# Sustainability and Precast Concrete

## 1. Is precast concrete a green building material?

Precast concrete contributes to green building practices in significant ways. The low water-cement ratios possible with precast concrete -0.36 to 0.38- mean it can be extremely durable. The thermal mass of concrete allows shifting of heating and cooling loads in a structure to help reduce mechanical-system requirements. Because precast concrete is factory-made, there is little waste created in the plant (most plants employ exact-batching technologies) and it reduces construction waste and debris on site, reducing construction IAQ concerns. The load-carrying capacities, optimized cross sections, and long spans possible with precast concrete members help eliminate redundant members, and concrete readily accommodates recycled content.

## 2. What makes precast concrete so durable?

The primary ingredients of concrete -sand, gravel, and cement- are mineral based. When mixed with water, the cement chemically reacts to create a crystalline matrix with a high compressive strength. This matrix binds the sand and gravel together, creating concrete. Unlike other construction materials that can rust, rot, or otherwise degrade when in the presence of moisture, concrete can actually get stronger if there are unhydrated cement particles available to react with the water.

## 3. Is precast concrete different from other types of concrete?

Precast concrete is different because it is made in a factory by highly experienced personnel who apply stringent quality-control measures. In the factory environment, precasters are able to achieve consistency in temperature and moisture and low watercement ratios that are not possible in field-fabricated concrete. Precast concrete can easily attain strengths of 5000 psi to 7000 psi or more, with densities that minimize permeability.

## 4. Is precast concrete energy-efficient?

The thermal mass of precast concrete absorbs and releases heat slowly, shifting air conditioning and heating loads to allow smaller, more efficient heating, ventilating, and air conditioning (HVAC) systems. Insulation is often used in architectural panels and sandwich wall panels to increase thermal efficiency, with continuous insulation (ci) in walls being possible. The resulting savings are significantup to 25% on heating and cooling costs.

## 5. Does precast concrete contain recycled materials?

Precast concretes fresh and in-place performance can improve when several common industrial byproducts are added. Fly ash, slag, and silica fume, which would otherwise go to landfills, can be incorporated into concrete as supplementary materials. These by-products can also reduce the amount of cement that is used in concrete.

Reinforcement is typically made from recycled steel. (Steel is one of the most recycled building materials, and can be reused again and again.) Insulation and connections within the precast concrete also contain recycled content.

## 6. Can precast concrete members be reused?

Precast concrete members are unique in that they are individually engineered products that can be disassembled. Designers can easily plan future additions to buildings, because the precast concrete components can be rearranged. Once removed, precast concrete members may be reused in other applications.

Precast concrete is also friendly to downcycling, in which building materials are broken down, because it comes apart with a minimum amount of energy and retains its original qualities. An example of downcycling would be the use of crushed precast concrete as aggregate in new concrete or as base materials for roads, sidewalks, or concrete slabs.

# Materials

## 1. What is the difference between concrete and cement?

While the terms are sometimes used interchangeably, concrete and cement are not the same. Concrete is a building material, a composite of aggregates including sand and gravel, plus cement, water, and other materials. Cement is a key ingredient of concrete, typically making up 10% to 12% of the volume.

## 2. What does cement do to concrete?

Cement does what its name implies-it cements the aggregates and other ingredients together. A fine powder that is usually gray or white in color, cement is hydraulic, meaning it chemically reacts with water. As the concrete components are mixed, cement helps turn the mixture into a flowable, formable emulsion, finally binding the components, as the concrete cures, into the rock-like substance used for everything from simple sidewalks to sophisticated skyscrapers.

## 3. What is portland cement?

Portland cement is a typical ingredient of concrete, and the most widely used type of cement. It was invented in the early nineteenth century and named after the fine building stones it resembled that were quarried in Portland, England. The innovation of portland cement marked a milestone in the construction history, as it created a far stronger bond than the plain crushed limestone of the day. Today it remains the best-performing and most economical binder used in concrete.

## 4. What are supplementary cementitious materials (SCMs)?

SCMs are used in concrete as cement replacement and/or to modify the properties of the fresh or hardened mixture. The ingredients are typically the by-products of other industrial processes, including fly ash, which is left over from coal burning power plants, and slag, which is produced during the production of steel. Other examples include silica fume and calcined clays.

