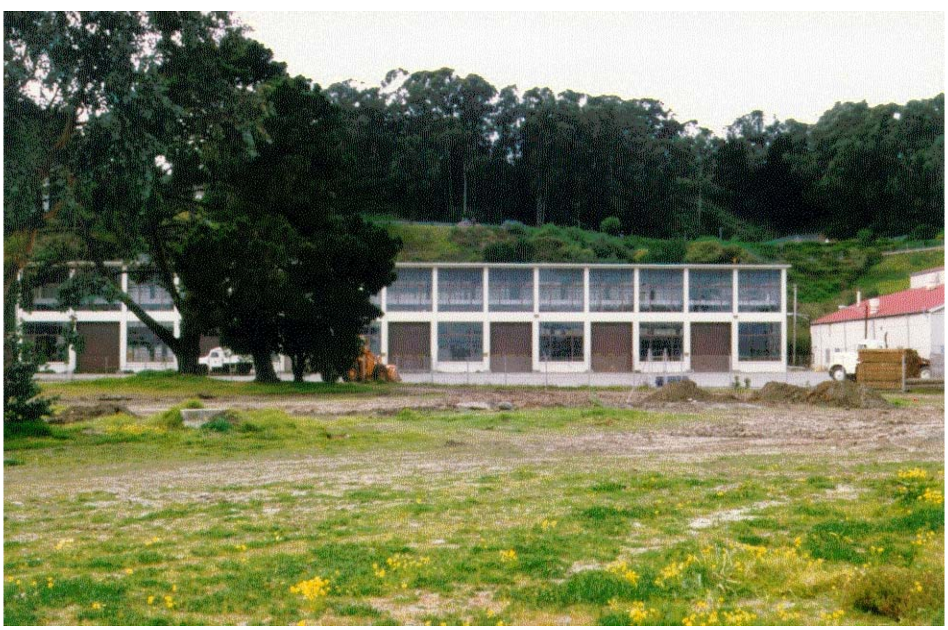

Figure 3. Site disturbance resulting from poorly planned staging of construction materials (source, R. Young).

Recommendations

- Minimize disturbance of the terrain around the building and elsewhere on the site, thus eliminating potential erosion and secondary pollution while preserving important landscape features or archeological resources.
- Survey and document areas where the terrain will be altered to determine the potential impact to important landscape features or archeological resources.
- Maintain proper drainage to assure that water does not erode foundation walls, drain toward the building, or damage and erode the landscape.
- Remove toxic building materials only after thorough testing has been conducted and less invasive abatement methods (such as encapsulation) are deemed inadequate.
- Develop and use maintenance practices that respect infrastructure such as cleaning out debris from drainage systems.
- Develop sediment and erosion control plans and pollution prevention plans that reflect best management practices for stormwater management, available on the USEPA web site, show below. The plans should prevent wind or water soil erosion during construction, subsequent sedimentation in storm sewer or receiving streams, air pollution from dust and particulate matter, and hazardous material and petroleum, oil, and lubricant (POL) discharges into storm water systems.

Cautions

Failing to maintain adequate site drainage can lead to buildings and site features being damaged or destroyed. Changing site grading can cause water to drain improperly leading to catastrophic failure.

Comments

Sustainability guidelines and historic preservation guidelines are complementary on the issue of erosion. The Secretary of the Interior's Standards recommend:

> Protecting and maintaining the building and building site by providing proper drainage to assure that water does not erode foundation walls; drain toward the building; nor damage or erode the landscape.

They differ in the means and methods to be used in preventing erosion. *LEED*® and SPiRiT suggest "*maintaining vegetated ground cover and providing ground cover that will meet this prerequisite.*" While maintaining **existing** ground cover may comply with Secretary of the Interior's Standards, the use of **new** ground cover on an historic site must be compatible and complementary with existing cover.

Additional information is available in the *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*, Chapter 4, "Management Measures for Urban Areas," Section II, "Urban Runoff," through URL:
http://www.epa.gov/owow/nps/MMGI/Chapter4/index.html

Post Construction Stormwater Management

Issue

Minimize the post-construction disruption of natural water flows by reducing storm water runoff from impervious areas, increasing on-site infiltration, and reducing contaminants in the runoff.

Recommendations

- Develop and implement a stormwater management plan that results in no net increase in the peak discharge rate of stormwater runoff from the site after new conditions are established. If the existing site has 50 percent or greater impervious surface, then implement an enhanced stormwater management plan resulting in a 25 percent decrease in the peak rate of stormwater runoff after new conditions are established.
- Significantly reduce impervious surfaces, maximize on-site stormwater infiltration, and retain existing pervious and vegetated areas.
- Capture rainwater from impervious areas of the building for groundwater recharge or reuse within the building (see Chapter 3, "Water Usage," p 18).
- Where compatible, use biological stormwater management features such as constructed wetlands, stormwater filtering systems, bioswales, bio-retention basins, and vegetated filter strips for pollutant load reduction. Use open vegetated swales where space permits to reduce drainage velocity and erosion, reduce system maintenance, increase vegetative variety, and support wildlife habitat.
- Remove nonsignificant site features that detract from (or have altered) the spatial organization and land patterns.
- Design and install any new water feature compatible with the historic context and preserve the historic character of the landscape. For example, site a new retention basin or vegetative swale in a secondary, or nonsignificant, space in the cultural landscape (Birnbaum et al., *Guidelines for the Treatment of Cultural Landscapes*, p 78).

- Design new topographic features so that they are as unobtrusive as possible and preserve the historic landscape. For example, design and install drainage systems to protect historic topographic features (Birnbaum et al., *Guidelines for the Treatment of Cultural Landscapes*, p 62).

Comments

Limiting the disruption of natural water flows by minimizing storm water runoff is desirable. In the case of an existing historic building, the material choices, orientation, and siting of the building have already been determined, requiring that a successful stormwater management system be developed around existing parameters. If impervious surfaces are determined to be historically significant, their reduction is not viable. "*Distinctive materials, features, finishes, and construction techniques or examples of craftsmanship that characterize a property will be preserved"* (Secretary of the Interior's Standards for Rehabilitation). If a surface is determined **not** historically significant, it may be altered to meet stormwater management guidelines. The capture of rainwater from impervious areas of the building for groundwater recharge or reuse within the building is encouraged so long as the significant features of the historic building are not disturbed.

"Vegetated swales" can be used as long as they do not compromise the overall landscape pattern and any landscapes that help define the overall historic character of a building must be preserved.

Further information can be obtained from the *Soil and Water Conservation Society* web site, at URL:
http://www.swcs.org/

The USEPA web site can be found at URL:
http://www.epa.gov/OW

A complete guide to storm water management practices and technologies is available in the *Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters*, Chapter 4, "Management Measures for Urban Areas," Section II, "Urban Runoff" through URL:
http://www.epa.gov/owow/nps/MMGI/Chapter4/index.html

The *National Park Service Historic Landscape Initiative* web site is at URL:
http://www2.cr.nps.gov/hli/index.htm

Building Additions

Issue

Additions to buildings and structures may be contemplated as long as the design does not compromise historic elements of the existing structure.

Recommendations

- Locate exterior additions at the rear or on an inconspicuous side of a historic building.
- Place new additions such as balconies and greenhouses on noncharacter-defining elevations and limit them in size and scale in relationship to the historic building.
- Design required rooftop additions so they are set back from the wall plane and are as inconspicuous as possible when viewed from the street.
- Place a new addition that may be necessary to increase energy efficiency on noncharacter-defining elevations.

Comments

New additions for adaptive reuse require location selection. "*Because such expansion has the capability to radically change the historic appearance, an exterior addition should be considered only after it has been determined that the new use cannot be successfully met by altering noncharacter-defining interior spaces"* (Secretary of the Interior's *Standards for Rehabilitation*). The feasibility of an addition should be based primarily on historic preservation considerations. (Figures 4 and 5 show a good example of how well designed construction additions can maintain a building's historic appearance.) The Secretary of the Interior's Standards recommend:

> Locating the attached exterior addition at the rear or on an inconspicuous side of a historic building, [and] Placing new additions such as balconies and greenhouses on noncharacter-defining elevations and limiting size and scale in relationship to the historic building.

Figure 4. Marine Hospital, ME, front view of original building (source, R. Young).

Figure 5. Marine Hospital, ME, side view showing new addition (source: R. Young).

Parking, Impervious Surfaces, and Heat Island Effects

Issue

The amount of impervious surface (paved) on a site should be minimized to reduce heat island effects and encourage alternatives to private automobile usage. Heat islands, thermal gradient differences between developed and undeveloped areas, are often caused by heat absorbing materials in the built environment. This effect can be ameliorated by reducing the amount of impervious surfaces, causing a lower microclimate temperature of the site, lowering building energy consumption, and reducing the temperature stress on wildlife habitat.

