# Sustainable Building Assessment

# Bright Angel Trailhead Plaza
# Grand Canyon National Park

A Partnership Project of
Grand Canyon National Park
Ecological Monitoring & Assessment Program, Northern Arizona University
College of Engineering, Forestry, and Natural Sciences, Northern Arizona University

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## Project Background

Grand Canyon National Park is one of our country's most famous national parks. The park received national park status in 1919, three years after the creation of the National Park Service. Given its natural beauty, Grand Canyon National Park is one of the most popular destinations in the world, annually hosting nearly five million people. Visits vary widely by the month, averaging approximately 675,000 visitors in July and, roughly, 175,000 visitors in January.

One of the most popular places in the park for visitors is the Bright Angel Trailhead. The Bright Angel Trail is one of the oldest and most important access points to the canyon. The trail connects both sides of the national park, providing the only continuous access between the North Rim and South Rim. Given its strategic location, the trail is heavily used. The trail is a popular tourist route, and mule trains use the trail to carry supplies and tourists to Phantom Ranch at the base of the canyon. The trail also acts as a conduit for the park's water infrastructure. A pipeline carries water from the North Rim across the bridge, where it is then pumped in stages up to the South Rim.

Because it is located close to parking, lodging, and the railroad depot, the Bright Angel Trailhead is also an important access point for the South Rim of the Park. According to park officials, as many as ten thousand people may visit the Bright Angel trailhead on a summer day. Additionally, the trailhead is the terminus for mule trains that carry cargo and passengers into the canyon. Currently, two portable toilets serve this important park access point.

Given the popularity and intense usage of the area, the park has created a master plan to redevelop the area. Under the current improvement plan, the Bright Angel Trailhead area will be redesigned to create a new plaza near the trail entrance. As part of the redevelopment, a new restroom facility and shade structure will be constructed adjacent to the existing mule corral. This plaza will provide an area for hiker staging and orientation, mule rider orientation, visitor meetings and will also act transitional zone between the trailhead and the parking area. To match the historic character of the area, the plaza will be designed to be "informal and rustic in character, but designed for high levels of visitor use" (GCNP Environmental Assessment, November 2007).

As part of the redevelopment, a restroom facility will be designed and constructed. According to the preliminary plan, the restroom will consist of two separate buildings that will include ten unisex toilet rooms. The approximate size of each restroom building is approximately 300 square feet. Additionally, a large shade structure and seating will be constructed adjacent to the restrooms. This shade structure will act as a focal point for the plaza and will also house informational signage and maps for the public's use.

The Park Master Plan calls for the use of sustainability features in the plaza design. According to the EA, "the restrooms would employ energy efficient building design principles as much as possible, which may include solar power for heating and lighting, skylights, low-flush toilets, and careful selection of building materials."

## Sustainable Building Design

Buildings have a major impact on the environment. According to the United States Department of Energy, buildings use over 40% of the nation's energy supply, and 65% of the nation's electricity. The construction and demolition of buildings also generate large quantities of waste. Recent studies of landfill use suggest that building materials use nearly 40% of landfill capacity. Our buildings also use 25% of the nation's water supply, and, in the process, they generate large quantities of water effluents. Additional energy and chemicals are required to treat this water and dispose of the solid wastes.

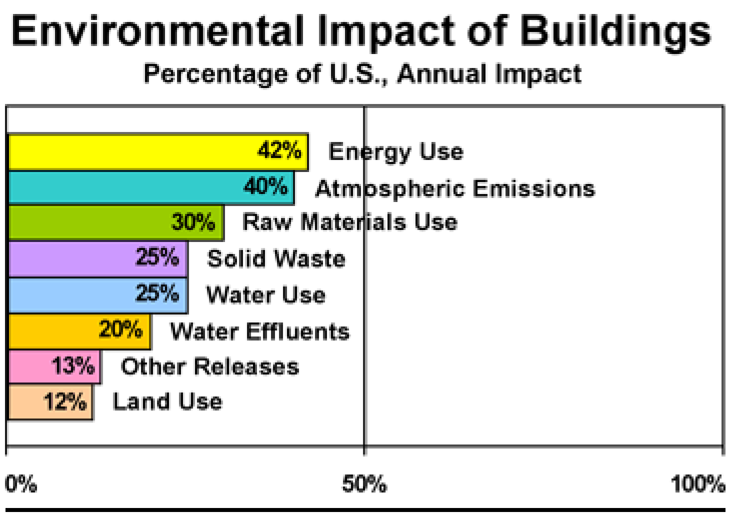



Fig. 1. Systematic Evaluation and Assessment of Building Environmental Performance (SEABEP), paper for presentation to "Buildings and Environment," Paris, 9-12 June, 1997 (Levin, 1997).

Over the last two decades, architects, engineers, builder's and material manufacturers have worked collectively to create a new type of design system that considers all phases of a building's life cycle including design, construction, operations, and disposal. This idea is called *whole building design* or more simply *sustainable design.* The main objective of sustainable design is to create efficient structures that optimize energy, water, and material usage and minimize the pollution associated with building usage. Buildings that are designed and constructed with these principles in mind are sometimes call High Performance Buildings or Green Buildings.

Typically, sustainable design is guided by six principles:

1. Optimize site selection.
2. Optimize energy usage.
3. Protect and conserve water.
4. Optimize indoor environmental quality.
5. Utilize environmentally friendly products.
6. Optimize the operations and maintenance of the building during its life cycle.

**Optimize Site Selection**

The success of a sustainable design is often dependent upon site selection. The location, landscaping and orientation of a building affect the local ecosystems, transportation opportunities, and energy usage. As an example, one of the strategies behind creating a high performance building is to use the sun to heat, cool, and create lighting for the building. As such, the orientation of the building is often critical to optimizing the design. To maximize and control solar energy, most green buildings are sited with their long axis on a line that points east and west. Because building materials contain large amounts of "embodied energy," sustainable design emphasizes reusing existing buildings or redeveloping previously polluted "brownfield" sites.

The Whole Building Design Guide suggests that a designer consider these site design criteria:

- Minimize development of open space by the selection of disturbed land, brownfields, or building retrofits.
- Control erosion through improved landscaping practices.
- Reduce heat islands using landscaping and building design methods.
- Minimize habitat disturbance.
- Restore the health of degraded sites by improving habitat for indigenous species through native plants and closed-loop water systems.
- Incorporate transportation solutions along with site plans that acknowledge the need for bicycle parking, carpool staging, and proximity to mass transit.
- Encourage alternatives to traditional commuting.
- Consider site security concurrently with sustainable site issues.
- Location of access roads, parking, vehicle barriers, and perimeter lighting, among others, are key issues that must be addressed.

