# LCA Shows that Precast Concrete Does Not Impose Any More Environmental Burden than Other Materials

(This is part three of a four-part series)

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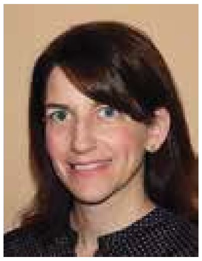
In previous parts of this series, the benefits of using life-cycle assessment (LCA) to predict environmental-impact potential of products, processes, or services were highlighted. When LCA is used to compare complex systems using a full set of environmental impacts over the full service life, designers can better assess the sustainability of their design choices and make fair comparisons between materials or systems. And because LCA can show different results depending on the system boundary chosen, the quality of the data, and the timeframe selected for comparisons, the best way to evaluate the full environmental impact of a product is through a cradle-to-grave, ISO-compliant LCA.

It is with that background knowledge that the precast concrete industry began a cradle-to-grave, ISO-compliant, comparative assertion LCA in 2009. This article will highlight some of the results of that study.

## Background

In 2009, the Precast/Prestressed Concrete Institute (PCI), Canadian Precast/Prestressed Concrete Institute (CPCI), and the National Precast Concrete Association (NPCA), began a research program to better understand precast concrete's environmental life-cycle performance.



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Overall, the research objectives were to:

1. foster a better understanding of the environmental impacts of precast/prestressed concrete components and their use in high-performance structures;
2. better understand precast concrete's environmental life-cycle performance in mid-rise precast concrete buildings compared to alternative structural and envelope systems;
3. benchmark the industry's performance in order to track its improvements;
4. increase transparency in the marketplace.

## Scope

This LCA study used the U.S. EPA Tool for the Reduction and Assessment of Chemical and Other Environmental Impacts (TRACI) impact assessment method, which output the following midpoint indicators:

- Global Warming Potential
- Acidification Potential
- Potential Respiratory Effects
- Eutrophication Potential
- Photochemical Smog Creation Potential
- Ozone Depletion Potential

In addition, the following inventory items were tracked:

- Total Primary Energy
- Solid Waste
- Water Use
- Abiotic Resource Depletion

The methodology employed in this study complied with international standards ISO 14040:2006[1] and ISO 14044:2006[2] for conducting life-cycle assessments. The research was conducted by a team comprised of Morrison Hershfield, the Athena Institute, and Venta, Glaser & Associates.

## Baseline Building

The basis of comparison chosen for the study was a five-story commercial office building that provides space for 130 people and meets minimum building and energy code requirements. The service life of the building was assumed to be 73 years, the median life for large commercial buildings according to published literature.

The study evaluated 15 design cases consisting of five different building envelope systems combined with three different structural systems (Table 1). To consider different climate conditions, the 15 cases were modeled in four U.S. locations (Denver, Memphis, Miami, and Phoenix). The case using precast concrete for both the envelope and structural systems (designated "P-P") was defined as the baseline for comparison.

## Results

Ten specific environmental impact and life-cycle inventory categories were evaluated for each of the 15 cases, in each of the four cities. To provide a simplified characterization for the purpose of this article, the discussion below focuses on the coefficient of variation (COV) of the results for the

*Table 1. Summary of the 15 Building Types / Assemblies.*

| Building envelope type and abbreviation | Structure type and abbreviation | | |
|---|---|---|---|
| | Steel (S) | Cast-in-place concrete (C) | Precast concrete (P) |
| Curtain wall (CW) | CW-S | CW-C | CW-P |
| Brick and steel stud (S) | S-S | S-C | S-P |
| Precast concrete (P) | P-S | P-C | P-P |
| Insulated precast concrete (Pi) | Pi-S | Pi-C | Pi-P |
| Insulated precast concrete and thin-brick veneer (Pib)* | Pib-S | Pib-C | Pib-P |

*Thin-brick veneer is bricks that are 13 to 16 mm ($^1/_2$ to $^5/_8$ in.) thick, cast into the precast concrete panels.*

15 building cases for each environmental impact and life-cycle inventory category. Refer to **Table 1** for a summary of the 15 building assemblies.

In many categories, the 15 different building cases had a COV of 2% or less, which shows that there is not much difference between the buildings within a given city. These categories include Global Warming Potential, Total Primary Energy, Acidification Potential, Potential Respiratory Effects, Eutrophication Potential, Photochemical Smog Creation Potential, and Solid Waste.