Recommendations

- Minimize the amount of parking provided and afford alternatives to private automobile usage. Once parking is at a minimum, the heat island effects should be reduced through a variety of methods that do not compromise the historical aspects of the building. Many historic buildings exhibit mature landscaping that already meets sustainability goals.
- Minimize impervious surfaces by sizing parking capacity at minimum requirements or adding no new parking. Consider the removal of excess parking.
- Consider "shared" parking among several buildings using a minimum number of parking areas as opposed to random, multiple parking lots.
- Provide preferred parking for carpools or vanpools for 5 percent or more of the building occupants.
- Design any required new parking, loading docks, or ramps to be as unobtrusive as possible, minimizing any negative effects on the historic character of the setting.
- Add bike paths and walkways to encourage walking and enhance connectivity to mass transit and other buildings.
- Provide secure bicycle storage and afford convenient clothes changing/shower facilities for cyclists, joggers, and walkers.
- Retain plant materials, trees, and landscape features, especially those that perform passive solar energy functions such as sun shading and wind breaks. Shade at least 30 percent of the site's nonroof, heat absorbing, impervious surfaces.
- In the absence of shading, use light-colored/high-albedo materials (reflectance of at least 0.3) for 30 percent of the site's nonroof impervious surfaces.
- Use an open-grid pavement system with a net impervious area of less than 50 percent.
- Place parking underground.

Cautions

Do not place parking facilities directly adjacent to historic buildings as automobiles can damage buildings or important landscape features. The location, size, and composition of the parking area shown in Figure 6 give a prime example of poor parking lot design; parking is too close to the building, has dark surfaces and little or no shade.

Figure 6. Impervious surfaces of large parking areas located close to buildings can give rise to "heat island effects" (source, R. Young).

Retain the historic relationship between buildings and the landscape through the design of required new features so as to preserve historic spatial organization and land patterns.

Do not introduce new features that are visually incompatible in size, scale, design, material, color, and texture.

Comments

Sustainability guidelines suggest:

> shade (calculated on June 21, noon solar time) using native or climate tolerant trees and large shrubs, vegetated trellises, or other exterior structures supporting vegetation. Substitute vegetated surfaces for hard surfaces.

The Secretary of the Interior's Standards recommend "*Retaining the historic relationship between buildings and the landscape*." Also, the Secretary of the Interior's Standards do not recommend "*Introducing a new landscape feature, including plant material, that is visually incompatible with the site, or that alters or destroys the historic site patterns or vistas*." Landscapes should be preserved if they are important to defining the overall historic character of a building. New landscape features such as shade trees may be used if they are visually compatible with the site and do not alter or destroy historic site patterns or vistas. Native trees or shrubs are preferable if new trees are to be introduced on a historic site.

Historic considerations may preclude the use of underground parking or an open grid pavement system. The Secretary of the Interior's Standards state that "*placing parking facilities directly adjacent to historic buildings where automobiles may cause damage to the <historic> buildings or to important landscape features*" is not recommended, as well as "*locating any new construction on the building site where important landscape features will be damaged or destroyed, for example, removing a lawn and walkway, and installing a parking lot.*" A compromise solution is the unobtrusive location of new parking lots using a material such as an open grid pavement system or light colored asphalt.

The location of a historic building cannot and should not be changed to facilitate the use of mass transit or alternative transportation. Some features such as bicycle racks and pathways can be incorporated in the reuse of an historic building while retaining the historic relationship between the building and the landscape and fostering alternative transportation. Similarly, new additions or features, necessary for successful adaptation, may be added as long as they are unobtrusive and maintain the historic building/landscape relationship. Any new parking and pedestrian pathways should also be designed to maintain the historic building/landscape relationship. Ascertain original pedestrian circulation patterns and use them to lay out and design new pathways on the site.

Exterior Lighting and Light Pollution

Issue

Use efficient exterior lighting while eliminating light pollution from the building site.

Recommendations

- Follow, but do not exceed, Illuminating Engineering Society of North America (IESNA) foot-candle level, cut-off angles, and uniformity of light requirements as stated in the *Recommended Practice Manual: Lighting for Exterior Environments* (RP-33-99).
- Design exterior lighting to put the light where it is needed using luminaires that contain the light within the design lighted area so no unplanned lighting leaves the building site. This can be achieved using cutoff luminaires that provide shielding of emitted light to reduce light pollution.

- Do not illuminate exterior landscaping and building architectural features simply for enhancement.
- Design exterior lighting consistent with security lighting requirements.
- Install automatic controls on exterior lighting using photocells and motion detectors.

Cautions

Do not replace historical light features that are energy inefficient, rather, improve their energy efficiency through retrofit of key components; for example, preserve an entire historic light standard by retrofitting the luminaire with a more efficient lamp and ballast system.

Comments

Site lighting design must balance energy efficiency, night vision, light pollution, security, and aesthetics. Some compromises may be necessary. While an historic luminaire in its original location should not be altered, it may be retrofitted to become more efficient. New lighting resulting from rehabilitation or other changes to a historic building should follow the requirements above. Additional information about exterior lighting is available from the *Illuminating Engineering Society of North America* web site, at URL:

http://www.iesna.org/

and from the *International Dark-Sky Association* web site located at URL:

http://www.darksky.org/ida/index.html

3 Water Usage

The consumption and availability of water is becoming an increasingly important issue. During the first three quarters of the 20th century, the quantity of fresh water consumed in the United States increased 10-fold, while the population quadrupled (Gleick 2001). Communities are rethinking their priorities for water usage and water is being used more efficiently. While water withdrawals have fallen by more than 20 percent since their peak in 1980, the demands of rapid urban development combined with increasing needs of agriculture and industry has caused water availability problems in certain geographic areas. This issue will continue to increase in importance as population and development pressures require increasing amounts of potable water. Increased efficiency of water usage can easily be accomplished in an adaptive reuse project and that is compatible with the requirements of historic preservation.

Landscaping and Irrigation

Issue

The use of potable water for landscape irrigation should be limited or eliminated.

Recommendations

- Use high efficiency irrigation technology such as micro-irrigation, moisture sensors, or weather-based controllers.
- Capture rain or recycled site water to reduce potable water consumption for irrigation.
- Specify water-efficient, native or adapted, climate tolerant plantings.
- Work with regulators to investigate systems, methods, devices, or technologies of equivalent or superior effectiveness to those prescribed by regulation so that unnecessary alterations can be avoided (Guidelines for the Treatment of Cultural Landscapes).
- Improve the efficiency of existing features through nondestructive means. For example, use a water recirculating system in a fountain rather than uncontrolled continuous discharge to a storm system.

Comments

Many existing historic landscapes already incorporate native or adapted plant species, so irrigation may not be required. If landscape irrigation is present, investigate its removal. Any new plantings should be consistent with the historical nature of the existing landscape.

The USEPA's web site on water efficiency is available at URL:
http://www.epa.gov/OWM/water-efficiency/index.htm

Water and Wastewater Reduction

Issue

The generation of wastewater and potable water demand should be limited or reduced.

Recommendation

- Specify water conserving plumbing fixtures that meet or exceed Energy Policy Act (EPACT) of 1992 fixture requirements
- Consider ultra high efficiency or dual flush toilets and waterless urinals.
- Install low-flow aerators on faucets.
- Install self-closing or electronically controlled faucets.
- Use alternatives to potable water, such as gray water or captured rainwater, for sewage transport.
- Use recycled or stormwater for heating, ventilation, and air conditioning (HVAC)/process make up water.
- Install high efficiency cooling tower systems designed to minimize water consumption from drift, evaporation, and blow down.

Cautions

Cooling towers should be carefully placed to be unobtrusive and to blend with the historic character of the building and setting. More information on water reuse can be found at the U.S. Environmental Protection Agency (USEPA) web site, URL:
http://www.epa.gov/region9/water/recycling/index.html

4 Building Enclosure and Energy Systems

Improving energy efficiency and enhancing conservation during rehabilitation and adaptive reuse of an historic building affords significant opportunities to reduce environmental impact and life cycle costs. Some historic building or site features such as cupolas, shutters, transoms, skylights, sunrooms, porches, and plantings play secondary energy-conserving roles. Before retrofitting historic buildings for energy efficiency, first identify existing historic features to assess their inherent energy conserving potential. If retrofitting measures are necessary, such work must be carried out with particular care to ensure that the building's historic character is retained. As larger quantities of moisture are typically present in the interiors of most historic buildings, retrofit measures must be thoroughly examined to minimize moisture-related deterioration. Materials that are chemically or physically incompatible with existing materials, or that are improperly installed, can cause serious harm to historic materials or pose significant health and safety problems. The basic building components should be surveyed to identify methods of construction and presence of insulation. The presence of adequate vapor barriers should be determined, sources of air infiltration should be identified, and the condition of the exterior wall materials and the roof should be assessed to determine the weather tightness of the building.