**Optimize Energy Usage**

As noted earlier, buildings use a large piece of the nation's energy production. There are also increasing concerns with energy security and the impact of greenhouse gases on world climate. It is obvious that energy costs will play an increasing role in facility operating and maintenance costs. For instance, some analysts predict that "cap and trade initiatives will cause electrical energy costs to triple in cost over the next five to ten years." Given these challenges, it is essential that designers find new ways to optimize the energy usage of buildings. Some strategies include:

- Reduce heating, cooling, and lighting loads through climate-responsive design and conservation practices.
- Employ renewable energy sources such as daylighting, passive solar heating, photovoltaics, and geothermal.
- Specify efficient HVAC and lighting systems that consider part-load conditions and utility interface requirements.

- Optimize building performance by employing energy modeling programs and optimize system control strategies by using occupancy sensors and air quality alarms.
- Monitor project performance through a policy of commissioning, metering, and annual reporting.

**Protect and Conserve Water**

Particularly in the American West, fresh water is a scarce resource. Water and energy are also inexorably linked. According to some reports, electricity production uses 48% of the nation's potable water supply, and the distribution, pumping, and treatment of both water and wastewater requires large quantities of energy. Accordingly, it makes sense to design buildings that will conserve water resources and recycle water efficiently. Some design considerations include:

- Reduce, control, and treat surface runoff.
- Use water efficiently through ultra-low flow fixtures, elimination of leaks, water conserving cooling towers, and other actions.
- Improve water quality by eliminating pollutants in potable water.
- Recover non-sewage and gray water for on-site use.
- Establish waste treatment and water recycling systems and practices.
- Apply FEMP Best Management Practices for Water Conservation.

**Utilize Environmentally Friendly Products**

All building materials use large quantities of embodied energy. Embodied energy includes all of the energy required to extract, manufacture, transport, and dispose of a material during its useful life. For instance, steel that is manufactured in China may be substantially cheaper than steel manufactured in the United States, but it also has a much higher embodied energy because it has to be shipped across the ocean. At the same time, buildings should be designed to minimize the effect of materials on human health and the environment. For these reasons, it is important to utilize materials that minimize environmental impacts including global warming, indoor air pollution, resource depletion, and waste generation. Some strategies include:

- Renovate existing facilities, products, and equipment whenever possible, such as historic structures or used furniture.
- Evaluate the environmental preferability of products using a life-cycle assessment (LCA) approach.
- Maximize the recycled content of all new materials, especially from a post-consumer perspective.
- Specify materials harvested on a sustained yield basis, such as lumber from certified forests.
- Encourage the use of recyclable assemblies and products that can be easily "de-constructed" at the end of their useful lives.

- Limit construction debris, encourage the separation of waste streams, and encourage recycling during the construction process.
- Eliminate the use of materials that pollute or are toxic during their manufacture, use, or reuse.
- Give preference to locally produced products and other products with low embodied energy content.

**Optimize Indoor Environmental Quality (IEQ)**

A report by the World Health Organization in 1984 suggests that 30% of Americans live or work in sick buildings. Other studies show that the indoor environmental quality of a building can have significant impacts on human health, human comfort, and human productivity. To optimize IEQ, sustainable design incorporates strategies that maximize ventilation and fresh air, eliminate materials that "off gas" pollutants like volatile organic compounds (VOCs), and utilize systems that can filter biological and radiological pollutants. Some design criteria include:

- Facilitate quality IEQ through good design, construction, and operating and maintenance practices.
- Value aesthetic decisions, such as the importance of views and the integration of natural and man-made elements.
- Provide thermal comfort with a maximum degree of personal control over temperature and airflow.
- Supply adequate levels of ventilation and outside air to ensure indoor air quality.
- Prevent airborne bacteria, mold, and other fungi through heating, ventilating, air-conditioning (HVAC) system designs that are effective at controlling indoor humidity, and building envelope design that prevents the intrusion of moisture.
- Avoid the use of materials high in pollutants, such as volatile organic compounds (VOCs) or toxins.
- Assure acoustic privacy and comfort through the use of sound absorbing material and equipment isolation.
- Control disturbing odors through contaminant isolation and careful selection of cleaning products.
- Create a high performance luminous environment through the careful integration of natural and artificial light sources.

**Optimize Operation and Maintenance Practices**

The operation and maintenance of a building generates significant costs during a building's life. As such it is important for designers to specify products and systems that are durable and require low maintenance. This means creating buildings that are easy to clean and operate. According to the Whole Building Design Guide, operations and maintenance should seek to:

- Train building occupants, facilities managers, and maintenance staff in sustainable design principles and methods.

- Use a building commissioning process to ensure that the building has been constructed according to specifications.
- Purchase cleaning products and supplies that are resource-efficient and non-toxic;
- Use automated monitors and controls for energy, water, waste, temperature, moisture, and ventilation.
- Reduce waste through source reduction and recycling to eliminate disposal off-site.
- Minimize travel by supporting telecommuting programs and enabling teleconferencing.

## Sustainable Site Recommendations

According to the park website, the Bright Angel Trailhead restroom will serve several functions: "The project's primary objectives include enhancing the area's signing, shade, seating, and restroom availability, improving paths and connecting trails, eliminating rim edge vehicle parking to provide enhanced pedestrian circulation, and creating a sense of place—an area visitors will immediately recognize as the Bright Angel Trailhead." There are several sustainable design ideas that may optimize the use of the site.

### Rainwater / Stormwater Collection

According to the National Weather Service, the average precipitation on the South Rim is 12.37 inches per year. Dependent upon the roof configuration of the shade structure and the restrooms, it may be possible to collect rainwater and use it for landscape irrigation, hand washing, and toilet flushing, or watering the mules. According to *Rainwater Harvesting for Drylands and Beyond* (Lancaster, 2006), the calculation for potential rainwater is as follows: Catchment Area (square feet) x Average Rainfall (ft.) = Total Rainwater (cubic feet). If we assume that each of the restrooms will have a 300 square foot roof (20 ft. x 15 ft.) and that the shade structure is approximately 400 square feet, then we can calculate the potential rainwater that can be harvested at 1,000 (sf.) x 1.03 (ft.) = 1030 (cubic feet). Since there are 7.481 gallons per cubic foot of water there is a potential for collecting approximately 7,600 gallons of water each year**.** This amount could also be supplemented by collecting water off of the roofs of other buildings in the area. This strategy would require the addition of a cistern system for storing the collected water, which would add additional costs to the project. Cisterns constructed out of ferro-cement could be included as design elements in the plaza architecture.

Fig. 2. Ferro-cement Rainwater Cistern (http://www.soilutions.net).

