Sustainable Concrete Technologies for Precast Structures

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Presentation Outline

• What is sustainability?
• The Sustainability market
  – The Provocation
  – Global Outline
  – Mexican Details
• GreenSense Concrete
• Eco Efficiency Analysis
• Project Profile
  Perot Museum
What is sustainability?

The best-known definition comes from Our Common Future (the so called “Brundtland Report”) prepared under the auspices of the World Council on Environment and Development in 1987, which defines sustainable development as:

“Development that meets the needs of the present without compromising the ability of future generations to meet their own needs.”
Green Building Basics
On a Global Basis

The case for green building – current construction is not sustainable

Buildings Consume:
- 70% of all electricity
- 37% of all energy
- 28% of all water
- 30% of wood + materials

Buildings Produce:
- 35% solid waste to landfills
- 36% CO₂ emissions
- 45% SO₂ emissions
- 19% NOₓ emissions
- 10% fine particulate emissions
Megatrend: Sustainability
Sustainability is organized, measured and growing
Global Green Building Activity Is Growing!

Average 2012 Green Share of Building Project Activity (Total Sample)

Levels of Green Building Activity by Firms Around the World (2009–2015 Expected)
Global #1 Reason for Sustainable Construction is Social, not Economical!
Characteristics of “Green” Products
(2013 World Green Building Report)

- Highly Energy Efficient: 73%
- Durable: 71%
- Made of Recycled Content: 53%
- Non-Toxic: 51%
- Cradle-to-Grave/Cradle-to-Cradle Lifecycle Data Provided: 31%
“US Green Construction”

Since 2005, New Green Building Market Has Grown Eight-Fold

Source: 2013 Dodge Construction Green Outlook
Mexico

Construction Forecast

Mexico Construction Industry

- Construction industry value, MXNbn (LHS)
- Construction industry, real growth % y-o-y (RHS)
México: Evolución estimada de emisiones por edificios a 2050

Fuente: SBCI-UNDP
Cifras estimadas de evolución del consumo de electricidad por usos finales en el sector residencial

Projected Electricity Consumption by usage in the residential sector in Mexico

Fuente: SBCI-UNDP
The General Law on Climate Change was sanctioned on June 5 2012, and outlines stringent CO2 emission targets of 30% 'below business-as-usual levels' by 2020, and a 50% reduction on 2000 levels by 2050. It also aims to increase renewable electricity generation so it contributes at least 35% to the total generation mix by 2024.
Mexican Renewable Energy

- Mexico has an estimated 45GW solar potential and 71GW wind power potential
- Mexico beat its own renewable energy target by generating 26% of electricity from renewables in 2012, aiming for 35% by 2024
- Mexico will require an estimated 27GW of new capacity over the next 15 years to cover growing demand
How Building Design affects Energy Consumption

Utilizing best design practices for the building envelop can save at least 40% of the total energy consumption of the building.

— Note: If the current practices are continued energy consumption with increase 90% by 2050.

Source: New Buildings Institute
One way to impact the sustainable approach to construction is to use **concrete**!
Concrete and Sustainable Construction

When considering the lifetime environmental impact of a building material from extraction, production, construction, operation, demolition and recycling, concrete is an excellent choice for sustainable construction.

- Reduced carbon footprint
- Thermal transmission
- Thermal mass and storage
- Service-life
- Storm water management
- Living/working environment
- Safety and security
- Reuse and recycle

Characteristics of Green Products
(Percentage of Manufacturers and Suppliers Whose Products Include These Characteristics)

- Highly Energy Efficient: 73%
- Durable: 71%
- Made of Recycled Content: 53%
- Non-Toxic: 51%
- Cradle-to-Grave/Cradle-to-Cradle Lifecycle Data Provided: 31%
One approach to sustainability in construction is the use of GreenSense Concrete in structural design to capture the characteristics of a “green” product.
What is Green Sense Concrete?