Either ASHRAE/IESNA 90.1-1999 or Corps of Engineers Technical Instruction 800-1, whichever is more conservative, should be the minimum standard of energy performance for the adaptive reuse. Their prescriptive aspects should be considered as minimums, as better energy performance can often be cost effective. Optimize energy performance by integrating all aspects of project design; including efficient mechanical systems, effective and operational controls, maximizing passive tempering and natural ventilation, and upgrading the lighting, building envelope, and fenestration to reduce energy system size and operating times. View the building as a whole system and optimize the design through an integrated team approach. All of the design disciplines need to work together and ensure that the building systems function as a whole and are optimized as such. If disciplines work independently, each will make assumptions for the worst case and size or design their system accordingly. This tends to result in systems that are grossly oversized, do not function well together, and compromise the building's functioning as an integrated whole. It results in poor operation efficiency and poor space conditioning.

Once building performance has been optimized, active renewable energy systems should be considered. Technology is advancing in photovoltaics and building-integrated systems are now becoming cost effective. Electricity and other energy sources should be evaluated in light of their environmental impact, not just their costs. Distributed generation technologies such as fuel cells and microturbines using heat recovery should also be considered. Once the design and construction has been completed, the building should go through a commissioning process to ensure all systems operate as intended. Education of the building operations and maintenance staff ensures that systems are operated as designed and are maintained at optimal performance throughout their life.

Building Envelope

Issue

Use the envelope enclosure to minimize space conditioning loads.

Recommendations

- Install thermal insulation in attics and unheated cellars and crawlspaces to reduce thermal loads and increase the efficiency of the mechanical systems.
- Install insulating material on the inside of masonry walls to increase energy efficiency unless there is character-defining interior molding around the window or other interior architectural detailing that must be preserved.
- Maintain porches and double vestibule entrances to retain heat or block the sun and provide natural ventilation.

Cautions

- Do not apply thermal insulation with high moisture content into wall cavities, as it may damage historic fabric.
- Before installing wall insulation, consider its effect on interior molding or other architectural detailing.

Windows and Glazing

Issue

Improve energy efficiency of the building through effective fenestration.

Recommendations

- Use the inherent energy conserving features of a building by maintaining windows and louvered blinds in good operable condition for natural ventilation.
- Improve the thermal efficiency of windows with weather-stripping, storm windows, caulking, interior shades, and if historically appropriate, blinds and awnings.
- Install interior storm windows with airtight gaskets, ventilating holes, and/or removable clips to ensure proper maintenance and avoid condensation damage to historic windows.
- Install exterior storm windows that do not damage or obscure the windows and frames.
- Replace entire windows with high performance windows if the original windows are severely deteriorated and cannot be restored.
- If windows are in good condition, investigate replacing single glazing with high performance multi-pane sealed units.
- Add skylights to make direct use of sunlight and reduce the demand for electrical lighting. They may also function as passive solar collectors. Operable skylights may also induce natural ventilation and cooling.

Cautions

- Keep historic shading devices and keep them in an operable condition.
- Replace historic multi-paned sashes with new thermal sashes that match original appearance.

Do not install interior storm windows that allow moisture to accumulate and damage the window.

- Do not install new exterior storm windows that are inappropriate in size or color.
- Do not replace windows or transoms with fixed thermal glazing or permit windows and transoms to remain inoperable. Use them for their energy conserving potential.
- Preserve the essential character of the fenestration.
- Skylights should be placed out of view from main elevations and principle views and care should be taken to avoid types that are inconsistent with historic period features.

Comments

“Fenestration,” the physical arrangement of openings in a building’s exterior envelope (Deal, Nemeth, et al. 1998), typically involves the design and disposition of window assemblies and doors. Window assembly components include frame, sash, glazing, spacers, and any accompanying hardware. Glazing describes the transparent or translucent component of the window assembly. Good fenestration design can significantly improve the energy performance characteristics of a building with resultant positive impacts on the building occupant satisfaction and performance.

A window opening's basic function is the introduction of natural light and ventilation into the interior of a structure. The advent of clean, efficient, mechanical systems has diminished the natural ventilation component. Improved artificial light sources have led to a perceived decrease in the necessity for natural daylighting. As improved building systems increasingly control, modify, or simulate natural processes, the design parameters for windows and glazing systems have changed (Figure 7).

Figure 7. Windows and glazing can decrease the perceived need for natural light (source, R. Young).

In the 1970s, window design focused on mitigating unwanted solar heat gains and increased insulating capabilities in response to the energy crisis. Contemporary lighting systems can now be configured to automatically modulate depending on the amount of natural light supplied to a space. While fenestration system improvements (advanced glazing, improved glass coating and edge sealing techniques, suspended films, improved window frames, and sealant technologies) have substantially altered the function of windows and their impacts on interior spaces, these technological advances have not substantially altered the window's basic, historic function, and windows are increasingly valued for daylighting, energy savings, and fresh air. Many historical buildings were originally designed to meet these functions and any modernization of historic buildings should maintain these aspects of the original design. The referenced technical report *Energy Conservation Strategies for Windows and Glazed Surfaces* is available for downloading at URL:

http://www.cecer.army.mil/td/tips/browse/publications.cfm

Modifications to windows in historic buildings can be a contentious undertaking. Replacement of original windows is generally not recommended by the Secretary of the Interior's Standards. Consultation with the SHPO, and sometimes NPS, would be required before this could be done. The NPS Preservation Briefs on windows provide additional information on making existing sashes more energy efficient. Windows are a significant character-defining feature of an historic building and their modification for energy efficiency and sustainability is an important issue requiring great care and a thoughtful approach.

Interior Features

Issue

Improve efficiency through enhancement and retention of energy saving interior features.

Recommendations

Retain historic interior shutters and transoms exploiting their inherent energy conserving features.

Remove any dropped ceilings and return to original ceiling heights.

Comments

Many historic buildings were designed for daylighting with tall windows, clerestories, and transoms for directing light into interior spaces. Maintaining or restoring these features meets both goals of sustainability and historic preservation. Original ceiling heights encourage natural convection and enhance stratification that is beneficial in summer months as hot air rises. Ceiling fans redirect hot air back to floor level in winter months.

Exterior Colors and Materials

Issue

Use appropriate selection of exterior colors and materials to improve the thermal response of the building and reduce heat island affects.

Recommendations

Historic paint colors and finishes should be researched and reused; historic colors and finishes were often based on site and climatic conditions. Use ENERGY STAR Roof-compliant, high-reflectance and low emissivity roofing materials.

Cautions

The replacement or modification of exterior walls and roofs should consider the importance of the facade to the building as a whole and to its surroundings.

Comments

Exterior wall color affects building energy demands as light colors reflect more of the sun's heat, keeping walls cooler and, conversely, darker colors absorb more of the sun's heat. Darker colors are generally selected in northern or colder climates and lighter colors in southern or warmer climates. Masonry and stone materials absorb and retain heat, radiating it back out at a slower rate than many other materials. The issue of radiant heat transfer is addressed through the material properties of absorbance, emissivity, and reflectance. As the absorptivity and emissivity of a material increase, the reflectivity generally decreases (Vonier, Smeallie, et al. 1981). Additional information about color and its relationship to energy is available at URL:

http://www.colormatters.com/energymatters.html

The use of light-colored materials may also be restricted by historic guidelines. The Secretary of the Interior's Standards recommend "*repainting with colors that are appropriate to the historic building.*" Therefore, although using light-colored, highly reflective materials may be helpful from a sustainable point of view, it may not always be appropriate on historic buildings. If paint analysis reveals that a building's original color is a light or reflective color, it may justify a return to the original color (Figure 8).

Figure 8. Returning a building to its original color may be helpful from a sustainable point of view (source, R. Young).

If there is no physical reason to repaint (chalking, blistering, peeling, or cracking of paint), then repainting should wait until necessary (Preservation Brief 10). Another layer of paint simply for color's sake may cause a maintenance problem through paint accumulation, ultimately causing cracking and peeling.

New roofing with "*high reflectance and low emissivity*" may not comply with the Secretary of the Interior's Standards recommending:

> Identifying, retaining, and preserving roofs—and their functional and decorative features—that are important in defining the overall historic character of the building. This includes the roof's shape … as well as its size, color, and patterning. [This guidance precludes] applying paint or other coatings to roofing material that has been historically uncoated.