As an example, let's look at Global Warming Potential. Global Warming Potential (GWP) is mainly a function of the energy use of the building and the type (source) of electricity in the particular city. The GWP of electricity from the electricity grid in Denver is more than the GWP of electricity in the other cities because it has much less contribution from nuclear (which is a low CO2-intensive source of electricity). Therefore, even though the buildings in Denver use the least amount of electricity, they have the highest GWP. Further, the relative difference between the wall U-factors within a city are different among cities because energy code requirements are different for each city. For example, the code requires more insulation in curtain walls in Phoenix than in Miami. Therefore, when comparing the GWP of concrete curtain wall buildings, Miami is lower (better) than their counterparts in Phoenix. **Figure 1** data show:

- In Denver, GWP varies from 58 to 62 million kg $CO_2$ eq. and the coefficient of variation (COV) is 2%.
- In Memphis, GWP varies from 45 to 46 million kg $CO_2$ eq. and the COV is 1%.
- In Miami, GWP varies from 50 to 51 million kg $CO_2$ eq. and the COV is less than 1%.
- In Phoenix, GWP varies from 44 to 46 million kg $CO_2$ eq. and the COV is 1%.

These small COVs indicate that there is not much relative difference in GWP between the buildings within a given city.

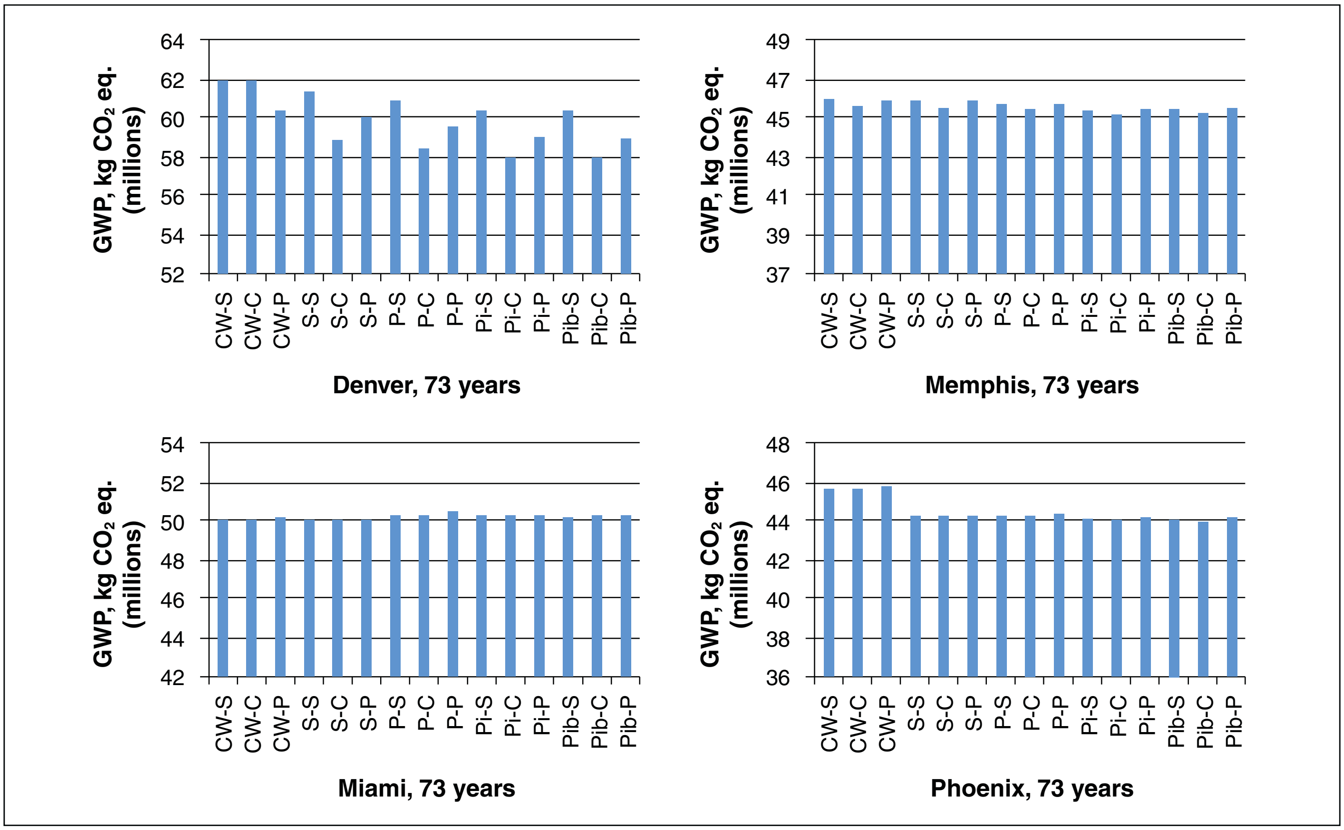

*Figure 1. Global Warming Potential (GWP) of the 15 buildings for each of the four cities; coefficient of variation* for the data varies from 0 to 2%. Note that the scale of the vertical axis is different for each city.*

**These small COVs indicate that there is not much relative difference in GWP between the buildings within a given city.*

For the following three categories, some slight variances were observed.