As industrial by-products, some SCMs may not be part of an ideal future. As sustainable development extends to other industries, less and less of these materials may be available to be recycled into concrete. In the meantime, SCMs offer an opportunity to improve concrete performance with a recycled material that would otherwise have to be disposed of in landfills.

## 5. What do supplementary cementitious materials (SCMs) do to concrete?

SCMs work with cement to bind the aggregates and other concrete ingredients, and can improve concrete's fresh properties as well as its strength and durability. Light-colored SCMs, such as white silica fume or metakaolin, are used in architectural-face concretes. Certain SCMs, such as fly ash, may alter the color of the concrete or delay set times, which may be offset by chemical accelerating admixtures. SCMs work through either hydraulic or pozzolanic reactions.

## 6. What are hydraulic and pozzolanic reactions?

These terms describe how concrete sets and then hardens. Hydraulic reactions occur when a reactive ingredient is mixed with water. Cement is hydraulic, and so are Class C fly ash and certain types of ground-granulated blast-furnace slags. Pozzolanic reactions occur in the presence of calcium hydroxide ($Ca(OH)_2$), which is a by-product of the hydration of cement. Class F fly ash, silica fume, calcined clays, and most slags are pozzolanic.

Both hydraulic and pozzolanic reactions increase the strength and durability of finished concrete, and alter the fresh properties of concrete.

# Manufacturing

## 1. How is precast concrete made?

Precast concrete is made in a factory, where a dedicated batch plant produces a specially designed concrete for precast products such as structural beams, columns and double tees, architectural cladding, and wall systems. Aggregates usually come from nearby quarries, and cement and other ingredients are often supplied by local manufacturers.

The mixed concrete is placed into a form around reinforcement and, often, prestressing strands that provide load-resisting camber to the finished precast concrete member. After the member is cured, the precast concrete product is stripped from the form and moved to the precasters yard for finishing and storage prior to shipping to the jobsite.

## 2. What steps are precast operations taking toward sustainability?

PCI Producer Members meet local and state ordinances and emissions requirements. Initiatives within the industry include:

Use of local materials in all mixtures; local aggregate resources
Water reclamation and recycling
Reducing cement requirements by lowering watercement ratios
Admixtures such as hardening accelerators to eliminate applied heat in curing
Use of self-consolidating concrete (SCC) for quicker placement, no vibration, and reduced surface defects
Use of environmentally friendly thin brick in place of conventional brick in precast concrete systems
Carbon-fiber reinforcement that allows lighter and larger concrete sections with less embedded energy and no corrosion
Use of supplemental cementitious materials (SCMs) to reduce cement consumption; participation in Cool Climate Concrete
Enclosed sandblasting facilities with 100% process-waste control
Standardizing wood form parts for multiple reuse; recycling discarded forms into mulch or fuel
Recycling all scrap steel and reinforcement
Reducing and reusing product packaging received in facilities

## 3. How much cement is in precast concrete?

Typical concrete contains approximately 10% to 12% cement by volume. The cement chemically reacts with water to bind together the aggregates and other ingredients of the concrete. According to the Department of Energy (DOE), cement production contributes between 1% and 2% of global carbon dioxide emissions through the burning of fossil fuels and process-related emissions.

The amount of cement used in precast concrete may be reduced by up to 60% through substitution by supplementary cementitious materials (SCMs). The amount of cement substitution possible is affected by the mixture design requirements, the products and processes of individual precast concrete manufacturers and plants, and the local availability of materials.

## 4. What is being done about $CO_2$ emissions during the cement-manufacturing process?

Since 1975, the cement industry has reduced $CO_2$ emissions by 33%. Today, cement production accounts for less than 1.5% of U.S. carbon dioxide emissions, well below other sources such as electric generation plants for heating and cooling the homes and buildings we live in (33%) and transportation (27%).

In 2000, the cement industry created a new way to measure $CO_2$ emissions. Recently introduced guidelines will allow for greater use of limestone as a raw material in cement, ultimately reducing $CO_2$ by more than 2.5 million tons per year. By the year 2020, plans call for further reduction of $CO_2$ emissions to 10% below the 1990 baseline through investments in equipment, improvements in formulations, and development of new applications for cements and concretes that improve energy efficiency and durability.