Therefore, unless the roof is currently comprised of reflective or low emissivity material, it should not be replaced with such and if the roofing has deteriorated to a point that it cannot be repaired, it should be replaced in kind, using physical evidence (historical, pictorial, and/or physical documentation) as a model to reproduce the feature. "If the same kind of material is not technically or economically feasible, then a compatible substitute material may be considered" (Secretary of the Interior's Standards, "Roofing"). The use of a substitute material with high reflectance and low emissivity may be considered if it conveys the same visual appearance. Additional information on roofing materials and products is available at URL:

http://energystar.gov/index.cfm?c=roof_prods.pr_roof_products

Information about heat island effects and building materials is available at the *Lawrence Berkeley National Laboratory* web site, at URL:

http://eetd.lbl.gov/HeatIsland/

Mechanical Systems and Ventilation

Issue

Improve the energy efficiency and effectiveness of HVAC systems.

Recommendations

- Replace air conditioning systems containing CFCs with new high efficiency units or natural gas fired units that do not use CFCs or HCFCs. Typically, select units based on part load efficiency and of the proper type for the application and size. On large units, cooling towers are significantly more efficient than smaller air-cooled condensers.
- Replace boilers and furnaces with high efficiency, low NOx, units.
- Replace domestic hot water heaters with high efficiency units.
- Consider ground source (geothermal) heat pumps.
- Reduce the required amount of ducting by having an equipment room on each floor and design ducts for minimum turns and pressure losses. Use lower velocity systems with variable air volume with large ducts and small fans.
- Lay out piping for straight runs with minimum turns and pressure drops with larger pipes and smaller pumps (Figure 9).

For mechanically ventilated buildings:

- Use ventilation heat recovery for systems of 4,000 cu ft/min.
- Control ventilation using carbon dioxide (CO_2) monitors. Set the controls to maintain indoor CO_2 levels no higher than 530 parts per million above outdoor CO_2 levels.
- Turn off mechanical ventilation when buildings are unoccupied. Maintain natural/nonmechanical ventilation systems in operation to prevent moisture build up and other problems if the building is left unoccupied.
- Design ventilation systems to produce an air change effectiveness (E) greater than or equal to 0.9 as determine by ASHRAE Standard 129-1997.

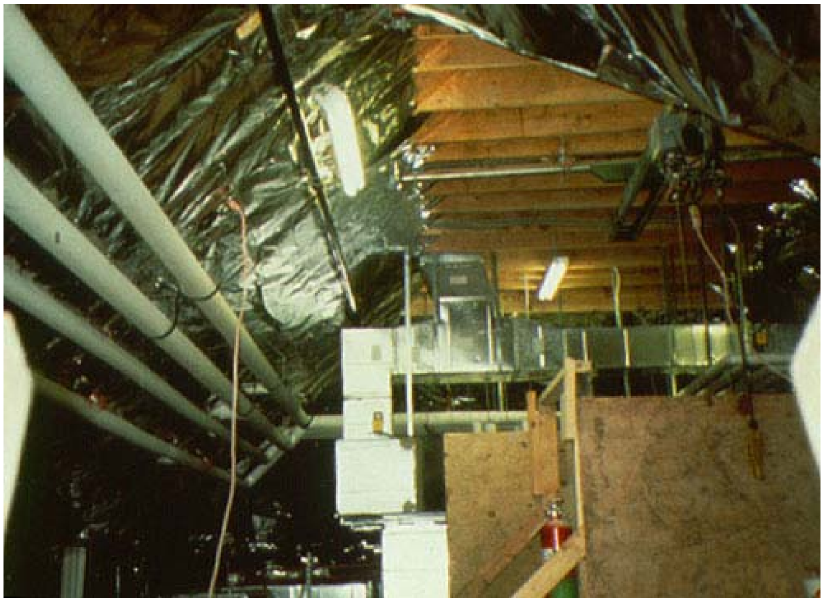

Figure 9. Upgraded service systems can be installed in attic spaces (Source: R. Young).

- Use direct digital control (DDC) for HVAC systems and include continuous commissioning within the monitoring and control package. (See "Controls and Thermal Comfort," p 42 and "Operations and Maintenance," p 55.)
- Identify, retain, and preserve the visible features of early mechanical and other building systems that are visible and important in defining the overall historic character of the building. These may include radiators, vents, fans, grilles, plumbing fixtures, switch plates, and luminaires.

Cautions

Recover any CFCs from removed equipment to prevent its escape into the environment. In buildings with masonry construction, the removal of radiant heating systems may lead to future water damage, mold, and mildew problems as air systems may not remove moisture from the walls.

Comments

Historical buildings were often designed to be compatible with the local climate. As a result, simply returning the building to its original configuration will often reduce energy consumption, after which additional efficiencies can often be obtained based on life cycle cost analyses and appropriate technology selections.

Additional resources on energy efficiency in buildings are abundant on the web. Some ready sources are:

- Building Technology Center at Oak Ridge National Lab, at URL: http://www.ornl.gov/btc/
- National Renewable Energy Laboratory, at URL: http://www.nrel.gov/
- Pacific Northwest National Laboratory, at URL: http://www.pnl.gov/
- Department of Energy Efficiency and Renewables, at URL: http://www.eere.energy.gov
- Lawrence Berkeley National Laboratory, at URL: http://www.lbl.gov/
- Whole Building Design Guide, at URL: http://www.wbdg.org/

Interior Lighting

Issues

Improve interior lighting effectiveness and reduce energy consumption.

Recommendations

Install high efficiency lamps, reflectors, and ballasts. Fluorescent lamps should use T-8's with electronic ballasts.

Replace incandescent luminaires and lamps wherever feasible with compact fluorescent lamps.

Use a combination of task and reduced ambient lighting.

Install light-emitting diodes (LED) for exit lighting.

Lighting Controls:

- Install occupancy sensors where cost effective.
- Install dual level switching on multiple lamp luminaires.
- Establish zones for lighting controls in daylit areas and use daylight dimming.

Comments

Historical buildings were originally designed for daylighting, a feature that should be preserved and enhanced. Design updated lighting systems and switching to retain that feature. Reuse existing historical luminaires, adding updated components and lamps to increase efficiency and effectiveness.

Renewable Energy

Issues

Promote sustainability through the use of active and passive renewable energy.

Recommendations

- Add roof-mounted solar collectors for domestic hot water heating.
- Add roof-mounted photovoltaic cells for electrical generation.
- Add wall-mounted solar collectors.
- Add integrated photovoltaic building elements.
- Add sunspaces for isolated gain passive solar collection.
- Add thermal mass to enhance passive tempering.

Cautions

Design and install solar collectors to be compatible with the configuration, color, and texture of the roof and walls. Sunspaces and thermal mass should be added only if compatible with the character of the building.

Comments

The existing site and building configuration must lend itself to renewable energy, as solar energy systems require access to the sun's path. Photovoltaic technology is becoming more cost effective, especially building integrated systems, and many buildings will be retrofitted in the future as costs come down and fossil fuel and electricity prices go up. Any redesign of roof structures should accommodate potential solar systems. Sunspaces should be located to provide maximum energy benefits and to not obstruct or visually impair the appearance of the building (Figure 10). Glazing surfaces should be on a plane compatible with the building's facades and lines and the size and scale of the sunspace should be compatible with the scale of the building.

Figure 10. Passive solar orientation with east/west shade trees is a good use of renewable energy (source, R. Young).

Additional information about renewable energy applications is available from:

National Renewable Energy Laboratory web site, at URL:
http://www.nrel.gov/

Sandia National Laboratory web site, at URL:
http://www.sandia.gov/Renewable_Energy/renewable.htm

Distributed Generation

Issue

Install onsite generating capability that is more efficient and produces less pollution than grid source electricity.

Recommendations

- Install microturbine generators with heat recovery.
- Install fuel cells with heat recovery.
- Install a reciprocating engine driven generator with heat recovery.

Comments

Distributed power generation technology is rapidly approaching the commercial stage of development, becoming more economical, reliable, cleaner, and flexible than grid source electricity. The increased use of these small, modular gas-fueled power systems will revolutionize the power market. Distributed generation systems provide fuel flexibility by operating on natural gas, propane, or fuel gas (derived from any hydrocarbon source). Distributed generation technology can provide standby power, combined heat and power, peak shaving, grid support, or standalone capacity resulting in enhanced reliability, high quality power, higher conversion efficiency, reduced line losses, peak power cost avoidance, low emissions, and siting flexibility.