### Water Use

For the 15 different building cases:

- Within a given city, the COV of Water Use is 14%, which shows that there is some difference between the buildings within a given city.
- In all cities, regardless of envelope, the buildings with steel structures have the highest potential water use.
- The reason for the similarity is that most of the water use is during the operating energy stage, and is the same in all buildings regardless of building or location (23,984 $m^3$).
- The reason for the difference is that in the buildings with steel structures, the elevator and stairwell walls—which are concrete masonry—embody more water use (9882 $m^3$) than all the water embodied in the buildings with cast-in-place or precast concrete structures (3104 m3 to 4916 $m^3$). The elevator and stairwell walls in the buildings with cast-in-place or precast concrete structures are cast-in-place concrete and embody 175 $m^3$).

### Abiotic Resource Depletion

For the 15 different building cases:

- Within a given city, the COV of Abiotic Resource Depletion is 36%, which shows that there is a large difference between the buildings within a given city.
- The majority of the abiotic resource depletion is embodied in the manufacturing stage.
- Regardless of city, the buildings with largest potential for abiotic resource depletion are the buildings with steel structures. Looking deeper into the data, in the buildings with steel structure the majority of the abiotic resource depletion is embodied in the steel decking of the floors and roof (2.40 kg Sb eq. for the steel floors and roof out of 3.62 kg Sb eq. for the total manufacturing stage).

In comparison, the total abiotic resource depletion embodied in the manufacturing stage of buildings with cast-in-place concrete or precast concrete structures (1.66 to 2.02 kg Sb eq.) is less than that embodied in just the floors and roof of the buildings with steel structures.

### Ozone Depletion Potential

For the 15 different building cases:

- Within a given city, the COV of Ozone Depletion Potential varies from 0 to 15%, depending on the city, which shows that there are some regional differences between the buildings within some cities and none in others.
- Most of the ozone depletion potential is embodied in the extruded polystyrene (XPS) insulation; therefore, the ozone depletion potential is directly proportional to the amount of XPS insulation in the buildings over their life cycle.
- All the buildings have XPS insulation in the roof, and during the maintenance stage, when the roof is replaced every 20 years, the insulation is also replaced. Over the life of the building, more XPS insulation is used in the roofs of all buildings than is used in the walls of the buildings with cast-in-place or precast concrete envelopes. Therefore the main driver of ozone depletion potential is the XPS insulation in the roof.
- All of the XPS insulation in the buildings in Miami is in the roof and it is the same amount in all buildings; therefore, the ozone depletion potential is essentially the same for all buildings (COV is close to 0%).
- In the walls of the study, XPS insulation is only used in the cast-in-place and the precast concrete walls in Phoenix, Memphis, and Denver. So the buildings with cast-in-place and precast concrete walls have a greater ozone depletion potential than the building with curtain wall and brick on steel stud walls.

## Similar Overall Life-Cycle Environmental Impact

This study confirmed a basic conclusion of most balanced LCA studies of commercial buildings, such as the MIT Research: Life Cycle Assessment of Commercial Buildings[3] namely, that there is presently not a significant difference in life-cycle impacts between steel, cast-in-place concrete, and precast concrete structural systems. Although concrete is sometimes perceived to have a higher environmental impact due to energy use and carbon dioxide emissions associated with manufacturing portland cement. The fact is, as shown by this research, precast concrete does not impose additional environmental burden than other materials.

Hence, material and system selection can be based on the inherent attributes and benefits of the material or system. Precast concrete inherently offers many high-performance attributes, and is being used to help projects meet and exceed their high-performance goals during design, construction, and operation. Therefore, the benefits of precast concrete can be utilized to meet high-performance goals without any more environmental burden relative to other materials and systems.

Furthermore, since the use phase has the most impact on the life cycle of a building, selecting materials and systems that provide energy reducing benefits, such as precast concrete envelope systems, are very important to reducing overall environmental impact.

## Next Steps

Through its LCA research, the precast concrete industry is increasing transparency and developing a more-thorough picture of the environmental impact of its products or processes. The last article in this series will focus on the steps some precasters are taking in their manufacturing facilities to reduce environmental impacts and increase transparency.

### References

1. International Standards Organization (ISO). 2006. *Environmental Management—Life Cycle Assessment—Principles and Framework*. ISO 14040, ISO, Geneva, Switzerland.
2. ISO. 2006. *Environmental Management—Life Cycle Assessment—Requirements and Guidelines*. ISO 14044, ISO, Geneva, Switzerland.
3. MIT Research: Life Cycle Assessment of Commercial Buildings, National Ready-Mixed Concrete Association, CSR05 – September 2011.

**For more information on these or other projects, visit www.pci.org/ascent.**