# Precast Concrete Contributions to LEED Certification

## 1. What is LEED?

The U.S. Green Building Council (USGBC) developed Leadership in Energy and Environmental Design (LEED) Green Building Rating systems to assist with market transformation to a more stable, efficient, and environmentally sound approach to design and construction. The LEED products are voluntary, consensus-based systems used as standards for certification and design guides for sustainable construction and operation.

LEED includes a growing portfolio of rating products serving specific market sectors:

New Construction (LEED-NC)
Existing Buildings (LEED-EB)
Commercial Interiors (LEED-CI)
Core & Shell (LEED-CS)
Homes (LEED-H)
Neighborhood Development (LEED-NH)

Note: With its rigorous metrics, LEED rating systems are emerging as a key means to measure sustainable design practice. Other paths include Green Globes and Energy Star.

## 2. How does LEED-NC work?

The LEED-NC rating system assigns points to aspects of sustainable performance in six categories:

Sustainable Sites
Water Efficiency
Energy and Atmosphere
Materials and Resources
Indoor Environmental Quality
Innovation and Design

To achieve LEED certification, project teams must satisfactorily document achievement of all the LEED prerequisites and a minimum number of points. Project teams submit design concepts and plans to the USGBC, often assisted by a LEED Accredited Professional (LEED AP). USGBC assigns an expected rating to the project, and gives a formal rating after the team completes a construction submittal.

## 3. How many points are required for a project to be LEED-NC Certified?

LEED-NC certifies buildings to four levels of increasing sustainable performance:
Certified (26–32 points)
Silver (33–38 points)
Gold (39–51 points)
Platinum (52–69 points)

## 4. How does precast concrete contribute to LEED-NC rating points?

Precast concrete:

minimally disrupts the site (area and time)
reduces damage to drainage paths and natural habitats
increases open area when multi-level parking structures are used
reduces the heat-island effect because of concrete's light color
improves energy efficiency and thermal comfort
reuses and recycles formwork, keeping materials out of the landfill
uses recyclable concrete and steel
can be reused or recycled
can use waste and recycled materials such as slag, fly ash, and silica fume
is generally made from materials that are extracted and manufactured regionally
does not off-gas, and does not need to be sealed or painted

## 5. What LEED-NC points does precast concrete contribute toward?

Precast concrete and other materials contribute to LEED points by providing performance and properties that are measured by the LEED program. At this time, PCI endorses potential precast concrete contributions for up to 20 LEED points (see LEED Project Checklist) and possibly more, depending on the project.

For a detailed discussion of precast concrete's contributions to green building practices, including LEED points, please refer to "Achieving Sustainability with Precast Concrete" by Martha VanGeem, CTL Group, which was published in the January–February 2006 issue of the *PCI Journal*.

## 6. How can precast concrete reduce the heat-island effect described in the LEED Sustainable Sites credit (SSc7.1)?

Sustainable Sites credit 7.1 is intended to reduce heat islands, meaning the thermal gradient difference between developed and undeveloped areas. The heat-island effect is partially attributed to the dark surfaces of roofing and paving, and the additional heat in developed areas increases HVAC loads and contributes to the creation of smog. Reducing heat islands minimizes impact on microclimate and human and wildlife habitat.

Precast concrete parking structures that place at least 50% of the spaces under cover (for example, underground, under a building, or under a deck or roof) can reduce this effect. Any roof used to shade or cover parking must have a solar reflective index (SRI or albedo) of at least 29. In addition, high-albedo vertical precast concrete wall surfaces reduce the heat-island effect.

## 7. Do recycled materials in concrete (fly ash, slag) contribute to LEED points?

Yes, under the recycled content credit MR 4.1 and 4.2.

## 8. Is the 500-mile-radius requirement for local-material content limited to the finished precast concrete product, or does it also apply to the raw materials?

Credit MR 5.1-5.2 applies to all materials extracted, processed, and manufactured within a 500-mile radius of the project site.

## 9. How can precast concrete contribute to Innovation and Design in LEED?

Projects earn Innovation and Design credits when they demonstrate exemplary performance in a recognized LEED credit area, or bring new approaches and technologies such as carbon-fiber reinforcing that reduce weight and embedded energy and advance sustainable design. Because of its significant contributions to LEED, and its inherent green characteristics, precast concrete offers an excellent platform on which creative project teams can base their sustainable design plans.