Further information is available on the web at the following sites:

U.S Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory (ERDC-CERL), Fuel Cells, at URL:

http://www.dodfuelcell.com

and general information, at URL:

http://www.cecer.army.mil

National Energy Technology Laboratory, general information on technologies, at URL:

http://www.netl.doe.gov/

5 Building Materials

Sustainable design for adaptive reuse requires a holistic approach to the use of existing buildings including a comprehensive evaluation of materials. While conventional construction projects are typically evaluated only on first cost basis, high-performance, sustainable buildings consider all life-cycle costs. Reusing construction materials and using environmentally friendly materials leads to a high quality design that accounts for the environmental costs associated with creating, procuring, and assembling materials, as well as their impact on building occupants when completed (Kobet, Lee, et al. 1999). The existing building materials in the building, and those proposed in the renovation, must be evaluated through a life cycle assessment (LCA) ascertaining their impacts over their entire life span from manufacture to reuse or disposal. The LCA must include "upstream effects," how the resources for a material or product are extracted and how it is manufactured; material performance, longevity, and required maintenance; and, "downstream effects," material or product impacts associated with its disassembly, reuse, or disposal.

The selection of project materials, finishes, and systems has impacts on all aspects of an integrated design. The role of mass can affect building thermal and energy performance and should be modeled and predicted. The strategic placement of massive materials can impact the HVAC system design and performance requirements. Daylighting design is dependent upon surface finishes, their light reflectance properties, and color selections in the spaces. Poor quality carpet can be replaced with an alternative surface treatment that eliminates dust contamination and volatile organic compounds (VOCs) creating a healthier and more productive space.

This section provides recommendations on material usage including maximum reuse of the existing structure, use of salvaged materials, selection of new materials, and disposition of construction waste to ensure maximum benefits are achieved with minimal environmental impact.

Building Reuse

Issue

Adaptively reuse large portions of existing structures, lowering the impact of new construction, and requiring less energy, material resource, and land use.

Recommendations

Reuse existing building structure, materials, and infrastructure to reduce the demand for new materials. A viable adaptive reuse goal is maintenance and preservation of the entire existing building structure and shell (exterior skin, framing, roof, and windows). Figures 11 and 12 show a "before" and "after" example of how this goal can be achieved. Windows require special treatment as discussed in Chapter 4, "Building Enclosure and Energy Systems" (p 20), but the goal should be to keep them also. Both *LEED*® and SPiRiT recommend maintaining at least 50 percent of nonshell component such as walls, floor coverings, and ceiling systems.

Cautions

Nonhistoric dropped ceilings should be removed and the components should be recycled (Figure 13).

Comments

The tenets of the Secretary of the Interior's Standards and the National Park Service's Preservation Briefs support maximum reuse of the building structure and, consistent with sustainable design, encourage maximum reuse of the existing building components, restoration of passive aspects of the original design, and preservation of the interior components that are of a historic nature.

Use of Salvaged Materials

Issue

Use salvaged materials to reduce the environmental impact of new materials.

Figure 11. Building reuse "before" (source, R. Young).

Figure 12. Building reuse "after" (source, R. Young).

Figure 13. The removal of non-historic dropped ceiling at Fort McPherson, GA reduces the use of new materials (Source: Fort McPherson).

Recommendations

Specify refurbished or salvaged materials from other buildings for 10 percent of the building materials.

Cautions

Do not reuse plumbing or mechanical equipment that does not meet or exceed current code requirements for safety, energy, and resource efficiency.

Comments

Older fixtures, luminaires, moldings, and architectural features are often of high quality, have unique aesthetic appeal, and fit well with the fabric of the historical building (Figure 14). Take care to maintain such historic integrity.

Figure 14. Use of salvaged materials, Fort Douglas, UT (Source: R. Young).

Material Selection

Issue

Select materials based on life cycle performance evaluations to minimize environmental impact and resource requirements.

Recommendations

- Use value-engineered products that make more efficient use of resources such as engineered lumber.
- Select durable and heavy materials that can provide thermal mass.
- Avoid materials with toxic, carcinogenic, or otherwise harmful content.
- Select materials with low VOC content including adhesives, paints, sealants, flooring, and composite wood products (Table 1).
- Specify local, sustainably harvested timber and wood products. Use wood-based materials that are certified in accordance with the Forest Stewardship Council, or equivalent, for components such as framing, flooring, finishes, furnishings, and other construction applications like bracing and forms.
- Specify materials that are resourced and manufactured within the region (500 miles).
- Specify materials with a high post consumer recycled content (20 percent) and a high post industrial recycled content (40 percent).
- Choose materials with the lowest embodied energy that will accomplish the task (consider this on a life-cycle basis).
- Minimize and recycle packaging materials delivered to the site.

Table 1. Recommended low VOC content levels.

Materials or Product	VOC Content Level*
Form release agents	350 g/L
Plastic laminate adhesive	20 g/L
Casework and millwork adhesives	20 g/L
Transparent wood finish systems	350 g/L
Cast resin countertop silicone sealant	20 g/L
Garage deck sealer	600 g/L
Water based joint sealants	50 g/L
Nonwater based joint sealants	350 g/L
Portland cement plaster	20 g/L
Gypsum drywall joint compound	20 g/L
Terrazzo sealer	250 g/L
Acoustic panel ceiling finish	50 g/L
Resilient tile flooring adhesive	100 g/L
Vinyl flooring adhesives	100 g/L
Carpet adhesive	50 g/L

Materials or Product	VOC Content Level*
Carpet seam sealer	50 g/L
Water-based non-flat paint and polychromatic finish coatings	150 g/L
Water-based flat paint	50 g/L
Solvent-based paint	380 g/L
High performance water-based acrylic coatings	250 g/L
Pigmented acrylic sealers	250 g/L
Catalyzed epoxy coatings	250 g/L
High performance silicone	250 g/L
Casework sealant	50 g/L
Liquid membrane-forming curing and sealing compound	350 g/L
PVC welding	480 g/L
*Source: USEPA Green Program Information Packet (USEPA 1999).	

Cautions

Do not specify materials that use ozone-depleting materials.

Comments

Base material selections on life-cycle costs and impacts, not first costs.

Construction Waste Management

Issue

Reduce landfill impacts and encourage resource recycling.

Recommendations

Develop a construction waste management plan that maximizes diversion of construction, demolition, and land clearing materials from landfills and into the recycling chain. The plan should have provisions and guidance on the handling and disposition of any hazardous materials during the demolition phase. Make the plan part of the project specifications and require the contractor to report on material diversion.

Cautions

During the demolition process, the presence of hazardous materials may present a challenge. If a historic property is found to contain hazardous materials, such as asbestos or lead paint, the Secretary of the Interior's Standards recommend:

> Removing toxic building materials only after thorough testing has been conducted and only after less invasive abatement methods have been shown to be inadequate.

The removal of toxic or hazardous building material should accommodate the safety of the building, the individuals performing the work, the environment, and the community (Figure 15).

Comments

Construction and demolition wastes are major contributors to U.S. landfills. A typical project generates 2 to 2.5 lb of construction waste per square foot (Paladino 2001), the majority of which can easily be recycled.

Figure 15. Toxic or hazardous building material should be carefully removed, stored, and disposed (source, CERL).

6 Indoor Environment

A healthy and productive indoor environment is a crucial goal of sustainable design. The indoor environment includes indoor air quality, effective lighting, thermal comfort, effective ventilation, and acoustic privacy. According to the USEPA, the average American today spends 90 percent of their time indoors where indoor air pollution can be up to 96 times greater than outdoor pollution levels (Building Green 2001). Indoor air quality (IAQ) is a major health concern evidenced by increased asthma and sensitivity to chemical exposure within U.S. society. Poor indoor environmental quality, including air quality, can significantly impact workers' health and productivity, incurring significant liability exposure that impacts both the Federal and private sectors. Prevention is much more cost effective than responding to problems after the building is constructed.

Adaptive reuse of an existing structure introduces issues that are more complex than those encountered in new construction. Existing materials and finishes may be unhealthy and may require either removal or encapsulation, e.g., lead-based paint, asbestos, PCBs, etc. Lead paint can severely affect human health, especially in children, and nearly every historic building has some lead paint. Confusion is common within the building rehabilitation industry regarding safe and appropriate treatments. The safest techniques are fully compatible with retaining historic building components (Livingston, Gordon, et al. 2000). Such issues must be addressed and project materials, systems, methods, and construction processes must protect and enhance the indoor environment. Research indicates that people need connectivity with the outside, control over their environment such as temperature and lighting levels, privacy and freedom from noise, and natural lighting. All of these parameters must be effectively addressed while attending to the requirements and restrictions of adaptively reusing an historic structure.