**Rainwater Gardens / Bioswales**

Stormwater runoff can also be collected and used to irrigate rainwater gardens. Typically these gardens use drought resistant native plants to create a low water xeriscape. The garden could be incorporated in the design and used as a tool for educating visitors on how rainwater can be used to maintain sustainable gardens.

Similarly, stormwater from the new parking lot can be directed into bioswales. A bioswale is a low-lying area that has been contoured and planted with vegetation that can tolerate wet and dry conditions. When it rains, water runs off the hardscape into the bioswale, where the water is retained in the soil, evaporated, absorbed by plants, or allowed to infiltrate back into the water table. These strategies will help sustain native species, minimize soil erosion, and help mitigate the treatment of stormwater runoff.

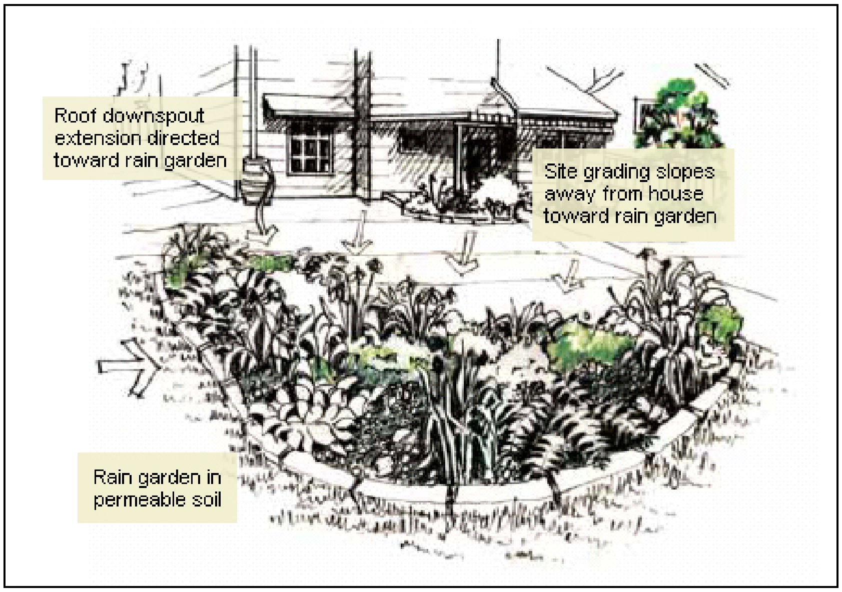



Fig. 3. Rainwater directed to bioswales.

**Porous Pavement**

Porous or pervious paving is a concrete surface that allows water (3-8 gallons per minute) to pass through it into the ground below. This minimizes the requirement for stormwater retention, sequesters pollutants and allows for groundwater recharge. There are some concerns with porous paving. Dirt and dust can compromise the permeability of the surface, and the system is not effective if it is installed on a subgrade with low permeability. Cost is approximately $7.50 SF

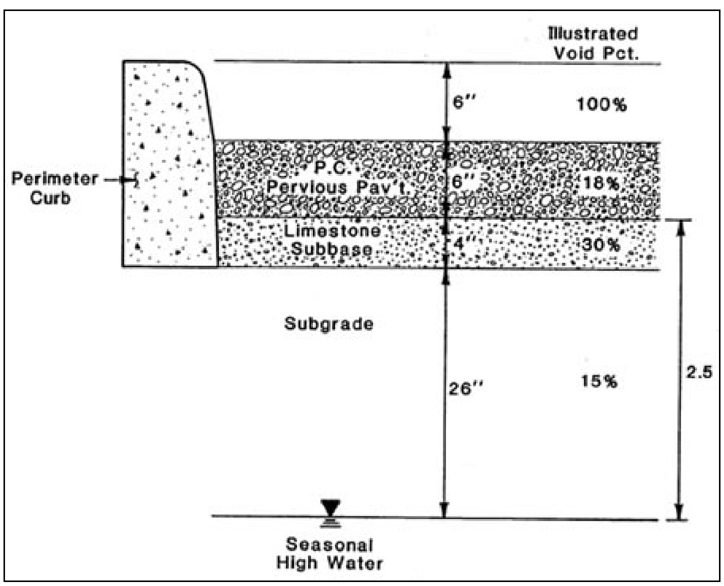



Fig. 4. Porous or pervious paving (Portland Cement Association).

**Educational Signage**

One of the objectives of sustainable design is to train building occupants, facilities managers, and maintenance staff in sustainable design principles and methods. Accordingly, the plaza should incorporate a signage system that illustrates each of the sustainable strategies that have been incorporated in the design.


Educational Signage – Applied Research and Development Building NAU

**Pedestrian / Mass Transit / Bicycling**

Given its strategic location, the site will provide a terminus for the heavily used Bright Angel Trail, the South Rim pedestrian trail, and the park mass transit systems. To promote bicycle usage at the canyon, the park should consider the incorporation of bike racks, bike storage, and bike route signage as part of the plaza development.

## Minimizing Energy Usage

One of the primary objectives of sustainable design is to reduce energy usage. Generally, buildings use energy for several purposes. As indicated in the graph below, one primary purpose is for heating and cooling the building; the second primary usage is for convenience power and lighting. A third purpose is for water heating.

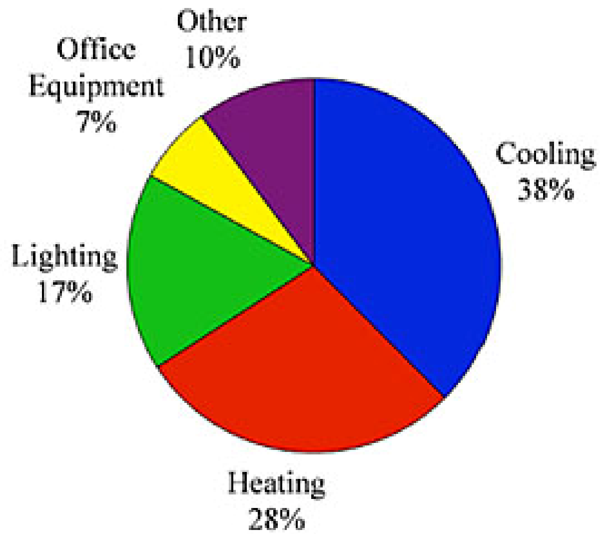



Fig. 5. Energy usage in sustainable design of buildings.

Because the restroom buildings will not be designed for continuous occupancy, the facility will not use large quantities of energy.  Heating and cooling loads can be minimized through thoughtful, high-mass design, and the lighting loads can be reduced through the use of daylighting. A heating load analysis for each building was completed as part of this study, and with typical construction assemblies, we can assume that the building will have a maximum heating load of approximately 35,000 btus/hr.