An environmentally-friendly, cost-effective concrete mix optimization service in which recycled materials are used with special chemical admixtures to meet or exceed performance targets.

Reduced Environmental Footprint

- Fly Ash (Type F or C)
- Slag Cement
- Limestone Fines
- Aggregate Fines

Other Materials
- Non Spec. Silica Fume
- Aged Cement Kiln Dust
- Rice Husk Ash
- Burnt Oil Shale Fines
- Glass Powder
- Metakaolin
GreenSense Concrete for Precast

Start with an existing reference mix

Advanced Level of Mix Optimization

Region
- Available Materials
- Reactivity Levels
- Regional Admixtures

Recipe
- Characterization
- Gradations
- Custom Software
- Proportioning Expertise

Chemistry
- Novel Chemistry
- Custom Molecules
- Rheology
- Slump Retention

Cash and carbon costs are minimized!

Customized Specific Green Sense™ Concrete Mix Design
Advanced Concrete Technology

Redefining the concrete space

- Proportioning Expertise
- Recycled Materials
- Admixtures
- Workability Retention

Workability

Cost

Durability

Porosity

Green Sense Concrete
Reference Concrete
Green Sense™ Concrete Benefits

**Producer**
- Lower Mix Cost
- Improved Workability and Finishability
- Improved Control of Strength Development

**Engineer**
- Improved Durability
- Less Shrinkage
- Less Cracks

**Owner**
- Increased Service Life & Reduced Environmental Impact
How do you quantify the benefits of Green Sense Concrete? The EEA!

Quantifying Concrete Sustainability
The Eco-Efficiency Analysis quantifies the economical and ecological impact of any Concrete mix design.

- Customized Interactive Program specifically for concrete
- Compares five different concrete mix designs for six environmental impact areas
- Third party validated by TUV and NSF following ISO 14040 and 14044
The Eco-Efficiency Analysis methodology has been third-party validated by TÜV Rheinland® (certificate number: 5711150561).

*TÜV appraises, tests and certifies technical equipment and products according to international quality standards and then registers those in compliance.*

Methodology validation by NSF International. (Protocol P352)

*NSF International, a not-for-profit, non-governmental organization, develops national standards and provides third-party conformity assessment services.*

Data acquisition and calculation is done according to the environmental protocol ISO 14040 and 14044 (ecological part).
Impact of Raw Materials

EEA concrete analyses can be conducted on ready mixed, precast, manufactured concrete products, paving, self-consolidating and pervious concrete.
How Does the Eco-Efficiency Analysis Work?

- **Data Input**
  - Producer Information
  - Raw Material Sources
  - Raw Material Costs
  - Mix Design
  - Transportation Distances

- **Database**
  - Environmental profiles
  - Sums Raw Material data
  - Calculations
  - Compares mix designs

- **Report Options**
  - Select
    - Raw Material Costs
    - Transportation Distances
    - Annual Production Data
    - Mix Proportions
    - Mix Design Costs
    - Environmental Fingerprint
    - Mix Design Portfolio
    - Water Savings
    - Environmental Overview
    - Energy Consumption
    - Photochemical Ozone Depletion Potential
    - Global Warming Potential
    - Acidification Potential
    - Ozone Depletion Potential
    - Risk Potential
    - Raw Material Consumption
    - Land Use

- **Custom Environmental Report**
  - Qualitative
  - Quantitative

- **Output**
Eco-Efficiency Analysis of Concrete

Data Input
- Mix Design
- Transportation Distances

Computer Analysis
- Environmental profiles
- Sums raw material data
- Calculations
- Compares mix designs

Custom Quantitative Environmental Report

Custom Environmental Report
Qualitative
Quantitative
Environmental Impact Categories

- **Consumption of Energy**
  - Cumulative energy utilized in the production, use & disposal phases
  - Fossil and renewable resources are included

- **Emissions**
  - Described by categories
    - Air
    - Water
    - Solids

- **Toxicity Potential**
  - Potential effect on human health toxicity

- **Risk Potential**
  - Potential for physical haz. (i.e. work accid. & occupational disease)
  - Based on published stat. data (e.g. insurance assoc.)