Indoor Air Quality (IAQ)

Issue

Maintain a healthy and productive indoor environment through effective ventilation and proper indoor air quality.

Recommendations

- Meet the requirements of ASHRAE Standard 62-1999, Ventilation for Acceptable Indoor Air Quality and approved Addenda, including the Ventilation Rate and Indoor Air Quality Procedures.
- Locate ventilation intakes away from contaminant sources.
- Prohibit smoking in the building or provide smoking areas that are physically isolated (no cross contamination) from the rest of the building occupants per existing Federal Guidelines.
- Install a building automation system that integrates ventilation control and CO_2 monitoring, one capable of accommodating the use of operable windows.
- During construction, meet the requirements of the Sheet Metal and Air Conditioning National Contractors Association (SMACNA) IAQ Guideline for Occupied Buildings Under Construction.
- Protect all absorptive materials from moisture and material contamination during construction and phase interior fit-out so that “off-gassing” materials do not contaminate materials that might absorb such emissions.
- Flush out the building with outside air for 2 weeks before occupancy.
- Replace all filter media before occupancy.
- Use filter media with a Minimum Efficiency Reporting Value (MERV) rating of 13 or more.

Comments

ASHRAE Standard 62 specifies the minimum ventilation rates and indoor air quality levels necessary to reduce the potential for adverse health effects. Resources on IAQ are available on the web:

American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), at URL:
www.ashrae.org

U.S. Environmental Protection Agency (USEPA), at URL:
www.epa.gov/iaq

American Indoor Air Quality Council, at URL:
www.iaqcouncil.org

Sheet Metal and Air Conditioning National Contractors Association, at URL:
www.smacna.org

Controls and Thermal Comfort

Issue

Provide occupants with control over their physical environment and systems capable of meeting those demands.

Recommendations

- Provide operable windows and light switches to occupants near the building perimeter.
- Provide occupants with individual control of airflow, room temperature, and lighting of nonperimeter spaces.
- Design HVAC systems capable of maintaining conditions within ASHRAE Standard 55-1992, Addenda 1995, requirements for thermal comfort including humidity control.
- Use direct digital control (DDC) for HVAC systems and include continuous commissioning as part of the monitoring and control package (see "Operations and Maintenance," p 55).

Comments

In light of potential bioterrorism, building ventilation systems should be viewed as threat vectors. The option of no mechanical ventilation system, or one designed for complete and sure closure, while providing all occupants with operable windows may be viable. Such an option could enhance safety, while providing that vital linkage to the outside and allowing occupants control over their indoor environment.

Lead Paint and Historic Properties

Issue

Integrate lead-safe construction practices and techniques into the adaptive reuse process.

Recommendations

Worker environmental safety does not prohibit actions, but may dictate how they are done. Construction activities will disturb lead paint and such activities should be identified before the initiation of work. A safe work environment will include applying precautionary methods during the setup, scheduling, and performance of the project (Livingston, Gordon, et al. 2000).

Set up the site for safety and efficiency:

- Create safe, clean, well-vented, and well-lit work areas.
- Separate high dust from low dust areas.
- Isolate work dust from occupied spaces.
- Leave work and adjacent areas cleaner than when you found them.
- Minimize the generation of dust and debris
- Contain construction dust to protect the site (all demolition dust is unhealthy).
- Protect the workers.
- Clean the site to standards.
- Schedule work to reduce exposure while maximizing productivity.

Comments

Lead paint (Figure 16), a significant health and construction issue, can be addressed through the use of cost-effective lead-safe treatments that enable the retention of historic materials. Low-dust rehabilitation techniques result in healthier buildings and are recommended. Emphasis should be placed on making the building "lead-safe," not "lead-free." Since traditional techniques (lead encapsulation, removal, total replacement of wood windows, and the addition of additional exterior siding) will violate the integrity of the historic structure, better and more cost effective alternatives are recommended on the National Park Service's web site. Preservation Brief 37, *Appropriate Methods for Reducing Lead-Paint Hazards in Historic Housing*, is available for downloads, at URL:

http://www2.cr.nps.gov/TPS/briefs/brief37.htm

Indoor Chemical Usage

Issue

Control exposure of building occupants to hazardous chemicals during building operations (Figure 17).

Figure 16. Construction activities in historic properties often disturb lead paint (source, R. Young).

Recommendations

- Design the building and systems to minimize the potential for cross contamination or exposure to hazardous chemicals, including cleaning chemicals.
- Use entryway systems that capture dirt and particles at high volume entrances.
- Isolate and separately ventilate areas where chemical use occurs such as janitorial areas and copying/printing rooms.
- Provide adequate, secure storage for cleaning and maintenance chemicals.

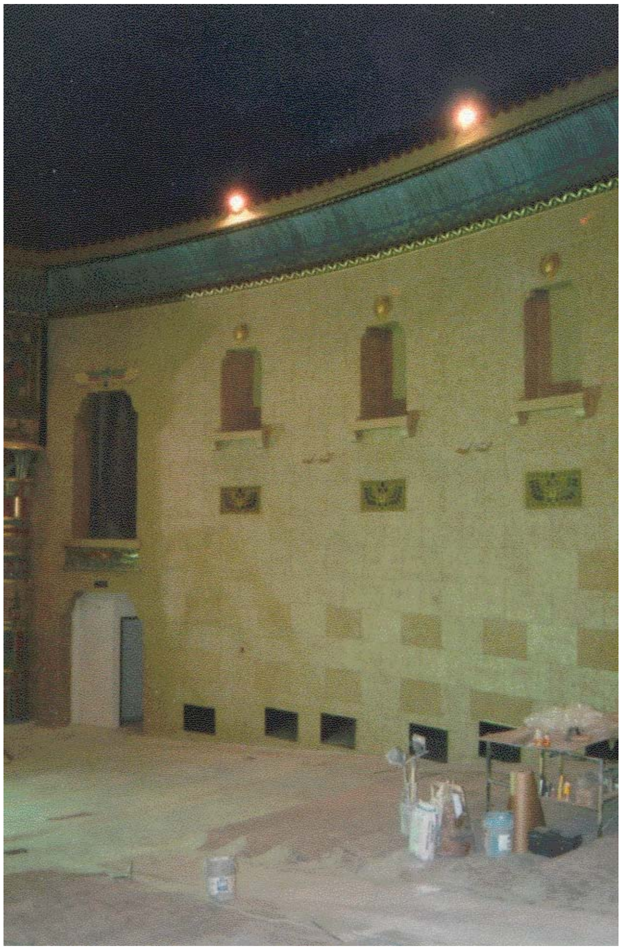

Figure 17. Indoor chemical use at Fort Douglas, UT (Source: R. Young).

Comments

Avoid the use of toxic chemicals by properly selecting cleaning and maintenance supplies. Find information on green housekeeping and cleaning materials at URL:

http://www.rochestermidland.com/division/institut/ghouse.html

The USEPA web site has several downloadable documents, such as *The Building Air Quality Action Plan: Maintaining and Improving IAQ Baseline – Step 5: Develop and Implement a Plan for Facility Operations and Maintenance*, at URL:

http://www.epa.gov/iaq/largebldgs/baqact5.html

Views and Daylighting

Issue

Provide connectivity with the outdoor environment and natural lighting.

Recommendations

- Design for daylighting and provide direct lines of sight to the outside glazing from interior spaces that are regularly occupied.
- Keep and refurbish existing tall windows, clerestories, and transoms.
- Provide for access to outside views by using a more open architecture within inside spaces.
- Use exterior and interior shading devices to control natural light for glare and contrast.
- Retrofit windows with high performance glazing where possible.

Comments

Natural light improves health, satisfaction, and performance of workers while reducing energy consumption and costs (Herz, Harding, et al. 2000). Many historic buildings were originally designed for daylighting (Figure 18) and such opportunities should be recovered and enhanced through an adaptive reuse. High performance glazing, compatible with historical windows as discussed in Windows and Glazing in Chapter 4, "Building Enclosure and Energy Systems" (p 20), should be considered. A good reference is *Tips for Daylighting with Windows, An Integrated Approach* (O'Connor, Lee, et al. 1997), which can be downloaded from the Lawrence Berkeley National Laboratory web site, at URL:

http://www.lbl.gov

Acoustic Environment /Noise Control

Issue

Provide appropriate acoustic conditions for user privacy and comfort.

Recommendations

Minimize environmental noise through appropriate use of insulation, sound-absorbing materials, and noise source isolation.

Figure 18. Many historic buildings were originally designed for daylighting (source, CERL).

Figure 19. An acoustic environment / noise control implementation at Fort Bliss, TX (source, Fort Bliss).