## 10. How does precast concrete contribute to the underlying sustainability concept of "Reduce, Reuse, Recycle"?

By reducing the amount of materials and the toxicity of waste materials

Precast concrete can be designed to optimize (lessen) the amount of concrete used in a structure or element
As one example, the use of carbon-fiber reinforcement or insulation can reduce:

- Amount of concrete needed in a precast concrete panel
- Weight of a precast concrete panel
- Transportation cost of precast concrete panel
- Amount of energy used to erect a precast concrete panel

Precast concrete generates low amounts of waste with low toxicity

- 2% of the concrete at a precast plant is waste
- 95% of the waste is used to manufacture new panels

By reusing products and containers and repairing what can be reused

Precast concrete panels can be reused when buildings are expanded or dismantled
Concrete pieces from demolished structures can be reused to protect shorelines
Wood or fiberglass formwork used to make precast concrete products is generally reused 40 or more times
Concrete and steel have practically unlimited service lives

By recycling as much as possible, including buying products with recycled content

Industrial wastes (fly ash, slag, and silica fume) can be used as partial replacements for cement
Wood and steel forms are recycled when they become worn or obsolete
Virtually all reinforcing steel is made from recycled steel
Insulation contains partially recycled material
Concrete in most urban areas is recycled as fill or road base

# Sustainability

## 1. What is sustainability and why is it important?

The United Nations Brundtland Commission Report (1987) defined sustainable development and urged the world to take note: "Sustainable development is that which meets the needs of the present without compromising the ability of future generations to meet their own needs." A growing global population is straining the finite resources available on the planet. Sustainability seeks to balance the economic, social, and environmental impacts, recognizing that population growth will continue. Sustainable development brings this evaluation to the design and construction industries, which have significant potential to reduce the negative impact of human activities on the environment.

## 2. Why is there demand for sustainable development?

According to the U.S. Green Building Council (USGBC), buildings in the United States consume nearly 10% of the world's energy, and over 30% of the total energy and more than 60% of the electricity in the United States. The U.S. Department of Energy reports that 51% of electricity comes primarily from the burning of coal, a fossil fuel that produces significant greenhouse gases during combustion.

With energy costs increasing, and concerns about environmental impact growing, the U.S. government is adopting green building programs. In addition, an increasing number of states are offering tax benefits for green public buildings, and large corporations are moving toward sustainable design for their facilities to reduce operations and maintenance costs.

## 3. What is a green building?

The U.S. Office of the Federal Environmental Executive (OFEE) defines green buildings as those that:

demonstrate the efficient use of energy, water, and materials

limit impact on the outdoor environment

provide a healthier indoor environment

Studies show that green buildings offer improved air quality and more access to daylight in addition to energy and cost savings. The USGBC estimates that green buildings cost 8% to 9% less to operate, and have a 7.5% greater building value.

## 4. What is the cost premium for a green building?

The USGBC cites an initial cost premium of anywhere from 0% to 2% for green buildings in the United States. As project teams become more experienced with building green, these costs should decrease. Generally, a 2% increase in construction costs will deliver a savings of 10 times the initial investment in operating costs for utilities (energy, water, and waste) in the first 20 years of the building's life.

## 5. What is the payback for a sustainable building project?

The financial payback of green building practice is measured in operating and maintenance savings over time offsetting initial costs of sustainable features. The payback varies from project to project, depending on the implemented sustainable features and other factors such as availability of materials and expertise of the design team. However, experienced design professionals maintain that green buildings do not have to cost more than non-green buildings.

Source: HOK Guidebook to Sustainable Design

## 6. How can I measure the costs and benefits of sustainable design?

Most project teams perform a comprehensive life-cycle cost assessment (LCC) prior to defining their sustainable goals for the project. The LCC predicts how long it will take to recoup additional first cost.

## 7. Do government projects require LEED certification?

More and more local, regional, and national government agencies require sustainable building practices or LEED certification. The Wall Street Journal reported that Michigan, Washington, and Arizona adopted guidelines to produce buildings that are more energy efficient and environmentally sensitive. The General Services Administration (GSA), U.S. Army, Department of State, Department of Energy (DOE), and Environmental Protection Agency (EPA) are adopting LEED or similar green-building standards. Twenty-five states including California, New York, Washington, and Oregon have adopted LEED, as have over 100 U.S. cities including Chicago, Boston, and San Francisco.