Table 1. Heat Loss Calculations for Restroom Building One.

| | | | | |
|---|---|---|---|---|
| | | **Building One** | | |
| | | | | |
| | | | | |
| | | | | |
| ***Conductive*** | | | | |
| | | | | |
| | U | A [surface area] | T [change in temperature] | U*A*T |
| East Wall | 0.4 | 234 | 60 | 5616 |
| South Wall | 0.4 | 95 | 60 | 2280 |
| North Wall | 0.4 | 95 | 60 | 2280 |
| West Wall | 0.4 | 234 | 60 | 5616 |
| Roof | 0.05 | 223 | 60 | 669 |
| Doors | 0.33 | 105 | 60 | 2079 |
| | F(2) | P(e) | T | |
| Floor | 0.83 | 35 | 40 | 1162 |
| | | | | |
| Total Heat Loss | 19,702 | BTU | | |
| | | | | |
| ***Infiltration*** | | | | |
| | | | | |
| Formula: | VOL ft^3 | ACH | T | Total |
| CFM=VOL*ACH/T | 2227 | 3 | 60 | 111 |
| | | | | |
| | | | | |
| | Constant(K) | CFM | Delta T | Total |
| Q(I)=K*CFM*T | 1.1 | 111 | 60 | 7349 |
| | | | | |
| Total Infiltration | 7349 | BTU | | |
| | | | | |
| ***Ventilation*** | | | | |
| | | | | |
| Formula: | Constant(K) | CFM | Delta T | Total |
| Q(I)=K*CFM*T | 1.1 | 85 | 60 | 5610 |
| | | | | |
| Total Ventilation | 5610 | BTU | | |
| | | | | |
| | | | | |
| Total Heat Loss (Btu/Hr) | | 32,661 | BTU | |

## Thermal Mass

Much of this heating / cooling load can be reduced through high-mass design. High-mass design uses building materials and assemblies to help collect and store heating and cooling. For instance, a traditional adobe building works like a heat sink, soaking up heat during the hot day, and re-radiating that heat during the cool evening. This passive strategy helps modulate rapid temperature swings, and reduces the energy needed for heating and cooling.

There are several high-mass design ideas that can be utilized on this project. For instance, heat losses through floors account for approximately 25% of heat losses in a building. Placing two inches of Dow Blue Board under the slab, and isolating the slab from the building edges with 1" foam strip that extends six inches below the slab, should insulate the floors. A poly vapor barrier should also be installed to help cure the concrete slab, and reduce the chances of radon migration through the floor.

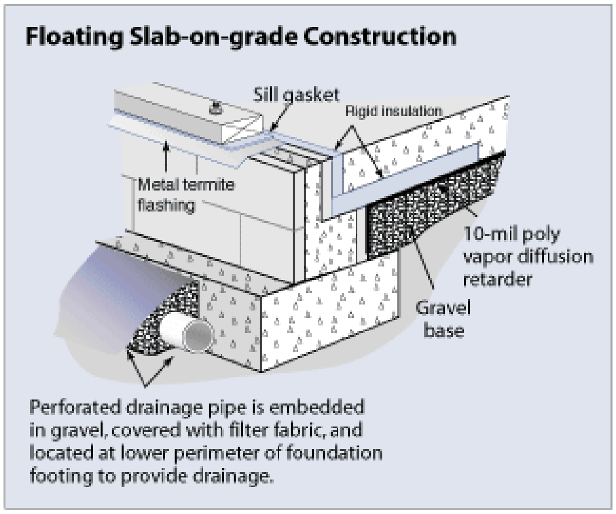



Fig. 6. Floating slab-on-grade construction (http://www.hometips.com).

Similar consideration should be given to the walls and the roof of the facility. Masonry block walls can act as an excellent thermal mass if they are insulated properly. For best results, the walls should be grouted solid, and then covered with rigid foam insulation on the outside of the wall. The exterior finish can then be applied to the outside of the foam. In this case, the foam helps isolate the thermal mass of the block wall.

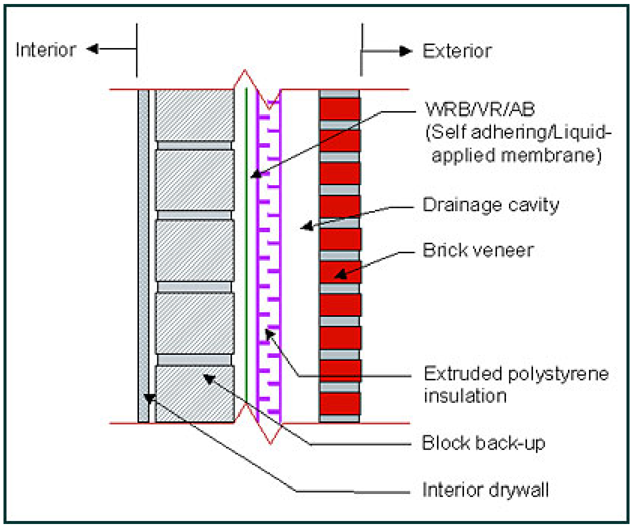



Fig. 7. Masonry insulation (http://www.masonrymagazine.com).

## Green Roof System

If properly constructed, the roof of each bathroom facility can also be used to help moderate temperature variations within the buildings. One increasingly used solution is a green or living roof. Like the sod houses of the nineteenth century, a layer of soil is added to the roof assembly. A green roof has several advantages. The soil can support drought-resistant plants, which help absorb stormwater and help to keep the roof cool through transpiration. The Center for Green Roof Research at Penn State University reports that a 4" green roof can retain 50% of total rainfall over a series of storm events. Green roofs reduce peak discharge rates by retaining runoff and creating longer flow paths. Research indicates that peak flow rates are reduced by 50% to 90%, compared to conventional roofs. Because the soil protects the roof from ultraviolet radiation, a green roof may effectively double the life of a membrane roof. Finally, the soil acts as an effective thermal mass and will protect the facility from the solar radiation effects of the intense sun. A green roof will cost more than a typical membrane roof system (approximately $5-6 sf.), however, the long-term operating and maintenance cost is much lower than for a traditional system.