Comments

Evaluate each occupied environment and determine the appropriate layout, materials, and furnishings design that is compatible with the building configuration, material selection availability, and effective workspace management.

7 Sustainable Design and Project Management

Integrated Design

The traditional design process, a linear progression from design to construction to occupancy, is driven by cost, schedule, and the desired quality. The adaptive and sustainable reuse of an historical building requires decisions that reflect the interconnections between environmental stewardship, cultural stewardship, and life cycle cost implications within the built environment. This requires an integrative process that brings all interested parties together for synergistic knowledge enhancement and effective decisions.

Sustainable design requires a comprehensive and inclusive process to facilitate resource efficiency, pollution avoidance, healthy and productive workspace, and lower costs. The traditional design process, linear, compartmentalized, and focused on upstream decision-making, severely impacts downstream building performance. The current design payment paradigm provides little incentive to work creatively to reduce total project costs over the life cycle or to promote high design standards. Rewards are few for those who create resource efficient, attractive, and productive working and living environments. Recent experience indicates that the economic return on more productive work environments will quickly repay any extra investment required in the design and construction process.

Successful sustainable designs must include the following steps:

1. Team building and goal setting
2. Design optimization
3. Construction documents and specifications
4. Construction
5. Commissioning
6. Operations and maintenance
7. Demolition and disposal

Much of the information in this chapter is adapted from the *State of Pennsylvania's Guidelines for Creating High-Performance Green Buildings* (Kobet, Lee, et al. 1999).

Team Building and Goal Setting

The greatest opportunities for project success lie in the initial stage of the process—team building and goal setting, as project changes are usually more costly and less desirable to make in the latter stages of design and construction. Therefore, sound sustainable design and development practices must be established at the "front end," the conceptual stage where process intervention is easy, well before final designs. The time required for planning and thinking must be acknowledged and planned for. All project stakeholders must be encouraged to proffer and evaluate design aspects in an atmosphere conducive to exploration and creative solutions. The goal of reducing project costs while increasing energy and resource efficiency must be viewed as viable. Success can be measured by the degree to which the interests of the occupants and the natural environment have been addressed. Properly done, an equitable balance between these latter two interests will be reflected in a project that is functionally superior, aesthetically pleasing, environmentally and culturally sensitive, and economically sound.

The most important and fundamental steps in sustainable design are the establishment of the "green" team and defining project goals, not to be overlooked or compromised in the pressures to meet budget and schedule. Habits of the past will get the same results as in the past. Different and better results require different and better processes. All team members must be educated, oriented, and focused on the goals, costs, and benefits of sustainable design and development. A lack of specific in-house talent can be addressed by using outside consultants. The team must work cooperatively and collaboratively to define requirements and identify synergistic opportunities. Knowledge within the various required disciplines and building systems must be shared, facilitating higher levels of required integration.

The team should include all stakeholders, representatives of all parties affected by the building. The conventional design team—the DPW, the architect, engineers, consultants, and contractors—working through a linear design process must now shift to a multidisciplinary, cooperative, and collaborative "total systems" approach. All team members must be actively engaged in the project definition and goal setting, early in the process, setting the stage for later project cooperation, collaboration, and effective design integration. A sustainable design team should also be broadened to include, in addition to the above mentioned, the user, O&M staff, the construction manager (District), the contractor, subcontractors and suppliers, historic preservation staff, occupational health and safety staff, and any other party with the affected community who could contribute to the process.

The team should set goals early in the process; developing a vision statement, developing goals to reflect the vision, defining design criteria, and prioritizing the design criteria. The vision statement should define the overall broad objective such as, "Adaptively reuse Building 542 while minimizing environmental impact and preserving our cultural heritage." The second step, goals that reflect the vision, should address issues such as "Save energy through restoring the daylighting and passive tempering." Such a goal can be further developed into a defined, achievable design criteria such as:

> The ambient light level will be lowered to 30 foot candles, and we will use transoms, clerestories, and T-8 fluorescent lamps with auto dimming and the windows will be restored to their original height and high visible transmittance glazing used.

The design criteria can then be prioritized. If, for example, natural lighting is more important than high efficiency luminaires or dimming controls, such prioritization will allow choices if budget constraints require them.

The following checklist of activities fall into the predesign stage of the design process:

- Assemble sustainable design team
- Develop project vision
- Establish project goals
- Establish project design criteria to meet goals
- Set priorities between the criteria and goals
- Develop a performance based building program
- Establish the conditioning energy and light budget
- Develop partnering strategies with the team
- Develop the project schedule
- Review codes and standards both for standard design issues and historical preservation issues
- Conduct any required research.

Design Optimization

Design optimization, the process of refining and maximizing the performance and cost effectiveness of all aspects of the project, addresses not only the schedule and budget, but also the total building performance. Evaluating and balancing the impacts of each system against another, long-term stewardship, and building operation, all within the context of historical properties, optimizes the building systems and their interrelationships.

After setting goals, criteria, and priorities in the predesign stage, the team must optimize all aspects of the project through a design process that consistently evaluates all systems and products to ensure that target goals are being met or exceeded. This process enables the myriad of choices to be handled in an orderly fashion while maintaining consistent goals and objectives. Matrices of green criteria such as performance levels or other information can facilitate evaluations among systems or products.

Computer modeling of buildings is an important tool for evaluating and integrating choices of system and envelope modifications to achieve optimum building performance. Modeling of historic buildings can represent special challenges; "as built" drawings may not be available and incremental past changes may have altered original building designs and performance (Geva 1998). Both the current and original conditions should be modeled, establishing the best starting point for choosing building modifications and upgrades to improve energy efficiency. Design choices such as minimal energy consumption and maximum daylighting cannot be correctly made without understanding system-integrated impacts such as the glazing, thermal envelope, mechanicals, thermal massing, and others. The results of computer modeling can provide factual information on which to base the choices of the design team. Though computer projections are often imprecise or inaccurate in predicting actual building performance, they can provide valid comparative information from which the relative performance of different systems and materials can be ascertained.

Other design aspects should be optimized in concert with building systems, including functional issues such as space utilization, shared services, flexibility, and adaptability. Building systems optimization also requires the coordination of structural changes and component construction strategies. Adaptations to alternate future use and function, and ultimate building disposition, should be considered early in the process, incorporating issues of recyclability and the future deconstruction and reuse of salvaged building components. Materials should also be efficiently used, minimizing waste in construction and the use of unique components and systems. During this process, the management of lead-based paint must be addressed though it should not pose an overriding issue in the planning process, just an additional factor in adaptive reuse designs and plans.

Design optimization processes vary with project types and goals and it is crucial for successful and sustainable adaptive reuse, balancing the issues of historic preservation, green design, high performance, and effective workspace. The project team must be committed to a continuous process of design improvement and optimization.

The following checklist of activities constitutes the design optimization stage of the design process:

- Develop sustainable solutions.
- Evaluate these solutions.
- Check costs and performance of the solutions.
- Integrate systems and optimize solutions.
- Refine the solutions.
- Recheck cost and viability.
- Document sustainable solutions.

Construction Documents and Specifications

Typical design documentation includes the construction drawings, specifications, and any change orders that materialize during construction and commissioning. Construction documents, representing the methods used to achieve the design intent, are included in the standard design drawings and specifications, but integrated systems drawings and supporting documents should also be developed as part of any adaptive reuse project. Such supporting documents add clarity and efficiency to the design and documentation of the well-planned adaptive reuse, including demolition and preservation issues.

Specifications work hand in hand with the construction drawings to provide information that cannot be effectively illustrated, or that requires special procedural or component emphasis. Many important aspects of sustainable building such as construction waste management and commissioning must be included in specifications as well as any methods to address lead paint and other hazardous material.

The following checklist of activities addresses the development of the construction drawings and specifications:

- Use the design documentation process to establish a clear statement of design intent.
- Include construction waste management, commissioning, lead-based paint and hazardous material amelioration, and O&M information in the specifications.
- Develop building system integration drawings to illustrate how the various systems and components relate to each other.
- Use the construction documents as a basis for a comprehensive set of operating instructions.

Construction

Construction is a crucial part of sustainable adaptive reuse and the game can easily be lost at this stage. The desires and concepts developed through planning and design must be implemented during the construction stage. Any applied "value engineering" must reflect true life cycle costs and not first costs. Any design alterations or changes made must consider their impact on the building "as a whole" and how performance will be altered after the change is made. Holistic designs can be (and often are) readily sabotaged at this stage. For example, spectrally selective glazing can be replaced by simple double pane glass, changing the solar heat gain coefficients for the windows along with the shading coefficients and visible transmittance This can alter building loads and render the heating and cooling systems too small, the daylighting system invalid, and result in unacceptable glare within the workspaces The end result is a poorly conditioned, low quality workspace—all for a minor cost savings in glazing.