- **Consumption of Raw Materials**
  - Materials are weighted according to reserves and global consumption

- **Land Use**
  - Degree of land development needed to fulfill the production, use & disposal of 1 m² of concrete

- **Global Warming Potential**
- **Ozone Depletion Potential**
- **Photochemical Ozone Creation Potential**
- **Acidification Potential**
The three concrete alternatives are shown to be progressively more environmentally preferable in relation to the reference mix.

### Ecological Fingerprint

- **Energy consumption**
- **Use of area**
- **RM consumption**
- **Emissions**
- **Toxicity potential**
- **Risk potential**

- **Reference Mix**
- **Fly Ash 15%**
- **Fly Ash 30%**
- **Fly Ash 38%**

### Alternatives:
- **Fly Ash 15%**
- **Fly Ash 30%**
- **Fly Ash 38%**
Eco-Efficiency Profile
Economical and Ecological Impact

The concrete with the lowest overall environmental burden and the most economical to produce move directionally toward the upper right quadrant.

Reference Mix
Fly Ash 15%
Fly Ash 30%
Fly Ash 38%
Example of CO₂ emissions, energy usage, and annual water consumption savings and practical equivalents compared to reference mix.

Environmental impact categories include:

- Energy consumption
- Emissions (air, water, and solid waste)
- Toxicity potential
- Risk potential
- Raw material consumption
- Use of area (land)

Based on an annual production of 45,000 m³ of concrete

<table>
<thead>
<tr>
<th>Smaller Carbon Footprint - Volume of Gasoline Equivalent</th>
<th>Alternative</th>
<th>kg CO₂ equiv./yr</th>
<th>Gas Saved (L/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly Ash 15%</td>
<td>2,379,239</td>
<td>1,045,039</td>
<td></td>
</tr>
<tr>
<td>Fly Ash 40%</td>
<td>6,388,671</td>
<td>2,806,107</td>
<td></td>
</tr>
<tr>
<td>Slag 50%</td>
<td>6,902,922</td>
<td>3,031,982</td>
<td></td>
</tr>
<tr>
<td>Green Concrete</td>
<td>6,716,672</td>
<td>2,950,176</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Energy Saved – Per Capita Equivalent - Mexico</th>
<th>Alternative</th>
<th>Annualized Energy Saved (MJ/yr)</th>
<th>Annualized Energy Savings Equiv. in Mexico (per capita /yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly Ash 15%</td>
<td>14,818,660</td>
<td>2,076</td>
<td></td>
</tr>
<tr>
<td>Fly Ash 40%</td>
<td>39,185,470</td>
<td>5,491</td>
<td></td>
</tr>
<tr>
<td>Slag 50%</td>
<td>34,128,540</td>
<td>4,783</td>
<td></td>
</tr>
<tr>
<td>Green Concrete</td>
<td>43,002,670</td>
<td>6,026</td>
<td></td>
</tr>
</tbody>
</table>

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<thead>
<tr>
<th>Water Saved - Truck Washout and Bottled Water</th>
<th>Equivalent Annualized # of Truck Washouts</th>
<th>Equivalent # of 1/2 liter Bottles of Water</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fly Ash 15%</td>
<td>192</td>
<td>327,155</td>
</tr>
<tr>
<td>Fly Ash 40%</td>
<td>800</td>
<td>1,363,145</td>
</tr>
<tr>
<td>Slag 50%</td>
<td>1,120</td>
<td>1,908,403</td>
</tr>
<tr>
<td>Green Concrete</td>
<td>1,761</td>
<td>2,998,920</td>
</tr>
</tbody>
</table>
Can this approach to sustainable construction Pay Off?