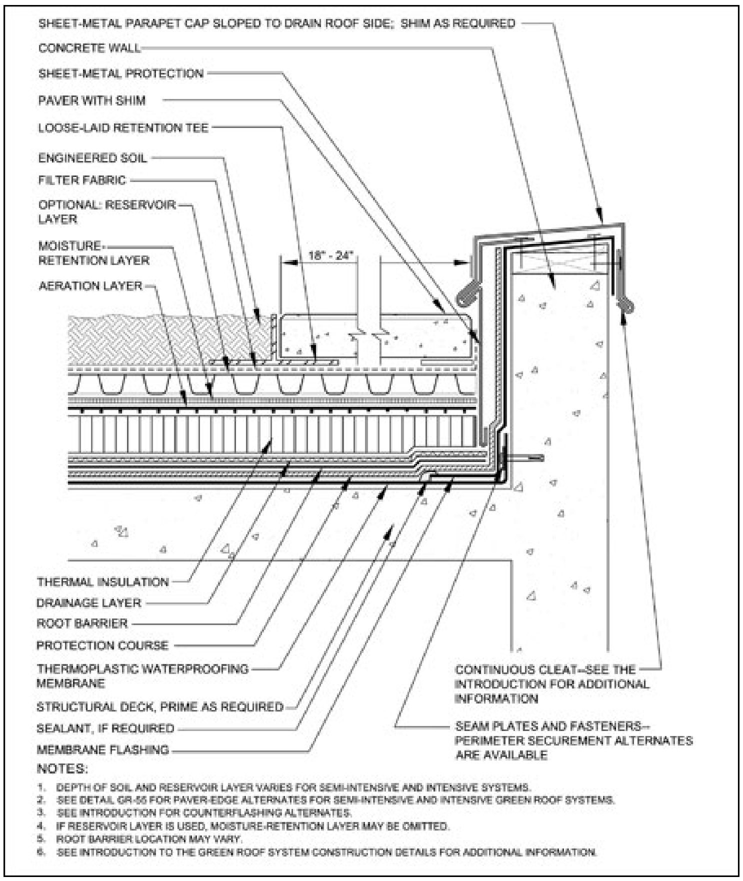



Fig. 8. Green roof detail (http://www.professionalroofing.net/).

## Heating and Cooling Systems

As part of this study, several solar heating systems were examined. Typically, these systems use a solar collector that is combined with a storage tank. Hydronic piping carries the heat to the floor, where it radiates into the room.

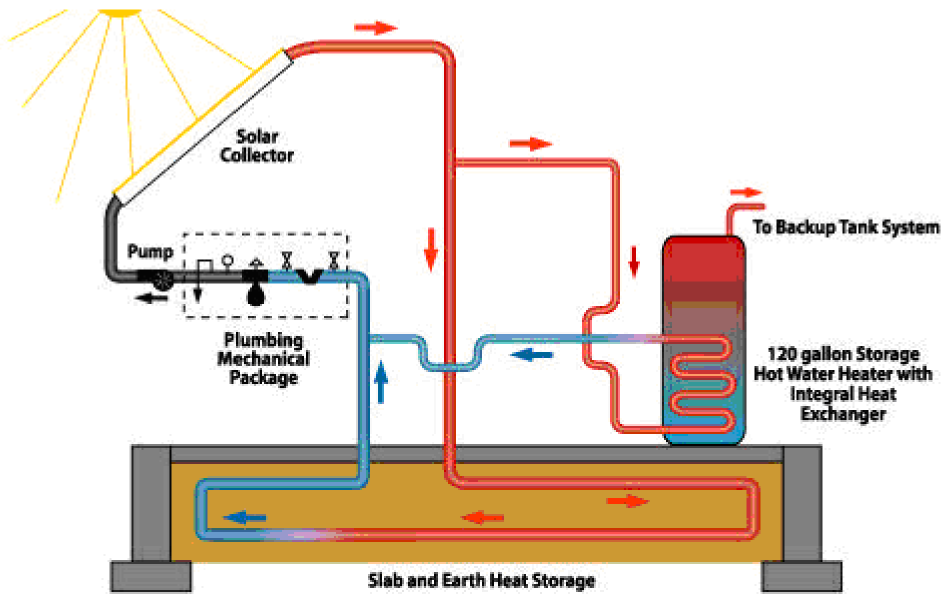



Fig. 9. Radiantec solar heating closed-loop system - Cost: $6,875 (Radiantec).

This closed-loop system provides a fairly simple solution for providing heat to the bathrooms. A small pump is used to move water through the system. The overall efficiency of the system is directly related to orientation and placement of the collector panels. There are several drawbacks to this system. If there is a possibility of freezing temperatures, the system needs to be drained to prevent damage to the piping. This will require monitoring and maintenance from park staff. Second, the current configuration of the restrooms does not provide adequate solar access for the panels. As designed, the restrooms are shaded on the south by large pine trees. If the solar collectors are placed on the roof, their efficiency may be compromised by the lack of solar access.