All changes should be submitted and reviewed to ensure compliance with the high performance standards established in the design. Any material substitution must be thoroughly "vetted," ensuring that the design intent is not subverted and hazards are not introduced that might compromise indoor air quality and health.

The design team must coordinate with the construction team and the general contractor must be responsible for implementing the "green" elements of the design in the construction process and be accountable for them. Sustainability goals must be articulated to the construction staff and the contractor made responsible for recycling construction waste, recovering recyclable building components during demolition, and protecting new building materials from moisture and weather damage and exposure.

Accurate "as built" drawings and other records must be maintained to assist in the commissioning and ongoing operation and maintenance of the completed project (see sections below).

Commissioning

As buildings have become more complex and incorporate new functions, new operational problems have surfaced, such as excessive energy costs, malfunctioning mechanical equipment, and uncomfortable working conditions. Building system problems can often be identified, documented, and corrected through the process called "commissioning," which can positively impact energy bills and occupant comfort (Manke, Hittle, et al. 1996). Commissioning is a systematic process of verifying and documenting building systems or subsystems performance against the building design criteria and the owner's operational needs. Ideally, the process begins during the design phase and lasts one year or more after the construction is complete. The commissioning process should include training of the building's operations and maintenance staff. *ASHRAE Guideline 1-1996, The HVAC Commissioning Process*, defines commissioning as the process of ensuring that systems are designed, installed, functionally tested, and capable of being operated and maintained to perform in conformity with the design intent. Commissioning begins with planning and includes design, construction, start-up, acceptance, and training, and can be applied throughout the life of the building. Since commissioning maximizes energy efficiency, it has the benefit of minimizing environmental impacts associated with the building's energy consumption (Paladino 2001).

Specific commissioning recommendations are:

- Engage a commissioning agent to oversee the commissioning process.
- Include commissioning requirements in the construction documents.
- Develop a commissioning plan.
- Verify the installation and proper performance of all building systems.
- Ensure that accurate as-built drawings and contract document revisions are maintained and distributed to all members of the commissioning team.
- Develop documentation and a training program for the building operators and occupants.
- Retain the commissioning documents as part of the permanent building records.

The systems that should be commissioned are as follows:

- *Mechanical*: boilers, all pumps, air handing equipment, chillers, cooling towers, and all HVAC controls and building automation systems.

- *Plumbing*: domestic hot water heaters, pumps, tanks, compressors, and controls.
- *Electrical*: Standby power, security systems, fire management systems, and controls.
- *Other*: Sprinklers, elevators, audio/visual systems, and controls.

Information on commissioning is readily available on the Internet. Technical documents may be found at the following sites:

- U.S. Army Corps of Engineers Huntsville Engineering and Support Center, TECHINFO Internet, at URL:
  http://www.hnd.usace.army.mil/techinfo/index.htm
- Construction Criteria Base, National Institute of Building Sciences, 1090 Vermont Avenue N.W., Suite 700, Washington DC 20005-4905, (877) 222-5667, (202) 289-7800, FAX (202) 289-1092, Email: ccb@nibs.org CCB Online, at URL:
  http://www.ccb.org
- U.S. Army Corps of Engineers Construction Engineering Research Laboratory, at URL:
  http://www.cecer.army.mil

Operations and Maintenance

Proper operation and maintenance of an adaptively reused building is essential to ensure both the longevity of the structure and systems and the continued benefits, such as energy efficiency and productive work environments, built into the project. Once commissioning is complete, the operations and maintenance staff must ensure that the equipment and systems perform as designed over the building life. Seemingly minor issues, such as the choice of cleaning materials, can have a significant negative impact on the indoor environment.

Both the O&M staff and occupants must be educated about building functions, operating procedures, and maintenance schedules. Proper design recognizes future needs and incorporates maintenance issues.

A well-designed cleaning regimen avoids the use of harsh cleaning chemicals while facilitating good hygiene and indoor air quality. Good indoor air quality will also require cleaning and maintenance of ductwork and space conditioning equipment, essential for avoiding mold or other pathogens. Pans and drains in HVAC systems must be kept clean and clog free.

Building controls require regular tuning and calibration for continued proper functioning and maintenance of space conditioning. A process of "continuous commissioning," where systems are continuously monitored to ensure proper operation and efficiency, can be done with a building automation system or through add-on software applications to the digital control systems.

Recommendations

- Include O&M issues and requirements in the initial design criteria.
- Adhere to manufacturers recommendations for proper O&M of building systems and equipment including warranty requirements.
- Educate building occupants and maintenance staff to the green aspects of the design and how they can ensure the continued benefits of high performance workspace.
- Use an environmentally responsible cleaning regimen that ensures good indoor air quality and occupant health.
- Maintain the building as a whole, as it was designed, not as a collection of separate components.

Demolition and Disposal

One-quarter to one-third of the total waste stream in the U.S. consists of construction and demolition (C&D) debris, most of which can be recycled or reused rather than sent to a landfill. Recycling and reusing materials conserves natural resources and saves on landfill disposal costs. This excess material, generated during the construction process, varies according to the nature of the projects from which it is generated. Generally, 70 to 90 percent of the nonhazardous material is recyclable.

Deconstruction is the process of selective dismantling or removal of materials from buildings before or instead of demolition for recycling or reuse (Beachley 1998). Examples include electrical and plumbing fixtures that are reused; steel, copper, and lumber that are reused or recycled; wood flooring that is remilled; and, doors and windows that are refinished for use in new construction or adaptive reuse. Sustainable adaptive reuse implements a construction waste management plan that maximizes diversion of construction, demolition, and land clearing materials from landfills and into the recycling/reuse chain. The plan should have provisions and guidance on the handling and disposition of any hazardous materials during the demolition phase. Make the plan part of the project specifications and require the contractor to report on material diversion.

Additional information is available at URL:
http://www.epa.gov/tribalmsw/thirds/recandd.htm

The U.S Air Force has a *Construction and Demolition Waste Management Guide* available for download at URL:
http://www.afcee.brooks.af.mil/eq/programs/progpage.asp?PID=61

Design Resources

Many sites on the World Wide Web discuss project design. The better ones are listed below. Especially recommended are the sites in the states of Florida and Pennsylvania and New York City.

- The Whole Building Design Guide Site, at URL:
  http://www.wbdg.org/
- Green Building in Canada Site, at URL:
  http://greenbuilding.ca/GBIC.htm
- The Oak Ridge National Laboratory Buildings Technology Center web site, at URL:
  http://www.ornl.gov/btc/
- Florida Sustainable Communities web site, at URL:
  http://fcn.state.fl.us/fdi/edesign/
- State of Pennsylvania High Performance Green Building web site, at URL:
  http://www.gggc.state.pa.us/building/default.
- City of New York High Performance Building Guidelines web site, at URL:
  http://www.ci.nyc.ny.us/html/ddc/pdf/greentoc.pdf

8 Conclusion

This work has shown how the concept of adaptive reuse can be applied to facilitate the preservation of historical structures that might otherwise fall into disrepair, decay, and eventual demolition. Adaptive reuse of existing structures can minimize the need for new buildings and infrastructure. When combined with principles of historic and sustainable design, and applied with care, thoughtful design, and flexibility, adaptive reuse can create more efficient and effective living and working spaces.

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U.S. Environmental Protection Agency (USEPA), *Green Programs Information Packet* (Kansas City, MO, 1999), p 196.

U.S. Green Building Council (USGBC), *LEED Green Building Rating System for New Construction and Major Renovations (LEED-NC) Version 2.1* (USGBC, November 2002 [rev. March 14, 2003]).

USGBC, *Leadership in Energy and Environmental Design (LEED)* (USGBC, 2004), accessible through URL: http://www.usgbc.org/LEED/LEED_main.asp.

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14. ABSTRACT

The construction of new buildings consumes significant amounts of raw materials and land assets that might be better used for other functions. This consumption of land and materials can be reduced when adaptive reuse of existing buildings is allowed to replace the demolition/reconstruction. Adaptive reuse can also facilitate the preservation of historical structures that might otherwise fall into disrepair and decay, and eventually be demolished. The resulting adaptive reuse of existing structures must incorporate principles of historic and sustainable design. This work formulated specific guidelines to help installation planners integrate concepts of sustainability into the adaptive reuse of historical buildings in a way that will enhance the built environment while preserving the nation's cultural endowment. These guidelines may also be generically applied to the adaptive reuse of any structure.

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