


ASTM INTERNATIONAL

Towards a Sustainable Future:
3D Concrete Printing

**International Conference for Sustainable
Construction Materials, Dubai, UAE**


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Motivation

- ▶ "Necessity is the mother of invention"
- English-language proverb
- ▶ **Climate change** has forced the construction industry to rapidly implement **innovations** globally.



- 1 ton of structural concrete (using ~14% cement) is estimated at 410 kg/m³ CO₂
- Reduced to 290 kg/m³ with 30% fly ash replacement of cement.


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Approaches



- ▶ Limited innovations in structural design:
 - Minor improvements made due to efficient usage of cross-sections and to material saving structural form and layout
 - Options for innovations: **Sustainability**
- ▶ Approaches for implementation:
 - LEED Certification
 - ASTM International
 - Durability, and
 - 3D Concrete Printing

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Approach: LEED Certification


- ▶ Leadership in Energy and Environmental Design
- ▶ Most popular green building certification programs worldwide
- ▶ Developed by the non-profit U.S. Green Building Council (USGBC)
- ▶ Allocate points based on the **potential environmental impacts** and **human benefits**



What is Green Design?

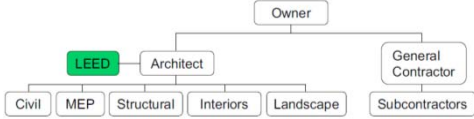
- ▶ Design and construction practices that significantly **reduce or eliminate the negative impact of buildings on the environment and occupants** that address:
 - Sustainable site planning
 - Safeguarding water and water efficiency
 - Energy efficiency
 - Conservation of materials and resources
 - Indoor environmental quality

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LEED Process

- ▶ LEED needs to be integrate into the design process
- ▶ Requires buy-in from entire team



```
graph TD; Owner[Owner] --- Architect[Architect]; Owner --- GC[General Contractor]; Architect --- Civil[Civil]; Architect --- MEP[MEP]; Architect --- Structural[Structural]; Architect --- Interiors[Interiors]; Architect --- Landscape[Landscape]; GC --- Subcontractors[Subcontractors]; LEED[LEED] --- Architect;
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```

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Dubai's Commitment to Sustainability

- ▶ Published: Dubai Municipality Green Building Regulations & Specifications
- ▶ UAE ranks among the top 10 countries in the world to hold LEED.
- ▶ Dubai ranks third among global cities with the highest number of green-certified buildings.

Desert Rose City

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Approach: ASTM International

- ▶ ASTM has development of **consensus standards** for sustainability.
- ▶ Complex subject involving environmental, economic and social considerations.
- ▶ Formed committee E60 on Sustainability on Performance of Buildings, has addressed sustainability in the building industry.

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ASTM E60

- ▶ The **acquisition, promotion, and dissemination of knowledge**, stimulation of research and the development of standards **relating to sustainability and sustainable development**.
- ▶ The committee shall include **environmental, social, economic**, and other issues **relating to sustainability**.
- ▶ Responsible for **supporting** and serving as a resource for **other ASTM committees** in their activities that include sustainability issues.

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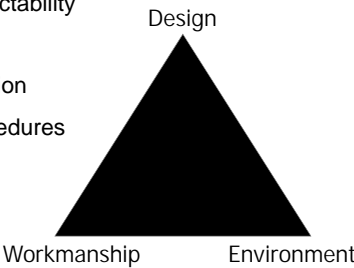
Approach: Durability

- ▶ **Causes of Deterioration**
 - Corrosion of steel
 - Alkali-silica reaction
 - Sulfate attack
 - Freeze-thaw/scaling
 - And more... (Delayed ettringite formation, acid attack, etc...)




Why Do Problems Occur?

- ▶ Design- Constructability
- ▶ Mix Design
- ▶ Materials Selection
- ▶ Placement Procedures
- ▶ Environment




How to Get Desired Performance?


- ▶ Specifications should require the performance for the intended service conditions.
 - Service-life,
 - Exposure conditions, and
 - Material requirements
- ▶ Caution: over-specification can bind the contractors and make the expected performance impossible to achieve

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Approach: 3D Concrete Printing


- ▶ Innovative design and construction practices are looking at additive manufacturing to improve sustainability of construction.
- ▶ Aim: reduce environmental impact at the same time as reducing economic costs



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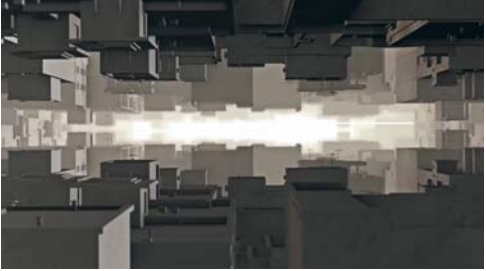
3D Concrete Printing


- ▶ **Lower costs** – the cost is much lower than traditional construction methods, also material transportation and storage on sites is limited;
- ▶ **Environmental friendly** construction processes and the use of raw materials with low embodied energy (i.e. construction and industrial wastes);
- ▶ **Reduced number of injuries and fatalities** onsite as the printers will be able to do most hazardous and dangerous works;
- ▶ **Time savings** – time required to complete the building can be considerably reduced.

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**3D Concrete Printing:
North American Perspective (1/2)**

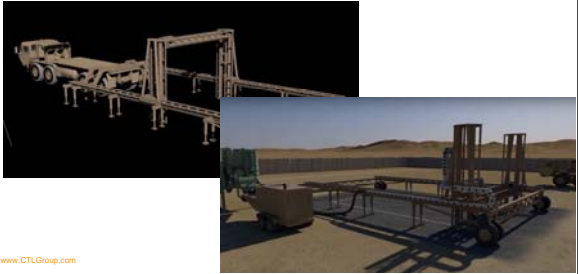
▶ NIST: National Institute of Standards and Technology



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**3D Concrete Printing:
North American Perspective (2/2)**

▶ U.S. Army Corps of Engineers: Engineer Research and Development Center (ERDC)



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3D Concrete Printing in Dubai

▶ Office of the future

- First 3D printed building


▶ 3D-printed high-rise (2020)

- 1,375 feet tall



Towards a Sustainable Future

- ▶ Combination of approaches for sustainability:
 - LEED certification
 - ASTM International – test methods and standards
 - Durability through design, workmanship, and understanding environment (>>*Service-life*)
- ▶ Future (continued) development:
 - Innovations in construction (i.e. 3D concrete printing)

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Questions & Answers