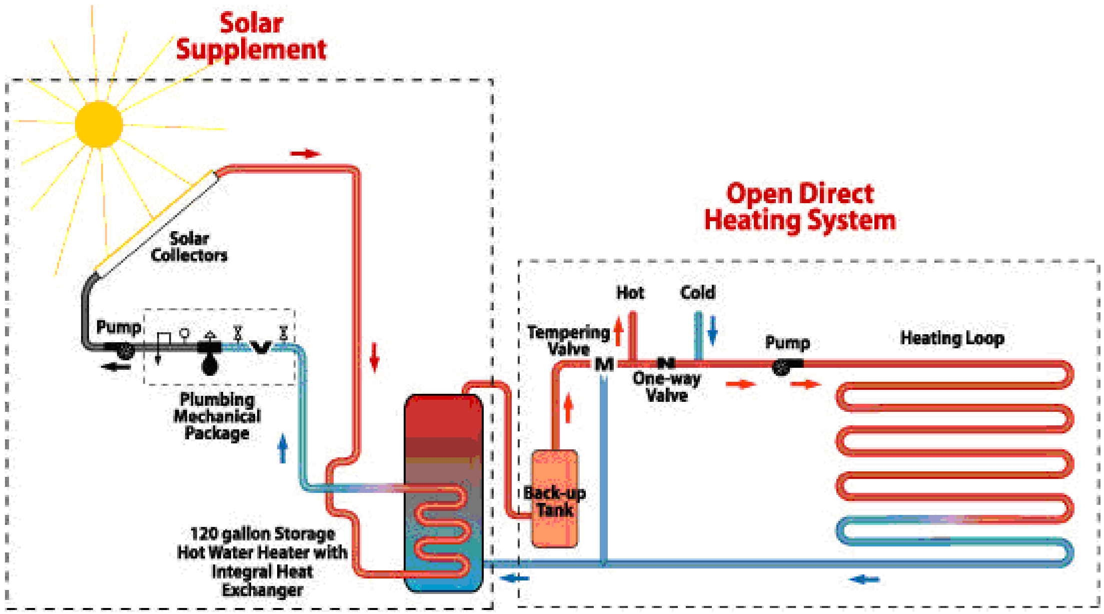
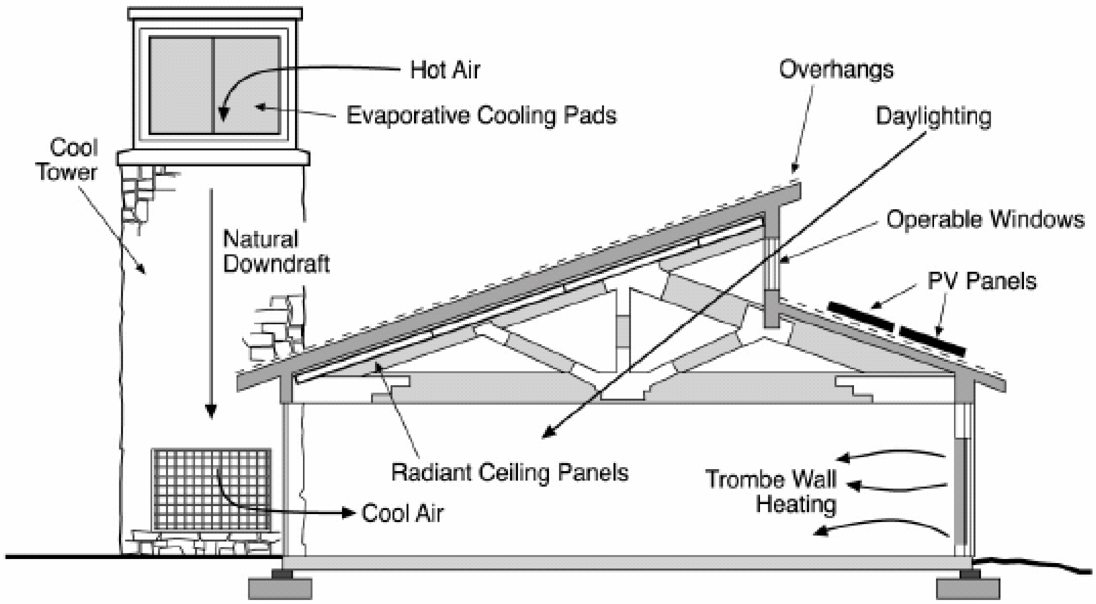



Fig. 10. Radiantec solar supplement open direct-heating system - Cost: $9,000 (Radiantec).

This variation eliminates the need for draining the system whenever there is a threat of freezing temperatures. Here, a glycol-based fluid acts as the heating medium, and heat is “exchanged” to a direct loop through a heat exchanger / hot water tank. This system requires more equipment and valves; so long-term maintenance would probably increase. Additionally, this system would require additional floor space to house the exchange mechanisms and pumps.

**Cooling Systems**

Zion National Park’s Visitor Center uses a passive cooling system to condition their building. Here, wind energy is used to push air into a solar chimney. Warm, dry air is cooled when it passes through an evaporative medium at the top of the chimney. The cool air then falls toward the bottom of the chimney, where it is used to cool the building. A fan could also be used to help move the air mechanically. This system could be used in conjunction with an on-site rainwater collection system to effectively cool both the restrooms and the plaza. Additionally, the towers could add an interesting architectural design element to the plaza. For a complete analysis of downdraft cooling systems, please see this article, “Refining the Use of Evaporation in an Experimental Down-draft Cool Tower” (Pearlmutter et al., 1996).




Source: NREL and NPS drawings.

Fig. 11. Heating and Cooling the Zion National Park Visitor Center (NREL and NPS).

## Electric Heating Systems

If properly insulated, a high-mass building shouldn't require a lot of heating energy. Because of the abundant solar energy available, heating loads are highly variable. Additionally, the current design of the restroom facilities uses individual doors for each restroom. Each time the door is opened, the heat will have a tendency to escape. As a result, it may be most economical to use small, electric space heater to temper the spaces. These systems are inexpensive, efficient, and easy to maintain.

## Ductless Mini-Split System

Ductless mini-split systems are small heat pump systems that were originally developed in Europe. Like air conditioning equipment, these systems have two components: an air handling unit and a remote condensing unit. The condensing unit is connected to the air handling unit with an umbilical conduit that contains the power, condensate, and refrigerant piping. Mini-split systems are small self-contained units that don't use ductwork, and, as a result, these systems can be used in a variety of installations. They can be mounted from the ceiling or in the wall or even mounted on a pre-manufactured stand. More importantly, mini-splits can be used to provide both heating and air conditioning from the same unit with excellent electrical efficiency. The coefficient of performance for most heat pump systems is between 2.5 and 3, which means that every watt of power generates between 2.5 and 3 watts of cooling or heating. The initial cost for these systems is approximately 30% higher than traditional heating / ac systems. Dependent upon electrical energy rates, the effective payback for these systems can be five to seven years (*Environmental Building News*, 2008).

### Photovoltaic Equipment

Photovoltaic (PV) systems convert sunshine into electrical energy. Typically, a system consists of PV panels or modules and the balance of system (BOS) equipment. The BOS equipment includes batteries, charger, controllers, inverters (for loads requiring alternating current), wires, circuits, grounding circuit, fuses, safety disconnects, outlets and a metal structure to support the PV modules. Most BOS systems equal or exceed the price of the PV modules. An engineering analysis would have to be applied to determine the total amount of PV required for the bathroom project, but with careful planning, the electrical requirements for lighting, heating, and ventilation would probably be less than 1 kilowatt (100 amps at 120 volts). As of June 2008, the U.S. index price for PV modules was $4.82 per watt. Given these assumptions, a budget of $10,000 would probably cover the cost of an adequate photovoltaic system. PV panels could be easily mounted on top of the shade structure.

### Building Commissioning

Most green building / sustainable design systems require that the developer hire an independent outside agent to “commission” the building. According to American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE), building commissioning can be defined as “a quality-oriented process for achieving, verifying, and documenting that the performance of facilities, systems, and assemblies meets defined objectives and criteria.” The commissioning process can be used to improve energy performance, train staff for operations and maintenance, and document as built conditions. Organizations that have researched commissioning claim that owners can achieve savings in operations of $4 over the first five years of occupancy as a direct result of every $1 invested in commissioning—an excellent return on investment (WBDG.org, 2008; DOE, 1998).

## Protect and Conserve Water

President Bush signed an executive order in summer of 2007, directing all federal agencies to “reduce water consumption intensity, relative to the baseline of the agency’s water consumption in FY 2007, through life-cycle cost-effective measures by 2% annually through the end of FY 2015 or 16 percent by the end of FY 2015 (FEMP, 2008).