- Concrete construction is a sustainable material that can be quantified.
- Many notable projects have been completed using this approach.
Projects

High-Value Sustainable Projects

- World Trade Center
- BASF Headquarters
- 432 Park Avenue
- SF Public Utilities Commission
- No. Carolina Bonner Bridge
World Trade Center
Continued

Now

When Completed

View from the Top!
Green Sense Concrete Project Example

World Trade Center
Tower One

- 59 MPa to 100 MPa pumped columns
- Innovative Green Sense Concrete mixture designs are exceeding the project performance requirements
- The environmental footprint of the concrete was reduced

<table>
<thead>
<tr>
<th>Environmental Impacts</th>
<th>Environmental Savings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy (kWh)</td>
<td>25,402,200 kWh savings</td>
</tr>
<tr>
<td>Resource Consumption (lb)</td>
<td>2,774,650 lb savings</td>
</tr>
<tr>
<td>Fossil Fuel Consumption (lb)</td>
<td>1,110,050 lb savings</td>
</tr>
<tr>
<td>GHG (lb CO₂ eq)</td>
<td>34,886,050 lb CO₂ reduction</td>
</tr>
<tr>
<td>POCP (lb ethene eq)</td>
<td>2,837 lb ethene reduction</td>
</tr>
<tr>
<td>AP (lb SO₂ eq)</td>
<td>221,820 lb SO₂ reduction</td>
</tr>
<tr>
<td>Water Production (gal)</td>
<td>155,466 gal water production savings</td>
</tr>
<tr>
<td>Water Emissions (gal)</td>
<td>5,247,050 gal water emissions savings</td>
</tr>
<tr>
<td>Solid Waste (lb)</td>
<td>1,720,100 lb solid waste savings</td>
</tr>
<tr>
<td>Land Use (ft²)</td>
<td>2,221,400 ft² land savings</td>
</tr>
</tbody>
</table>

Owner: Port Authority of New York and New Jersey
Concrete Contractor: Callovino Construction Co., New York
Concrete Producer: Eastern Concrete Materials, Elmhwood Park, N.J.
Admixture Supplier: BASF Construction Chemicals, Beachwood, Ohio
Sustainable Precast Project Profile

Perot Museum in Dallas, Texas, USA
Perot Museum is a 170 foot tall (51 meter), 180,000 ft² (16,740 m²) structure, clad in architectural precast panels

- Cost $185 Million USD
- Designer: Morphosis, Culver City CA
- Engineer: Datum Engineers and John A Martin & Associates
- Contractor: Balfour Beatty Construction, Dallas
- PCI Certified Precaster: Gate Precast Co, Hillsboro Texas.
- Precast Components: 700+ gray as cast architectural precast concrete panels
• The museum design makes it clear how versatile and innovative precast concrete can be.
• It also was an important part of the contribution to the sustainable impact to the overall structure.
Exterior Panels

The building’s outer skin is made up of 700+ textured precast concrete panels, totaling 4 million pounds (1.8 million kilograms).
Sustainable Contributions

- The building materials include **recycled** and locally sourced materials.
- The building’s irrigation and plumbing demands are met in the summer by recapturing air conditioning condensation.
- The building’s cube shape is more **energy efficient** than a rectangular building.
- The building has light wells in the learning labs that allow natural light to fill to rooms and rely less on artificial lighting.
- The building has a rainwater collection system filling two 25,000-gallon cisterns. (189,500 liters) for irrigation.
- Erection was **fast and efficient** due to the precast design
- Precast concrete design makes it **durable & non toxic**.
- Cradle to Grave **Life Cycle Analysis** (LCA) provided.
Sustainable Contributions

• The building’s water is heated by solar panels.
• The building uses drip irrigation, which is 90% efficient and 75% more efficient than sprinklers.
• The building’s interior is lit by LEDs and natural sunlight, including skylights for street-level rooms.
Accreditation

• In collaboration with consulting architect Good Fulton & Farrell, the Perot Museum is registered and working on three green-building accreditation programs: LEED, Green Globes and the Sustainable Sites Initiative.
Preguntas?