Getting water to the Grand Canyon’s South Rim and North Rim is also an energy-intensive operation. Water for the South Rim originates at Roaring Springs on the North Rim of the canyon. It is then collected and pumped uphill to the South Rim. This requires extensive pumping power. A study in process (See Schlinger Water /Energy Report ) at the Grand Canyon suggests that it takes approximately ten times more power (approximately 20 kW per 1,000 gallons) than a traditional water distribution system.

The EPA has also mandated that all plumbing fixtures meet the 1.6 gallon per flush (gpf) standard for low-flow operations. Fixtures that meet these criteria often carry the EPA's WaterSense logo. Like the highly successful Energy Star program for appliances, the WaterSense program ensures that a fixture meets the EPA's requirements for water use and conservation.

### Flushometers

Manufacturers have recently developed a new class of fixtures, termed high-efficiency fixtures or HEFs. These fixtures are extremely water-efficient. For instance, the Sloan Valve Company has introduced a new series of High-Efficiency Urinals (HEU) that utilize only a pint (0.125 gallon) of water to flush and High-Efficiency Toilets (HET) that flush at an average of 1.28 gpf. The new Sloan HEU and HET systems combine the vitreous china fixture with either a manual or sensor-operated Flushometer. The HEFs can contribute to LEED® Credits 3.1 and 3.2 for water use reduction. In normal situations, an HET toilet can save approximately 8,000 gallons a year over normal low-flow models.

### Dual-Flush Toilets

Designed for light and heavy flushes, dual-flush toilets tend to average less than 1.2 gallons per flush. They meet HET criteria of 1.28 gallons per flush or less (HET criteria) for dual-flush toilets identifies the effective flush volume as the average of one high flush and two low flushes). Dual-flush models are available from many well-known manufacturers with light-flush capacities, from .8 to 1.1 gallons per flush and heavy-flush capacities from 1.3 to 1.6 gallons per flush. These toilets typically operate with a handle that can move up or down, or a two-button system. One direction or button will activate the lower-flow flush, while the other will activate the higher-flow flush.

### Pressure-Assist Toilets

Pressure-assist, or pressurized-tank, toilets are another high-performance, low-consumption alternative. These toilets use either waterline pressure or a device in the tank to create additional force from air pressure to flush the toilet. The device in the tank could either be a storage device with compressed air that would require replacement or a tank that creates pressure when the tank is being filled. These toilets typically average 1.1 to 1.2 gallons per flush. Some pressure-assist systems move a greater volume of water at a significantly lesser volume of sound.

### Power-Assist Toilets

Power-assist toilets operate using a pump to force water down at a higher velocity than gravity toilets. Power-assist toilets require a 120V power source to operate the small fractional horsepower pump. Typical flush volumes are between 1 and 1.3 gallons per flush; dual-flush models are also available.

### Maintenance Issues

Park officials estimate that an average of 3,500 visitors pass by the Bright Angel Trailhead each day. As a result, the new restroom facility will have considerable usage. Given this potential demand, the restrooms should be designed for durability and low-cost maintenance. Each bathroom should be provided with wall-hung toilets to facilitate cleaning. To minimize stoppages, automatic flushometer-type HEFs should be considered. Additionally, a sill cock should be provided in each restroom and the floors should be sloped to ensure that the restrooms may be easily and quickly serviced.

## Optimize Indoor Environmental Quality (IEQ)

### Passive Ventilation

In a restroom facility, ventilation is a key consideration. There are two approaches to ventilation. One approach is to use a passive system, while the other approach uses a mechanical system. If properly designed, the building can create its own passive ventilation system. A passive system is ideal, because it doesn't use energy and it has low maintenance and operations requirements. Typically, the design utilizes the "stack effect" that occurs when hot air rises. Typically, windows or "high out vents" are installed on the leeward side of the building. On the windward side of the building, windows or vents are installed low on the walls. This creates a convection loop that exhausts warm air from the building while bringing cool air into the building. Windows or clerestories can also provide daylight, minimizing the need for lighting energy.

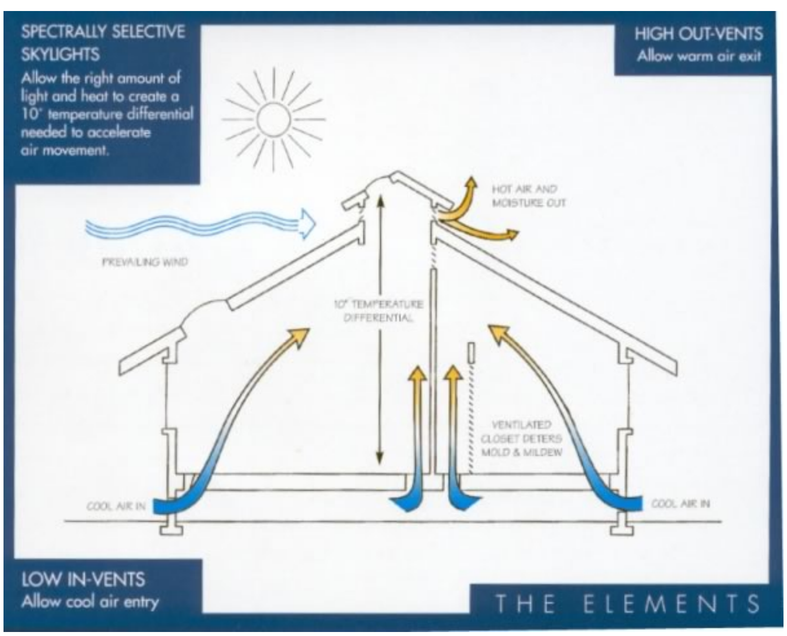



Fig. 12. *Heating and Cooling Your House Naturally* (MacDonald, 2006).

## Mechanical Ventilation

Electric exhaust fans are effective tools for ventilating a facility like these restrooms, but they also require energy, controls, and maintenance. An effective alternative is to use a solar powered exhaust fan. The WSE models shown here are used for ships and motor homes and they move 11.6 CFM. The solar-powered fans would work well at the Grand Canyon, because they would operate during the day when most of the visitors are present.

Fig. 13. WSE Solar Powered Extractor Ventilators

## Turbine Ventilators

Wind turbines are also dependable alternatives to electric ventilation systems. These systems work automatically, continuously, and silently, without operation or maintenance costs. Low wind speeds produce 126-147 CFM.

## Lighting

The park should consider using daylighting to light each of the restroom spaces. If properly designed, daylight can be used to provide much of the lighting without using utility provided energy. Individual tubular skylights could be used to provide most of the lighting in each bathroom. Exterior lighting for the plaza and interior night lighting could be easily provided by installing solar collectors and batteries on top of the shade structure. Careful consideration has to be given, to the type of solar panels used, the batteries employed, the lamps or LEDs – Light Emitting Diodes, and the circuitry that is utilized in the solar charger controller. The system should be connected to backup power to provide lighting when solar energy isn't produced. For a complete line of solar lighting products, see: http://solar-street-lighting.com.

## Utilize Environmentally Friendly Products

One of the principles of sustainable design is to use environmentally sensitive products that won't pollute the environment and products that have low-embodied energy. To minimize the embodied energy in products, the park should consider using materials that have been manufactured within 200 miles of the installation. Some products include: fly ash, recycled glass tiles, recycled metals, recycled roofing, FlexCrete blocks, insulated concrete forms, small-diameter pine, and construction and cleaning products with low VOCs.

### Fly Ash Concrete Slabs and Walks

Fly ash is a waste product that is produced at coal-fired power plants. Typically, fly ash is sent to the landfill, but increasingly, fly ash is being used as a substitute for cement in concrete mixes. Because cement has high energy content, the use of fly ash concrete can substantially reduce the embodied energy of the installation. Fly ash is produced at the Navajo Energy Plant in Page, and most local Ready Mix plants can provide fly ash concrete. Fly ash concrete can also be easily stained or diamond polished. Diamond polish is a very good finish for concrete floors. This diamond polish makes the concrete very dense, so that it protects the floor from absorption of oil or any other contaminants. Diamond polish makes the concrete floor 20% more impact resistant, compared to an unfinished concrete slab. Furnished and Installed costs for a 4" thick slab are typically $5 per square foot.

### Recycled Glass Tiles

These tiles are made from 100% recycled glass. The production of each tile uses 50% less energy than the production of similarly sized ceramic tiles and 75% less energy than cast-glass tiles. Tiles are made from 100% post-consumer or post-industrial sources. Colors come in hundreds of variations, styles, and finishes. Tiles come in a range of sizes from 1" x 1" to 6" x 6" that can be sold individually or in face-mounted sheets.

Fig. 14. Recycled glass tiles (Bedrock Industries).

**Recycled Metals**

Most steel produced in the United States is manufactured with recycled steel. Recycled steel is both durable and cost-effective, and it may be used in a variety of ways. For instance, Burns Wald-Hopkins Shambach Architects recently used 36" metal panels for the walls and partitions of public restrooms in Tucson. These panels can be specified with Kynar finish or weathering steel, producing a durable surface that is easy to clean. Recycled metal panels can also be used for roof decking, and for exterior walls. Gauges include: 24 ga., 22 ga., 20 ga, 18 ga. Metal Sales Manufacturing Corporation. Budget price is $5.00 per square foot.

**Recycled Roofing**

Re-New Wood manufactures ECO-SHAKE, a roofing product produced with 100% recycled materials made with reinforced vinyl and cellulose fiber. These shingles are designed to resemble and replace wood shake shingles. Eco-Shake is good for all climates, especially extreme weather, such as heavy snow or very high temperatures. The shingles have a 50-year warranty, freeze-thaw resistance, and UV protection. Budget pricing is $290 per roofing square (a roofing square is 100 square feet) plus shipping and handling (see http://www.eco-build.com/products/ecoshake/pricing.php).

**FlexCrete Blocks**

FlexCrete block is an autoclaved, aerated concrete block product that is made by using high volumes of fly ash. FlexCrete is available in rectangular blocks, tongue-and-groove panels for walls, floors and roofs, or, as unreinforced panels. All blocks and panels are entirely solid, making it easier to place and secure blocks and panels; less skilled labor is needed to work with these solid FlexCrete blocks. The FlexCrete blocks and panels can be drilled and shaped like wood, using standard hand tools. Ordinary motors and stuccos adhere to FlexCrete surfaces. FlexCrete blocks are manufactured locally in Page, Arizona, by Navajo FlexCrete Building Systems.

**ICF Wall System**

Insulated Concrete Forms (ICFs) are made of expanded polystyrene, the material similar to the Styrofoam used in ice chests. These forms consist of two panels that are connected by thick steel ties. Once the concrete is poured, the wall system can be covered with plaster on the inside, or stucco or veneer on the outside. These wall systems provide good insulation and thermal-mass values, which can effectively reduce heating and cooling loads. Costs are dependent upon quantity ordered, shipping destination, and engineering requirements.

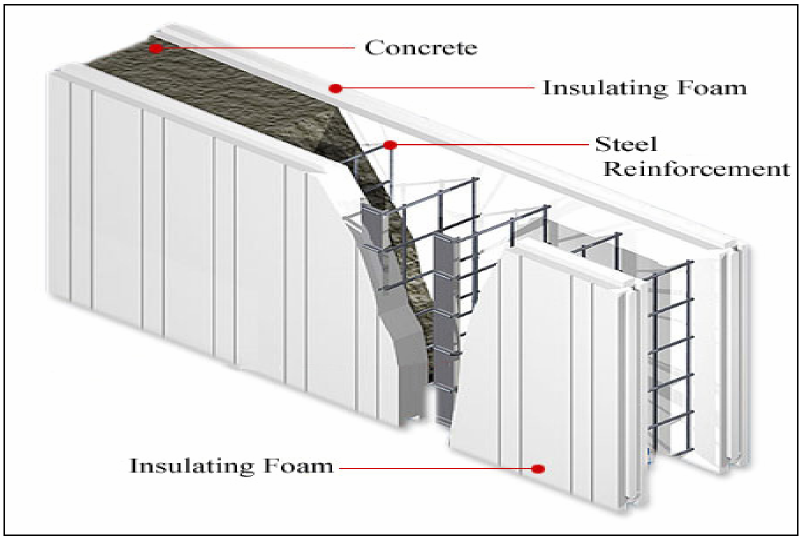



Fig. 15. ICF wall system (Mikey Block, Tucson, Arizona).

### Small-Diameter Pine

The Grand Canyon project is adjacent to the largest contiguous ponderosa pine forest in the world. A century of fire control has left the forest largely overgrown; the U.S. Forest Service, the City of Flagstaff, and the Greater Flagstaff Forest Partnership have implemented a wide-scale thinning effort to reduce fire danger and restore the health of the forest. (Small-diameter pine products could be used as columns and beams for the shade structure and the restroom roofs.)

### Low-VOC products

Many construction and cleaning products give off gas, high levels of toxic chemicals in the form of Volatile Organic Compounds (VOCs). These toxins are often found in paints, concrete sealers, adhesives, and caulking and sealing compounds. The specifications for the project should incorporate language that requires that all building products be VOC-free. Generally, VOC-free products are water-based or latex products.

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